Private Benefits from Public Investment in Climate Adaptation and Resilience

Joseph E. Aldy
joseph_aldy@hks.harvard.edu
Harvard Kennedy School

Jacob Bradt
jbradt@g.harvard.edu
Harvard Kennedy School

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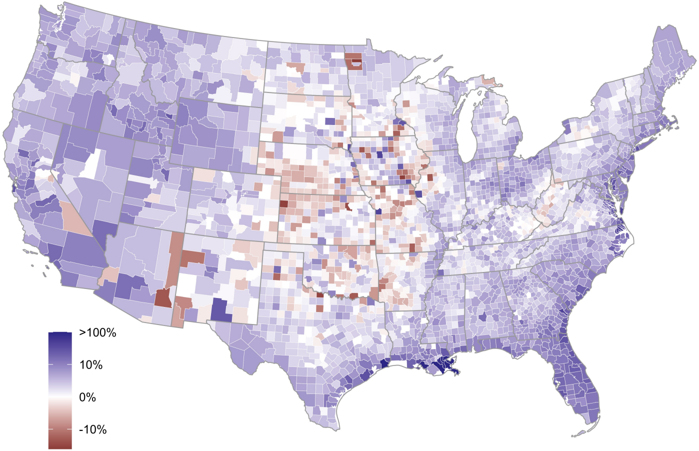
Flood risk in the US

Estimated Change in Properties with Flooding (2021-2051)



Source: First Street Foundation and Authors' calculations

- Flood events most costly disasters in US
- 2017: ∼\$300B in damages (NOAA)
- Share of US properties at risk of regular flooding ↑ 8.2% over next 30 years (FSF)

Flood risk in the US

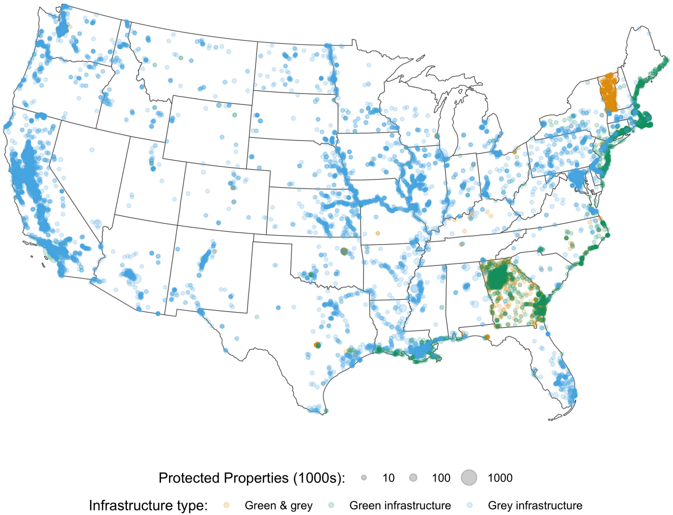
- Infrastructure Investment and Jobs Act: \$50+ billion for climate adaptation
- Historically, major form of flood risk adaptation: levees ▸ Adaptation types

Summary of findings

- As climate risks increase, public adaptation policy will prompt questions about the magnitude and distribution of benefits
- We use novel data on areas protected by US Army Corps of Engineers (USACE) levees to estimate the magnitude and incidence of this geographically-differentiated subsidy
  - → Estimate subsidized flood protection benefits amount to 13% of a home's value
  - → Largest subsidies flow to higher-income households
  - → Evidence of sorting into levee-protected areas ex-post by higher-income households
- Next steps
  - Extending analysis to other forms of public investment in flood risk adaptation
  - Explore likely behavioral responses using simple theory model

Outline

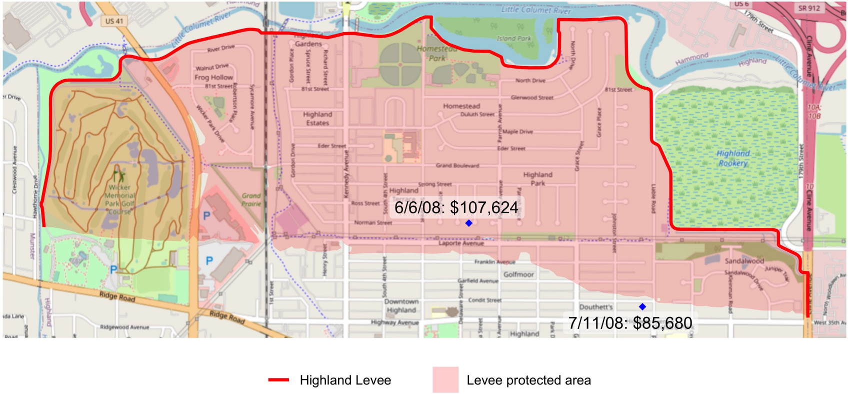
Flood risk adaptation infrastructure in the US



- Data on flood risk adaptation projects from First Street Foundation
- FSF data provide granular, hydrologically-accurate spatial extent of areas protected by projects
  → Identifies project beneficiaries

Estimating magnitude of public adaptation subsidies: Capitalization

Highland Levee - Highland, IN (constructed 2010)

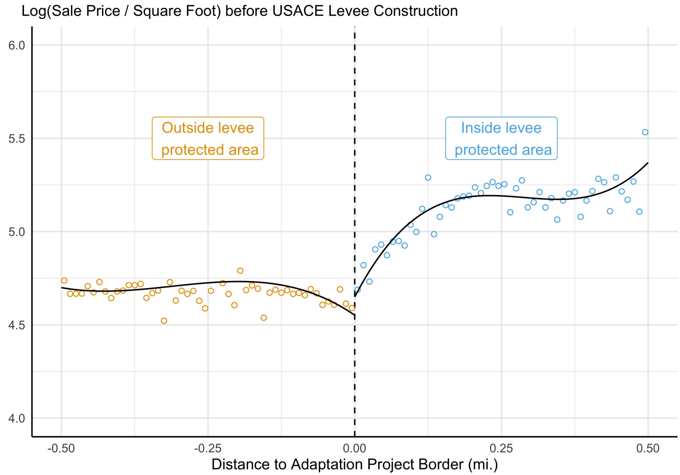


- Combine FSF adaptation project data with home sale data from Zillow (1990-present)
- Spatial RDD: compare sale price of homes on either side of protected area boundary

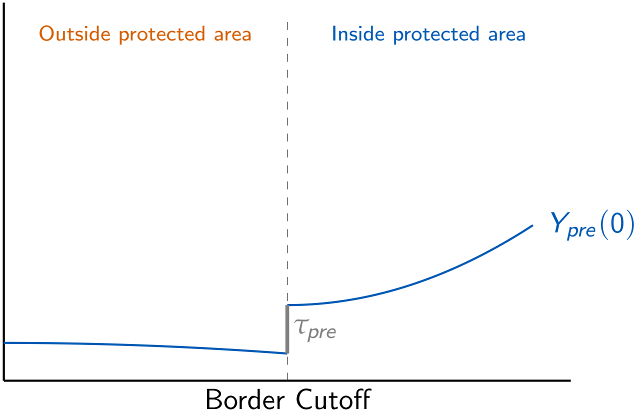
Endogeneity of adaptation infrastructure siting

- Problem: Location of protected areas is endogenous; may be affected by home values or other local characteristics
- USACE levees appear to protect higher value homes
  - Estimate pre-construction discontinuity of $+6\%$
  - Evidence that higher income areas more likely to receive an adaptation project

▸ Treatment endogeneity

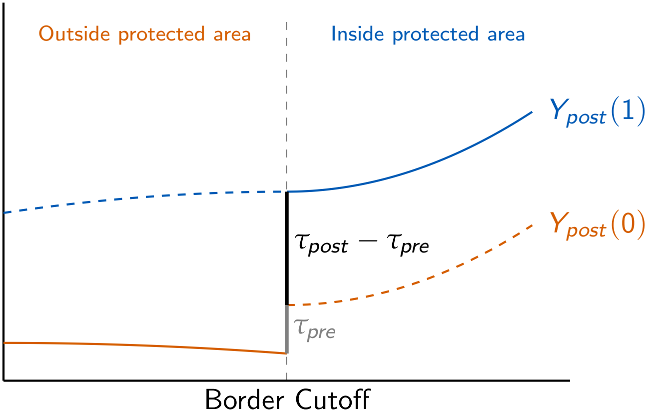


Addressing siting endogeneity: Difference-in-discontinuities (DiRD)



- Simple two-period setup: $t \in \{pre, post\}$
- Logic similar to DiD:
  - $\rightarrow$ Now focus on difference in the discontinuity before and after treatment, rather than avg. outcomes
- Pre-treatment RD measures effects of other changes and non-treatment sorting

Addressing siting endogeneity: Difference-in-discontinuities (DiRD)



- Simple two-period setup: $t \in \{pre, post\}$
- Logic similar to DiD:
  - $\rightarrow$ Now focus on difference in the discontinuity before and after treatment, rather than avg. outcomes
- Difference of post- and pre-treatment RD is the LATE of interest

Difference-in-discontinuities (DiRD)

- Estimand, identifying assumptions, and estimators formalized by Grembi et al. (2016) and Butts (2021)

- Let the sale price of property i at time $t \in \{pre, post\}$ be given by:

$$Y_{it} = f_t(D_i) + \underbrace{\gamma(D_i)\mathbb{1}(D_i \geq 0)}_{\text{pre-treatment discontinuity}} + \underbrace{\tau(D_i)\mathbb{1}(D_i \geq 0)\mathbb{1}(t = post)}_{\text{post-treatment discontinuity}} + \varepsilon_{it}$$

  where

  - D_i is a measure of geographic proximity to adaptation project boundary (> 0 implies inside)
  - $f_t(D_i)$ is the (potentially) time-varying, untreated location-specific component
  - $\gamma(D_i)$ is a time-invariant discontinuity at the cutoff
  - $\tau(D_i)$ is the treatment effect of interest

Difference-in-discontinuities (DiRD)

- Identifying assumptions: combine RDD and DiD assumptions
  → Continuity in potential outcomes at cutoff
  → *Local* parallel trends: time-invariant discontinuity constant over time

▸ Identification assumptions

- Time-invariant discontinuity at cutoff, $\gamma(D_i)$, allows for
  - Compound treatment so long as it does not change concurrently with treatment of interest
  - Baseline differences between treatment and control populations

⇒ Accounts for primary endogeneity concern of non-random siting of investments

Difference-in-discontinuities (DiRD)

- Follow standard RDD approach of local linear regression: functions of D_i are linear in Euclidean distance to adaptation project boundary (e.g., $\tau(D_i) = \beta_0 + \beta_1 D_i$)

- Pooled DiRD estimator adapted from Grembi et al. (2016) using repeat sales data
  - $\rightarrow$ Jointly estimates pre- and post- construction boundary RD

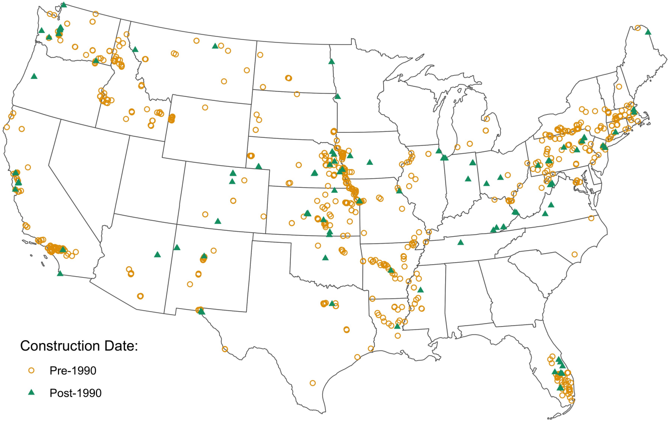
- Restrict sample to observations in the interval $D_i \in [-h, h]$ and estimate:

$$Y_{it} = \underbrace{\delta_0 + \delta_1 D_i + A_i(\gamma_0 + \gamma_1 D_i)}_{\text{Pre-construction RDD}} + \underbrace{T_{it}[\alpha_0 + \alpha_1 D_i + A_i(\beta_0 + \beta_1 D_i)]}_{\text{Post-construction RDD}} + f(coord_i) + \phi_i + \phi_{a(i)} + \phi_t + \varepsilon_{it}$$

where

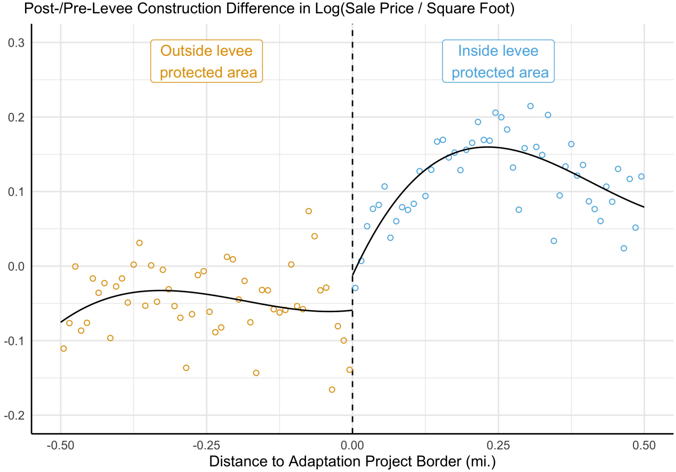
- $A_i = \mathbb{1}(D_i \geq 0)$
- ϕ_i, $\phi_{a(i)}$, ϕ_t= parcel, adaptation project, and month-of-sample FE, respectively
- $f(coord_i)$ = flexible polynomial in latitude-longitude following Dell (2010)
- β_0= DiRD estimand, coefficient on full treatment ($A_i \times T_{it}$)

Setting: USACE levees



- Focus on a subset of projects funded at the Federal level with consistently sourced data: USACE levees
- Benefits: (1) construction date available; (2) similar set of project types
- Soon: data on construction date for other project types

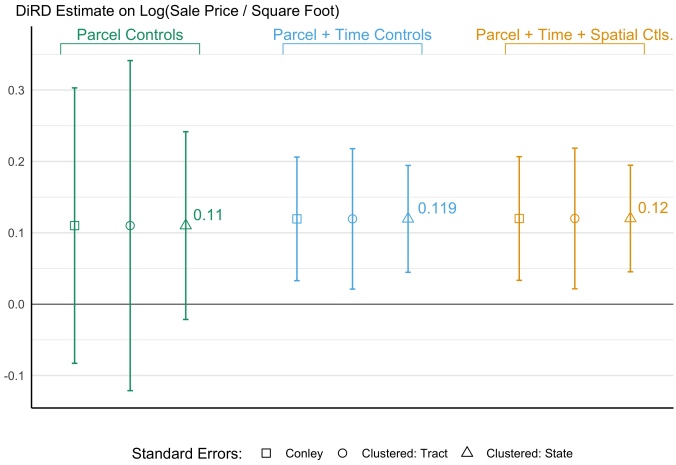
Pooled DiRD Estimates



- RD plot shows discontinuity in pre-/post-construction difference of average sale price
- Calonico et al. (2014) optimal bandwidth selector: $h = 0.38$ mi.
- Robustness check: RDD in pre-/post-construction difference

▸ RV density ▸ Results table ▸ BW robustness ▸ RDD-in-differences ▸ Falsification tests

Pooled DiRD Estimates



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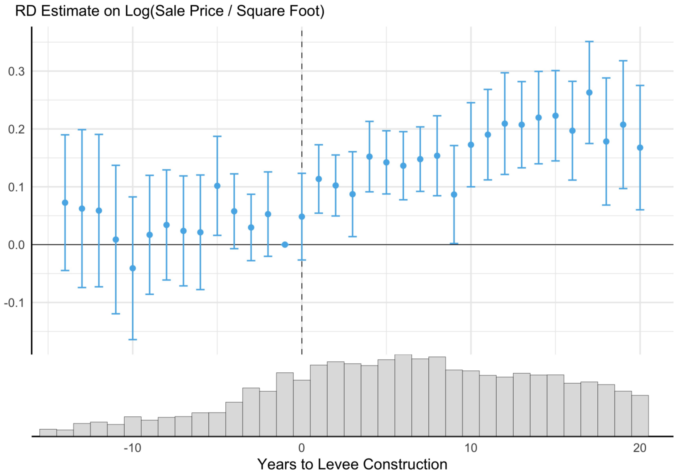
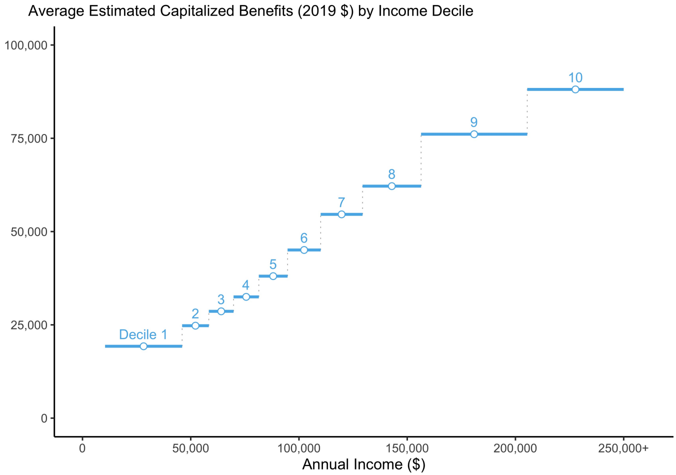
DiRD event study



- Joint estimation of boundary RDD by year relative to levee construction
- In the process of estimating pooled DiRD estimator that is robust to staggered adoption a la Sun and Abraham (2021)

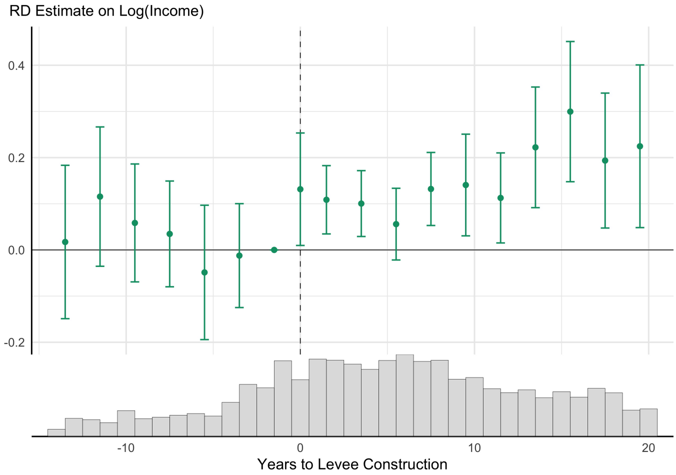
Incidence of protection benefits



- Link transaction data to demographic information using loan info, HMDA data
  - → Match 72% of ZTRAX observations w/ valid loan info

▸ HMDA match ▸ Capitalization by % income ▸ Capitalization by race

Ex-post sorting into protected areas



- Joint estimation of boundary RDD in income by 2-year bins relative to levee construction
- Pooled estimate: income ↑ 5% post-construction

▸ HMDA match

Summary and next steps

- Find suggestive evidence of substantial capitalization of flood protection benefits from public investments
- Improvements to current estimates:
  - Account for variation in discontinuity along boundary
  - Collect cost data on USACE levees for benefit-cost analysis
  - Further robustness checks
- In the process of collecting necessary data to expand current analysis to other adaptation project types in FSF database (e.g., beach renourishment, dams, pump stations)
- Policy implications
  - Simple theory model: inform likely efficiency implications on intensive/extensive margins
  - Bring attention to the siting process

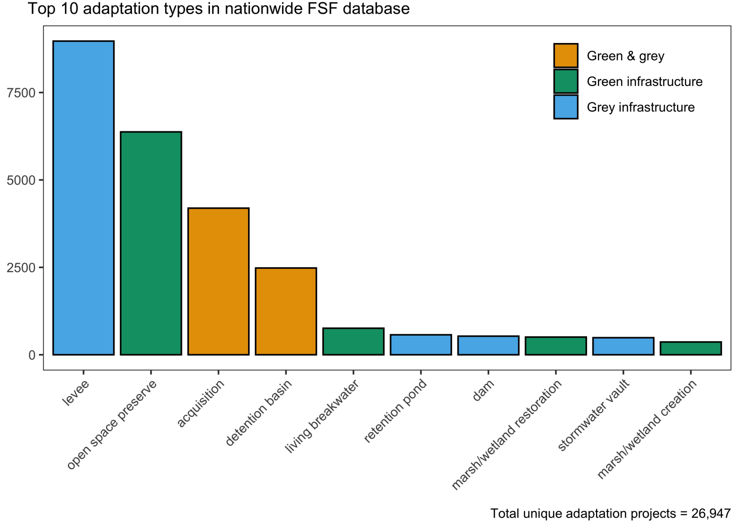
Thank you!

Please reach out with comments/questions

Email: jbradt@g.harvard.edu
Website: www.jacobbradt.com

Backup slides

Flood risk adaptation project types



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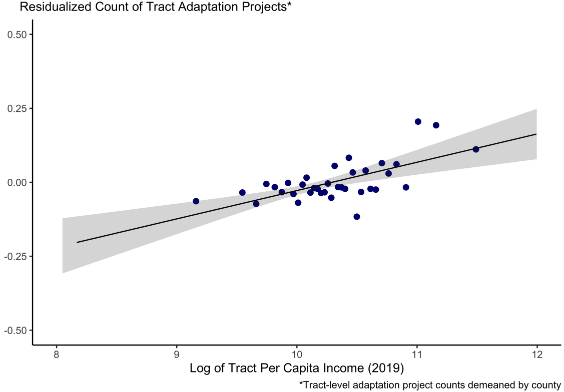
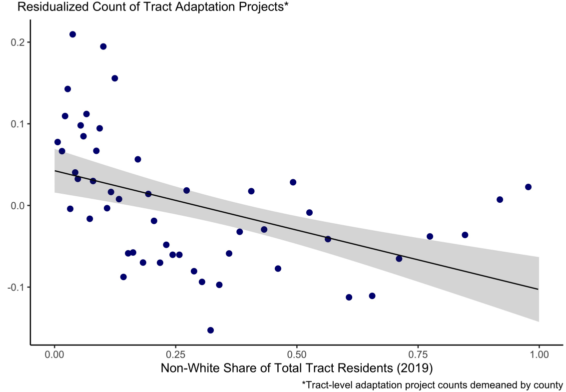
Endogeneity of adaptation infrastructure siting





- Find non-zero relationships between the number of adaptation projects in a Census tract and socioeconomic measures, suggesting non-random siting
- Above relationships are ex-post: could result from sorting post-construction

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Difference-in-discontinuities (DiRD) identification

- Identifying assumptions: combine RDD and DiD assumptions
  1. $f_t(D_i)$ is continuous at the cutoff, $D_i = 0$, $\forall t \in \{pre, post\}$
  2. $\tau(D_i)$ is continuous at the cutoff, $D_i = 0$
  3. $E[\varepsilon_{it}|D_i = D]$ is continuous at the cutoff, $D_i = 0$, $\forall t \in \{pre, post\}$
  4. $\gamma(D_i)$ is indeed time invariant ("local parallel trends")

- Continuity assumption on $E[\varepsilon_{it}|D_i = D]$ rules out time-varying sorting: households sorting into treatment post-construction in a way that influences house prices
  - Not a major concern since this sorting effect on prices is a real component of the subsidy

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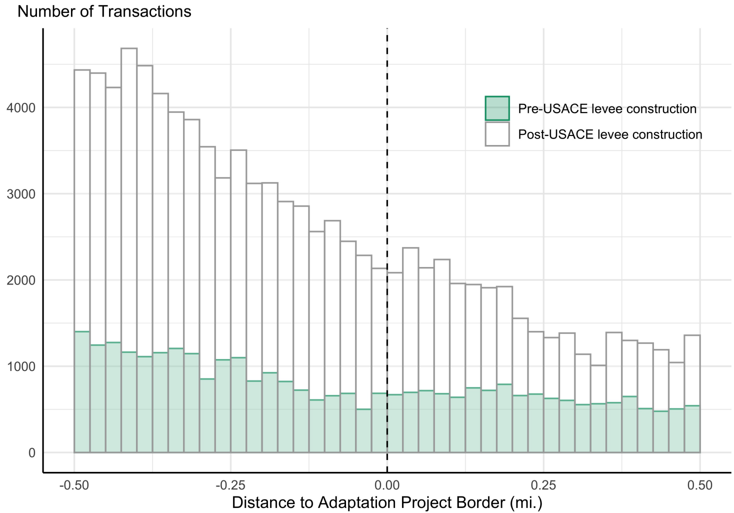
Running variable density



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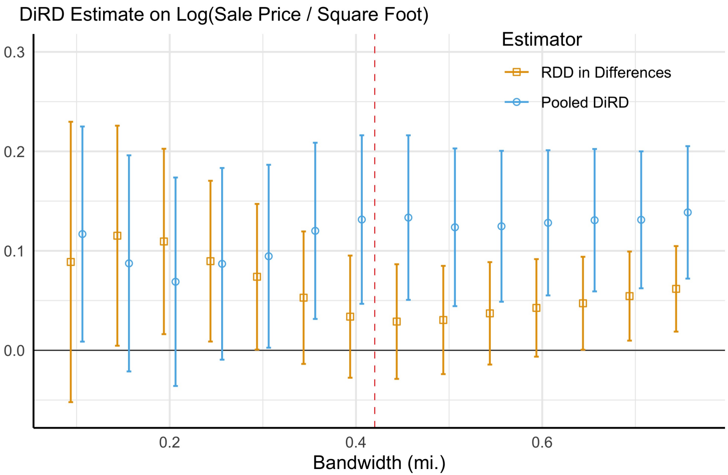
Bandwidth robustness



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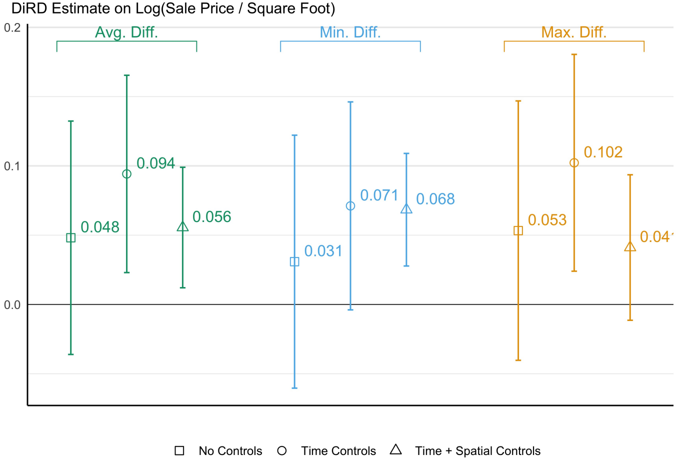
RDD on differenced data



- Three within-property, pre-/post-construction differences:
  - Diff. of average prices
  - Diff. of prices closest to construction date (“min”)
  - Diff. of prices furthest from construction date (“max”)

- Use bias-corrected estimator of Calonico et al. (2014)

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RDD on differenced data: Full estimates

	Average Difference				Minimum Difference				Maximum Difference			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
LATE	0.048	0.094	0.056	0.070	0.031	0.071	0.068	0.069	0.053	0.102	0.041	0.070
	(0.043)	(0.036)	(0.022)	(0.054)	(0.047)	(0.038)	(0.021)	(0.048)	(0.048)	(0.040)	(0.027)	(0.060)
h	0.230	0.213	0.420	0.547	0.206	0.221	0.615	0.690	0.240	0.215	0.364	0.488
Observations	4195	3883	8494	11413	3743	4021	13093	14989	4614	3926	7170	9961
Time Controls		Y	Y	Y		Y	Y	Y		Y	Y	Y
Spatial Controls			Y	Y			Y	Y			Y	Y
SE Type	BC	BC	BC	Tract	BC	BC	BC	Tract	BC	BC	BC	Tract

- Optimal bandwidth h computed following Calonico et al. (2014)
- Standard errors either robust, bias-corrected RDD SEs (Calonico et al., 2014) or bias-corrected, clustered RDD SEs (Calonico et al., 2019)
- Time controls account for temporal variation in prices before differencing
- Spatial controls include tract, levee FEs and flexible polynomial of latitude and longitude similar to Dell (2010)

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Pooled DiRD: Full estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LATE	0.110	0.110	0.110	0.119	0.119	0.119	0.120	0.120	0.120
	(0.099)	(0.117)	(0.062)	(0.044)	(0.050)	(0.035)	(0.044)	(0.050)	(0.035)
Parcel FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time Ctrls.				Y	Y	Y	Y	Y	Y
Spatial Ctrls.							Y	Y	Y
h	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380
SE Type	Conley	Tract	State	Conley	Tract	State	Conley	Tract	State
Observations	94,062	94,062	94,062	94,062	94,062	94,062	94,062	94,062	94,062
R^2	0.824	0.824	0.824	0.915	0.915	0.915	0.915	0.915	0.915

- Standard errors one of: Conley (1999), clustered by tract, or clustered by state
- Time controls include month-of-sample FEs and home age at time of sale
- Spatial controls include tract, levee FEs and flexible polynomial of latitude and longitude similar to Dell (2010)

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Falsification tests

	Construction Year + 5	Boundary at -0.05 mi.
LATE	0.025	0.049
	(0.040)	(0.043)
Parcel FE	Y	Y
Time Ctrls.	Y	Y
Spatial Ctrls.	Y	Y
h	0.380	
Standard-Errors	Conley	
Observations	28,993	
R^2	0.915	0.915

- Falsification tests: shift construction treatment date timing (+5 years) and protected area boundary (-0.05 mi. from true boundary)
- Time controls account for temporal variation in prices before differencing
- Spatial controls include tract, levee FEs and flexible polynomial of latitude and longitude similar to Dell (2010)

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Transaction-level demographic data

	Full Transaction Sample	Transactions w/ Loan Info
Nationwide Match Rate	0.397	0.716
State Match Rates		
Mean	0.299	0.640
Min	0.013	0.180
p25	0.134	0.610
Median	0.329	0.661
p75	0.419	0.723
Max	0.563	0.852

- Match ZTRAX transaction-level data (1990-2020) with demographic data from Home Mortgage Disclosure Act (2020)
- Match on: (1) Census Tract, (2) transaction year, (3) loan amount, and (4) lender name
- Match rates from literature: 54% (Bayer et al., 2016), 47% (Bakkensen and Ma, 2020) of all transactions

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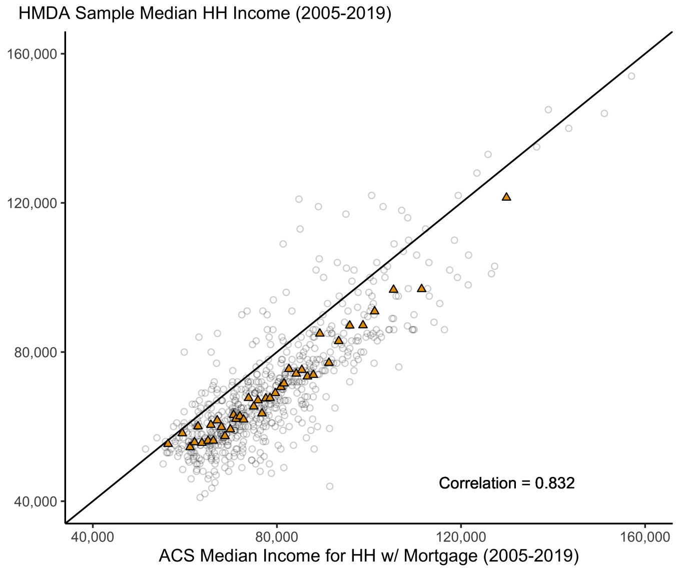
Transaction-level demographic data



- Compare ACS 1-year estimates and matched HMDA sample at state level for 2005-2019
- Can subset ACS HH income data to HH w/ mortgage
- Race/ethnicity ACS data only for owner-occupied HH

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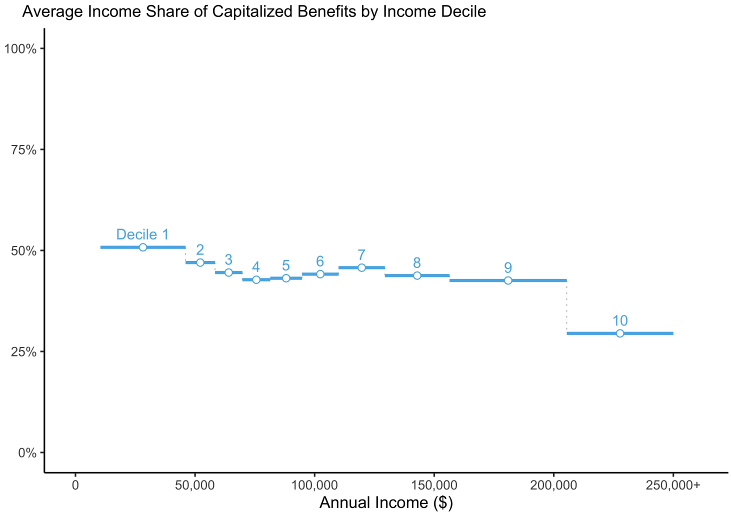
Income incidence of protection benefits



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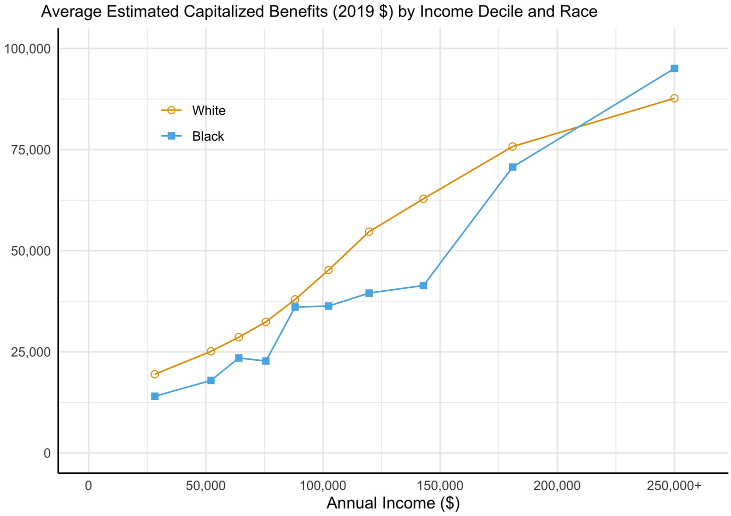

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