Virtual Seminar on Climate Economics

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Private Benefits from Public Investment in Climate Adaptation and Resilience

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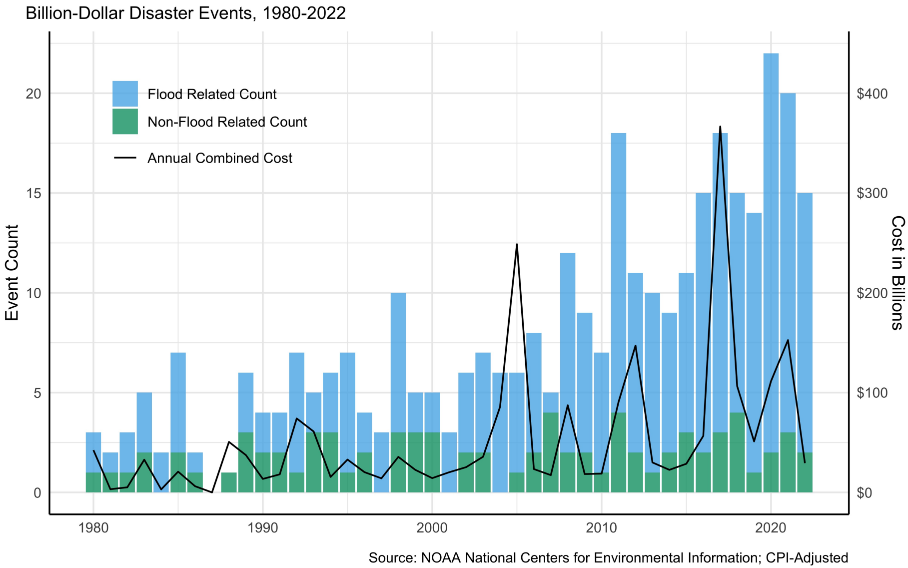
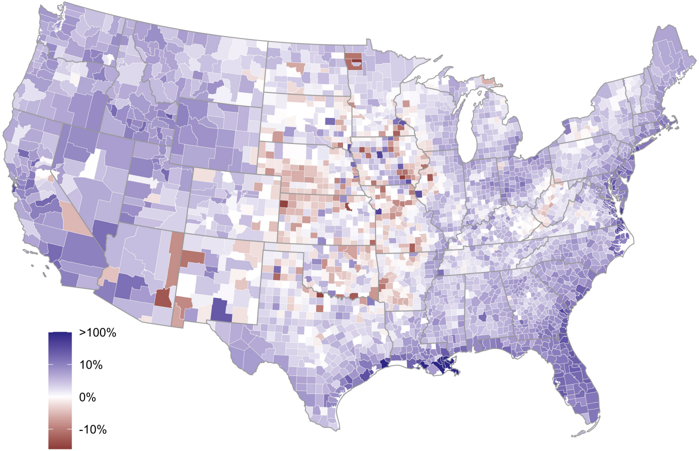
November 9, 2023

Flood events are the most costly disasters in US



Climate change will exacerbate flood risk in the US

Estimated Change in Properties with Flooding (2021-2051)



Source: First Street Foundation and Authors' calculations

- Share of US properties at risk of regular flooding ↑ 8.2% over next 30 years (FSF)

Research questions

- With growing natural hazard risks, policymakers face increasing imperative to invest in public adaptation
- These public investments provide private benefits, raising questions of who gains (or loses) and by how much?

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- These public investments provide private benefits, raising questions of who gains (or loses) and by how much?
- Motivating questions:
  - → What is the magnitude of private impacts from public investments in adaptation?
  - → What are the equity implications of these large transfers?
  - → How do these investments impact aggregate welfare?

Summary of results

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- Findings:
  1. Estimate subsidized flood protection benefits amount to 2.8% of a home's value
  2. Spillover effects to surrounding, unprotected properties in the form of increased flood risk can reduce home value by as much as 1.1%
  3. Flood protection benefits are progressive, but spillovers are regressive
  4. Ex post, USACE-constructed levee costs appear to exceed benefits

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  3. Flood protection benefits are progressive, but spillovers are regressive
  4. Ex post, USACE-constructed levee costs appear to exceed benefits
- Presence of spillover introduces local strategic incentives that drive policy outcomes
  - → Highlights difficulties for policymakers in using existing institutions for adaptation investments

Related literature

- Individual adaptation and adaptation policy
  - Auffhammer, 2022; Barreca et al., 2016; Baylis and Boomhower, 2021; Burke and Emerick, 2016; Kahn, 2016; Wagner, 2021
- Capitalization of flood risk and adaptive investments
  - Beltrán et al., 2019; Bernstein et al., 2019; Bin and Landry, 2013; Bin et al., 2008; Dundas, 2017; Dundas and Lewis, 2020; Fell and Kousky, 2015; Gopalakrishnan et al., 2018; Graff Zivin et al., 2022; Hallstrom and Smith, 2005; Kelly and Molina, 2022; Murfin and Spiegel, 2020; Ortega and Taşpınar, 2018; Walsh et al., 2019; Wang, 2021
- Public finance implications of climate change and impacts of place-based policies
  - Barrage, 2020; Busso et al., 2013; Fried, 2021; Goldsmith-Pinkham et al., 2021; Greenstone et al., 2010; Liao and Kousky, 2022; Mast, 2020

Related literature

- Individual adaptation and adaptation policy
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  → We evaluate economic questions around large-scale, public adaptation investments

- Capitalization of flood risk and adaptive investments
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  → We emphasize the importance of spillover effects and explore incidence

- Public finance implications of climate change and impacts of place-based policies
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  → We examine how strategic interactions drive adaptation investments and their outcomes

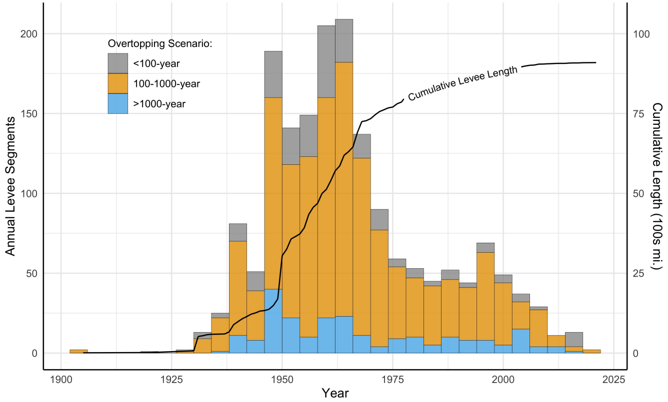
Outline

Outline

What is a levee?

- Man-made structure that diverts water flow during flood stages
- Provides flood protection to defined area, up to a certain flood severity
- Imposes flood risk spillovers to downstream/upstream areas (Heine and Pinter, 2012; Remo et al., 2018)

Federal levee construction peaked in the 1950's and 1960's



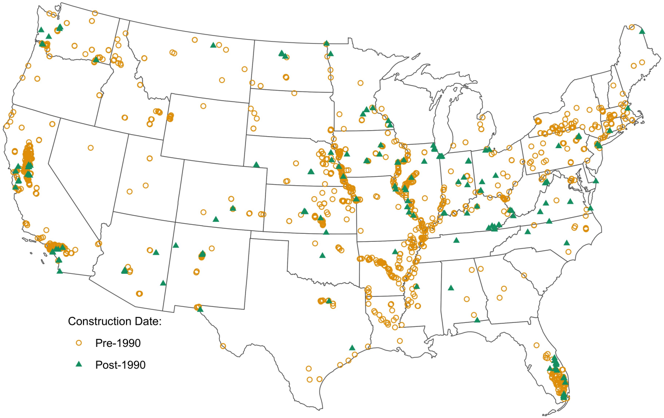
- USACE primary federal entity responsible for flood control
- USACE project delivery:
  - Project-level Congressional authorization & funding
  - Require local cost share (45% construction, 100% O&M)
- Recent shift from flood control to policies managing consequences (e.g., NFIP)

Why do we study levees?

- Unclear if US shift away from flood control to managing flood consequences is sustainable (e.g., fiscal solvency issues)
- Adaptation to evolving future flood risks likely requires policies that address vulnerabilities *and* policies that manage consequences
  - Historically, USACE levees are the single largest federal investment in flood control
- Levees have key similarities to other forms of public adaptation investments, particularly those with geographically-differentiated benefits and costs
  - E.g., federally-constructed sea walls follow same institutional process as levees
  - USACE currently studying sea walls in New York, NY; Miami, FL; Galveston, TX

Outline

Primary data



- Data on flood risk adaptation projects from First Street Foundation
  - Merge data from USACE National Levee Database
- Focus on USACE levees
  1. Construction date available
  2. Similar set of projects
- Combine levees with home sale data from Zillow (1990-2020) using ZTRAX coordinates
- Final estimation sample: 80 levee systems

▸ Summary stats.

Additional data

- Home Mortgage Disclosure Act (HMDA) → demographic data (1990-2020)
  - Fuzzy match HMDA and ZTRAX data on census tract, loan year, loan amount, and lender
  - Match rates: 42% (unconditional); 68% (conditional) ▸ HMDA match
- USGS National Hydrography Dataset → distance to water
  - Use ZTRAX coordinates and all relevant surface waters (e.g., estuaries, lakes/ponds, marsh, permanent and ephemeral rivers/streams) from NHD

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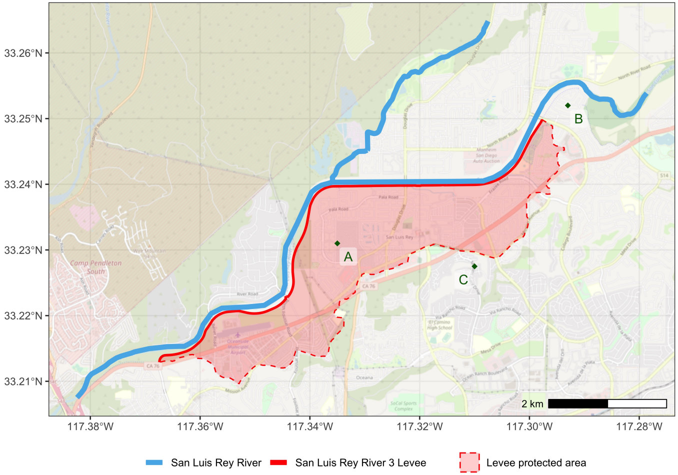
  - Use ZTRAX coordinates and all relevant surface waters (e.g., estuaries, lakes/ponds, marsh, permanent and ephemeral rivers/streams) from NHD
- FEMA Presidential Disaster Declarations → county-level major floods (1990-2020)
- National Flood Insurance Program (NFIP) Claims & Policies → tract-/county-level NFIP outcomes (2009-2020)

▸ Summary stats.

Effects of levee construction

San Luis Rey River 3 Levee - Oceanside, CA



- Identification challenges:
  - Siting endogeneity
  - Heterogeneous effects
- Potential effects of levee construction:
  1. *Protection effects* (A)
  2. *Spillover effects* (B)
  3. *Macro effects* (A, B, C)

Effects of levee construction: Identification

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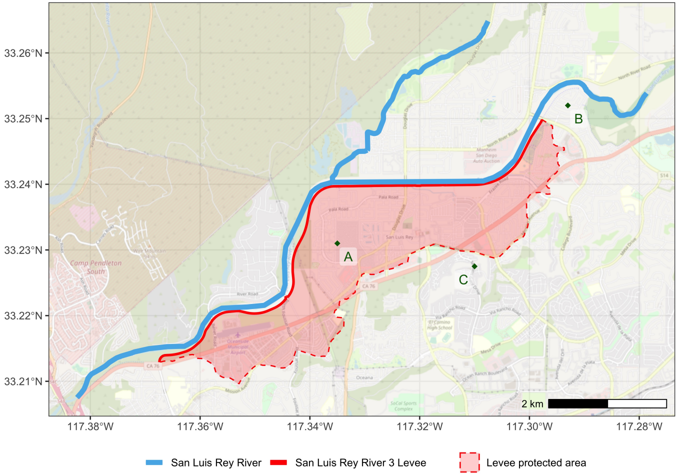


- $\Delta_t P$ = pre-/post-levee construction diff. in sale price

- Then for each property:

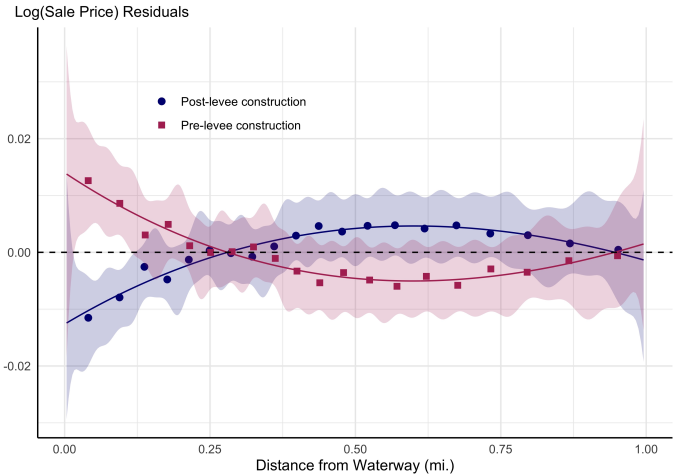
$$\Delta_t P_A = Macro + Protect$$
$$\Delta_t P_B = Macro + Spillover$$
$$\Delta_t P_C = Macro$$

- ID effects w/ double differences:

$$(Protect)_{DD} = \Delta_t P_A - \Delta_t P_C$$
$$(Spillover)_{DD} = \Delta_t P_B - \Delta_t P_C$$

$\Rightarrow$ $\|$ trends assumption: absent levee, A, B, and C on same trend

Defining property exposure



- Treatment of parcel i transacting at time t defined using:

$$T_{it} = \mathbb{1}\{\text{Sale occurs post levee construction}\}$$
$$L_i = \mathbb{1}\{\text{Parcel is within a leveed area}\}$$
$$W_i = \mathbb{1}\{\text{Parcel is spillover exposed}\}$$

- Note that $L_i = 1 \Leftrightarrow W_i = 0$
- Data-driven definition of W_i
  - Will allow for flexible W_i
  - Also explore using floodplain delineations to define W_i

Research design: Difference-in-Differences (DD)

- Use repeat sales data from properties inside leveed areas and within 5 mi of leveed area boundaries, excluding those within 0.1 mi around leveed area boundaries ("donut" design)

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- Separately identify flood protection and flood risk spillover effects by specifying property i's transaction price at time t, P_{it}, as:

protection effect

$$\log(P_{it}) = \alpha_1 (T_{it} \times L_i) + \alpha_2 (T_{it} \times W_i) + \xi_i + \mu_{l(i)t} + \delta_t + \varepsilon_{it}$$

spillover effects

  - ξ_i, $\mu_{l(i)t}$, δ_t are parcel, year-by-levee, and month-of-sample FE

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  - ξ_i, $\mu_{l(i)t}$, δ_t are parcel, year-by-levee, and month-of-sample FE

- $\mu_{l(i)t}$ fixed effect shuts down inadmissible comparisons (de Chaisemartin and D'Haultfœuille, 2020; Goodman-Bacon, 2021) ▸ Staggered treatment timing

Outline

Main capitalization estimates

	$k \leq 0.1$ mi.		$k \leq 0.2$ mi.	$k \leq 0.3$ mi.
	(1)	(2)		
Post × Intersects (α_1)	0.098***	0.029***		
	(0.015)	(0.009)		
Post × k mi. of Water (α_2)	-0.062***	-0.013*		
	(0.012)	(0.007)		
Parcel FE	Yes	Yes		
Sale Year-Sale Month FE	Yes	Yes		
Sale Year-Levee Segment FE		Yes		
Observations	1,244,323	1,244,323		
R^2	0.924	0.948		

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Main capitalization estimates

	$k \leq 0.1$ mi.		$k \leq 0.2$ mi.		$k \leq 0.3$ mi.
	(1)	(2)	(3)	(4)	
Post $\times$ Intersects (α_1)	0.098***	0.029***	0.095***	0.028***	
	(0.015)	(0.009)	(0.015)	(0.009)	
Post $\times$ k mi. of Water (α_2)	-0.062***	-0.013*	-0.062***	-0.011**	
	(0.012)	(0.007)	(0.009)	(0.005)	
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Post × k mi. of Water (α_2)	-0.062***	-0.013*	-0.062***	-0.011**	-0.064***	-0.008*
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Main capitalization estimates

- Differences between specifications w/ and w/o levee-year FE driven by negative weights
    - Large literature on issues w/ TWFE and staggered adoption (e.g., de Chaisemartin and D'Haultfœuille, 2020; Goodman-Bacon, 2021) ▸ Staggered treatment timing
  - → Estimate weight for each transaction under TWFE specification and find correlations which plausibly explain bias away from zero (e.g., income and weights pos. correlated) ▸ TWFE weights

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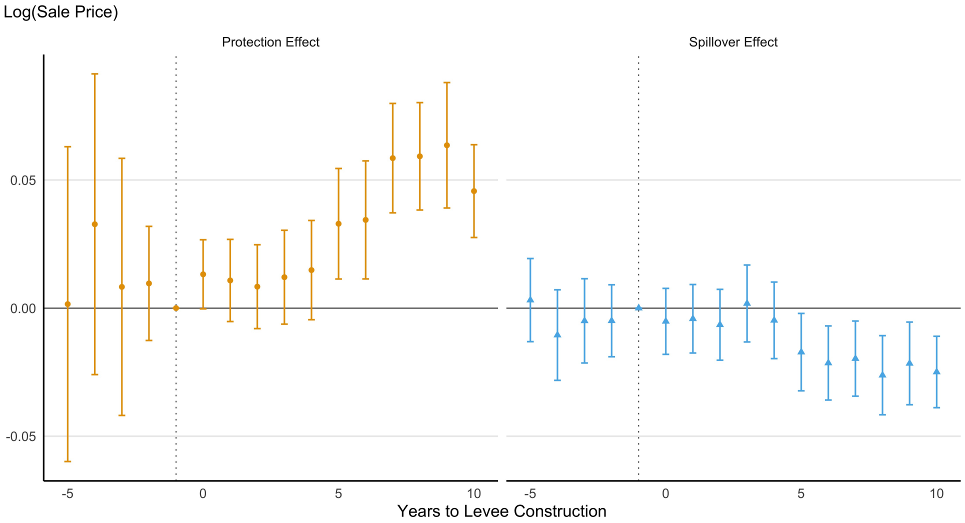
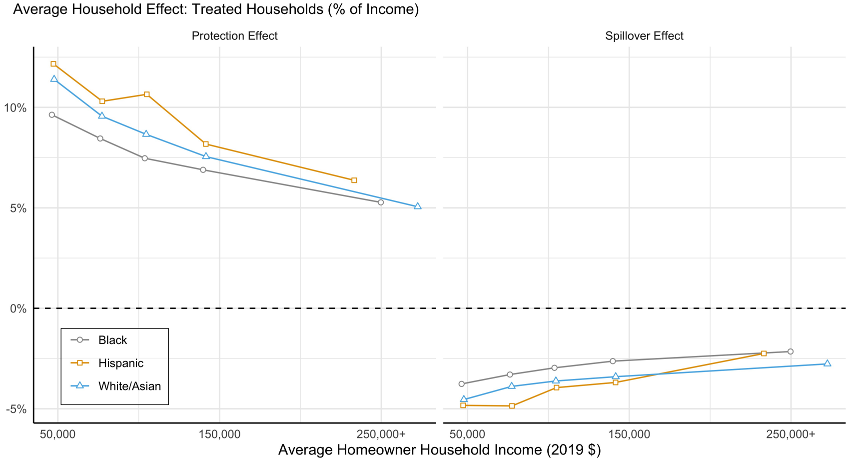
- Robustness checks:
  - Spillover exposure definition: ▸ Flexible fxn. of waterway distance ▸ Floodplain boundary
  - Selection concerns for protected parcels: ▸ Remodel probability
  - Capitalization results influenced by housing supply: ▸ Heterogeneity by supply elasticity
  - Richer set of capitalized impacts: ▸ Additional effects
  - Nearest-neighbor matching estimator to account for potential sorting ▸ Matching results
  - Alternative sample restrictions ▸ Alt. sample results
  - Alternative fixed-effect specifications ▸ Alt. fe results
  - Income-weighted results ▸ WLS results

Dynamic effects of levee construction



▸ Details

Incidence of levee construction: Treated households



- Avg. transfers by race/ethnicity and income for treated HH

Post-construction sorting

	log(Income) (1)	White/Asian (2)	Black (3)	Hispanic (4)
Post × Intersects	0.001	0.043***	-0.006	-0.041**
	(0.013)	(0.012)	(0.004)	(0.020)
Post × Distance to Water Bins				
[0.0, 0.1 mi]	-0.017	-0.043***	0.019***	-0.033**
	(0.011)	(0.010)	(0.005)	(0.015)
(0.1, 0.2 mi]	0.0006	-0.028***	0.010*	-0.010
	(0.009)	(0.008)	(0.005)	(0.012)
(0.2, 0.3 mi]	-0.009	-0.028***	0.014***	0.007
	(0.008)	(0.008)	(0.004)	(0.012)
(0.3, 0.4 mi]	-0.004	-0.013*	0.005	0.0003
	(0.008)	(0.007)	(0.003)	(0.012)
Parcel FE	Yes	Yes	Yes	Yes
Sale Year-Sale Month FE	Yes	Yes	Yes	Yes
Sale Year-Levee Segment FE	Yes	Yes	Yes	Yes
Dependent variable mean	138,319	0.787	0.043	0.174
Observations	646,825	646,837	646,837	387,507
R^2	0.817	0.668	0.690	0.816

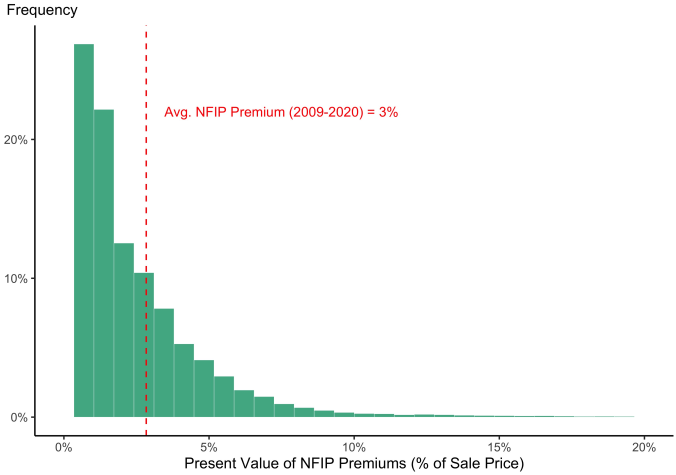
Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

- DD design with demographic outcomes
- Suggestive of sorting away from risk by white/asian households

▸ HMDA match details

Outline

Mechanism: NFIP premium discounts

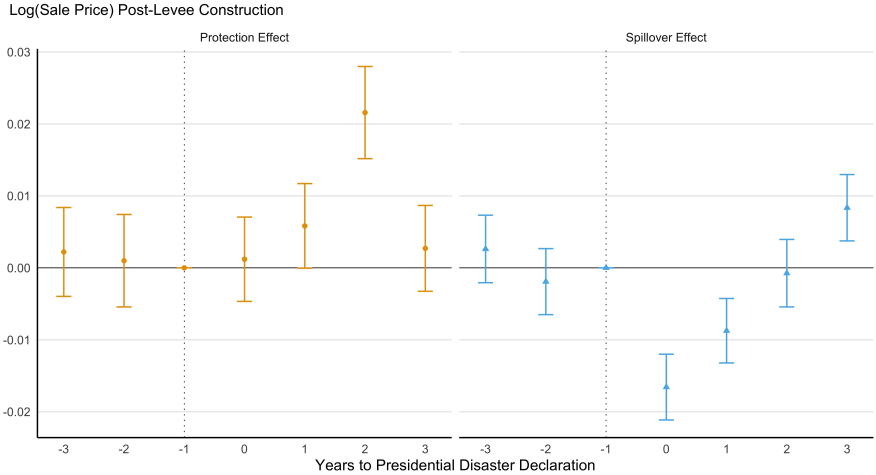


- Assume levee-protected HH take-up maximum NFIP coverage in perpetuity
  - → Average PDV of NFIP cost: 3% of home value
- While NFIP discount plays a role, other factors likely:
  - SFHA take-up 48% nationally
  - 25% of segments in sample are not FEMA-accredited

▸ FEMA levee accreditation results

Mechanism: Learning from flood exposure

- Households learn from experience (Bakkensen and Barrage, 2021; Gallagher, 2014)



▸ Details ▸ Pooled results ▸ NFIP claims

Aggregating benefits and costs of levees

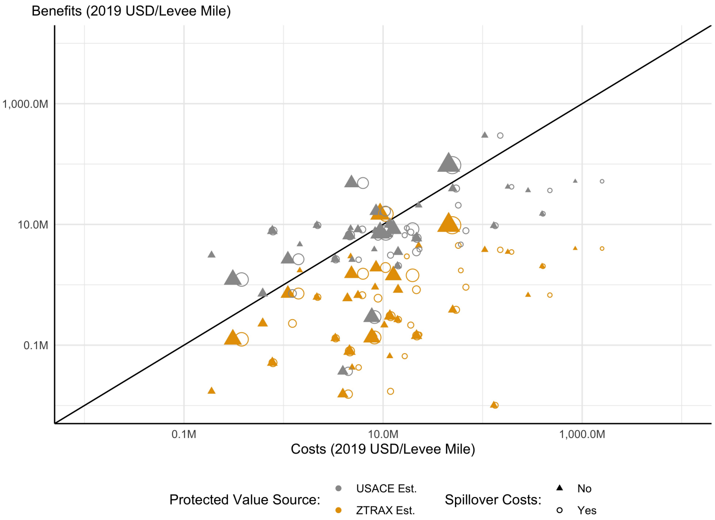
- Capture three types of benefits/costs
  1. Capitalized protection benefits and spillover costs
  2. Local public finance externalities (property tax revenue impacts)
  3. Upfront construction costs

- Total capitalized protection benefits and spillover costs calculated using: (1) assessed values from Zillow or (2) USACE's National Structure Inventory (+ preferred estimates)

- Calculate fiscal externality of, e.g., protection benefits, as:

$$FE_l^{protection} = \frac{\text{Total Protection Benefits}_l \times \text{Effective Tax Rate}_l}{\text{Long-term Interest Rate}}$$

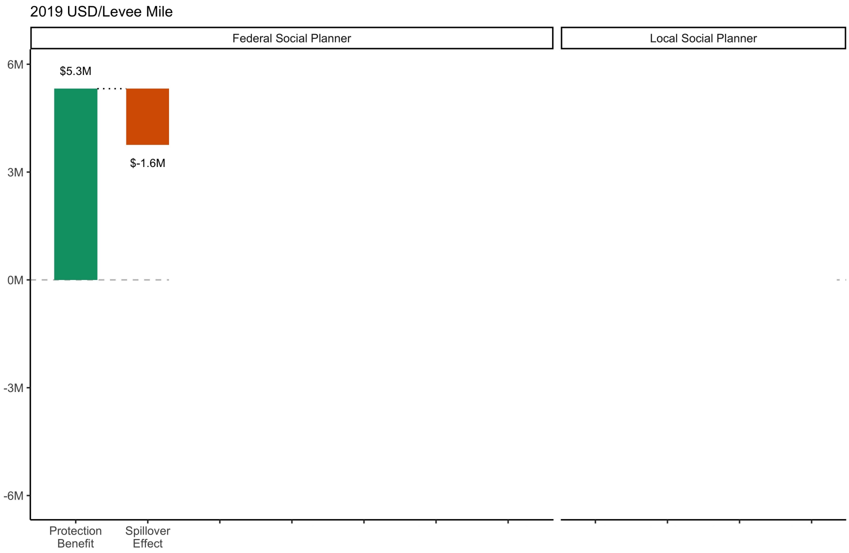
Estimated project-level benefits and costs



- Collect construction cost data for 37 projects
  - → Covers 53 of 80 levee systems in sample
- Normalize benefits and costs by levee size
  - Points proportional to levee size

▸ Benefit and cost components

External costs and local political economy



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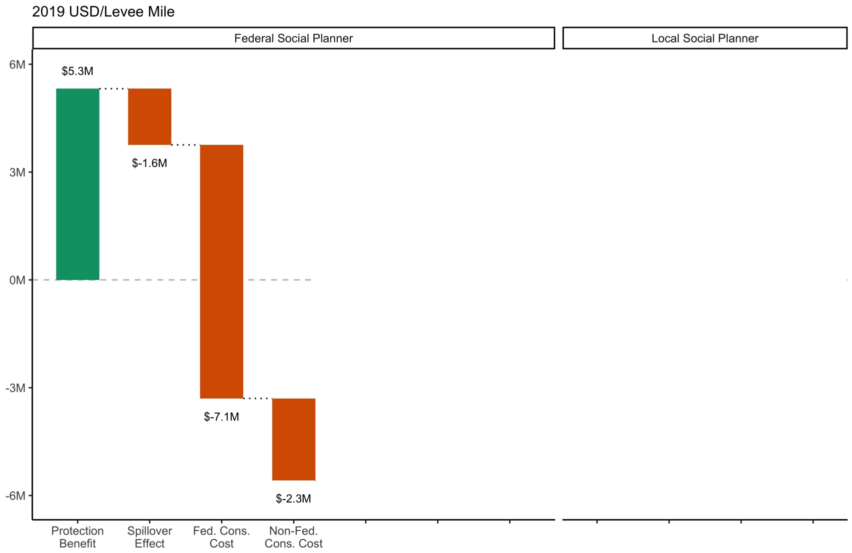

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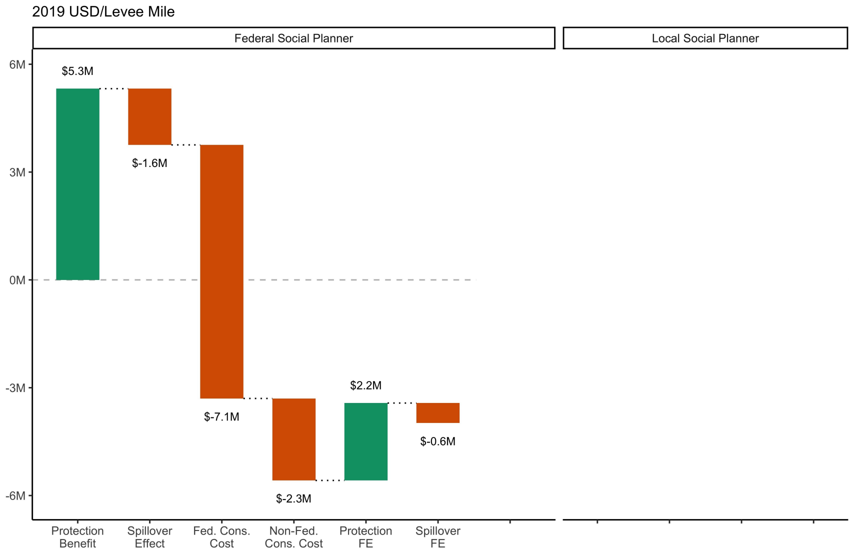

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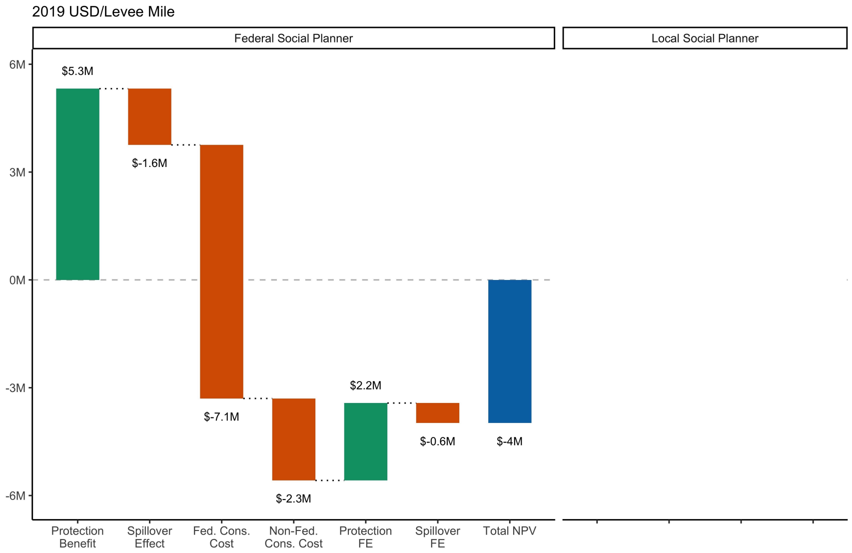

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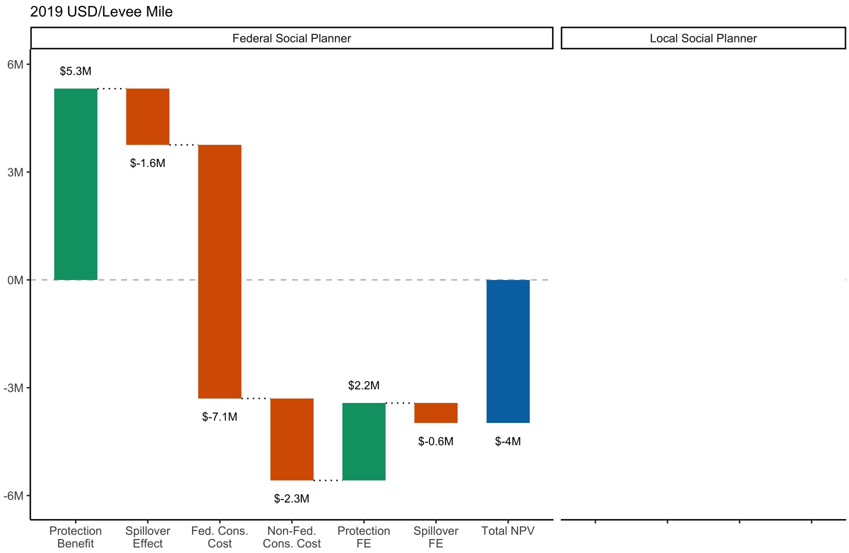
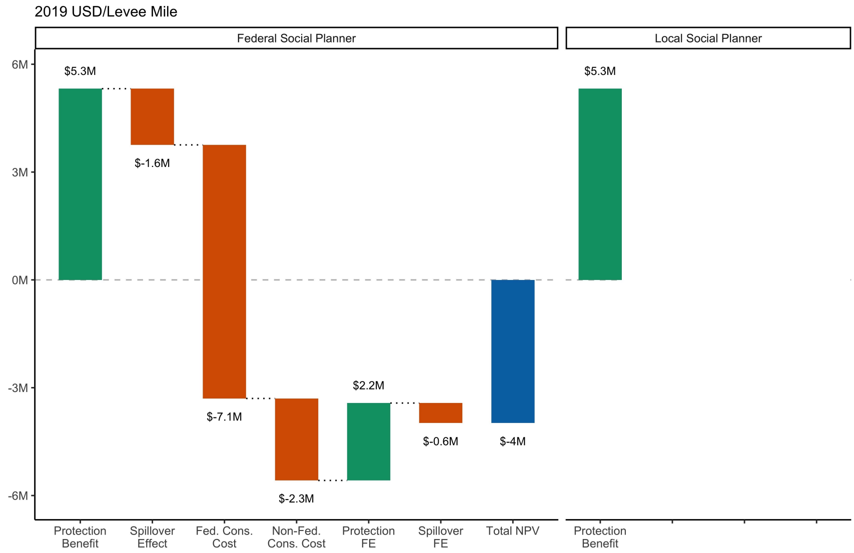


- 30% of projects impose spillovers on other counties

External costs and local political economy



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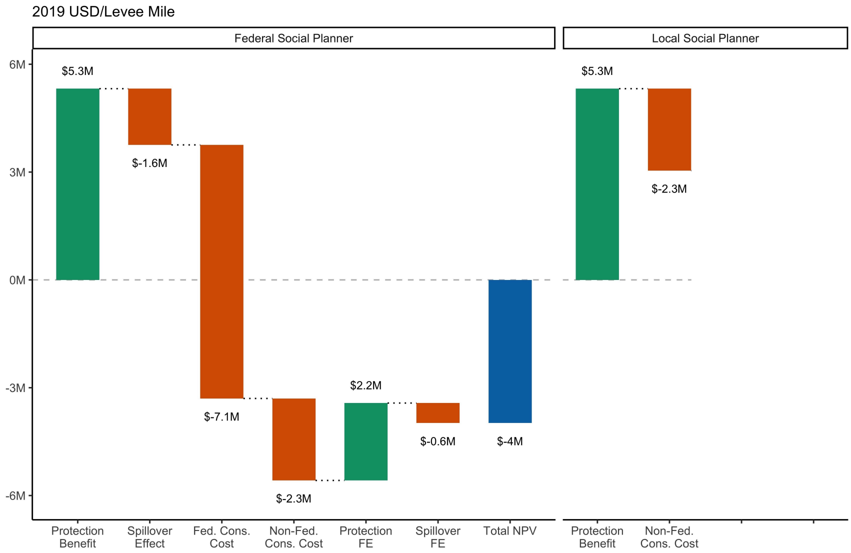

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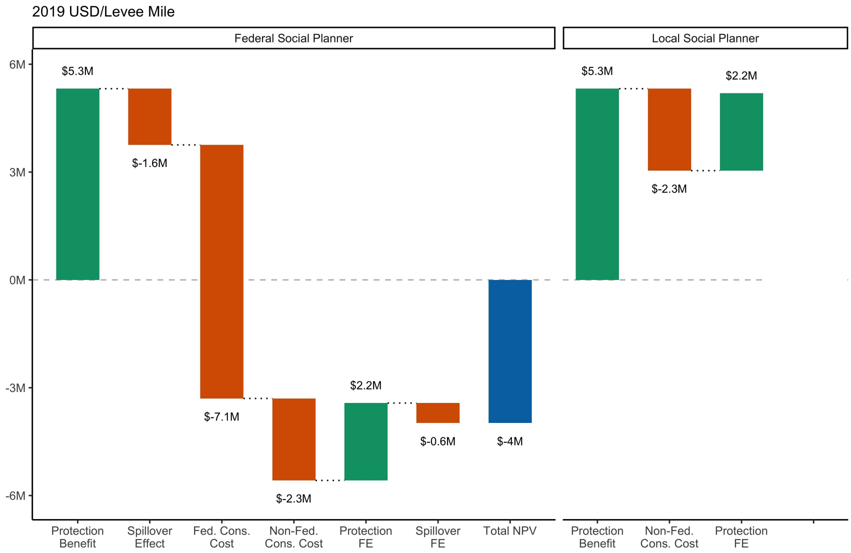

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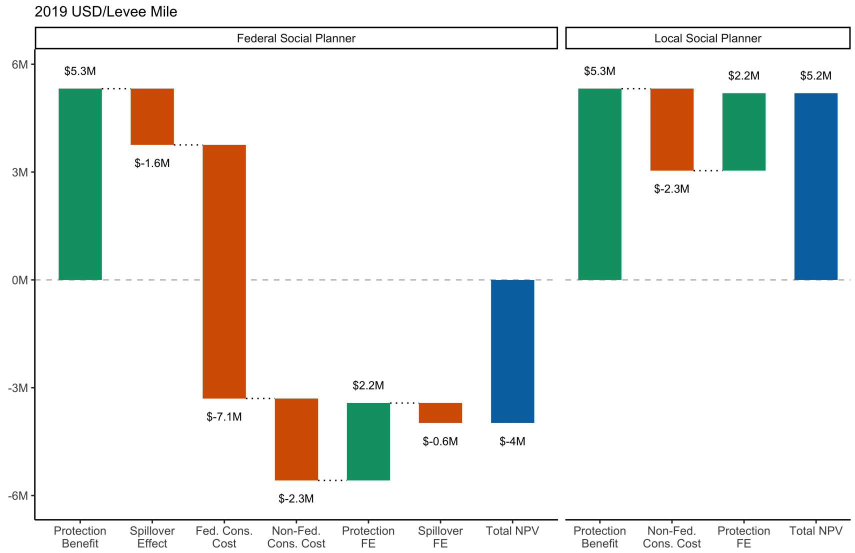
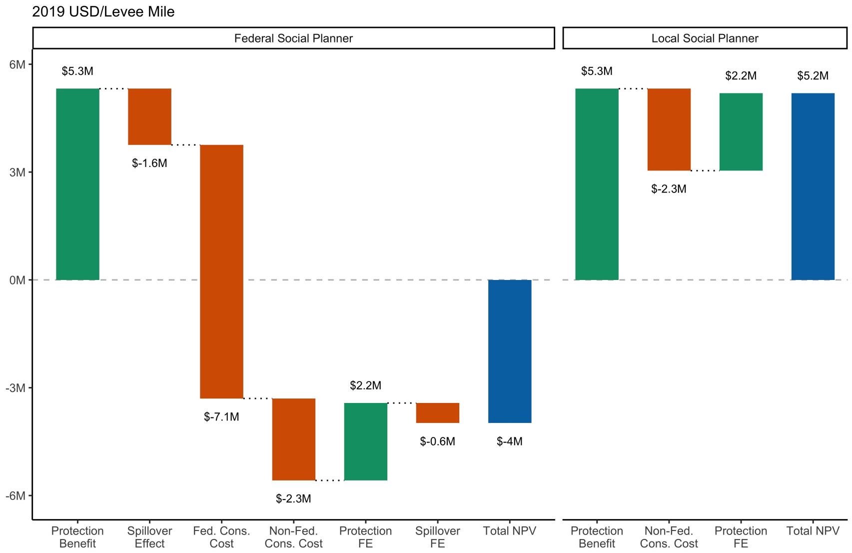


- 30% of projects impose spillovers on other counties

External costs and local political economy



- 30% of projects impose spillovers on other counties
- Correlation: levee construction and representation

▸ Committee membership

BCA results and aggregate welfare

- Important to note that BCA results are informative, but should not be viewed as complete measures of welfare impacts
  - → Capitalized effects $\neq$ true costs and benefits of changes in flood risk ▸ Incomplete capitalization
- Missing important benefit/cost categories (e.g., O&M costs, extensive/intensive effects, crowding out)
  - Evidence of crowding out of private adaptation ▸ NFIP impacts
  - Evidence of extensive margin effects ▸ New construction results

Outline

Summary

- We examine the case of USACE-constructed levees to better understand key economic questions around public adaptation investments

- Findings:
    1. Levee flood protection subsidies amount to 2.8% of a home's value
    2. Substantial flood risk spillovers: reduce home value by 1.1%
    3. Redistribution to lower income households partially offset by the regressivity of spillovers
    4. Ex post, USACE-constructed levee costs appear to exceed benefits

Takeaways

- USACE levees highlight the difficulties that policymakers face in using existing institutions for climate adaptation
- Presence of spillover costs and accounting of aggregate benefits and costs illuminate local strategic incentives that determine policy outcomes
  - → Policymakers should carefully consider strategic incentives in the design of adaptation policy
- More broadly, economists' insights can be valuable in studying public investments in climate adaptation

Thank you!

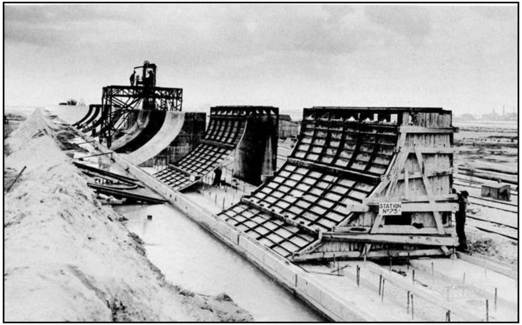


Figure: Construction of old Galveston, TX sea wall

Figure: Rendering of new Galveston, TX sea wall

Please reach out with comments/questions

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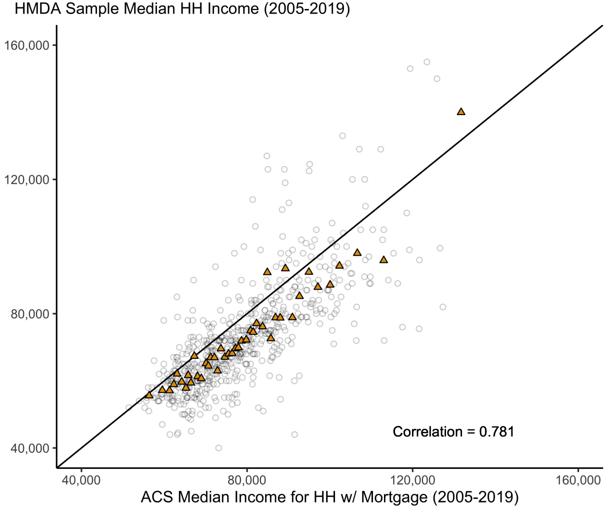
Backup Slides

Transaction-level demographic data



- Match ZTRAX transaction-level data with demographic data from Home Mortgage Disclosure Act
- Match rates: 42% (unconditional); 68% (conditional)
- Match rates from literature: 54% (Bayer et al., 2016), 47% (Bakkensen and Ma, 2020)

▸ Go back (data desc) ▸ Go back (incidence)

Summary statistics

	Unmatched Sample		HMDA Sample			
	Mean	Std. Dev.	Mean	Std. Dev.	Diff. in Means	Std. Error
Price (1000s 2019$)	390.465	286.726	406.597	262.969	16.133	0.410
Bathrooms	2.077	0.770	2.104	0.722	0.027	0.001
Bedrooms	3.235	0.837	3.275	0.807	0.040	0.001
Interior Area (ft.^{2})	1.781	0.739	1.793	0.714	0.012	0.001
Age (years)	40.022	28.494	34.803	25.508	-5.219	0.040
Levee Protected	0.121	0.326	0.132	0.339	0.012	0.000
Distance from Leveed Area (mi.)	-2.292	1.815	-2.213	1.821	0.079	0.003
Distance from Levee (mi.)	3.659	2.560	3.622	2.524	-0.037	0.004
Distance from Water (mi.)	0.631	0.480	0.643	0.484	0.012	0.001
Loan Amount (1000s 2019 $)	—	—	247.260	160.701	—	—
Income (1000s 2019 $)	—	—	128.298	732.087	—	—
Black	—	—	0.046	0.210	—	—
White	—	—	0.637	0.481	—	—
Hispanic	—	—	0.087	0.283	—	—
Asian	—	—	0.144	0.351	—	—
N	867,490		944,366			

Go back

Identification details

- Define $\Delta_t P$ = pre-/post-levee construction change in a property's price
- Given the definition of the 3 example parcels and our primary specification, note that

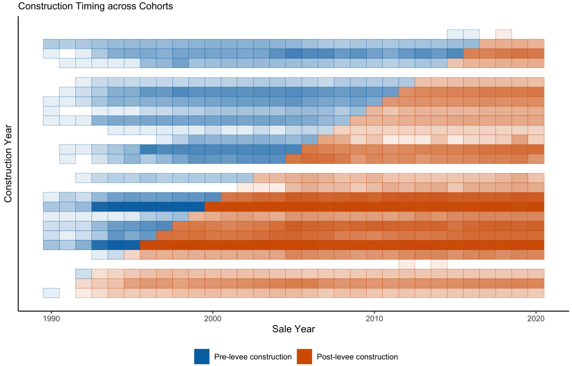
$$\begin{aligned}
\Delta_t P_A &= Macro + Protect &&= \alpha_1 + \Delta_t \mu_{l(i)t} + \Delta_t \delta_t \\
\Delta_t P_B &= Macro + Spillover &&= \alpha_2 + \Delta_t \mu_{l(i)t} + \Delta_t \delta_t \\
\Delta_t P_C &= Macro &&= \Delta_t \mu_{l(i)t} + \Delta_t \delta_t
\end{aligned}$$

- We can therefore identify the protection and spillover effects with the following double differences (DD):

$$\begin{aligned}
(Protect)_{DD} &= \Delta_t P_A - \Delta_t P_C = \alpha_1 \\
(Spillover)_{DD} &= \Delta_t P_B - \Delta_t P_C = \alpha_2
\end{aligned}$$

▸ Go back

Staggered treatment



▸ Go back

TWFE weights

- Large literature on issues w/ TWFE and staggered adoption (e.g., de Chaisemartin and D'Haultfœuille, 2020; Goodman-Bacon, 2021) ▸ Staggered treatment timing

- By the Frisch-Waugh-Lovell theorem, each observation's weight for each treatment in the TWFE specification given by:

$$\omega_{it}^{L} = \frac{\hat{\epsilon}_{it}^{L}}{\sum_{it} \hat{\epsilon}_{it}^{L}} \qquad \omega_{it}^{W} = \frac{\hat{\epsilon}_{it}^{W}}{\sum_{it} \hat{\epsilon}_{it}^{W}}$$

  where

$$\hat{\epsilon}_{it}^{L} = (T_{it} \times L_i) - \hat{\beta}_1 (T_{it} \times W_i) - \hat{\xi}_i - \hat{\delta}_t \qquad \hat{\epsilon}_{it}^{W} = (T_{it} \times W_i) - \hat{\beta}_1 (T_{it} \times L_i) - \hat{\xi}_i - \hat{\delta}_t$$

- Relationship between TWFE weights and observables may be informative
  - Positive correlation between TWFE weights and borrower income
  - Negative correlation between TWFE weights and levee overtopping scenario

▸ Go back

Spillover exposure definition: Flexible function of waterway proximity

	(1)	(2)
Post × Intersects	0.113***	0.030***
	(0.016)	(0.009)
Post × Distance to Water Bins		
[0.0, 0.1 mi]	-0.072***	-0.017**
	(0.012)	(0.007)
(0.1, 0.2 mi]	-0.062***	-0.010*
	(0.009)	(0.005)
(0.2, 0.3 mi]	-0.060***	-0.003
	(0.008)	(0.005)
(0.3, 0.4 mi]	-0.054***	-0.003
	(0.008)	(0.005)
Parcel FE	Yes	Yes
Sale Year-Sale Month FE	Yes	Yes
Sale Year-Levee Segment FE		Yes
Observations	1,244,323	1,244,323
R^2	0.924	0.948

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go back

Spillover exposure definition: Floodplain boundaries

Spillover Exposure Defined by:	Proximity to Water			Floodplain
	(1)	(2)	(3)	(4)
Post × Intersects	0.029***	0.028***	0.027***	0.028***
	(0.009)	(0.009)	(0.009)	(0.009)
Post x k mi. of Water	-0.013*	-0.011**	-0.008*	
	(0.007)	(0.005)	(0.005)	
Post × Floodplain				-0.013*
				(0.009)
$k \leq$	0.1 mi.	0.2 mi.	0.3 mi.	—
Parcel FE	Yes	Yes	Yes	Yes
Sale Year-Levee Segment FE	Yes	Yes	Yes	Yes
Sale Year-Sale Month FE	Yes	Yes	Yes	Yes
Observations	1,244,323	1,244,323	1,244,323	1,244,308
R^2	0.948	0.948	0.948	0.948

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go back

Minimal effect of levee construction on capital upgrades

	Pr(Parcel Remodeled)		
	(1)	(2)	(3)
Post x Intersects	-0.019**	-0.020**	-0.019**
	(0.008)	(0.008)	(0.008)
Intersects	0.017	0.017	0.017
	(0.024)	(0.024)	(0.024)
Post x k mi. of Water	-0.010	-0.008*	-0.002
	(0.007)	(0.004)	(0.004)
Tract FE	Yes	Yes	Yes
Sale Year-Levee Segment FE	Yes	Yes	Yes
Sale Year-Sale Month FE	Yes	Yes	Yes
Parcel Controls	Yes	Yes	Yes
$k \leq$	0.1 mi.	0.2 mi.	0.3 mi.
Observations	530,560	530,560	530,560
R^2	0.724	0.724	0.724

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go back

- Selection concern: behavior of flood protected HH differs
  - → E.g., ↑ capital upgrades
- No evidence that protection benefit driven by ↑ remodels post-levee construction

Inelastic housing supply attenuates spillover effect

	log(Sales Price)	
	(1)	(2)
Post x Intersects	0.028***	0.032***
	(0.009)	(0.007)
Post x Intersects x Elastic		-0.016
		(0.022)
Post x 0.2 mi. of Water	-0.011**	-0.0005
	(0.005)	(0.012)
Post x 0.2 mi. of Water x Elastic		-0.028*
		(0.014)
Parcel FE	Yes	Yes
Sale Year-Levee Segment FE	Yes	Yes
Sale Year-Sale Month	Yes	Yes
Observations	1,244,323	862,209
R^2	0.948	0.951

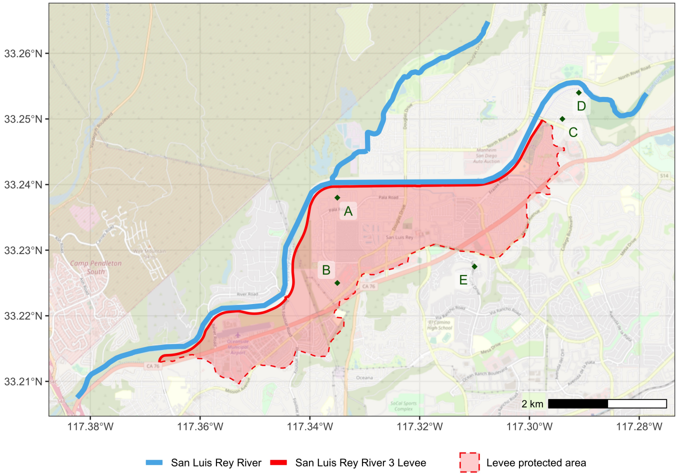
Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go back

- Concern: Levee construction influences control parcels through housing supply
- Housing supply elasticity estimates from Baum-Snow and Han (2023)
- Spillover effect larger in elastic markets
  - → Likely driven by extensive margin responses in protected areas

Broader set of effects of levee construction

San Luis Rey River 3 Levee - Oceanside, CA

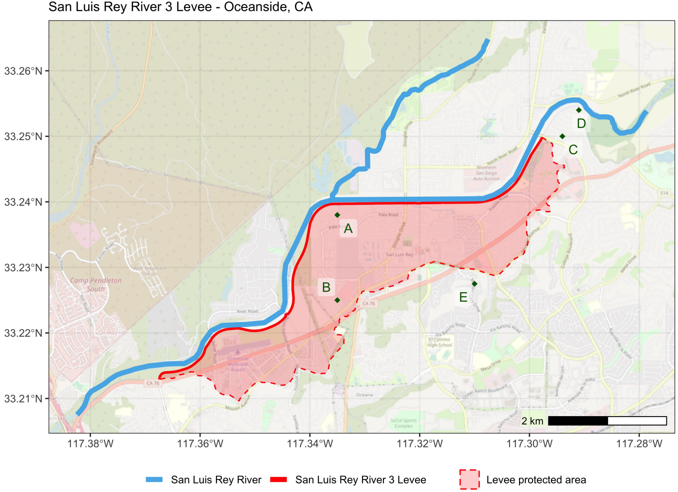


Potential effects of levee construction:

1. *Protection effects* (A, B)
2. *Adjacency effects* (A, C)
3. *Salience effects* (A)
4. *Spillover effects* (C, D)
5. *Macro effects* (A, B, C, D, E)

Go back

Broader set of effects of levee construction



- Define $\Delta_t P$ = pre-/post-levee construction change in a property's price
- Then for each property:

$$
\begin{aligned}
\Delta_t P_A &= Macro + Protect + Adjacency \\
&\quad + Salience \\
\Delta_t P_B &= Macro + Protect \\
\Delta_t P_C &= Macro + Adjacency + Spillover \\
\Delta_t P_D &= Macro + Spillover \\
\Delta_t P_E &= Macro
\end{aligned}
$$

$\Rightarrow$ Can use changes in prices across property types to identify effects

Go back

Expanded capitalization estimates

	$k \leq 0.1$ mi.		$k \leq 0.2$ mi.		$k \leq 0.3$ mi.	
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Intersects (α_1)	0.098***	0.026***	0.097***	0.027***	0.095***	0.027***
	(0.015)	(0.008)	(0.015)	(0.009)	(0.015)	(0.009)
Post × k mi. of Levee (α_2)	-0.0005	-0.019	0.054*	0.014	0.070***	0.018
	(0.043)	(0.029)	(0.029)	(0.015)	(0.024)	(0.011)
Post × k mi. of Water (α_3)	-0.062***	-0.014**	-0.063***	-0.012***	-0.066***	-0.009*
	(0.012)	(0.007)	(0.009)	(0.005)	(0.008)	(0.005)
Post × Intersects × k mi. of Levee (α_4)	-0.068	-0.021	-0.101***	-0.043**	-0.110***	-0.037**
	(0.050)	(0.035)	(0.037)	(0.019)	(0.032)	(0.016)
Parcel FE	Yes	Yes	Yes	Yes	Yes	Yes
Sale Year-Sale Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Sale Year-Levee Segment FE		Yes		Yes		Yes
Observations	1,279,984	1,279,984	1,279,984	1,279,984	1,279,984	1,279,984
R^2	0.924	0.948	0.924	0.948	0.924	0.948

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

▸ Go back

Robustness: Nearest-neighbor DD estimator

	$k \leq 0.1$ mi.	$k \leq 0.2$ mi.	$k \leq 0.3$ mi.
Post x Intersects	0.075^{***}	0.064^{***}	0.059^{***}
	(0.005)	(0.005)	(0.005)
Observations	422,265	422,265	422,265
R^2	0.713	0.720	0.727
Post x k mi. of Water	0.016^{**}	-0.0006	-0.014^{***}
	(0.007)	(0.004)	(0.003)
Observations	183,036	488,325	840,123
R^2	0.574	0.574	0.575

Cluster-robust standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

- Kuminoff and Pope, 2014 and Banzhaf, 2021 demonstrate bias from panel variation in settings with shifting price gradients (i.e., sorting)
- Follow Muehlenbachs et al., 2015 and match treated parcels to controls within years

▸ Go back

Robustness: Sample restrictions

	Preferred Spec.	Alternative Sample Restrictions			
	(1)	(2)	(3)	(4)	(5)
Post x Intersects (α_1)	0.028***	0.023***	0.033***	0.022**	0.024**
	(0.009)	(0.008)	(0.011)	(0.010)	(0.010)
Post x k mi. of Water (α_2)	-0.011**	-0.012**	-0.012**	-0.003	0.0009
	(0.005)	(0.005)	(0.005)	(0.007)	(0.010)
Donut BW (mi)	0.1	0.0	0.2	0.1	0.1
Control/Spillover BW (mi)	5.0	5.0	5.0	2.0	1.0
Parcel FE	Yes	Yes	Yes	Yes	Yes
Sale Year-Levee Segment FE	Yes	Yes	Yes	Yes	Yes
Sale Year-Sale Month	Yes	Yes	Yes	Yes	Yes
Observations	1,244,323	1,279,984	1,208,892	521,695	310,298
R^2	0.948	0.948	0.948	0.950	0.950

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go back

Robustness: Fixed effects

	$k \leq 0.1$ mi.		$k \leq 0.2$ mi.		$k \leq 0.3$ mi.	
	(1)	(2)	(3)	(4)	(5)	(6)
Post x Intersects (α_1)	0.054***	0.029***	0.053***	0.028***	0.053***	0.027***
	(0.011)	(0.009)	(0.011)	(0.009)	(0.011)	(0.009)
Post x k mi. of Water (α_2)	-0.012	-0.013*	-0.009*	-0.011**	-0.006	-0.008*
	(0.007)	(0.007)	(0.005)	(0.005)	(0.005)	(0.005)
Parcel, Month-of-sample FE	Yes	Yes	Yes	Yes	Yes	Yes
Sale Year-Levee System FE	Yes		Yes		Yes	
Sale Year-Levee Segment FE		Yes		Yes		Yes
Observations	1,244,323	1,244,323	1,244,323	1,244,323	1,244,323	1,244,323
R^2	0.948	0.948	0.948	0.948	0.948	0.948

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go back

Robustness: Weighted-least squares

	$k \leq 0.1$ mi.		$k \leq 0.2$ mi.		$k \leq 0.3$ mi.	
	(1)	(2)	(3)	(4)	(5)	(6)
Post x Intersects (α_1)	0.029***	0.039***	0.028***	0.038***	0.027***	0.038***
	(0.009)	(0.007)	(0.009)	(0.007)	(0.009)	(0.007)
Post x k mi. of Water (α_2)	-0.013*	-0.016**	-0.011**	-0.011**	-0.008*	-0.009**
	(0.007)	(0.007)	(0.005)	(0.005)	(0.005)	(0.004)
Weights	None	Income	None	Income	None	Income
Parcel FE	Yes	Yes	Yes	Yes	Yes	Yes
Sale Year-Levee Segment FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-of-sample FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,244,323	646,825	1,244,323	646,825	1,244,323	646,825
R^2	0.948	0.987	0.948	0.987	0.948	0.987

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go back

Event study specification

- Separately estimate the following specifications on the relevant subset of treatment and control parcels

$$\log P_{it} = \sum_{\tau=-5}^{10} \alpha_1^{\tau} \Big(L_i \times \mathbb{1}\{t = (LeveeYear_i + \tau)\} \Big) + \xi_i + \mu_{l(i)t} + \delta_t + \varepsilon_{it}$$

$$\log P_{it} = \sum_{\tau=-5}^{10} \alpha_2^{\tau} \Big(W_i \times \mathbb{1}\{t = (LeveeYear_i + \tau)\} \Big) + \xi_i + \mu_{l(i)t} + \delta_t + \varepsilon_{it}$$

where

- $LeveeYear_i$ indicates the year parcel i's nearest levee segment is constructed
- $\mathbb{1}\{t = (LeveeYear_i + \tau)\}$ is an indicator variable that equals 1 if a parcel's transaction year t occurs in event times τ relative to the levee construction year and zero otherwise

- Normalize treatment effects relative to $\tau = -1$

Go back

Mechanism: FEMA accreditation

	$k \leq 0.1$ mi. (1)	$k \leq 0.2$ mi. (2)	$k \leq 0.3$ mi. (3)
Post × k mi. of Water	-0.013*	-0.012**	-0.009**
	(0.007)	(0.005)	(0.005)
Post × Intersects	-0.005	-0.007	-0.008
	(0.019)	(0.019)	(0.019)
Post × Intersects × FEMA-accredited	0.052**	0.053***	0.053***
	(0.021)	(0.021)	(0.021)
Parcel FE	Yes	Yes	Yes
Sale Year-Levee Segment FE	Yes	Yes	Yes
Sale Year-Sale Month FE	Yes	Yes	Yes
Observations	1,244,323	1,244,323	1,244,323
R^2	0.948	0.948	0.948

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go back

Flood exposure specification

- Generate indicators of flood-related Presidential Disaster Declarations (PDDs) in annual bins

- Separately estimate the following specifications on the relevant subset of treatment and control parcels, restricting to transactions post levee construction

$$\log P_{it} = \sum_{\tau=-3}^{3} \alpha_1^{\tau} \left(L_i \times PDD_{c(i)t}^{\tau} \right) + \xi_i + \nu_{c(i)t} + \delta_t + \varepsilon_{it}$$

$$\log P_{it} = \sum_{\tau=-3}^{3} \alpha_2^{\tau} \left(W_i \times PDD_{c(i)t}^{\tau} \right) + \xi_i + \nu_{c(i)t} + \delta_t + \varepsilon_{it}$$

where

  - $PDD_{c(i)t}^{\tau}$ is a binary variable that equals 1 if the transaction of parcel i occurs in a county c that experiences a federal disaster declaration τ years relative to sale year t and 0 otherwise
  - $\nu_{c(i)t}$ is a county-by-year fixed effect

- Normalize treatment effects relative to $\tau = -1$

▸ Go back

Pooled flood exposure results

	(1)	(2)	(3)
High Flood Exp.	-0.005*	9.69×10^{-5}	-0.001
	(0.003)	(0.003)	(0.003)
High Flood Exp. × Intersects	0.043***		0.044***
	(0.006)		(0.006)
High Flood Exp. × Near Water		-0.027***	-0.026***
		(0.004)	(0.004)
Parcel FE	Yes	Yes	Yes
Sale Year-Levee Project FE	Yes	Yes	Yes
Sale Year-Sale Month FE	Yes	Yes	Yes
Observations	745,302	745,067	858,428
R^2	0.959	0.958	0.958

- Restrict data to transactions that occur after levee construction
- Regress log of real sale price on interactions between relevant treatment indicators and an indicator of whether a transaction is "high flood exposed"
    - Define as a transaction of a parcel falling within a county with a greater than 75th percentile value of lagged 24-month count of flood-related storm events (NOAA)

Go back

Effects of levee construction on NFIP outcomes

	$k \leq 0.1$ mi.		$k \leq 0.2$ mi.		$k \leq 0.3$ mi.	
	Take-up (1)	$/Claim (2)	Take-up (4)	$/Claim (5)	Take-up (7)	$/Claim (8)
Post × Intersects	-0.03***	-518.3	-0.03***	-269.9	-0.03***	-283.2
	(0.009)	(4,120.9)	(0.009)	(3,680.2)	(0.009)	(3,675.6)
Post x k mi. of Water	0.006	6,581.3**	0.001	5,478.6*	0.005	5,414.9*
	(0.007)	(3,315.2)	(0.008)	(3,181.0)	(0.009)	(3,216.0)
Sale Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Tract FE	Yes	Yes	Yes	Yes	Yes	Yes
Levee Project FE-Sale Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,284	1,374	19,284	1,374	19,284	1,374
R^2	0.9	0.9	0.9	0.9	0.9	0.9

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Regress aggregate NFIP outcomes, Y_{ct}, on a balanced panel at the census tract-by-year level:

$$Y_{ct} = \beta_1(T_{ct} \times L_c) + \beta_2(T_{ct} \times W_c) + \xi_c + \mu_{l(c)t} + \delta_t + \epsilon_{ct}$$

where ξ_c, $\mu_{l(c)t}$, and δ_t are tract, levee-by-year, and year fixed effects

▸ Go back (learning) ▸ Go back (BCA)

Aggregate benefits and costs

	Mean	Std. Dev.	Min.	Max.	N
Protection Benefits ($Mil./mi.)					
ZTRAX Housing Stock Estimate	1.066	2.136	0.007	10.930	37
USACE Housing Stock Estimate	9.608	14.027	0.000	71.202	37
Costs ($Mil./mi.)					
Construction Costs					
Total	60.781	157.651	0.189	852.161	37
Federal	49.007	130.027	0.003	664.098	29
Non-Federal	15.385	38.060	0.005	188.063	27
Spillover Effects	13.799	40.799	0.008	238.268	37
Fiscal Externalities					
Effective Tax Rate: Leveed Area	0.035	0.049	0.010	0.226	33
Effective Tax Rate: Spillover Area	0.032	0.044	0.006	0.208	34
Protection Benefits ($Mil./mi.)					
ZTRAX Housing Stock Estimate					
2% real interest rate	0.943	1.694	0.000	6.951	37
3.5% real interest rate	0.539	0.968	0.000	3.972	37
USACE Housing Stock Estimate					
2% real interest rate	21.086	73.863	0.000	449.851	37
3.5% real interest rate	12.049	42.207	0.000	257.058	37
Spillover Effects ($Mil./mi.)					
2% real interest rate	34.368	144.968	0.000	866.797	37
3.5% real interest rate	19.639	82.839	0.000	495.313	37

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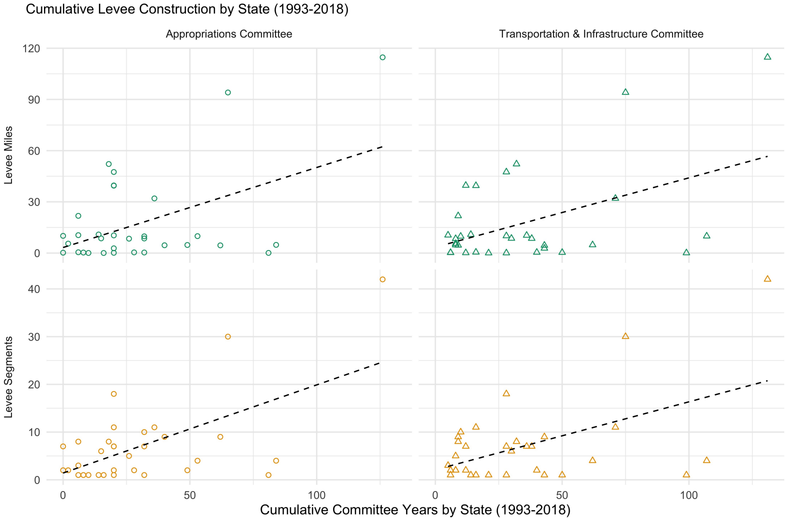
Local representation and levee construction are positively correlated



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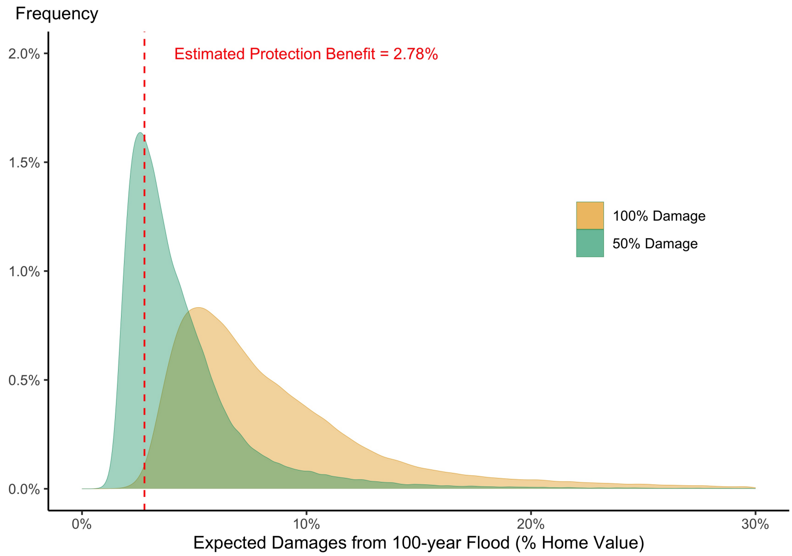
Incomplete capitalization of flood risk changes



Extensive margin impacts

Dependent Variable:	asinh(Home Age)		
Model:	(1)	(2)	(3)
Post x Intersects	-0.233**	-0.214**	-0.202**
	(0.095)	(0.095)	(0.095)
Post x k mi. of Water	0.223***	0.193***	0.159***
	(0.052)	(0.037)	(0.034)
Parcel FE	Yes	Yes	Yes
Sale Year-Levee Segment FE	Yes	Yes	Yes
Sale Year-Sale Month	Yes	Yes	Yes
$k \leq$	0.1 mi.	0.2 mi.	0.3 mi.
Observations	1,244,323	1,244,323	1,244,323
R^2	0.915	0.915	0.915

Clustered (Tract FE) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

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References I

Auffhammer, M. (2022).Climate Adaptive Response Estimation: Short and long run impacts of climate change on residential electricity and natural gas consumption. *Journal of Environmental Economics and Management*, *114*, 102669.

Bakkensen, L. A., & Barrage, L. (2021).Going Underwater? Flood Risk Belief Heterogeneity and Coastal Home Price Dynamics. *The Review of Financial Studies*, hhab122.

Banzhaf, H. S. (2021).Difference-in-Differences Hedonics [Publisher: The University of Chicago Press]. *Journal of Political Economy*, *129*(8), 2385–2414.

Barrage, L. (2020).The Fiscal Costs of Climate Change. *AEA Papers and Proceedings*, *110*, 107–112.

Barreca, A., Clay, K., Deschenes, O., Greenstone, M., & Shapiro, J. S. (2016).Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the Twentieth Century. *Journal of Political Economy*, *124*(1), 105–159.

Baylis, P., & Boomhower, J. (2021).The Economic Incidence of Wildfire Suppression in the United States. *American Economic Journal: Applied Economics*, *Forthcoming*, 51.

Beltrán, A., Maddison, D., & Elliott, R. (2019).The impact of flooding on property prices: A repeat-sales approach. *Journal of Environmental Economics and Management*, *95*, 62–86.

Bernstein, A., Gustafson, M. T., & Lewis, R. (2019).Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics*, *134*(2), 253–272.

Bin, O., Kruse, J. B., & Landry, C. E. (2008).Flood Hazards, Insurance Rates, and Amenities: Evidence From the Coastal Housing Market [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1539-6975.2007.00248.x]. *Journal of Risk and Insurance*, *75*(1), 63–82.

Bin, O., & Landry, C. E. (2013).Changes in implicit flood risk premiums: Empirical evidence from the housing market. *Journal of Environmental Economics and Management*, *65*(3), 361–376.

Burke, M., & Emerick, K. (2016).Adaptation to Climate Change: Evidence from US Agriculture. *American Economic Journal: Economic Policy*, *8*(3), 106–140.

Busso, M., Gregory, J., & Kline, P. (2013).Assessing the Incidence and Efficiency of a Prominent Place Based Policy. *American Economic Review*, *103*(2), 897–947.

de Chaisemartin, C., & D'Haultfœuille, X. (2020).Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects. *American Economic Review*, *110*(9), 2964–2996.

Dundas, S. J. (2017).Benefits and ancillary costs of natural infrastructure: Evidence from the New Jersey coast. *Journal of Environmental Economics and Management*, *85*, 62–80.

Dundas, S. J., & Lewis, D. J. (2020).Estimating Option Values and Spillover Damages for Coastal Protection: Evidence from Oregon's Planning Goal 18 [Publisher: The University of Chicago Press]. *Journal of the Association of Environmental and Resource Economists*, *7*(3), 519–554.

Fell, H., & Kousky, C. (2015).The value of levee protection to commercial properties. *Ecological Economics*, *119*, 181–188.

Fried, S. (2021).Seawalls and Stilts: A Quantitative Macro Study of Climate Adaptation. *The Review of Economic Studies*, (0), 42.

Gallagher, J. (2014).Learning about an Infrequent Event: Evidence from Flood Insurance Take-Up in the United States. *American Economic Journal: Applied Economics*, *6*(3), 206–233.

References II

Goldsmith-Pinkham, P., Gustafson, M. T., Schwert, M., & Lewis, R. C. (2021).Sea Level Rise Exposure and Municipal Bond Yields. *Working Paper*, 76.

Goodman-Bacon, A. (2021).Difference-in-differences with variation in treatment timing. *Journal of Econometrics*, *225*(2), 254–277.

Gopalakrishnan, S., Landry, C. E., & Smith, M. D. (2018).Climate Change Adaptation in Coastal Environments: Modeling Challenges for Resource and Environmental Economists [Publisher: The University of Chicago Press]. *Review of Environmental Economics and Policy*, *12*(1), 48–68.

Graff Zivin, J., Liao, Y., & Panassie, Y. (2022).How Hurricanes Sweep Up Housing Markets: Evidence from Florida. *Working Paper*, 60.

Greenstone, M., Hornbeck, R., & Moretti, E. (2010).Identifying Agglomeration Spillovers: Evidence from Winners and Losers of Large Plant Openings. *Journal of Political Economy*, *118*(3), 536–598.

Hallstrom, D. G., & Smith, V. K. (2005).Market responses to hurricanes. *Journal of Environmental Economics and Management*, *50*(3), 541–561.

Heine, R. A., & Pinter, N. (2012).Levee effects upon flood levels: An empirical assessment [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/hyp.8261]. *Hydrological Processes*, *26*(21), 3225–3240.

Kahn, M. E. (2016).The Climate Change Adaptation Literature. *Review of Environmental Economics and Policy*, *10*(1), 166–178.

Kelly, D. L., & Molina, R. (2022).Adaptation Infrastructure and its Effects on Property Values in the Face of Climate Risk. *Working Paper*.

Kuminoff, N. V., & Pope, J. C. (2014).Do "Capitalization Effects" for Public Goods Reveal the Public's Willingness to Pay? *International Economic Review*, *55*(4), 1227–1250.

Liao, Y. (, & Kousky, C. (2022).The Fiscal Impacts of Wildfires on California Municipalities [Publisher: The University of Chicago Press]. *Journal of the Association of Environmental and Resource Economists*, *9*(3), 455–493.

Mast, E. (2020).Race to the Bottom? Local Tax Break Competition and Business Location. *American Economic Journal: Applied Economics*, *12*(1), 288–317.

Muehlenbachs, L., Spiller, E., & Timmins, C. (2015).The Housing Market Impacts of Shale Gas Development. *American Economic Review*, *105*(12), 3633–3659.

Murfin, J., & Spiegel, M. (2020).Is the Risk of Sea Level Rise Capitalized in Residential Real Estate? *The Review of Financial Studies*, *33*(3), 1217–1255.

Ortega, F., & Taşpınar, S. (2018).Rising sea levels and sinking property values: Hurricane Sandy and New York's housing market. *Journal of Urban Economics*, *106*, 81–100.

Remo, J. W. F., Ickes, B. S., Ryherd, J. K., Guida, R. J., & Therrell, M. D. (2018).Assessing the impacts of dams and levees on the hydrologic record of the Middle and Lower Mississippi River, USA. *Geomorphology*, *313*, 88–100.

Wagner, K. R. H. (2021).Adaptation and Adverse Selection in Markets for Natural Disaster Insurance. *American Economic Journal: Economic Policy*, *Forthcoming*.

Walsh, P., Griffiths, C., Guignet, D., & Klemick, H. (2019).Adaptation, Sea Level Rise, and Property Prices in the Chesapeake Bay Watershed [Publisher: University of Wisconsin Press]. *Land Economics*, *95*(1), 19–34.

Wang, H. (2021).Flood Your Neighbors: Spillover Effects of Levee Building. *Working Paper*, 55.