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LETTER

Climate change as a migration driver from rural and urban Mexico

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Abstract

Studies investigating migration as a response to climate variability have largely focused on rural locations to the exclusion of urban areas. This lack of urban focus is unfortunate given the sheer numbers of urban residents and continuing high levels of urbanization. To begin filling this empirical gap, this study investigates climate change impacts on US-bound migration from rural and urban Mexico, 1986–1999. We employ geostatistical interpolation methods to construct two climate change indices, capturing warm and wet spell duration, based on daily temperature and precipitation readings for 214 weather stations across Mexico. In combination with detailed migration histories obtained from the Mexican Migration Project, we model the influence of climate change on household-level migration from 68 rural and 49 urban municipalities. Results from multilevel event-history models reveal that a temperature warming and excessive precipitation significantly increased international migration during the study period. However, climate change impacts on international migration is only observed for rural areas. Interactions reveal a causal pathway in which temperature (but not precipitation) influences migration patterns through employment in the agricultural sector. As such, climate-related international migration may decline with continued urbanization and the resulting reductions in direct dependence of households on rural agriculture.

1. Introduction

Climate change is an issue of global magnitude that will impact human populations through, for example, increases in frequency and intensity of storms, floods, and heat waves, as well as more gradual changes involving sea-level rise and desertification (IPCC 2013, 2014). Particularly poor, less developed countries (LDCs) will likely suffer most from climate change due to a less adequate infrastructure such as irrigation, combined with limited financial capital to develop technological protection including sea walls (see, Gutmann and Field 2010).

When climate change negatively impacts livelihoods, households may employ in situ (in place) adaptation strategies to meet basic needs (Bardsley and Hugo 2010, Davis and Lopez-Carr 2010). In situ strategies include selling assets, using formal and informal credit, reducing non-essential expenditures, and/or drawing on social networks and public programs for assistance (Gray and Mueller 2012). However, households may also send a member elsewhere as an ex situ strategy to diversify income sources through remittances. As such, migration functions as an informal insurance mechanism. This mechanism is most effective when the household member is sent to a destination where environmental and market conditions are largely uncorrelated with those at the origin (Stark and Bloom 1985, Massey et al 1993). This diversification strategy may be useful in times of climate stress (Black et al 2011). In addition, remittances not only benefit the migrant family but positively impact community development through various multiplier effects (Taylor et al 1996).

Evidence from around the world suggests that environmental factors influence migration patterns
(e.g., Gray and Bilsborrow 2013, Hunter et al 2013, 2015, Bohra-Mishra et al 2014, Mueller et al 2014). However, studies frequently find that the climate–migration association varies by location characteristics (e.g., Nawrotzki et al 2013), access to social networks (Hunter et al 2013), and demographic factors such as gender (Gray 2010). Yet, this body of research, and the generalizations emerging from collective results, have a decidedly rural focus. In fact, there is no published study available (to our knowledge) that contrasts climate migration from rural and urban areas. This lack of research is unfortunate, given continuing high levels of urbanization (Ravallion et al 2007). About 54% of the world’s population currently lives in urban areas (UNPD 2014) and in future decades the population of LDCs will be predominantly urban (Seto et al 2012).

Understanding the implications of climate variability and change for urban migration is of tremendous policy importance given the high levels of global population in urban regions (see Adamo 2010). In this letter, we report research results contrasting climate migration responses from rural and urban areas in Mexico, with a focus on international migration. Bringing physical climate science into social science, we employ two measures of climate extremes, the warm spell duration index and the wet spell duration index formalized by the Expert Team on Climate Change Detection and Indices (ETCCDI) (Peterson and Manton 2008).

2. Mexico as a setting for research on climate and migration

Mexico provides an excellent case for the study of international climate migration dynamics due to a long history of migration. Longstanding international labor migration between Mexico and the US has led to the establishment of strong transnational migrant networks (see supplement S1 for a detailed account of the history of Mexico-US migration). Such networks operate as migrant corridors and may strongly facilitate climate-related migration (Bardsley and Hugo 2010).

We conceptually consider migration a household-based strategy for income diversification to guard against the adverse influence of environmental and economic impacts (Stark and Bloom 1985, Massey et al 1993). Yet, we argue that climate variability and change influence livelihoods differently in rural and urban areas. In rural areas of Mexico, households depend heavily on agricultural production for sustenance and income generation (de Janvry and Sadoulet 2001, Wiggins et al 2002, Conde et al 2006). This reliance on agriculture combined with a lack of technological infrastructure (e.g., limited irrigation) makes rural Mexican households highly vulnerable to climatic shifts (Endfield 2007, Eakin and Appendini 2008, Schroth et al 2009).

In urban areas, however, the livelihood impacts of climate are more complex and often related to extreme events (Revi et al 2014). For example, flooding may damage wastewater systems (Revi 2008, Romero-Lankao 2010, Willems et al 2012), transportation infrastructure (Koete and Rietveld 2009, Gasper et al 2011), and buildings. These impacts negatively affect job availability and housing quality (CEPAL 2008). In addition, heat waves may result in negative health outcomes (Burkart et al 2011, WHO and WMO 2012, Klinenberg 2015) and may adversely impact the effectiveness of workers in manual occupations (see, Kovats and Akhtar 2008). In urban areas, heat waves are often intensified by the urban heat island effect which is due, in part, to daytime absorption and nighttime release of heat by concrete, pavement, and buildings (Wilby 2007, Adachi et al 2012). In short, while climate variability and change influence rural livelihoods through impacts on the agricultural sector, climate change may affect urban livelihoods through a broad spectrum of impacts to city functions, infrastructure, services, and employment opportunities.

Also important to consider is the connection between rural and urban regions. Adverse climatic conditions in rural areas may influence urban industries and livelihoods in various indirect ways (Wackernagel et al 2006, Boyd and Ibarra 2009). For example, urban residents may be employed in the agricultural sector near cities or work in factories processing agricultural outputs (Satterthwaite et al 2007). In addition, climate variability and change related to agricultural failure in rural areas may decrease food supply and increase urban food prices (Satterthwaite et al 2007). As such, adverse climatic conditions may directly impact rural livelihoods and at the same time indirectly impact urban livelihoods. Consequently, both rural and urban households may employ migration as a livelihood diversification strategy in the face of climate variability and change (see Adamo 2010).

3. Data and methods

To investigate the climate change–migration association for both urban and rural Mexico, we combined sociodemographic data from the Mexican Migration Project (MMP) with climate information from the Global Historical Climatology Network Daily (GHCN-D) data set (Menne et al 2012). While the MMP provides detailed migration histories and sociodemographic information, the GHCN-D provides daily temperature and precipitation readings for 214 weather stations across Mexico (see S2 for additional detail on the data).

In Mexico, the decision to migrate—particularly international migration—is often a household
decision and we, therefore, focused our analysis on household-level outmigration (Kanaiaupuni 2000, Cohen 2004). Our sample comprised 14,239 households located in 111 municipalities dispersed across Mexico. We employed geo-statistical interpolation to link spatial climate information to sociodemographic MMP data at the municipality level (see S3 for variable construction). Figure 1 shows the location of the weather stations as well as the 111 MMP municipalities, which are comprised of communities that can be considered either urban or rural. Communities located in a metropolitan area (a state’s capital city or other large city) or a city (smaller urban area of 10,000–100,000 inhabitants) are considered urban, while communities located in a town (2500–10,000 inhabitants) or a village (<2500 inhabitants) are considered rural.

The period under investigation is 1986–1999, an excellent timeframe for examination of the association between climate change and migration because much of Mexico experienced above normal temperature during the 1990s (Stahle et al 2009). This climatic pattern resembles projected temperature increases under future climate change scenarios (Gollins et al 2013, IPCC 2013). And on a practical note, the number of Mexican weather stations available within the GHCN-D dropped substantially for more recent years, rendering the spatial interpolation of climate data after 1999 unstable.

For the study of climate-migration dynamics, we used multi-level event history models that account for household clustering within municipalities (see S4 for details on the statistical methodology). Our outcome variable was international migration at the household level and we included a suite of important control variables such as indicators of access to migrant networks, occupation status, and socio-economic characteristics such as marital status and assets (Brown and Bean 2006). Community-level factors were also considered such as the level of agricultural employment and access to migrant networks (see supplement S3).

We first developed a reliable multivariate base model with these control variables to predict international migration from urban and rural Mexican communities (see S5).

4. Results and discussion

The results of the base model are in line with prior work on Mexican migration, suggesting that international migration from Mexico is influenced by a set of well-known socio-demographic factors. For example, households are more likely to send a migrant when they have good access to migrant networks (Fussell...
and Massey 2004) or when the household head is an uneducated young male (Fussell 2004). In contrast, the likelihood of sending a migrant is lower when young children are present (Nawrotzki et al 2013) or when the household owns a business (Massey and Parrado 1998). After testing the robustness of this base model, we added the warm spell duration index (WSDI) and the wet spell duration index (CWD) jointly, allowing for simultaneous control of temperature and precipitation effects (Auffhammer et al 2013). Table 1 provides separate estimates of the climate–migration association for rural and urban areas in Mexico, 1986–1999.

The results suggest that longer warm spell durations and wet spell durations lead to higher odds of international migration in the combined model of rural and urban areas (‘All’). But the temperature effect is three times as strong as the precipitation effect—a one standard deviation unit increase in warm spell duration leads to an increase of the odds of international migration by 15% (odds ratio (OR) = 1.15) while a one standard deviation unit increase in wet spell duration leads to an increase in the odds of an international move by 5% (OR = 1.05). This observation is in line with prior work that consistently finds stronger temperature than precipitation effects on migration patterns (Bohra-Mishra et al 2014, Mueller et al 2014). An increase in temperature may increase evapotranspiration and lead to drought conditions even if precipitation patterns do not change (Diffenbaugh et al 2015). In addition, technological responses to precipitation anomalies, such as irrigation, are more readily implemented than technologies to guard against adverse impacts of temperature extremes.

Table 1. Impact of climate change on the odds of international migration from rural and urban Mexico, 1986–1999.

|                | All | Rural | Urban |
|----------------|-----|-------|-------|
| Warm spell duration | 1.15*** | 1.22*** | 1.05 |
| Wet spell duration  | 1.05* | 1.06* | 1.02 |

Note: coefficients reflect odds ratios; climate effects were estimated using the fully adjusted multi-level event history models (table S2); municipality N: all = 111; rural = 68; urban = 49; a jackknife procedure, omitting one municipality at a time from the sample (Ruiter and De Graaf 2006, Nawrotzki 2012), demonstrated that the estimates were highly robust; \( p < 0.05, \* p < 0.01, \*\* p < 0.001. \)

lack of association could include: (1) the indirect effects on urban livelihoods through rural production deficits (e.g., job losses, increased food prices) are not sufficiently strong, (2) urban households have better access to alternative in situ (in place) adaptation strategies, or (3) migrant networks that facilitate climate migration (i.e., Bardsley and Hugo 2010) are under-developed in urban areas (Fussell and Massey 2004).

On the other hand, climate change measures exhibit statistically significant effects for migration from rural Mexican households. As noted above, rural populations in Mexico depend heavily on subsistence farming and agricultural employment, intensifying vulnerability to climate variability and change (Mueller et al 2014). Both heat waves and flooding have negative impacts on agricultural productivity. Corn, an important staple in Mexico, is particularly sensitive to heat stress (Schoper et al 1987, Tollenaar and Bruulsema 1988, Sanchez et al 2014), and a warming in temperature has been shown to reduce crop yields (Lobell and Field 2007, Bassu et al 2014). Similarly, flooding and excess soil moisture (saturation and waterlogging) impair plant growth (Ashraf and Habib-ur-Rehman 1999, Zaidi et al 2003), increase the risk of plant disease and insect infestation (see, Kozdrič and van Elsas 2000), and may delay planting or harvesting due to inability to operate machinery. As a result, precipitation and harvest yields are non-linearly related and when cumulative precipitation exceeds certain thresholds, a substantial decline in crop yields can occur (Rosenzweig et al 2002). Overall, we argue that through such adverse agricultural impacts, heat waves and flooding both increase livelihood insecurity and can lead to elevated migration probabilities from rural areas.

To further test this agricultural pathway for climate change effects on rural migration, we estimated a model of international migration with an interaction term, reflecting a combination of the climate change indices and a municipality-level measure of percentage males employed in the agricultural sector (table 2).

We observe a statistically significant interaction in the combined model (‘All’) and for the rural sub-sample, but only for the temperature effect (table 2). Figure 2 provides a visual representation of this important interaction—the warm spell duration has almost no effect on international migration when only a small proportion of local males are employed in the agricultural sector. However, with higher levels of male agricultural employment, warm spells are associated with greater likelihood of international migration. A similar pathway in which the temperature–migration association is moderated by agricultural income was initially suggested, but not empirically tested, by Mueller et al for Pakistan (2014).

Even so, no significant interaction emerged for the length of wet spells. Although longer wet spell
durations and possible flooding increase the likelihood of an international move from rural areas in general, this effect is not associated specifically with agricultural employment. This may indicate that flooding is equally harmful for non-agricultural sectors. Indeed, flooding not only damages agricultural production but also may have detrimental impacts on local infrastructure and other economic activities (CEPAL 2008). In short, we find evidence that climate change impacts rural migration through the agricultural sector, but only as related to temperature extremes.

5. Conclusion

Evidence continues to emerge suggesting that climate variability and change shapes migration patterns (Gray and Bilsborrow 2013, Mueller et al 2014). However, most existing research focuses exclusively on rural areas. Given trends of rapid urbanization (Seto et al 2012), it is of increasing policy relevance to investigate whether climate variability and change similarly influence the probability of international moves from urban areas (see Adamo 2010).

### Table 2. Interaction between climate change indices and the male labor force employed in the agricultural sector predicting the odds of international migration from rural and urban Mexico, 1986–1999.

|                        | All    | Rural | Urban |
|------------------------|--------|-------|-------|
|                       | $b$    | sig.  | $b$   | sig.  | $b$   | sig.  |
| Temperature interaction model |
| Warm spell duration    | 1.13   | ***   | 1.15  | ***   | 1.05  |       |
| Male labor in agriculture | 1.09  | **    | 0.98  |       | 1.19  | ***   |
| Warm spell duration x male labor in agriculture | 1.01  | *     | 1.03  | **    | 1.01  |       |
| Precipitation interaction model |
| Wet spell duration     | 1.06   | *     | 1.08  |       | 0.99  |       |
| Male labor in agriculture | 1.09  | **    | 1.00  |       | 1.17  | ***   |
| Wet spell duration x male labor in agriculture | 0.99  |       | 0.99  |       | 0.97  |       |

Note: coefficients reflect odd ratios; coefficients for male labor force employed in the agricultural sector relate to a 10% change; each row represents a fully adjusted interaction model (all controls of table S2 included) of which only the coefficients for the terms involved in the interaction are shown; variables were grand mean centered; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 

Figure 2. Interaction between warm spell duration index and the percentage of males employment in the agriculture sector on the probability of international migration across Mexico (combined rural and urban sample), 1986–1999.
This letter reports results from the first empirical study to contrast climate migration from rural and urban areas in Mexico. As a strength of this research project, we employ two ETCCDI climate change indices constructed based on daily temperature and precipitation information at a high spatial resolution. We find that heat waves and wet spells significantly increased international migration from Mexico during 1986–1999. However, our results show that adverse climate variability and change drive international outmigration only from rural areas. In addition, we find evidence that the influence of climate change on migration operates primarily through employment in the agricultural sector. However, this causal pathway emerges only for temperature but not for precipitation effects, suggesting the particular importance of temperature extremes for international migration from rural areas.

These findings have important policy implications. First, the results suggest that attempts to project international climate migration (e.g., Myers 2002, 2005, Christian Aid 2007, Stern 2007) must account for urban-rural differentials in the influence of climate on migration. Second, our study suggests that adverse climate variability and change will continue to increase international migration from rural areas. Adaptation programs should therefore target rural Mexican communities, potentially as a means of lessening the need for migration as an \textit{ex situ} strategy and to improve livelihoods and wellbeing of local populations.

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\textbf{References}

Adachi S A, Kimura F, Kusaka H, Inoue T and Ueda H 2012 Comparison of the impact of global climate changes and urbanization on summertime future climate in the Tokyo metropolitan area \textit{J. Appl. Meteorol. Climatol.} 51 2074–5

Adamo S B 2010 Environmental migration and cities in the context of global environmental change \textit{Curr. Opin. Environ. Sust.} 2 161–5

Adamo S B and de Sherbinin A 2011 The impact of climate change on the spatial distribution of populations and migration \textit{Population Distribution, Urbanization, Internal Migration and Development: An International Perspective} (New York: United Nations, Department of Economic and Social Affairs, Population Division) pp 161–95

Alexander L V et al 2006 Global observed changes in daily climate extremes of temperature and precipitation \textit{J. Geophys. Res. - Atmos.} 111 22

Allison P 1984 \textit{Event History Analysis} (Thousand Oaks, CA: Sage Publications)

Allison P D 2002 \textit{Missing Data} (Thousand Oaks, CA: Sage Publications)

Angelucci M 2012 US border enforcement and the net flow of Mexican illegal migration \textit{Econ. Dev. Cultural Change} 60 311–57

Ashraf M and Habib–ur–Rehman 1999 Interactive effects of nitrate and long-term waterlogging on growth, water relations, and gaseous exchange properties of maize \textit{(Zea mays L.)} \textit{Plant Sci.} 144 35–45

Aufmhammer M, Hsiang S M, Schlenker W and Sobel A 2013 Using weather data and climate model output in economic analyses of climate change \textit{Rev. Environ. Econ. Policy} 7 181–98

Aznar J C, Glaouegen E, Tapsoba D, Hachem S, Caya D and Begin Y 2013 Interpolation of monthly mean temperatures using cokriging in spherical coordinates \textit{Int. J. Climatol.} 33 758–69

Barber J S, Murphy S A, Axinn W G and Maples J 2000 Discrete-time hazard analysis \textit{Sociol. Methodol.} 30 201–35

Bardales D K and Hugo G J 2010 Migration and climate change: examining thresholds of change to guide effective adaptation decision–making \textit{Population Environ.} 32 238–62

Bassu S et al 2014 How do various maize crop models vary in their responses to climate change factors? \textit{Glob. Change Biol.} 20 2301–20

Bates D, Maechler M, Bolker B M and Walker S 2014 \textit{lme4: Linear Mixed-Effects Modeling Using Eigen and S4} Vienna, Austria \url{https://cran.r-project.org}

Bates D M 2010 \textit{lme4: Mixed-Effects Modeling with R} (New York: Springer)

Bindoff N L et al 2013 Detection and attribution of climate change: from global to regional \textit{Climate Change 2013: The Physical Science Basis. Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change} ed T F Stocker et al (New York: Cambridge University Press)

Black R, Bennett S R G, Thomas S M and Beddington J R 2011 Migration as adaptation \textit{Nature} 478 447–9

Bohra-Mishra P, Oppenheimer M and Hsiang S M 2014 Nonlinear permanent migration response to climatic variations but minimal response to disasters \textit{Proc. Natl Acad. Sci. USA} 111 9780–5

Bohlad P 2012 \textit{GIS Fundamentals: A First Text on Geographic Information Systems} 4th edn (White Bear Lake, MN: Eider Press)

Boyd R and IbarraMara M E 2009 Extreme climate events and adaptation: an exploratory analysis of drought in Mexico \textit{Environ. Dev. Econ.} 14 371–95

Bronaugh D 2014 \textit{R Package Climdex.} \url{pcic:PCIC Implementation of Climdex Routines} (Victoria, British Columbia, Canada: Pacific Climate Impact Consortium)

Brown S K and Bean F D 2006 \textit{International Migration Handbook of Population} ed D Posten and M Skeldon (New York: Springer) pp 347–82

Burkart K, Schneider A, Breitner S, Khan M H, Kraemer A and Endlicher W 2011 The effect of atmospheric thermal conditions and urban thermal pollution on all–cause and cardiovascular mortality in Bangladesh \textit{Environ. Pollut.} 159 2035–43

Caesar J, Alexander L and Vose R 2006 Large-scale changes in observed daily maximum and minimum temperatures:
Taylor J E, Arango J, Hugo G, Kouaouci A, Massey D S and Pellegrino A 1996 International migration and community development Population Index 62 397–418
Tolenaar M and Bruulsema T W 1988 Efficiency of maize dry-matter production during periods of complete leaf-area expansion Agronomy J. 80 580–5
UNPD 2014 World Urbanization Prospects: The 2014 Revision (New York, NY: United Nations Population Division)
Wackernagel M, Kitzes J, Moran D, Goldfinger S and Thomas M 2006 The ecological footprint of cities and regions: comparing resource availability with resource demand Environ. Urbanization 18 103–12
WHO and WMO 2012 Atlas of Health and Climate (Geneva, Switzerland: WHO Press)
Wiggins S, Keilbach N, Preibusch K, Proctor S, Herrejon G R and Munoz G R 2002 Discussion—Agricultural policy reform and rural livelihoods in central Mexico J. Dev. Stud. 38 179–202
Wilby R 2007 A review of climate change impacts on the built environment Build Environ. 33 31–45
Willems P et al 2012 Impacts of Climate Change on Rainfall Extremes and Urban Drainage Systems (London: IWA Publishing)
Zaidi P H, Rafique S and Singh N N 2003 Response of maize (Zea mays L.) genotypes to excess soil moisture stress: morphophysiological effects and basis of tolerance Eur. J. Agronomy 19 383–99