Tornadic Activity, Demographic Change, and Inequality in the American Heartland, 1980-2015

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Abstract:

From 1980 to 2010, communities in the heartland of the United States saw dramatic shifts in the composition, concentration, and spatial distribution of their ethnoracial and impoverished families. In this paper, I contribute to a growing literature on the demographic consequences of natural hazards by using georeferenced data on the population of severe tornadoes—a particularly exogenous and acute natural hazard—linked to local block group data to demonstrate a previously-overlooked contributing factor to inequality in the nation's heartland. Results from spatially-weighted multilevel models of block-group level (n=114,796) demographic change will explore the extent and conditions under which severe tornado activity resulted in changes in the proportion and size of racial minority, foreign-born, and impoverished families. This research advances the empirical research on the demographic consequences of natural hazards and suggests a theoretical reevaluation of the direction and nature of the relationship between the environment and human society.

Introduction:

How do places change after the occurrence of a severe natural hazard, such as a tornado, hurricane, or flood? Natural hazards—and the subset officially declared by the government as "disasters"—are local shocks to communities, wreaking havoc on both the population and the local built environment. The existing sociological literature concludes that natural hazards and disasters do not just happen indiscriminately, but their effects are mediated through the existing social inequalities and the structure of communities. Recently, sociologists and demographers have developed new methods and relied on new datasets to move beyond the case study methodology to test generalizable hypotheses about post-disaster social change.

The overall findings from this growing literature are somewhat mixed. Studies conclude, for example, that natural disasters have exacerbated impacts on poorer, non-white, and unemployed residents (Schultz and Elliott 2013; Pais and Elliott 2010; Rendall et al. 2017; Boustan et al 2017). Others, however, find no significant aggregate-level change in population or earnings (Strobl 2011; Deryugina 2017). The extant literature suffers, however, from problems related to geographic scale. Most studies rely on county-level hazard data, such as SHELDUS, and/or county-level outcomes, which lack the fine-grained geographic detail necessary to capture demographic change. Moreover, the literature often lacks an explicit discussion of how different types of natural hazards might have different consequences, due to variation in their predictability, damage extent, and scale. One must exercise conceptual care when, for example, equating damages and subsequent demographic change resulting from floods with those from earthquakes, given how families may sort around flood plains in non-random ways.

Thus, the existing research on natural hazards suffers from several shortcomings. One methodological and one theoretical. Scholars of the social and demographic consequences of natural disasters have made analytic trade-offs (generalizability and scale). Existing literature on the demographic consequences of natural disasters primarily uses counties as their units of analysis (e.g. Schultz and Elliott 2012). However, several studies have analyzed the tracks of hurricanes. Pais and Elliott (2008) track tract-level change after the "billion" dollar Atlantic and Gulf hurricanes of the 1990s, but as such only focus on the most extreme and damaging hurricanes. Logan, Issar, and Xu (2016) also follow specific hurricane tracks. However, they model county-level outcomes using the more-fine grained, neighborhood specific tracks.

Issues of racial diversity and immigration are at the forefront of the scholars' minds interested in social inequality. This research adds a dimension unconsidered in the existing dialogue around race and immigration by highlighting the discriminate ways natural hazards exacerbate inequalities. It calls for a shift in environmental sociology and a refocus on the way the natural environment continues to exert influence on the structure and organization of society.

Tornadoes and the Heartland:

The communities and families in America's heartland, however defined, have received remarkably less scholarly attention recently from sociologists and kindred scholars relative to their fellow urban and coastal counterparts (Lobao and Meyer 2001). The mismatch between pollsters' predictions and the actions of the electorate in the 2016 presidential election brought this oversight into sharp relief. Shortly after, scholars and members of the popular press lamented the social sciences inability and critiqued our disinterest in understanding the perceptions and experiences of this large swath of the United States, from the Rust Belt and Midwest, to the Great Plains (Dodd, Lamont, and Savage 2017). This scholarly oversight is even more striking given the demographic change undergone by these places since the mid-20th century with the increase in and destinations of international migrants, and the changes in the American economy, most notably, the decline in manufacturing and farming.

This paper turns its attention to this part of the United States and seeks to capture its complexity and relationship to the natural environment. Tornadoes in this part of the United States form from supercells thunderstorms, when winds blow warm moisture near the earth's surface below cold, dry air above into a rotating vertex below. Tornadoes are extremely difficult to forecast, especially relative to other types of natural hazards, such as hurricanes. The average amount of time between a tornado warning and the arrival of the storm is 13 minutes. They can also form almost anywhere, but tend to concentrate in the plain, Midwest, and Southern states. In this way, tornadoes are arguably the most exogenous form of natural hazards, as families are not able to predict where a tornado will hit and sort around it.

At the same time, tornadoes differ from other types of natural hazards in other ways. Compared to floods or hurricanes, they are the most acute form of natural hazard, with very little spill over damage. Their specific trajectories are therefore easy to trace, and their damage is more soundly linked to geospatial reference. Moreover, tornadoes tend to be less damaging than other forms of natural hazards. Still, by focusing exclusively on severe tornado tracks in the

United States, I am able to precisely estimate the relationship between a natural hazard and demographic change, without conflating neighboring demographic shifts with a causal part of the hazard's effect.

<u>Data</u>

Data on tornadoes come from the Severe Weather GIS (SVRGIS) database from the Storm Prediction Center at the National Oceanic and Atmospheric Administration (National Oceanic and Atmospheric Administration 2018). The SVRGIS contains the exact geographic latitude and longitude coordinates for the starting and ending points and the width in yards for the population of recorded tornadoes from 1950-2017 and is updated annually. The SVRGIS also includes data on the estimated property loss (a nine-part categorical variable), resulting number of injuries and fatalities, and the tornado magnitude based on the Fujita (F) scale (Fujita 1971) and the Enhance-F scale after 2007 (McDonald and Mehta 2004).

I plot the tracks of the population of recorded tornadoes from 1980-2015 onto standardized 2010 block group geographic boundaries from the United States Decennial Census to identify the frequency and intensity that exact subparts of neighborhoods experienced tornadoes. Historical block group data from the 1980, 1990, and 2000 censuses come from GeoLytics, Inc., and 2010 and 2015 data come from the American Community Surveys (2008-2012 5-Year Estimates and the 2009-2016 5-Year Estimates) (GeoLytics 1980, 1990, 2000).

My primary outcomes of interest are:

Racial composition: (1) % non-Hispanic black and (2) % Hispanic

Immigrant concentration: (3) % foreign-born

Poverty: (4) % family poverty, (5) % elderly poverty, and (6) % family with children poverty

<u>Analytic Strategy:</u>

The descriptive part of my analysis begins with an exploration of both tornado-level and block-group level data. In the inferential part of my study, my analytic approach mirrors those of kindred sociologists studying neighborhood change (e.g. Hall, Crowder, and Spring 2015). As an example, to estimate the effect of severe tornadoes in the 1990s on demographic change from 1990-2000, the model will be as follows:

$$\left(y_{kjc,2000} - y_{kjc,1990}\right) = \beta_{0c} + \beta_1 torn_{jc} + \beta_2 torn_{jc}^2 + \beta_3\left(y_{kjc,1990} - y_{kjc,1980}\right) + \beta_4 \boldsymbol{R}_{jc} + \beta_5 \boldsymbol{W}_{jc} + e_{jc}$$

$$\beta_{0c} = \gamma_{00} + \gamma_{01} torn_c + \gamma_{02}\left(y_{kc,2000} - y_{kc,1990}\right) + u_{0c}$$

where y_{ktc} represents the percent or size of racial/immigrant/impoverished group *k* in block group *j* located in county *c* (in 1990, 2000, or 2010); $torn_{tc}$ is the block group tornado frequency and intensity, expressed as a second-order polynomial to account for the nonlinearity in the association between tornado activity and demographic change; $\mathbf{R}_{tc}$ and $\mathbf{W}_{tc}$ are vectors of neighborhood characteristics in 1990, 2000, and 2010. The intercept is allowed to vary across counties and is a function of the frequency of tornadoes at the county level. All models also include state-level fixed effects to account for variation in states disaster aid policies.

Descriptive Results:

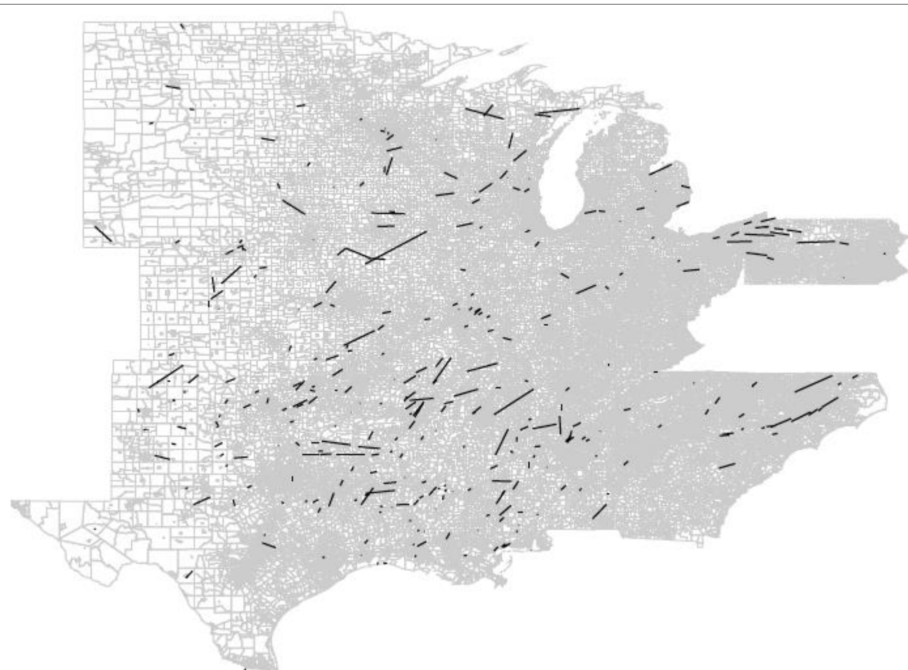
I begin with tornado-level descriptive statistics. Table 1 presents the descriptive statistics for the population of severe tornadoes. There were 340, 406, 300, and 225 F3-F5 tornadoes in the 1980s, 1990s, 2000s, and 2010-2015, respectively. The number of deaths from tornadoes in this part of the United States remained around 400 per decade until 2010-2015, the time frame which includes the Joplin Tornado of 2011, which itself killed 158 people. The average length of severe tornadoes has increased across the decades from 16.4 in the 1980s to over 23 miles in 2010-2015. They have also become consistently wider in yards. Part of these increases represent a real increase in tornado intensity, but part may also represent changes in data quality and reporting accuracy by the NOAA.

Figure 1 contains the severe tornado tracks on block groups in the United States from 1980-2015. I restrict my analysis to the severe tornadoes in 24 states, which make-up 98% of all severe tornado activity over this time-period. The tornado tracks are relatively dispersed geographically in the 1980s and 1990s. From 2010 to 2015, there was a concentration of severe tornado activity in the Ozark region of the United States.

Table 1. Tornado-Level Descriptive Statistics

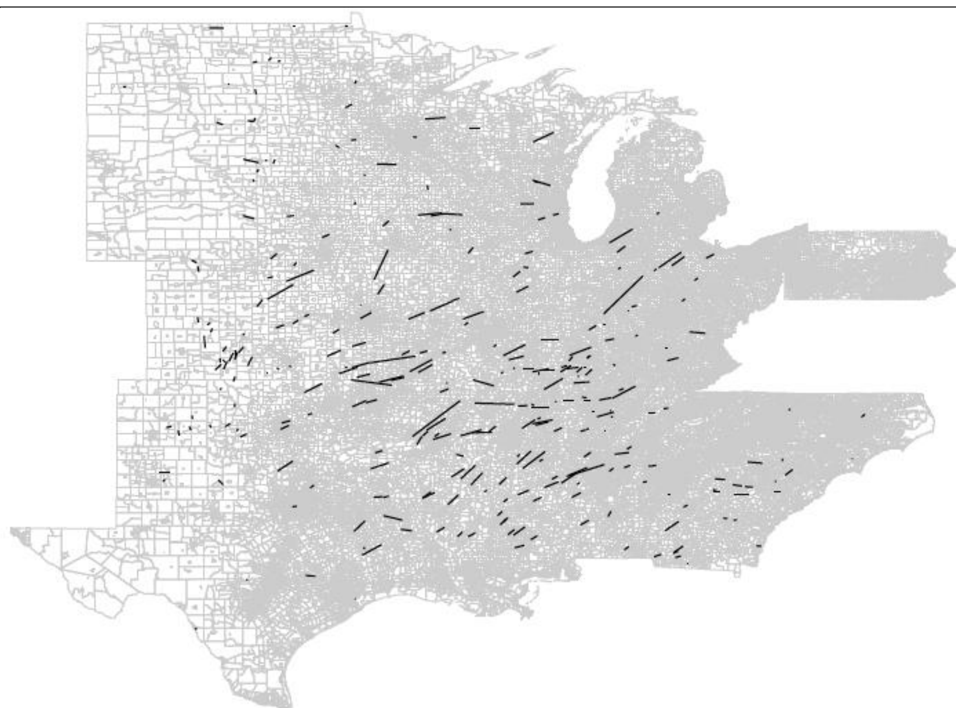
	1980-1989	1990-1999	2000-2009	2010-2015
Magnitude				
F3	276	315	255	166
F4	61	81	43	52
F5	3	10	2	7
Fatalities	393	406	387	709
Injuries	7,296	6,433	4,766	7,456
Property Damage	5.82 (1.28)	5.64 (1.50)	5.51 (2.28)	4.92 (2.91)
Length (miles)	16.40 (17.26)	17.68 (18.14)	18.46 (16.93)	23.12 (22.87)
Width (yards)	408.32 (445.92)	533.32 (502.16)	651.64 (550.97)	905.58 (658.17)
Total	340	406	300	225

Figure 1. Severe Tornado Tracks 1980-2015
1980-1989

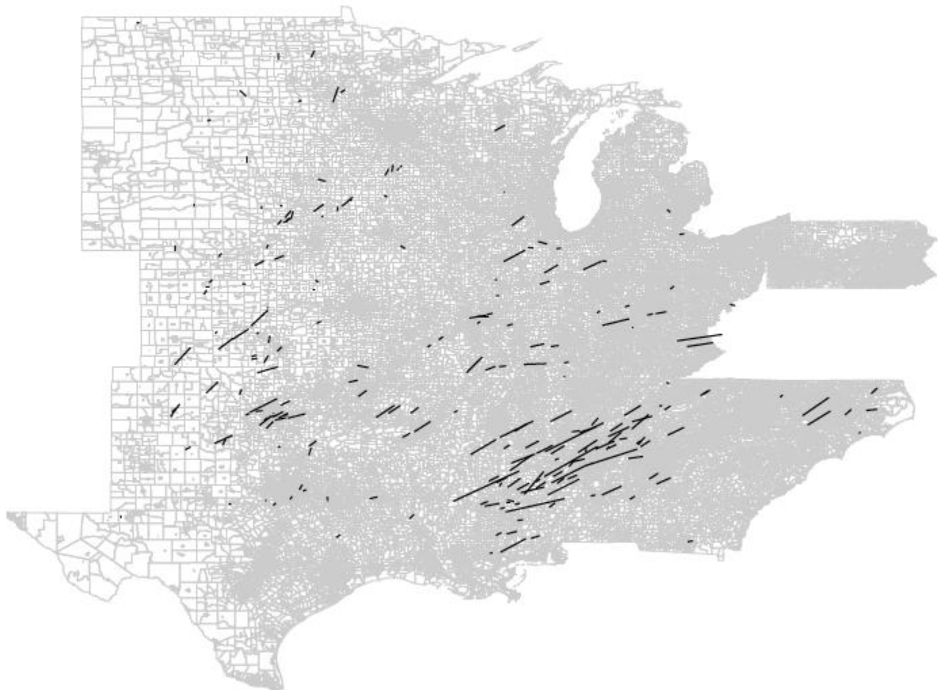


1990-1999

2000-2009



2010-2015



In the next steps of my research, I will explicate my specific hypotheses and then begin estimating parameters in a multivariate modeling framework. I will follow the research plan and modeling strategy as described above to test the relationship between tornado strikes and demographic change, focusing on the six outcomes of interest related to ethnoracial diversity, immigrant concentration, and poverty.

I will further my analysis by restricting my analysis to comparing block-groups only within counties that experienced a severe tornado during the time-period to test my findings sensitivity to control group selection. Finally, I will explore interactions to test for heterogeneous effects of tornado activity. In this analysis, I am specifically interested in interacting the occurrence and intensity of tornado activity with the percent population rural, as studies show that the consequences of natural disasters differ in urban, suburban, and rural places (Elliott and Pais 2010).

<u>References</u>

Boustan, Leah P., Matthew E. Kahn, Paul W. Rhode, and Maria L. Yanguas. 2017. "The Effect of Natural Disasters on Economic Activity of US Counties: A Century of Data." *NBER Working Paper No. 23410.*

Deryugina. T. 2016 *(Forthcoming 2017).* "The Fiscal Cost of Hurricanes: Disaster Aid versus Social Insurance." *American Economic Journal: Economic Policy.*

Dodd, Nigel, Michele Lamont, and Mike Savage. 2017. "The Trump/Brexit Moment: Causes and Consequences: Introduction to Special Issue." *British Journal of Sociology* 68(S1): 1-2.

Elliott, James R. and Jeremy Pais. 2010. "When Nature Pushes Back: Environmental Impact and the Spatial Redistribution of Socially Vulnerable Populations." *Social Science Quarterly* 91(5): 1187-1219.

Fujita, T. Theodore. 1992. "Mystery of Severe Storms." Chicago: University of Chicago Press.

Fujita, T. Theodore. 1971. "Proposed characterization of tornadoes and hurricanes by area and intensity." SMRP Research Paper 91: University of Chicago.

GeoLytics. 2008. "Census CD: 1990 in 2010 boundaries, Release 1.1." Branchburg, NJ: GeoLytics, Inc.

GeoLytics. 2012. "2010 Summary File (SF1) in 2010 Boundaries." Branchburg, NJ: GeoLytics, Inc.

Hall, Matthew, Kyle Crowder, and Amy Spring. 2015. "Neighborhood foreclosures, Racial/Ethnic Transitions, and Residential Segregation." *American Sociological Review* 80(3): 526-549.

Lobao, Linda and Katherine Meyer. 2001. "The Great Agricultural Transition: Crisis, Change, and Social Consequences of Twentieth Century US Farming." *Annual Review of Sociology* 27(2001): 103-124.

Logan, J.R., S. Issar, & Z. Xu. 2016. "Trapped in Place? Segmented Resilience to Hurricanes in the Gulf Coast, 1970-2005." *Demography* 53(5): 1511-1534.

McDonald, J R. and K Mehta. 2004. "A Recommendation for an Enhanced Fujita Scale (EF-Scale)" Wind Engineering Center: Texas Tech University.

National Oceanic and Atmospheric Administration, Nave, Sherri (ed.) 2018. "Storm Data." January 2018: Volume 60, No. 1. Accessed August 20, 2018. https://www.ncdc.noaa.gov/IPS/sd/sd.html

Pais, Jeremy F., and James R. Elliott. 2008. "Places as Recovery Machines: Vulnerability and Neighborhood Change After Major Hurricanes." *Social Forces* 86(4): 1415-1453.

Strobl, Eric. 2008. “The Economic Growth Impact of Hurricanes: Evidence from US Coastal Counties.” *IZA Discussion Paper No. 3619, July*

Schultz, Jessica and James R. Elliott. 2013. “Natural Disasters and Local Demographic Change in the United States.” *Population & Environment* 34(3): 293-312.