Climate Change, Income Shocks and Violence: Understanding Migration from Central America*

Sarah Blodgett Bermeo and David Leblang

Presented at Global Research in International Political Economy Seminar
April 28, 2021
Draft: Comments Welcome

Abstract

Negative effects of climate change are expected to produce large increases in migrants in the coming decades. The mechanisms by which climate change will lead to increased migration are not well theorized. We conceptualize climate change as producing negative income shocks. These shocks alter the relationship between income and migration that would be predicted based on the general level of development in a country. There is ample evidence of a positive relationship between increased income from development and emigration for a wide band of country income levels. This relationship is reversed when a country experiences a negative income shock: lower income due to a shock can increase migration, leading to a negative relationship between income and migration. Further, we hypothesize that the emigration rate due to a shock is likely to be influenced by the viability and attractiveness of internal migration options. We test our hypotheses using subnational data on apprehensions of Honduran migrants at the U.S. southern border between 2012 and 2019, obtained from a Freedom of Information Act request. We find that departments within Honduras that experienced a negative income shock due to low rainfall have increased apprehensions at the U.S. border the following year. When violence levels are high in a department the magnitude of this relationship increases, suggesting that worse local conditions lead to increased emigration. These results have practical applications for policymakers considering responses to climate change that might ease migration pressures.

*Sarah Bermeo is Associate Professor of Public Policy and Political Science, Sanford School, Duke University (email: sarah.bermeo@duke.edu); David Leblang is Ambassador Henry J. Taylor and Mrs. Marion R. Taylor Endowed Professor, Politics Department and Frank Batten School of Leadership and Public Policy, University of Virginia (email:leblang@virginia.edu). We thank Cynthia Joseph for valuable research assistance on this project.

The number of climate migrants is estimated to grow to anywhere from 25 million to 1 billion people by 2050, possibly exceeding the current total of all worldwide migrants as drought, sea-level rise and violent storms increase in frequency and intensity (Brown, 2008). Despite the widespread belief that climate change will lead to significant increases in international migration, the mechanisms by which this increase will occur are not well-theorized. Well-established findings regarding the nexus between development and migration overwhelmingly show that for countries below a certain income threshold, income and migration have a positive relationship: higher income is associated with increased levels of migration (Zelinsky, 1971; Clemens, 2020). To the extent that projected increases in climate migration are expected to result from decreases in income for many people in poor countries, they do not fit neatly into existing theory.

Since the seminal work of Zelinsky (1971), researchers have consistently found evidence supporting the idea of a "mobility transition" that produces a "migration hump", with emigration increasing as a country develops up until a certain point, at which time further development is associated with decreases in migration. One possible application of this theory to climate change would suggest that if a country is on the positively sloped portion of the "hump" linking income and migration, when income declines due to a climate shock then migration should also decline. This interpretation would be inconsistent with numerous predictions of large increases in migration as the impacts of climate change grow. It is also inconsistent with large increases in observed migrant flows from places experiencing prolonged drought - a negative income shock - such as has been observed in many recent years in the Dry Corridor of Central America.

To better understand the link between climate change and migration, it is necessary to conceptualize the impacts of climate change as a negative shock to the normal migration-development relationship. At any level of development, there exists a set of people that would be predicted by the general relationship between development and migration to emigrate from their country of origin. This can be due to some combination of their wage at home relative to abroad (wage gap), accumulated wealth, education, location, connections abroad, and other factors. A shock can be conceptualized as something that occurs to throw a country off this

normal development-migration path; something that shifts the curve linking migration and development. Climate change can operate as a negative income shock, changing migration levels from what they would have been in the absence of such a shock. This can lead to increases in migration associated with decreases in income.

Income shocks may disproportionately affect some groups within a country while having little impact on others. Climate change is likely to affect subsets of the population large enough to have measurable impacts on total emigration, yet its impacts will be disproportionate across groups within a country. Disentangling development impacts on migration from those caused by a sub-national shock is generally hampered by lack of data on emigration at a sub-national level.

We use data from a Freedom of Information Act request that include subnational location of birth for Honduran migrants apprehended at the US southern border between 2012 and 2019 to study the link between climatic changes and migration. During this period Honduras suffered from a multi-year drought linked to climate change. Declines in precipitation (which create negative income shocks) vary significantly at the subnational level and over time, making it possible to examine how these variations are associated with different levels of migrant apprehensions in the United States. We include a measure of average wealth in our analysis, which also varies at the subnational level, so that we are able to observe the link between apprehensions and precipitation shocks, while controlling for baseline wealth.

During this time Honduras has also experienced exceptional levels of violence, consistently ranking among the countries of the world with the highest homicide rates per capita.[1] Like precipitation shocks, homicide rates also vary at the subnational level in Honduras. This allows us to examine whether the association between a negative income shock and emigration depends on other factors in a country, such as high levels of violence, that might decrease the viability or attractiveness of internal migration.

Our analysis shows a clear association between decreases in rainfall in a department and increases in migrant apprehensions from that department the following year in the United States.

[1]World Bank, World Development Indicators.

We find that the magnitude of the link between rainfall deviations and migration increases when violence is higher. As violence makes internal migration less desirable or possible, a negative economic shock in a subnational region is associated with more emigration from that region to the United States.

These findings help us better understand the link between negative income shocks and migration, contributing to a broad literature that has often been unable to distinguish shocks from long-term development. The results also contribute to the literature on climate migration and particularly to the study of links between climatic factors and other root causes, such as violence, that influence migration decisions.

Understanding the role of negative economic shocks in driving migration is particularly important for crafting policy, including in the growing area of concern related to climate migration. Many wealthy states have indicated a desire to curb migration by addressing root causes in migrant sending countries. Given the strong evidence of a "migration hump", scholars have rightly urged caution in assuming aid or trade programs that foster development will lead to lower migration. This is useful advice when the root cause of migration is development. When a negative shock pushes migration higher than predicted by its location on the "migration life cycle" path, addressing the root causes of the shock is likely to lead to decreased migration flows. In countries where shocks have caused migration to be abnormally high for their stage of development, our analysis suggests that effective outside assistance can lower migration to its steady state rate.

1 Migration and Income

Early, relatively simple models of migration argued that individuals move abroad in order to maximize a future income stream. From this perspective, migration occurs if the expected wage in a destination exceeds the expected wage in the home country and the costs of moving (Sjaastad, 1962, e.g.,)). According to this theory, a larger wage gap between home and destination countries would, all else equal, result in higher levels of migration.

In practice, the simple wage-gap model runs counter to observed fact: as poorer countries develop, they go through a phase of increased migration until they reach a certain income level, after which migration begins to fall again. This idea of a "mobility transition" was hypothesized by Zelinsky (1971) and the relationship between average country income and emigration rates has since been described as an "inverted-U" or "migration hump" with numerous studies finding strong statistical support for this relationship (See Clemens (2020) and Bencek and Schneiderheinze (2020) for an overview of the literature).[2]

The increasing levels of migration as average income initially rises have been associated with multiple causes. At very low average wage rates, individuals who desire migration may face financial constraints that make migration impossible. As wages rise, the wage gap between the home and destination country may decrease but the ability to afford migration increases; the latter may carry more weight than the former for certain segments of the income distribution (Faini and Venturini, 1994; Hatton and Williamson, 1994, 1998).

Other scholars look at broader transformations that occur as societies develop. Returns to education from migration may be higher than returns in the domestic labor market; since education increases with development the rise in development will be associated with an increase in emigration (Clemens, 2020; Hanson, 2010; Massey et al., 1993). Development can be accompanied by a demographic transition within a country, causing a sharp increase in young workers entering the labor market and resulting in emigration to ease domestic labor supply pressure (Hatton and Williamson, 1998; Hanson and McIntosh, 2010). Migration policies abroad may favor more highly skilled workers, creating increased opportunity for migration as development increases the skills of the workforce (Clemens, 2014). Development can lead to rising income inequality, causing some people to choose migration because they feel worse-off relative to reference groups. Increased trade linkages, transportation and communication

[2]Studies include Clark, Hatton and Williamson (2004); Clemens (2014); Dao et al. (2018); De Haas (2007); de Haas et al. (2019); Faini and Venturini (2010); Hatton and Williamson (2003); Massey et al. (1993); Skeldon (1997).

networks, and knowledge gleaned from previous migrants can facilitate migration as a country develops (Beine, Docquier and Ozden, 2011; Massey et al., 1993; Martin and Taylor, 1996; Faini and Venturini, 2010).

The difference between societal-level determinants that evolve relatively slowly over time with development and sudden shocks is key to our theory. A main reason that the wage gap model fails to explain migration is that as a country develops and wages rise, other societal changes also occur. These changes often have opposite impact on likelihood to migrate than the declining wage gap between home and destination countries that occurs as countries grow wealthier. Up until a certain income level (estimated by Clemens (2014) at around $7000 per capita), these other factors more than offset the declining wage gap, causing more people to migrate. At higher income levels this reverses, with the declines in the wage gap causing fewer people to emigrate. The simple wage-gap model would predict emigration demand well if all else were equal; it is the changing of other factors with development that causes the wage-gap model to lose much of its explanatory power at middle-income levels.

Dao et al. (2018) examine the relative impact of individual (micro) and societal (macro) determinants of emigration. They find that for a broad span of average country incomes, macro (societal) determinants explain the positive relationship between development and migration. While capital constraints may be important in keeping migration low when average country incomes are below $1,500, Dao et al. (2018, p. 90) conclude that microeconomic drivers such as the wage gap and capital constraints are less important in the upward sloping part of curve. They argue that in countries with per capita incomes between $1,500 and $6,000 “The upward segment of the mobility transition curve is mostly explained by the changing skill composition of working-age populations at origin in addition to macroeconomic drivers (i.e., network size and gravity drivers) that are constant or else adjust very slowly. In other words, by factors that do not change in the short-run.”

The impacts of climate change can create a negative income shock, for example decreasing the productivity of cropland, while not altering the slow-moving societal determinants of

migration (at least in the short-term). The income shock occurs and the level of education, social networks abroad, and perhaps even accumulated wealth do not change as quickly. It is as if the wage gap between home and potential destination countries has widened and *all else has remained equal.* Given this, we would expect the predictions of the wage-gap model to hold: the decrease in income due to a sudden shock, holding many societal factors constant, should be associated with an increased desire for migration. The larger the shock, the higher the percentage of people who will be predicted to choose migration.

In addition to the wage gap, a few other factors point to a likelihood of increased migration following a shock. If individuals have accumulated wealth and if they anticipate the wage gap will persist, they may choose to migrate before they use all their savings supporting a certain standard of living with lower wages. In addition to this, the loss of income is likely associated with a feeling of relative deprivation from the previous reference point before the shock. Individuals are sensitive to this sense of loss and can become more risk seeking when attempting to restore themselves to their previous level of welfare and reverse their loss (Kahneman and Tversky, 1979).

This leads us to the following hypothesis:

H1: When faced with a climatic shock that has a negative impact on income relative to previous levels, individuals are more likely to migrate and larger or more prolonged shocks are likely to be met with greater migration, everything else remaining equal.

For developing countries we still expect a positive relationship between accumulated or average levels of wealth at the time of a negative shock and migration. Accumulated assets create the ability to migrate while a negative wage shock increases the desire to migrate. Separating out these two variables - accumulated wealth and wage shocks - is important for understanding the level of migration response of communities when faced with a climatic event that has a negative impact on wages.

1.1 Income Shocks and Violence

Climate shocks may create a desire to move, but movement need not result in emigration. Researchers at the World Bank predict large increases by 2050 in internal migration due to climate change (Rigaud et al., 2018). Internal migration and emigration can be related, particularly if large internal movement creates stress on existing structures or generates unrest or violence, any of which could increase the desirability of emigration both for those who have previously moved within their country and those who have not. Scholars have linked the civil war in Syria to preceding increases in internal migration (Ash and Obradovich, 2020) and rapid rural to urban migration is creating stress on cities in Central America (Manzi, 2020). The likelihood that climate-related income shocks lead to emigration, rather than internal migration, is likely a function of the viability and desirability of internal migration options.

In Honduras, as well as some of its neighboring countries, high levels of violence are a factor that could influence this decision. We expect that when high levels of violence make local migration options less attractive, individuals will be more likely to emigrate than to relocate internally. This implies an interactive relationship between climate-related income shocks and violence, leading to the following hypothesis:

H2: When levels of violence are high, the magnitude of the relationship between an income shock and emigration will be higher than when levels of violence are lower.

2 Honduras Emigration

Our empirical analysis focuses on migration to the United States of family units from Honduras for the period 2012-2019. Honduras is a small country, with a population 9.7 million people and income per capita of $2,575, making it one of the poorest countries in the Western Hemisphere.[3]

[3]World Bank, World Development Indicators.

This also places Honduras squarely within the range of incomes for countries that are projected to be on the upward portion of the inverted-U that constitutes the migration hump: the relationship between income and migration would be expected to be positive, absent a shock.[4]

The Central American region is considered highly susceptible to the impacts of climate change, particularly those associated with increased intensity and frequency of storms, sea-level rise, and drought. During the period or our study the Dry Corridor of Central America, which runs through portions of Honduras, experienced a severe and prolonged period of reduced precipitation and drought. This created a sharp increase in acute food insecurity, particularly for subsistence farmers in affected areas.[5] Emergency appeals for food assistance note that farmers in some areas lost 60-80% of their crops during at least one harvest.[6] In many areas, crops have failed multiple times in the last five years due to decreased rainfall. Organizations working in the region note that as crops have failed (a negative income shock) people list emigration as a coping strategy.[7]

Honduras has also experienced high and persistent levels of violence. Homicide rates declined from a high of 84 per 100,000 people in 2011 to 39 per 100,000 people in 2018, but this still left Honduras with one of the highest homicide rates in the world.[8] Violence, death-threats

[4]The upward-sloping portion of the inverted-U, where income and migration have been found to have a positive relationship, ranges from approximately $500 to $7,000 (Clemens, 2014; Dao et al., 2018); while there is some variation in these estimates, all studies would include per-capita income at the level observed in Honduras on the upward-sloping portion.

[5]World Food Programme report, "Food Security and Emigration", August 2017.

[6]Food and Agricultural Organization report June 2016: http://www.fao.org/3/br092e/br092e.pdf.

[7]World Food Programme, "Erratic Weather Patterns in the Central American Dry Corridor Leave 1.4 Million People in Urgent Need of Food Assistance," April 25, 2019. Gustin, Georgina. "Ravaged by Drought, a Honduran Village Faces a Choice: Pray for Rain or Migrate," *Inside Climate News,* July 8, 2019.

[8]World Bank, World Development Indicators.

and extortion related to international drug trafficking and gang activity are repeatedly documented by international groups.[9] Elevated levels of corruption and poor governance contribute to these problems and prevent meaningful domestic solutions (Restrepo, 2021).

Against this background of high food insecurity, violence, corruption and poor governance, the number of Honduran families traveling to the United States has grown significantly. Figure 1 shows the growth in total apprehensions of Hondurans at the U.S. southern border as well as apprehensions of individuals traveling as part of a family unit. Given the multiple and possibly intertwined factors that are likely contributing to this increased emigration, we turn to subnational variation in emigration rates, climate shocks and violence to better understand the root causes.

3 Data

The study is based on data for approximately 320,000 apprehensions by United States Customs and Border Protection (CBP) of individuals born in Honduras and arriving as part of a family unit at the US southern border during the fiscal years 2012-2019. "Apprehension" includes those who voluntarily present themselves to border patrol, in some cases to seek asylum. Data were obtained through a Freedom of Information Act request and identify city and department of birth for those apprehended. United States fiscal years run from October through September (e.g. fiscal year 2019 ends in September 2019). The yearly totals closely align with published country-level totals of family unit apprehensions, verifying that the data obtained through the FoIA request represent the universe of apprehensions in this category. (Note: we have comparable data for Guatemala and El Salvador and are currently working to clean them and add those countries to the study).

The unit of analysis is the department-year. In Honduras, a department is a sub-national political unit similar to a state. We aggregate the number of individuals apprehended by

[9]See Human Rights Watch report "Honduras: Events of 2020" and Insight Crime's "Honduras profile" (https://insightcrime.org/honduras-organized-crime-news/honduras/#criminal-groups).

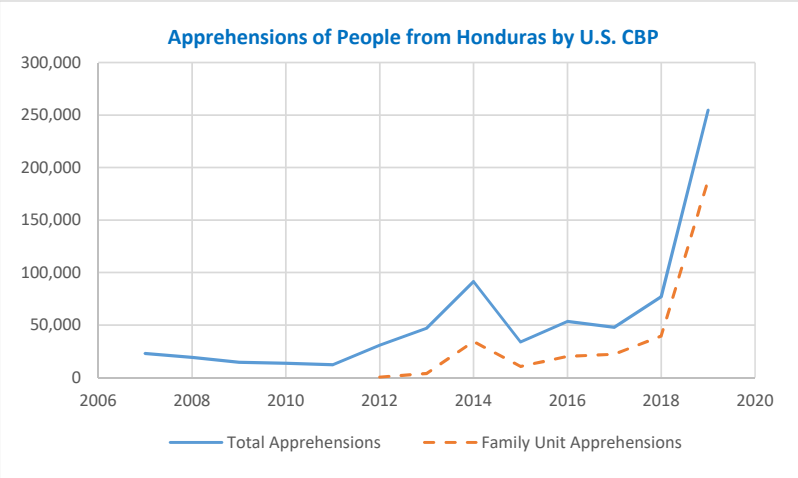

Figure 1: Apprehensions of People from Honduras by U.S. CBP. Data for total apprehensions are from the US Customs and Border Protection website. Data on Family Unit apprehensions were supplied in response to a Freedom of Information Act request.

department-year.[10] These data represent some (unknown) portion of all those who emigrated from a department in a given year. Some family units who emigrate may remain in countries other than the United States and some may arrive in the U.S. but not be apprehended by CBP. In particular, Mexico has become an important destination for Central American migrants in recent years. Given this, the data we have represent a lower bound on actual emigration from a department. We have no reason to think that likelihood of arriving in the United States and being apprehended by CBP varies across departments or is correlated with any of our variables of interest, although models using department fixed effects as a robustness check will alleviate any concern along these lines.

In keeping with various measures used in the literature on migration, we employ two separate measures of apprehensions as alternate dependent variables. We use the natural log of the apprehension rate, calculated as apprehension for a department in year *t* divided by departmental population. Alternatively, we use the natural log of total apprehensions from a department in year *t*, controlling for population as an independent variable. Although zeros on the dependent variable are often a concern for dyadic migration analysis, that is not the case here where we are measuring total yearly emigration from a department.[11]

We are interested in department-level characteristics that might correlate with emigration rates. One of our key variables of interest is departmental deviations in rainfall from historical means. As noted above, multiple departments in Honduras experienced sharp declines in rainfall relative to historic averages during the time period of our analysis, particularly in the area that is

[10]For 82% of apprehensions the department of birth was specified. When the department was not specified but city of birth was specified, we attempted to match the recorded city to a department. After this process we were able to assign 95% of apprehensions to a specific department. Full coding rules for assigning department are available from the authors.

[11]There are only three observations with zero values, all for small departments in year 2012, and there the value is changed to 1 before taking the natural log.

part of the "Dry Corridor" of Central America. Data on precipitation for cropland measured at the department level are available in ten-day increments from the Food and Agricultural Organization.[12] We construct multiple measures of rainfall deviation to ensure that our conclusions are not dependent on use of a specific measure.

For our first measure of rainfall deviations, we calculate negative rainfall deviation as the percent difference in department observed rainfall during the rainy season (April-October) from the twenty-year average of rainfall for the department in the same months. We invert this in the statistical analysis for ease of interpretation: higher negative deviations have higher values.[13] There is no assumption that the "average" value is optimal for a department; simple correlations between deviations and apprehensions show that apprehensions decline for values above the average. We calculate the departmental average simply to account for differences across departments. Calculation for negative rainfall deviation (*x* and *t* index department and year, respectively): $-100(\frac{observedrainyseasonprecipitation_{xt}-averagerainyseasonprecipitation_x}{averagerainyseasonprecipitation_x})$

Our second measure of rainfall deviation is calculated based on monthly averages. We calculate the monthly deviation from long-term mean for each department-year-month and then use the median value of this for a department-year as a measure of median rainfall deviation. This is also inverted so that larger negative deviations are associated with higher values. Our final rainfall measure is simply the natural log of precipitation for the department-year; this cannot be inverted, so the coefficient on this variable is anticipated to have the opposite sign as that of other measures of rainfall deviation. Figure 2 shows a scatterplot between the log of apprehensions and precipitation deviations from long-term average during the rainy season (inverted).

---

[12] Available at http://www.fao.org/giews/earthobservation/country/index.jsp?lang=en&code=HND; accessed June 2020.

[13] Twenty-year average calculated 1989-2008, representing the first 20 years for which the data are available.

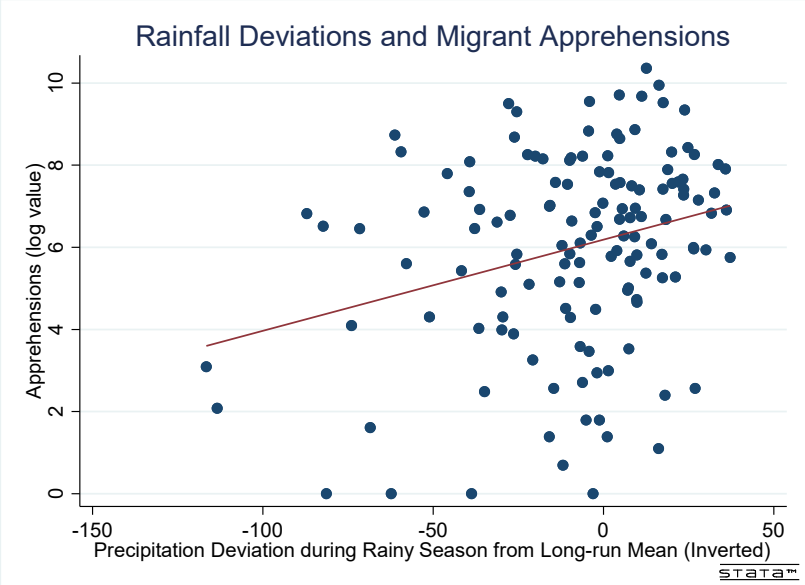

Figure 2: Rainfall Deviations and Migrant Apprehensions, Scatter Plot.

The official Honduran census from 2013 (latest census) is used to measure department population; when the dependent variable is based on total apprehensions (not apprehension rate), the natural log of department population is used in the analysis.[14] Data on homicides by department are from the Secretaria de Seguridad Policia Nacional in Honduras.[15] We calculate the homicide rate per 100,000 people (based on 2013 census) and use the natural log in the analysis. The department-specific mean international wealth index score from Global Data Lab Area Database 4.0 is used to proxy mean resources available; these are based on household surveys and the values used are from 2011 (latest available), which is a baseline right before the time period analyzed.[16]. Note that this variable varies across departments but not over time within a department. We include a year trend variable to pick up common trends that are not department-specific.

Table 1 shows the total number of family unit apprehensions by CBP at the U.S. southern border during fiscal years 2012-2019 by department of birth in Honduras. Departments are listed by descending number of total apprehensions and summary statistics for each department are included. The largest number of those apprehended list Cortes as department of birth. Cortes is the most populous department and includes the city of San Pedro Sula; it also has the highest average number of homicides of any department in this period.

The apprehension rate (as percent of population) is quite high for some departments: both Colon and Olancho had apprehensions at the US border during this period that totaled more than 7% of their 2013 population. These two departments also experienced severe rainfall deficits, each observing at least one year where rainfall during the rainy season was down more than 20% from its average. Atlantida, Copan and Ocotepeque also saw apprehensions totaling more than

[14] Available at https://www.ine.gob.hn/V3/baseine/; accessed March 2021.

[15] Available at https://www.sepol.hn/sepol-estadisticas-incidencia-departamento.php; accessed March 2021.

[16] Available at https://globaldatalab.org; accessed March 2021)

Department of Birth	Apprehensions	Population	Percent Population Apprehended	Largest Negative Rainfall Deviation	Mean Homicide Rate	Wealth Index
Cortes	56,220	1,621,762	3.5%	-24.8%	98	74.9
Olancho	38,866	537,306	7.2%	-35.8%	54	56.8
Yoro	29,516	613,473	4.8%	-23.3%	76	63.9
Atlantida	25,688	449,822	5.7%	-11.1%	92	69.4
Colon	24,913	319,786	7.8%	-23.5%	69	65.9
Copan	24,708	382,722	6.5%	-27.9%	72	57.8
Francisco Morazan	23,186	1,553,379	1.5%	-17.4%	65	72.1
Santa Barbara	17,355	434,896	4.0%	-36.1%	61	60.2
Comayagua	15,645	511,943	3.1%	-4.7%	61	65.4
Choluteca	10,120	447,852	2.3%	0.0%	26	51.3
Lempira	9,204	333,125	2.8%	-26.5%	53	44.1
Ocotepeque	8,216	151,516	5.4%	-37.2%	56	60.8
Valle	7,158	185,227	3.9%	-5.9%	20	55.7
Intibuca	5,409	241,568	2.2%	-9.8%	30	47.2
El Paraiso	5,148	458,472	1.1%	-12.4%	27	51.7
La Paz	2,785	206,065	1.4%	-21.1%	26	52.4
Islas de la Bahia	929	65,932	1.4%	n/a	32	74.7
Gracias a Dios	220	94,450	0.2%	-26.9%	22	33.1

Table 1: Based on observations used for the analysis in Table 2.

5% of their population, with Atlantida experiencing one of the highest homicide rates and Copan and Ocotepeque experiencing large negative rainfall shocks. The data in Table 1 confirm broad variation across departments in percentage of people migrating, as well as variation in homicide rates and rainfall deviations.

4 Analysis

Our analysis examines the relationship between family unit apprehensions from a department and department-specific characteristics. We estimate the following equation, using a random effects model with robust standard errors clustered on department, with *x* and *t* indexing department and year, respectively:

$$Ln(Apprehensions)_{x,t} = \beta_0 + \beta_1 * RainfallDeviation_{x,t-1} + \beta_2 * Ln(HomicideRate)_{x,t-1} + \beta_3 * Wealth_x + \beta_4 * Ln(Population)_x + \beta_5 * Year + \gamma_x + \epsilon_{x,t}$$

To ensure we are capturing measurements from before or during the apprehension period, we lag homicides and rainfall deviation by one year (this is necessary due to the fiscal year not corresponding with a calendar year). We do not include department fixed effects in our main specifications as that would not allow us to control for measures of wealth and population, which vary across departments but not over time within a department in our data. Results including

department fixed effects are discussed below.

Table 2 shows the relationship between both total apprehensions (Models 1-3) and apprehension rate (Models 4-6) and various measures of department rainfall deviations, as well as homicide rates and control variables. As seen in Model 1, an increase in the size of a negative rainfall deviation (less rain than average) during the rainy season is associated with a significant increase in the number of apprehensions at the US southern border the following year. This effective is substantial: a change in the value of rainfall deviation from the 25th to the 75th percentile is associated with an expected increase in yearly apprehensions from a department from 320 to 541, a 69% increase. This relationship holds when using the median monthly deviation from long-term average to estimate rainfall deviations (Model 2). It also holds when using the log of total rainfall for the year (less rainfall is associated with more apprehensions); unlike the deviation variables the level variable is not inverted so the sign is opposite for the same directional relationship. Models 4-6 show that the relationship is similar when apprehension rate is used as the dependent variable.

While the coefficient on the departmental homicide rate is positive in all specifications, it reaches statistical significance only in Model 3. For multiple reasons, we do not interpret this as evidence that violence has no impact on migration decisions. Homicide rate is a crude measure of violence that was on the decline throughout this period, while other forms of violence that are less easily measured at the department level remained high.[17] Additionally, while the decline in homicides is a positive development, Honduras consistently ranks in the five countries with the highest homicide rates. Rising migration in the presence of a persistently high homicide rate, even

[17]There was a sizeable overall decline in homicides in Honduras during this period (from a high of 84 per 100,000 in 2011 to a low of 39 per 100,000 in 2018 according to the World Banks World Development Indicators). On other forms of violence see https://www.hrw.org/world-report/2021/country-chapters/honduras, https://reliefweb.int/report/honduras/death-threats-and-gang-violence-forcing-more-families-flee-northern-central-america and https://insightcrime.org/honduras-organized-crime-news/.

	Log Apprehensions			Log Apprehension Rate		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Precip Rainy Deviation(lag)	0.015***			0.015***		
(inverted)	(0.00)			(0.00)		
Precip Median Deviation(lag)		0.012***			0.013***	
(inverted)		(0.00)			(0.00)	
Ln Precipitation(lag)			-1.780***			-1.725***
			(0.00)			(0.00)
Ln Homicide Rate(lag)	0.174	0.230	0.499*	0.133	0.180	0.426
	(0.49)	(0.40)	(0.07)	(0.63)	(0.54)	(0.15)
Wealth Index (2011)	0.071***	0.071***	0.064***	0.055**	0.054**	0.039*
	(0.01)	(0.00)	(0.00)	(0.02)	(0.01)	(0.05)
Ln Population (2013)	0.646*	0.613*	0.439			
	(0.07)	(0.06)	(0.17)			
Year	0.710***	0.706***	0.734***	0.707***	0.702***	0.730***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	-1438.826***	-1430.151***	-1472.805***	-1422.927***	-1413.230***	-1457.654***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	136	136	136	136	136	136

Table 2: Migrant Apprehension and Precipitation Deviations for Honduran Departments, 2012-2019. Unit of analysis is department-year. Dependent variable is the natural log of apprehensions from department in Models 1-3 and the natural log of apprehension rate in Models 4-6. Random effects models with standard errors clustered on department. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

in the context of a relative decline, is consistent with an interpretation of the cumulative impact increasing over time as people lose confidence in the governments ability to improve security.[18]

Evidence of a cumulative effect on migration from the multiple problems plaguing Honduras including violence, climate change, corruption and poor governance is further reinforced by the strong and significant impact of the year trend variable. This is consistent with an interpretation that migrants and asylum seekers increasingly see these problems as persistent rather than temporary.

The positive relationship between the wealth index and apprehensions suggests that those from departments with higher initial wealth are more likely to migrate. If a squared term of the wealth index is added to the models, a nonlinear relationship similar to that observed in previous literature linking development levels to migration is observed: a positive and significant coefficient on the wealth term and a negative and significant coefficient on the squared term

[18]In a study of unaccompanied child apprehensions from Central America and homicide rates at the municipal level (a smaller administrative unit than used here), Clemens (2017) finds that higher homicide rates are linked to increased apprehensions.

	Log Apprehensions			Log Apprehension Rate		
	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Precip Rainy Deviation(lag)	-0.060***			-0.056***		
(inverted)	(0.00)			(0.00)		
Precip Rainy*Homicide Rate	0.020***			0.020***		
	(0.00)			(0.00)		
Precip Median Deviation(lag)		-0.058**			-0.053**	
(inverted)		(0.02)			(0.03)	
Precip Median*Homicide Rate		0.019***			0.018**	
		(0.01)			(0.01)	
Ln Precipitation(lag)			2.306			2.397
			(0.28)			(0.24)
Ln Precipitation*Homicide Rate			-1.110**			-1.120**
			(0.05)			(0.04)
Ln Homicide Rate(lag)	0.229	0.253	8.370**	0.149	0.171	8.368**
	(0.41)	(0.40)	(0.04)	(0.61)	(0.59)	(0.03)
Wealth Index (2011)	0.070***	0.069***	0.065***	0.057***	0.053***	0.041**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.05)
Ln Population (2013)	0.678**	0.616**	0.446			
	(0.02)	(0.03)	(0.15)			
Year	0.697***	0.702***	0.725***	0.690***	0.694***	0.721***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	-1412.275***	-1421.714***	-1483.816***	-1389.615***	-1397.387***	-1468.483***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	136	136	136	136	136	136

Table 3: Migrant Apprehension, Precipitation Deviations, and Homicides for Honduran Departments, 2012-2019. Unit of analysis is department-year. Unit of analysis is department-year. Dependent variable is the natural log of apprehensions from department in Models 1-3 and the natural log of apprehension rate in Models 4-6. Random effects models with standard errors clustered on department. $*p < 0.10$; $**p < 0.05$; $***p < 0.01$.

(including the squared term does not alter the conclusions regarding other variables). This is an interesting contrast to the findings on rainfall deviations, which show that negative income shocks are associated with increased apprehensions. This suggests that the impact of income on likelihood of migration is a complex mix dependent on both initial resources and unexpected shocks, and that these two forces can have opposite relationships with observed migration patterns. When we include an interactive term between wealth and rainfall (not shown), the coefficient on the interaction term is not significant and including it does not alter other findings.

Table 3 examines the interactive relationship that precipitation and homicides have with apprehensions. Models in Table 3 are analogous to those in Table 2 but add the interactive term between the rainfall variables and the homicide rate. In each case, the coefficient on the interaction term is significant and indicates that the magnitude of the link between rainfall deviations and emigration increases when violence is higher.

Table 4 explores the interactive relationship between rainfall and homicides in more depth.

Homicide Rate (per 100,000 people)	Estimated Slope	Rainfall Deviation 50^{th} Percentile	Rainfall Deviation 75^{th} Percentile
26	0.007*	366	400
46	0.018***	405	518
81	0.030***	448	670

Table 4: Estimated Apprehensions by Rainfall and Homicide Rate. Based on Table 3, Model 1. Numbers converted from log values.

The first column shows the level of homicides per 100,000 people at its mean value (46) and its value one standard deviation below (26) and above (81) the mean (converted from log values). The second column shows that the estimate of the slope value relating negative rainfall deviation and apprehensions varies across homicide levels: higher homicide rates are associated with a larger increase in apprehensions in response to an increase in rainfall deviation (this difference in slope across homicide rates is statistically significant). Figure 3 shows this relationship graphically for the same homicide rates.

The final two columns of Table 4 show expected values of apprehensions for the given homicide rate when negative rainfall deviations are at the 50^{th} and 75^{th} percentile of observed deviations. When the homicide rate is lower (26), an increase in the rainfall deviation from the 50th to the 75th percentile is associated with an expected increase in apprehensions from 366 to 400, an increase of 34 apprehensions or 9%. The magnitude of this increase is significantly higher when the homicide rate is 81: the same increase in rainfall deviation is associated with an expected increase in apprehensions from 448 to 670, an increase of 222 apprehensions or 49.6%.

The above results regarding the relationship between precipitation deviations and apprehensions are robust to the inclusion of department fixed effects, although these must be estimated without the time-invariant department variables of wealth and population. The explanatory power of the fixed effect models is almost identical to that of the models reported above, suggesting that the wealth variable is absorbing much of the department fixed effect. In fixed effects models including the interaction term between homicides and precipitation, the

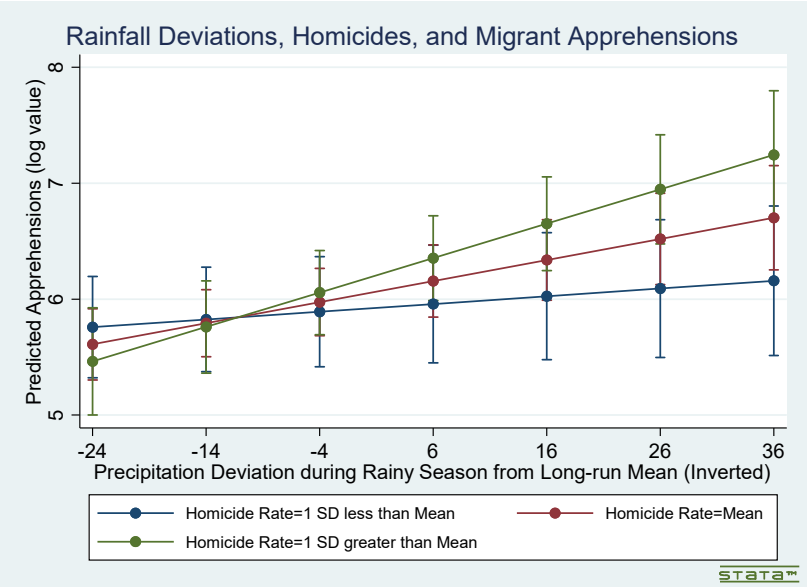

Figure 3: Rainfall Deviations, Homicides and Migrant Apprehensions.

interaction term has the same sign as in the random effects models but sometimes falls short of conventional levels of significance (e.g. in the fixed effects version of Models 7, 8 and 9, p=0.12, 0.07 and 0.16, respectively, for the coefficient on the interaction term). We also estimated the models excluding 2019, which saw a large spike in apprehensions; the results are qualitatively similar in terms of both sign and significance when 2019 is excluded.

5 Conclusion

The results of our analysis support the hypothesis that climate-related negative income shocks are associated with increased emigration. Negative deviations in precipitation from the long-term average are correlated with increases in apprehensions at the U.S. border the following year. There is also support for the hypothesis that emigration decisions depend partly on other conditions: the magnitude of the relationship between precipitation deviations and apprehensions increases for a department when homicide rates are also higher in the department.

These findings have implications for how we understand the likely impacts on migration from climate change, or other negative income shocks. When a change in income is the result of a shock, rather than part of the normal development trajectory of a country, the direction of the relationship with migration is flipped. Honduras has an average income that would place it squarely in the range where the theory of a migration hump would lead us to expect a positive relationship between income and emigration. We observe this for the wealth variable: wealthier departments in Honduras are associated with higher levels of apprehensions at the U.S. border. For negative rainfall deviations we observe the opposite: these negative income shocks are also associated with increases in apprehensions.

The results can inform how policymakers in migrant destination countries consider the links between their policy responses to the impacts of climate change in migrant source countries and the likely impact on migrant flows. Several scholars have correctly pointed out, based on the overwhelming evidence in favor of a migration hump relationship between development and migration, that efforts to increase development in migrant sending countries may also increase

migration in the short-term, until income per capita reaches a sufficient level to be on the downward-sloping portion of the relationship between income and migration. This suggests that foreign aid given for development in an effort to ease migration pressures can be counterproductive from the point of view of policymakers in the destination country (Clemens and Postel, 2018; Lucas, 2019).

The expectation that foreign aid to stem migration is likely to be counterproductive need not hold when migration is the result of a shock, rather than a normal outcome of the development process. If development is the root cause of a migration flow, following the migration hump model, then it makes sense that more development would not be expected to decrease migration. However sometimes a shock - due to violence, climate change, natural disaster or another cause - is responsible for an increase in migration over that which would be expected by its normal development trajectory. An implication from this study is that decreasing the impact of the shock can decrease migration, moving it back toward the steady-state level for its stage of development.

The results presented above are important, but partial. The multi-faceted impacts of climate change are still being assessed and we lack data on most countries to allow for the type of analysis conducted above on emigration from subnational units. As more and better data on climate impacts and migration become available, preferably at subnational levels, the findings are likely to become more nuanced and precise. Given the likely importance of climate change impacts in shaping migration, development, and policy moving forward, we should expected a growing research agenda to unfold in this space.

References

Ash, Konstantin and Nick Obradovich. 2020. "Climatic Stress, Internal Migration, and Syrian Civil War Onset." *Journal of Conflict Resolution* 64(1):3–31.

Beine, Michel, Frdric Docquier and Caglar Ozden. 2011. "Diasporas." *Journal of Development Economics* 95(1):30–41. Symposium on Globalization and Brain Drain.
URL: *https://www.sciencedirect.com/science/article/pii/S0304387809001187*

Bencek, David and Claas Schneiderheinze. 2020. "Higher economic growth in poor countries, lower migration flows to the OECD: Revisiting the migration hump with panel data.".

Brown, Oli. 2008. "Migration and Climate Change." IOM Migration Research Series.

Clark, Ximena, Timothy J. Hatton and Jeffrey G. Williamson. 2004. "What Explains Emigration Out of Latin America?" *World Development* 32(11):1871–1890.
URL: *https://www.sciencedirect.com/science/article/pii/S0305750X04001391*

Clemens, Michael A. 2014. Does Development Reduce Migration? In *International Handbook on Migration and Economic Development*, ed. Robert E.B. Lucas. Northampton, MA: Edward Elgar.

Clemens, Michael A. 2017. "Violence, Development, and Migration Waves: Evidence from Central American Child Migrant Apprehensions." Center for Global Development Working Paper 459.

Clemens, Michael A. 2020. The Emigration Life Cycle: How Development Shapes Emigration from Poor Countries. Technical report. Center for Global Development Working Paper 540.

Clemens, Michael A. and Hannah M. Postel. 2018. "Deterring Emigration with Foreign Aid: An Overview of Evidence from Low-Income Countries.".

Dao, Thu Hien, Frederic Docquier, Chris Parsons and Giovanni Peri. 2018. "Migration and development: Dissecting the anatomy of the mobility transition." *Journal of Development Economics* 132:88–101.

De Haas, Hein. 2007. "Turning the Tide? Why Development Will Not Stop Migration."

Development and Change 38(5):819–841.

URL: *https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-7660.2007.00435.x*

de Haas, Hein, Mathias Czaika, Marie-Laurence Flahaux, Edo Mahendra, Katharina Natter, Simona Vezzoli and Mara Villares-Varela. 2019. "International Migration: Trends, Determinants, and Policy Effects." *Population and Development Review* 45(4):885–922.

URL: *https://onlinelibrary.wiley.com/doi/abs/10.1111/padr.12291*

Faini, Riccardo and Alessandra Venturini. 1994. Migration and Growth: The Experience of Southern Europe. CEPR Discussion Papers 964 C.E.P.R. Discussion Papers.

Faini, Riccardo and Alessandra Venturini. 2010. *Migration and Culture (Frontiers of Economics and Globalization, Volume 8)*. Bingley: Emerald Group Publishing chapter Development and Migration: Lessons from Southern Europe, pp. 105–136.

Hanson, Gordon H. 2010. Chapter 66 - International Migration and the Developing World. In *Handbooks in Economics*, ed. Dani Rodrik and Mark Rosenzweig. Vol. 5 of *Handbook of Development Economics* Elsevier pp. 4363–4414.

URL: *https://www.sciencedirect.com/science/article/pii/B9780444529442000045*

Hanson, Gordon H. and Craig McIntosh. 2010. "The Great Mexican Emigration." *The Review of Economics and Statistics* 92(4):798–810.

URL: *http://www.jstor.org/stable/40985795*

Hatton, Timothy J. and Jeffrey G. Williamson. 1994. "What Drove the Mass Migrations from Europe in the Late Nineteenth Century?" *Population and Development Review* 20(3):533–559.

Hatton, Timothy J. and Jeffrey G. Williamson. 1998. *The Age of Mass Migration: Causes and Economic Impact*. New York, NY: Oxford University Press.

Hatton, Timothy J. and Jeffrey G. Williamson. 2003. "What Fundamentals Drive World Migration?" *Discussion Paper No. 2003/23, World Institute for Development Economics Research* .

Kahneman, Daniel and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision Under Risk." *Econometrica* 47(2):263–291.

Lucas, Robert E. B. 2019. "Migration and development The role for development aid." Delmi Research overview 2019:5.

Manzi, Laura. 2020. "Migration from rural areas to cities: challenges and opportunities.".

Martin, Philip L. and J. Edward Taylor. 1996. *Development Strategy, Employment, and Migration: Insights from Models*. Paris: Organization for Economic Cooperation and Development chapter The anatomy of a migration hump, pp. 43–62.

Massey, Douglas S., Joaquin Arango, Graeme Hugo, Ali Kouaouci, Adela Pellegrino and J. Edward Taylor. 1993. "Theories of International Migration: A Review and Appraisal." *Population and Development Review* 19(3):431–466.

Restrepo, Dan. 2021. "To Stanch Migration, Washington Must Address a Deeper Crisis." *Foreign Affairs* .

Rigaud, Kanta Kumari, Alex de Sherbinin, Bryan Jones, Jonas Bergmann, Viviane Clement, Kayly Ober, Jacob Schewe, Susana Adamo, Brent McCusker, Silke Heuser and Amelia Midgley. 2018. *Groundswell: Preparing for Internal Climate Migration*. Washington, DC: World Bank.

Sjaastad, Larry A. 1962. "The Costs and Returns of Human Migration." *Journal of Political Economy* 70(5):80–93.

Skeldon, Ronald. 1997. *Migration and Development: A Global Perspective*. Harlow: Longman.

Zelinsky, Wilbur. 1971. "The Hypothesis of the Mobility Transition." *Geographical Review* 61(2):219–249.