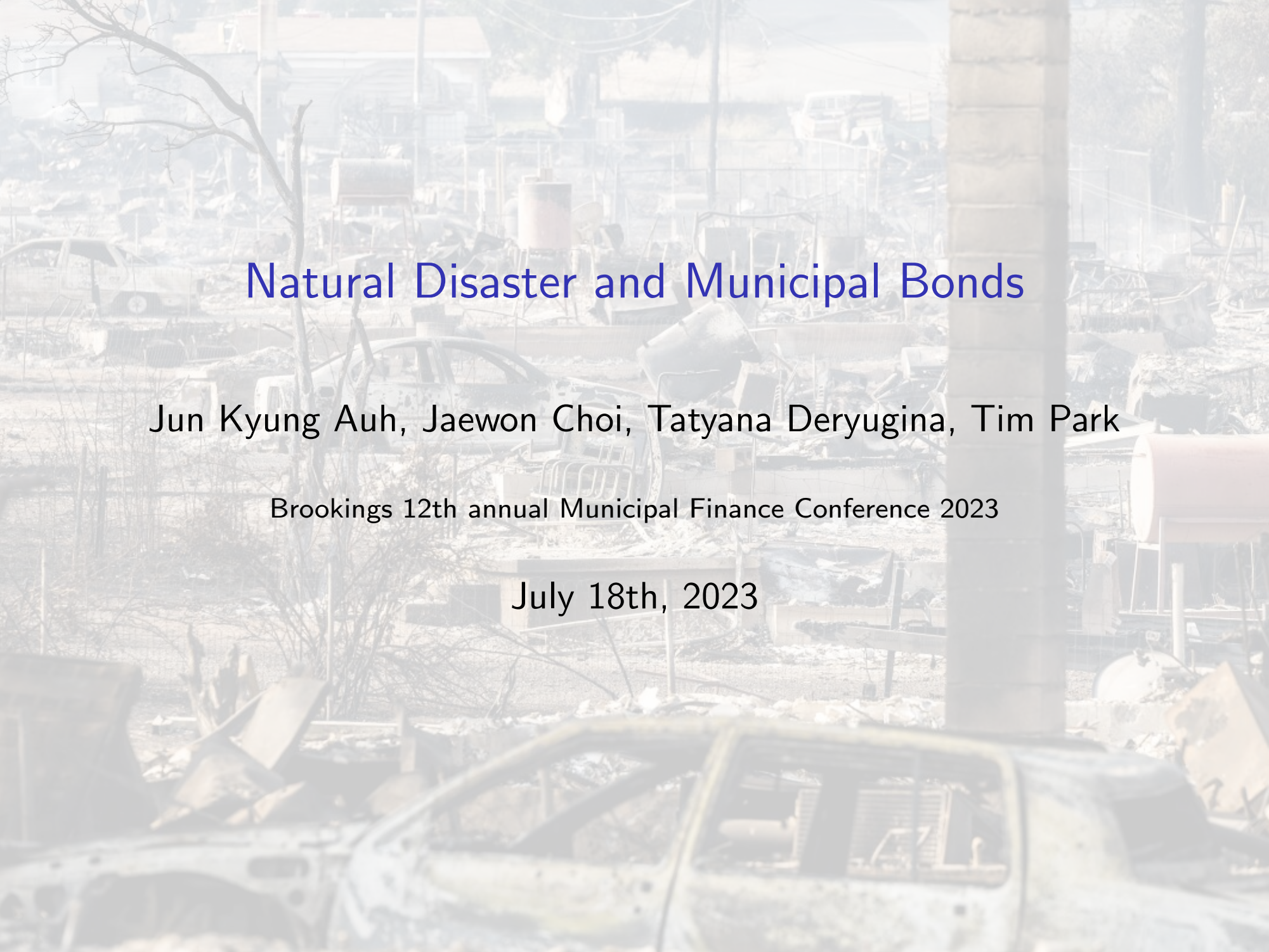

Natural Disaster and Municipal Bonds

Jun Kyung Auh, Jaewon Choi, Tatyana Deryugina, Tim Park

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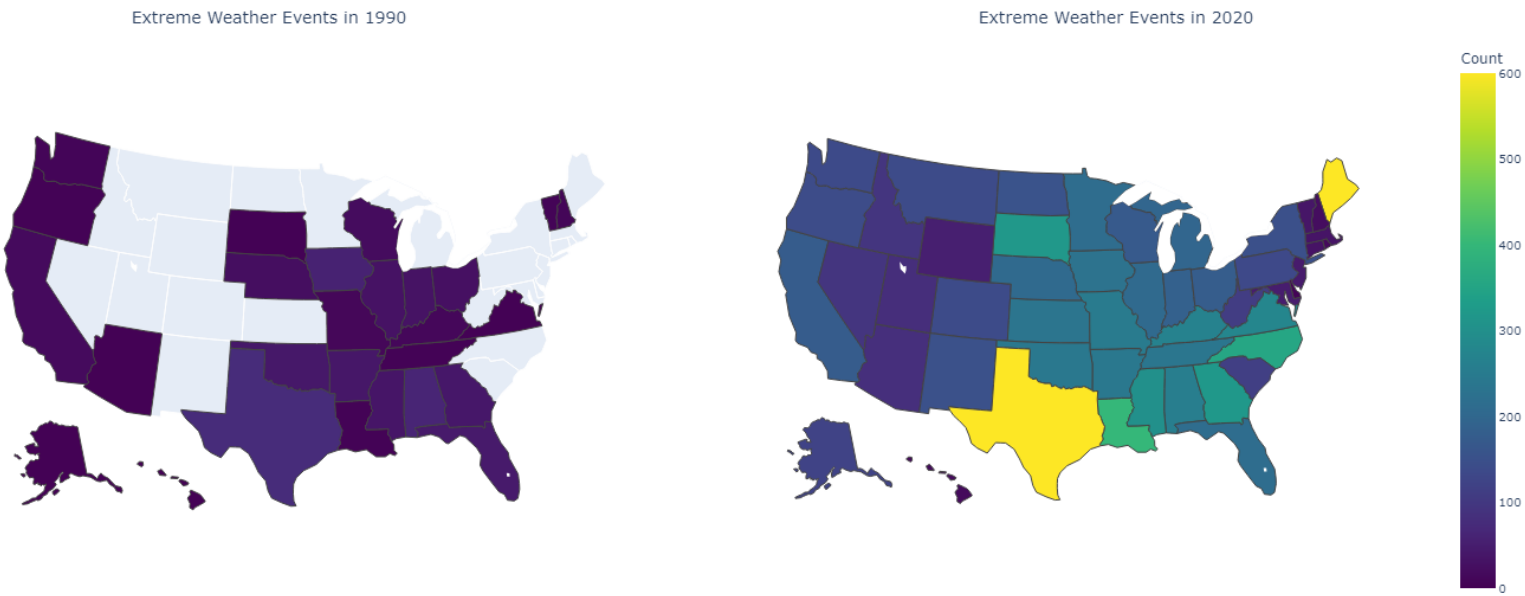
Natural Disasters Over Time

- Frequency and severity of natural disasters are growing:
  - Growth in the number of disaster and emergency declarations in the US averaged 7% in 1990–2020.
  - Physical damage averaged over $11 million per affected county.



Asset Pricing Implication

- Widespread belief among professionals, academics, and regulators that asset prices underestimate climate risks.
  - Physical climate risks, however, rank as the top climate risk over next 30 years (Stroebel and Wurgler 2021).
- A potential reason for such underestimation of physical climate risk is that the effects are subject to:
  1. Confounding effect (e.g., stock prices of companies whose operations are geographically scattered).
  2. Statistical power to detect climate risks is low (e.g., slow-moving climate risks).
- Natural disasters provide an ideal setting to estimate the price implication of physical climate risk

Our Strategy

- We focus on municipal bond returns (as opposed to bond yields or credit ratings).
- Why is studying municipal bond returns important?
  1. Can speak directly to the portfolio performance and wealth of bond investors.
  2. Allows to compare returns of the *same* bonds before and after disasters.
  3. Bond returns in high frequency reveal the pattern of investors' response in terms of intensity and immediacy.
- Using high-frequency return around *exogenous* events alleviates a concern for omitted variable problem without relying on an identification assumption (Painter (2020); Goldsmith-Pinkham et al. (2023)).

Impact and Mechanisms are Ex-Ante Unclear

- Can even have positive long-run effects on local economy:
  - "Creative destruction" or "build back better" (Strobl (2011); Deryungina et al. (2018))
- The price impact (if any) could be mainly driven by risk-aversion or liquidity premium, as opposed to physical damage.
  - Is it expected cashflow or discount rate?
- We dissect the sample in multiple dimensions that are correlated with physical damage but uncorrelated with other factors.
  - REV versus GO
  - Insured versus Uninsured
  - Direct measure of physical damage
  - Post-disater aid

Data

- Municipal Bond Data
  - Municipal Securities Rulemaking Board (MSRB)
  - Mergent Municipal Bond Database
- County-level Economic and Financial Data
  - Regional Economic Information System (REIS) from Bureau of Economic Analysis (BEA)
  - Census of Governments
- Natural Disaster Data
  - Spatial Hazard Events and Losses Database for the United States (SHELDUS)
  - Federal Emergency Management Agency (FEMA) Database

Bond Returns

- Sparse trading makes it impossible to perform a high frequency analysis with raw data.
  - Municipal bonds are rarely traded ($<$3 times per year).
  - Hard to perform disaster-event studies with no available traded prices in high frequency.
- But many counties have hundreds of bonds outstanding at any given time.
- Solution: employ the repeat sales approach to obtain weekly bond returns for many US counties
  - Motivated by real-estate literature (e.g., Case and Shiller 1987)
  - Has been successfully applied to corporate bonds (Spiegel and Starks 2016; Robertson and Spiegel 2017)

Repeat Sales

- To overcome scarce tradings in municipal bond markets, we use the repeat sales methodology to estimate **county-level weekly returns**.
- Estimate $\{R_t^c\}$ based on the following model:

$$R_{i,b:s} = \sum_{t=b+1}^{s} R_t^c + e_{i,b:s}$$

  - $R_{i,b:s}$ is log return of bond i issued by county c from week b to s.
  - R_t^c is county-level weekly log returns at week t.
- For each county c, we regress individual bond log returns on week-year indicators that equal 1 if $b < t \leq s$.
- We are effectively estimating time fixed effects of bonds issued by county c.

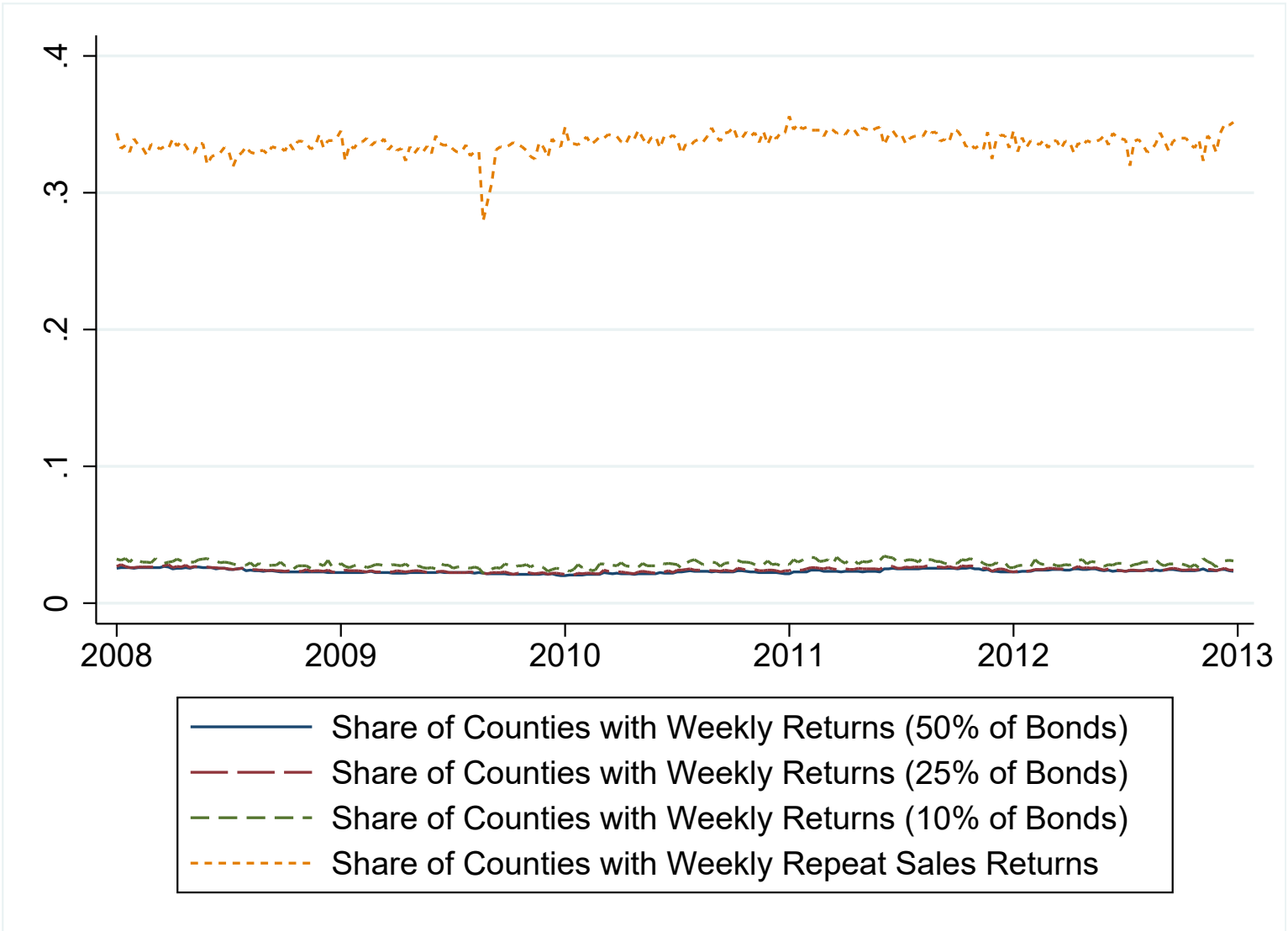
Repeat Sales (Illustration)

- Municipal bonds issued by Montgomery County in MD.
  - Bond A: R1% log return from 2023w1 to 2023w4
  - Bond B: R2% log return from 2023w1 to 2023w3
  - Bond C: R3% log return from 2023w2 to 2023w4
- No subsequent prices, so no weekly returns.
- We run the following regression to apply repeat sales:

$$\begin{bmatrix} R1\% \\ R2\% \\ R3\% \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} R_{2023w2} \\ R_{2023w3} \\ R_{2023w4} \end{bmatrix} + \varepsilon$$

- $\hat{R}_{2023w2}$, $\hat{R}_{2023w3}$, and $\hat{R}_{2023w4}$ are estimated repeat sales returns in this example.

Counties Covered by Repeat Sales vs. Actual Returns



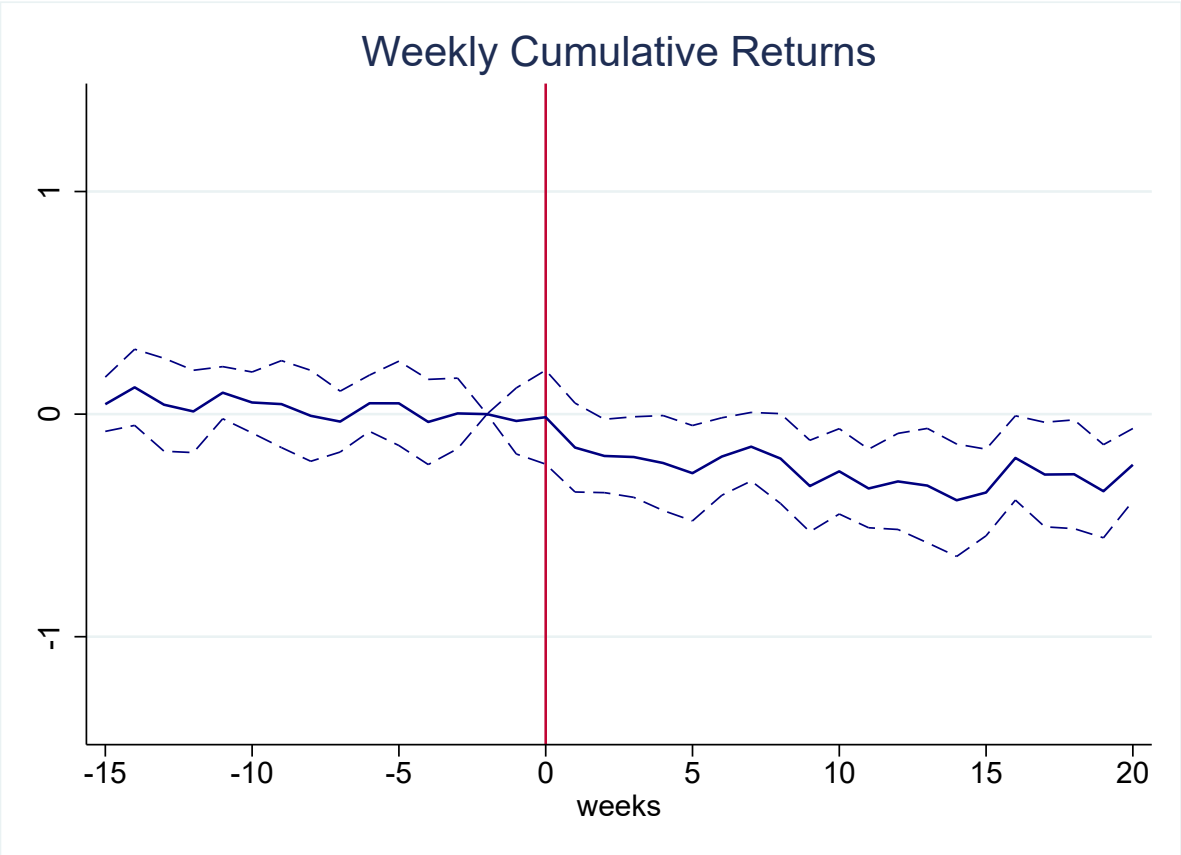
Event Study

- Using repeat sales estimation, we construct weekly cumulative abnormal returns.
- For each extreme weather event indexed by (c, t), weekly cumulative abnormal return at week τ from $t - 15$ is:

$$WCAR_{c,t,\tau} = \sum_{s=-15}^{\tau} (R^c_{t+s} - R^b_{t+s})$$

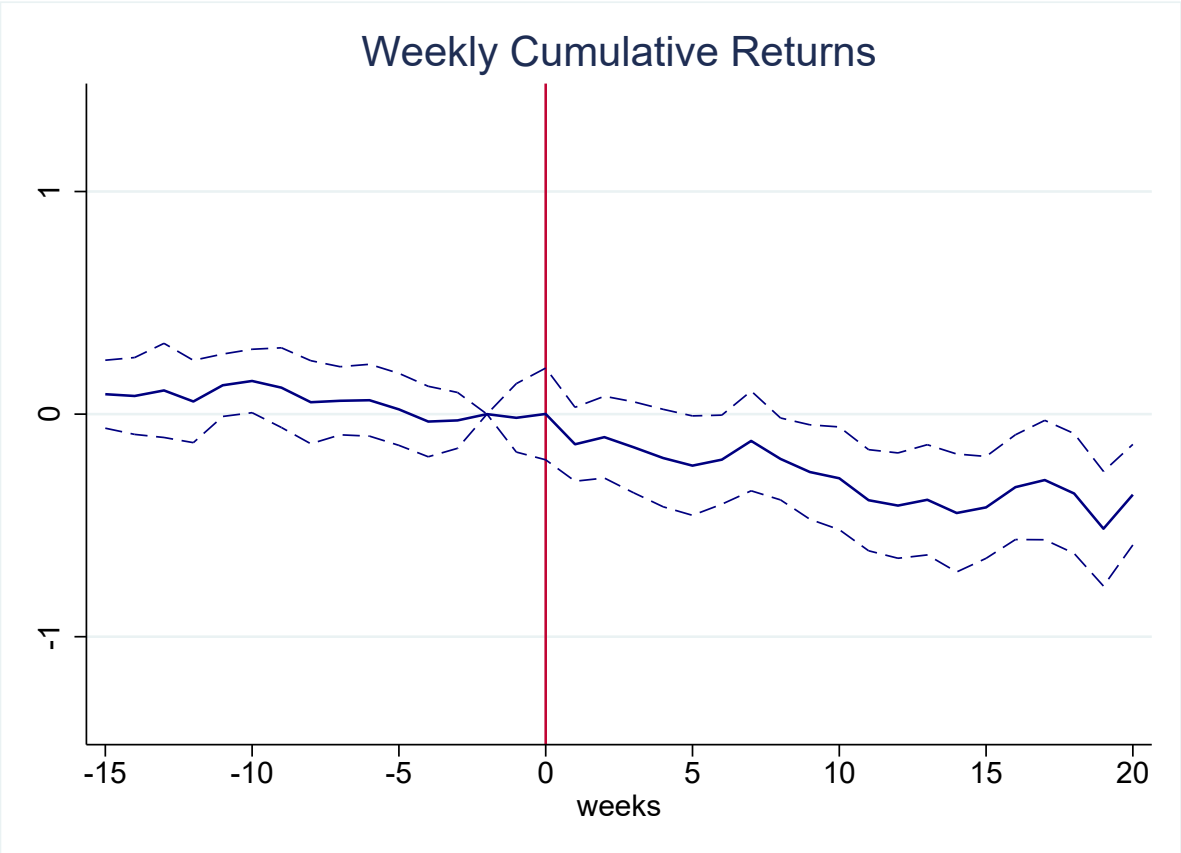
  - R^b_{t+s}: Average repeat sales return of 20 benchmark counties.
  - Benchmark counties chosen among disaster-unaffected counties 500+ miles away that most closely match based on **lagged average coupon, credit rating, maturity, population, income per capita and unemployment rate**.

CAR Around Natural Disasters: All Uninsured Bonds



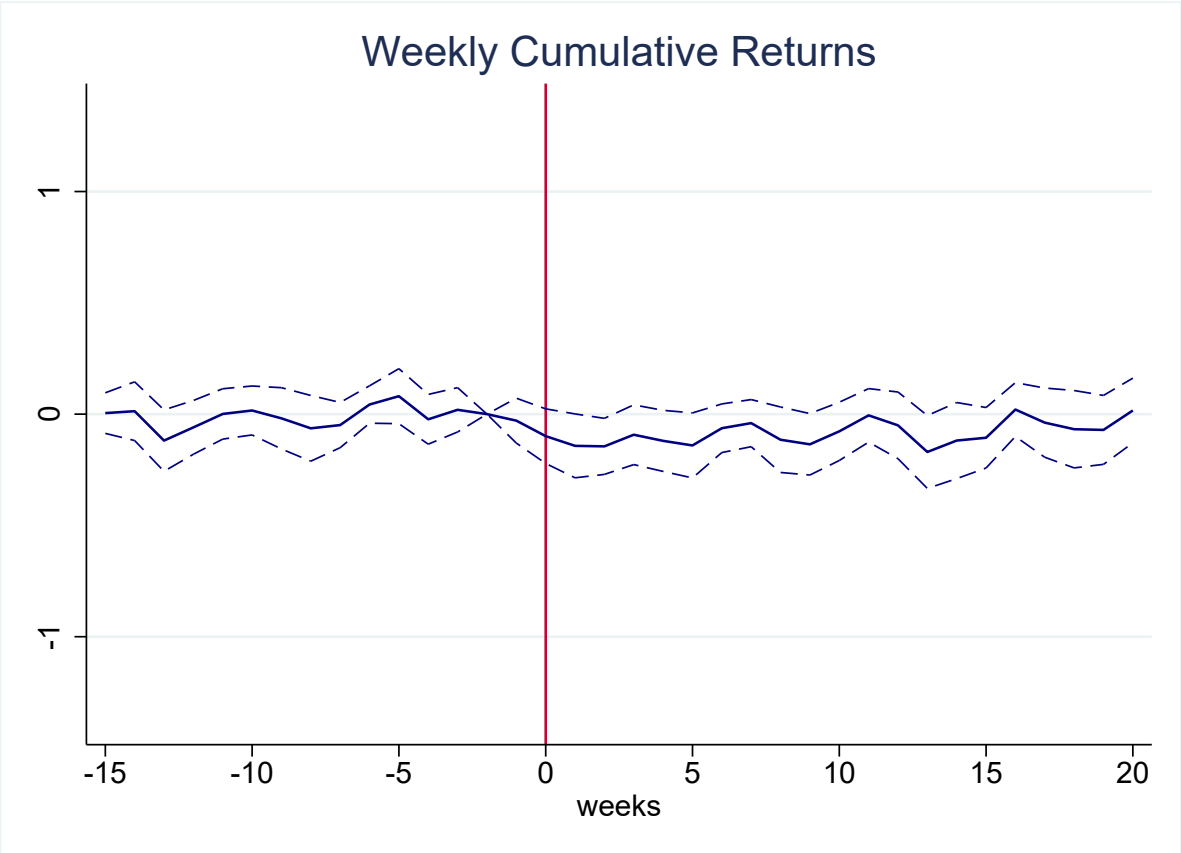
- Overall, uninsured muni bonds experience negative return (31bps over 10 weeks).

CAR Around Natural Disasters: REV Bonds



- REV bonds show more severe negative price drops (51bps over 10 weeks).

CAR Around Natural Disasters: GO Bonds



- GO bonds do not exhibit significant price impact around natural disasters.

CAR Around Natural Disasters

- For brevity and statistical power, we focus on the difference between monthly CAR until t-2 versus CAR until t+4.

$$MCAR_{c,t,\tau} = \beta Post_{c,t,\tau} + \sum_{p=-1}^{12} \gamma(p) D^{M}_{c,t,\tau}(p) + \sum_{q=0}^{10} \delta(q) E^{M}_{c,t,\tau}(q) + \alpha_c + \epsilon_{c,t,\tau}$$

- β estimates the difference:

Dep Var: CR	All Bonds	REV Bonds	GO Bonds
Post	-0.3144**	-0.5089**	-0.1277
	(-2.3279)	(-2.5602)	(-1.0594)
County FE	YES	YES	YES
No. of Obs.	1996	1185	1316
Adj. R-Squared	0.31	0.32	0.3

With Raw Returns?

Dep Var: CR	Raw Returns	
	REV Bonds	GO Bonds
Post	-1.2733	-0.0127
	(-1.0952)	(-0.0015)
County FE	YES	YES
No. of Obs.	38	15
Adj. R-Squared	0.22	0.1

- The raw returns give us very little observation and no statistical power.
- Showcases the merit of the repeat sales approach.

How About Insured Bonds?

Dep Var: CR	All Bonds	REV Bonds	GO Bonds
Post	-0.099	-0.1419	-0.06
	(-1.2862)	(-1.5319)	(-0.5195)
County FE	YES	YES	YES
No. of Obs.	3191	2052	1987
Adj. R-Squared	0.25	0.2	0.3

- Bond insurance effectively protects investors from natural disasters.
- Suggests such a price impact is caused by physical damage to cashflow as opposed to liquidity demand or behavioral resaons.

Physical Damage Matters for REV Bonds

	Below Med	Above Med	Below Med	Above Med
Dep Var: CR	REV Bonds	REV Bonds	GO Bonds	GO Bonds
Post	-0.3502	-0.6132*	-0.1243	-0.1986
	(-1.5429)	(-1.8343)	(-0.7799)	(-1.3201)
County FE	YES	YES	YES	YES
No. of Obs.	594	591	658	658
Adj. R-Squared	0.36	0.43	0.37	0.37

- Reiterates that the pattern is driven by rational investors' reaction to damaged cashflow.
- Above-Med: average per-capita damage is $528
- Below-Med: average per-capita damage is $6.14

Undoing the Damage by Federal Disaster Aid: REV Bonds

Dep Var: CR	Zero Aid	Below Med	Above Med
	REV Bonds	REV Bonds	REV Bonds
Post	-1.1954*	-0.7086**	-0.2969
	(-1.9769)	(-2.3249)	(-1.2096)
County FE	YES	YES	YES
No. of Obs.	242	537	648
Adj. R-Squared	0.29	0.34	0.37

- Zero aid: average per-capita damage is $54
- Some aid: average per-capita damage is $336
- Federal disaster aid helps mitigate negative shocks on REV bonds.

Historical Disaster Frequency and Investor Reaction

Panel A: By Pre-2000 Historic Damage

	Below Med	Above Med	Below Med	Above Med
Dep Var: CR	REV Bonds	REV Bonds	GO Bonds	GO Bonds
Post	-0.6014***	-0.4246	-0.3034**	0.0372
	(-2.6991)	(-1.5729)	(-2.1214)	(0.2171)
County FE	YES	YES	YES	YES
No. of Obs.	610	575	658	658
Adj. R-Squared	0.28	0.37	0.26	0.32

Panel B: By Projected Flood Risk

	Below Med	Above Med	Below Med	Above Med
Dep Var: CR	REV Bonds	REV Bonds	GO Bonds	GO Bonds
Post	-0.6657**	-0.2441	-0.1464	-0.0834
	(-2.5070)	(-0.9536)	(-0.8607)	(-0.5136)
County FE	YES	YES	YES	YES
No. of Obs.	743	442	886	430
Adj. R-Squared	0.33	0.27	0.3	0.35

- Below Med $\rightarrow$ Counties with lower disaster frequency.
- The physical risk appears to be priced ex-ante.

Municipalities' Leverage and GO Bond Returns

Dep Var: CR	Low Severity	High Severity	Low Severity	High Severity
	GO Bonds	GO Bonds	REV Bonds	REV Bonds
Post × Levered	-0.0548	-0.5517**	-0.0635	0.2924
	(-0.2199)	(-2.3262)	(-0.1459)	(0.6155)
Post	-0.1518	-0.0142	-0.4773*	-0.5838*
	(-0.9086)	(-0.0600)	(-1.7731)	(-1.6831)
County FE	YES	YES	YES	YES
No. of Obs.	456	398	408	379
Adj. R-Squared	0.41	0.53	0.46	0.5

- If a municipality has high debt to tax revenue ratio (bad creditworthiness), it has less room to maneuver to make up for the cashflow damage.
- Severe disasters may negatively affect its GO bond returns.

Revenue Concentration and GO Bond Returns

Dep Var: CR	Low Severity GO Bonds	High Severity GO Bonds	Low Severity REV Bonds	High Severity REV Bonds
Post×Concentrated	0.2266	-0.5454*	0.2388	-0.01
	(0.7484)	(-1.9232)	(0.3992)	(-0.0176)
Post	-0.3643	-0.0652	-0.4649	-0.8143
	(-1.3679)	(-0.2497)	(-0.8535)	(-1.2748)
County FE	YES	YES	YES	YES
No. of Obs.	276	262	238	220
Adj. R-Squared	0.52	0.49	0.5	0.58

- If a municipality have a concentrated source of revenue, severe disasters may negatively affect GO bond returns.
- More direct evidence that GO bonds' resiliency is related to revenue diversification.

Conclusion

- We use the repeat sales methodology to study how natural disasters affect municipal bond returns.
- Municipal bond market responds negatively but slowly to disasters:
  - indicative of underreaction by investors.
- An average disaster causes 31bps negative return, translating into $9.2 million investor loss (average physical damage is $19 mil.)
- Overall, our findings show that the post-disaster reaction is consistent with investors' rational reaction, rather than subjective perception changes.