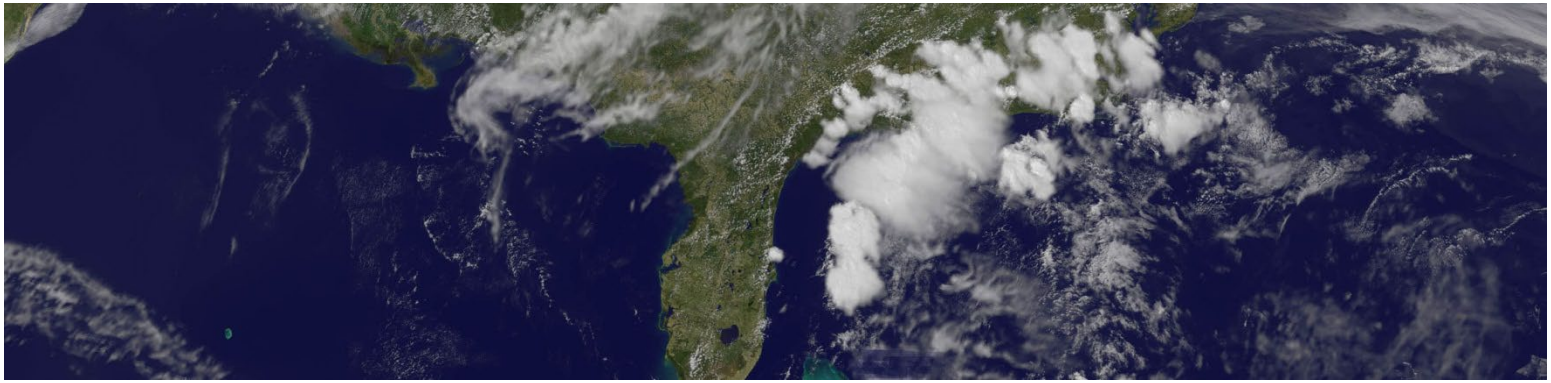

Extreme Weather Events and Rural-to-Urban Migration

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Raisa Saif, Program in Environmental Studies, University of Oregon
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WEAI/AERE – July 1, 2012 – San Francisco

Climate Change?

- Expected to result in changes in the frequency, severity, and geographic extent of severe weather
- Low-lying countries such as Bangladesh likely to be hardest hit
  - Concern? Migration from rural areas into cities
  - High-frequency spatially disaggregated migration data are hard to find for many developing countries

- Look to U.S. to see if severe weather affects migration patterns, even in a developed country

U.S. County-level Data

- County-to-county migration data are available from the Statistics of Income (SOI) division of the Internal Revenue Service (IRS)
  - Best quality, free download: 2004 – 2010

- Data on severe weather events available from SHELDUS (Hazards and Vulnerability Research Institute, Dept. Geography, Univ. of South Carolina)
  - Goes back to 1960, but with less information for 1985-1995.

IRS Migration Data: Limitations

- IRS censors data that might reveal identities
  - If county-to-county flow is <10 returns ("households"), the data are aggregated with other counties
- Focus on "significant flows" between counties
  - Aggregated flows can be added to the model (tedious)
  - Planned for next edition of the paper
- Also, people who do not file taxes are excluded
  - E.g. Miss lowest-income and some retired individuals
  - (Control for poverty rates and %65+ in sensitivity analyses)

Significant County-Migration Flows (n=576,680)

Measures of Significant (n>=10) County-to-County Migration Flows
Panel data, county pairs, 2005-2010; n=576,680 total flows

VARIABLES	(1) 2005	(2) 2006	(3) 2007	(4) 2008	(5) 2009	(6) 2010
Tax returns	87.15	87.62	86.33	86.95	86.49	87.40
(~ "households")	(323.5)	(327.8)	(314.9)	(316.4)	(316.4)	(327.4)
Total exemptions	166.7	167.3	163.6	162.0	160.9	163.0
(~ "individuals")	(636.9)	(647.5)	(611.4)	(595.7)	(597.4)	(621.2)
Observations	94,814	98,401	96,759	98,861	96,426	91,419

Extreme Weather Events

- **Types** of extreme weather = 10
  - Floods, droughts, hailstorms, heat waves, hurricanes, severe storms, tornadoes, wildfires, wind storms, winter weather
- Alternative **measures** of extreme weather = 7
  - Any event during the year?, Number of events, Total days with events, Total crop damage, Total property damage, Total injuries, Total fatalities

Extreme Weather: Types and Measures

Measures of Extreme Weather for Origin Counties (unconditional)
Panel data; ~3074 counties by six years: 2005-2010 (4/16-4/15) = 18,445 observations

VARIABLES	(1) At least one event	(2) # Events	(3) Total days	(4) Crop Damage (x 10^6)	(5) Property Damage (x 10^6)	(6) Injuries	(7) Fatalities
Floods	0.312	0.694	1.847	0.120	1.119	0.0166	0.0214
Droughts	0.0268	0.103	3.270	0.186	0.030	0.000208	n.a.
Hail storms	0.178	0.478	0.479	0.0486	0.262	0.0129	0.00103
Heat waves	0.0398	0.0533	0.269	0.0267	0.00039	0.103	0.0257
Hurricanes	0.0493	0.0725	0.141	0.175	3.932	0.0477	0.0500
Severe storms	0.226	0.696	0.708	0.00139	0.044	0.0262	0.00266
Tornadoes	0.165	0.249	0.250	0.00745	0.284	0.203	0.0196
Wildfires	0.0224	0.0312	0.132	0.0151	0.094	0.0257	0.00233
Wind storms	0.0583	0.114	0.139	0.0022	0.0082	0.00399	0.00206
Winter (severe)	0.260	0.496	0.977	0.186	0.030	0.0553	0.0142

Exogeneity?

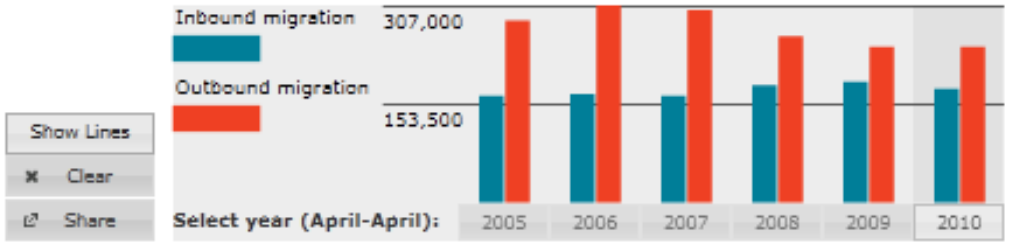
- Weather events can be treated as purely exogenous
  - At the year-to-year level, human migration decisions do not affect the weather
- Myriad other factors may affect migration, especially local economic conditions
  - Controlling for local economic conditions can increase the explanatory power of the model
- Reduced form specification
  - Weather can affect employment, earnings, and number of establishments (structural model could be contemplated)
  - Weather causes migration via two channels:
    - directly
    - indirectly, through its effects on economic activity
  - We want the overall effect of weather on migration

Specification considerations

- Dependent variable is counts of households moving between each county pair
  - 3100 x 3100 pairs = about 10 million pairs
  - Six years of data = potentially 60 million flows!
  - Limited to flows >10 = about 500,000 flows
- Expect greater migration flows when
  - Origin county is more populous
  - Destination county is more populous
  - The two counties are closer together

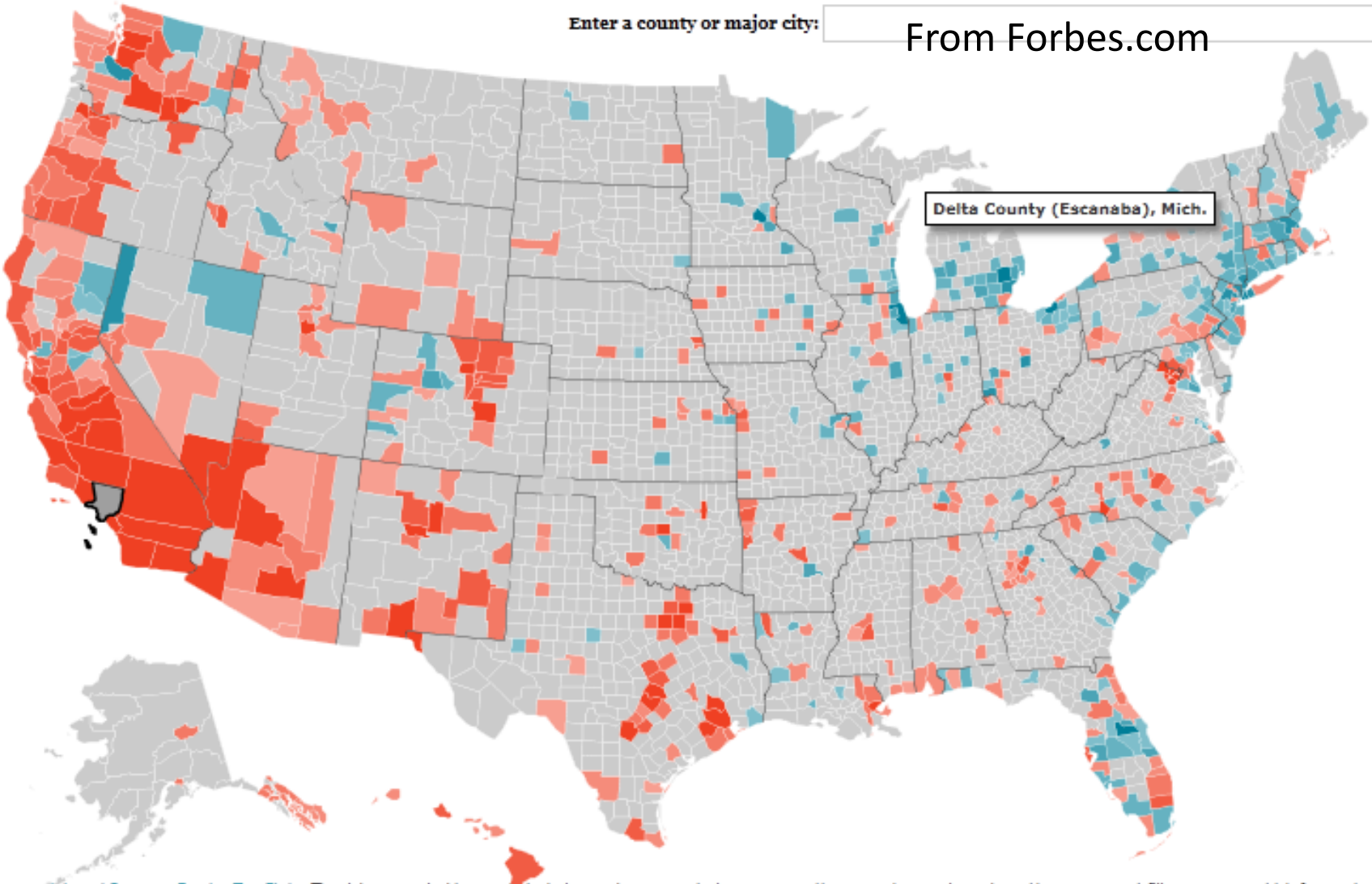
Los Angeles County (Los Angeles), Calif.

Population (2010): 9,818,605
Population (2005): 9,786,373
Inbound income per cap. (2010): $23,900
Outbound income per cap. (2010): $24,400
Non-migrant income per cap. (2010): $24,000



Enter a county or major city:

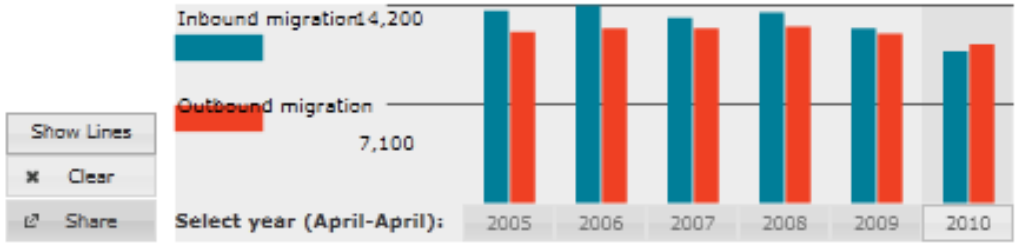
From Forbes.com



Source: Internal Revenue Service Tax Stats. The data presented here only include people represented as an exemption on an income tax return. Years represent filing seasons, which for most people end on April 15, but they include returns received as late as the end of September. For best results, please use FireFox, Chrome, Safari, or Internet Explorer 9.

Lane County (Eugene), Ore.

Population (2010): 351,715
Population (2005): 335,831
Inbound income per cap. (2010): $19,500
Outbound income per cap. (2010): $20,000
Non-migrant income per cap. (2010): $24,000



Show Lines
Clear
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Enter a county or major city:

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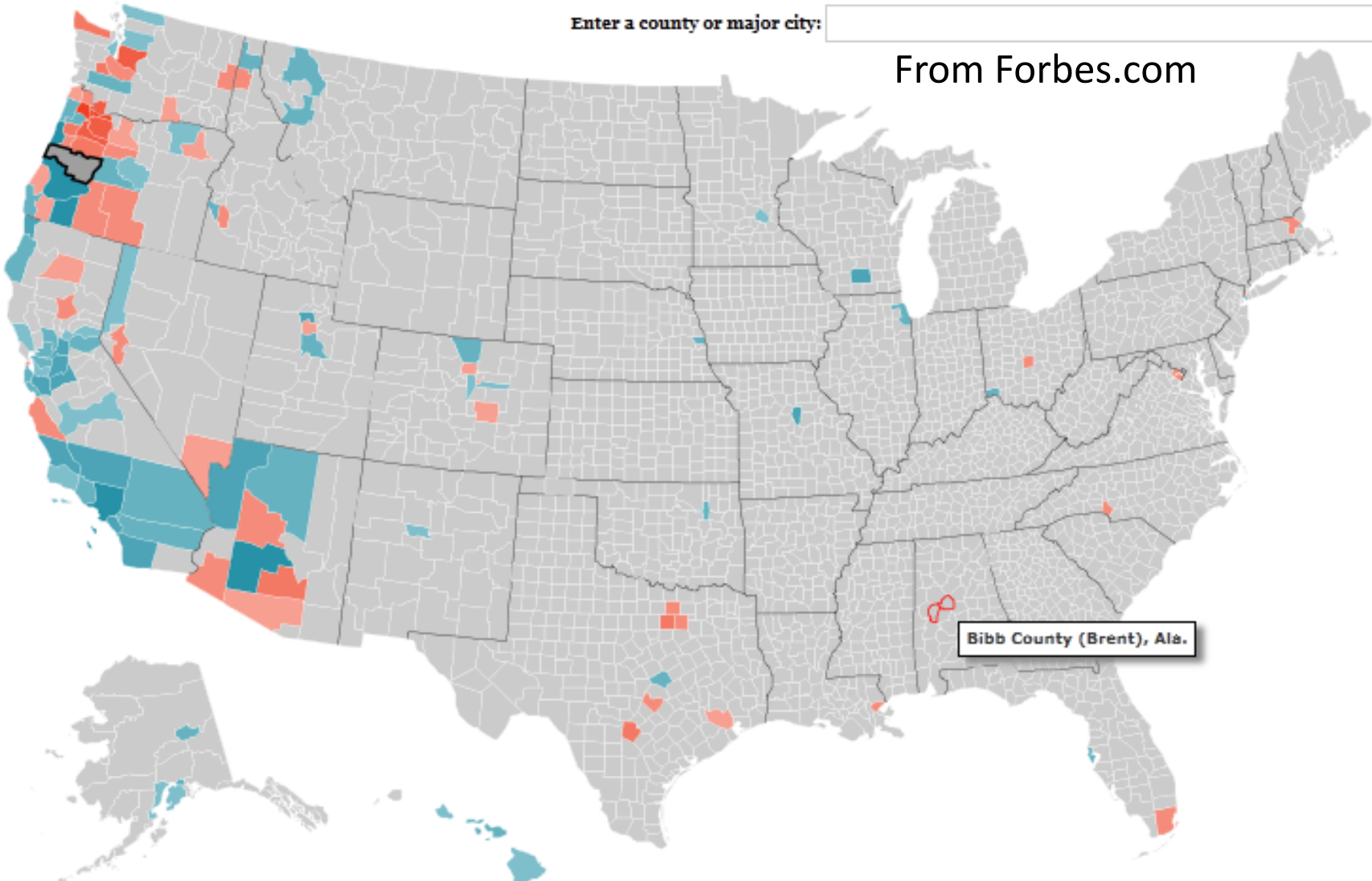

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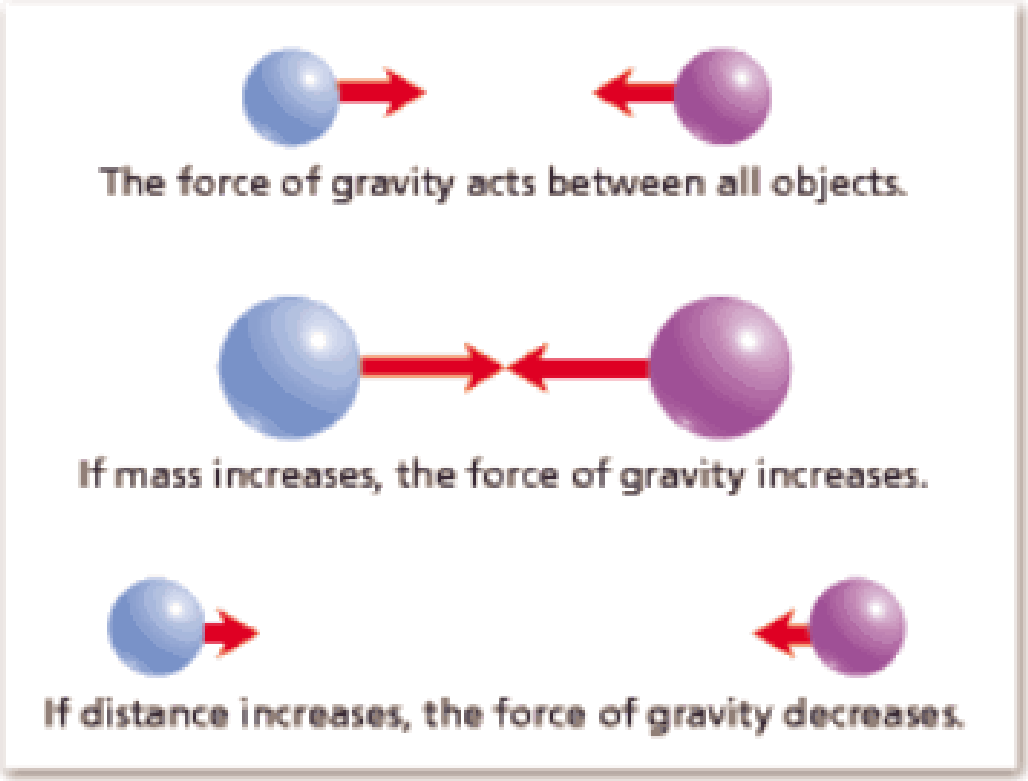
Gravitational Attraction

- Elementary physics: $A = \frac{g\ m_1 m_2}{d^2}$



Generalized Gravity Model

$$migration_{ijt} = g\left[X_{ijt}\right]\frac{\left(Pop_i\right)^{\beta_1}\left(Pop_j\right)^{\beta_2}}{\left(distance_{ij}\right)^{2\beta_3}}\exp\left(\varepsilon_{ijt}\right)$$

- Take logs:

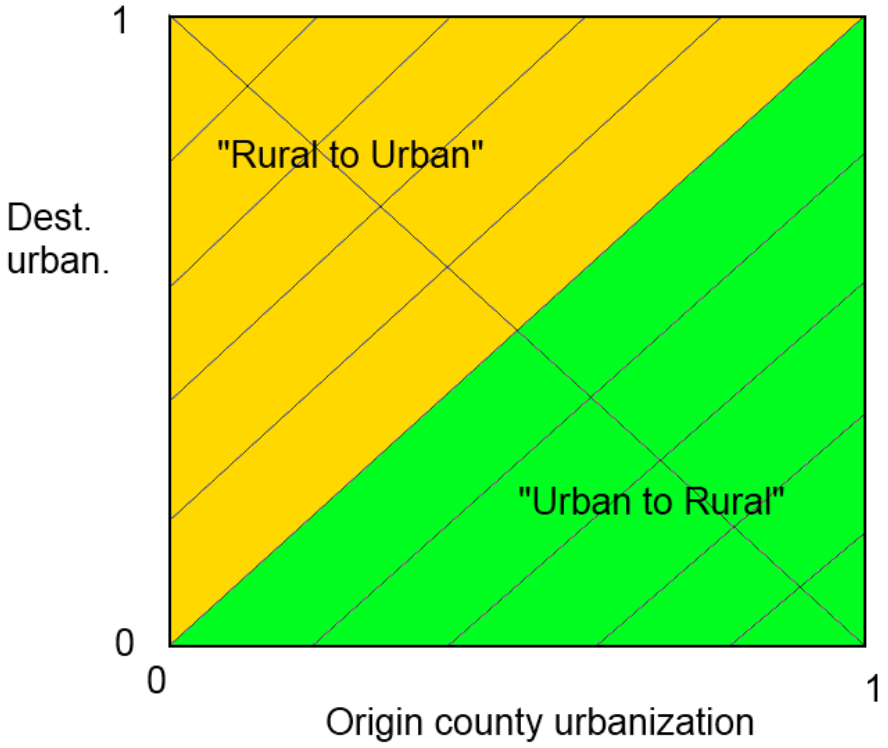
$$\log\left(migration_{ijt}\right) = \log\left(g\left[X_{ijt}\right]\right) + \beta_1\log\left(Pop_i\right) + \beta_2\log\left(Pop_j\right) - 2\beta_3\log\left(distance_{ij}\right) + \varepsilon_{ijt}$$

- (Incidentally) can test whether $\beta_1 = \beta_2 = \beta_3 = 1$

Key question

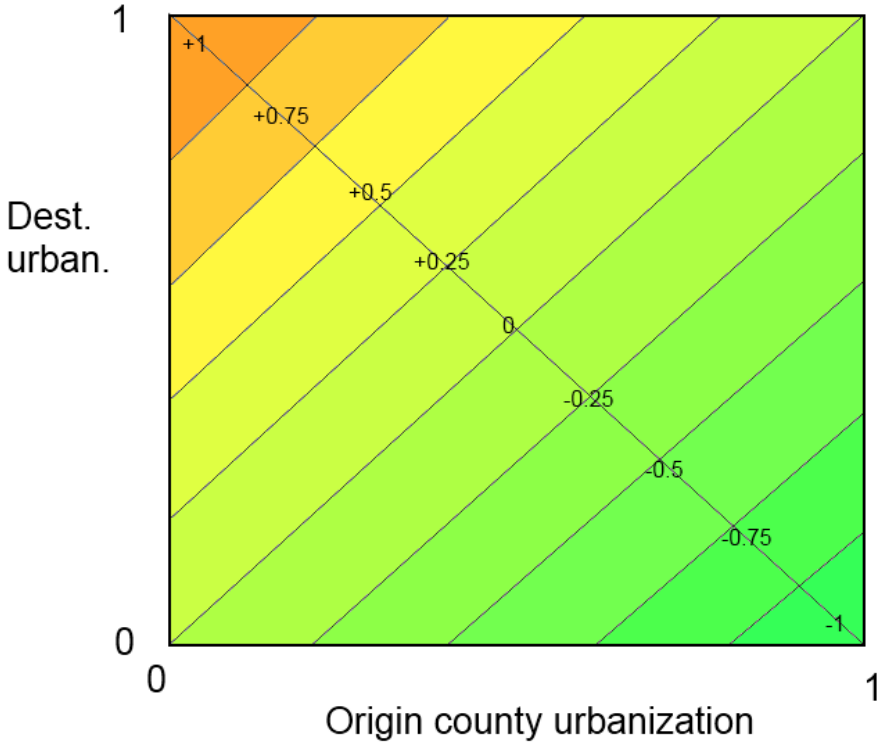
- How can we capture “rural to urban” migration?
- Each gross flow, in either direction, is a potential observation (subject only to censoring at 10 returns)

All flows can be placed into two groups (according to urbanization in 2000)



- Could divide flows into two groups
- Does extreme weather increase flows for one group and decrease flows for the other?

Instead, strive for a model that identifies more “groups” (continuous)



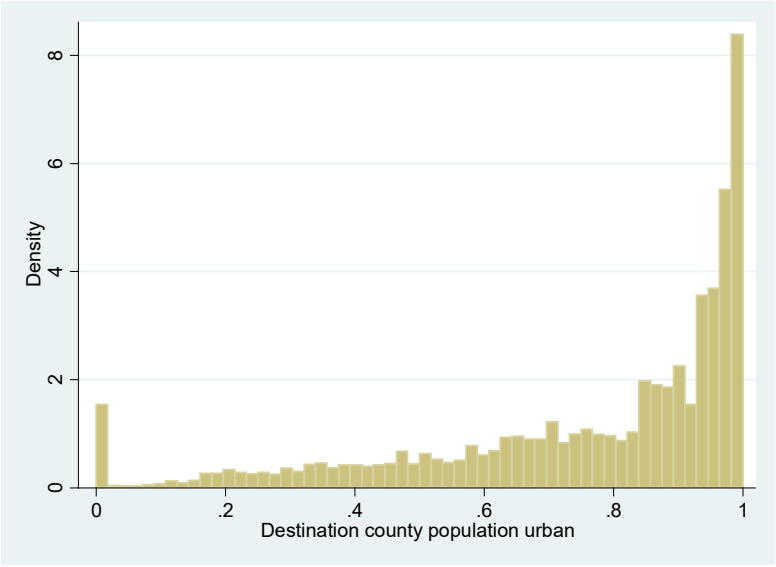
- Destination urbanization – origin urbanization
- One-dimensional measure, values shown along the diagonal
- Convert “iso-difference loci” in two dimensions to just one dimension

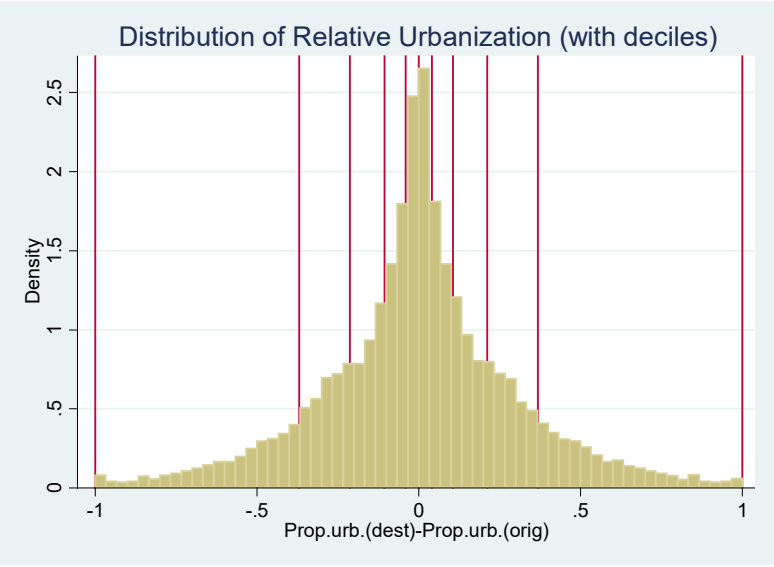
Relative urbanization?

Proportion urbanized, across counties (2000 Census)

Difference in urbanization (destination – origin)

$$\left[PropUrban_j - PropUrban_i \right]$$





Other controls, errors

- Fixed effects for:
  - Origin state (captures unobserved heterogeneity—constant within each state over time)
  - Destination state (likewise)
  - Year (captures unobserved factors common across all counties, but changing over time, …e.g. national-level business cycles)
- Errors clustered on the origin county
  - Reduces statistical significance substantially (state fixed effects do not capture all error components)

Estimating specification

$$\log\left(migration_{ijt}\right) = \log\left(g\left(X_{ijt}\right)\right) + \beta_1 \log\left(Pop_i\right) + \beta_2 \log\left(Pop_j\right) - 2\beta_3 \log\left(distance_{ij}\right) + \varepsilon_{ijt}$$

- Or, expanding the first term:

$$\begin{aligned}\log\left(migration_{ijt}\right) = {} & \beta_0 + \sum_{k=1}^{10} \beta_{4k} weather_{kit} \\ & + \beta_4 \left[PropUrban_j - PropUrban_i\right] \\ & + \sum_{k=1}^{10} \beta_{5k} \left(weather_{kit} \times \left[PropUrban_j - PropUrban_i\right]\right) \\ & + \beta_6 originStateFE + \beta_7 destStateFE + \beta_8 timeFE \\ & + \beta_1 \log\left(Pop_i\right) + \beta_2 \log\left(Pop_j\right) - 2\beta_3 \log\left(distance_{ij}\right) + \varepsilon_{ijt}\end{aligned}$$

- Key derivative:

$$\frac{\partial E\left[\log\left(migration_{ijt}\right)\right]}{\partial\left(weather_{kit}\right)} = \beta_{4k} + \beta_{5k}\left[PropUrban_j - PropUrban_i\right]$$

Interpretation of Derivatives

$$\frac{\partial E\left[\log\left(migration_{ijt}\right)\right]}{\partial\left(weather_{kit}\right)} = \beta_{4k} + \beta_{5k}\left[PropUrban_j - PropUrban_i\right]$$

Effect on

[*expected log migration flow* between counties in period t]

of

[a *one-unit increase in extreme weather type k*

in the origin county in time period t]

- Depends on two parameters and the relative proportion urbanized of the destination versus origin counties
- If key coefficient is positive: Effect of extreme weather on the flow is greater as the destination is relatively more urbanized than the origin

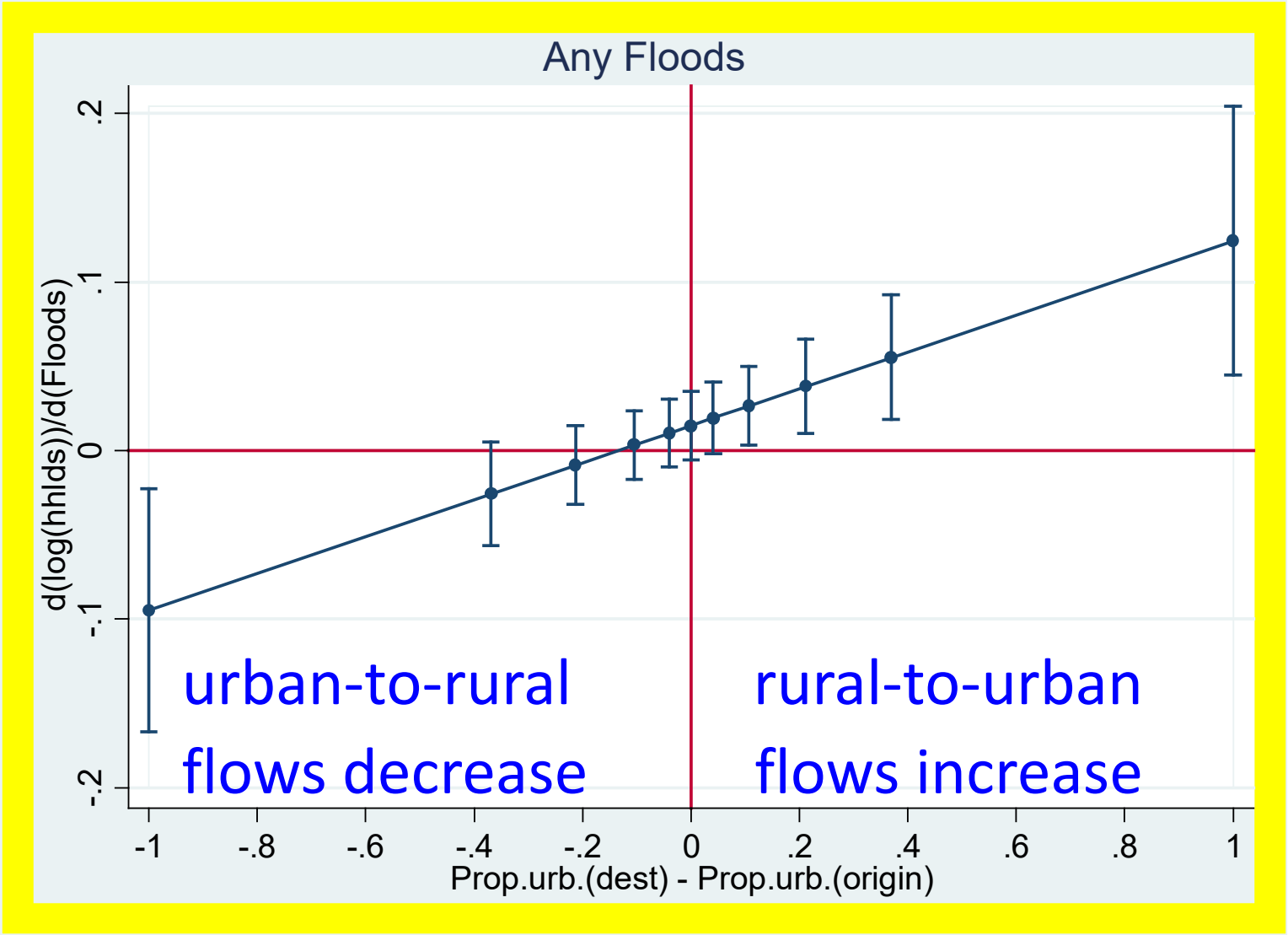
Summarizing Results?

- 7 candidate measures of impact?
  - 7 basic models, each with 10 types of weather
  - 10 derivatives for each model = 70 derivatives
- Summarize evidence using graphs which show these derivatives as a function of the urbanization differential:

$$\frac{\partial E\left[\log\left(migration_{ijt}\right)\right]}{\partial\left(weather_{kit}\right)} = \beta_{4k} + \beta_{5k}\left[PropUrban_j - PropUrban_i\right]$$

- Linear function: positive slope supports relatively more "rural to urban" than "urban-to-rural" migration due to severe weather

$$\frac{\partial E\left[\log\left(migration_{ijt}\right)\right]}{\partial\left(Any\ Floods?_{kit}\right)}$$ = f(relative urbanization)



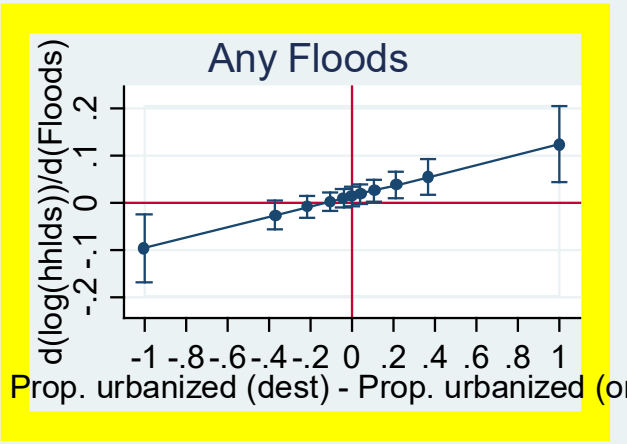
Coming up? Many graphs

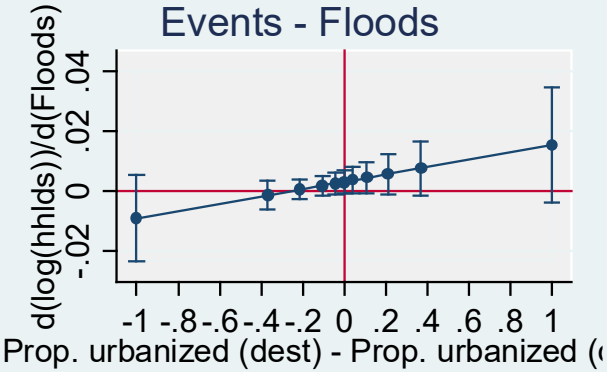
- Each page shows:
  - One type of weather hazard
  - Seven graphs = effect of a different measure of the weather hazard on migration flows, as a function of the relative urbanization of the destination
  - Yellow or gold frame? Derivative is nonzero for *at least some decile* of "relative urbanization"
  - No frame? Zero derivative *not rejected* at any decile
  - For a given measure of a weather shock, if there is:
    - "Rural to Urban" migration dominant= line will slope up
    - "Urban to Rural" migration dominant= line will slope down

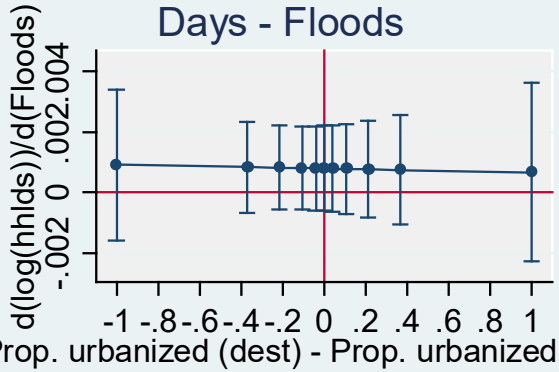
Floods

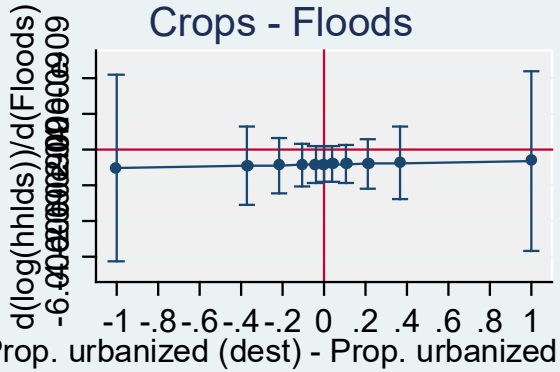
Floods: -**Any flooding?** Little effect between *equally* urbanized counties; increased flow to more-urbanized counties, decreased flow to less urbanized counties

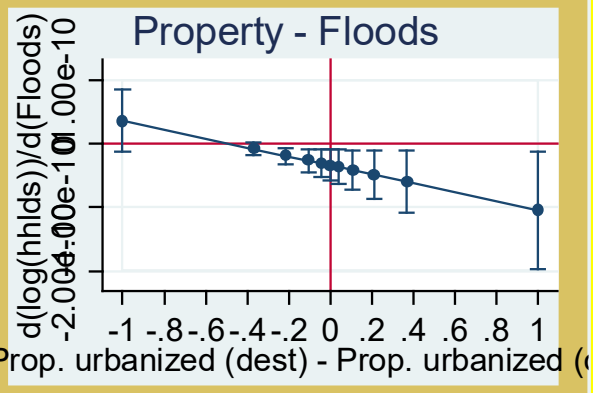
- **Injuries, Fatalities**: similar
- **Property damage**? Less migration (assets gone?)

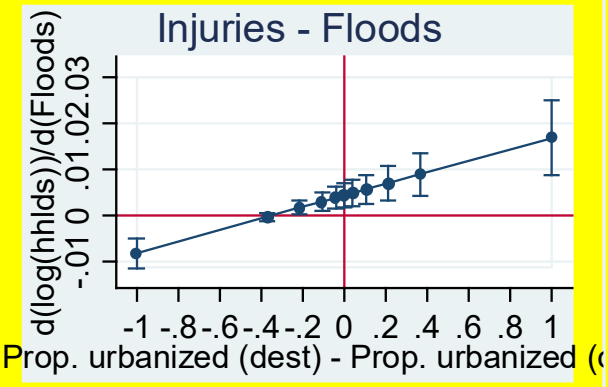


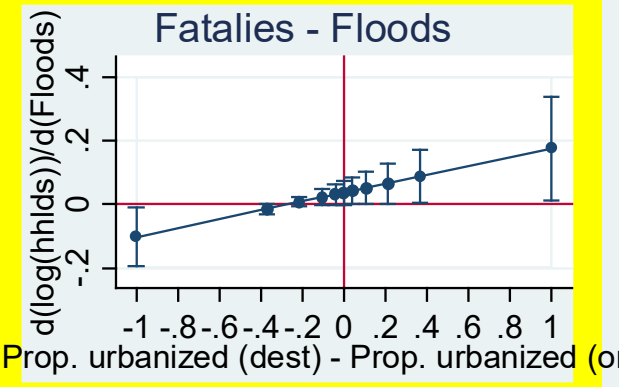










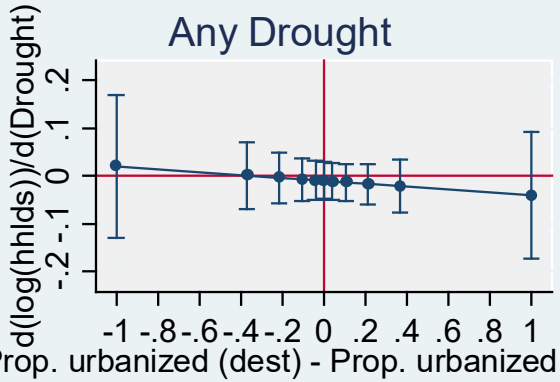


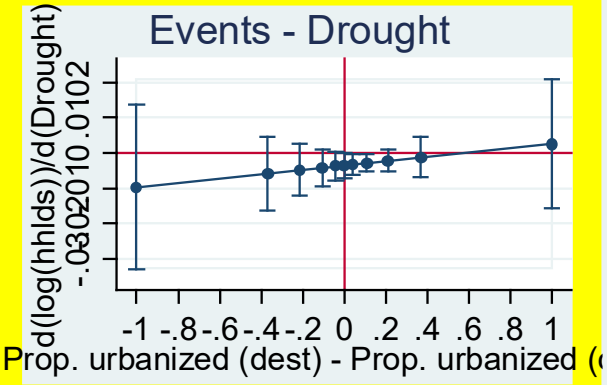
Drought

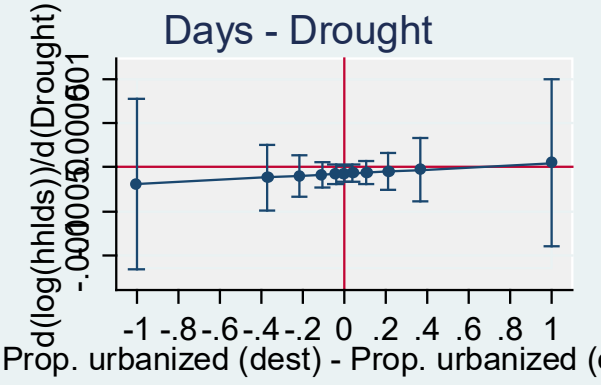
Drought:

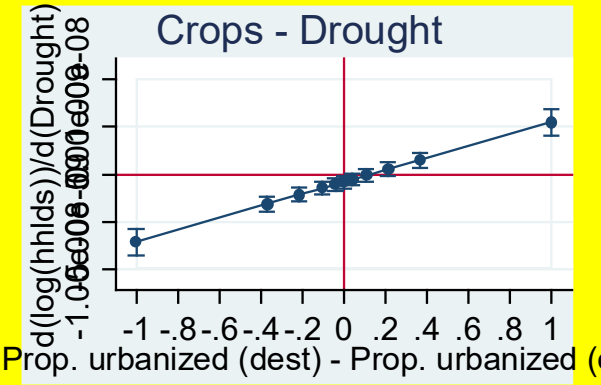
- Events, Crop Damage, Property Damage: Perhaps less migration between *equally* urbanized counties; significant rural-to-urban flows

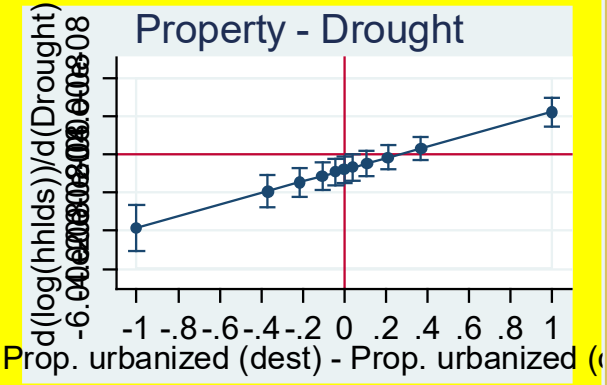
- Injuries: How are *people* injured by drought?

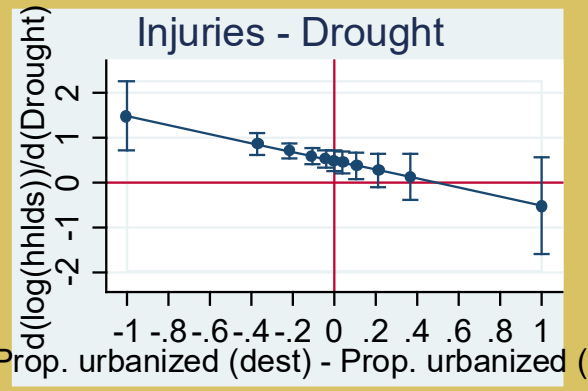










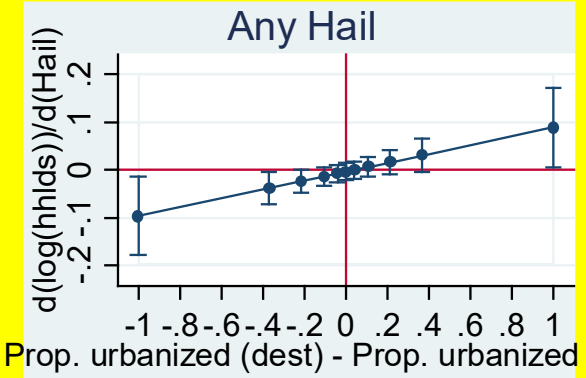


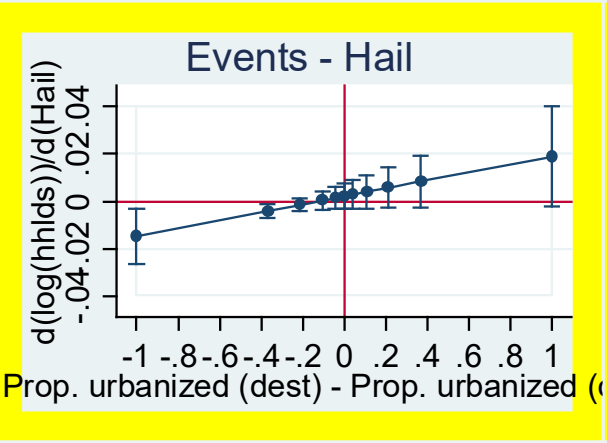
no fatalities

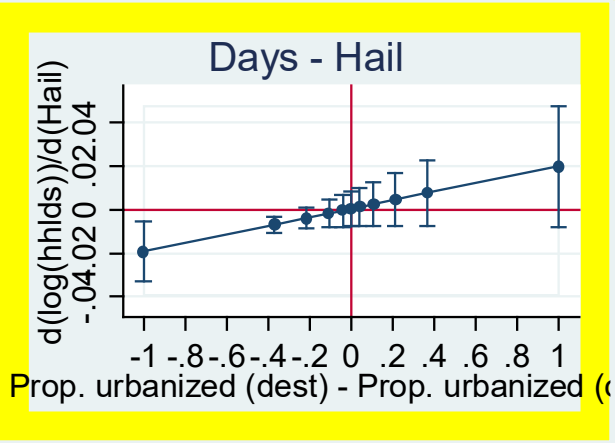
Hail Storms

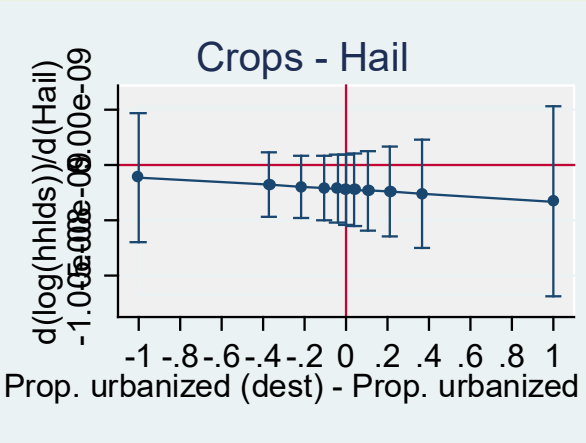
Hail Storms

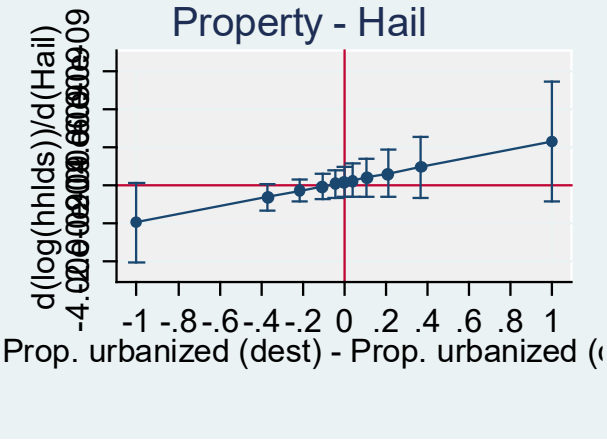
- **Any hail, events, days, fatalities:** Rural-to-urban migration indicated
- **Crop damage, property damage, injuries** – cannot reject zero

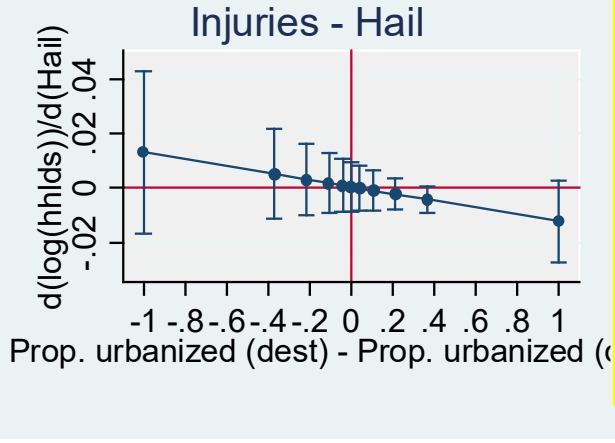


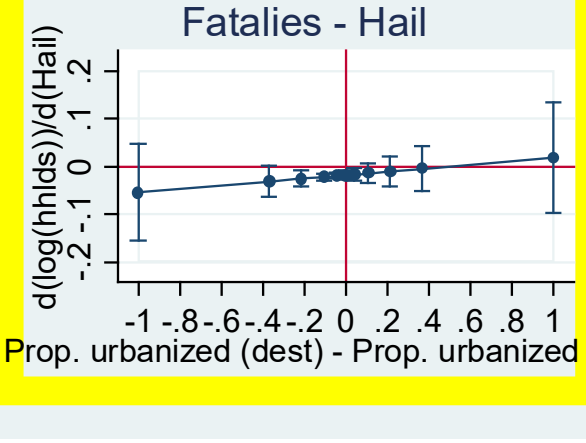








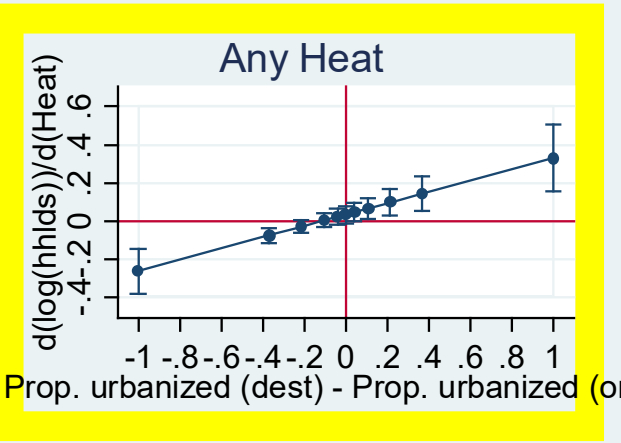


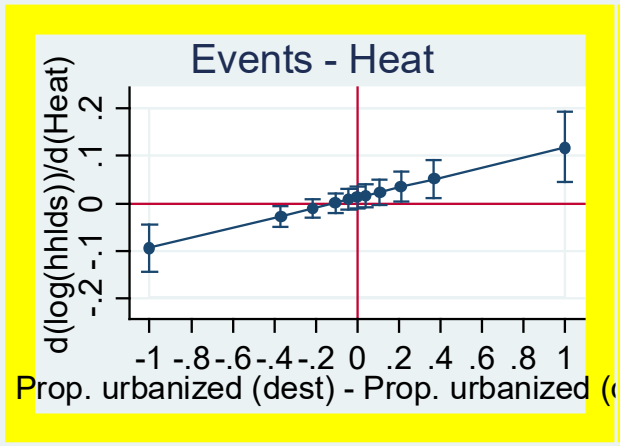


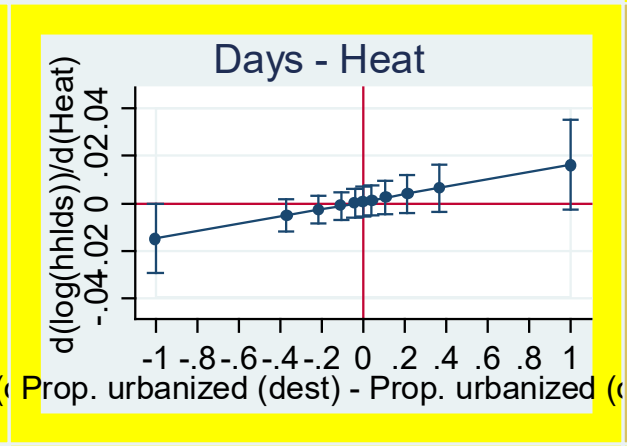
Heat Waves

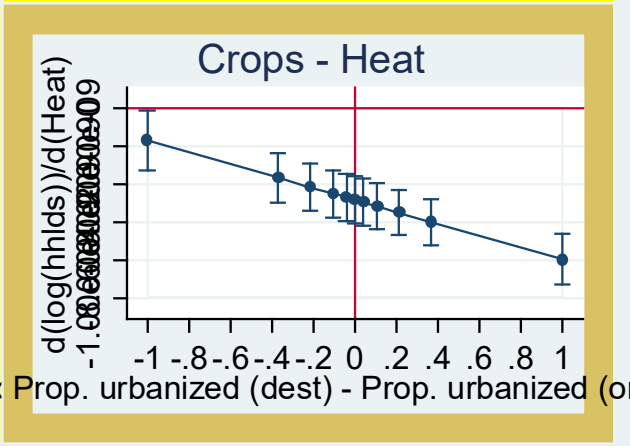
Heat waves

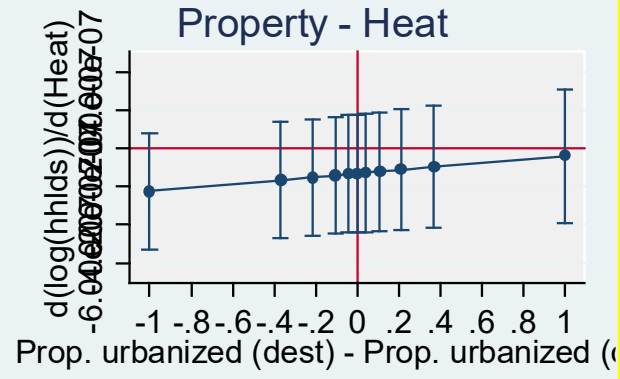
- Rural-to-urban migration dominates
- Not much effect between equally urban counties
- Except **crop damage =** lost assets; (ability to move?)

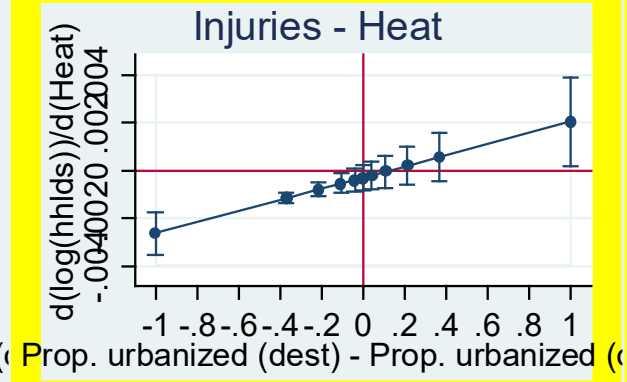


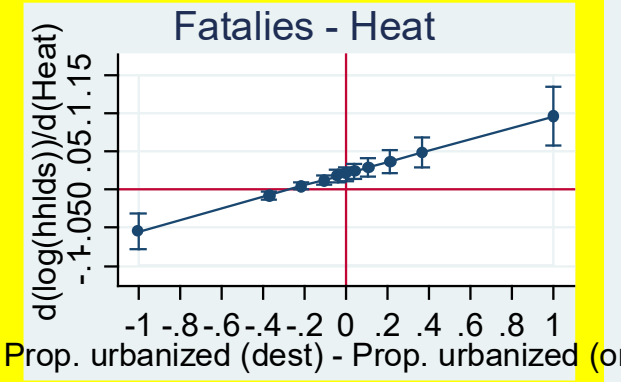








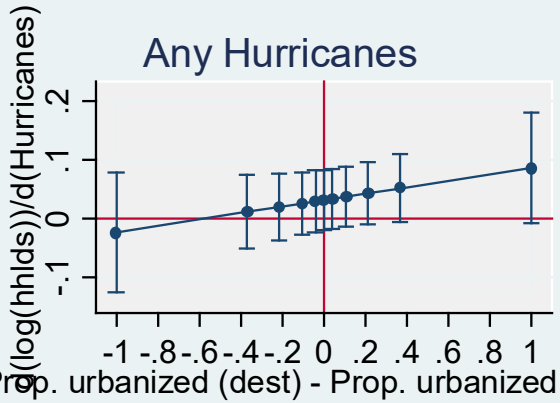


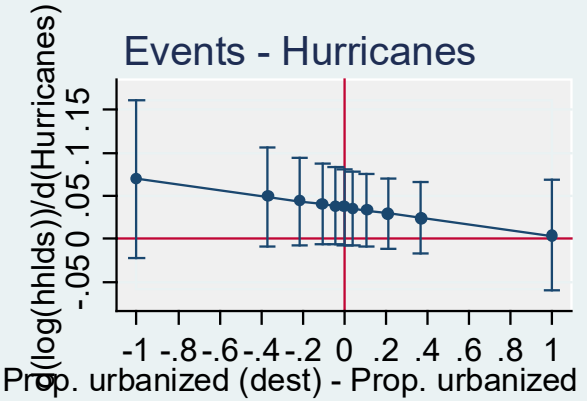


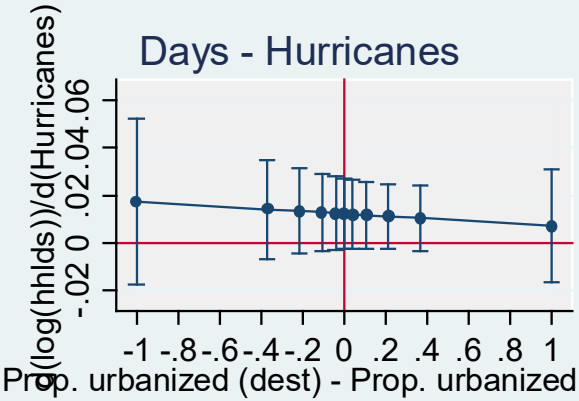
Hurricanes

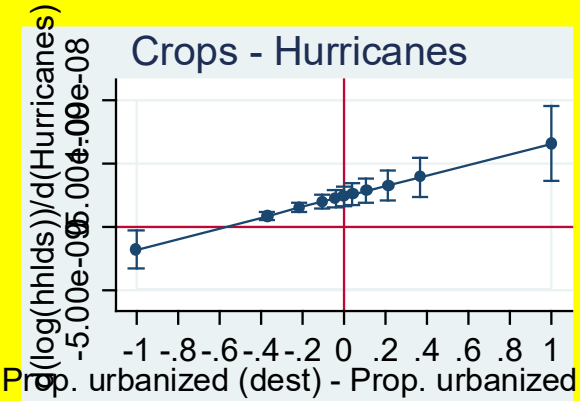
Hurricanes

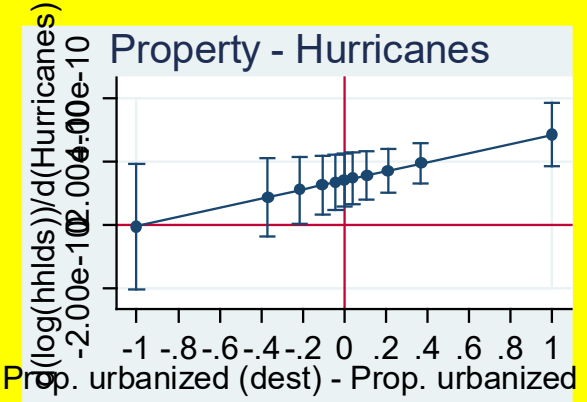
- rural-to-urban migration dominates
- **Property, fatalities;** hurricanes in origin county increase migration at all relative urbanization levels
- interpret with **caution**: relatively few events

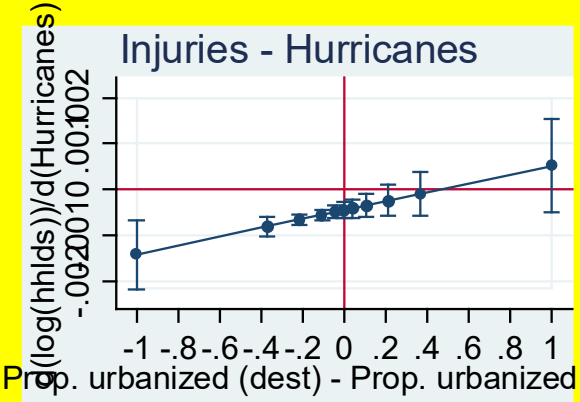


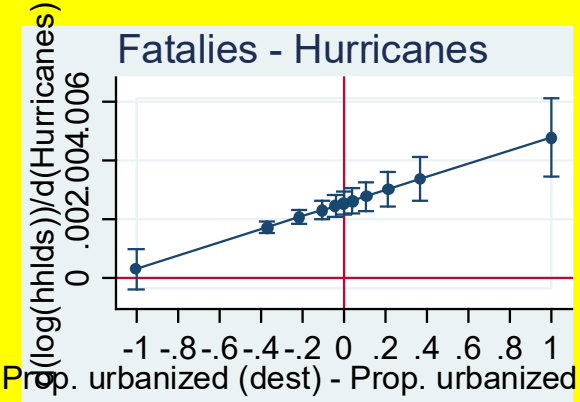








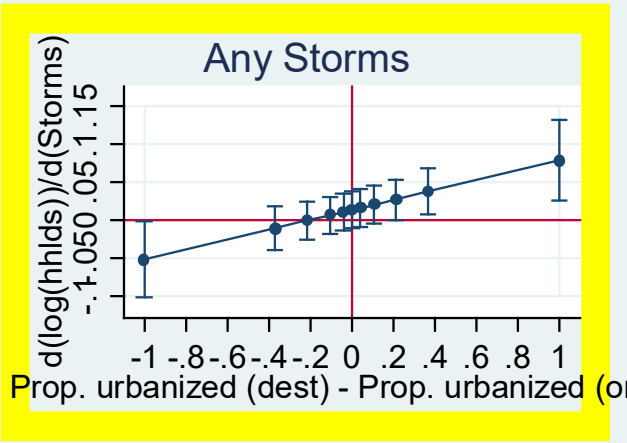


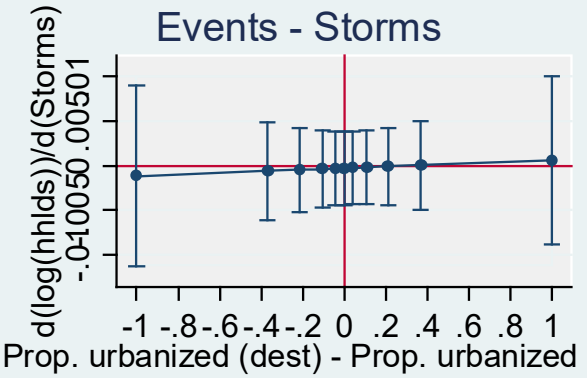


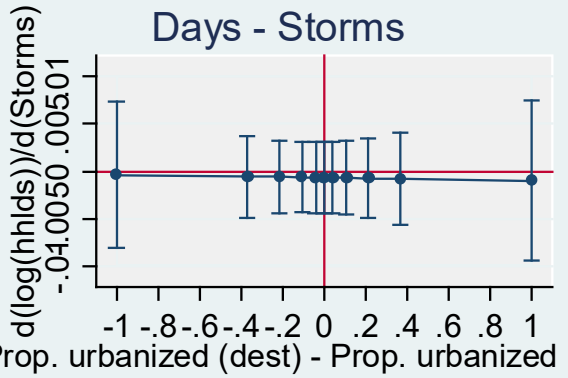
Severe Storms

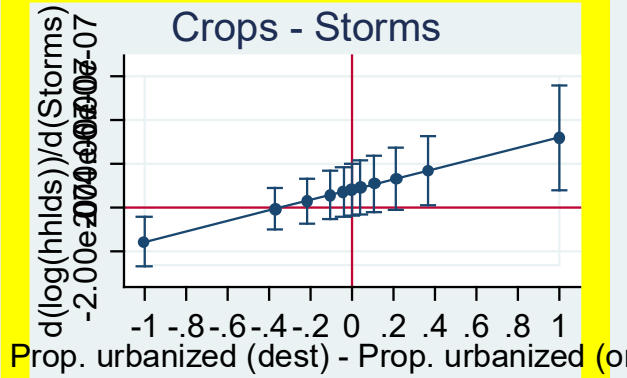
Severe storms

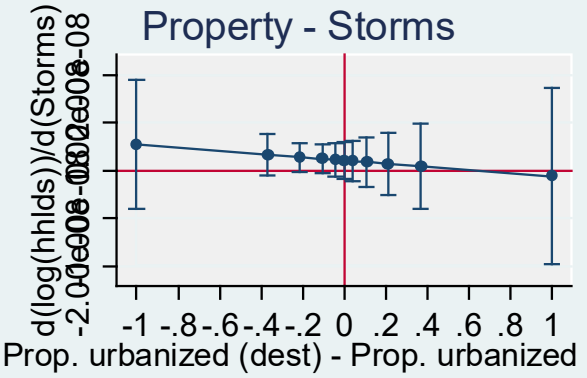
- rural-to-urban migration dominates when the derivatives are non-zero at any decile

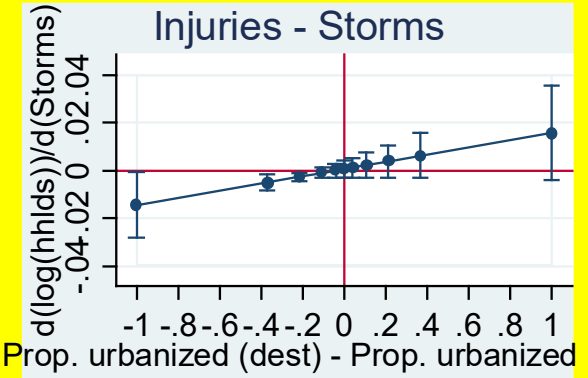


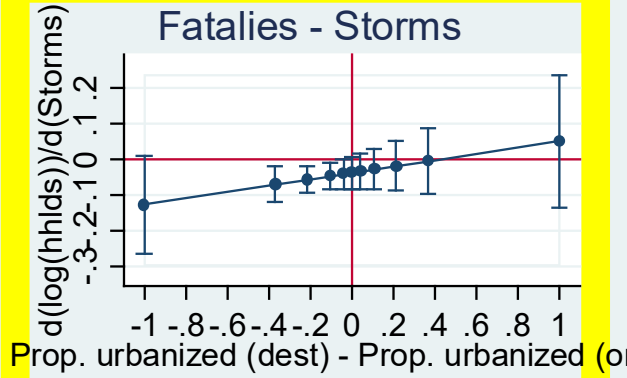








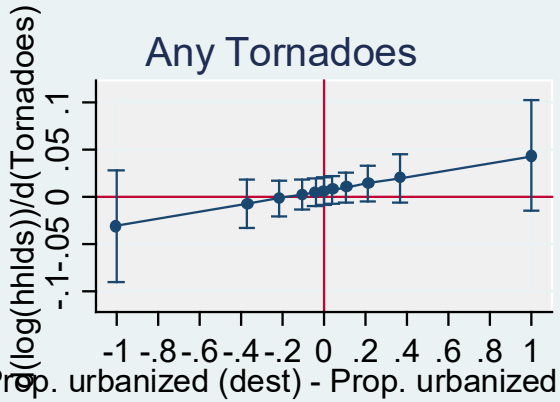


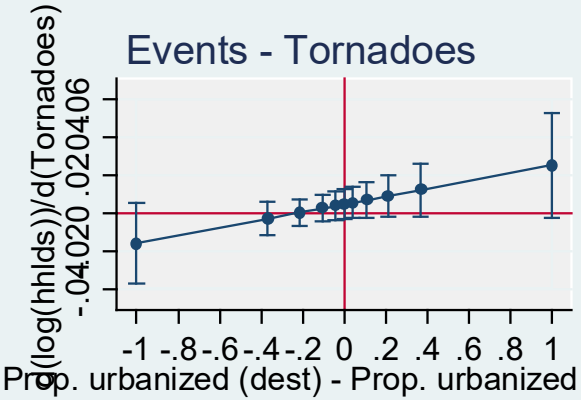


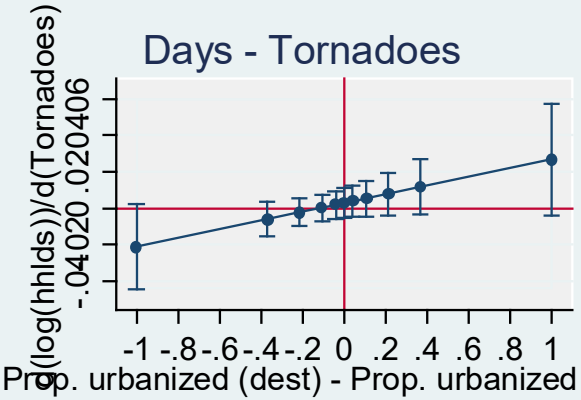
Tornadoes

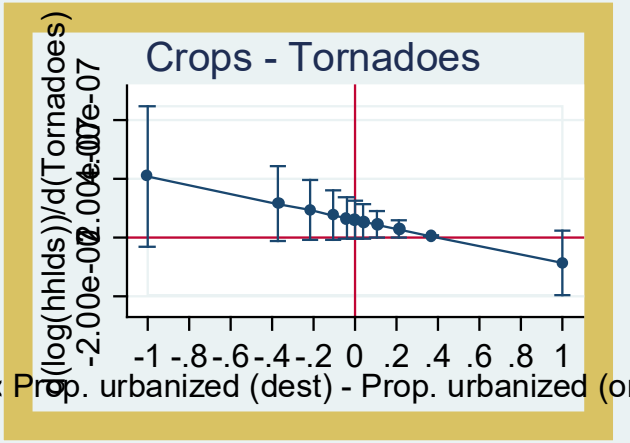
Tornadoes

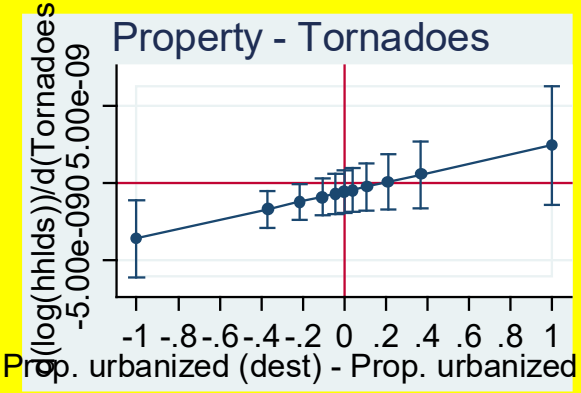
- surgical in their extent; most of county untouched
- **property damage**: urban-to-rural migration decreases
- **crop damage:** increases migration between similarly urbanized counties; may decrease rural-to-urban migration overall (not significant at extremes)

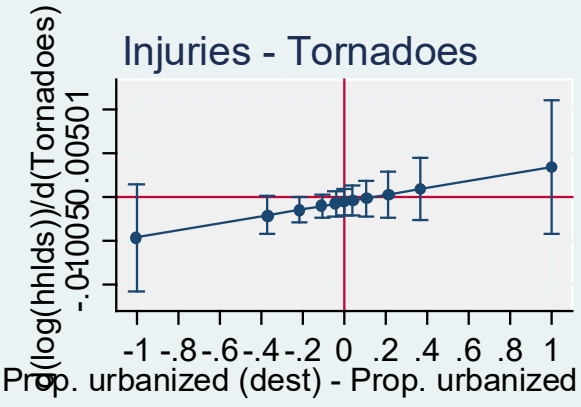


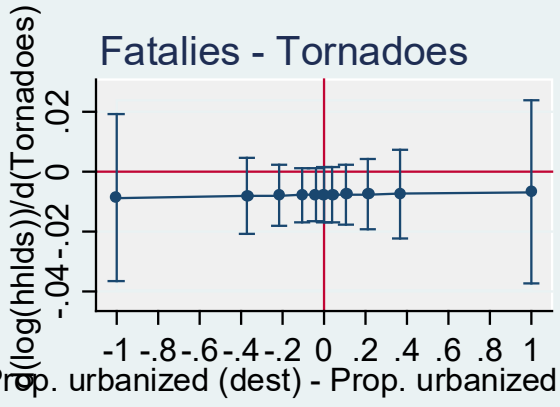








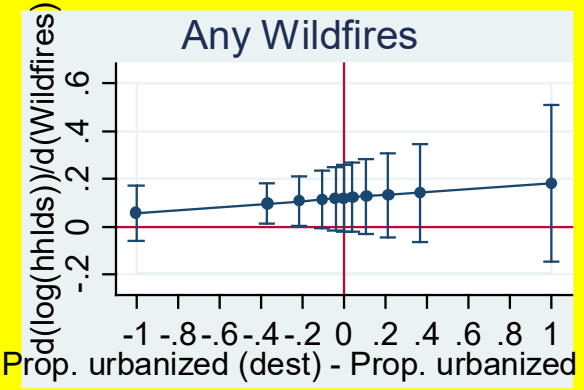


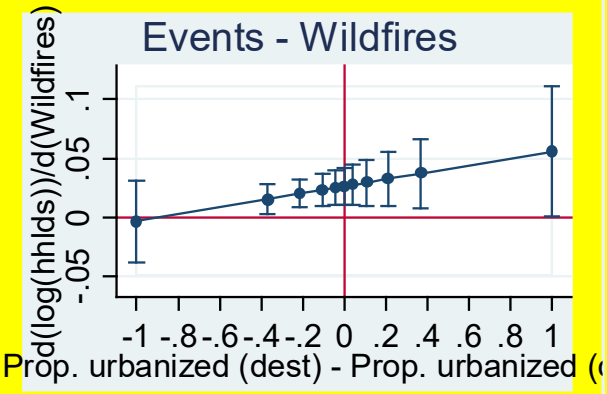


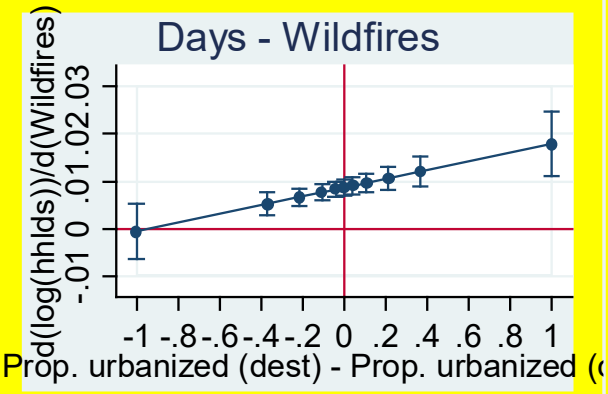
Wildfires

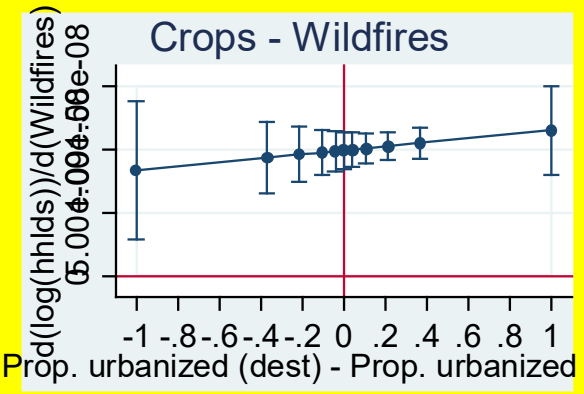
Wildfires

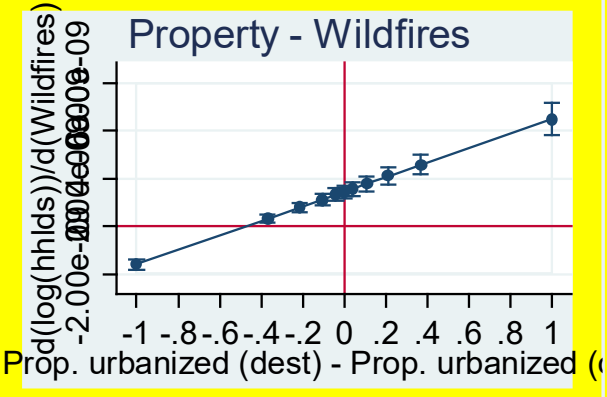
- The **most striking** set of results
- out-migration increases even for equally urbanized county pairs (at x=0)
- rural-to-urban flows dominate

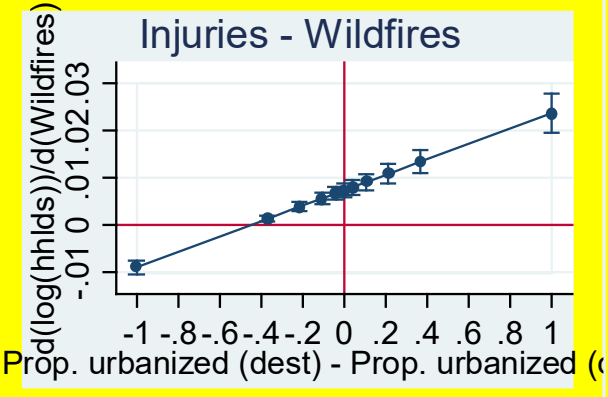


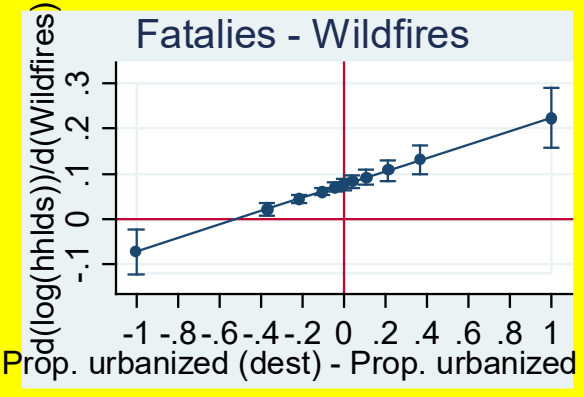








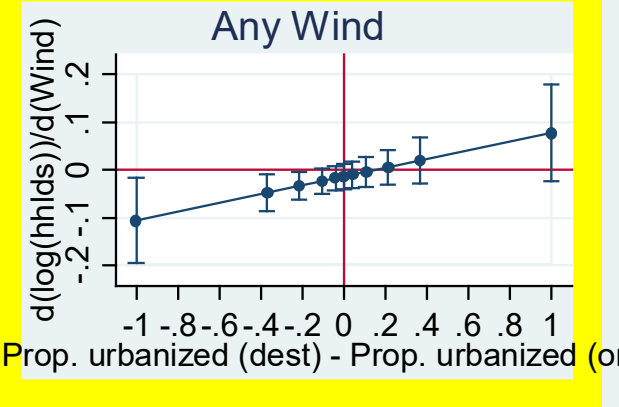


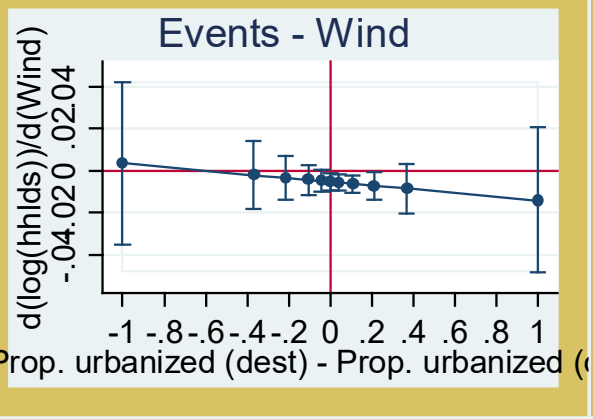


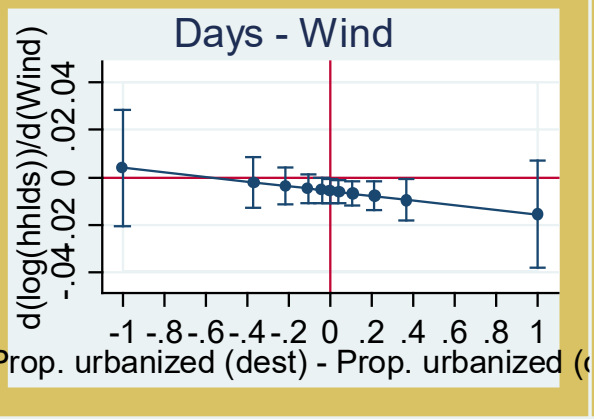
Wind Storms

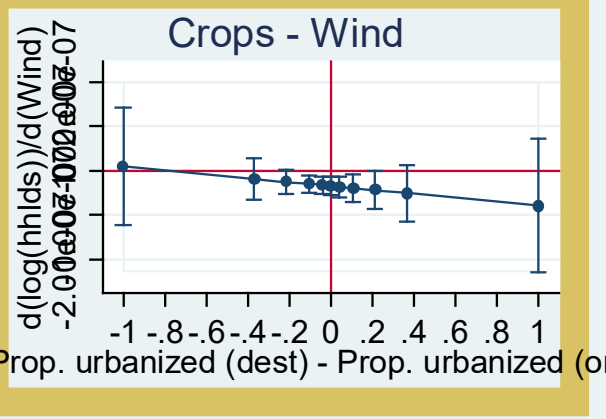
Wind storms

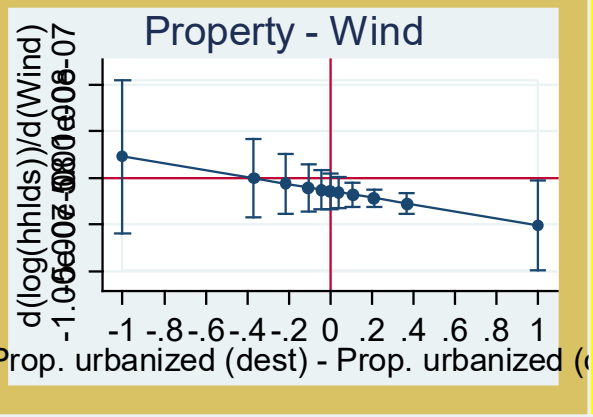
- **events, days, crop damage, property damage**: decreases migration for *equally urbanized* county pairs (around x=0)
- **Any wind, injuries?** May *decrease* urban-to-rural moves, but *not increase* rural-to-urban moves…

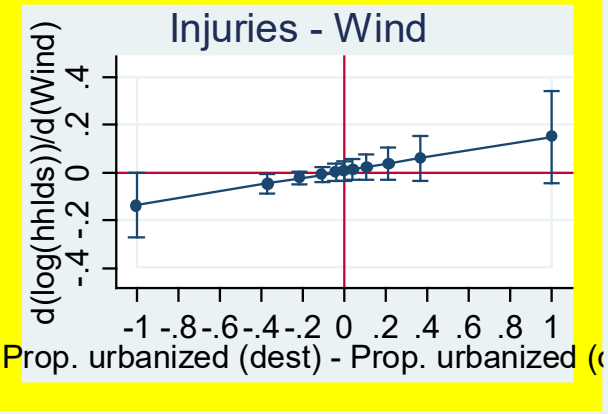


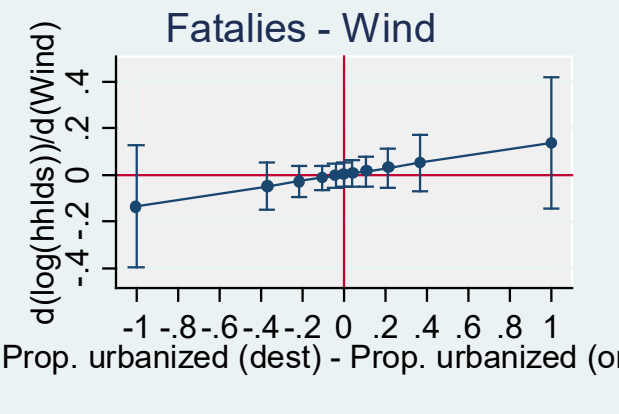








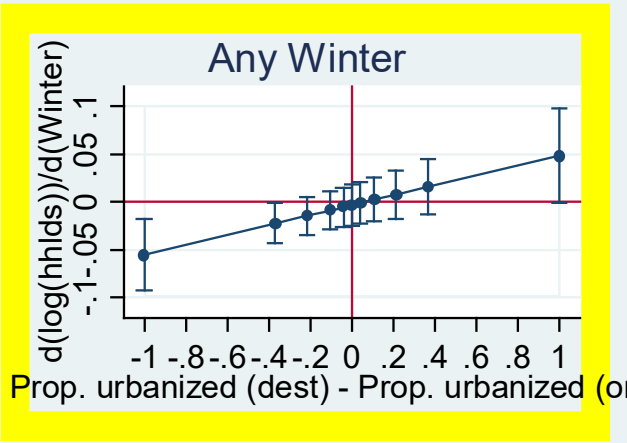


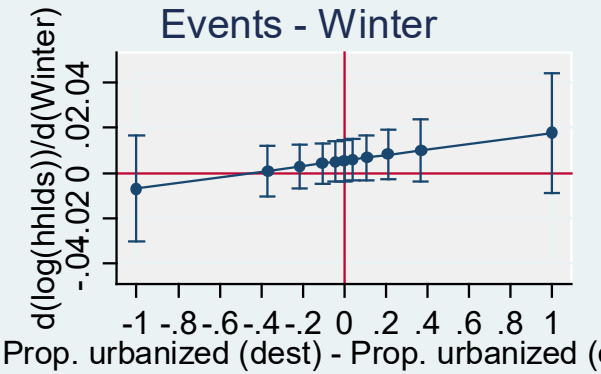


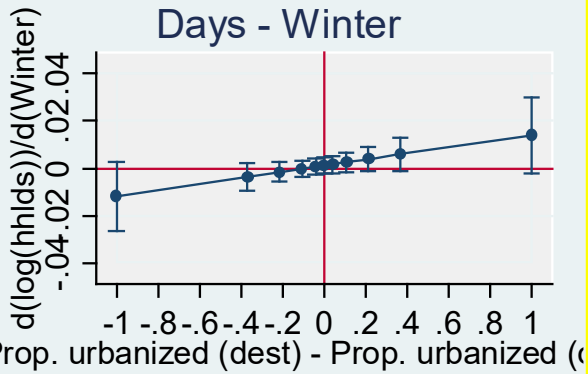

2132
2134
Severe
Winter

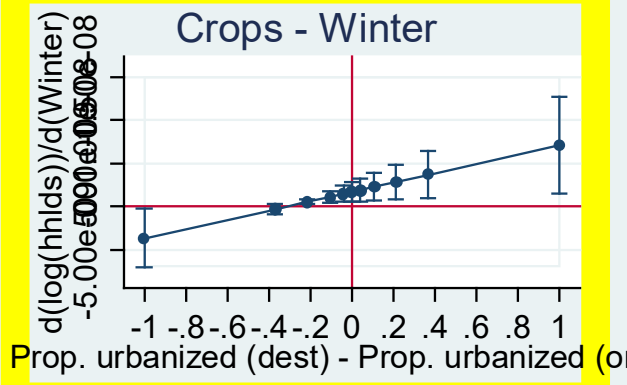
Severe winter weather

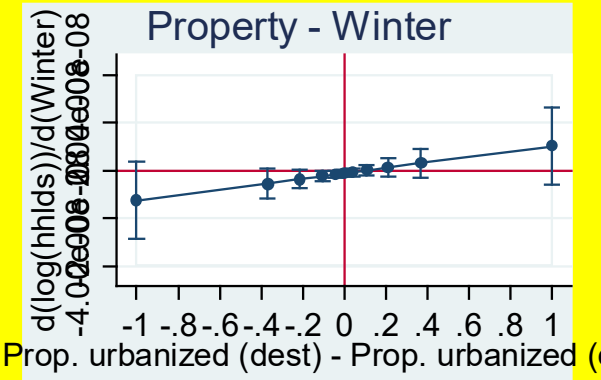
- rural-to-urban pattern dominates

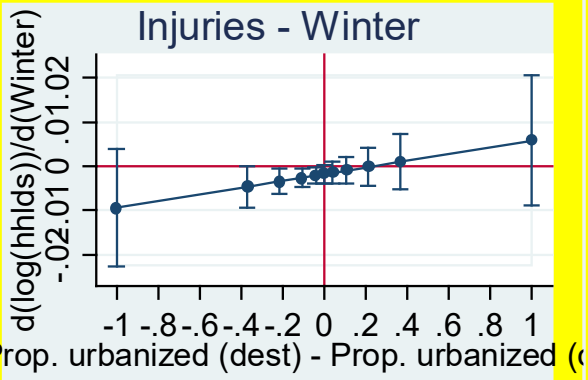


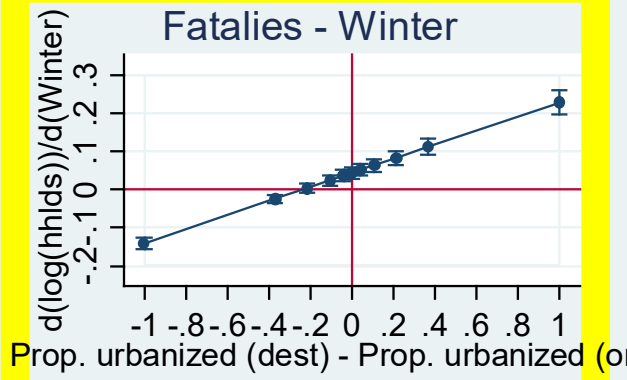












Summary of graphical evidence

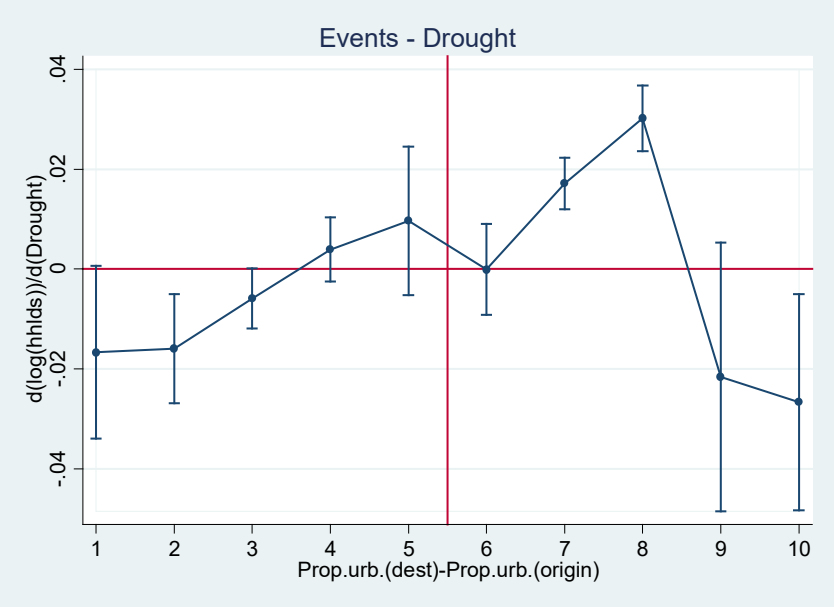
- Substantial evidence for dominance of rural-to-urban migration:
  - Hail storms
  - Hurricanes
  - Severe storms
  - Wildfires***
  - Severe winters
- Mixed evidence:
  - Wind storms
- Rural-to-urban migration increased for all but one measure of weather impact:
  - Floods (except property)
  - Drought (exc. injuries?)
  - Heat (exc. crop damage)
  - Tornadoes (except crop damage)

  [Asset losses may limit migration ability]

Sensitivity Analyses

- Alternative specifications
  - Households (#returns) vs individuals (#exemptions)
  - Log versus linear dependent variable (Loyalty to gravity model? Option to recover <10 flows?)
  - Different assumptions about error distributions (clustered, robust, classical)
  - Additional controls (e.g. poverty rates, proportion of seniors – affects uncounted migration)
  - Relative urbanization nonparametric (decile bins, quintile bins)

Preview: Non-parametric? Decile bins



- Top deciles of urbanization diff. may behave differently
- From extremely rural to extremely urbanized counties.
- Speculate: If drought in origin county harms income/wealth, highly urbanized counties may not be affordable or attractive destinations

Next enhancements…

- Add heterogeneity in the other generalized gravity parameters (coefficients on logs of population and log of distance).
- Increase generalization to reduce error variance
  - Tied to literature on determinants of migration
- Reconsider clustered vs. robust errors
  - Disconcerting that robust CIs are much narrower than errors clustered at origin-state levels

Overall?

- Even in the U.S., extreme weather tends to
  - Increase rural-to-urban migration, and/or
  - Decrease urban-to-rural migration
  - Except in cases where there has likely been substantial losses to real assets
- U.S. housing, livelihoods, infrastructure relatively resilient to extreme weather
- With similar data and models for many developing countries, would expect to see even greater effects

End of Presentation

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End of Presentation

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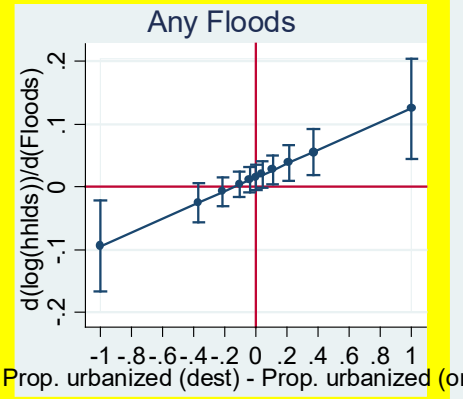
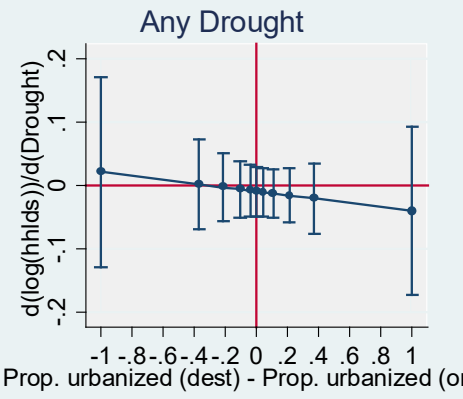
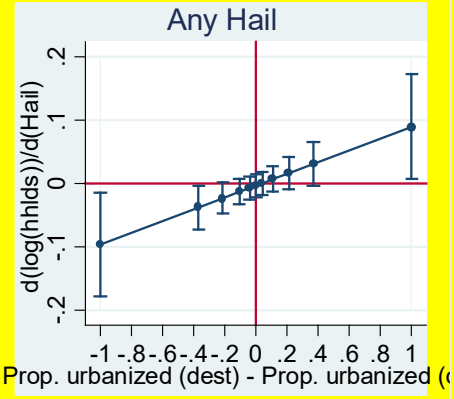
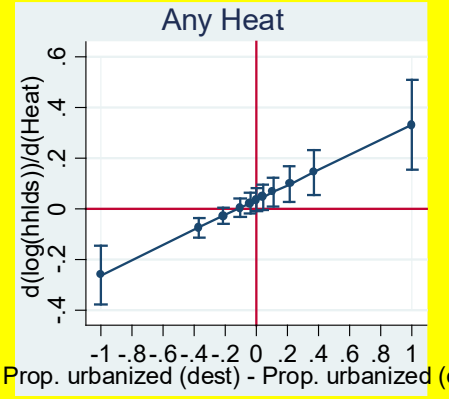
Measure: Any events?

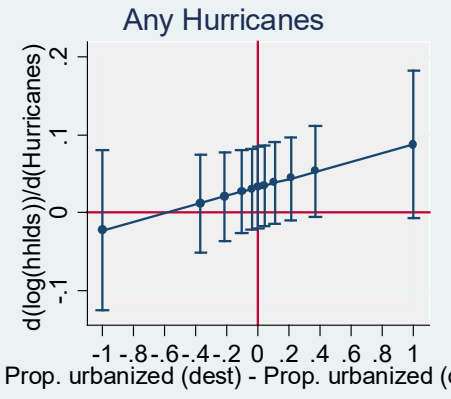
- Floods, Hail, Heat, Storms, Wildfires, Wind, Winter Weather
- Increase flows from rural to urban
- Decrease flows from urban to rural

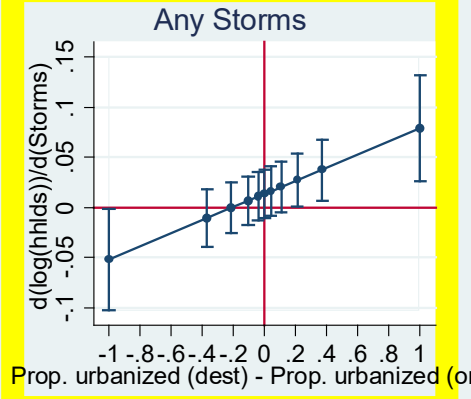


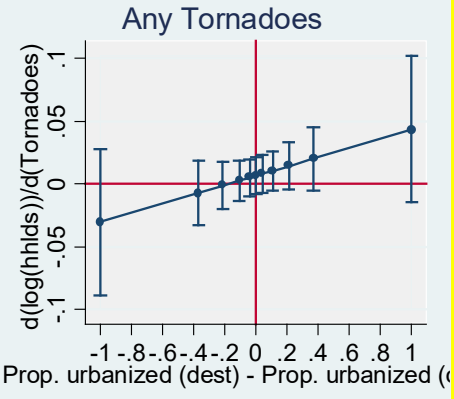


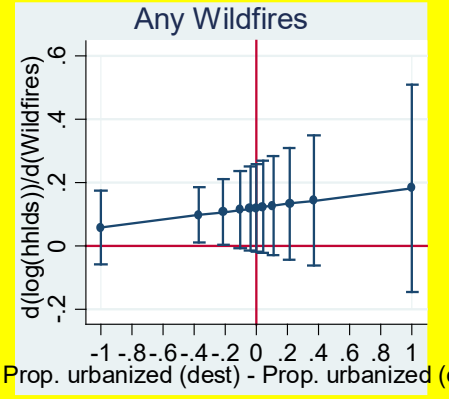


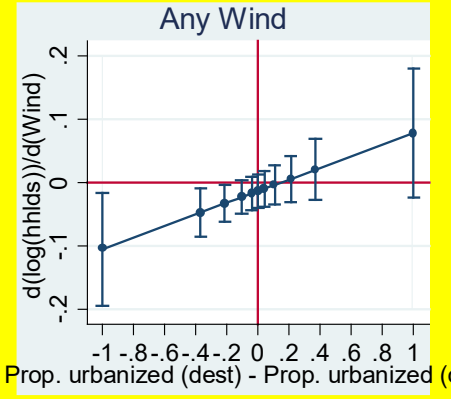


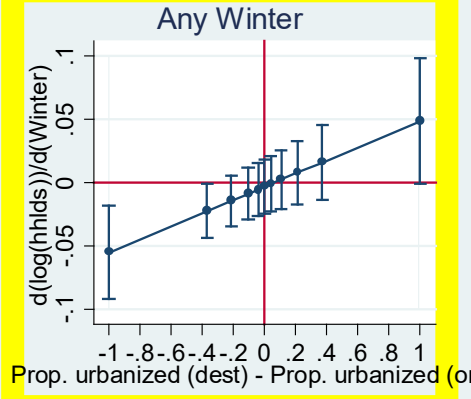


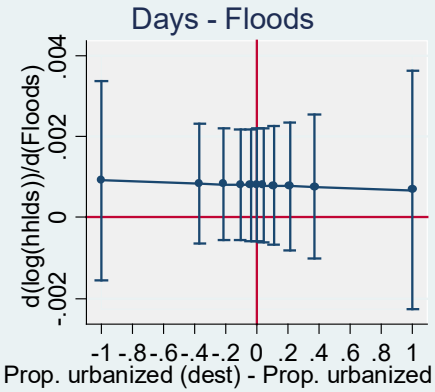


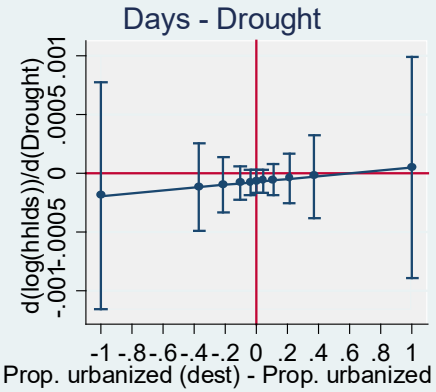


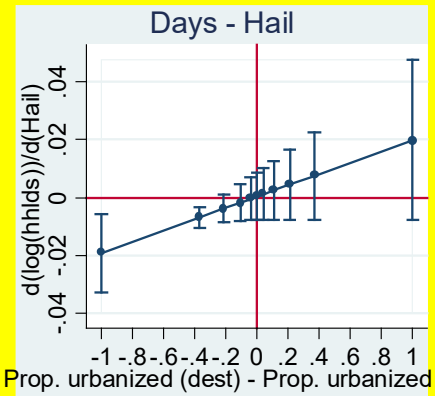


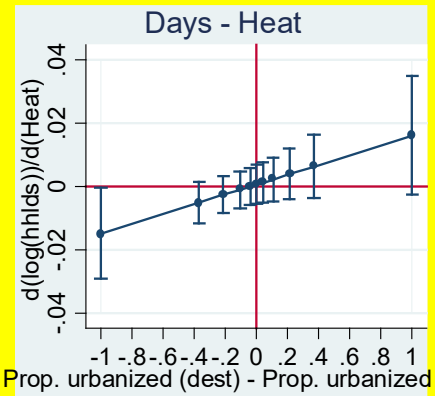


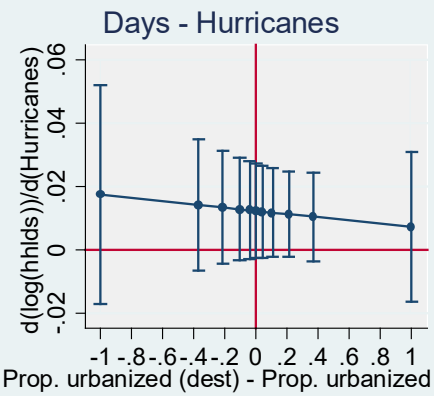


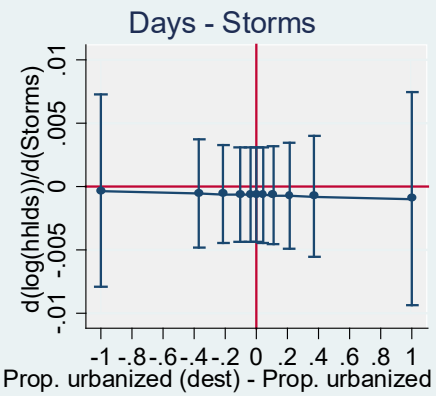

Days - Floods
d(log(hhlds))/d(Floods)
-.002
0
.002
.004
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (origin)

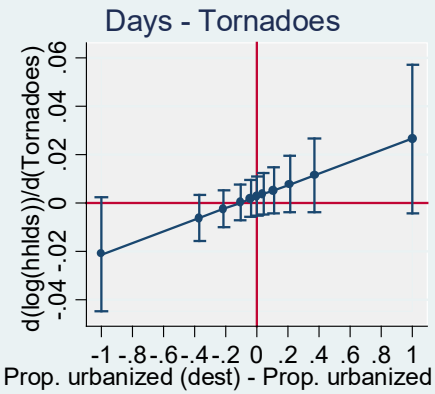

Days - Drought
d(log(hhlds))/d(Drought)
-.001
-.0005
0
.0005
.001
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (origin

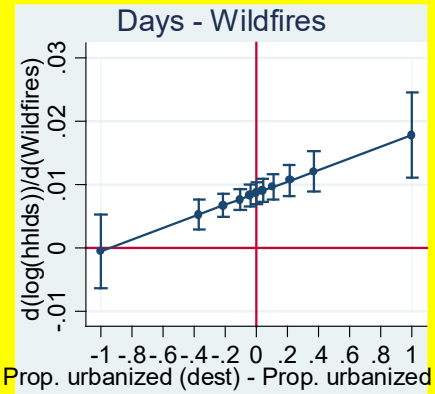

Days - Hail
d(log(hhlds))/d(Hail)
-.04
-.02
0
.02
.04
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (

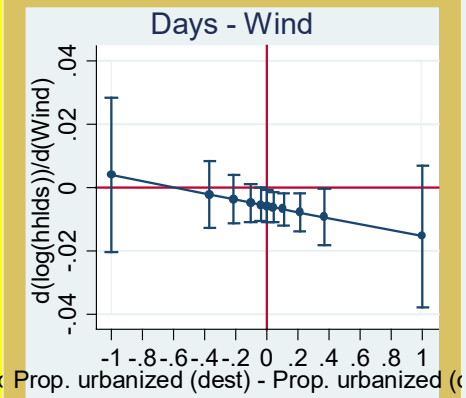

Days - Heat
d(log(hhlds))/d(Heat)
-.04
-.02
0
.02
.04
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (

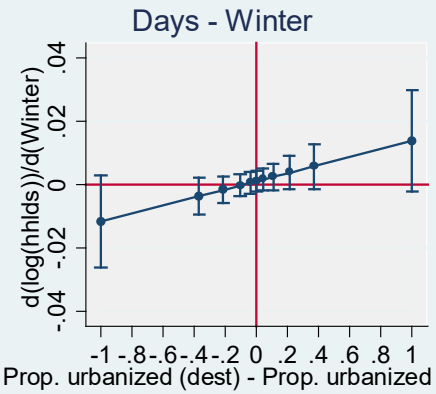

Days - Hurricanes
d(log(hhlds))/d(Hurricanes)
-.02
0
.02
.04
.06
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (


Days - Storms
d(log(hhlds))/d(Storms)
-.01
-.005
0
.005
.01
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (origin


Days - Tornadoes
d(log(hhlds))/d(Tornadoes)
-.04
-.02
0
.02
.04
.06
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (

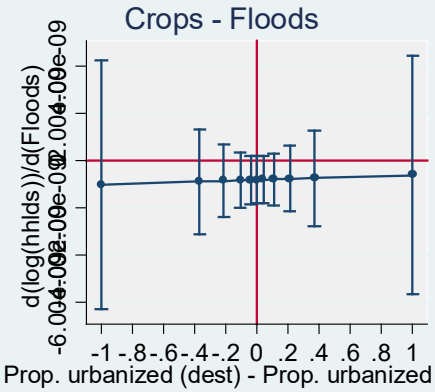

Days - Wildfires
d(log(hhlds))/d(Wildfires)
-.01
0
.01
.02
.03
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (

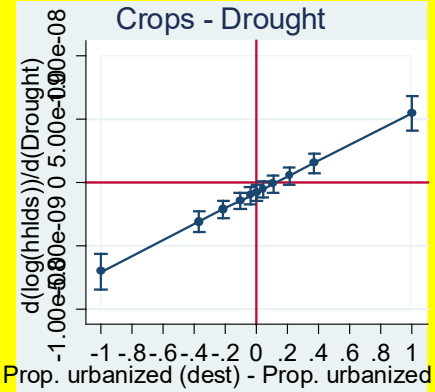

Days - Wind
d(log(hhlds))/d(Wind)
-.04
-.02
0
.02
.04
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (

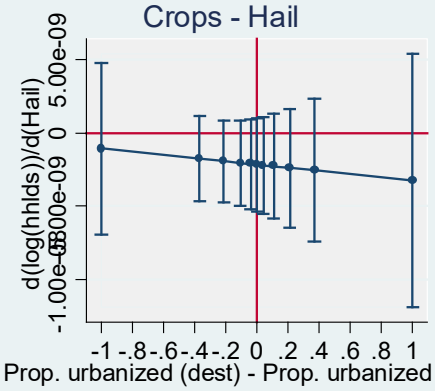

Days - Winter
d(log(hhlds))/d(Winter)
-.04
-.02
0
.02
.04
-1 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1
Prop. urbanized (dest) - Prop. urbanized (origin

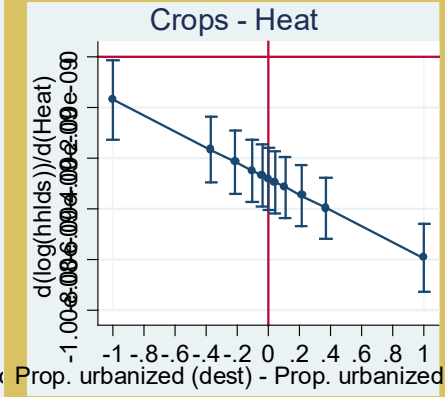
Measure: Crop Damage

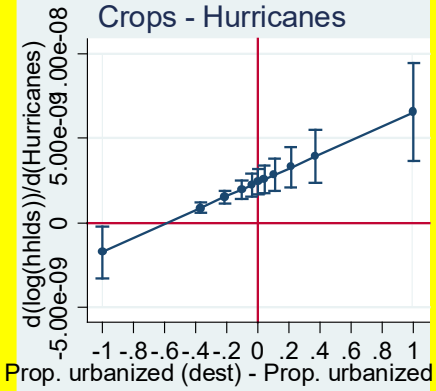
- Drought, Hurricanes, Storms, Wildfires, Winter Weather: Increased flows from rural to urban
- Heat, Tornadoes, Wind: Decreased flows from rural to urban

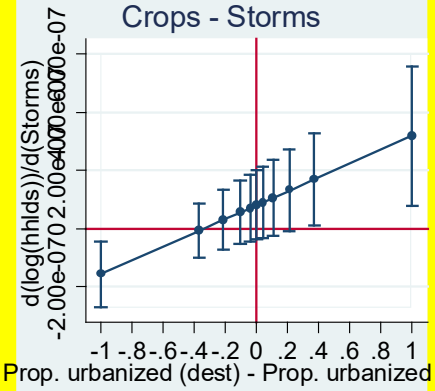


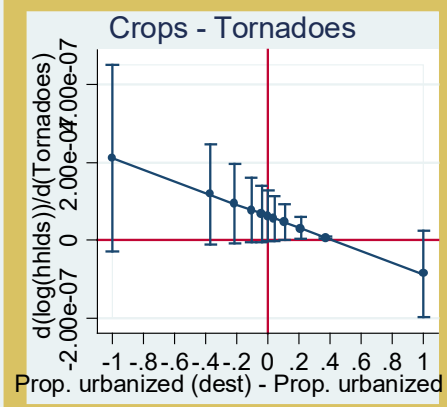


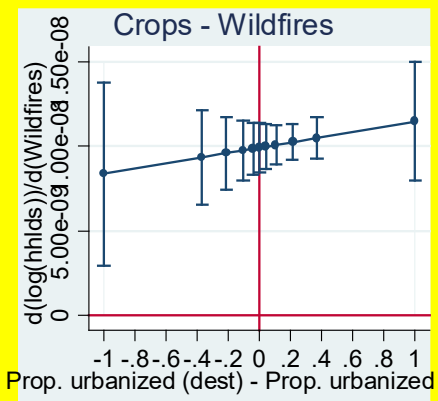


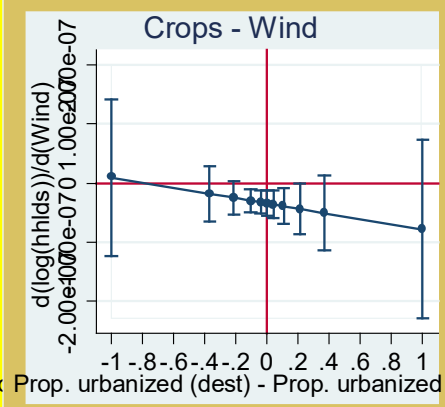


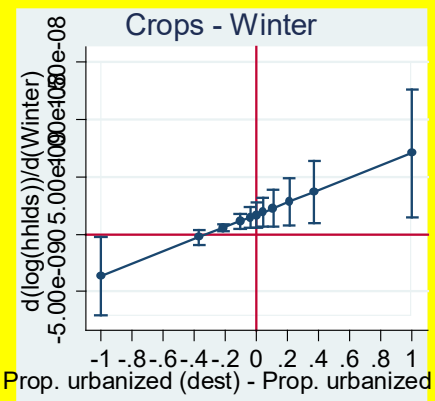






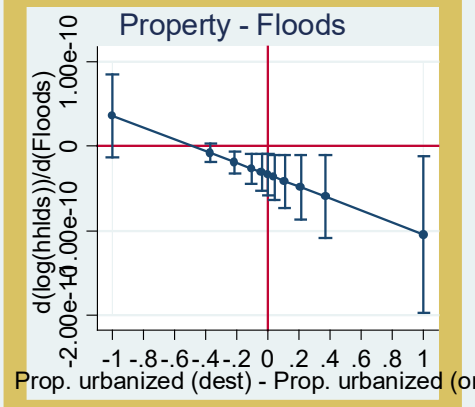


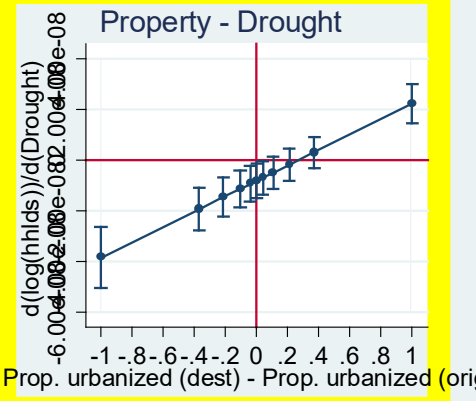


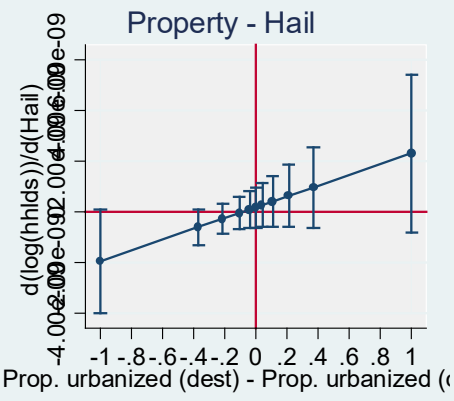


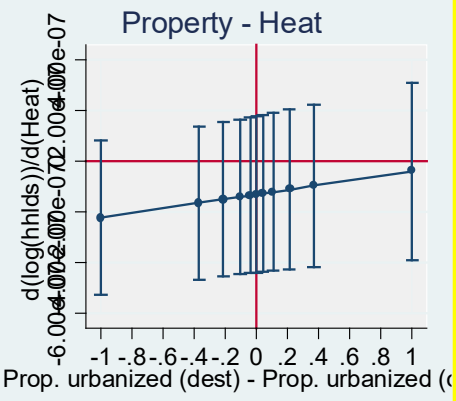
Measure: Property Dmg

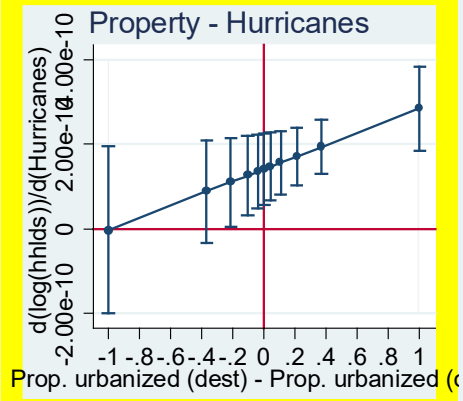
- Drought, Hurricanes, Tornadoes, Wildfires, Winter Weather: Increased flows from rural to urban
- Floods, Wind: Decreased flows from rural to urban

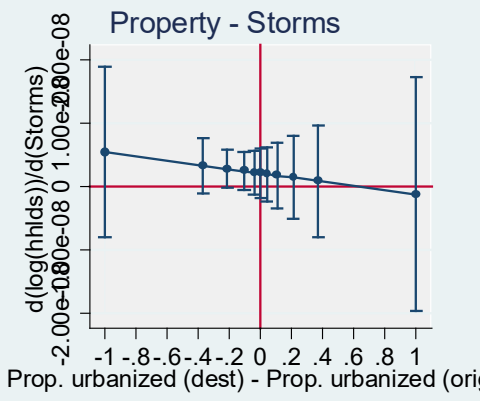


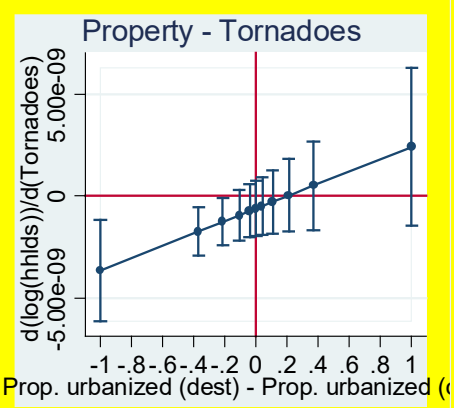


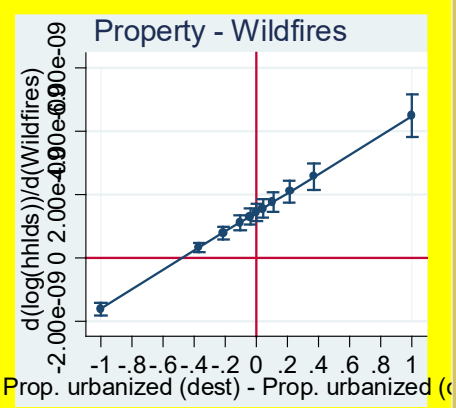


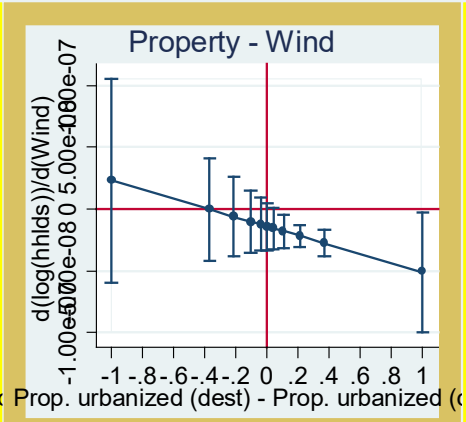


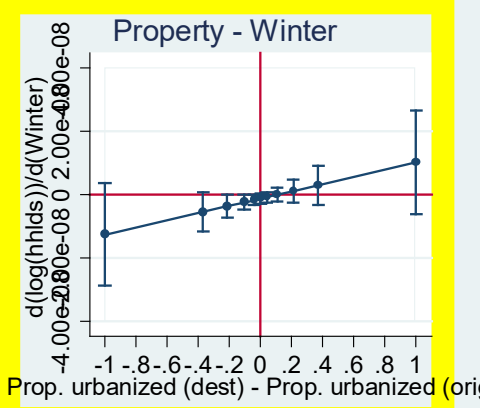






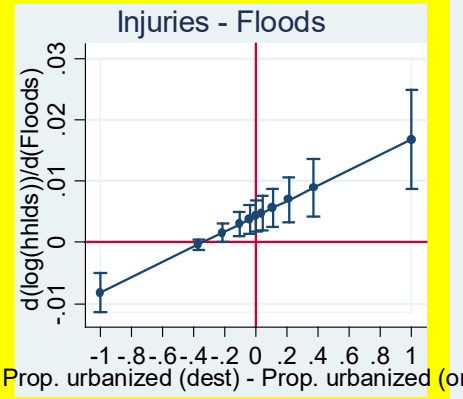


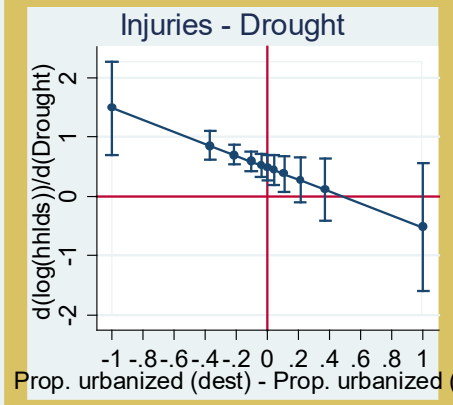


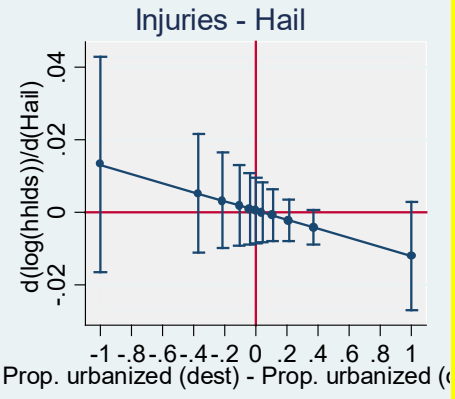


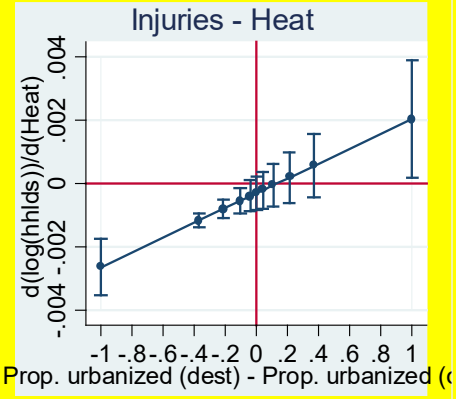
Measure: Injuries

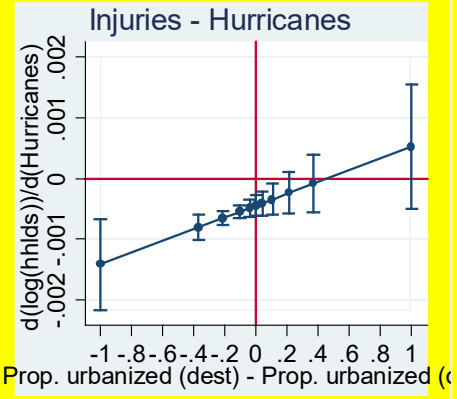
- Floods, Heat, Hurricanes, Storms, Wildfires, Wind, Winter Weather: Increased flows from rural to urban
- Drought: Decreased flows from rural to urban

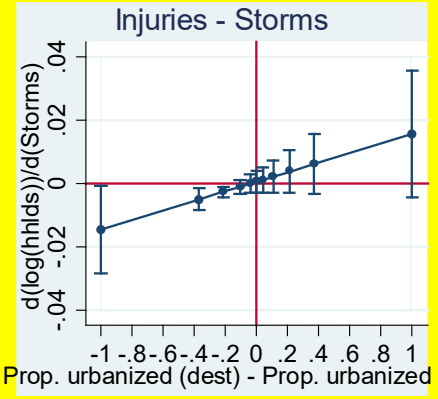


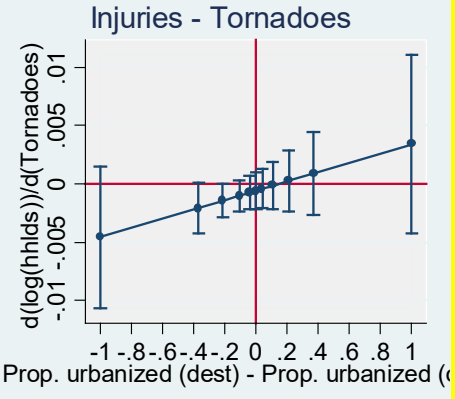


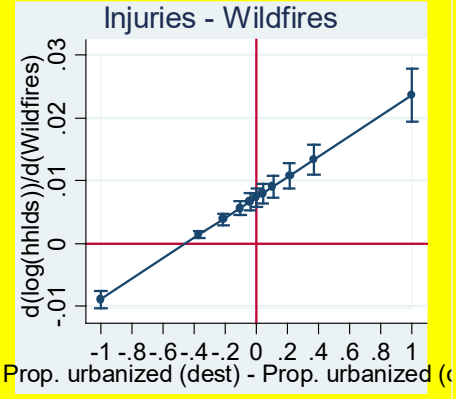


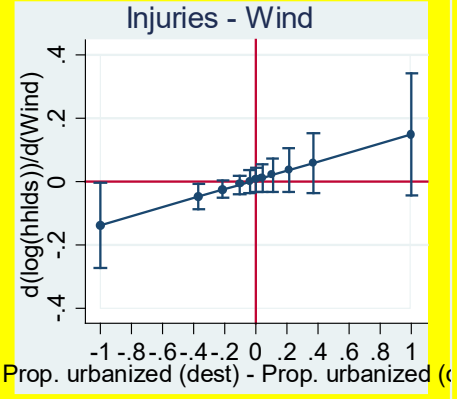


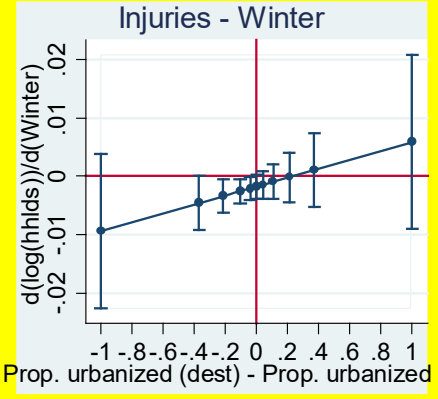








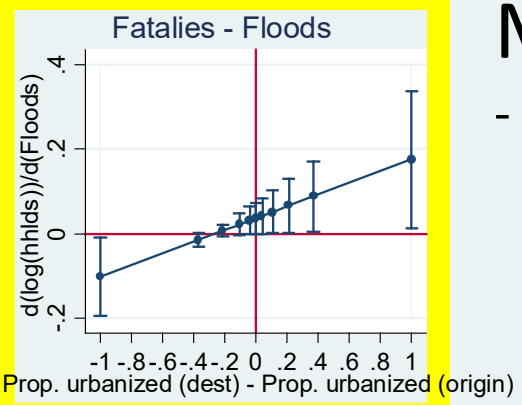


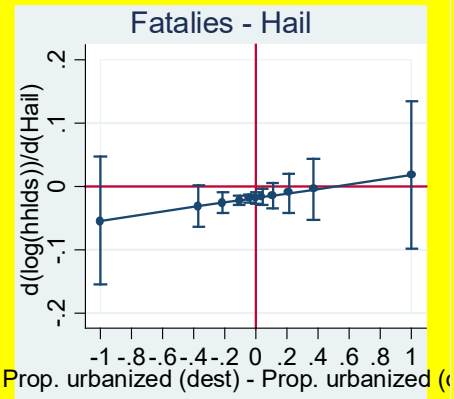


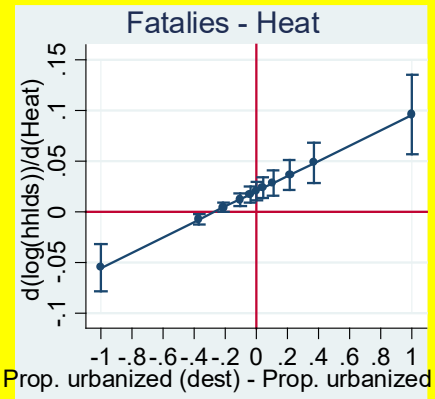
Measure: Fatalities

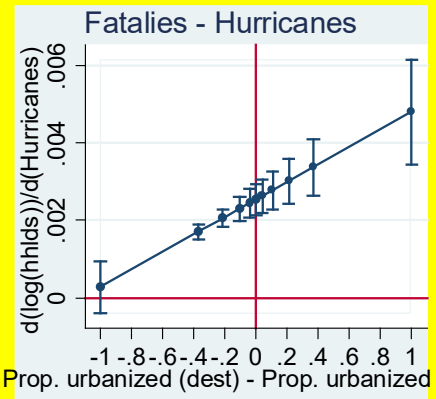
- Floods, Hail, Heat, Hurricanes, Storms, Wildfires, Winter Weather: Increased flows from rural to urban

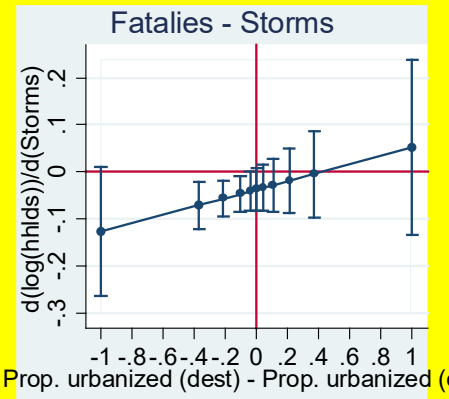
(no drought fatalities)

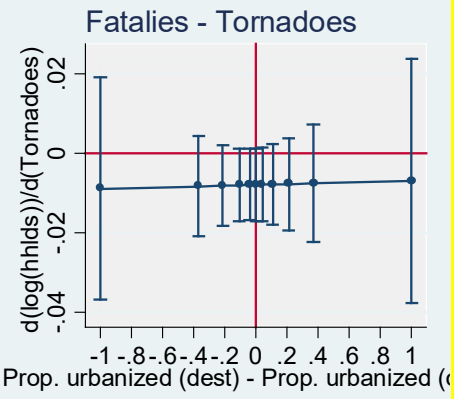


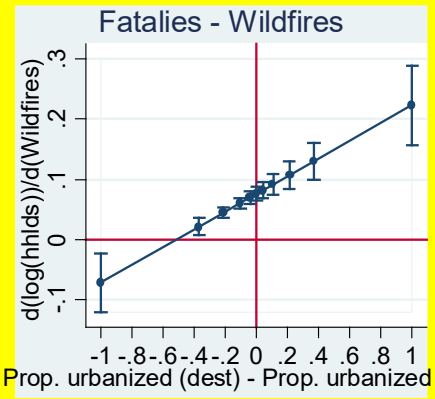


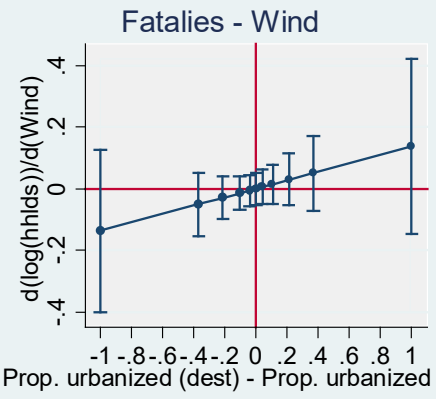


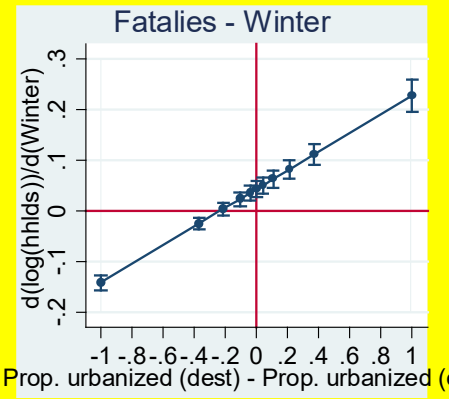












Alternatively

- By type of extreme weather:
  - Consider how many different measures of this type of weather yield derivatives suggesting rural-to-urban migration impacts