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Tornado Vulnerability and Impacts in the United States (research in progress—comments & suggestions are appreciated)

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Literature Review

- Wildavsky (1988) interprets the degree of regional safety as a natural product of a growing market economy.
- International Studies
 - Anbarci *et al.*, 2005; Kahn, 2005; Toya and Skidmore, 2007; Kellenberg and Mobarak, 2008) demonstrate a distinguishable and predictable pattern between losses from natural disaster events and several measures of economic development
 - Many others...

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Outline

- Tornado Vulnerability
 - Economic and Demographic Factors
 - Poverty
 - Quality of Housing Infrastructure
 - Telecommunication Access
 - Family Structure
 - Education
- Tornado Impacts on Perceptions and Preferences
 - Trust
 - Risk (loss aversion)
 - Time

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Literature Review

- Within Country Studies
 - Horwich (2000) studied the Kobe earthquake. He argues that increased income translates to a general increase in demand for safety.
 - Many others...
- Our Contribution
 - Study thousands of US tornados over many years
 - County level data (disaggregated)
 - Tornados are localized events (as opposed to hurricane, typhoon, or earthquake)

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Socio-economic Characteristics and Tornado Impacts Analysis

- **Data on tornadoes**
 - NOAA (National Oceanic and Atmospheric Administration)
 - Detailed tornado activity, deaths and magnitudes
 - Tornado data are aggregated and averaged over 8 time periods by county : '68-'72, '73-'77, ... , '98-'02, '03-'07 (more than 40,000 tornados)
 - The unit of observation : Counties in U.S. total 3,135

- **Data on socio-economic and housing factors**
 - U.S. Decennial census of population
 - 3,135 counties of U.S. over 1970 – 2010 period.

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Table 3. Summary Statistics

	Mean	Standard Deviation	Number of Observations
Dependent Variable			
Log (Number of Death+1)	0.0244	0.1419	25088
Independent Variables			
Log (Fscale+1)	0.3360	0.4241	25088
Lag_log(tornado+1)	0.7001	0.7046	21946
Log (Per Capita Income)	7.9508	1.1991	24939
Log (Top 10% Income)	11.5614	0.4062	25089
Tornado Alley	0.3297	0.4701	25088
Log (Persons Total)	10.1371	1.3651	25082
Pct Urban Population	0.3844	0.3027	18774
Pct Over 65	0.1318	0.0413	25082
Pct Under 18	0.2791	0.0464	25082
Poverty Rate	0.1329	0.0693	25082
Pct BA degree	0.1357	0.0738	25062
Log (Female-Headed hhd)	6.9506	1.5774	25061
Log (Mobile home)	6.6718	1.3338	25047
Log (No Telephone)	6.3065	1.4273	24578

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Tornadoes and Fatality over 1968-2007

Table 1. Total number of tornadoes by county over 1968–2007

No. of Tornadoes	Freq.	Percent
0	10,013	39.91
1	5,674	22.62
2	3,361	13.40
3	2,135	8.51
4	1,285	5.12
5	846	3.37
6	542	2.16
7	350	1.40
8	238	0.95
9	158	0.63
10 to 19	427	1.70
20 to 29	50	0.20
30 or over	9	0.04
Total	25,088	100.00

* 8 time blocks for each 3,135 counties consist total observations.

Table 2. Deaths induced by tornadoes over 1968–2007

Fatalities	Freq.	Percent
0	39,702	97.69
1	510	1.25
2	161	0.40
3	79	0.19
4	37	0.09
5	25	0.06
6	27	0.07
7	21	0.05
8	5	0.01
9	8	0.02
10 to 19	39	0.10
20 to 29	11	0.03
30 or more	14	0.03
Total	40,639	100.00

* Total 40,639 tornadoes occurred during 1968–2007

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Quality of Home Infrastructure—Mobile Homes






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Empirical Specification

- Nature of Data
 - Many Zero Observations (truncated)
 - Panel (counties over time)
- Random Effects Tobit

$$\ln(\text{impact}_{jit}) = \max(0, \ln(\text{impact}_{jit}))$$

$$\ln(\text{impact}_{jit}) = \beta_m(y_{jit}) + t_i + e_{jit}$$

where impact_{jit} is 1 plus the total number of deaths (injuries and economic damages) caused by a tornado j in county i during period t , y_{jit} represents a vector of j variables that may determine the deaths (or injuries) caused by the extreme event (e.g., severity, past tornado events, natural logarithm of per capita income in real U.S. dollars, a measure of human capital, population, measures of poverty and other demographic variables, and t represents a series of time indicator variables.

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Influence of Tornadoes on Perceptions and Preferences

- Shocks Can and Do Influence How We Perceive the World
 - Family Tragedy
 - Economic Shocks
 - Terrorism
 - Natural Disasters
- We Consider the Affects of a Tornado Shock on
 - Trust (Survey Techniques)
 - Risk Preferences (Experimental Techniques)
 - Time Preferences (Experimental Techniques)
- Changes in Attitudes Regarding Trust, and Preferences for Risk and Time Many Affect Decision-Making
 - Public Infrastructure Reinvestment
 - Private Reinvestment
 - Social Cohesion

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Table 4. Socio-economic determinants of tornado impacts
Tobit Random Effects Regressions Results

Dependent var.: Log (death+1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log (Fscale+1)	1.435*** (28.32)	1.432*** (28.3)	1.433*** (28.25)	1.426*** (28.27)	1.437*** (28.32)	1.432*** (28.09)	1.434*** (28.07)
Lag_log(tornado+1)	0.050** (2.42)	0.054*** (2.62)	0.049** (2.37)	0.054*** (2.61)	0.044** (2.13)	0.051** (2.43)	0.048** (2.29)
Log (Per Capita Income)	-0.012 (-0.08)	0.096 (0.56)	-0.304*** (-2.93)	-0.176* (-1.72)	-0.156 (-1.57)	-0.225** (-2.01)	0.079 (0.42)
Log (Top 10% Income)	-0.334 (-0.85)	-0.072 (-0.16)	-0.820** (-2.23)	-0.688** (-1.99)	-0.437 (-1.23)	-0.506 (-1.25)	-0.095 (-0.19)
Tornado Alley	0.209*** (6.83)	0.211*** (6.97)	0.209*** (6.83)	0.218*** (7.1)	0.201*** (6.61)	0.206*** (6.67)	0.210*** (6.71)
Log (Persons Total)	0.118*** (5.9)	0.116*** (5.82)	0.127*** (6.36)	-0.099 (-1.39)	0.042 (1.47)	0.079*** (2.29)	-0.075 (-0.85)
Pct Urban Population	-0.209*** (-2.6)	-0.183** (-2.22)	-0.184** (-2.21)	-0.202** (-2.53)	-0.080 (-0.95)	-0.207** (-2.55)	-0.132 (-1.52)
Pct Over65	-1.173** (-2.28)	-1.340** (-2.52)	-1.246** (-2.32)	-1.031** (-1.98)	-0.586 (-1.1)	-1.223** (-2.35)	-0.548 (-0.94)
Pct Under18	-1.274** (-2.11)	-1.438** (-2.34)	-1.095* (-1.8)	-1.066* (-1.76)	-0.457 (-0.74)	-1.200** (-1.98)	-0.755 (-1.13)
Poverty Rate	1.104*** (2.72)	1.242*** (2.96)					0.704 (1.25)
Pct BA degree		-0.385 (-1.2)	-0.132 (-0.42)				0.110 (0.31)
Log (Female-Headed hhd)				0.200*** (3.27)			0.115 (1.41)
Log (Mobile home)					0.091*** (4.02)		0.086*** (3.52)
Log (No Telephone)						0.045* (1.68)	-0.013 (-0.44)

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Oklahoma City Tornado, 2013

- On May 20, 2013 a category five tornado struck the suburbs of Oklahoma City.
- The tornado, more than a mile wide, resulted in massive damage and 24 fatalities.
- Moore was the primary suburban community in the tornado's path and had been struck by another category five tornado on May 3, 1999.

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Strategy

- Immediately collect data, using survey and experimental methods, on preferences for time and risk as well as trust levels from three populations;
 - 1) individuals impacted directly (i.e., loss of life, injury or property damage) by the 2013 tornado event,
 - 2) individuals from the surrounding community who experienced the event, but were not directly impacted, and
 - 3) individuals residing in a similar (demographically) community in the Oklahoma City metro area, but which has not experienced a significant tornado event recently.
- We also administered a follow-up survey within 12–16 months of the event with respondents from the first two populations to better understand the dynamics of near post-disaster time, risk and trust preferences

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Strategy—Experimental Methods

- Elicit individual preferences using multiple lottery choice mechanisms (similar to Holt and Laury, 2002)
 - Risk (over gains)
 - Ambiguity (risk over gains and losses, but where the probabilities are unknown)
 - Losses (risk with regard to losses as opposed to gains).

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Strategy

- Mailed custom postcards with a request to participate in an online survey
- Offered a base incentive of a \$15 electronic gift card from Amazon.com to complete the survey plus any earnings from the risk and time preference elicitation (also Amazon.com gift cards, but of variable value)
- The cards contained a URL and a unique one-time identifier that the individual was required to enter before beginning the survey
- The survey was developed using an online software service
- The survey included questions about what sorts of physical impacts the tornado had to them personally and their post-tornado experiences, demographic questions, and questions designed to elicit time, risk and trust preferences

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- **Initial Survey and Follow-up survey**
 - Initial Survey within about 6 months of the event.
 - Follow up survey within 12–16 months with same respondents to better understand the dynamics of near post-disaster time, risk and trust preferences.
- **Trust and Risk, Ambiguity, Loss, and Time Preference**

TRUST variables	1. Strongly Disagree	2. Disagree somewhat	3. Agree somewhat	4. Strongly agree
Risk Aversion _Safechoices (0 - 10)	Higher more risk averse			
Ambiguity Aversion _Safechoices (0 - 10)	Higher more ambiguity averse			
Loss Aversion _Safechoices (0 - 10)	Higher more loss averse			
Time Preference _NOWchoices (0 - 15)	Higher more impatient			

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Table 5. Summary Statistics

Category	Variable	Mean (Standard Deviation)
Demo graphic	Age	Age of respondent 45.5097 (15.6253)
	Female	Dummy 1= female, 0 = male 0.5560 (0.4978)
	Married	Dummy 1 = Married, 0 = Other 0.5637 (0.4969)
	White	Dummy 1 = White, 0 = Other 0.8649 (0.3425)
	Voter	Dummy 1 = registered voter 0.8533 (0.3545)
	HouseOwn	Dummy 1 = owner of the house 0.7066 (0.4562)
	Education	Highest level of education completed 10.8340 (2.5410)
	Income_2012	Household's total annual income in 2012 5.2162 (1.8341)
Impact	IMPACT_1 : Lost my place of residence	0.1699 (0.3763)
	IMPACT_2 : My place of residence was damaged	0.3977 (0.4904)
	IMPACT_3 : I experienced property damage	0.4826 (0.5007)
	IMPACT_4 : My family/friends experienced loss or damage to their place of residence	0.5328 (0.4999)
	IMPACT_sum1234 : Sum of four IMPACT dummies	1.5830 (1.4073)

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Literature Review

- Toya and Skidmore, 2014
 - Cross-country empirical study—natural disaster increase trust
- Chong, Fleming, and Bejarano, 2011
 - Survey methods—those affected by the 2010 Chilean earthquake were less trustworthy, relative to those who were not affected
- Cassar, Healy, and von Kessler, 2011
 - Survey and experimental methods—those affected by 2004 Thailand tsunami
 - Are more trusting
 - Are more risk averse
 - Have a higher discount rate

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Table 5.(cont'd) Summary Statistics

Category	Variable	Mean (Standard Deviation)
Tornado-Affected	=1 if directly affected by a tornado	0.6564 (0.4758)
Trust (1 - 4)	In general, you can trust people.	2.8378 (0.5678)
	Nowadays, you can't rely on anybody.	2.2317 (0.8401)
	How much trust do you have in your local (city or county) government?	2.8340 (0.7415)
	How much trust do you have in your neighbors?	3.1429 (0.8014)
	How much trust do you have in your police and fire departments?	3.4402 (0.6815)
	How much trust do you have in your friends?	3.6873 (0.5344)
Risk	Risk Aversion_ Safechoices (0 - 10)	5.2896 (3.4015)
Ambiguity	Ambiguity Aversion_ Safechoices (0 - 10)	5.6062 (3.2646)
Loss	Loss Aversion_ Safechoices (0 - 10)	4.9336 (3.7618)
Time Pref.	Time Preference_ NOWchoices (0 - 15)	4.2026 (5.4102)
Total observations		259

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Ordered Logit Regressions Results

1. In general, you can trust people.

→ Higher number is associated with more trust

	1	2	3
<i>In general, you can trust people.</i>			
Tornado-affected	0.725** (2.450)		
IMPACT_1		0.088 (0.210)	
IMPACT_2		-0.158 (-0.390)	
IMPACT_3		0.458 (1.070)	
IMPACT_4		0.320 (0.830)	
IMPACT_Sum1234			0.206** (2.010)
Age	0.018* (1.900)	0.018* (1.920)	0.018* (1.940)
Female	0.293 (1.010)	0.283 (0.960)	0.289 (1.000)
Married	0.005 (0.020)	-0.041 (-0.130)	0.000 (0.000)
White	-0.022 (-1.010)	-0.035 (-0.090)	-0.067 (-1.140)
Voter	0.248 (0.630)	0.289 (0.720)	0.252 (0.640)
HouseOwn	-0.343 (-1.010)	-0.324 (-0.940)	-0.386 (-1.140)
Education	0.162*** (2.720)	0.164*** (2.740)	0.164*** (2.750)
Income_2012	0.041 (0.480)	0.046 (0.540)	0.044 (0.520)

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Ordered Logit Regressions Results

2. Nowadays, you can't rely on anybody.

→ Higher number is associated with less trust

<i>Nowadays, you can't rely on anybody.</i>	1	2	3
Tornado-affected	-0.561** (-2.250)		
IMPACT_1		-0.051 (-0.150)	
IMPACT_2		-0.378 (-1.130)	
IMPACT_3		-0.083 (-0.240)	
IMPACT_4		-0.215 (-0.690)	
IMPACT_Sum1234			-0.198** (-2.310)

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Ordered Logit Regressions Results

4. How much trust do you have in your neighbors?

→ Higher number is associated with more trust

<i>How much trust do you have in your neighbors?</i>	1	2	3
Tornado-affected	0.500** (1.960)		
IMPACT_1		0.263 (0.740)	
IMPACT_2		-0.023 (-0.070)	
IMPACT_3		-0.068 (-0.190)	
IMPACT_4		0.474 (1.430)	
IMPACT_Sum1234			0.146* (1.670)

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Ordered Logit Regressions Results

3. How much trust do you have in your local (city / county) government?

→ Higher number is associated with more trust

<i>How much trust do you have in your local (city or county) government?</i>	1	2	3
Tornado-affected	0.636** (2.390)		
IMPACT_1		-0.400 (-1.140)	
IMPACT_2		-0.210 (-0.600)	
IMPACT_3		0.428 (1.170)	
IMPACT_4		0.531 (1.600)	
IMPACT_Sum1234			0.185** (2.050)

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Ordered Logit Regressions Results

5. How much trust do you have in your police and fire departments?

→ Higher number is associated with more trust

<i>How much trust do you have in your police and fire departments?</i>	1	2	3
Tornado-affected	0.667** (2.500)		
IMPACT_1		-0.340 (-0.940)	
IMPACT_2		-0.061 (-0.170)	
IMPACT_3		0.314 (0.830)	
IMPACT_4		0.429 (1.240)	
IMPACT_Sum1234			0.167* (1.830)

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Ordered Logit Regressions Results

6. How much trust do you have in your friends?
 → Higher number is associated with more trust

How much trust do you have in your friends?	1	2	3
Tornado-affected	0.572* (1.900)		
IMPACT_1		-0.719* (-1.720)	
IMPACT_2		-0.776* (-1.760)	
IMPACT_3		0.716 (1.600)	
IMPACT_4		0.912** (2.260)	
IMPACT_Sum1234			0.189* (1.770)

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- ### Other Measures of Risk and Time Preferences
- Risk Aversion (no significant differences)
 - Ambiguity Aversion (no significant differences)
 - Time Preferences (no significant differences)
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Ordered Logit Regressions Results (Loss Aversion)

7. Loss Aversion_Safechoices (0 – 10)
 → Higher number is associated with more loss aversion.

Loss Aversion	1	2	3
Tornado-affected	0.477* (1.850)		
IMPACT_1		-0.090 (-0.260)	
IMPACT_2		0.147 (0.420)	
IMPACT_3		0.410 (1.150)	
IMPACT_4		-0.008 (-0.020)	
IMPACT_Sum1234			0.153* (1.770)

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Comparison : Initial vs. Follow-up survey

Variable	Variable Description	Initial survey			Follow-up survey		
		Affected	Not Affected	Difference	Affected	Not Affected	Difference
Trust (0-4)	In general, you can trust people.	2.9000	2.7191	0.1809***	2.8889	2.8286	0.0603
	Nowadays, you can't rely on anybody.	2.1588	2.3708	-0.2120**	2.1389	2.1714	-0.0325
	How much trust do you have in your local (city or county) government?	2.9118	2.6854	0.2264***	2.8333	2.7714	0.0619
	How much trust do you have in your neighbors?	3.2000	3.0337	0.1663**	3.1019	2.8571	0.2447*
	How much trust do you have in your police and fire departments?	3.5118	3.3034	0.2084***	3.4815	3.4000	0.0815
Risk	Risk Aversion_Safechoices (0-10)	5.4759	4.9342	0.5417	5.5053	5.5517	-0.0465
	Ambiguity Aversion_Safechoices (0-10)	5.7162	5.3974	0.3188**	5.7826	5.2667	0.5159
Loss	Loss Aversion_Safechoices (0-10)	5.2119	4.3733	0.8386**	5.8261	5.8182	0.0079
Time Pref.	Time Preference_NOWchoices (0-15)	4.1883	4.2308	-0.0425	3.2211	3.2500	-0.0289
No. of Observations		170	89		108	35	

* Mean values and Mann-Whitney-Wilcoxon test results are reported.
 (***) : significant at 0-5%, ** : significant at 5-10%, * : significant at 10-20%

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Conclusions

- Tornado Vulnerability
 - Income Matters
 - Poverty Matters
 - Quality of Home Infrastructure seems very important
 - Family structure is also important
- Affects of Tornados on Trust, Risk and Time Preferences
 - Trust Increases
 - Loss Aversion Increases
 - But the Impacts Do Not Appear to be Long-lasting
 - Implications
 - Willingness to Invest in Community and Personal Infrastructure Depends on Trust, Loss Aversion and Time Preferences
 - Make Decisions Regarding Rebuilding in Immediate Aftermath of Disasters

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