Weather-Related Disasters and International Migration

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Abstract

Weather related disasters are well documented as motivating the internal displacement of people. What is less well understood is how weather related disasters affect international migration. This is important for several reasons: individuals face fewer barriers for migration within countries than between countries; the frequency of these weather related disasters has been and is expected to continue increasing in both frequency and severity as a consequence of global warming; empirical validation of the policy levers that might potentially affect migration has been virtually unexplored. Our paper provides a first step in remedying these limitations. This research poses clear empirical challenges since it requires that we employ a much larger database than previously used, and that we construct models that anticipate the potential for heterogeneous responses to both environmental and policy variables. Like the policy response to other impacts of global warming, our paper concludes with a discussion of both adaptation and mitigation strategies.

Keywords: global climate change, statistical model of migration, public policy

1. Introduction

Since the 1930s, weather-related disasters have led to substantial periods of internal migration in many countries. The drought and dust bowl conditions of the 1930s led to the migration of nearly three million people from the Great Plains of the US and Canada. Many migrated within and from Florida due to Hurricane Andrew in 1992 and the hurricanes of 2004. Hurricanes Katrina and Rita displaced nearly two million people in and from Louisiana and Mississippi in 2005, many of whom have not returned to their homes. Millions migrated within Bangladesh and the Philippines, and nearly ten million have migrated in Africa's Sahel region alone. While these cases and a number of others are stark and well documented, the implications for international migration remain largely unstudied. Studies have observed some cases in which weather-related disasters played a role in cross-border migration, but it is unclear whether the disasters play a general or anecdotal role in international migration.

This problem is particularly important since weather-related disasters are expected to increase as a result of global warming. Indeed, the frequency and severity of weather-related disasters appears to already be increasing. Expressed in real terms, the average global economic loss caused by natural disasters rose from about 12 billion dollars per year in the 1970s to more than 80 billion dollars per year since 2000 (United Nations, 2008). The average number of affected people across the world increased from 25 million per year in the 1960s to about 300 million per year since 2000, and the average annual number of disasters increased from 30 to nearly 400 over the same period (EM-DAT, 2009a). Of course, some of this change can be attributable to other processes such as increases in population (Strömberg, 2007), increases in the fraction of people living in vulnerable areas (Pielke et al., 2008), and improved reporting and communications technology (Peduzzi, 2005). Today, weather-related disasters consist of about three quarters of all natural disasters (UNISDR, 2008; EM-DAT, 2009a; 2009b). The Intergovernmental Panel on Climate Change (IPCC) concludes that global climate change has likely played a role in this trend and expects that as it progresses, the intensity, frequency, and geographic scope of weather-related disasters that, unless mitigated, will increase (IPCC, 2007a, 2007b).

It is this potential connection between global climate change and international migration that motivates our paper. Before we can examine any of the policy steps that might be use to respond to such a migration pattern, we need to understand and predict its magnitude. The empirical literature on international migration ignored the impacts of environmental factors, including weather, focusing almost exclusively on socioeconomic and some political factors.

We develop a theory for the role of weather-related disasters in the pressures for international migration. Based on this theory, we develop an empirical model and estimate it for a large sample of country-pairs from 1986 to 2006. The model controls for the influence of traditional socioeconomic and political determinants as well as non-weather-related natural disasters. But, it allows for a more contextual model in which disasters may not affect all countries migration decisions identically. We conjecture that some countries may be better able to cope with disasters than others and that this ability to cope reduces the incentives to migrate.

We find that at sample geometric mean values, a rise in weather-related disasters in the country of origin pushes people to leave, whereas a rise in weather disasters in the destination attracts people to come, all other things being equal. We adaptation strategies in which the marginal effect of weather related disasters on migration can be reduced to zero. We compare the potential for success of these adaptation strategies to mitigation in which greenhouse gasses and the growth in weather related disasters is curtailed.

In the remainder of this paper, Section 2 discusses the background and previous studies for our problem. Section 3 develops an empirical model of migration including a discussion of variables and potential econometric issues. Section 4 presents our data and data sources. Section 5 presents the statistical results, and Section 7 summarizes and discusses policy implications.

2. Background and Prior Literature

Our paper brings together two bodies of literature that study determinants of migration. The economic-population literature has employed statistical methods in examining the role of various economic and socio-political determinants in international migration. The environmental studies literature has primarily described the role of weather-related disasters in specific episodes, but with the exception of two studies has not employed statistical methods in studying general migration patterns. This section overviews the two bodies of literature, and evaluates the implications for this study.

The migration literature is too large to be fully reviewed here. For surveys of this literature see Martin and Widgren (2002) or Martin and Zucher (2008). In this paper we limit our attention to non-forced migration crossing international borders.[1] Generally, the empirical studies in this literature estimate some kind of spatial interaction model in which migration from an origin country A to a destination country B. One set of studies examines migration from many origins to one destination. For example, Karemera et al. (2000) analyze migration from 70 countries to the US or Canada in 1976-1986. They find that adjacency, larger origin population and destination income, and relaxed immigration quota raise migration, and larger origin freedom restriction, political instability, and income reduce it. Clark et al. (2007) look at migration to the US from 81 countries in 1971-1998. They find that larger lagged migration and origin income and migration quotas promote migration, and a larger distance reduce it. Brücker and Siliverstovs (2006) examine migration from 17 European countries and Turkey to Germany in 1967-2001 for a model with lagged migration, wages, and employment rates, though their goal is comparing results for different estimators (see Section 6).

Another set analyzes migration for many origins and destinations. Hatton and Williamson (2003), for example, study 21 African countries in 1977-1995, using data created as residuals from demographic accounting. They find that a larger destination-to-origin wage ratio, and origin population, refugee outflow, and gross domestic product (GDP) per capita growth increase migration. Pedersen et al. (2008) analyze migration into 22 OECD countries from 129 countries in 1990-2000. They find larger lagged migration and origin population promotes migration, larger distance and origin's GDP per capital reduce migration, while the destination GDP per capita, both unemployment rates, and the origin democracy

[1]Forced migration is defined as those forced to relocate due to deprivation of liberty or physical being. Those crossing international borders are counted as refugees, and those moving within a country are counted as internally displaced. For an example, see Melander and Öberg (2007).

have no effect. Finally, Mayda (2009) examines migration into 14 OECD countries from 79 origins in 1980-1995. She finds that a larger destination income or a smaller origin migration restriction increase migration, a larger distance reduces it, and changes in the origin's income has no effect.

The previously described empirical literature does not consider weather-related disasters among the causes of migration. However, there are a number of case studies describe migration due to weather-related disasters. The argument is not that the migration in these cases is solely driven by the disasters, but rather that the disasters play an important role in the movement in conjunction with other determinants. For example, since the 1970s, storms, floods, droughts, and landslides are estimated to have contributed to migration of about 600,000 people in Bangladesh (Reuveny, 2008; Lee, 2001) and 4 million in the Phillippines (Reuveny and Peterson Allen, 2008; Cruz et al., 1992). In the 1980s, droughts led to migration of more than half a million in Ethiopia and similar numbers in India and Zimbabwe (Reuveny, 2007, Scoones, 1992). Nearly 10 million reportedly migrated in the Sub-Saharan Sahel in the 1960s-1980s alone (El Hinnawi, 1985; Jacobson, 1989; Kane, 1995). Reuveny (2007) provides a number of other examples.

Weather-related disasters have also played a role in internal migration in North America, particularly in the US. For example, sandstorms and a drought in the 1930s led to migration of about 2.5 million from the US Great Plains and 300,000 from the Canadian Great Plains (Reuveny, 2007, 2008; Worster, 1979). About 40,000 of the nearly 350,000 Floridians displaced by Hurricane Andrew in 1992, and 52,000 of the nearly 1.7 millions Floridians displaced by hurricanes in 2004 are estimated to have moved to other counties or states; another 144,000 displaced Floridians moved in 2004 within their county (Smith and McCarty, 1996; 2004). In Louisiana and Mississippi, about 400,000 out of the two millions displaced by Hurricanes Katrina and Rita in 2005 migrated within or out-of-state (Reuveny, 2008; Times, 2006; White House, 2006). It is estimated that around 300,000 left the five most severely hit parishes in Louisiana alone (Hori et al., 2009).

Weather-related disasters are also said to have played a role in international migration. About 12-17 millions have moved from Bangladesh to India since the 1950s due to floods, storms, and droughts

(Swain, 1996; Reuveny, 2008), and perhaps 300,000- 400,000 left North Korea to China due to floods, tidal waves, and droughts (Yoon, 1998; Chu-Whan, 1999; Lee, 2001). Around a million people reportedly moved from Ethiopia and Eritrea to Sudan, and from Mauritania to Senegal since the 1960s due to droughts and famines, and possibly 900,000 Mexicans moved internally and to the US due to droughts (Reuveny, 2007). In 1998, Hurricane Mitch led to a large migration from Honduras and Nicaragua estimated at 100,000 to 150,000 people based on US government sources, though many more probably entered illegally (Krikorian, 1999; Migration News, 1999; INS, 2002, 2003).

The case study literature gives a good reason to suspect that weather-related disasters play some role in migration, but it does not quantify the effect relative to the forces addressed by the economic-population literature, and cannot indicate whether the role of disasters can be generalized across many countries and years. To our knowledge only two studies have attempted to address these issues.

Naudé (2009) studies out-migration from 43 African countries in five-year intervals from 1975 to 2005. Controlling for the lagged migration, economic effects and violence, he finds that a rise in total number of climatic, seismic, and biological disasters in a country increases its out-migration. Reuveny and Moore (2009) is perhaps the only study that examines the role of weather-related disasters in a country-pair framework. Using 15 OECD destinations and 107 OECD and non-OECD origins in 1986-1995, and controlling for political-economic and geographical effects, they find that a rise in the sum of number of people affected and killed by disasters in the origin promotes migration.

The statistical literature on bilateral migration examines the push and pull factors but does not examine policy implications of empirical finding (see the studies cited above). The general discussion and case study literature on environmental migration takes a common approach (e.g., Reuveny, 2007, 2008; Reuveny and Peterson, 2008; Perch-Nielsen et al., 2008; Brown, 2008; Black et al., 2008; Piguet, 2008). After demonstrating the problem based on case studies or causal observations, studies list policies to minimize the impacts by adaptation and mitigation assistance. The statistical studies of weather disasters and migration also do not push the policy envelope much. Reuveny and Moore (2009) call for adaptation in less developed countries financed by the developed countries, but their model does not have a policy hook. Naudé (2009) spends very little on policy, arguing that while disasters promote out migration in Africa, economic development and violent conflict prevention is a more important concern. Black et al. (2008) spends more time than others discussing policy solutions, though the recommendations refer to internal migration more than international migration. Among their recommendations are: 1) the incorporation of migration and climate change into national adaptation and development plans; 2) ensuring the social protection of more vulnerable or poorer migrants; 3) help those moving to slum areas of large cities with housing, safe water, health, education, employment; 4) defusing tensions caused by migration exacerbated by climate change may involve crossing a sensitive border; 5) expand the definition of a 'refugee' to include people displaced by climate change factors. No information is given to substantiate the effectiveness of these policies.

Our review of the literature suggests a number of shortcomings that limit the applicability of these studies for a serious discussion of public policy. Relatively few papers examine the effects of weather related natural disasters on migration, Naudé (2009) and Reuveny and Moore (2009) are exceptions. Among these papers, only Reuveny and Moore examines the effects of environmental variables on migration using a spatial interaction approach employing characteristics of both the origin and destination. Failure to do this is problematic because weather-related natural disasters affect all countries and if factors push individuals to leave a country with a large number of disasters, then it would make them less inclined to go to another country with a large number of disasters. Still, even they fail to examine any role for disasters in destination countries. Naudé only considered out-migration in Africa making it difficult to generalize the results to the rest of the world. Both papers presume that weather disasters affect all countries in identical ways. Given the asymmetry of the findings (only disasters in origins were considered) in both papers that impacts are context based. Finally, while some papers offer policy recommendations for either mitigation or adaptation, these recommendations are simply asserted and are not based in any empirical models. In the model that follows, we develop a context based model for migrations impacts, estimate it in a manner that reflects econometric issues, and make some first steps in the policy area by incorporating policy variables directly into our estimated model.

3. Models of Migration

Like much of the literature, we posit a model in which the motivation to migrate is the result of a rational decision-making process that reflects forces working in each country and at the country-pair level. Our version takes the general form of a spatial interaction model:

<1> $$M_{od} = f(x_o, x_d, x_{od})$$

The standard socioeconomic literature often refers to x_o as a vector of push factors (at the origin country of migrants), x_d as a vector of pull factors, x_{od} as country-pair (dyad) or network factors to explain migration from the origin to destination, M_{od}. While mathematically motivated individual level optimization models are possible (for example, Mayda, 2009), they generally do not add much beyond the formal statement of aggregate level behavior described in equation 1. A major task of the literature cited above is concerned with determining a sets of variables, push, pull and spatial interaction. An alternative classification scheme for the variables in these three categories are variables that are representative of expectations and other variables which characterize risk. For example, push and pull variables that represent the economic expectations that a migrant could expect are GDP per capita in the origin and destination. Given the purpose of our paper, we also identify several variables that are related to risk. Natural disasters, and political instabilities are such risk related variables.

In the subsections that follow, we motivate a set of variables for our model. Given the purpose of our paper we focus on weather related natural disasters first, following it with other risk related push and pull variables, spatial interaction variables and other control variables. We end this section with a brief discussion of the functional form and other econometric considerations for our model.

3a. Weather-Related Disasters and Migration Pressure

It is intuitive that weather related disasters are a plausible push factor, increasing out-migration where they occur. We consider weather related disasters to include events such as storms, floods, droughts, temperature extremes, extreme precipitation, resulting landslides and wild fires. These disasters and other natural disasters in the origin can destroy homes, industrial plants, natural resources, transportation and communication infrastructures along with other physical capital, lowering expectations about future earnings. Scarcities may develop and prices may rise, lowering the purchasing power. The loss of physical capital may take away individual livelihoods, leading to unemployment and corresponding further reductions in demand.

Weather related disasters are expected to have an especially devastating effect on the agricultural and food producing sectors of the economy. Droughts and heat waves lead to water stress for plants reducing agricultural output. Lower river and lake levels damage fisheries and limit the ability to provide irrigation. Windstorms and floods can wipe out crops and livestock and top soil, rendering the land unfit for production for years to come.

Weather-related disasters pose threats to individual health and safety. They may destroy medical facilities and access to treatment at a time when they are needed most. The destruction of sewage systems and treatment facilities can promote epidemics and infestations. These disasters may threaten the capacity of police and security forces to maintain law and order. With the destruction of communication networks, the government may have less information, hampering relief efforts. Public grievances may rise leading to political instability.

Myopic and risk averse residents are likely to overemphasize these effects in assessing the payoff of long term economic decisions such as capital investment, returns to education, and the future stream of income from staying put. While shocks to the system like this create winners and losers, and they are likely to clearly take a more devastating toll on the poor, the effects are economy wide stimulating out-migration by all incomes groups.

In addition to these internal factors, the consequences of natural disasters can be exacerbated by factors outside of the country. Risk averse behavior by foreign investors can further reduce physical capital flows into the country, leading to still further reductions in production, trade, and employment.

These processes promoting out-migration are intuitive, but their effects can be mitigated or even dominated by other factors. People affected by weather-related disasters may be too weak, sick or poor to migrate. Having lost family members and friends, property, and financial investments in destroyed businesses, people in affected regions may also not be able to find the mental energy required or be too impoverished to fund the associated expenses with starting anew in another country.

The length of time for which law and order and public health are diminished may be very different depending on a country's capacity to react to these threats. Some governments can mobilize police and military forces and medical treatment in anticipation of possible chaos.

Reconstruction efforts to replace damaged infrastructure can increase employment. The replacement of out dated capital with new capital can create longer lasting employment opportunities. Public and private insurance could compensate for damages, and public and private emergency funds could cover relief and rehabilitation efforts. Other potential sources of funds for this reconstruction are foreign aid and remittances. This may also create an opportunity to refocus investment from physical capital to human capital.

Countries can develop coping mechanisms to mitigate the consequences of disasters. For example, to deal with floods and sea waves and surges, they can modify watersheds, build levees, flood-proof buildings and infrastructure, enlarge water retention basins, divert water by canals, and forest or terrace hillsides. Warning systems may prompt people to temporarily leave affected areas, reducing fatalities. More stringent codes can increase the resiliency of buildings and infrastructure. A robust social safety net reduces the initial consequences of lost livelihoods. Financial assistance may entice people to resettle internally.

We stated these channels in terms of forces operating at the origin country, but the same logic applies also for the destination country. Our discussion suggests a contingency theory in which the effect of a weather related disaster depends on the administrative, economic and social capacity of the country to absorb the consequences. It suggests a relatively complex model in which the sign of effects are unambiguous, pushing individuals from origins with weather related disasters.

3b. Other Variables

Our discussion of weather related natural disasters suggests that we should also control for other disasters: non-weather-related natural disasters and political disasters (civil strife or war). We include earthquakes, volcanic eruptions and tsunamis as non-weather-related. As with our weather disaster theory, an increase in non-weather disasters in either the origin or destination country can increase or decrease the bilateral migration flow. Civil wars represent situations where the government lacks the capacity to maintain law and order, and implement reconstruction efforts. Civil war in the origin may reduce emigration, as people may not be able to leave the country or it may increase emigration since people may flee the fighting. Civil war in the destination are expected to reduce immigration if people try to avoid war regions. Similarly, between the origin country and destination country (a dyadic variable) is expected to have a negative effect on migration, though they may accept some dissidents and refugees.

Next, we include demographic and socioeconomic control variables that are often used in the migration literature. GDP per capita provides a measure of the economic opportunities associated with living in a particular country. Our rational choice model would suggest that individuals in areas with low GDP per capita would have a high demand to move to countries with high GDP per capita. In a simple model GDP in the origin to be negatively related to migration and GDP per capita in the destination to be positively related to migration. Our previous discussion suggests that at low GDP per capita levels, people may lack the ability to finance the move to a new country. Consequently, we include both linear and quadratic terms for GDP per capita in the origin. We expect the effect to follow an inverted U curve, increasing with GDP per capita and then decreasing, indicating that as GDP increases it promotes emigration but the effect eventually reverses. An argument for including a quadratic term for GDP per capita in the destination is much weaker.

Our discussion of weather-related disasters suggested that impact of a disaster may depend on a country political and economic capacity to absorb it. We proxy this capacity with GDP per capita. Consequently, our model includes an interaction between GDP per capita and weather-related disasters. Our expectation is that a weather related disaster will lead to more out-migration in countries with low GDP per capita than it does in origin countries with high GDP per capita. In high GDP destinations, weather-related disasters may not discourage migration as job opportunities may be created by reconstruction efforts.

Higher population in the origin country is likely to increase emigration. Higher population in the destination country is also likely to increase immigration. Larger populations indicate more potential individuals to move and a higher capacity of a destination country to absorb new people. These expectations are closely associated with early migration studies using gravity models which assume identical origin and destination effects. To the extent that larger populations indicate fewer opportunities for others, it suggests that secondary effects for this variable are to increase emigration and reduce immigration.

3c. Potential Policy Variables

The model includes two foreign aid flows provided to the country of origin: bilateral aid from the destination country to the origin, and multilateral aid to the origin country from the rest of the world. Our multilateral aid variable indicates the total aid provided by international organizations and other countries, excluding the destination. Our discussion about weather related disasters suggested that one adaptation strategy would be to help countries develop the governmental capacity to cope with jobs, reconstruction, law and order, and public health issues following a disaster. A rise in either foreign aid variable may decrease the emigration, as aid can improve the quality of life in the affected origin. However, an increase in foreign aid may also increase emigration as the improving conditions at home may enable more people to finance the move. The bilateral and collective aid flows may also have opposite effects as both flows may signal better relations with the donor countries, shifting emigrants from one destination to another.

Each of our foreign aid variables may interact with weather disasters at the origin by affecting the emigration. In other words, the marginal effect of weather disasters may be affected by aid, or, stated alternatively, the marginal effect of aid may be affected by weather disasters. The marginal effect of weather disasters on emigration may decline with aid, as the conditions improve at home, but it may also rise with aid as the improved conditions enable people to finance the move. The marginal effect of aid may decline with weather disasters, reducing emigration, but it may also increase with disasters, enabling more people to leave.

3e. Econometric and Functional Form Considerations

Our model is designed to be estimated using a panel of directed dyads as the unit of analysis.[2] Our purpose differs from many of the socio-political models which are focused on explaining the variation in migration from one dyad to another basing that explanation on between dyad variation. Our purpose is more focused on within dyad variation. A major difference between these purposes is how important it is to attribute migration to variables that do not change over time such as country area, distance between countries, shared borders, common language, colonial histories, etc. Instead, we allow these time invariant variables to be captured by a very large number of individual dyad effects.

There is a natural tendency for many of our variables to systematically change over time. In order to control for this time trend, we include fixed annual time effects. Both the dyad effects and time effects are likely to be correlated with other variables in the model leading us to include them in as fixed effects. Country effect models and random effects models form two testable restricted versions of this model.

In data such as ours, the same variable can naturally come in markedly different sizes. For example, China's population size is more than 1.3 billion while Israel's population size is barely eight million. Migration levels are likely to be similarly varied with their variability proportional to their predicted values, a clear symptom of heteroskedasticity. The most common way to mitigate this heteroskedasticity is to estimate the model in log-log form. Consequently, we include all interval-ratio variables in log form, but leave dummy variables unchanged. This has a number of additional benefits for the robustness of our model. For example, it is not clear how our key variables, weather-related disasters, should enter the model–unadjusted, per capita, or per unit area terms. Because such adjustments occur in ratio terms, and because the log of the ratio is simply the difference in the logs, as long as these adjusting variables, population and area, are accounted for in the model, the major effect of these alternative specifications is to change the value and interpretation of the control variable coefficient.

One complication is that our interval-ratio variables are not negative, they are sometimes zero and

[2] Thus, for example, the emigration flow from France to Germany in some year may differ from the flow from Germany to France in that year; both directed dyads are included in the sample.

the log is not defined. To avoid this difficulty, we simply add 1 to the value of our variables before taking logs. This has the advantage of avoiding sample truncation (were the ln(0) observations simply dropped) with corresponding biased estimates, but it does mean that we can not interpret the coefficients in the model strictly as elasticities and it does mean that our argument of insensitivity to alternative specification of variables above is not exactly true. Consequently, for example, our dependent variable is $\ln(Migration_{od} + 1)$. The variables to be logged in our analysis do not have negative values. Unfortunately, they often do have zero values making taking logs impossible. Our approach is to add one to variables in which logs are taken. There are two consequences. First we do not lose observations as a result of the logging process. Second, we do lose the ability to interpret coefficients as elasticities. As the magnitude of both the dependent and independent variables increase, the coefficients more closely approximate the elasticity.

The inclusion of interaction terms and quadratic terms in our model tends to create some collinearity. Our approach is to estimate the model as a second order log Taylor series approximation around the geometric mean of the variables rather than around the origin, in effect, replacing variables with something close to their Legendre orthogonol polynomials.[3] One of the side benefits of this decision is that our first order terms can be interpreted as marginal effects at the geometric mean of the sample, while the second order and interaction terms describe how those marginal effects change at points away from the geometric mean.

The GDP per capita and population size in the origin and destination may be affected by the migration flow as more labor leaves or joins the economy. While this potential endogeneity may be weak, we take a conservative approach and replace these variables by using their first lagged value. This approach reflects the logic that the current emigration flow cannot affect the previous year levels of any

[3] For example over the range 0 to 2, x and x^2 are very correlated, but (x-1) and $(x-1)^2$ are not. This transformation to deviation from mean log form is common in estimating production technologies such as the translog where flexible functional forms necessitates including higher order and interaction terms.

variable and is used widely in the literature.[4] The resulting model to be estimated is of the form:

$$\ln(M_{od,t}+1) = \alpha_{od} + \tau_t + \sum_k \beta_{o,k} \, [\ln(x_{o,kt}+1) - \ln(\bar{x}_o+1)] + \sum_k \beta_{d,k} \, [\ln(x_{d,kt}+1) - \ln(\bar{x}_d+1)]$$

$$+ \sum_k \gamma_{o,k} \, [\ln(w_{o,kt}+1) - \ln(\bar{w}_o+1)] \, [\ln(x_{o,kt}+1) - \ln(\bar{x}_o+1)]$$

<2>

$$+ \sum_k \gamma_{d,k} \, [\ln(w_{d,kt}+1) - \ln(\bar{w}_d+1)] \, [\ln(x_{d,kt}+1) - \ln(\bar{x}_d+1)]$$

$$+ \sum_k \delta_{od,k} \, [\ln(x_{od,kt}+1) - \ln(\bar{x}_{od}+1)] + \varepsilon_{od,t}$$

where bars over variables indicate the geometric mean, o subscripts indicate variables and coefficients associated with the origin while d subscripts indicate variables and coefficients associated with the destination, and od subscripts indicate dyadic variables. Coefficients α and τ indicate fixed dyad and time effects, β include first order effects on origin or destination variables x, γ are used for interaction effects between weather related variables, w, and origin or destination related variables, and δ are coefficients for dyad variables. As a small modification to this functional form, we do not take the log of our two dummy variables, civil war in the origin and war between the origin and destination, though we do subtract off the arithmetic mean.

Finally there is likely to be some residual heteroskedasticity and/or some serial correlation with either an autoregressive or moving average process. We use clustered standard errors, clustered on dyad, to construct our confidence intervals and hypothesis tests.

4. Data

The sample includes an unbalanced panel of 178 origins and 178 destinations from 1986 to 2006. Our sample includes over 28,500 observations and 3,909 country-pairs. About three quarters of the data are inflows into the OECD countries from the OECD and the non OECD countries. The remaining observations are inflows into the non OECD countries from the OECD countries. There are 4,842 original

[4] For example, see Mayda (2009), Reuveny and Moore (2009), Naudé (2009), and Pedersen et al. (2008). Since these are used as control variables, resolving this simultaneity does not have any important policy implicaitons.

zero values that indicate no emigration. The sample does not include the migration inflows into the non OECD countries from other non OECD countries, for which we could not locate systematic reliable data. Even so, our panel is perhaps the largest bilateral migration data set assembled so far in the literature.

The data for the directed migration variable are expressed in individuals. The 1990-2006 migration data come from OECD (2009a). The 1986-1989 migration data come from SOPEMI (1990) and USINS (1996). All of these sources report legal flows into the OECD countries from the OECD and the non OECD countries, and flows into the non OECD countries from the OECD countries, as recorded by the OECD countries. The OECD (2009a) includes many more countries than SOPEMI (1990) and USINS (1996). When a flow is reported as both inflow and outflow (e.g., France reports inflow from Germany and Germany reports outflow to France) we assume the inflow is more accurate use it. As in essentially all statistical studies, our sample do not include estimates of illegal migration.

The key independent variables measure the weather disasters in the origin and destination, respectively. They include wind storms, droughts, floods, extreme temperatures, heat waves, extreme precipitation, and rain related landslides. We measure weather disasters by their total incidence per year in a country, the total number of people they affect (those needing immediate assistance), the total number of people they kill, and these total numbers divided by each country's population or area. Symbolically, we will refer to these six variables as WDA_O, WDI_O, WDK_O, for weather related disasters in the origin for affected individuals, the number of incidents and number killed. WDA_D, WDI_D and WDK_D are similarly defined for the destination. Our primary source of this data is EM-DAT which defines natural disasters as events in which one or more of the following criteria are met: (1) At least one hundred people were affected (i.e., needed medical treatment, shelter, food, water, rescue, and so forth); (2) At least 10 people died or were assumed dead as a result of the disaster; (3) The government of the affected country declared a state of emergency; (4) The government of the affected country called for an outside help.

For the years 1986-2004, we use data from the GEO Portal (2010), which presents yearly totals for each country of the number of people affected or killed by natural weather and non weather disasters, respectively. For 2005 and 2006, we generate separate yearly aggregates by summing up the number of people affected or killed by weather or non weather disasters, respectively, which are available per disasters in EM-DAT. We also consider adjusting our natural disaster measures by dividing them by population or country area.[5]

The data for the non-weather disaster indicators also come from GEO Portal (2010) for 1986-2004 and from EM-DAT (2008) for 2005 and 2006. These natural disasters include earthquakes, volcanic eruptions, tsunamis, and infestations. They are measured in the same ways as the weather disasters, and we use the same measurement approach to weather and non weather disasters in any given estimation. Our variable names are NWDA_O, NWDI_O, NWDK_O for the number affected, the number of incidents and the number killed in non-weather disasters in the origin, with similar variable names for the destination.

The data for the GDP per capita and population of the origin and destination countries come from the Penn Tables 6.3 (Heston, Summers and Aten, 2009). The GDP per capita data are expressed in 2005 constant dollars and the populations are expressed in thousands of individuals. To streamline the presentation, from here on we use the notation $ to denote 2005 constant dollars. Our variable names are GDP_O and GDP_D for the per capita GDP in the origin and destination respectively.

The data for the foreign aid flow from the destination to the origin and for the foreign aid flow from the rest of the world, including both multilateral organizations and other countries, to the origin come from the OECD (2009b). Foreign aid include grants and humanitarian disbarments expressed in 2005 constant dollars, per capita in the origin. The OECD (2009b) reports the Official Direct Assistance to the non OECD countries from the international aid organizations and the OECD countries. We assume

[5] EM-DAT includes also monetary estimates of the damage, but only for about 30% of the cases. These data may be inexact due to imperfect insurance markets, poor bookkeeping and data collection, the assumptions needed to create them, and the tendency of countries to overstate them in order to secure external aid (Skidmore and Toya, 2002; Kahn, 2005; Raschky, 2008).

the non OECD countries do not give aid to the OECD countries and set their data cells to zero.[6] Our variable name for per capita bilateral aid from the destination to the origin is AID_DO and per capita aid from all other countries and international organizations (the rest of the world) is AID_RO.

The data for the presence of a war between the origin and the destination come from Maoz (2005) for the 1986-2001 time period and from UCDP/PRIO (2009) for the 2002-2006 time period. These sources list interstate militarized conflicts between two state actors. We include all conflicts that kill at least 1000 people per year, which also is a customary threshold in the literature. Our dyadic variable is WAR_OD.

A table of summary measures for our variables, including arithmetic and geometric means (the point of our approximation) as well as labels is presented in Table 1.

[Insert Table 1]

5. Estimation Results

The rapid increase in the number of weather related natural disasters is presented in Figure 1. This shows a dramatic increase since 1980 (also clearly present since the 1950s) in the number of incidents. This trend shows approximately a 4% increase in the frequency of disasters per year. Critics argue that this is weak evidence for global warming, and can be attributed to population increases (Strömberg, 2007), increases in the fraction of people living in vulnerable areas (Pielke et al., 2008), and improved reporting and communications technology (Peduzzi, 2005).

[Figure 1 about here]

As a point of comparison, we also show the trend for non-weather related disasters. This shows a much smaller, approximately 1% increase over time. We might consider this trend to be at least a crude measure of the biases associated with the three factors above.

Table 2 presents the results for a model that measures disasters by the total number of people they affect per country in a year.

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[6] Some non OECD countries (e.g., China) provide foreign aid to non OECD countries, but these data points are not included in the sample since we do not have migration flows for these dyads.

[Insert Tables 2]

The Hausman test indicates that a random effects model is not consistent (p level < 0.000), and so we specify the country-pair effects as fixed effects and employ the fixed effects model. The dyadic fixed effects are found to be jointly significantly different from zero (p level < 0.000). The yearly fixed effects are also found to be jointly significantly different from zero (p level < 0.000). The R-squared scores obtained for all the models are all around 0.91, indicating a good fit to the data.

5a. Alternative Specifications of Natural Disasters

We consider four alternative specifications of the model in Table 3. These involve altering the primary of natural disasters to 1) number affected divided by country population; and 2) number affected divided by land area of the country; 3) number of incidents; 4) number killed. With a very small number of exceptions, coefficients are approximately the same sign, magnitude, and level of statistical significance.

Each of these alternative of the exposure to disasters has some modeling appeal. A country is more intensely affected if a higher fraction of their population is affected (column 1). A country is more affected if there are more disasters per unit area (column 2). A country is more threatened if more of the weather events cross the threshold to be come disasters (column 3). Fatalities represent the ultimate in social disruption (column 4). In each case the robustness of these results stems from the initial robustness of our modeling choice. It is not clear which of these models is the correct one to estimate. It does not matter which we use since they all generate approximately the same results. Because of these modeling robustness, we will focus our attention on interpretation of the results in Table 2.

5b. Marginal Effects at the Mean

In discussing the results, we first examine the marginal effect of each variable holding all the other variables at their sample geometric means. In this case, the marginal effect is given by the estimated coefficient and the contribution of the interaction terms washes out at the geometric mean of the variables.

<3> $$\frac{\partial \ln(M_{od}+1)}{\partial \ln(WDA_o+1)} = \beta_{wo} + \sum_k \gamma_{ok} \left[\ln(x_{ok}+1) - \ln(\bar{x}_k+1)\right] \approx \frac{\partial \ln(M_{od})}{\partial \ln(WDA_o)}$$

The interpretation of this effect is not quite an elasticity.[7] Because numerically computed elasticities and our coefficient estimates are so close we will interpret the estimates as though they are elasticities. We then examine the marginal effects away from the mean, discuss the sizes of the marginal effects, and present results from additional analyses that use different measures of disasters. In the origin country, the marginal effect of weather disasters, ln(WD_O), on emigration is positive and statistically significant. For the average country in the sample, an increase in the number of people affected by weather disasters promotes emigration from the affected country. On average, people adapt to weather disasters at home by way of moving elsewhere. Thus, if the problem of weather disasters will get worse as climate change progresses as expected, the pressure to emigrate from the affected countries may grow.

The marginal effect of non-weather disasters, ln(NWD_O), is not significant and is small, only one tenth the magnitude of weather related disasters. This result suggests that changes in the number of people affected by non-weather disasters do not play much of a role on average in emigration. It should be remembered though, in our time period the non-weather disasters affected much fewer people than the weather disasters, and so this percentage change is operating on a smaller base. The effect of disasters are comparable across disaster type (see Table 3).

The marginal effect of the population size in the country of origin, ln(Pop_O), is positive and significant. The interpretation is that an increase in population in the country of origin increases the pool of potential migrants, and intensifies the pressure on the domestic national pie. These forces work together to promote emigration.

The marginal effect of GDP per capita in the origin country, ln(GDP_O), is negative and significant. On average, better economic conditions, a higher level of development, and a higher standard of living in the country of migration origin, all of which are captured by the higher GDP per capita, reduce emigration from that country.

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[7]The discrepency between this marginal effect and an elasticity is a very small factor:

$$elasticity = \beta_{wo} \left(\frac{M+1}{M}\right) \left(\frac{WRD}{WRD+1}\right)$$

The marginal effect of civil war in the origin, CWar_O, is positive and significant. The occurrence of a civil war in a country pushes more people to leave the country on average. People are thus more inclined to leave facing a civil war then to stay and join the fight, and they find ways to live the country despite the political turmoil.

In the destination country, the marginal effect of weather disasters, ln(WD_D), on immigration is positive and significant. As the number of people affected by weather disasters increases in a country, it sees a larger number of immigrants from any given origin, on average. This result is consistent with one of the interpretations we discussed, according to which the immigrants come, or perhaps are 'invited', to work in the reconstruction/recovery efforts. It seems particularly appealing here since about three quarters of the migration in our sample flows into the OECD countries; the OECD residents may find the disaster reconstruction efforts to be too labor intensive. The issue can be further studied in future research.[8]

The marginal effect of the number of people affected by non-weather disasters in the destination country ln(NWD_D) is positive and significant. An increase in this disaster variable also increases immigration to the destination. This particular result is in line with the abovementioned reconstruction efforts-rendition and it too can be further studied in future research.

The marginal effect of GDP per capita in the destination, ln(GDP_D), is positive and significant. An increase in GDP per capita in the destination, which indicates better economic conditions and a higher standard of living, attracts more immigration to the country on average.

The population size in the destination country, ln(POP_D), does not seem to play a role in the immigration on average. The larger population in the destination may offer more ways to blend in and signal a larger economy with more opportunities, but it may also indicate more competition for jobs and a greater domestic pressure for tougher immigration barriers. The net effect is thus about zero.

The marginal effect of civil war in the destination country, CWar_D, is negative and significant. Countries that experience a civil war see less immigration on average than countries that do experience a

[8] The reconstruction of New Orleans following Hurricane Katrina is a case in point, involving many immigrants from Latin America.

civil war. Potential immigrants shy away from political tense and unstable countries, the spirit of which is in line with our finding that civil war at home promotes emigration.

The marginal effect of war between the origin and the destination, War_OD, is not significant. War does not play much of a role in emigration on average, though this result may not be general. Our 1986-2006 sample includes only the 1991 Gulf War, the 2001 Afghanistan War, and the 2003 Gulf War, and there are only 20 migration data points for fighting country-pairs. Our result may reflect the nature of our sample. Future research may address this issue, though the migration data are not readily available for non-OECD country-pairs, which experienced most of the wars in the recent decades.

Finally, the marginal effect of the foreign aid given by the destination to the origin, ln(Aid_DO), per capita in the origin is positive and significant. An increase in aid from the destination to the origin promotes emigration from the origin to that destination, on average. The interpretation is that the destination willingness to give aid may serve as an indicator of closer ties between the origin and destination, or the bilateral aid enables the move by providing more financial resources, both of which forces are expected to promote more emigration to the donor country.

The marginal effect of the foreign aid from the rest of the world to the origin, ln(Aid_RO), per capita in the origin is negative. An increase in foreign from international organization other countries reduces emigration to the particular destination in the dyad. This result is consistent with the interpretation that bilateral aid is viewed as a sign for closer relations between the residents of the two countries. It is also possible that the nature of the collective aid differs on average from the nature of the bilateral aid. For example, the collective aid may be more geared toward long term development than toward disaster assistance.

Taking a broader view, we find that a larger number of people affected by weather disasters in the origin pushes more people to leave on average, while a larger number of people affected by weather disasters in the destination attracts people to come. As the number of people affected in the future increases as a result of global warming, the two effects will reinforce one another. This reinforcing effect is found to be robust in additional analyses that employ other measures of weather disasters below.

5c. Marginal Effects Away from the Geometric Mean

So far, we have examined the average effects. We now turn to the effects obtain away from the mean, which brings the interaction terms into the picture. For our purposes the most important effects describe how context, the values of GDP per capita and the AID variables, affect the relationship between weather-related disasters and migration, for both the origin and destination countries. For the origin country this is described by applying equation 3:

$$\frac{\partial \ \ln(M_{od})}{\partial \ \ln(WDA_o)} \approx .01717 - .0046[\ln(AIDDO) - \ln(AID\overline{DO})] - .00631\ln(AIDRO) - \ln(AID\overline{RO})] + .00376[\ln(GDP) - \ln(G\overline{DP})]$$

Holding the remaining two aid variables at their geometric means, a rise in the GDP per capita in the country of origin increases the marginal effect of the people affected by weather disasters. Though the effect is small, and only marginally statistically significant, a richer and more developed country faces greater weather motivated emigration than a poorer and less developed country.

Holding ln(Aid_RO) and ln(GDP_O) at their means, the marginal effect of the number of people affected by weather disasters in the origin declines with the foreign aid from the destination. When this aid is larger than about $56 per capita per year in real terms, or $2.7 billion for a country with the mean population (48.35 million), the marginal effect becomes negative. The destination country can decrease the number of immigrants from an origin facing a larger number of people affected by weather disasters by providing it more foreign aid, but the price is high.

Holding ln(Aid_DO) and ln(GDP_O) at their sample mean, when the collective aid to the origin is larger than about $62 per capita per year, or about $3 billion for the mean population country, the marginal effect of the people affected by weather disasters also becomes negative. International organizations and other countries can also reduce the emigration from an origin facing more people affected by weather disasters by providing it more aid. The two aid variables tend to support the notion that countries can enhance their capacity to deal with these disasters if they are given the resources to do so.

The marginal effect of weather-related disasters in the destination can be determined similarly. Decreases in GDP per capita in the destinations makes the marginal effect of weather-related disasters decline. By the time GPD per capita declines to $1,400, roughly the income of most of central Africa, the marginal effect of weather related disasters in the destination is zero.

Though not of central interest in this paper, marginal effects of GDP in the origin on out-migration increase with weather related disasters, and they decline as GDP increases, following an inverted U shape. With WDA_O held at its geometric mean, the turning point is at a GDP per capital level of $2218. One third of the world's countries and more than half of the world's population (including India and China) has per capita incomes less than this value. This suggests that economic development of these countries, irrespective of the outcomes of weather-related disasters, will initially place higher pressures on the rest of the world for migration. The marginal effect of higher GDP in destination countries is always positive over the range of our sample, and it is increasingly so as GDP rises.

5c. Size of Effects

The above subsections show that the weather disasters significantly promote emigration, but they do not indicate the size of the effect. This subsection examines the sizes of the effects in the model.

The emigration changes caused by the %1 increases in each variable are approximately %0.01717 and %0.01032 for the number affected in the origin and the destination, respectively. These values seem small, and possibly easily dismissed. But at even a three percent annual growth rate, weather related natural disasters will increase by 80% in the next twenty years. This corresponds to a four fold increase in the pressures to migrate out of disaster prone countries at geometric mean values. It leads to a more than doubling of in-migration at geometric mean values of other variables. This assumes that disasters increase in frequency only, with no increase in severity. Stemming this tide has, of course, two possible approaches: reduce the growth rate in weather related disasters, or altering the marginal effect through adaptation strategies that improve the capacity for countries to cope with those disasters.

6. Summary and Policy Implications

In this article, we examine the effect of weather disasters on bilateral emigration for a large sample country-pairs from 1986 to 2006. Given the availability of data, about three quarters of the migration flows in our sample are to the developed countries, and the remaining flows are from the developed to developing countries. Controlling for the effect of many non-weather disaster-related forces that can play a role in migration, including non-weather disasters, we find that increased weather disasters in both the origin and destination countries substantively promote bilateral migration. These findings are robust across a broad range of measurement options.

Assuming business as usual climate change policy, a progressive increase in the incidence, severity, and scope of weather disasters worldwide can be expected. In light of our model, it follows that the impact of weather disasters on migration under severe climate change in the future may be much larger than the current impact. While some policy options for restricting legal immigration, such as quotas, are clear, they do not necessarily stem the tide of illegal migration. Indeed, legal and illegal migration flows are essentially motivated by similar forces-- migrants move in order to better their life. Some migrant manage to obtain all the formal papers and legally enter their desired destination. Others are not able to do so and enter illegally. The size of illegal immigration has been growing worldwide for sometimes now, particularly into the developed countries.[9]

In some cases neither legal nor particularly illegal immigrants are welcome. Many people in destination countries believe that the arrival of migrants would change the culture, damage the local economy, political system, law and order, and national security. Some people reject migrants also because of their different ethnicity, religion, or culture. Facing these political pressures at home, governments typically limit the number of incoming migrants. In the recent decades, hostility to immigration,

[9] For example, it is estimated that 11-12.4 million illegal immigrants live today in the US and 500,000-800,000 have come each year in the recent decade (Papademetriou and Terrazas, 2009; Passell and Cohn, 2009, 2008; Hoefer et al., 2006). About 8 million live in Europe today and 500,000-1 million have entered per year in the recent decade (Commission of the European Communities, 2009; Brady, 2008; Atta, 2006).

especially to illegal immigration, has become quite common. Examples of violence include France (CBC News, 2007), Italy (CNN, 2010), Spain (BBC News, 1999), Britain (UK Migration News, 2001), Australia (Inglis, 2006; YaleGlobal, 2010), the US (HuffingtonPost, 2010; New York Times, 2010, Reuveny, 2008), Greece (BBC News, 2009a, 2009b), Russia (Schwartz, 2008), South Africa (Guardian, 2010; Cape Argus, 2009; Time, 2008), and India, Ethiopia, Eritrea, Senegal, Mauritania, Honduras, and El Salvador (Reuveny, 2007, 2008). Tensions between pro- and anti-immigration residents are growing in the US (Digital Journal, 2010; CNSNews, 2010; Wolverton, 2010). The Economist (2008a, 2008b) describes hostility in the US, Europe, Russia, and India. Reuveny (2007) provides 19 cases (mostly in less developed countries) of violence between residents and intrastate or interstate migrants due to environmental decline, including weather disasters.

The recent controversial legislation in Arizona is a case in point, but anti-immigration sentiments exist elsewhere in the US and in others countries, notably, Europe.[10] Even internal migration may also elicit of this type of hostile response.[11] Many public official frame the prospect of climate change-induced emigration as a grave threat to national security.[12] It seems prudent to search for solutions to prevent these outcomes. We need not continue business indefinitely as usual.

Our model explores two possible ways to alter the pressure for migration. The first is simple simply reduces the rate of growth in weather related disasters by reducing green house gasses. The second

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[10] See, e.g., Papademetriou (2005), MigrationWatch UK (2006), Camarota and Jansenius (2008), The Economist (2008a, 2008b), Commission of the European Communities (2009), European Commission (2009), and Mehan and Howes (2010).

[11] This response is not unique to less developed countries, where national cohesiveness may arguably be weaker. For example, many of the people fleeing the US Great Planes during Dust Bowl of the 1930s or escaping New Orleans due to Hurricane Katrina in 2005 were met with similar rejection (Reuveny, 2008).

[12] See, for example, the outlooks of US Deputy Under Secretary of Defense Hicks (Parthemore and Rogers, 2010), former US Commander-in-Chief of the Central Command General Zinni and Army Chief of Staff General Sullivan (CNA, 2007), former US Vice President Al Gore (2007), and the Schwartz and Randall (2003) report apparently commissioned by the US Department of Defense (N.Y. Times, 2004), and the IPCC (2007b). Kaplan (2000), Mitchell (2006), Reuveny (2007, 2008), Smith (2007), The Economist (2008a, 2008b) and Parsons (2010) provide additional examples.

approach seeks to reduce the effect that weather related disasters have on the pressure to migrate. Our finding suggest that destination countries can reduce the inflow of migrants due to weather disasters by increasing foreign aid to affected origin countries, or by getting international organizations and other countries to do so. Driving the weather disaster-induced propensity to migrate zero, however, requires expenditures on the order of $3 billion per year, per country. This is a large expense to collectively be incurred on a regular basis.[13]

Another problem with using foreign aid as our policy tool is has to do with GDP per capita. Large amounts of foreign aid can quickly increase the recipient's GDP per capita.[14] Based on our model, if recipient's GDP per capita is less than about $2,218, as it is today for most of the less developed countries, a rise in GDP per capita would initially promote migration, wiping out some of even all of the effect of the foreign aid. The marginal effect of foreign aid itself can also be problematic. When the intensity of weather disasters in the origin is smaller than about 8 million people affected, which is quite a large disaster, the next dollar in aid promotes emigration, not reducing it. This is in addition to the effects that rising GDP has on energy consumption and ultimately the release of more green house gasses.

Moreover, to be able to provide such large amounts of foreign aid to origin countries, the destinations' economies would need to flourish; otherwise there may be a huge public outcry at home, demanding to stop the donation. A flourishing destination economy, however, is more attractive for immigrants and this attractiveness increases as the destination is hit by more weather disasters. A successful destination economy hit by weather disasters, we find, reinforces the emigration promoting effect of an unsuccessful origin economy hit by weather disasters.

The problem in using foreign aid in order to reduce emigration due to weather disasters can be traced to the principle of targeting: it does not directly address the source of the problem, which is the

[13] To gain some insight, today, only Iraq, Afghanistan, Israel, Egypt receive foreign aid on the order of several billion dollars per year, and only one country gives these amounts of aid, the US.

[14] Consider, for example, the stellar effect of the American Marshall plan on the Western European economies after World War II.

intensifying weather disasters. Using foreign aid policy to fix a problem of emigration due to weather disasters is akin to using trade barriers to fix a balance of payment or an unemployment problem at home. This second best approach can work in the sense of having an effect on the problematic variable, but there are usually side effects that can alter the overall cost benefit analysis.

Put in other words, using foreign aid policy in addressing our problem amounts to employing an adaptation strategy whose bad side effects can actually increase, not reduce, the emigration. The first best approach in addressing our problem, in contrast, is naturally to attack its source. What we need is climate change mitigation.

To be sure, our approach is problematic. The developed countries will most likely reject it and even if approved it may face a collective-action barrier as countries would try to shift burdens to others. Our plan may be initiated eventually in response to some severe crisis, but then it may be too late. It seems better to put in place an aggressive mitigation plan today and hope for the best than take a do nothing approach; there is simply too much at stake. This idea, of course, applies to all public policy; we try to address problems before they become too large. This policy approach has served us well, but, unfortunately, if the current state of the affairs is any indication for the future, it is unlikely that it will implemented anytime soon.

References

Atta A. (2006), "Porous Borders: Illegal Immigration in Europe," Harvard International Review, 28(3).

BBC News (2009a) "Immigrants Hurt in Greek Violence," May 10, http://news.bbc.co.uk/2/hi/8042409.stm

BCC News (2009b), "Greek Police Flatten Migrant Camp,"July 12, http://news.bbc.co.uk/2/hi/8146597.stm

BBC News (2000), "Mutual Fears Behind Spain's Race Riots ," February 8, http://news.bbc.co.uk/2/hi/europe/635514.stm

Brücker, H., and B. Siliverstovs (2006), "On the Estimation and Forecasting of International Migration: How Relevant Is Heterogeneity Across Countries?," Empirical Economics, 31: 735-754.

Bodvarsson, O. B. and H. Van den Berg (2009), The Economics of Immigration: Theory and Policy, New York: Springer.

Borda, R. D. A. and R. Mahia (2010), Determinants of Migration Flows Between EU and MPC: The Case of Algeria, Egypt, Morocco, and Tunisia, Saarbrücken, Germany: LAP Lambert Academic Publishing.

Brady H. (2008), EU Migration Policy: An A-Z, Center for European Reform (CER), London, UK, www.cer.org.uk.

Camarota, S. A. and K. Jansenius (2008), Homeward Bound: Recent Immigration Enforcement and the Decline in the Illegal Alien Population, Center for Immigration Studies, Washington DC.

Cape Argos (2009), Media: Tension Brewing in Townships Over Foreigners, June 1, South Africa, www.antieviction.org.za/2009/06/02/media-tension-brewing-in-townships-over-foreigners/#more-2566.

CBC News (2007), In Depth, France Riots: Understanding the Violence, November 28, Canada. www.cbc.ca/news/background/paris_riots/

Chu-Whan, S. (1999), "North Korean Escapees Are Treaty-defined Refugees," International Conference of NGOs, Seoul, South Korea.

Clark, X., T.J. Hatton, and J.G. Williamson (2007), "Explaining U.S. Immigration, 1971-1998," The Review of Economics and Statistics, 89(2): 359-373.

CNA (2007), "National Security and the Threat of Climate Change," The CNA Corporation, Alexandria, VA, http://www.SecurityAnd Climate.cna.org.

CNN (2010), Migrants Leave Italian Town Amid Violence, January 11, US. www.cnn.com/2010/WORLD/europe/01/11/italy.migrant.violence/index.html.

CNSNews.com (2010), Arizona Sheriff Says Cops Are Being Killed by Illegal Alliens; Joins Call for U.S. Troops at Border, April 20, Arlington, VA, http://www.cnsnews.com/news/article/64385.

Commission of the European Communities (2009), Communication From he Commission to the European Parliament and the Council: An Area of Freedom, Security, and Justice Serving the Citizen, COM 262/4, Brussel, Belgium.

COW (2006), Direct Contiguity Data, 1816-2006, V. 3.1, Correlates of War Project, http://correlatesofwar.org.

Cruz, M.C., C.A. Meyer, R. Repetto, and R. Woodward (1992), Population Growth, Poverty, and Environmental Stress: Frontier Migration in the Philippines and Costa Rica, Washington, DC: World Resources Institute.

Digital Journal (2010), Rioting Violence, Mar Protests of Arizona Immigration Laws, Toronto, Canada, www.digitaljournal.com/article/291517.

El-Hinnawi, E. (1985), Environmental Refugees, Nairobi, Kenya: United Nations Environment Programme.

EM-DAT (2008), The OFDA/CRED International Disaster Database – Université Catholique de Louvain, Brussels, Belgium, http://www.emdat.be/.

EM-DAT, 2009a. Trends and Relationships Periods 1900-2008. Emergency Events Database, Centre for Research on the Epidemiology of Disasters, Université Catholique de Louvain, Belgium. http://www.EM-DAT.be/Database/Trends/trends.html

EM-DAT, 2009b. EM-DAT Database Advanced Search, Emergency Events Database, Centre for Research on the Epidemiology of Disasters, Université Catholique de Louvain, Belgium. http://www.emdat.be/Database/AdvanceSearch/advsearch.php.

European Commission (2009), An Opportunity and a Challenge: Migration in the European Union, Directorate-General for Communication, Luxemburg: Publication Office of the European Union.

GEO Portal (2010). UNEP/DEWA/GRID-Europe. Global Environment Outlook. United Nations Environment Programme, Nairobi, Kenya, http://geodata.grid.unep.ch/.

Gore, A. (2007), An Inconvenient Truth. New York: Rodale Books.

Guardian (2010), Warning of Xenophobic Violence in South African After World Cup: Foreign Migrants and Refugees Fear Attacks after Tournament, May 17, UK, www.guardian.co.uk/world/2010/may/17/south-africa-world-cup-xenophobic-violence.

Hatton, T.J., and J.G. Williamson (2003), "Demographic and Economic Pressure on Emigration Out of Africa," The Scandinavian Journal of Economics, 105(3): 465-486.

Heston, A., R. Summers, and B. Aten (2009), Penn World Table Version 6.3, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, http://pwt.econ.upenn.edu/.

Hoefer M., N. Retina and C. Campbell (2006), Estimates of the Unauthorized Immigrant Population Residing in the United States: January 2005, Office of Immigration Statistics: Policy Directorate, Department of Homeland Security, Washington DC.

Hori, M., M.J. Schafer, and D.J. Bowman (2009), "Displacement Dynamics in Southern Louisiana after Hurricanes Katrina and Rita," Population Research and Policy Review, 28(1): 45-65.

HuffingtonPost (2010), "Report: An 'Astonishing' Rise in Anti Immigrant, Anti-Government Groups," March 2, www.huffingtonpost.com/2010/03/02/report-an-astonishing-ris_n_482409.html.

IMF (2008), Directions of Trade Statistics, International Monetary Fund, Washington, DC, http://www2.imfstatistics.org/DOT/.

Inglis, C. (2006), On the Beach: Racial Confrontation in Australia, Migration Information Resources, Migration Policy Institute, Washington DC.

IPCC (2007a), "Climate Change 2007: The Physical Science Basis, Summary for Policymakers," Intergovernmental Panel on Climate Change, Geneva, Switzerland, http://www.ipcc.ch.

IPCC (2007b), "Climate Change 2007: Impacts, Adaptation, and Vulnerability, Summary for Policymakers," Intergovernmental Panel on Climate Change, Geneva, Switzerland, http://www.ipcc.ch.

Jacobson, J.L. (1989), “Environmental Refugees: Nature’s Warning System,” Populi, 16(1): 29-35.

Kahn, M.E. (2005), “The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions,” Review of Economics and Statistics, 87(2): 271-284.

Karemera, D., V.I. Oguledo, and B. Davis (2000), “A Gravity Model Analysis of International Migration to North America,” Applied Economics, 32: 1745-1755.

Krikorian, M. (1999), “Here to Stay There’s Nothing as Permanent as a Temporary Refugee,” Center for Immigration Studies, Washington, DC, http://www.cis.org.

Lee, S. (2001), Environment Matters: Conflicts, Refugees, & International Relations, Tokyo: World Human Development Institute Press.

Maoz, Z. (2005), Dyadic MID Dataset V. 2.0, http://psfaculty.ucdavis.edu/zmaoz/dyadmid.html.

Martin, P., and J. Widgren (2002), “International Migration: Facing the Challenge,” Population Bulletin, 57(1): 3-40.

Mehan, R. and N. Howes (2010), Immigration: A Debate Crippled by a Lack of Accurate Data, Straight Statistics, April 26, London, UK, www.straightstatistics.org

Melander, E., and M. Öberg (2007), “The Threat of Violence and Forced Migration: Geographical Scope Trumps Intensity of Fighting,” Civil Wars, 9(2): 156-173.

Migration News (1999), “Hurricane Mitch,” February, Vol. 6(4).

Migration News (2001), “UK: Ethnic Violence,” August, Vol. 8(8).

MigrationWatch UK (2006), “An Amnesty for Illegal Immigrants?” Policy, Amnesty & Voting 11.7, Guildford, UK

Mitchell, S.M. (2006), “Introduction to Special Issue: Conflict and Cooperation Over International Rivers,” Political Geography, 25(4): 357-360.

Naudé, W. (2009), “Natural Disasters and International Migration from Sub-Saharan Africa,” Migration Letters, 6(2):165-176.

New York Times (2004), “The Sky Is Falling! Say Hollywood and, Yes, the Pentagon,” February 29.

New York Times (2008), “Moscow’s Immigrants Face Wave of Skinhead Violence,” February 19.

OECD (2009a), International Migration Database, Organization of Economic Cooperation and Development, Paris, France, http://stats.oecd.org/

OECD (2009b), DAC2a ODA Disbursements, Organization of Economic Development and Cooperation, Paris, France, http://stats.oecd.org/.

Papademetriou, D. G. (2005), The Global Struggle with Illegal Immigration: No End in Sight, Migration Information Source, Migration Policy Institute, Washington DC.

Papademetriou, D. G. and A. Terrazas (2009), Immigrants in the United States and the Current Economic Crisis, Migration Information Source, Migration Policy Institute, Washington DC.

Parsons, R. J. E. (2010), Climate Change: The Hottest Issue in Security Studies?” Risk, Hazards & Crisis in Public Policy, 1(1): 87-116.

Parthemore, C., and W. Rogers (2010), “Promoting the Dialogue: Climate Change and the Quadrennial Defense Review,” Working paper for the Center for a New American Security, Washington, DC, http://www.cnas.org/node/4008.

Passell, J. S. and D. Cohn (2009), A Portrait of Unauthorized Immigrants in the United States, Pew Hispanic Center, Washington DC.

Passell, J. S. and D. Cohn (2009), Trends in Unauthorized Immigration: Undocumented Inflow Now Trails Legal Inflow, Pew Hispanic Center, Washington DC.

Pedersen, P.J., M. Pytlikova, and N. Smith (2008), “Selection and Network Effects—Migration Flows into OECD Countries 1990-2000,” European Economic Review, 52: 1160-1186.

Peduzzi, P. (2005), “Is Climate Change Increasing the Frequency of Hazardous Events?,” Environmental and Poverty Times, 3 (February 22), 7.

Pielke, R. A. Jr., J. Gratz, C.W. Landsea, D. Collins, M.A. Saunders, and R. Musulin (2008), “Normalized Hurricane Damage in the United States: 1900–2005,” Natural Hazard Review, 9(1), 29-42.

Raschky, P.A. (2008), “Institutions and Losses from Natural Disasters,” Natural Hazards and Earth System Sciences, 8(2): 627-634.

Reuveny, R. (2007), “Climate Change-induced Migration and Violent Conflict,” Political Geography, 26: 656-673.

Reuveny, R. (2008), “Ecomigration and Violent Conflict: Case Studies and Public Policy Implications,” Human Ecology, 36: 1-13.

Reuveny, R., and W.H. Moore (2009), “Does Environmental Degradation Influence Migration? Emigration to Developed Countries in the Late 1980s and 1990s,” Social Science Quarterly, 90(3): 461-479.

Reuveny, R., and A. Peterson Allen (2008), “On Environmental Refugees and Implications for the Future,” Ecología Política, Vol. 33: 21-36, 2007.

Schwartz, P., and D. Randall (2003), “An Abrupt Climate Change Scenario and Its Implications for United States National Security,” Global Business Network, San Francisco, CA, http://www.gbn.com/ArticleDisplayServlet.srv?aid=26231.

Scoones, I. (1992), “Coping with Drought: Responses of Herders and Livestock in Contrasting Savanna Environments in Southern Zimbabwe,” Human Ecology, 20(3): 293-314.

Skidmore, M. and H. Toya (2002), “Do Natural Disasters Promote Long-run Growth?,” Economic Inquiry, 40(4): 664-687.

Smith, P. J. (2007), "Climate Change, Mass Migration, and the Military Response," Orbis, 51(4):617-633.

Smith, S.K., and C. McCarty (1996), "Demographic Effects of Natural Disasters: A Case Study of Hurricane Andrew," Demography, 33(2): 265-275.

Smith, S.K., and C. McCarty (2006), "Florida's 2004 Hurricane Season: Demographic Response and Recovery," Paper presented at the Southern Demographic Association meeting, Durham, NC.

SOPEMI (1990), "Continuous Reporting System on Migration: SOPEMI." Paris: Organization for Economic Co-operation and Development, Directorate for Social Affairs, Manpower, and Education.

Strömberg, D. (2007), "Natural Disaster, Economic Development, and Humanitarian Aid," Journal of Economic Perspectives, 21(3): 199-222.

Swain, A. (1996), "Environmental Migration and Conflict Dynamics: Focus on Developing Regions," Third World Quarterly, 17(5): 959-974.

The Economist (2008a), "The Politics of the Gun," Special Report: Migration, January 3, London: UK.

The Economist (2008b), "Keep Out," Special Report: Migration, January 3, London: UK.

Time (2008), South Africa Violence: Beyond Racism, May 30, Cape Town, South Africa, www.time.com/time/world/article/0,8599,1810805,00.html

UCDP/PRIO (2009), Armed Conflict Dataset, Uppsala Conflict Data Program, Uppsala University, Sweden, and International Peace Research Institute, Oslo, Norway, http://www.prio.no/CSCW/Datasets/Armed-Conflict/UCDP-PRIO/.

UNISDR (2008), "Disaster Statistics, Occurrence: Trends-century. International Strategy for Disaster Reduction." Geneva, Switzerland. http://www.unisdr.org/disaster-statistics/occurrence-trends-century.htm.

United Nations (2008), "World Economic and Social Survey 2008: Overcoming Economic Insecurity." Department of Economic and Social Affairs. New York: United Nations.

USINS (1996), Statistical Yearbook of the Immigration and Naturalization Service, U.S. Department of Justice, Washington, DC, http://www.dhs.gov/files/statistics/publications/archive.shtm

White House (2006), The Federal Response to Hurricane Katrina: Lessons Learned, February 23, Assistant to the President for Homeland Security and Counter-terrorism, Washington, DC.

Wolverton (2010), "Other States Consider Arizona-style Anti-immigration Statutes," The New American, May 11, www.thenewamerican.com/index.php/usnews/immigration/3531-other-states-consider-arizona-style-anti-immigration-statutes.

Worster D. (1979), Dust Bowl: The Southern Plains in the 1930s, New York: Oxford University Press.

YaleGlobal (2010), "Anti-Immigration Backlash Roils Ties Between Australia and India," Online Magazine, March 5, New Haven, CT, www.yaleglobal.yale.edu.

Yoon, Y.S. (1998), On the Situation of North Korean Defectors in China, Field Survey Report Conducted in China in 1998, Seoul: Korea Political Development.

Table 1. Summary statistics of the data sample

Variable	Description	Obs	Arithmetic Mean	Geometric mean	Std. Dev.	Max
M_OD	Migration flow from origin to destination (thousand)	28719	1.99000	1.64841	10.5387	946.167
WDI_O	Number of weather-related disaster at origin	28687	2.23833	2.11804	4.09271	34
WDA_O	People affected by weather-related disaster at origin (million)	28719	1.69716	1.17125	16.6945	342.021
WDK_O	People killed by weather-related disaster at origin	28719	114.056	4.48291	1583.27	139469
NWDI_O	Number of non-weather-related disaster at origin	28718	0.17209	1.08829	0.75112	11
NWDA_O	People affected by non-weather-related disaster at origin (million)	28719	0.02500	1.01233	0.35447	20.004
NWDK_O	People killed by non-weather-related disaster at origin	28719	84.5993	1.21972	1873.98	73338
Pop_O	Population at origin (million)	28719	48.3548	14.2155	149.171	1313.97
GDP_O	GDP per capita at origin ($000)	28719	20.6084	13.8847	17.2894	74.3661
CWar_O	Civil war at origin	28719	0.03618	-	0.18675	1
WDI_D	Number of weather-related disaster at destination	28675	3.83937	2.65475	6.9359	34
WDA_D	People affected by weather-related disaster at destination (million)	28719	1.10725	1.15022	12.8156	342.021
WDK_D	People killed by weather-related disaster at destination	28719	97.6102	6.25815	577.015	30005
NWDI_D	Number of non-weather-related disaster at destination	28719	0.22713	1.12228	0.79921	11
NWDA_D	People affected by non-weather-related disaster at destination (million)	28719	0.01792	1.00980	0.24875	20.004
NWDK_D	People killed by non-weather-related disaster at destination	28719	80.0272	1.26216	1613.59	73338
Pop_D	Population at destination (million)	28719	62.1279	21.2410	133.417	1313.97
GDP_D	GDP per capita at destination ($000)	28719	23.3139	17.9003	15.0149	76.2276
CWar_D	Civil war at destination	28719	0.02270	-	0.14896	1
War_OD	War between origin and destination	28719	0.00063	-	0.02503	1
Aid_DO	Aid per capita from destination to origin	28719	2.03770	1.41446	21.2952	1353.71
Aid_RO	Aid per capita from Rest of the world to origin	28719	19.3249	4.23999	49.1096	1462.03

Table 2: Basic model

Variables	People Affected by Disasters
ln(WD_O)	0.01717***
	(0.00216)
ln(NWD_O)	0.00178
	(0.00225)
ln(Pop_O)	1.40377***
	(0.30569)
ln(GDP_O)	-0.30619**
	(0.13117)
CWar_O	0.14430***
	(0.04582)
ln(WD_D)	0.01032***
	(0.00239)
ln(NWD_D)	0.00663***
	(0.00254)
ln(Pop_D)	0.00952
	(0.35091)
ln(GDP_D)	0.96868***
	(0.15909)
CWar_D	-0.28219***
	(0.09534)
ln(Aid_DO)	0.05172*
	(0.02953)
ln(Aid_RO)	-0.06381***
	(0.02281)
ln(WD_O) x ln(Aid_DO)	-0.00464**
	(0.00223)
ln(WD_O) x ln(Aid_RO)	-0.00631***
	(0.00158)
War_OD	0.44794
	(0.30831)
ln(WD_O) x ln(GDP_O)	0.00376*
	(0.00206)
ln(WD_D) x ln(GDP_D)	0.00701***
	(0.00165)
$\ln(GDP\_O)^2$	-0.09288***
	(0.03581)
$\ln(GDP\_D)^2$	0.10791***
	(0.03699)
Constant	0.39172***
	(0.11255)
Observations	28719
R-squared	0.911

Note: Each variable is logged and centered on its mean logged value. Robust standard errors clustered by dyad are shown in parentheses. Dyadic and yearly fixed effects are estimated but not shown.

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Additional Analyses

Variables	People Affected by Disasters per Population	People Affected by Disasters per Area	Incidence of Disasters	People Killed by Disasters
ln(WD_O)	0.01712***	0.01698***	0.07477***	0.01422***
	(0.00216)	(0.00216)	(0.01320)	(0.00403)
ln(NWD_O)	0.00175	0.00156	0.00149	-0.00975**
	(0.00225)	(0.00226)	(0.02141)	(0.00474)
ln(Pop_O)	1.39880***	1.40333***	1.49447***	1.30353***
	(0.30557)	(0.30583)	(0.30407)	(0.30573)
ln(GDP_O)	-0.30647**	-0.30971**	-0.27786**	-0.28895**
	(0.13099)	(0.13118)	(0.13059)	(0.13070)
CWar_O	0.14407***	0.14419***	0.14626***	0.15307***
	(0.04589)	(0.04594)	(0.04621)	(0.04620)
ln(WD_D)	0.01003***	0.01004***	0.06669***	0.02834***
	(0.00240)	(0.00239)	(0.01290)	(0.00450)
ln(NWD_D)	0.00653**	0.00656***	0.01495	-0.02027***
	(0.00254)	(0.00254)	(0.02439)	(0.00700)
ln(Pop_D)	0.01060	0.01119	0.07950	0.07972
	(0.35127)	(0.35106)	(0.35202)	(0.35027)
ln(GDP_D)	0.95969***	0.96072***	0.97928***	0.97627***
	(0.15966)	(0.15960)	(0.15994)	(0.16080)
CWar_D	-0.28242***	-0.28228***	-0.28529***	-0.24945***
	(0.09527)	(0.09524)	(0.09531)	(0.09384)
ln(Aid_DO)	0.05820*	0.05763*	0.04511	0.05627*
	(0.03004)	(0.02998)	(0.02929)	(0.02948)
ln(Aid_RO)	-0.06528***	-0.06311***	-0.05919***	-0.06167***
	(0.02288)	(0.02294)	(0.02283)	(0.02254)
ln(WD_O) x ln(Aid_DO)	-0.00493**	-0.00535**	-0.05453***	-0.01994***
	(0.00227)	(0.00230)	(0.01978)	(0.00613)
ln(WD_O) x ln(Aid_RO)	-0.00597***	-0.00603***	-0.02982**	-0.00266
	(0.00155)	(0.00155)	(0.01281)	(0.00431)
War_OD	0.44842	0.44716	0.43384	0.46869
	(0.30798)	(0.30798)	(0.34670)	(0.31185)
ln(WD_O) x ln(GDP_O)	0.00399*	0.00360*	0.01222	0.00395
	(0.00204)	(0.00204)	(0.01728)	(0.00538)
ln(WD_D) x ln(GDP_D)	0.00637***	0.00637***	0.04245***	0.01956***
	(0.00164)	(0.00164)	(0.01251)	(0.00425)
$\ln(GDP\_O)^2$	-0.09245***	-0.09402***	-0.08687**	-0.08689**
	(0.03585)	(0.03588)	(0.03595)	(0.03598)
$\ln(GDP\_D)^2$	0.10594***	0.10566***	0.10396***	0.10394***
	(0.03713)	(0.03711)	(0.03707)	(0.03722)
Constant	0.39181***	0.39541***	0.35994***	0.32326***
	(0.11257)	(0.11263)	(0.11362)	(0.11207)
Observations	28719	28719	28,642	28,719
R-squared	0.911	0.911	0.910	0.910

Note: Each variable is logged and centered on its mean logged value. Robust standard errors clustered by dyad are shown in parentheses. Dyadic and yearly fixed effects are estimated but not shown.

*** p<0.01, ** p<0.05, * p<0.1

Figure 1. Total number of weather and non-weather related disasters in the world in 1980-2009 (compiled from EM-DAT, 2010).