

INTRODUCTION

Climate variability has been implicated in changing patterns of human migration around the world. However, the direction and strength of slow-onset environmental stressors, such as temperature and precipitation shocks, on migration has not been clear, especially in the United States. Most previous studies in this context have focused on acute, rapid-onset environmental disasters such as floods and hurricanes (Boustan, Kahn, and Rhode 2012; Smith and Mccarty 2009). Although several studies have examined the effects of temperature and precipitation on migration in the United States, they either focused on certain regions such as the Great Plains (Gutmann et al. 2005) and the corn belt (Feng, Oppenheimer, and Schlenker 2012) or were conducted at high levels of aggregation, such as the state level (Poston et al. 2009). An up-to-date and longitudinal study of environmental migration with full coverage of the contiguous United States is much needed. We addressed this gap by linking net migration rate (NMR) estimates and decennial census data to climate data in the last four decades. We then used spatial fixedeffects models to measure environmental effects on NMR while controlling for sociodemographic confounders and decade and county fixed effects.

Climate exposures affect NMR by posing threats to sustainable livelihoods and livability, and their impacts differ across places and subpopulations. We seek to answer the following three questions to decipher the relationship between climate exposures and NMR: (1) How do temperature and precipitation variability affect the county-level NMR? (2) Do environmental effects on the county-level NMR differ by the counties' metropolitan status? (3) Do environmental effects on the county-level NMR differ across age groups?

DATA, VARIABLES, AND METHOD

	Variable	Source	
Dependent variable	County-level NMR	Winkler et al. (2013)	
Environmental factors	Decennial mean precipitation Precipitation anomaly Decennial mean temperature Decennial mean temperature (PRISM, 0.04-deg, ~ 4 k)		(b) Gride
	Temperature anomaly		
Sociodemographic factors	Household income Employment rate Rent	U.S. Decennial Census and the American Community Survey (1970-2010)	
	Housing price Homeownership		(c) Cour
Additional controls	Decade fixed effects County fixed effects		

Table 1. Datasets and variables

Method: Spatial fixed-effects model of NMR as a function of inter-censal climate exposures, net of sociodemographic controls and county and decade fixed effects.

Climate Variability and County-Level Net Migration in the United States, 1970-2010 Shuai Zhou, Guangqing Chi, and Brian Thiede Department of Agricultural Economics, Sociology and Education, Pennsylvania State University

EXPLORATORY SPATIAL DATA ANALYSIS



Fig 1. The process of extracting countylevel climate measure through clipping and averaging the gridded data



RESULTS

Table 3. Results of spatial lag fixed-effects models

	All-age					
	All		Nonmetro		Metro	
Mean precipitation	-0.02		-0.02		-0.20	
Mean precipitation, squared	-0.00		-0.00		0.00	
Mean temperature	0.53		1.85		10.92***	
Mean temperature, squared	-0.12***		-0.17***		-0.47***	
Precipitation anomaly		-2.00		-4.13**		0.10
Precipitation anomaly, squared		-1.05		0.79		-11.12
Temperature anomaly		-20.45***		-18.17**		-22.33 ⁺
Temperature anomaly, squared		-152.88***		-159.47*		-202.79**

Specification B: Age-specific NMR and climate average

	Age 15-64			Age 65+		
	All	Nonmetro	Metro	All	Nonmetro	Metro
Mean precipitation	-0.05	-0.06	-0.23	0.05	0.04	0.01
Mean precipitation, squared	-0.00	-0.00	0.00	-0.00	-0.00	-0.00
Mean temperature	-1.79	-0.24	11.77***	6.71***	6.81***	13.58***
Mean temperature, squared	-0.06	-0.10*	-0.52***	-0.27***	-0.29***	-0.46***

Specification C: Age-specific NMR and climate anomaly

	Age 15-64			Age 65+			
	All	Nonmetro	Metro	All	Nonmetro	Metro	
Precipitation anomaly	-2.48	-5.41**	0.93	0.71	1.30	0.19	
Precipitation anomaly, squared	-1.85	0.04	-15.59	-3.56	-7.75	-6.12	
Temperature anomaly	-27.59***	-22.28**	-31.86*	8.48+	5.88	15.71	
Temperature anomaly, squared	-143.03**	-184.40*	-176.31*	-324.87***	-250.53***	-416.13***	

Note: *** p<0.001, ** p<0.01, * p<0.05, + p<0.10. Sociodemographic, decade fixed effects, and diagnostics are not shown

PREDICTIONS Specification: All counties, age 65+ 1415 Mean temperature (Specification: Metro counties, age 15-6 Mean temperature

- tipping point of 14°C.
- population aged 15-64.

ACKNOWLEDGEMENTS

This research was supported in part by the National Science Foundation (Award # SES-1823633), the USDA National Institute of Food and Agriculture and Multistate Research Project (# PEN04623), and the Eunice Kennedy Shriver National Institute of Child Health and Human Development (Award # P2C HD041025).

References and detailed results are available upon request. Email: sxz217@psu.edu



• Mean temperature has a non-linear association with the overall NMR in metro counties, which tends to follow an inverted-U-shaped pattern. It is positively associated with the overall NMR up to a yearly mean temperature of 11°C, after which it has a negative effect.

• Mean temperature also has a non-linear, inverted-U-shaped relationship with age-specific NMRs in metro counties with tipping points of a yearly mean temperature of 10°C and 14°C. In non-metro counties, temperature is only a significant predictor of the NMR among the population aged 65+ with a

• When temperatures are measured using anomalies, we found a strong negative effect on NMR for the

• Precipitation measured using mean and anomalies is not a significant predictor of NMR.