Is climate stress driving tropical depopulation?
PAA Extended Abstract

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Abstract: This research explores the effect of climate shocks on the population growth rate of tropical countries, which are considered to be particularly vulnerable to global climate change through multiple pathways. Though the literature suggests that climate stress has implications for the population mobility path in particular, the region and country-specific nature of this research has made attempts at a global synthesis challenging. Addressing this limitation, we use census data and gridded climate data to quantitatively analyze the implications of climate change for province-level population growth across time and space for the global tropics. Preliminary findings suggest that above average temperatures have a suppressing effect on the annual population growth rate across the tropics while precipitation anomalies have a nonlinear suppressing effect on the annual population growth rate.

Introduction

The purpose of this research is to explore the effect of climate shocks—specifically high temperatures and below and above average rainfall— on the populations of tropical countries, which are considered to be particularly vulnerable to global climate change through multiple pathways. These pathways include direct population displacement from extreme weather events; the human health ramifications of extreme heat for neonates, the elderly, and outdoor laborers; and the implications of heat stress and uncertain and uneven rainfall patterns for crop yield, particularly for areas with high amounts of rain reliant agriculture. Regardless of the pathway, the question remains as to what effect temperature and rainfall anomalies have on population growth (or decline) across the tropics.

A growing literature has examined the consequences of climate change and variability for internal migration, which is likely to far outnumber international moves induced by climate. This literature suggests that temperature in particular has important influences on population mobility (Bohra-Mishra et al. 2014; Gray & Wise 2016; Nawrotzki et al. 2016; Thiede et al. 2016; Call et al. 2017), but the region and country-specific nature of this research has undermined attempts at a global synthesis. To address this gap in the literature, we directly investigate the consequence of climate change for district-level population growth across time and space for the global tropics. This notably improves on previous attempts to forecast population distribution under future climates (Nieves et al. 2017; Rigaud et al. 2018), which have relied on extrapolation of static climate-population relationships without direct examination of population change.

Data

All data for this analysis come from the Integrated Population and Environmental Data (IPUMS TERRAPOP) database. From this database, we extracted district level data on thirty-six tropical countries (see Figure 1 for geographic distribution) with at least 3 or more years of census data. Using these data, we construct our outcome variable, annual population growth rate, using the formula:

$$\frac{\left(\frac{Current\ population\ size - Baseline\ population\ size}{Baseline\ population\ size}\right) * 100}{Years\ between\ current\ population\ estimate\ and\ baseline\ population\ estimate}$$

We also use these international census data to construct control variables for educational attainment, sex ratio, population density, and dependency ratio, all of which have been linked in the literature with the annual population growth rate. Educational attainment is the percentage of the district population with less than an elementary school education. We use the total number of men and women to construct the sex ratio (female to male) and similarly use the total number of people in each five-year age group to generate our dependency ratio (number of people aged under 15 and above 65/number of people ages 15-65). Population density is calculated by dividing the total population size for the district over the geographic area in square kilometers for that district.

Our climate data were extracted from the University of East Anglia Climatic Research Unit (CRU) data provided through IPUMS TERRAPOP. These temperature and precipitation data have a monthly temporal resolution and a spatial resolution of 0.5° by 0.5°, which is roughly 30 km^2 across the global tropics. To measure local deviations from the historical climate, our predictors of interest, we transform these values into climate anomalies, defined as the z-score of the mean monthly temperature or precipitation, over a decade relative to a 1950-2013 reference period (see Table 1 for total and regionally subdivided summary statistics).

Methods

To examine the relationship between climate shocks and population growth rates, we employ a fixed effects panel data regression approach, modeling the district-level population growth rate at the global and regional scales as a function of linear and quadratic decadal climate shocks and controlling for district-level educational attainment, sex ratio, population density, dependency ratio, and census year. We employ a fixed effects approach in order to remove the effect of time-invariant variables that we are unable measure from our analysis, so that we are able to assess the effect of our climate variables on population growth rates, all else being equal.

Discussion and conclusions

Preliminary findings suggest that above average temperatures have a suppressing effect on the annual population growth rate across the tropics, while both below and above average temperatures are associated with an increase in the annual population growth rate (see Table 2 and Figures 2 and 3). Above average temperatures may both reduce local fertility and may induce out-migration by reducing crop productivity. Below average rainfall, conversely, may be suppressing out-migration by reducing while above average rainfall may be enabling higher fertility by improving agricultural yield.

The relationship between annual population growth rate and climate anomalies also appears to be regionally variable. In the African region, precipitation anomalies appear to be the most significant predictor of annual population growth rate. This may be attributable to the reliance on rainfed agriculture common across sub-Saharan Africa, where the population is still largely rural and heavily dependent on agriculture. No climate effects have emerged as of yet for the Asian region. In Central America, below average temperatures appear to be suppressing annual population growth, likely once again through an agricultural pathway. The pattern in the South American region mirrors that of the broader pattern across the tropics, with above average temperatures suppressing population growth while above and below average precipitation is associated with higher population growth rates.

Future work will allow for spatial autocorrelation between adjacent districts through spatial statistical modeling approaches, as spatial autocorrelation may be impacting the results of these analyses. Further, we intend to consider the interaction our climate variables with one another, as hot and wet conditions have different implications for human health and agriculture than hot and dry conditions, for instance. Finally, we also intend to interact our demographic controls with the climate predictors, to determine whether the effects of heat vary by population density or educational attainment, for example.

References

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Table 1. Summary statistics (N=number of geographic unit-years)

	All Regions (N=7,169)		**Africa (N=1,690)**		**Asia (N=1,976)**		**Central America (N=955)**		**South America (N=2,548)**	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Temperature Z-Score	0.44	0.90	0.88	0.71	0.48	0.90	0.46	0.85	0.12	0.89
Precipitation Z-Score	-0.04	0.96	-0.47	0.86	-0.07	0.88	0.04	0.94	0.23	0.98
Annual population growth rate (%)	2.61	3.37	3.41	3.83	2.27	3.06	2.99	4.02	2.19	2.85
Population density (pop/km2)	796	3,597	1,916	6,689	862	2,410	271	937	200	785
Less than primary school education (%)	63.27	22.62	75.25	17.76	62.91	22.73	67.41	23.79	54.05	20.77
Sex ratio (female to male)	1.00	0.08	1.03	0.08	1.00	0.08	0.99	0.08	0.98	0.08
Dependency ratio (dependent to working population)	0.84	0.20	0.94	0.20	0.75	0.17	0.92	0.20	0.80	0.19

Table 2. Fixed effects regression predicting district annual population growth rate

Predictors	All Regions	Africa	Asia	Central America	South America
Climate anomalies					
Temperature Z-Score	-0.284***	0.0052	-0.2	2.521***	-0.414***
Temperature Z-Score x Temperature Z-Score	0.0698	-0.155	-0.127	-0.821**	-0.00815
Precipitation Z-Score	-0.0523	0.143	-0.0924	-0.0412	-0.130*
Precipitation Z-Score x Precipitation Z-Score	0.0720**	0.270*	0.0177	0.179	0.0402
Population characteristics					
Population density (pop/km2)	6.117***	13.81***	6.075***	10.81***	-0.217
Less than primary school education	-0.00189	-0.0306	-0.0347*	0.0671*	-0.015
Sex ratio	-1.089	5.579	-0.106	4.25	-4.098**
Dependency ratio	1.078*	-2.673	-0.864	-0.895	1.512
Constant	-20.52***	-67.40***	-24.80***	-45.29***	6.737**
Observations	7,169	1,690	1,976	955	2,548
Number of geographic units	2,569	813	637	385	734
R-squared	0.188	0.397	0.194	0.453	0.106

***p<0.001, **p<0.01, *p<0.05, +p<0.1
Survey year fixed effects included but not shown

Figures

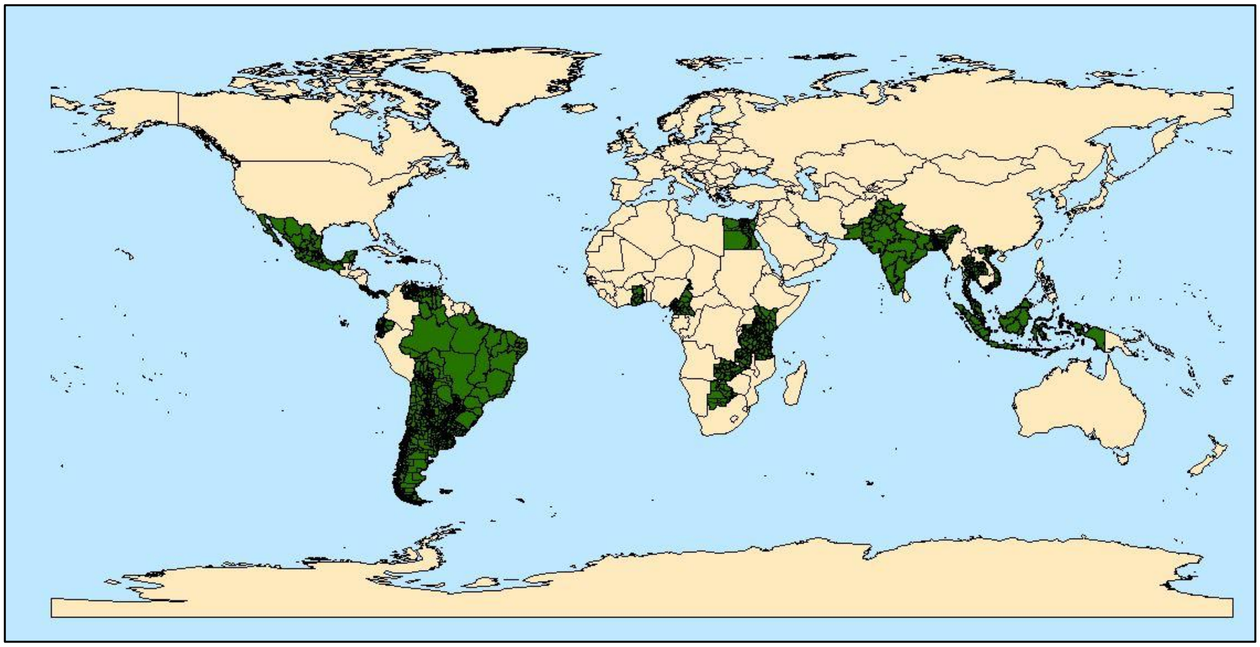

Figure 1. Geographic distribution of 36 tropical countries included in the analysis

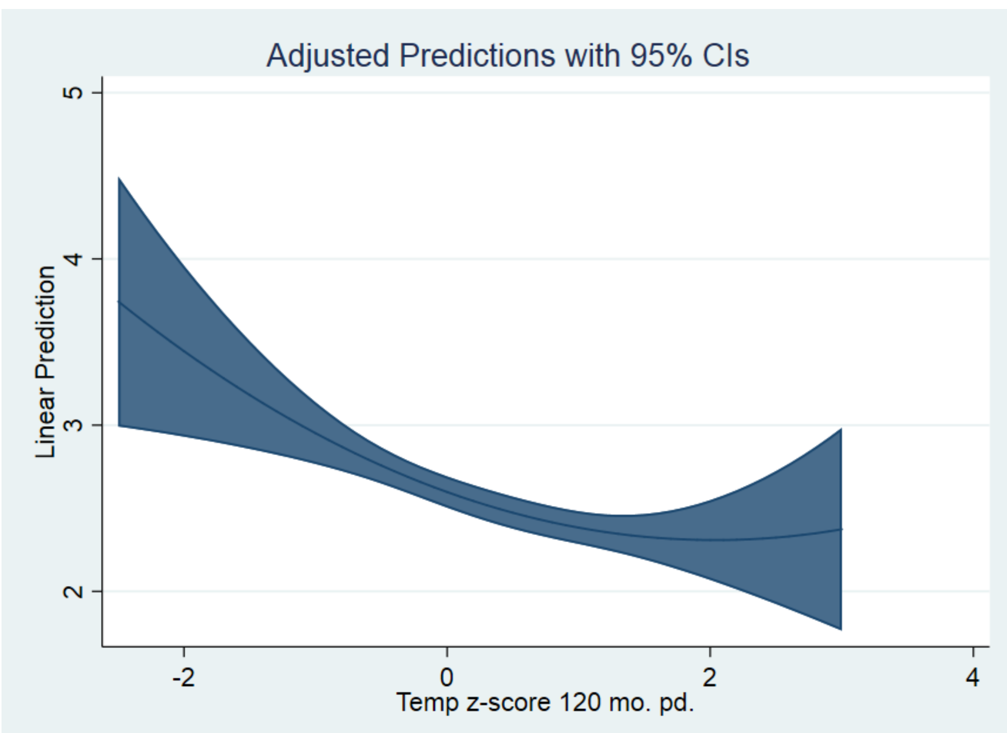

Figure 2. Temperature implications for population growth rate across the tropics

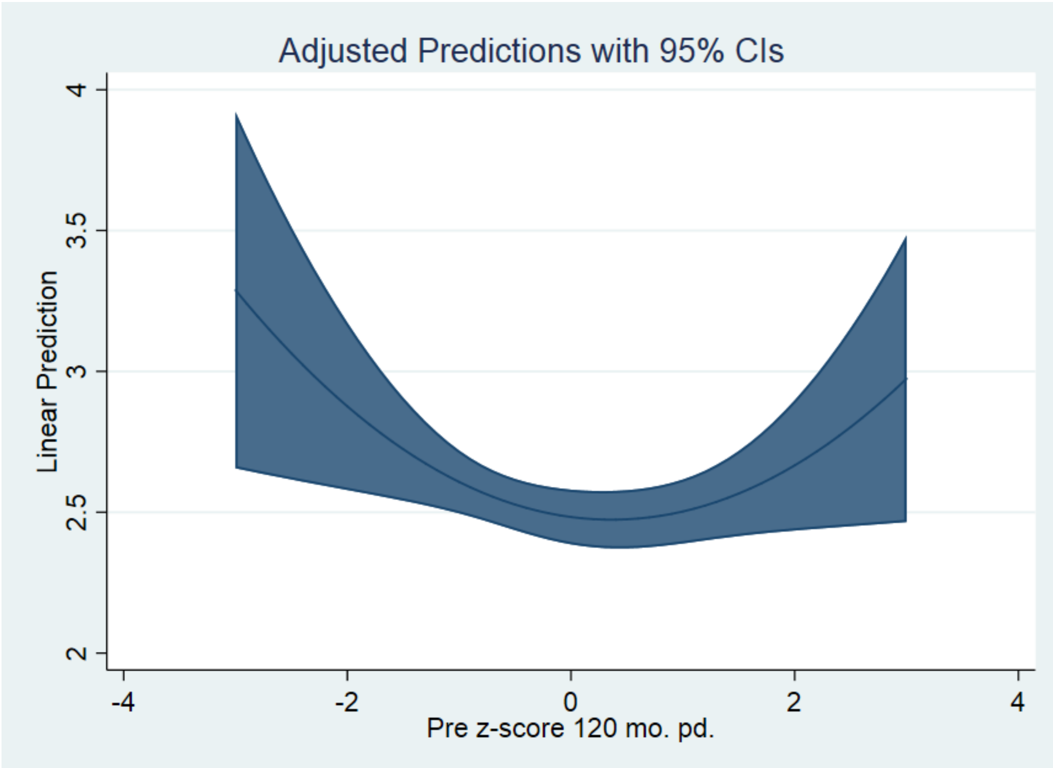

Figure 3. Precipitation implications for population growth rate across the tropics

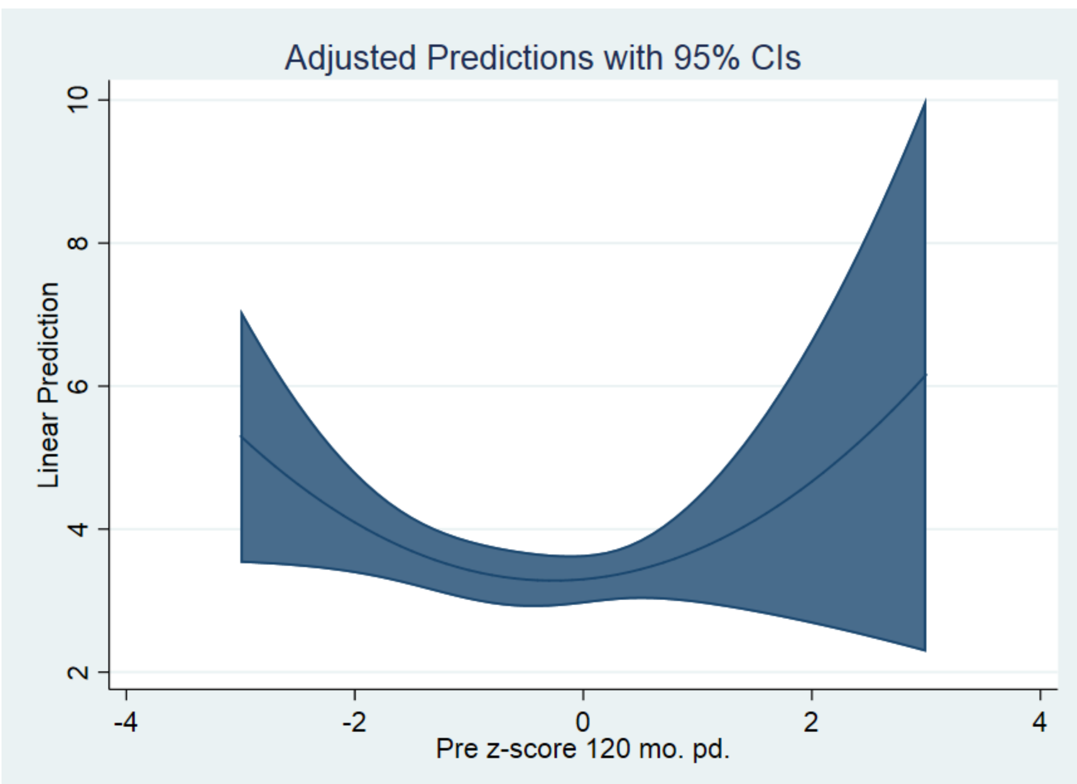

Figure 4. Precipitation implications for population growth rate, Africa

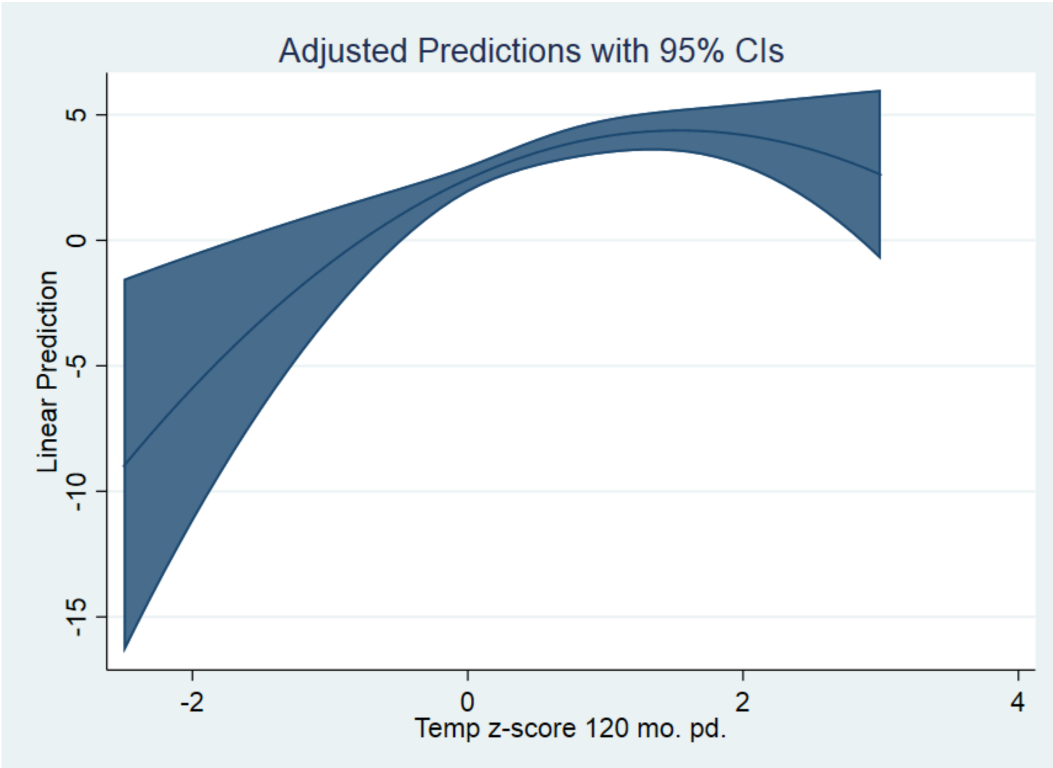

Figure 5. Temperature implications for population growth rate, Central America

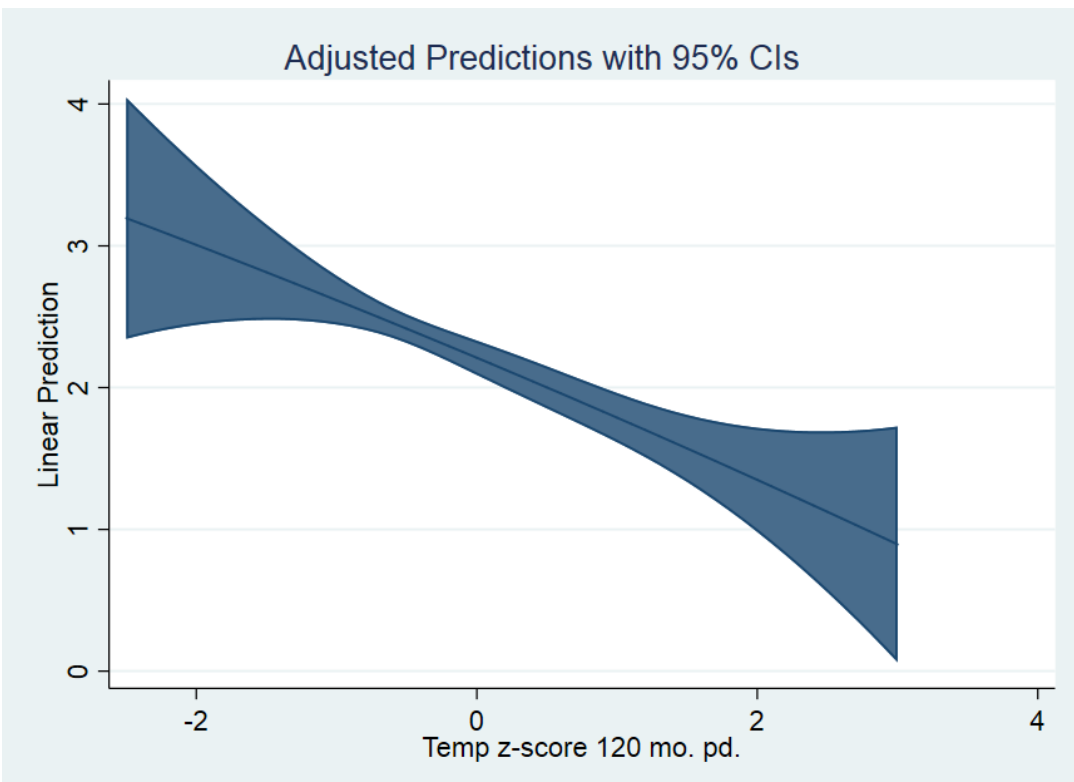

Figure 6. Temperature implications for population growth rate, South America

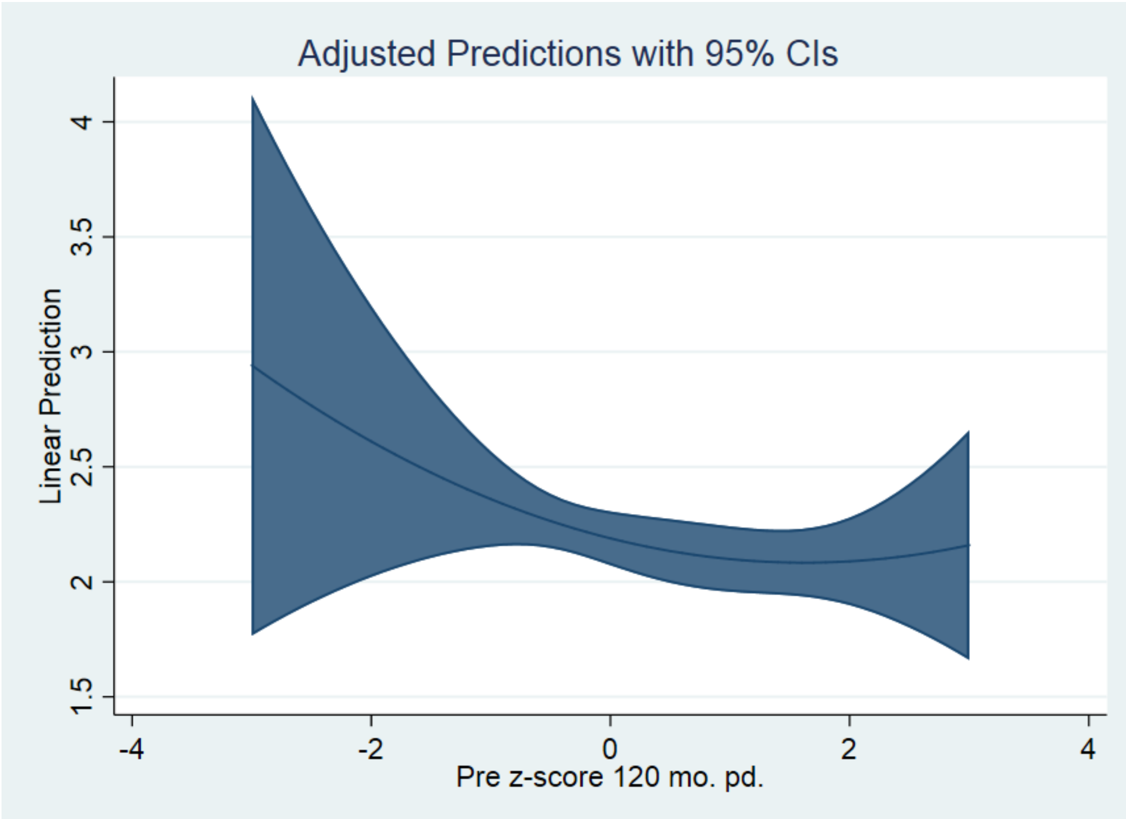

Figure 7. Precipitation implications for population growth rate, Central America