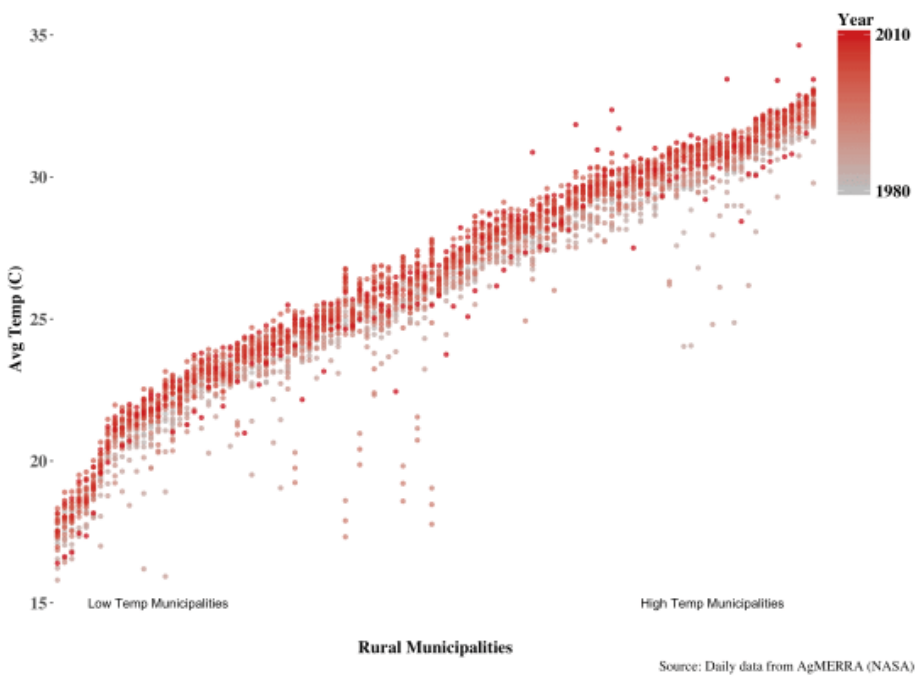
Online Appendix for

Anticipatory Migration Responses to Rural Climate Shocks

BY ESTEBAN J. QUIÑONES, JENNA NOBLES, FERNANDO RIOSMENA, & RAPHAEL NAWROTZKI

Rising Annual Temperature in Mexico: The dark upper red layer in Figure 1 demonstrates the widespread increase in average annual temperatures in Mexico from 1980 to 2010. Each rural municipality included in the MxFLS is presented in its own column, from the municipalities with the lowest average temperature on the left to the highest average temperature on the right. Annual average temperatures are presented in progressively darker hues from 1980 in light gray up to 2010 in dark red. The shifting climate distribution across the spectrum of low, medium, and high average temperature municipalities (left to right) is accompanied by an increased probability of climate-induced crop shocks.

FIGURE 1 — RISING ANNUAL TEMPERATURE IN MEXICO



Heat-induced Catastrophic Crop Losses: Table 2 demonstrates that extreme heat waves, represented as (1) total HDDs, (2) total extreme deviation days, and (3) total heat wave interaction from 2000-2002, have a positive, statistically significant effect on the proportion of neighboring households experiencing a crop shock in rural, agricultural communities. In column

1, we see that experiencing 10 additional consecutive HDDs increases the proportion of neighbors in a community suffering a crop shock by approximately 2.5 percentage points, which is roughly a 31 percent increase relative to the mean of 8.3 percent.[9] In column 2, we see that experiencing 10 more consecutive days of extreme heat deviation days increases the proportion by approximately 7 percentage points, which is roughly equivalent to an 87 percent increase.

TABLE 2 — THE IMPACT OF HEAT WAVES ON CROP LOSSES (FIRST STAGE)

	Community proportion with crop loss		
	(1)	(2)	(3)
	HDDs	Deviation days	Interaction
Total HDDs	0.073***		
	(0.014)		
Total extreme deviation days		0.025***	
		(0.004)	
Total heat wave interaction			0.052***
			(0.006)
F-stat (MP)	73	75	74
N		2,908	
Mean		0.083	

Notes: F-stat (MP): Montiel-Pflueger (2013). Robust standard errors are clustered at the municipality level in parentheses. Fixed effects for 12 states. Controlling for (i) Individual covariates: age, sex, marital or informal union, years of education, student or any employment stats; (ii) Household covariates: land size, ejido land, other land, household size, # of females, # of males, head age, head education, migration history, access to loan, piped water, toilet; (iii) Community covariates: % of agricultural employment, bus stop, hospital, secondary school, market; as well as, (iv) Municipality covariates: % of land irrigated, % of land maize, population, economic diversity, and migration intensity. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Source: Author calculations.

First-stage F-statistics ranging from 75 for extreme deviation days and 73 for HDDs, well above the heteroskedastic-robust rule-of-thumb of 23 (Montiel Olea and Pflueger, 2013), indicate that both instruments are strong. We interact the instruments to upweight instances where both the HDD and extreme deviation thresholds are crossed. We estimate a 5.2 percentage point increase in catastrophic crop losses with an F-statistic of 74. We rely on the total heat wave interaction as the preferred instrument to focus on variation from cases where both agronomic (HDD) and behavioral expectations (deviations) thresholds are surpassed.

Mechanism Robustness Check: It remains possible that there are alternative explanations for the observed *ex ante* migration. Prime candidates include general equilibrium labor shifts, crop

[9] For additional details regarding first stage results see https://tinyurl.com/yckbm9x7.

losses within the household, reductions in living standards and productivity, or increased violence and crime associated with extreme heat events.

Changes in the demand for and value of labor in the community are particularly concerning. In order to assess the extent to which changes in the local labor market represent an alternative explanation, we show the relative percentage of individuals who report each type of employment activity over time in Table 3 and find that the relative share for each employment category is nearly identical. In fact, the difference of the relative proportions for each category over time are no larger than 1 percent. This is not indicative of a substantial (contemporaneous or lagged) general equilibrium shift in labor, which effectively rules out this alternative explanation.

TABLE 3 — RELATIVE PROPORTION OF EMPLOYMENT CATEGORIES (INDIVIDUAL LEVEL UNITS)

	(1) 2002	(2) 2005
Agricultural self-employment (0/1)	0.24	0.25
Agricultural wage employment (0/1)	0.20	0.19
Non-agricultural self-employment (0/1)	0.24	0.23
Non-agricultural wage employment (0/1)	0.33	0.34
Number of individual level observations	3,062	2,659

Notes: Means reported in all cases.
Source: Author calculations.

To assess whether alternative explanations such as crop losses within the household, reductions in living standards, health status, and productivity, or increased violence and crime are influential, we implement a mechanism testing method developed by Acharya, Blackwell, and Sen (2016). This is of heightened concern in the context of an IV, as the salience of an alternative explanations would imply a violation of the exclusion restriction. While this is ultimately a conceptual issue, this approach may help characterize the validity of alternative explanations and, thereby, the plausibility that an exclusion restriction is met. This method facilitates exploring whether variation in an instrument (i.e., exposure or treatment) explains an outcome, net of a mechanism (mediator). This can be thought of as a falsification test of the exclusion restriction. If correlation between an instrument and an outcome remains strong and statistically significant after netting out the influence of the mechanism of interest, then alternative mechanisms are likely relevant and satisfying the exclusion restriction is unlikely.

Accordingly, we test whether correlation remains between extreme heat and migration outcomes, net of the catastrophic crop loss mechanism.

TABLE 4 — TEMPERATURE-AGRICULTURE MECHANISMS TEST

	Total Heat Wave Interaction	
	(1)	(2)
	ACDE	95% CI
Panel A: International Migration (0/1)		
2002-2003	0.0001	[-0.0051, 0.0054]
2004-2005	0.0002	[-0.0141, 0.0144]
2002-2005	0.0001	[-0.0650, 0.0653]
Panel B: Domestic Migration (0/1)		
2002-2003	0.0012	[-0.0118, 0.0142]
2004-2005	0.0007	[-0.0162, 0.0175]
Lower 2002-2005	0.0017	[-0.0200, 0.0235]
Upper 2002-2005	0.0021	[-0.0346, 0.0387]
Number of individual level observations	2,908	

Notes: ACDE = Average Controlled Direct Effect coefficient. Bootstrapped 95% confidence intervals (CIs) derived via 1,000 iterations of resampling with replacement at the municipality level. Fixed effects for 12 states. Controlling for (i) Individual covariates: age, sex, marital or informal union, years of education, student or any employment stats; (ii) Household covariates: land size, ejido land, other land, household size, # of females, # of males, head age, head education, migration history, access to loan, piped water, toilet; (iii) Community covariates: % of agricultural employment, bus stop, hospital, secondary school, market; as well as, (iv) Municipality covariates: % of land irrigated, % of land maize, population, economic diversity, and migration intensity. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Source: Author calculations.

The collection of results presented in Table 4 generally indicate that, net of heat-induced crop losses, extreme heat deviations do not have a statistically significant relationship with migration outcomes. We see that all Average Controlled Direct Effect (ACDE) coefficient estimates are statistically insignificant and the magnitudes of the coefficients are minuscule. For example, the remaining effect of extreme heat on migration decisions ranges from 0.0001 to 0.0021 percentage points. These are equivalent to proportionately small increases of 0.025 to 0.035 percent, which *cannot* be distinguished from zero due to a lack of statistical significance.

This evidence indicates that there is *not* a strong relationship between extreme heat and labor decisions outside of the agricultural crop loss mechanism. This suggests that alternative explanations associated with extreme heat are not influential. This can also be interpreted as partial evidence regarding the plausibility that the exclusion restriction may be satisfied. In combination with the lack of substantial general equilibrium labor dynamics, this evidence rules out the most prominent alternative explanations. While it is possible that other mechanisms independent of extreme heat remain, this empirical exercise provides comprehensive evidence that catastrophic crop losses are likely the dominant temperature-induced mechanism shaping migration reallocations.

Descriptive Statistics:

TABLE 5 — DESCRIPTIVE STATISTICS: MIGRATION, CATASTROPHIC CROP LOSSES, AND HEAT WAVES (INDIVIDUAL LEVEL UNITS)

	(1)	(2)
	Mean	S.D.
Panel A: Individual Migration *(0/1)*		
International		
2002-2003	0.003	0.052
2004-2005	0.006	0.078
2002-2005	0.04	0.19
Domestic		
2002-2003	0.03	0.16
2004-2005	0.02	0.15
Lower 2002-2005	0.05	0.22
Upper 2002-2005	0.05	0.22
Panel B: Community Crop Losses		
Proportion with crop loss (0/1)	0.083	0.103
Panel C: Municipality Heat Waves		
Total HDDs	15.51	30.98
Total extreme deviation days	26.41	10.34
Number of individual level observations	2,908	

Notes: The *ex ante* analytical sample is comprised of 2,908 individual units, that span 1,161 households, over 45 rural communities and municipalities.

Source: Author calculations.

TABLE 6 — INDIVIDUAL AND HOUSEHOLD CHARACTERISTICS (INDIVIDUAL LEVEL UNITS)

	(1)	(2)
	Mean	S.D.
Panel D: Covariates		
Individual		
Age	40.96	18.89
Male (0/1)	0.48	0.50
Union (0/1)	0.62	0.49
Years of Education	4.83	3.93
Student (0/1)	0.08	0.27
Household		
Land (ha)	5.63	15.81
Land ejido (0/1)	0.73	0.44
Land private (0/1)	0.20	0.40
Land other (0/1)	0.11	0.31
Size	5.37	2.50
Number of adult females	0.75	0.88
Number of adult males	0.74	0.94
Head age	52.98	14.09
Head education	3.50	3.38
Previous migrant (0/1)	0.44	0.50
Loan	0.22	0.42
Piped water	0.83	0.38
Toilet	0.37	0.48
Number of individual level observations	2,908	

Notes: The *ex ante* analytical sample is comprised of 2,908 individual units, that span 1,161 households, over 45 rural communities and municipalities.

Source: Author calculations.

TABLE 7 — COMMUNITY AND MUNICIPALITY CHARACTERISTICS (INDIVIDUAL LEVEL UNITS)

	(1)	(2)
	Mean	S.D.
Community		
Agricultural Employment (0/1)	0.25	0.10
Bus Stop (0/1)	0.48	0.50
Hospital (0/1)	0.06	0.24
Secondary School (0/1)	0.21	0.41
Market (0/1)	0.13	0.33
Municipality		
% of Land Irrigated	35.29	37.49
% of Land with Maize	10.67	13.85
% of Land with Coffee	2.45	6.63
% of Land with Wheat	1.97	3.81
Population (10,000s)	5.98	11.54
Economic Diversity Index	0.68	0.22
Marginalization Index	-0.23	0.87
Migration Index	-0.01	0.91
Number of individual level observations	2,908	

Notes: The *ex ante* analytical sample is comprised of 2,908 individual units, that span 1,161 households, over 45 rural communities and municipalities.

Source: Author calculations.