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Do Rainfall Deficits Predict U.S.-bound Migration from Rural Mexico? Evidence from the Mexican Census

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Abstract

Environmental and climatic changes have shaped human mobility for thousands of years and research on the migration-environment connection has proliferated in the past several years. Even so, little work has focused on Latin America or on international movement. Given rural Mexico's dependency on primary sector activities involving various natural resources, and the existence of well-established transnational migrant networks, we investigate the association between rainfall patterns and U.S.-bound migration from rural locales, a topic of increasing policy relevance. The New Economics of Labor Migration (NELM) theory provides background, positing that migration represents a household-level risk management strategy. We use data from the year 2000 Mexican census for rural localities and socioeconomic and state-level precipitation data provided by the Mexican National Institute for Statistics and Geography. Multilevel models assess the impact of rainfall change on household-level international out-migration while controlling for relevant sociodemographic and economic factors. A decrease in precipitation is significantly associated with U.S.-bound migration, but only for dry Mexican states. This finding suggests that programs and policies aimed at reducing Mexico-U.S. migration should seek to diminish the climate/weather vulnerability of rural Mexican households, for example by supporting sustainable irrigation systems and subsidizing drought-resistant crops.

Keywords

Rainfall; Drought; International migration; IPUMS; Mexico; Multilevel modeling; New Economics of Labor Migration

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Migration has historically been a common strategy to avert the consequences of weather events and/or a changing climate (Kniveton et al. 2008; McLeman and Smit 2006). Individuals may temporarily or permanently relocate, seeking to escape the hazards of high-intensity disasters such as hurricanes, flooding, and mudslides (e.g., Trenberth et al. 2007) or lower-intensity, longer-duration events such as droughts (Gray 2009; Henry, Schoumaker, and Beauchemin 2004; Hunter, Murray, and Riosmena 2011). The number of migrants displaced by adverse weather conditions that accompany climate change is predicted to increase substantially through the twenty-first century, with estimates ranging from 50 million to 1 billion (Boano 2008; Myers 2002, 2005; Stern 2007). The vast range of projections reflects the challenge of defining environmental migration (Warner et al. 2010) as well as different assumptions concerning the future of vulnerability and adaptation strategies.

The association between climatic variability and migration may further depend on factors such as household socioeconomic status (Gray 2009) and, more importantly, the existence of networks in sending communities (Lindstrom and Lauster 2001; Hunter et al. 2011). As this research suggests, migration can be used as a strategy of livelihood risk diversification, particularly among households with a certain amount of financial or social endowments. In this context, the migration of a household member serves as an informal insurance system to mitigate the negative effects of unemployment, market fluctuations, or (particularly relevant for our study), crop failure (Lucas and Stark 1985; Rosenzweig and Stark 1989; Stark and Levhari 1982).

Take the case of Mexico-U.S. migration, one of the largest and longest-sustained international flows of people in the world and the main source of both legal and undocumented migration to the U.S. (Hoefer, Rytina, and Baker 2012; Martin and Midgley 2010). Rural areas have historically been an integral part of this stream (Durand, Massey, and Zenteno 2001) and continue to have large representation (Hamilton and Villarreal 2011; Riosmena and Massey 2012:18). In rural and coastal areas, weather events and climatic variability may increase out-migration flows, particularly along established migration corridors (Bardsley and Hugo 2010). This may be more likely to happen in drier places (e.g., Henry et al. 2004), given the extreme vulnerability of natural resource dependent populations to the loss of ecosystem services (e.g., water supply) that severely affect farming.

Despite the abundance of historical evidence (e.g., Brooks et al. 2005; Fang and Liu 1992; Fixico 2003; Lamb 1995; Tyson et al. 2002; VanGeel, Buurman, and Waterbolk 1996) and an increase in public and political interest in the connection between climate change associated weather events and international migration, there are surprisingly few empirical studies of contemporary manifestations of this connection (Kniveton et al. 2008). This paper addresses this void. We use household-level nationally representative data from the 2000 Mexican census, supplemented with rainfall and contextual economic information, to study the association between rainfall deficits and international out-migration from rural Mexico.

Conceptual Framework: The New Economics of Labor Migration Theory

The New Economics of Labor Migration (NELM) theory was developed as an alternative to the neoclassical migration framework. The neoclassical framework emphasizes that migration is largely a response to inter-regional (or international) differences in labor supply and demand (Todaro 1976). At the micro-level, individual rational actors decide to migrate because of cost-benefit calculation which leads them to expect a positive net return from a movement (Todaro and Maruszko 1987).

In contrast NELM has arisen to challenge many of the assumptions and conclusions of neoclassical theory and accommodates empirical regularities not considered by neoclassical economics (Stark and Bloom 1985, Katz and Stark 1986). NELM posits that migration decisions are not made to maximize the utility of isolated individual actors; rather, larger social units are key, most notably the family or household co-residents (Massey et al. 1993, Taylor 1999). In the Mexican context, migration decisions are indeed made jointly (though not equally) within the household or family (e.g., Hondagneu-Sotelo 1994). Costs and returns are shared according to an implicit contract between the migrant-to-be and the family members left behind (Sana and Massey 2005; Stark and Bloom 1985).

Further, migration is used not only to maximize expected gain, but to minimize risk and loosen constraints associated with market failures in sending areas (Stark and Bloom 1985, Katz and Stark 1986, Massey et al. 1993, Taylor 1999). Diversifying the household income portfolio through migration is particularly important for poor families in rural areas of less developed countries (LDCs), who may have limited access to formal risk management institutions and insurance markets (Lucas and Stark 1985; Stark and Levhari 1982). If local economic conditions deteriorate, the household can rely on migrant remittances

(Rosenzweig and Stark 1989), which serve as either an *ex ante* risk mitigation strategy or an *ex post* means of weathering economic shocks (Gray 2010; Halliday 2006).[1]

Risk diversification is perhaps even more crucial in places with low economic diversity where livelihoods heavily depend on the local environment, such as areas with subsistence agriculture (Liverman 1990). Droughts may be particularly harsh on crop yield in rain-fed areas in dry climates, given nonexistent or insufficient water storage, profuse plant transpiration, and rapid soil evaporation. Although, climatic factors are typically not the only or primary driver of out-migration, they act in combination with other macro-level and contextual factors (Jonsson 2010; McLeman and Smit 2006; Suhrke 1994). In addition, individual and household characteristics such as vulnerability and available coping strategies ultimately determine household response to environmental conditions (Meze-Hausken 2000, McLeman and Hunter 2010).

In places with no accessible crop insurance programs, as in much of Mexico, households may respond proactively to the risk of drought through self-insuring by sending one or more workers abroad to remit earnings. This guarantees some family income even if the harvest is unsuccessful (Massey et al. 1993). Remittances may also help finance irrigation systems or the purchase of drought-resistant seeds. In rural areas, families wishing to invest in productive assets frequently encounter unreliable or underdeveloped banking systems (Massey et al. 1993), and local moneylenders may charge high interest or require unpaid labor services (Katz and Stark 1986). Under these circumstances, migration provides an alternative source of capital (Lindstrom 1996).

Consideration of migration timing is also key. Households may use migration to insure a stable income by sending a migrant proactively before a climatic shock (*ex ante*). Families not engaged in *ex ante* measures might be unable to meet their livelihood demands in the wake of a climatic shock (e.g. drought), resulting in *ex post* adaptation strategy of deploying a member abroad to find work elsewhere and remit money to help sustain the household (Meze-Hausken 2000). As we expect that most of the relationship between rainfall deficits and subsequent migration reflects *ex post* behavior, we review this work next.

Drought as Migration Driver

Environmental factors may influence household-level migration decisions through sudden-onset natural disasters (e.g., flooding, storms) (Smith and McCarty 2009), slow-onset incremental environmental changes (e.g., soil degradation, deforestation, sea-level rise) (Carr, Lopez and Bilsborrow 2009; Gutmann and Field 2010; Shen and Gemenne 2011), and static environmental conditions (e.g., elevation, topography) (Bates 2002; Gray 2009). In this study we focus on droughts, which arguably constitute a hybrid between sudden- and slow-onset drivers of migration. Droughts occur faster than sea-level rise, deforestation, and soil degradation, but they take much longer to impact places than flooding and storms.

Evidence from around the globe suggests that rainfall deficits and droughts affect migration patterns, especially in farming areas in developing countries, partly because of the absence or inefficiency of insurance and capital markets. Most studies that connect droughts to population dynamics come from Africa. For Mali, Findley (1994) found that the migration of women and children increased dramatically during the 1983–1985 drought years, and that there was less long-distance migration and more circular (temporary) migration. Similarly, Henry et al. (2004) observed in Burkina Faso that especially males living in drier areas were

[1]For research consistent with these patterns in the Mexican setting, see Lindstrom (1996), Massey and Espinosa (1997), and Riosmena (2009).

more likely to move temporarily to other rural areas but less likely to migrate abroad. Drawing on qualitative field work in Tigray, North Ethiopia, Meze-Hausken (2000) found that temporary migration in search of off-farm employment was one of the early measures undertaken by households in the face of drought, while permanent migration of the entire household was a means of last resort. There is little research from Asia, but a case study of a village in western Orissa, India, found that droughts significantly increased the number of households that sent a migrant to work outside the community (Juelich 2011). Likewise, Massey, Axinn, and Ghimire (2010) found that environmental factors were associated with migration in Nepal, especially short-distance moves.

The Significance of Mexico

Although short-distance, internal migration is a frequent response to environmental change (Black, Kniveton, and Schmidt-Verkerk 2011; Meze-Hausken 2000; Warner et al. 2009), international migration is likely in the aftermath of droughts particularly in places with well-established migratory traditions (Bardsley and Hugo 2010, Fussell and Massey 2004). Mexico-U.S. migration has a long history. Sustained, massive movement of labor migrants dates back to recruitment efforts by U.S. employers in the early twentieth century and displacement caused by the Mexican Revolution (Cardoso 1980). Migration plummeted during the Great Depression (Hoffman 1974) but emerged again in 1942 in response to the Bracero Program, a binational labor accord with Mexico aimed at providing farm labor during World War II (Calavita 1992). The Bracero Program continued until 1964, when it was discontinued as part of broader civil rights and immigration reforms. Nevertheless, immigration from Mexico continued in both unauthorized and legal ways, frequently in a circular fashion (Cornelius 1992; Massey, Durand, and Malone 2002).

During the 1990s and for most of the first decade of the twenty-first century, legal and unauthorized migration streams increased considerably (Martin and Midgley 2010; Passel and Cohn 2011) as emigration out of Mexico increased (Hill and Wong 2005) and short-term return migration rates plummeted (Massey et al. 2002; Riosmena 2004). An increase in legal migration during this period is attributable to two large-scale legalization programs that were part of the 1986 Immigration Reform and Control Act (IRCA). IRCA also included provisions to penalize the hiring of undocumented migrants for the first time in U.S. history and increased the border patrol budget. This marked the beginning of substantial border enforcement efforts in the 1990s and 2000s, which included several other bills appropriating more resources and personnel to various kinds of border patrol operations (Orrenius and Zavodny 2003).

Despite the increase in resources, border enforcement efforts proved to be overall ineffective as a means to deter undocumented emigration from Mexico (Angelucci 2012; Massey and Riosmena 2010). The existence of well-established migrant networks in many sending areas and labor demand (particularly in new destinations, e.g., Kandel and Parrado 2005) were more important factors explaining the continued increase in emigration.

Historically, much of U.S.-bound migration has come from rural areas in central-western Mexico (Durand et al. 2001), and although migrant flows have urbanized along with the country, rural communities are still an integral part of the U.S.-bound movement. Riosmena and Massey (2012: Table 2) estimate that 40 percent of Mexico’s U.S.-bound migrants in 2001–2006 came from places with fewer than 2,500 inhabitants, a much higher proportion than rural people’s share of the total population at 22 percent.

Although substantial research has examined the social, economic, and policy drivers of Mexican migration to the U.S. (e.g., Angelucci 2012; BSM 1998; Cohen 2004; Hamilton and Villarreal 2011; Hanson and Spilimbergo 1999; Jones 1995; Kanaiaupuni 2000;

Lindstrom and Lauster 2001; Massey and Espinosa 1997; Massey, Durand, and Malone 2002; Massey, Goldring, and Durand 1994; Massey and Riosmena 2010), far less is known about the role of environmental change in these flows. This is surprising, as rural Mexican livelihoods are highly dependent on subsistence agriculture on rain-fed lands. Although farming is not the main source of income of Mexican smallholders, it is a central component of their livelihood portfolio (Wiggins et al. 2002; Winters, Davis, and Corral 2002). Further, only 25 percent of Mexico's 20 million hectares of crop land are irrigated (Leiva and Skees 2008), making rural Mexicans vulnerable to climatic changes that alter rainfall regimes and reduce crop yields (Eakin 2005; Thomas and Twyman 2006; Vasquez-Leon, West, and Finan 2003). The inability to make a living is then an important contributor to the decision of rural Mexican families to send a member elsewhere (Schwartz and Notini 1994).

We draw on three studies of how decreasing rainfall is associated with (U.S.-bound) migration from rural Mexican households.[2] Two studies (Hunter et al. 2011; Munshi 2003) use data from the Mexican Migration Project (MMP), which provides retrospective data for a nonrandom selection of Mexican communities mostly located in states of historically high migration prevalence. Munshi (2003) used state-level precipitation patterns as an instrumental variable to predict the size of the international migrant network available to people in rural sending communities in order to identify the effect of networks on the wages of Mexican migrants in the United States. In contrast, Hunter et al. (2011) employed a categorical measure for dry, normal, and wet years in which the state-level rainfall measurement was one standard deviation either below or above a 30-year average. Both studies observed that a decrease in rainfall was strongly associated with an increase in Mexico-U.S. migration. However, the results lack generalizability because the data came from a nonrandom cross-section of communities located in only 7 (Munshi 2003) or 12 (Hunter et al. 2011) of the 32 Mexican states.

The third study employs nationally-representative data to investigate the association between climatic shocks and migration, but at a relatively coarse scale. Using data from the 2000 Census and the 2005 Population Count (a mid-decade census-like enumeration), Feng, Krueger, and Oppenheimer (2010) found a negative association between state-level crop yields (as a proxy of climatic shifts) and state-level U.S. migration rates. Specifically, their modeling exercise predicted that a 10% reduction in crop yields would motivate an additional 2% of the Mexican population to emigrate. However, state-level analyses may be subject to the ecological fallacy and do not allow for adequate control of household-level factors shaping migration decision-making (e.g., Hondagneu-Sotelo 1994; Lindstrom 1996; Massey and Espinosa 1997; Stark and Bloom 1985).[3]

We build upon this work by analyzing the relationship between emigration and precipitation patterns at the household level, using representative data for all 32 Mexican states. The strength of our analysis is its recognition that migration decisions are influenced by forces operating at different scales including the household level (e.g., socioeconomic status) and the community context (e.g., migrant networks), as well as by structural macro-level forces (e.g., state-level GDP change). We account for this hierarchical structure by using multilevel

[2]In a report published by the International Organization of Migration (IOM), Kniveton and colleagues (2008) analyze the association between migration and rainfall using MMP data for the Mexican states of Zacatecas and Durango. A decrease in rainfall is significantly associated with a decrease in international out-migration to the U.S. for Durango, but for Zacatecas this correlation is not significant. However, these results lack reliability, because the study used bivariate associations and a small migrant sample size, and they are therefore not considered in our discussion.

[3]There is also some evidence that in Mexico migration may be associated with sudden-onset events. Using the 2000 Mexican Census, Saldaña-Zorilla and Sandberg (2009) found that local susceptibility to natural disasters is associated with the municipal out-migration rate (which includes both internal and international movement). Here, susceptibility (and the "push" to migrate) included absence of credit and associated declines in income.

models. However, our cross-sectional design prevents definitive conclusions regarding the causal order of observed associations.

Data

Data came from the 2000 Mexican General Population and Housing Census long form (MGPHC), harmonized and made available by the Integrated Public Use Microdata Series (IPUMS) (MPC 2011, Ruggles et al. 2003). These data are well suited for this project, since they provide individual and household level characteristics as well as retrospective migration information. The year 2000 MGPHC used a stratified cluster probability sample, and data collection was conducted by the *Instituto Nacional de Estadística, Geografía e Informática* (INEGI). The data used represent a sample of 1 percent of the total population, a commonly used density (Saenz and Morales 2006). We limited our analysis to localities with fewer than 2,500 inhabitants, on the assumption that migration would depend on weather/climate more in agricultural dependent rural areas than in cities (cf. Feng et al. 2010).

State-level rainfall information came from the Mexican Migration Project (MMP)[4] supplementary data file “ENVIRONS,” which contains monthly precipitation data collected at weather stations of the National Water Commission (CONAGUA by its Spanish acronym; see González, Cháidez and Ontiveros 2008) and compiled by INEGI.

Measures

Dependent Variable

The year 2000 Mexican census long form included a section on international migration, in which respondents were asked whether any regular household member had moved abroad between January 1995 and the date of the interview and whether or not they had returned by the census year. While it is not possible to differentiate an individual’s country of destination in the public-release micro-data, the U.S. is by far the most common international destination. According to aggregated tabulations from the 2000 census available from INEGI, where information of country of destination was available, 94 percent of people who were living in another country in 1995 and had returned to a rural locality in Mexico by 2000 had lived in the U.S.[5] Thus, we use the terms international migration and Mexico-U.S. migration interchangeably. As the MGPHC does not differentiate between types of border crossing, our variable combines both documented and undocumented migration.[6]

Our theoretical framework suggests that sending a migrant is a household decision to diversify risks either before or after an environmental shock. Thus, we aggregated the available data to the household level, in line with other recent studies (Arias and Roa 2008; Booysen 2006; Hunter et al. 2011). Our outcome variable was coded 1 if a household had at

[4]The MMP is a collaborative research project based at Princeton University and the University of Guadalajara (PUGU 2011) and provides high-quality data for public use.

[5]We obtained this figure by doing a query at http://www.inegi.org.mx/sistemas/olap/proyectos/bd/consulta.asp?p=14048&c=10252&s=est#, last consulted July 13, 2012.

[6]Our migration measure does not include members of entire households that emigrated abroad during this time (and did not return by the interview date). While this omission could bias our estimates, the amount of error is likely to be small in rural areas, where migrants are more likely to return (Cornelius 1992; Riosmena 2004). In addition, our theoretical framework assumes that the majority of international moves are the result of *ex-post/ex-ante* household-level responses towards environmental stressors. We are unable to separate such moves from moves that are solely based on economic considerations or motivated by normative expectations of male young adults who might view migration to the U.S. as a rite of passage (e.g., Kandel and Massey 2002). Using a measure of migration that combines all of these various migration motivations can be considered as conservative. We might expect a much stronger relationship for moves solely motivated by risk/insurance considerations and environmental factors.

least one member migrating to an international destination and 0 otherwise. About 8 percent of the households in our study had sent a member out of the country between January 1995 and the census date (see Table 1 for descriptive statistics).

Independent Variables

Given the structure of our data, our analysis is multilevel, with households nested in municipalities and municipalities nested in states. Level 1 comprises of household characteristics, included mainly for control purposes. Level 2 includes measures for social networks and overall marginalization at the municipality-level, and level 3 uses a measure of state-level change in GDP as well as state-level rainfall decline, the variable of main concern.

Household-level Indicators—Numerous quantitative studies on rural migration have demonstrated the importance of demographic, social, and economic factors including age, gender, education, and income (White and Lindstrom 2006). We calculated household income as the sum of the total income (in pesos), from all sources, of all household members in the previous month (the average exchange rate in 2000 was 7.92 pesos/USD). On average, a household had 2,149 pesos (about $271) available per month. For the analysis the measure was adjusted for household size by dividing the sum by the square root of the number of individuals per household (Franzen and Meyer 2010). The variable was the log transformed to account for the skewed distribution. In the context of rural areas (which tend to be particularly poor), household income should be positively associated with international migration, since it provides the necessary resources to fund such a move (Brown and Bean 2006).

In rural areas of developing countries, income may come in monetary and nonmonetary forms from multiple sources that can change from year to year and even from season to season (Montgomery et al. 2000). As such, physical assets are a more stable measure of a household's well-being. We followed Mberu's (2006) example and constructed a physical asset index by using a variety of items available in the IPUMS data set.[7]

Home ownership is another form of physical capital important for migration (Massey et al. 2010) and was accounted for by a dummy variable (1=owner, 0=renter). About 88 percent of the households in our sample owned their home. For the Mexican context it has been shown that a primary motivation for international migration to the U.S. is to finance the acquisition or construction of a home in the absence of accessible mortgage markets (Durand et al. 1996; Massey and Parrado 1994). Thus, we might expect that renters would be more likely than homeowners to send migrants to the U.S. (Clark, Deurloo, and Dieleman 2003; White and Lindstrom 2006). However, if migrants who remitted money for the home purchase stayed in the U.S. afterwards to earn additional money for home maintenance supplies, purchase of appliances (refrigerators, washing machines, TV, etc.), children's education, or intensification of agricultural production (Davis and Lopez-Carr 2010), we might expect to find that more migrant households owned their homes. Alternatively, a positive association might exist because wealthier households are in a better position to finance a costly move (Gray 2010).

[7]First, items were included that reflect the physical quality of housing units, in terms of materials used for building the wall, the roof, and the floor; the nature of toilet facilities; the number of rooms in the house; type of sewage disposal; type of water supply (piped vs. nonpiped); cooking fuel (electricity, charcoal, wood, etc.); and whether a hot water heater was available. Second, households were asked to report about the ownership of various means of personal transportation and other household durables—a car, a bicycle, television, radio, videocassette recorder, telephone, refrigerator, and washing machine. These variables were coded on a continuous scale or as dummies, with higher values indicating higher levels of physical capital. All items were used to form a standardized scale with a Cronbach's alpha reliability of .859.

We included educational attainment as a reflection of human capital (Saenz and Morales 2006), an important factor in migration (Lindstrom and Ramirez 2010; Takenaka and Pren 2010). Following Booysen (2006), we constructed a household-level variable of human capital as the average years of schooling among adult (age ≥15 years) household members. On average, individuals had four years of schooling. Most empirical studies find that education is positively associated with migration probabilities (Lauby and Stark 1988; Lindstrom and Ramirez 2010).

An additional measure of human capital frequently used in migration studies is employment status (Massey et al. 2010). We calculated a household employment ratio reflecting the number of household members employed (all ages) divided by the total number of household members. On average 32% of household members were employed.

Like Booysen (2006), we included a variable for age of household head, ranging from 15 to 100+ years in our sample (mean = 47 years). No clear evidence in the literature predicts an association between age of household head and out-migration. On the one hand, older household heads may be in a better position to assist a move through accumulated capital and knowledge. On the other hand, older household heads may be in a lifecycle stage where the children have already left the home, and these households may therefore not have the human capital available to send a migrant (Juelich 2011).

An additional variable accounts for the number of children below age five per household (ranging from 0 to 6, with a mean of less than one). The presence of young children in a household has been found to deter migration (White and Lindstrom 2006), a relationship recently confirmed for the Mexican context (Riosmena 2009).

Community/Municipality-level Indicators—The odds of migration are strongly dependent on the number of relatives, household members, and friends who have already migrated, providing the social capital to facilitate further movements (Fussell and Massey 2004; Massey et al. 2010; Massey and Riosmena 2010). To capture this social network effect we include a variable from the 1990 Mexican census (INEGI 2011) that measures the percentage of return migrants in the municipality during the five years prior to the census, a measure employed by other researchers (Lindstrom and Lauster 2001). Municipalities had return migration rates ranging from zero to 7.4 percent, with an average of 0.2 percent across Mexico.

It is important to also account for community-level socioeconomic characteristics. As NELM theory explains (e.g., Massey et al. 1993), individuals tend to migrate to more developed regions from less developed ones that lack functioning markets (labor, capital, insurance) and economic diversity (e.g., predominantly agricultural regions). To control for this potentially confounding factor, we employed an index of marginalization available from CONAPO (*Consejo Nacional de Poblacion*) and constructed from the same 2000 census data using principal components analysis.[8]

State-level Indicators—As the main predictor we employed a measure of change in precipitation patterns between two periods: 1988–1993 and 1994–1999. Since our migration data pertain to 1994–1999, we used 1988–1993 as our rainfall reference period, on the assumption that a substantial action like international migration is more likely to respond to

[8]The index reflects the proportions of a municipality's households (1) with dirt floors, (2) without indoor plumbing or a toilet, (3) without electricity, (4) without access to piped water, and (5) with more than two people per room, as well as the proportion of adults in the municipality (6) who are illiterate, (7) who have not completed primary education, and (8) who earn less than twice the minimum wage. This measure has been used in other studies of Mexican migration (e.g., Riosmena et al. 2012; Saldana-Zorrilla and Sandberg 2009).

recent weather changes than cumulative changes developing over several decades.Measuring rainfall deficits (as compared to other environmental indicators) has the methodological advantage of capturing a number of related changes in different sectors that affect livelihoods: a decline in crop production (Feng, Krueger, and Oppenheimer 2010), a reduction in arable land (e.g., due to desertification), drought-related livestock loss (Halliday 2006), and a reduction in employment opportunities in weather-dependent sectors. Figure 1 provides a graphical depiction of the study period.

For a more meaningful interpretation of the regression coefficients we transformed our precipitation change measure to reflect a decrease in rainfall, which is equivalent to an increase in dryness. Note that this transformation results in a positive sign for decrease in rainfall (increase in dryness) and a negative sign for an increase in rainfall (decrease in dryness). Some states exhibited a significant decrease in rainfall (42%), whereas in other regions rainfall increased (−68%) relative to the prior period. There was an overall decrease in rainfall (9%) across the study period, in line with projections about the impact of climate change for Latin America (IPCC 2007).

The period 1994–1999 has been described as a historically rare period of drought comparable to the great Mexican drought of the 1950s (Aparicio and Hidalgo 2004; Stahle et al. 2009). This drought occurred mainly in states with generally drier climates, mostly in northern Mexico (Stahle et al. 2009). To classify states as dry or wet, we used annual precipitation data provided by Mexico's National Water Commission for the years 1941 to 2005 (see González et al. 2008). States with average precipitation below the countrywide 64-year mean (876 mm) are characterized as dry (18 states), the others as wet (14 states). Figure 2 shows the 64-year average for each state (right panel) and the dichotomous classification as wet or dry (left panel). We expected to find stronger associations between changes in rainfall patterns and out-migration in dry states and therefore stratified most of our analyses according to this regional classification.

If our dichotomous classification performs as expected, we should clearly see a rainfall decrease between the reference period (1988–1993) and the study period (1994–1999), in line with the climatology literature (Stahle et al. 2009). As Figure 3 shows, this is indeed the case. For dry states (left panel) a downward slope characterizes the average rainfall measure (solid black line). In contrast, wet states (right panel) do not display a clear trend in average precipitation. We hypothesize that the decline in precipitation for dry states is related to an increase in out-migration, as has been observed by other studies (e.g., Feng et al. 2010).

It might be argued that our rainfall measure merely captures the effects of poor economic conditions in sending areas during the late 1990s, following the forced devaluation of the peso – yielding the "worst economic crisis since the Great Depression" (McKenzie 2006:139). This economic recession might have spurred international out-migration from rural areas. In order to account for the change in economic conditions, we constructed an inflation-adjusted GDP change measure that compares the mean state-level GDP for 1995–1999 to that for 1985–1994 (INEGI 1994, 2001). For some states, GDP decreased by as much as 32 percent, while other states witnessed gains up to 76 percent.

Estimation Strategy

Our multilevel modeling approach adjusted for clustering, different sample sizes at different levels, and heteroscedastic error terms. We modeled the log odds to migrate (m), for each household i located in municipality j in state k, using a three-level binomial logistic model. We estimated the logistic models assuming a binomial error distribution for the response m_{ijk} as

$$LOGIT\left(\pi_{ijk}\right)=\beta_0+\beta_1(X_{1ijk})+\beta_2(X_{2ijk})+\ldots+\beta_7(X_{7ijk})+\beta_8(Y_{1jk})+\beta_9(Y_{2jk})+\beta_{10}(Z_{1k})+\beta_{11}(Z_{2k})+\beta_{12}(Z_{3k})+\beta_{13}(Z_{2k}*Z_{3k})+\nu_{0k}+\eta_{0jk}. \quad \text{(Equation 1)}$$

In equation 1, the parameter β_0 represents the log odds of having an international migrant when all other predictors are zero. Parameters β_1 to β_7 represent the effect of the various household level control variables X_1 to X_7 (age of head, number of young children, household income, etc.) on the odds of out-migration. Parameters β_8 and β_9 are the effect of the municipality level predictors Y_{1jk} (return migration rate) and Y_{2jk} (marginalization index). Parameter β_{10} shows the effect of state-level change in GDP (Z_{1k}). The effect of rainfall change (variable Z_{2k}) is represented by parameter β_{11}, while β_{12} predicts the effect of the dichotomous variable for wet vs. dry states (Z_{3k}). Since we assumed that a change in rainfall pattern is more important for dry than for wet states, we included an interaction term, for which the effect is represented by parameter β_{13}. Finally, our models allow the intercept β_0 to vary across level-2 units (municipalities) and level-3 units (states), and thus partition the error into two separate random effect terms, η_{0jk} and ν_{0k}. The state random effects (ν_{0k}) and municipality random effects (η_{0jk}) are assumed to be normally distributed, with variance $\sigma^2_{\nu 0}$ and $\sigma^2_{\eta 0}$ quantifying the between-municipalities and between-state variation in the log odds of out-migration.

For more precise estimates of the fixed and random effects parameters, the final models were fitted using the predictive (or penalized) quasi-likelihood estimation procedure, including 2nd order terms of the Taylor series expansion (PQL2), which is used to transform a discrete response to a continuous response model. After applying the linearization the models were estimated using iterative generalized least squares (IGLS) (see Goldstein 2003 for further details). The models were fitted using MLwiN 2.25 software (Rasbash et al. 2009) run in STATA 11 (StataCorp LP, College Station, Texas) by using the macro *runmlwin* (Leckie and Charlton 2011). For ease of interpretation, we present the results of the fixed part of the model as odds ratios and transform the random effects to median odds ratio (MOR) estimates as suggested by Larsen and Merlo (2005).[9]

Results and Discussion

Multivariate Associations

We set out to test whether rainfall deficits encourage out-migration from rural areas in Mexico to international destinations. Table 2 presents the multivariate results in odds ratios. Model 1 includes all household-level control variables as well as the municipality-level predictors, which are return migration rate and the marginalization index; Model 2 then adds state-level GDP change and precipitation measures; to investigate nonlinearity potentially related to drought severity, Model 3 adds a quadratic term for rainfall decrease; finally, Model 4 tests an alternative specification by introducing an interaction term between dryness increase and the dummy variable for location characteristics (dry vs. wet states).[10]

[9]The MOR was calculated as follows: MOR= exp((sqrt(2*σ2)*ϕ−1(0.75)), where ϕ(·) is the cumulative distribution function of the normal distribution with mean 0 and variance 1, ϕ-1(0.75) is the 75th percentile (0.674), exp(·) is the exponential function, and sqrt is the square-root (Larsen and Merlo 2005). The MOR is always greater than or equal to 1. If the MOR is 1, there is no variation between clusters. Large MOR values reflect substantial between-cluster variation. In contrast to the raw variance components, the MOR has the benefit of being directly comparable with the fixed-effects odds ratios. In addition the MOR has a substantively more meaningful interpretation. The MOR quantifies the variation between clusters by comparing two cases from two randomly chosen, different clusters.

[10]The full model was checked for multicollinearity using the variance inflation factor (VIF) test. The VIF values for all variables remained smaller than two (except for the interaction and its involved variables). Heuristics suggest that values below ten indicate that multicollinearity is of no concern.

The random effects in the fully adjusted model (Model 4) suggest strong variation in household-level migration rates across municipalities and states. Because the variance components have been transformed into median odds ratio (MOR) estimates, the random effects can be interpreted as follows: If we randomly select two similar households, the odds of embarking on an international move are 152.6 percent higher for the household residing in the state with the higher migration propensity than for that in the state with the lower migration propensity. This variation is slightly smaller between municipalities, amounting to 112.9 percent for two randomly chosen households from different municipalities within the same state.

The control variables behave largely as expected. The household's life-cycle stage appears to be an important predictor for migration (White and Lindstrom 2006). Even though young adults are the most mobile subpopulation, this changes once children are present. Our models show that families with children below age five are less likely to send out a migrant, a finding in line with previous studies (Massey and Riosmena 2010; Riosmena 2009). Also at the end of the life-cycle, when children have left the parental household, migration becomes increasingly less likely as the household cannot spare the human capital to send out a migrant (Juelich 2011).

In line with the findings of Mberu (2006) and Halliday (2006), our data suggest that migrant households are relatively better off than nonmigrant households; migrants have a higher asset index, higher overall family income, and higher likelihood of homeownership. Two explanations for this positive association may be given. First, international migration is expensive, and more affluent households might be better positioned to finance a move (Takenaka and Pren 2010). Second, remittances from moves of household members prior to the observation period might increase household wealth (Taylor 1996) and the likelihood of a subsequent migration out of the same household.

The negative associations between household education and migration and between the proportion of household members employed and migration were unexpected and require additional explanation. Studies show that education is positively related to rural-to-urban migration but not necessary to international migration (Massey 1987; Henry et al. 2004; Stark and Taylor 1991). An inverse relationship between education and international migration may occur because the economic returns to schooling are higher for migrants within Mexico than for migrants in the U.S. (cf. Taylor 1987). This is particularly true for illegal migrants, since without documents migrants are confined to poorly paid jobs regardless of their education (Taylor et al. 1996). The negative association between employment proportion and out-migration might be explained by a reduced demand for risk diversification when a large number of household members are already employed, particularly in different sectors of the economy.

As we expected, our social network measure of municipality-level return migration rate was positively associated with out-migration. This result is in line with a number of other studies (Bohra and Massey 2009; Gray 2009; Lindstrom and Lauster 2001) and likely reflects experience, knowledge, and resources passed down from return migrants to aspiring migrants (Fussell and Massey 2004).

Because the control variables performed as predicted, our modeling platform can be judged to be statistically sound and therefore can be used to analyze the effects of the environmental variable on migration. We first included the dryness increase measure in our analysis without additional specification (Model 2). The coefficient was positive (b=1.086), indicating an overall increase in international out-migration for a decline in rainfall, but did not reach significance. Since it is possible that the association between rainfall decline and out-migration is nonlinear, we included a squared term (Model 3); and indeed, a significant coefficient indicates that a quadratic shape of the curve better approximates the underlying relationship, suggesting migration to be higher in places with both the highest and lowest precipitation. Moreover, as explained in the methods section, we expected to find a stronger association between rainfall deficits and migration out of dry states, which could partially explain this nonlinearity. To test this assumption we included an interaction term between the rainfall change variable and the state classification of wet vs. dry in the final model (Model 4). The interaction term is significant at the 5 percent level, likely indicating a substantial difference between wet and dry states in the impact of a change in precipitation patterns on international out-migration. Figure 4 shows both the quadratic relationship and the interaction.

Figure 4(a) depicts the U-shaped nonlinear main effect of rainfall. For the few states that experienced a sizable increase in rainfall (negative values on the left side of the x-axis), the predicted probability for out-migration is elevated, suggesting perhaps a disruptive effect of excess rainfall on local livelihoods. The likelihood of emigration drops with a decrease in rainfall until the bend-point is reached at a 16% increase in rainfall. As rainfall further declines, the probability of out-migration starts to rise rapidly and is highest at a rainfall deficit of 40%.

Note, however, that not all states have experienced a change in rainfall patterns. The included interaction term accounts for these differences in weather patterns. Figure 4(b) illustrates that, for wet areas, an increase in dryness was negative associated with the odds of out-migration (dashed gray line). In contrast, there was a strong positive association between decrease in rainfall and migration out of dry states (solid black line): an increase in dryness by 10% increased the odds of out-migration by 35.5%. Finally, note that the relationship between rainfall and U.S.-bound migration does not seem to be an artifact of the peso crisis and declining economic conditions, since we controlled for changes in state-level GDP, which did not significantly predict out-migration. Similarly, Fussell and Massey (2004) find that the economic crisis of 1982–1985 did not significantly predict international out-migration from Mexico to the U.S., a somewhat puzzling result in both cases.

Stratified Models

To further explore location specific differences, we ran the models separately for dry and wet states, allowing the effect of all variables to vary according to this climate classification. A significant difference between wet and dry states for the rainfall measure confirmed the findings from our interaction models (see Table 3). Only for dry states was a decrease in rainfall associated with an increase in out-migration.[11] Besides the dryness measure, we found significant differences on a few control variables -- the impact of socioeconomic status (asset index), employment status, and age of the household head were stronger in dry compared to wet states.

Perhaps the most interesting difference emerged for the impact of social networks. For wet states, a 1 percent increase in rate of return migrants in the local municipality increased the odds for out-migration by 89.4 percent, while for dry states the same increase was associated with an increase in odds of only 38.4 percent. Thus, for wet states, social network effects are a chief driver of out-migration, while for dry states, the effect of social networks is less strong and environmental factors become an important “push” factor. Figure 5 visually

[11]To investigate whether the non-significant relationship for wet states can be attributed to the impact of Puebla we removed this state from the model. The rainfall decrease coefficient became positive (b=1.092, z=0.45) but did not reach significance. Due to convergence issues this model was fitted using the PQL1 instead of PQL2 estimation procedure.

depicts the differential impact of social networks on the predicted probabilities of out-migration.

In order to explore the relationship among social networks, environmental factors, and out-migration in more depth we included an interaction term between dryness increase and migration return rate in Model A (not shown). The interaction coefficient was negative ($b_{\text{log odds}} = -0.035$), suggesting that the weaker the social network effect the stronger the impact of dryness becomes. However, the interaction coefficient did not reach significance, and thus the direction of the coefficient should be interpreted tentatively at best.

Seasonality

The employed rainfall measure is rather crude and uses the annual average precipitation rates. To explore the potential impact of seasonality and timing we constructed the rainfall change measure separately for each month (see Table 4).

Table 4 displays regression coefficients for the monthly rainfall decline measures that were obtained by running a set of fully adjusted multilevel-models. For all significant coefficients the relationship between out-migration and rainfall decline is positive. We observed two distinct seasons in which a rainfall decline appears to constitute a significant motivation for an international move. First, during the month of July and August a rainfall decline matters. This period overlaps with the sensitive growing season of corn (*Zea mays*), characterized by flowering (anthesis) and heading (Smeal and Zhang 1994). Since corn is arguable the most important staple crops in Mexico (Eakin 2000), drought conditions during the growing season might have detrimental impacts on rural Mexican’s livelihoods. However, in many regions of Mexico corn is grown twice a year. Planting of this second harvest starts as early as November 12 and continues throughout December up to the beginning of January (Baez-Gonzales et al. 2002). Thus, the period from November to February in which precipitation patterns predict out-migration in our models coincides with this second corn growing season. In addition, crops rely heavily on stored soil moisture to reach maturity. As a result of a winter of below-average precipitation, the summer crop may begin with inadequate soil moisture leading to an elevated risk of crop failure (McLeman et al. 2010). Thus, the observed association between rainfall decline and outmigration during the winter months might also stem from a secondary impact of soil-moisture storage on summer corn yield.

Robustness tests

As a final step, we conducted a number of tests to explore the robustness of our main finding that a decline in rainfall significantly predicts international out-migration. All tests confirm that the finding is particularly robust for dry states, and is significant for Mexico as a whole if we exclude the state of Puebla.[12]

Conclusions

In this study we investigated whether a decrease in rainfall is associated with international out-migration from Mexico. We find that rainfall deficits are not associated with out-migration across all states equally. In dry states, located mostly in the northern part of the country, we found a strong and significant association between rainfall deficits and international out-migration. In contrast, we found no such association in wet states, mostly located South and East of Mexico City. An additional key finding of the present analysis is that the physical environment interacts in complex ways with social and economic factors. This was illustrated through the differential impact of social networks on out-migration in wet compared to dry states. In wet states precipitation is unrelated to out-migration and social networks are the key driver of a move. Contrary, in dry states a decline in rainfall provides a strong motivation for an international move and social networks become less relevant.

Substantive Contributions

The new economics of labor migration (NELM) theoretical framework suggests that households may use out-migration to manage risk in imperfect insurance markets (Stark and Levhari 1982; Lucas and Stark 1985; Rosenzweig and Stark 1989), either in anticipation of a shock, *ex ante*, or in response to one, *ex post* (Halliday 2006). Our study provides evidence that "risk" in the NELM framework results not only from macroeconomic or political factors but also from environmental dynamics. In agricultural communities, especially in arid northern Mexico, rainfall deficits pose a substantial risk to farming households. These households are most likely to send a member abroad to diversify their income sources.

Other substantive and policy implications of our results depend on aspects of migration beyond the limits of our data. For instance, these results would have different implications depending on whether rainfall associated migration differs from migration with more "conventional" motivations (e.g., Lindstrom and Lauster 2001; Riosmena 2009). Weather-related moves might tend to be shorter and to be used as a subsistence rather than an investment strategy (Lindstrom 1996), and might therefore have lower economic multiplier effects on sending communities (Taylor et al. 1996). Differences in migration motivations could also potentially explain the stronger effects of rainfall decrease on migration in dry relative to wet states. For instance, part of these differences could be the result of poorer institutional capacity in dry states. Future research should elucidate the motivations of Mexico-U.S. migrants during droughts and other weather events in more detail.

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[12]Five robustness tests were performed. First, we used a repeated split sample procedure that randomly divided the sample of dry states (Model A, Table 3) into two groups of equal numbers of households and then ran the multilevel regression for each group separately. This procedure was repeated 150 times, resulting in 300 independent model estimations. We then calculated the mean and standard deviation of the coefficients and z-scores of the dryness increase measure across all iterations. This provides an indication regarding the stability of the parameter estimation when the model is fitted on a random subsample. The mean value of all iterations (b=1.311) came close to the observed coefficient (b=1.305), with a relatively small standard deviation (0.029). Also, the mean z-score (2.75) was only slightly smaller than the estimated value (2.84) for Model A, with a standard deviation of 0.25. Even if the standard deviation is subtracted from the mean, the z-score does not drop below the 5% level, and thus both the rainfall decrease coefficient and its significance can be considered robust.

Second, we ran a jackknife type procedure to test for influential states by removing one state at a time from the sample of dry states in Model A of Table 3 (c.f., Ruiter and DeGraaf 2006). Regardless of which state was removed from the sample, the rainfall decrease measure remained significant.

Third, we reran Model A after removing the six states that border the U.S.: Baja California del Norte, Chihuahua, Coahuila, Nuevo Leon, Sonora, and Tamaulipas. It can be expected that emigration behavior in these states is quite different from that in the rest of Mexico owing to the economic and cultural influence of high concentrations of foreign-owned factories ("maquiladoras") and the lower costs of border crossing (Feng et al. 2010). When these states were removed from the analysis the association remained similar in strength (b=1.311) and increased in significance (z=3.51, p<.001).

Fourth, it might be argued that our wet/dry classification masks differences in land use or number of people employed in the agricultural sector. To explore this potential problem we performed a group mean comparison (t-test) between wet and dry states on major land use categories (forest, crops, pasture in square kilometers, obtained from the MMP supplemental file ENVIRONS) and the percentage of household heads employed as skilled agricultural and fishery workers. Wet and dry states did not differ on land use characteristics. However, a significant difference was detected for occupational categories with a higher percentage of household heads in wet states (48%) working in the agricultural and fisher sector than in dry states (34%). We then included the occupation and land-use variables one at a time in the interaction model (Model 4, Table 2) to control for these potentially confounding characteristics. Regardless which variable was included the interaction term between wet/dry areas and rainfall decline stayed significant.

Finally, we investigated the impact of outliers or influential cases on our main finding. Figure 4(a) reveals that the state of Pueblo constitutes an unusual case, with relatively high migration probability under conditions of substantial rainfall increase. If we remove this state from Models 3 and 4 in Table 2, both the nonlinear term and the interaction term become insignificant, and a significantly positive linear relationship (b=1.268, p<.05) emerges across the remaining 31 Mexican states, in which a decline in rainfall predicts international out-migration. To explain this unique association between substantial out-migration under high levels of precipitation in Pueblo we can speculate that similarly to drought conditions excessive rainfall and associated flooding has detrimental impacts on crop yields. These results, thus, seem to suggest that extreme weather events at both ends of the continuum (wet to dry) and their impact on the agriculture sector may increase international outmigration.

Our results also suggest that particularly dry conditions during the late 1990s could have contributed (along with economic conditions and the existence of well-established migrant networks) to reduce the deterrent effect of increased border enforcement on the likelihood of undocumented migration from Mexico. Although the data in our study do not permit for the evaluation of this claim, future research on the effectiveness of immigration policies and practices should consider the role of environmental conditions.

Policy Recommendations

Policy recommendations with regard to drought-induced migration depend heavily on whether migration is viewed as brain-drain (Fan and Yakita 2011) or as brain circulation, which implies “innovation adoption and diffusion” (Stark and Bloom 1985:176). If the aim is to reduce drought-induced migration, well-functioning and reliable insurance and capital markets could be useful mechanisms. Government insurance programs can significantly affect household risk management strategies (cf. Massey et al. 1993) through, for example, crop insurance (Bardsley, Abey, and Davenport 1984), rainfall insurance (Zeuli and Skees 2005), and/or irrigation insurance (Leiva and Skees 2008).

Although our precipitation variable is not a direct measure of climatic change (as it is not an indicator of long-term trends), our results could have implications if climate change increases the frequency and length of below average rainfall periods (IPCC 2007, Solomon et al. 2009). In this context, assisting rural farm households in their adaptation to shifts in weather patterns seems to be important. As examples, policies and programs could be designed to subsidize irrigation systems and improve technologies for water collection and storage, such as in-field rainwater harvesting (Baiphethi et al. 2009). In addition, access to drought-resistant crop varieties (Shiferaw, Kebede, and You 2008) and agricultural extension services could help rural households create more sustainable agricultural livelihoods (Aubee and Hussein 2002).

Limitations and Future Research

A number of limitations deserve mention. First, our use of census data allows generalization but limits us to a cross-sectional analysis. It is likely that the migratory response to drought follows a time-lagged cause response model (e.g., Henry et al. 2004). In contrast, if farmers become convinced that unfavorable climatic conditions will be sustained indefinitely, they have a larger incentive to invest in irrigation and other infrastructure that would mitigate the effects of these conditions (Feng et al. 2010). To explore this complexity in the migratory response would require longitudinal data, allowing the inclusion of time-varying predictors (e.g., Halliday 2006).

In this regard it is also important to stress that this study explores the impact of rather extreme climatic conditions. The years that correspond to the census question about household-level migration to the U.S. (1994–1999) were unusual dry compared the reference years (prior to 1994). Although, other studies looking at different periods (Feng et al. 2010, Hunter et al. 2011), find overall similar results to our study, future research should continue investigating the rainfall-change migration relationship during less dry or even exceedingly wet periods.

Second, additional climatic and environmental factors would be useful. For example, soil moisture content as well as temperature extremes during sensitive crop development periods (McLeman et al. 2010) may substantially affect agricultural production and thus could trigger out-migration. In addition, a municipality-level variable for irrigated vs. rain-fed farming would better isolate the impact of rainfall on out-migration. Future research might consider such variables by employing satellite imagery and geographical information system (GIS) technology.

Finally, more qualitative research is warranted to investigate the underlying causal mechanisms that connect a change in precipitation patterns and international out-migration. It is still a puzzle why droughts increase international out-migration in some countries but deter it in others. On the one hand, studies from Africa uniformly suggest that droughts deter international out-migration (Findley 1994; Henry et al. 2004). On the other hand, studies of Mexico, including this paper, show increases in international out-migration under drought conditions (Feng et al. 2010; Hunter et al. 2011; Munshi 2003). Potential explanation might be distance, with Mexico geographically closer to preferred international destinations, prevalence of established migration networks, and transportation costs (independent of distance). In addition, institutional differences as related to governmental policy and agricultural support programs between as well as within countries (e.g., between wet and dry states) might explain differences in the association between changes in rainfall patterns and migratory responses (c.f., Eakin 2000).

The present study adds to our growing knowledge about the complex relationship between environment and migration, but many questions remain unanswered. We argue that demographers must invest more time and resources in exploring the environment-migration nexus, which is likely to become a highly relevant topic in future decades under the unprecedented impact of global climate change (IPCC 2007).

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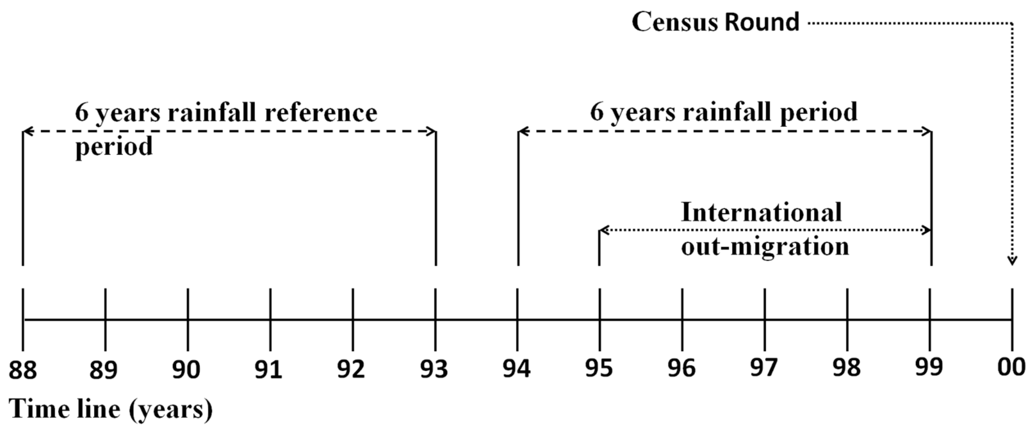

Figure 1.
Graphical depiction of the construction of the rainfall measure

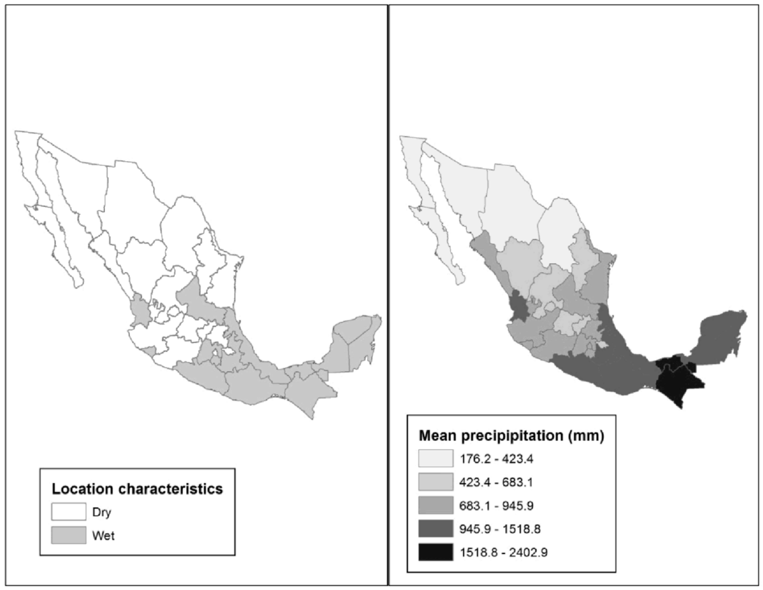

Figure 2.
Mean precipitation and dry/wet classification of Mexican states

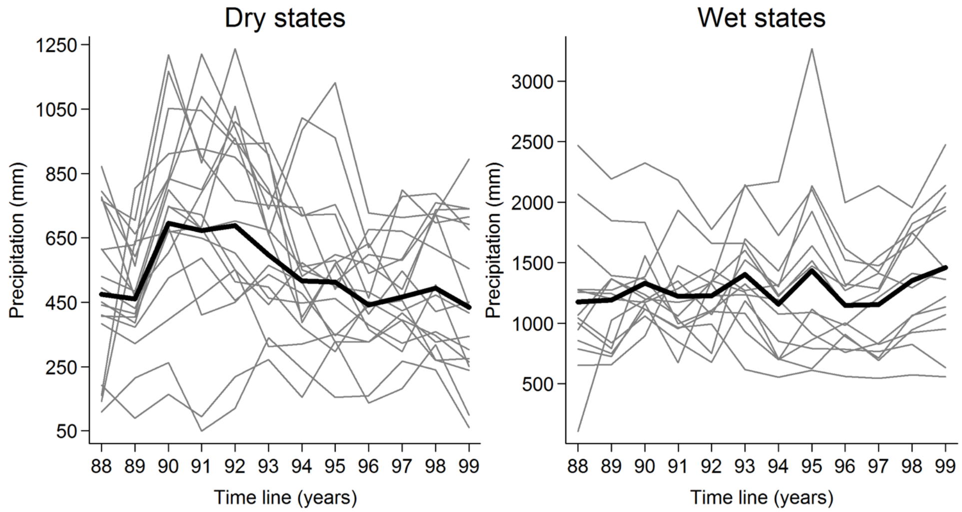

Figure 3. Average annual precipitation in wet and dry states, 1988–1999

Note: Gray lines represent different states. The solid black line represents mean precipitation values for dry and wet states respectively.

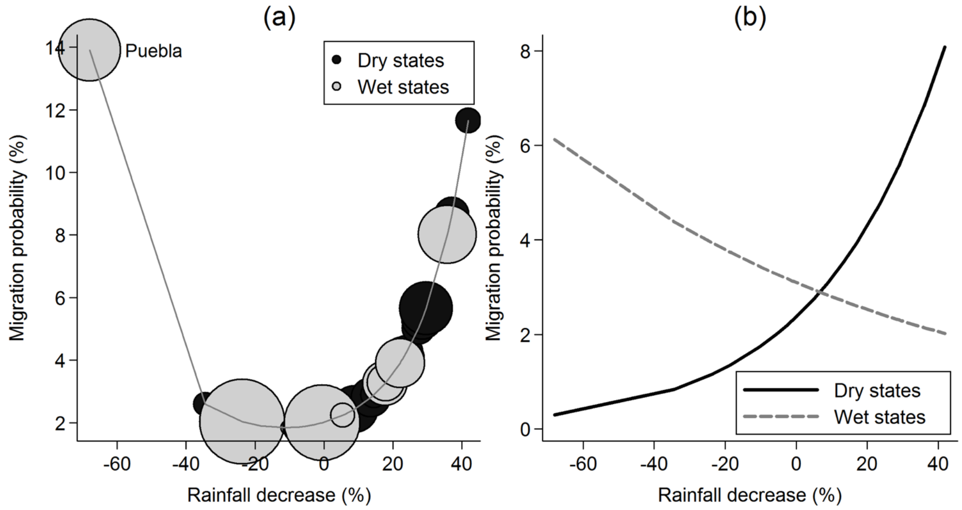

Figure 4. Predicted probability for international out-migration from rural Mexico as a function of rainfall decrease

Note: Panel (a) shows predicted probabilities of international out-migration across all Mexican states. Circles are weighted by the population (number of households) of each state. The unusual state on the far left is the state of Puebla. Panel (b) shows the differential effect of rainfall decrease on out-migration for dry vs. wet states. Predicted probabilities relate to the average household and were calculated with mean values for other covariates.

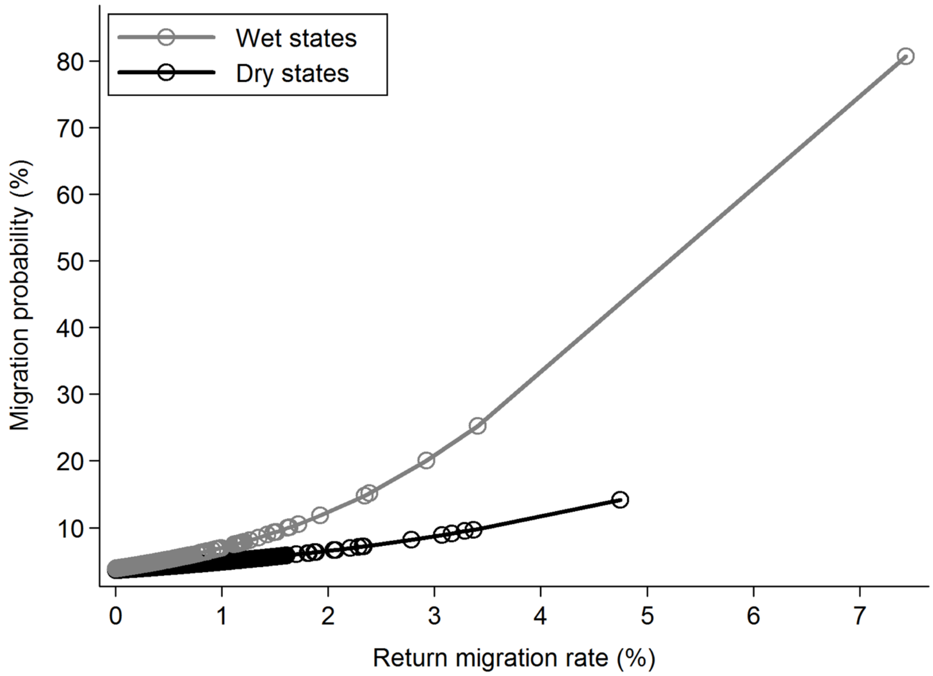

Figure 5. Predicted probability for international out-migration from rural Mexico as a function of social networks for dry and wet states

Note: Data for return migration rate was available at the municipality level. Predicted probabilities relate to the average household and were calculated with mean values for the other control variables.

Table 1

Summary statistics of selected variables for the study of the association between dryness and international out-migration from rural Mexico

	N	Mean	Std. Dev.	Min	Max
Outcome variable:					
Households with member(s) moved abroad[a]	80,455	0.08	0.28	0	1
Household-level covariates:					
Age of household head	82,309	47	17	15	100
No. children < 5 years	82,907	0.54	0.77	0	6
Average HH education	82,907	4.44	3.03	0	18
HH members employed	82,907	0.32	0.26	0	1
HH income	82,907	2,149	14,834	0	1,357,143
Home owner	81,145	0.88	0.32	0	1
Asset index	82,597	0.01	0.56	−1.36	2.42
Aggregate-level covariates:					
Return migration rate (%)	2,343	0.20	0.42	0	7.44
Marginalization index	2,343	0.02	0.99	−2.18	3.39
GDP change ratio (%)[b]	32	15.65	20.80	−32.14	75.75
Rainfall decrease[c]	32	9.49	23.71	−67.95	41.84
Wet states (REF=dry)[d]	32	0.44	0.50	0	1

[a]Reference period is from January 1995 to interview date (February 7–18, 2000).

[b]Reference period is 1995–1999 vs. 1985–1994.

[c]Reference period is 1994–1999 vs. 1988–1993.

[d]*Dry states (18)*: **Aguascalientes**, Baja California del N, Baja California del S, Coahuila, Chihuahua, Distrito Federal, **Durango**, Guanajuato, Hidalgo, Jalisco, Michoacan, Nuevo Leon, Queretaro, Sinaloa, Sonora, Tamaulipas, Tlaxcala, Zacatecas; *Wet states (14)*: Campeche, **Colima**, Chiapas, Guerrero, Mexico, Morelos, **Nayarit**, Oaxaca, Puebla, Quintana Roo, **San Luis Potosi**, Tabasco, Veracruz, Yucatan. Note: States in bold font are located in region of historically high migration to U.S. (Durand and Massey 2003).

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$

Source: 2000 Mexican Population and Housing Census 1% sample via IPUMS International (Ruggles et al. 2003).

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Table 2

Odds ratios from multilevel models predicting international out-migration from rural Mexican households

	Model 1		Model 2		Model 3		Model 4	
	b	sig.	b	sig.	b	sig.	b	sig.
Household-level covariates:								
Intercept	0.026	***	0.026	***	0.018	***	0.020	***
Age of household head	0.997	*	0.997	*	0.997	*	0.998	*
No. children < 5 years	0.892	***	0.897	***	0.897	***	0.899	***
Average HH education	0.969	***	0.970	***	0.970	***	0.970	***
HH members employed	0.333	***	0.349	***	0.350	***	0.354	***
HH income (logged)	1.078	***	1.073	***	1.073	***	1.072	***
Home owner	1.596	***	1.573	***	1.569	***	1.565	***
Asset index	2.540	***	2.446	***	2.434	***	2.415	***
Aggregate-level covariates:								
Return migration rate (%)	1.673	***	1.615	***	1.617	***	1.600	***
Marginalization index	1.037		1.044		1.042		1.045	
GDP change ratio (%)[a]			1.002		0.994		1.001	
Rainfall decrease[b]			1.086		1.167	*	1.355	*
Rainfall decrease squared					1.070	**		
Wet states (REF = dry)[c]							1.334	
x Rainfall decrease							0.663	*
Variance components								
Between states[d]	2.692	***	2.735	***	2.406	***	2.526	***
Between municipalities[d]	2.470	***	2.191	***	2.202	***	2.129	***
N	77,464		77,464		77,464		77,464	

[a]Reference period is 1995–1999 vs. 1985–1994.

[b]Coefficients for rainfall decrease refer to a 10% increment.

[c]*Dry states (18)*: **Aguascalientes**, Baja California del N, Baja California del S, Coahuila, Chihuahua, Distrito Federal, **Durango**, Guanajuato, Hidalgo, Jalisco, Michoacan, Nuevo Leon, Queretaro, Sinaloa, Sonora, Tamaulipas, Tlaxcala, Zacatecas; *Wet states (14)*: Campeche, **Colima**, Chiapas, Guerrero, Mexico, Morelos, **Nayarit**, Oaxaca, Puebla, Quintana Roo, **San Luis Potosi**, Tabasco, Veracruz, Yucatan. Note: States in bold font are located in region of historically high migration to U.S. (Durand and Massey 2003).

[d]Variance components are displayed as median odds ratios (MOR) for ease of interpretation (Larsen and Merlo 2005).

*$p < 0.05$;

**$p < 0.01$;

***$p < 0.001$

Source: 2000 Mexican Population and Housing Census 1% sample via IPUMS International (Ruggles et al. 2003).

Table 3

Odds ratios from multilevel models predicting international out-migration from rural Mexican households located in (A) dry and (B) wet states

	A. Dry states[d]		B. Wet states[d]		A vs. B[e]	
	b	**sig.**	**b**	**sig.**	**z-value**	**sig.**
Household-level covariates:						
Intercept	0.035	***	0.029	***	0.38	
Age of household head	0.996	**	1.000		−2.14	*
No. children < 5 years	0.890	***	0.928	**	−1.08	
Average HH education	0.970	***	0.972	***	−0.18	
HH members employed	0.355	***	0.451	***	−2.18	*
HH income (logged)	1.067	***	1.056	***	0.94	
Home owner	1.621	***	1.359	***	1.87	
Asset index	2.423	***	2.006	***	2.95	**
Aggregate-level covariates:						
Return migration rate (%)	1.384	***	1.894	***	−2.69	**
Marginalization index	1.130	*	1.022		1.67	
GDP change ratio (%)[a]	0.989		1.021		−1.38	
Rainfall decrease[b]	1.305	**	0.919		1.99	*
Variance components						
Between states[c]	1.878	**	3.517	*		
Between municipalities[c]	1.943	***	1.669	***		
N	30,436		47,028			

[a]Reference period is 1995–1999 vs. 1985–1994.

[b]Coefficients refer to a 10% decrease in rainfall.

[c]Variance components are displayed as median odds ratios (MOR) for ease of interpretation (Larsen and Merlo 2005).

[d]*Dry states (18)*: **Aguascalientes**, Baja California del N, Baja California del S, Coahuila, Chihuahua, Distrito Federal, **Durango**, Guanajuato, Hidalgo, Jalisco, Michoacan, Nuevo Leon, Queretaro, Sinaloa, Sonora, Tamaulipas, Tlaxcala, Zacatecas; *Wet states (14)*: Campeche, **Colima**, Chiapas, Guerrero, Mexico, Morelos, **Nayarit**, Oaxaca, Puebla, Quintana Roo, **San Luis Potosi**, Tabasco, Veracruz, Yucatan. Note: States in bold font are located in region of historically high migration to U.S. (Durand and Massey 2003).

[e]Coefficient comparison follows Paternoster et al. (1998).

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$

Source: 2000 Mexican Population and Housing Census 1% sample via IPUMS International (Ruggles et al. 2003)

Table 4

Exploring seasonality for the impact of rainfall decline on international out-migration from rural areas in wet states

Months	b	sig.	Month	b	sig.
January	1.256	***	July	1.271	**
February	1.241	*	August	1.149	**
March	1.013		September	1.116	
April	0.978		October	1.069	
May	1.027		November	1.119	*
June	1.012		December	1.141	***

A separate model was run with precipitation measures for each month. All models controlled for age of household head, no. children < 5 years, average household education, household members employed, household income (logged), home owner, asset index, return migration rate, marginalization index, and GDP change.

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$

Source: 2000 Mexican Population and Housing Census 1% sample via IPUMS International (Ruggles et al. 2003)