Environmental Migration in the United States 1970 – 2020

Shuai Zhou
Ph.D. candidate
Rural Sociology and Demography (Dual Title)

1

Previous literature and knowledge gap

- Globally, previous studies primarily focused on environmental changes in the developing world
- In the US, studies were centered on rapid-onset environmental disasters. A few studies on slow-onset environmental variabilities used aggregated data at the regional level or crude level

  Gutmann et al. (2005): Great Plains region, 1930-1990
  Poston et al. (2009): The entire US at the state level, 1995-2000
  Feng et al. (2012): Corn belt region, 1970-2009

- There is a knowledge gap regarding the impact of slow-onset environmental variability on migration in developed setting

2

Research questions

- How do environmental and sociodemographic factors affect the county-level migration rates in the U.S. across rural and urban counties and age groups?
- What are the spatial patterns and dimensions of environmental migration in the U.S.?
- How do individuals respond to slow-onset environmental variability and other individual- and county-level contextual characteristics?

3

Theoretical approaches

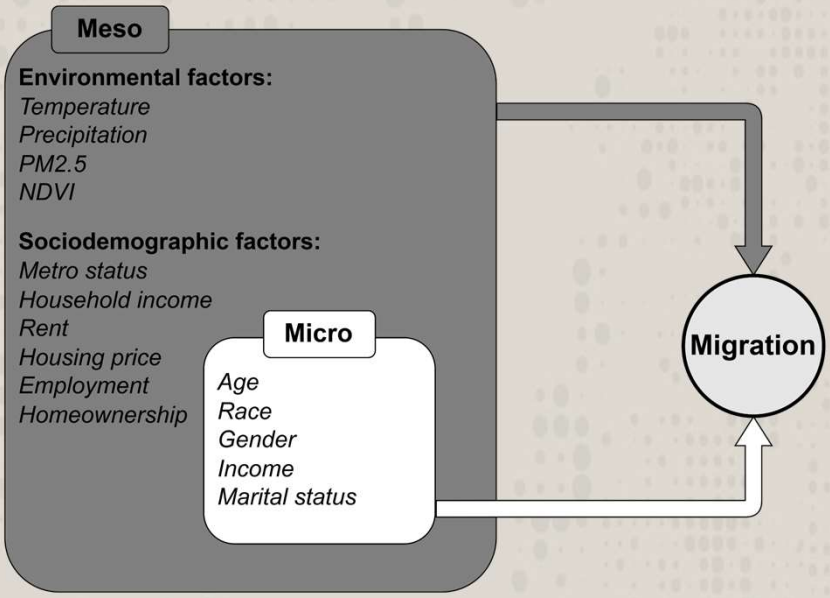
- **Social-ecological approach**

  Environmental migration is a function of the elements of a social-ecological system and their interactions within the system
- **Sustainable livelihood and adaptation approach**

  Environmental impacts on migration depend on livelihood changes and adaptative capabilities of the involved population

4

Research framework



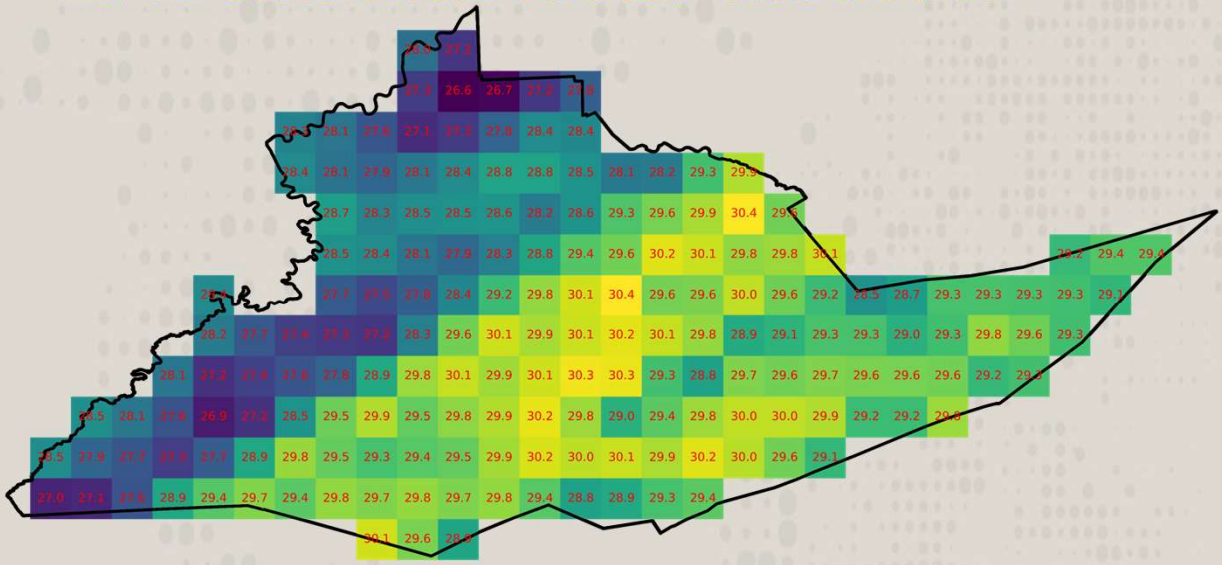
5

Migration definitions

- **Aggregate migration measures**
  - Net migration rates (NMRs)
  - In-migration rates (IMRs)
  - Out-migration rates (OMRs)
- **Individual migration measure**
  - Moves across county boundaries between the ACS years

6

Environmental factor extraction



County-level temperature = 28.97°C

7

Environmental variability measure

$$\textbf{\textit{Climate anomaly}}_{i,t} = \frac{\textbf{\textit{Level}}_{i,t} - \mu_i^{LR}}{\sigma_i^{LR}}$$

$Level_{i,t}$ = Annual/Decadal average in county *i* at time *t*

μ_i^{LR} = Long-run (previous 30-year) average in county *i*

σ_i^{LR} = Long-run (previous 30-year) standard deviation in county *i*

8

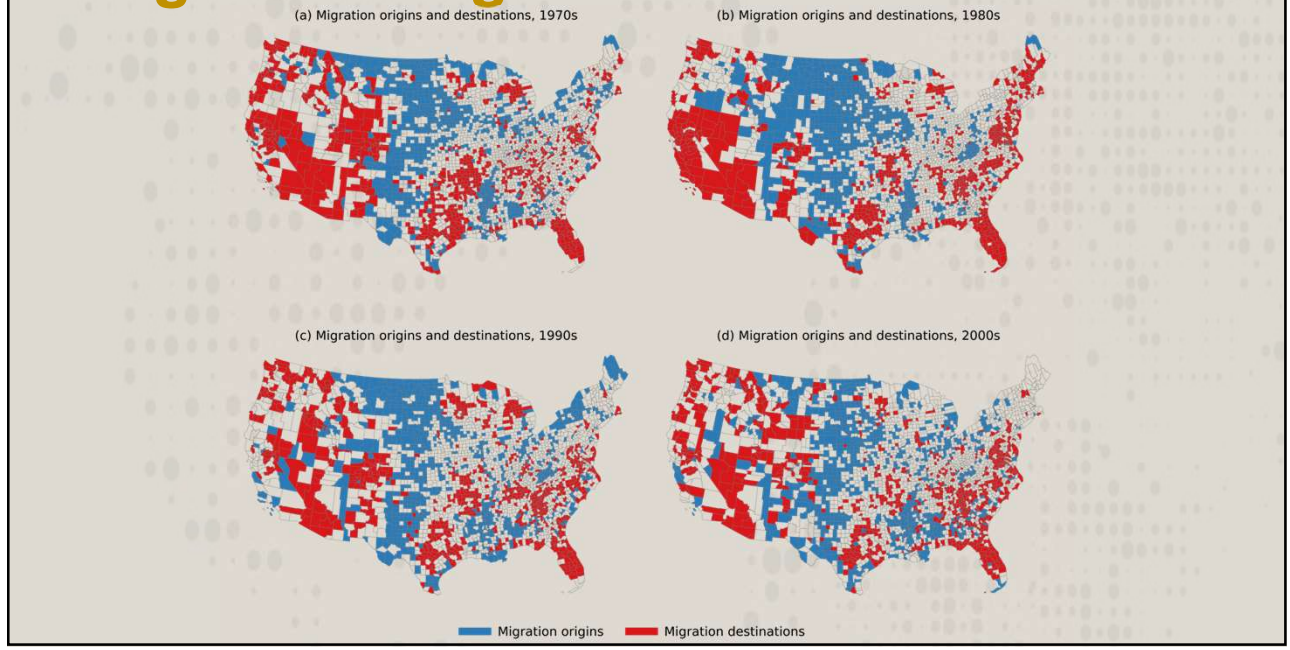
Introduction

Migration in the U.S.

1970 – 2010

9

Migration origins and destinations

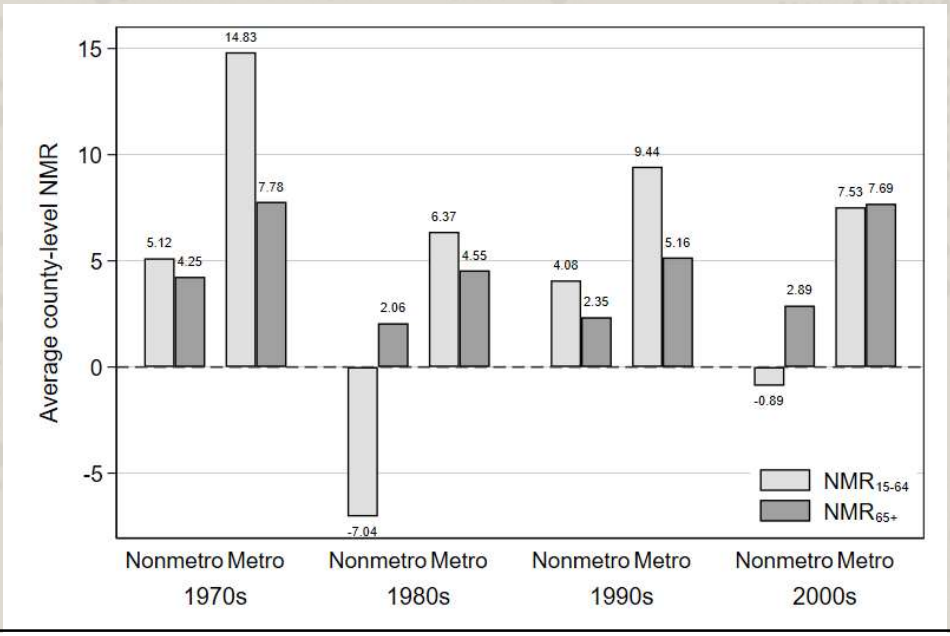


10

Gendered migration patterns

11

Age-specific migration patterns



12

Findings

- Migration origins are spatial clustered at the Great Plains areas, while migration destinations are spatially clustered at coastal and warm areas
- Males are mobile than females
- The younger generation is more mobile than the elder generation; metro areas are more attractive to the younger generation, while nonmetro areas are more attractive to the elder generation, especially in the 2000s

13

Chapter 1

Environmental Impacts on Migration

1970 – 2010

14

Research objectives

- Explore environmental impacts on migration
- Investigate heterogeneous environmental effects on age- and place-specific migration patterns

15

Data and variables

Data source	Year	Variables
NMR	1970–2010	NMRs
IRS	2011–2020	IMRs and OMRs
PRISM	1970–2010	Environmental factors
Census	1970–2010	Sociodemographic factors
USDA	1993	Rural-urban classification

16

Analytical approach

$$Y_{i,t} = \beta_0 + \beta X_{i,t} + \varepsilon_{i,t}$$

where $Y_{i,t}$ is the migration rates of county *i* at time *t*; β_0 is the intercept; $X_{i,t}$ is a matrix of environmental, socioeconomic, and demographic factors; and β is the estimated coefficient. $\varepsilon_{i,t}$ is the error term. County and decade effects are included.

17

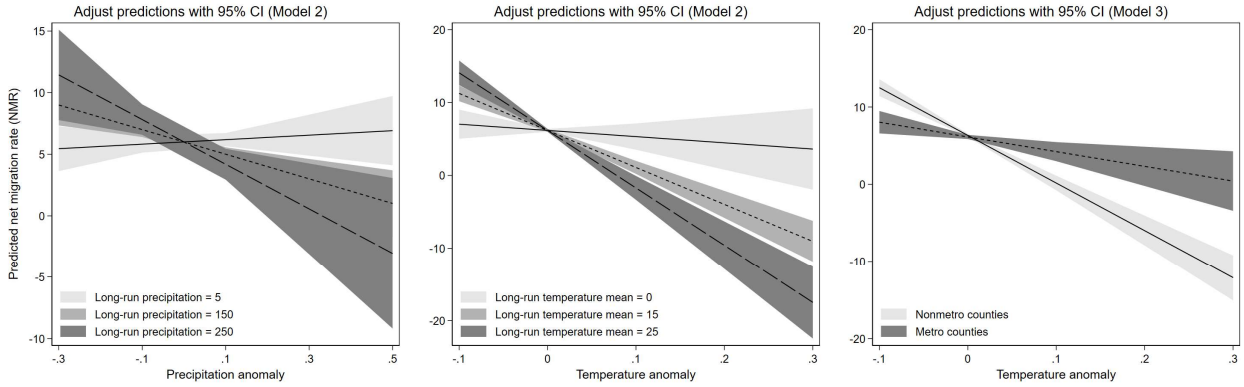
Overall environmental effects

	NMR_{All}		
	Model 1	Model 2	Model 3
Climatic variables			
Prec anomaly	-4.66***	2.23	-4.15**
Temp anomaly	-49.66***	-8.53	-61.63***
Climatic interactions			
Prec anomaly * Long-run prec average		-0.08*	
Temp anomaly * Long-run temp average		-2.82***	
Prec anomaly * Metro			-3.39
Temp anomaly * Metro			42.60***

Note: *** p<0.001, ** p<0.01, * p<0.05. Sociodemographic factors and model diagnostics are not show.

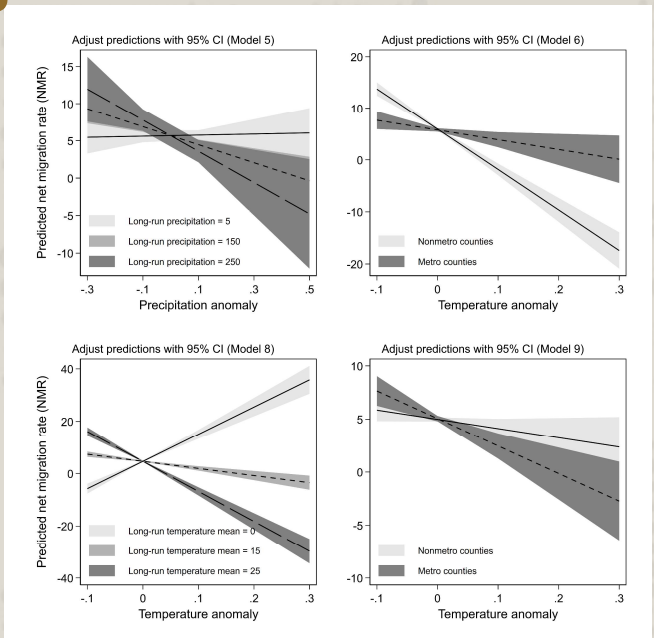
18

Overall environmental effects (cont.)



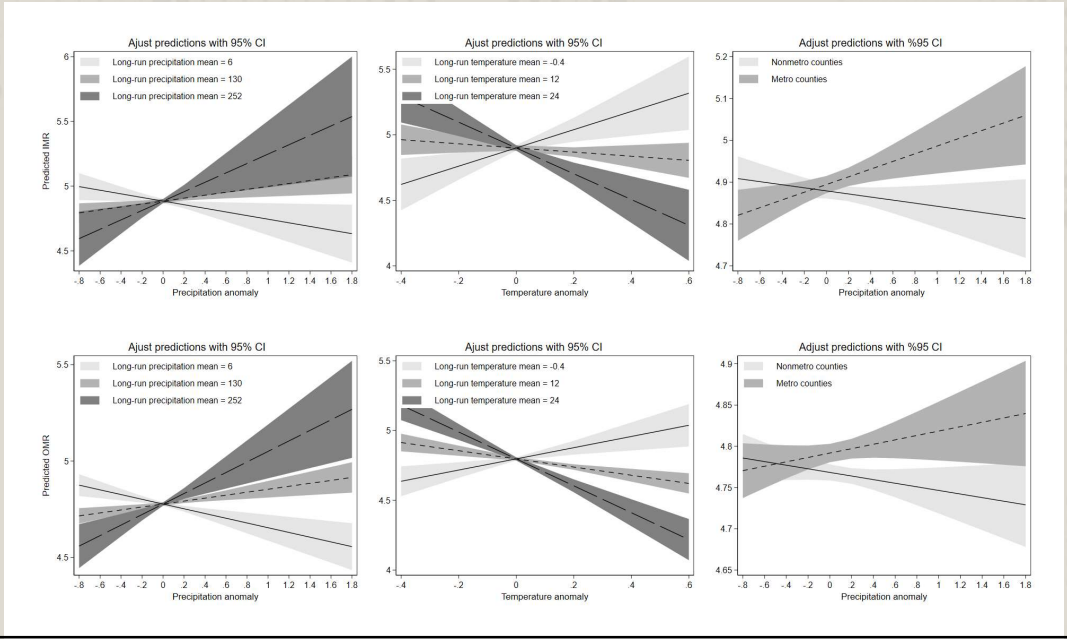
19

Heterogeneous environmental effects



20

Direct-specific environmental effects



21

Findings

- The elder generation was more responsive to environmental variability than that of the younger generation
- Rural areas were hit harder by environmental variability, with significant exoduses of their younger generations

22

Chapter 2

Spatial Dimensions of Environmental Migration

1970 – 2010

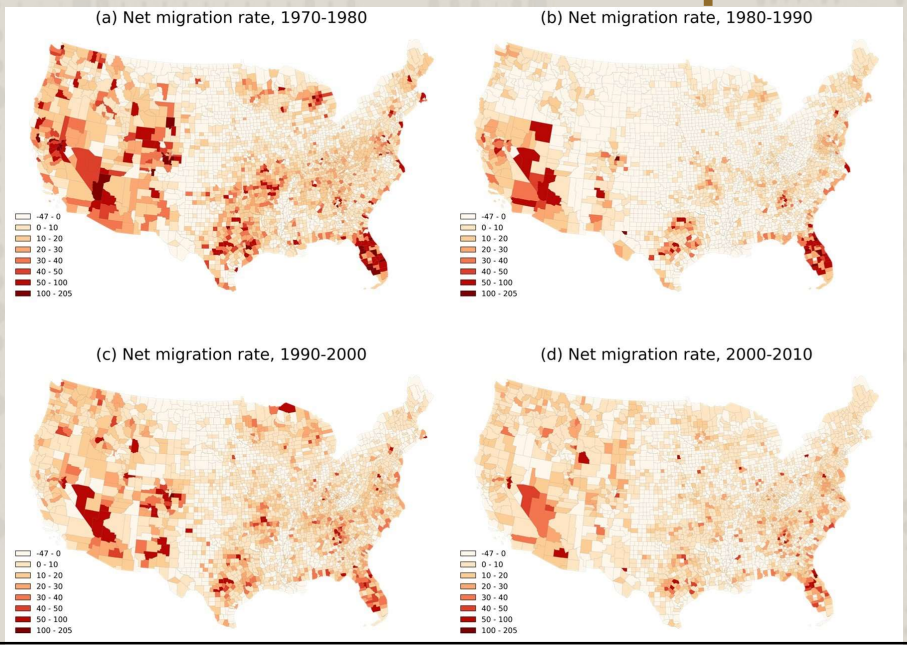
23

Why spatial methods

- Migration is a spatial phenomenon (Johnson et al. 2005; Chi and Zhu 2019)
- Failing to incorporate spatial effects may bias environmental impacts on migration (Saldaña-Zorrilla and Sandberg 2009; Chi and Zhu 2019)

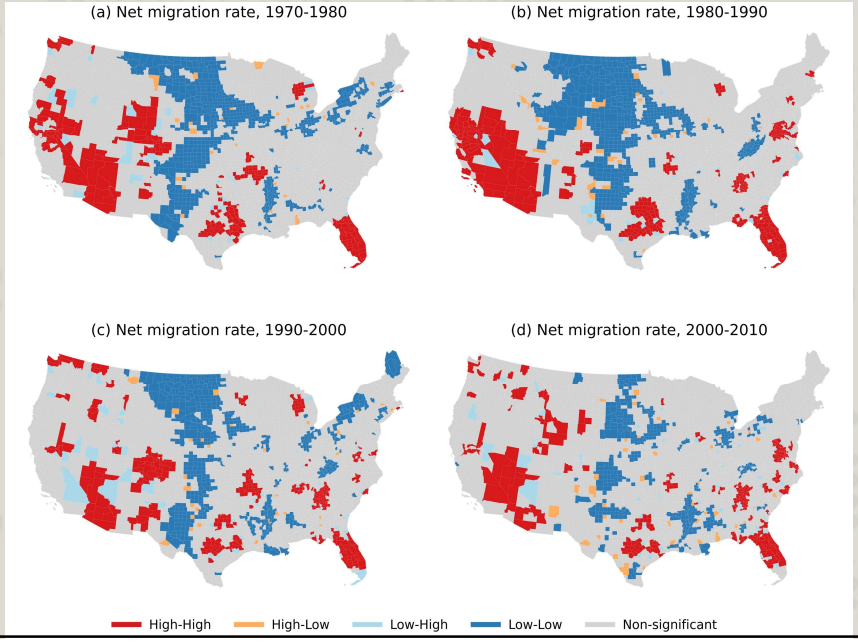
24

Spatial dimensions: Choropleth map



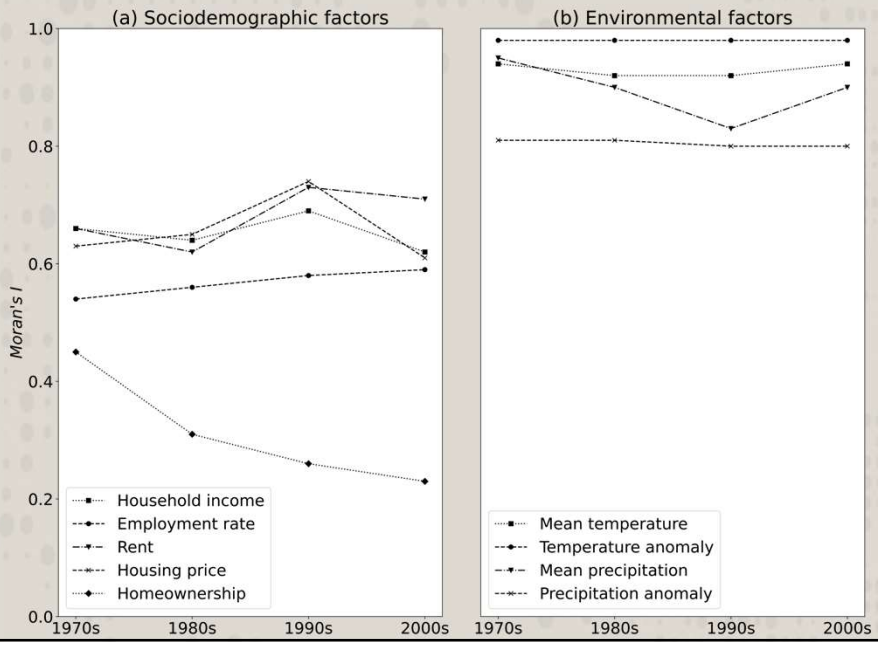
25

Spatial dimensions: LISA map



26

Spatial dimensions: *Moran's I*



27

Analytical approach

- **Spatial lag model (SLM)**

$$Y_{it} = X_{it}\beta + \rho W Y_{it} + \varepsilon_{it}$$

- **Spatial error model (SEM)**

$$Y_{it} = X_{it}\beta + u_{it}, u_{it} = \rho W_{u_{it}} + \varepsilon_{it}$$

where Y_{it} is the NMRs of county *i* at time *t*; X_{it} is a matrix of environmental and sociodemographic factors; and β is the estimated coefficient; ρ is the spatial lag parameter; W is the spatial weight matrix; ε_{it} and u_{it} are the error terms.

28

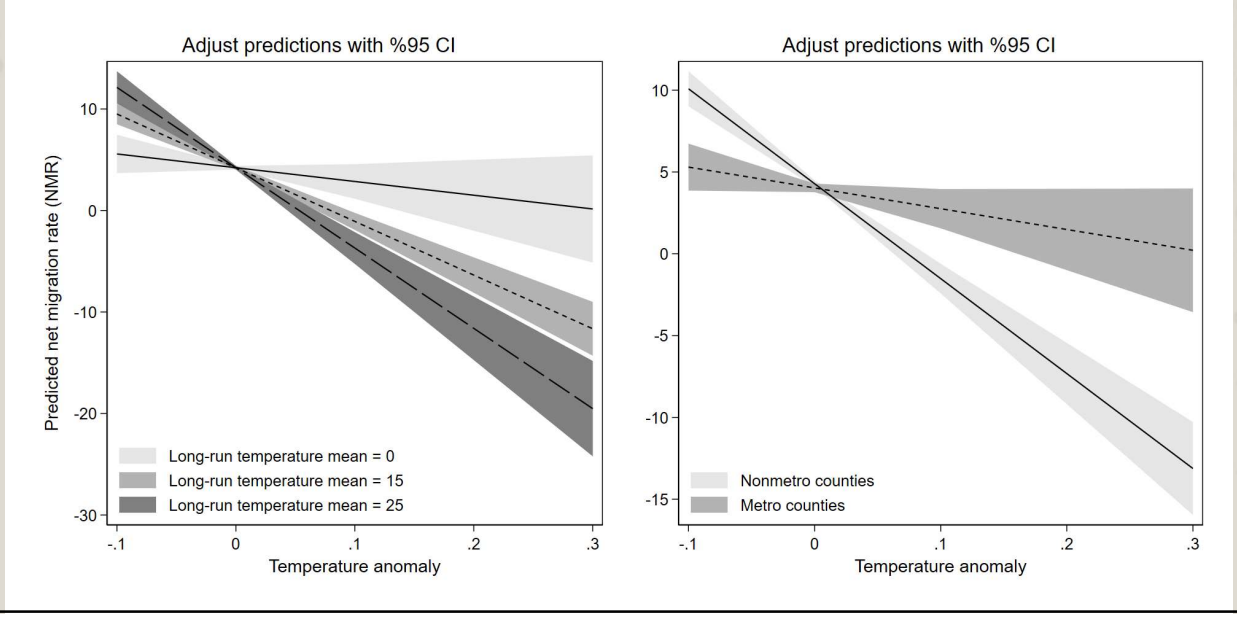
Results

	NMR_{All}		
	OLS	SLM	SEM
Climatic variables			
Prec anomaly	1.395	0.834	2.319
Temp anomaly	-25.721**	-14.638*	-16.076
Climatic interactions			
Prec anomaly * Long-run prec average	-0.059	-0.024	-0.046
Temp anomaly * Long-run temp average	-2.623***	-1.744***	-2.909***
Prec anomaly * Metro	-4.244*	-2.256	-2.023
Temp anomaly * Metro	45.310***	33.003***	28.896***

Note: *** p<0.001, ** p<0.01, * p<0.05. Sociodemographic factors and model diagnostics are not show.

29

Results (cont.)



30

Findings

The spatial models further confirmed findings from the previous chapter using fixed-effects aspatial models, which strengthened the conclusion that environmental variability affects migration in the U.S. and exerts heterogeneous influences on migration patterns across different age groups and rural-urban dichotomy

31

Chapter 3

Individual Migratory Response to Environmental Variability 2010 – 2020

32

Why multilevel analysis

- Multivariate method does not efficiently consider the data hierarchy (e.g., individuals nested in households, households nested in higher geographic or administrative units)
- Spatial analysis encounters ecological fallacy, which states that conclusion from aggregate level may not hold at individual level
- Multilevel method is well-suited for data with hierarchies and exploring and disentangling level-specific effects

33

Data and variables

Data source	Variables
ACS Microdata	Migration status and covariates
PRISM	Temperature and precipitation
ACAG	PM2.5
NOAA	NDVI

34

Two-level logistic regression

$$Logit(\Pr(Y_{ij}=1)) = \alpha_0 + \alpha_{0j} + \alpha_1 X_{1ij} + \cdots + \alpha_k X_{kij} + \beta_1 Z_{1j} + \cdots + \beta_m Z_{mj}$$

Level-1 (individual) variables:
- Age
- Personal income
- Gender
- Marital status
- Race
- Education

Level-2 (county) variables:
- Climate anomalies
- Household income
- Housing price
- Employment rate
- Homeownership
- Metro status

Note: Climate anomalies include anomalies in precipitation, temperature, PM2.5, and Normalized Difference Vegetation Index (NDVI).

35

General models

Level-1 variables	
Age	-0.010***
Personal income	-0.001***
Gender, Male (Ref. = Female)	0.097***
Marital status, Married (Ref. = Unmarried)	-0.071***
Race, NHB (Ref. = NHW)	-0.209***
Race, Hispanics (Ref. = NHW)	-0.335***
Race, Others (Ref. = NHW)	0.022***
Education, College and above (Ref. = Below college)	0.170***
Level-2 variables	
Precipitation anomaly	0.017**
Temperature anomaly	0.075***
NDVI anomaly	-0.249***
PM2.5 anomaly	-0.006***

Note: *** p<0.001, ** p<0.01, * p<0.05. NHB=Non-Hispanic Black, NHW=Non-Hispanic White. Level-2 sociodemographic factors and model diagnostics are not show.

36

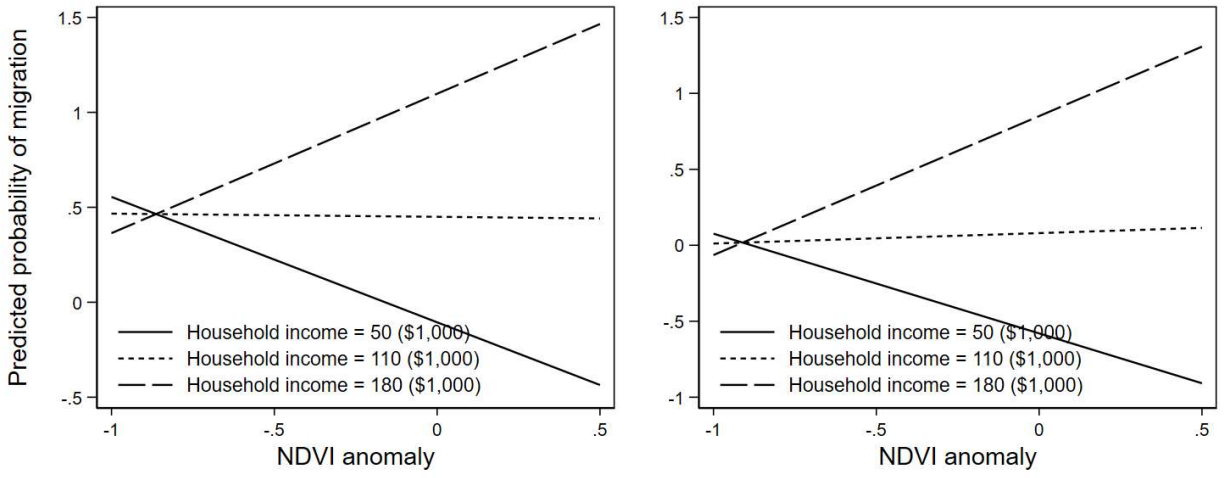
Age-specific models

	Mig_{15-64}	Mig_{65+}
Level-2 variables		
Precipitation anomaly	0.016**	0.033
Temperature anomaly	0.093***	-0.127*
NDVI anomaly	-0.247***	-0.193***
PM2.5 anomaly	-0.092***	-0.001

Note: *** p<0.001, ** p<0.01, * p<0.05. Level-1 variables, Level-2 sociodemographic factors and model diagnostics are not show.

37

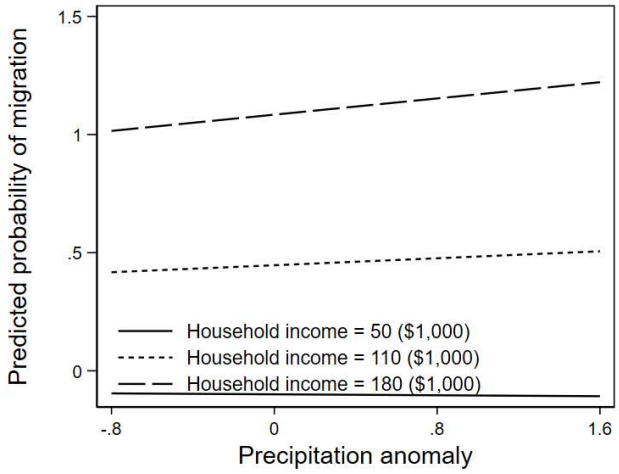
Climate-Income interaction



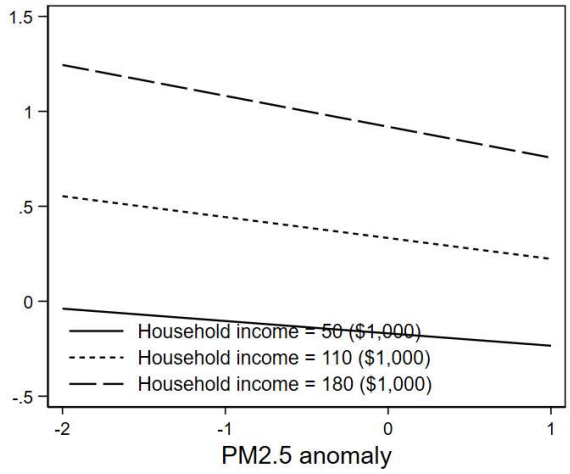
$Migration_{15-64}$ **$Migration_{65+}$**

38

Climate-Income interaction (cont.)



Migration$_{15\text{-}64}$



Migration$_{15\text{-}64}$

39

Findings

- Being male, non-Hispanic white, and highly educated increased migration probability
- Precipitation and temperature anomalies generally increased migration probability, while PM2.5 and NDVI anomalies decreased migration probability
- The elder generation was responsive to temperature and environmental amenity, while the younger generation preferred places with environmental amenity, economic well-being, and affordable living costs

40

Conclusion

41

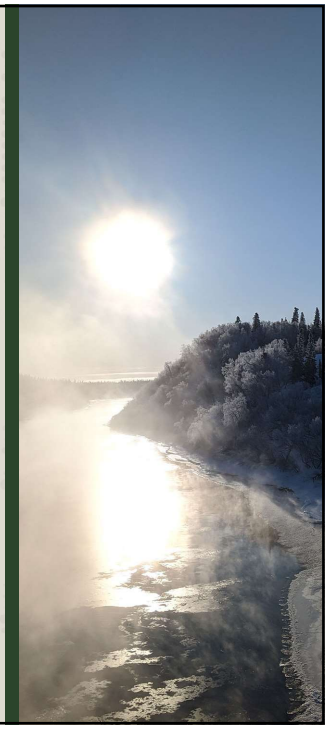
- Environmental variability affected migration in the U.S., even after controlling for covariates that are known to affect migration
- Rural areas were hit harder by environmental variability with increasing depopulation processes, especially the younger generation
- The elder generation was more likely to move to places with warm temperature and rich natural amenities; while the younger generation preferred places coupled with natural amenities, working opportunities, and affordable living costs

42

EDeN Environmental Demography Network

Thank you

Shuai Zhou, Ph.D. candidate
Rural Sociology and Demography (Dual Title)
The Pennsylvania State University
801 Oswald Tower, University Park, PA 16802
sxz217@psu.edu



43