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Collaboration Through
Insights-Driven Solutions

Exploring Sustainability: Housing and Environmental Risks

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Estimating the Effects of Natural Disasters: Evidence from Hurricane Harvey

Wesley Miller

Texas Real Estate Research Center at Texas A&M University

Research Question

How does flood damage impact residential mobility decisions?

Annual Count of County-Level Natural Disasters

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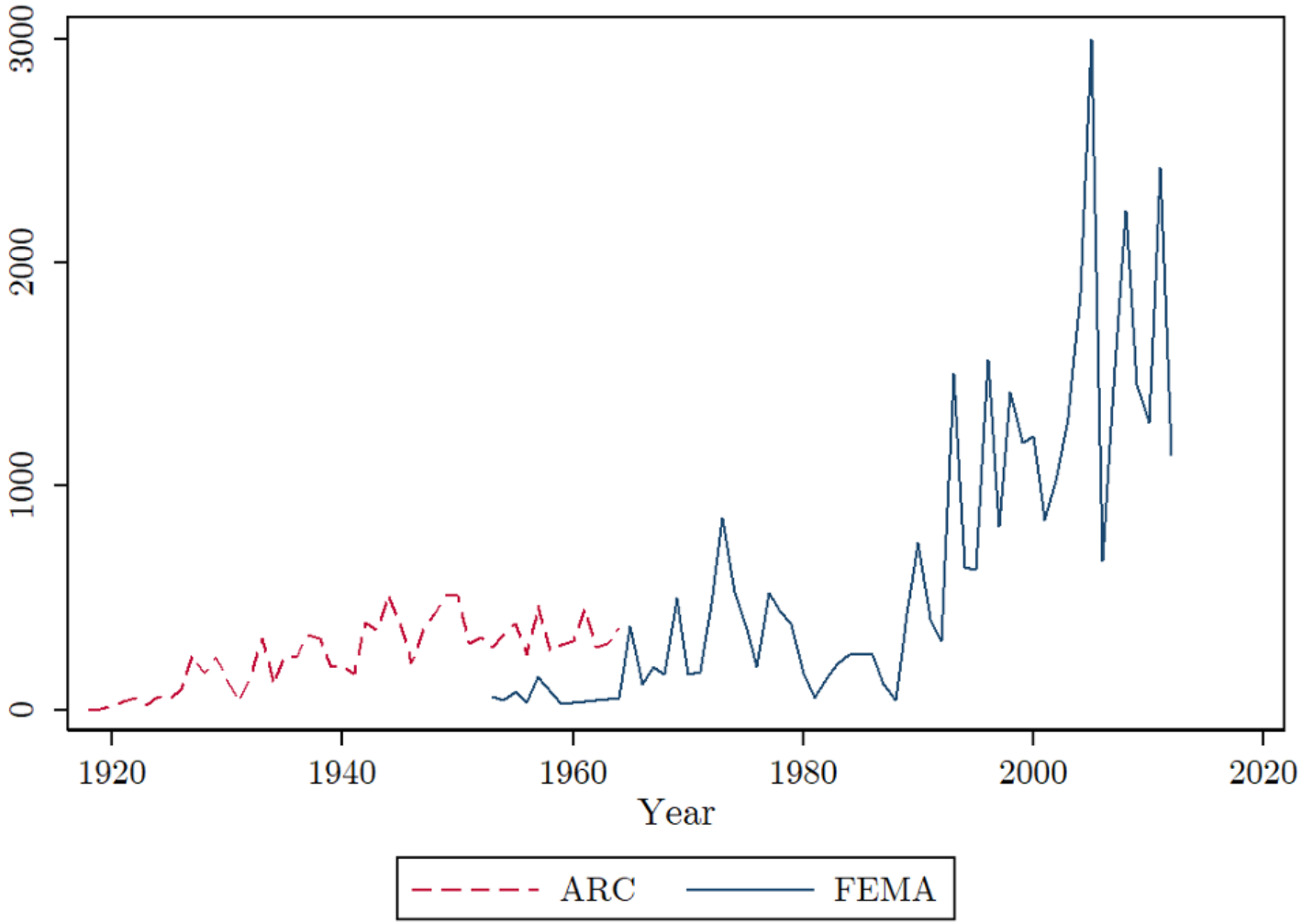
- Number of Billion Dollar Disasters Tripled During the 2010s
- More than $100 Billion Spent by Federal Agencies Since 2017
- More Disasters are Affecting More People



Source: Boustan et al. (2020)
Note: American Red Cross (ARC)

How are Individuals Affected

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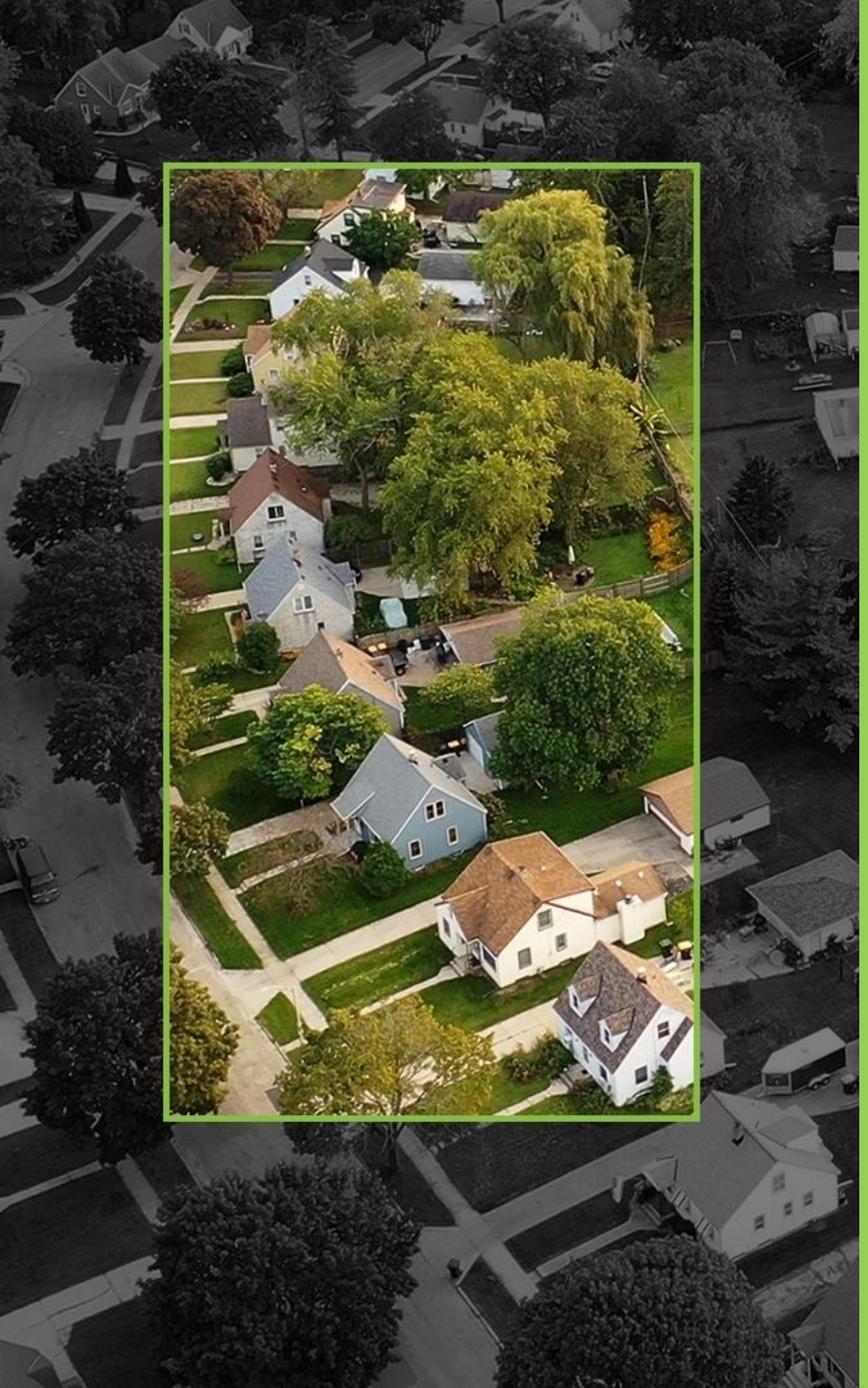
- Natural Disasters are Destructive
- Hurricane Katrina's Indirect Benefits
  - Improved Health and Decreased Mortality (Deryugina and Molitor, 2020)
  - Higher Test Scores and Earnings (Sacerdote, 2012; Deryugina et al., 2018)
- Hurricane Katrina's Idiosyncrasies
  - Near-Universal Evacuation
  - Positive Effects Based on Displacement



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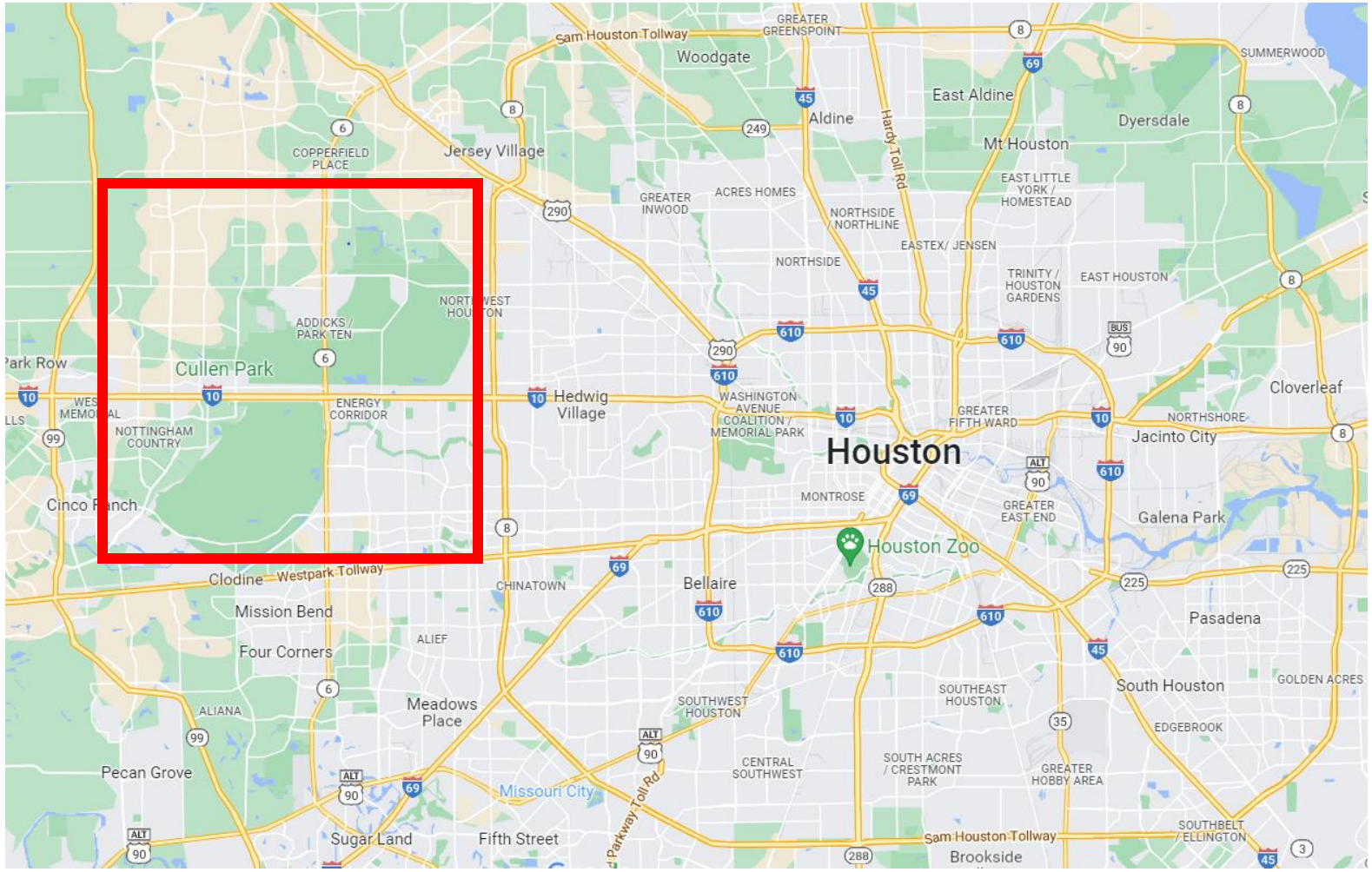
Hurricane Harvey

- Landed in Texas in August 2017
- 60 Inches of Rain
- 204,000 Homes Flooded
- $125 Billion in Damage

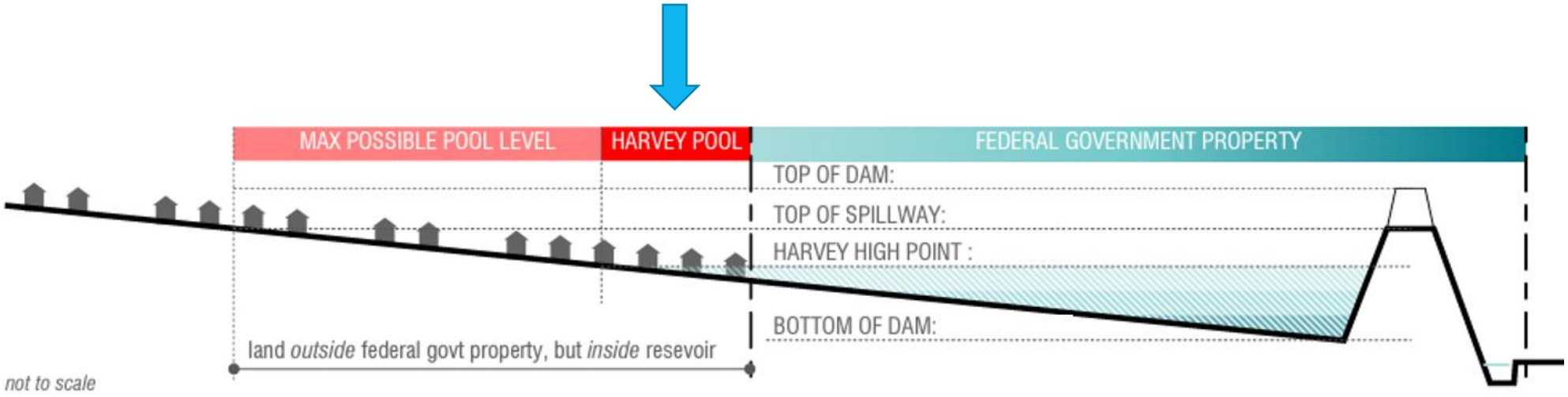
Hurricane Harvey in Houston

- Addicks and Barker Reservoirs
- Flood Plains vs. Flood Pools



Houston Reservoirs

- Federal government purchased “at-risk” land in the 1930s.
  - Water pools in this area during storms
- Residential neighborhoods developed at higher elevations.
  - Never flooded before Harvey.



Damage in the Flood Pools

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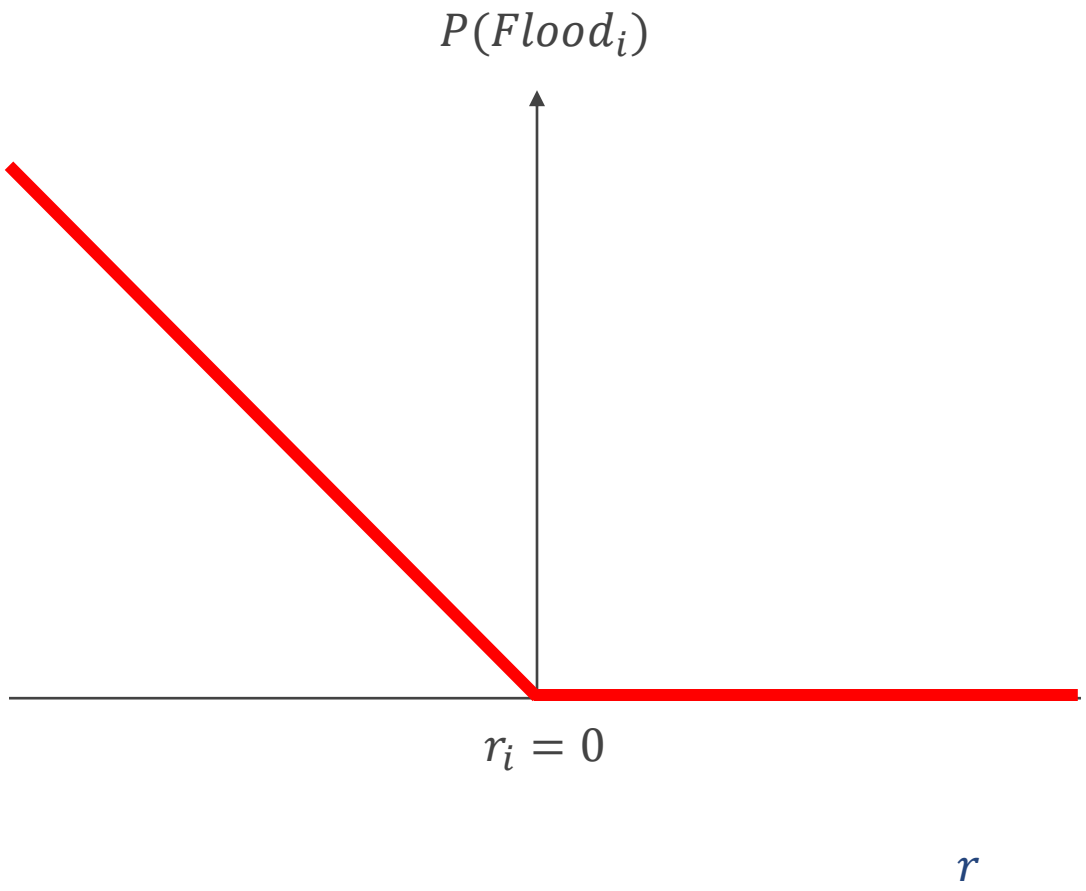
Homes in the Cinco Ranch area along S. Mason Road north of the Westpark Tollway are surrounded by water from Barker Reservoir, Saturday, September 2, 2017, in Houston.

Mark Mulligan, Staff Photographer / Staff photographer

Empirical Strategy

- $ResidentialMobility_i = \alpha_n + \beta Damage_i + \epsilon_i$
  - Damage is correlated with proximity to water, mitigation measures, elevation, etc.
- $Damage_i = \alpha_n + \gamma r_i + \beta 1\{r_i \geq 0\} + \theta r_i 1\{r_i \geq 0\} + \xi_i$
  - Regression-Kink Design
  - r_i is property i's feet above flood water



Data

Variables and Sample Selection

Data

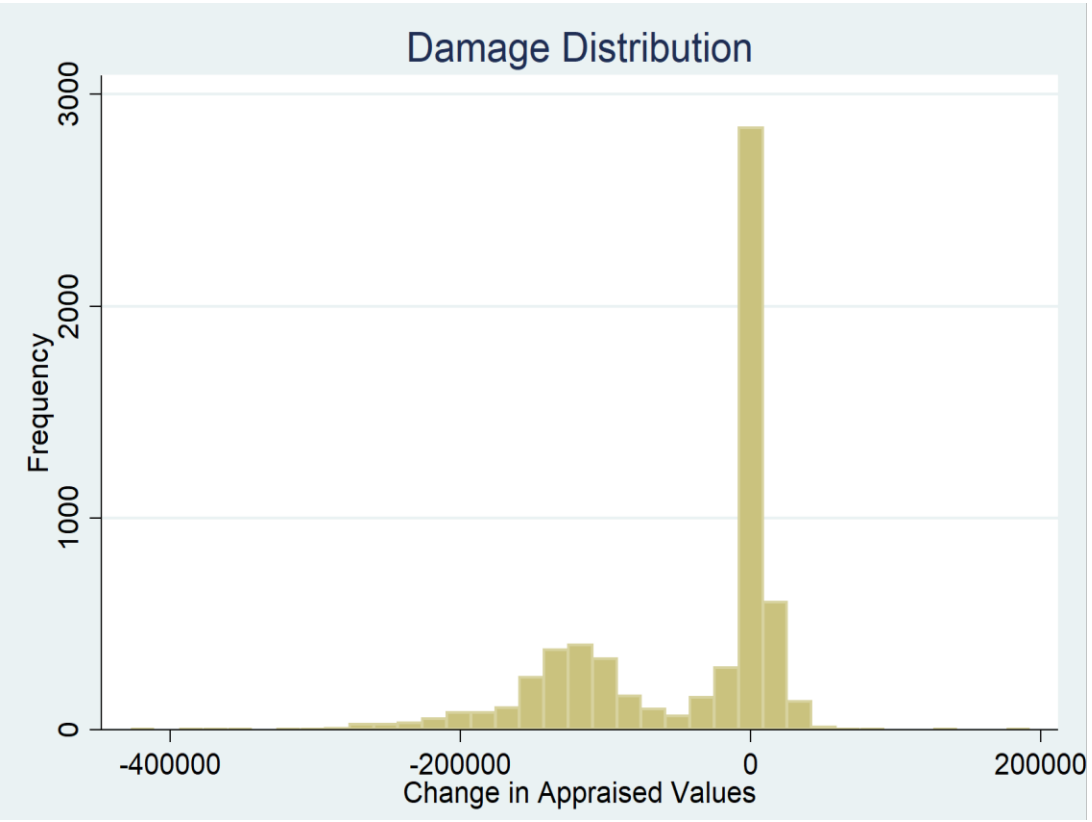
Elevation

Maximum Ground Elevation

LiDAR Data – Houston-Galveston Area Council

Assumption – Bottom of the structure lies at the maximum ground elevation.

Data



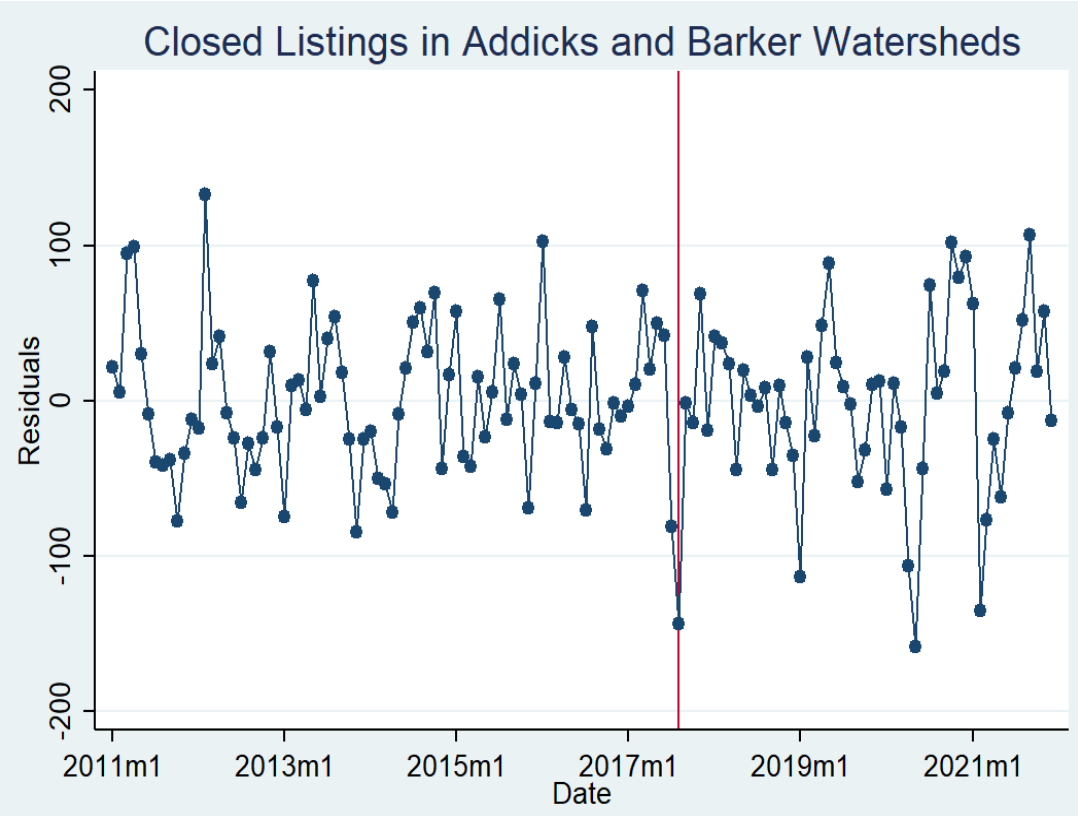
Flood Damage

$$Damage_i = Appraisal_i^{2018} - Appraisal_i^{2017}$$

County Appraisal Districts

Assumption – Appraised values reflect market values as of January 1st of each year.

Data



Residential Mobility

$P(HomeSale_i \leq x\ Months)$

Closed Listings through TX Multiple Listing Services

Assumption – Transactions through the MLS are representative of all home sales in sample area.

2 Watersheds and 2 Counties

- N = 131,143
- 99% Built Between 1973-2009
  - Median = 1999
- 99% Between 1K and 5K SQFT
  - Median = 2,224 SQFT

Single-Family Homes (2017)

Watershed	Fort Bend County	Harris County
Addicks	0	82,633
Barker	22,737	25,773

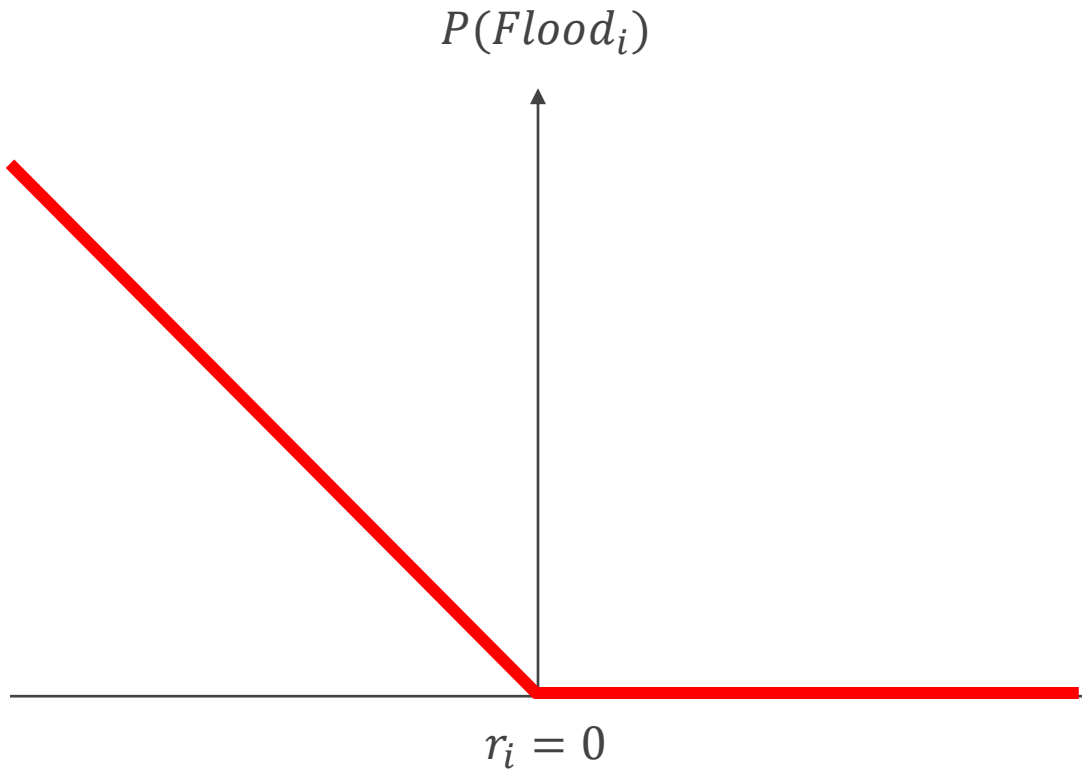
Average Appraised Value (2017)

Watershed	Fort Bend County	Harris County
Addicks	.	$184,426
Barker	$348,993	$251,256

1st Stage

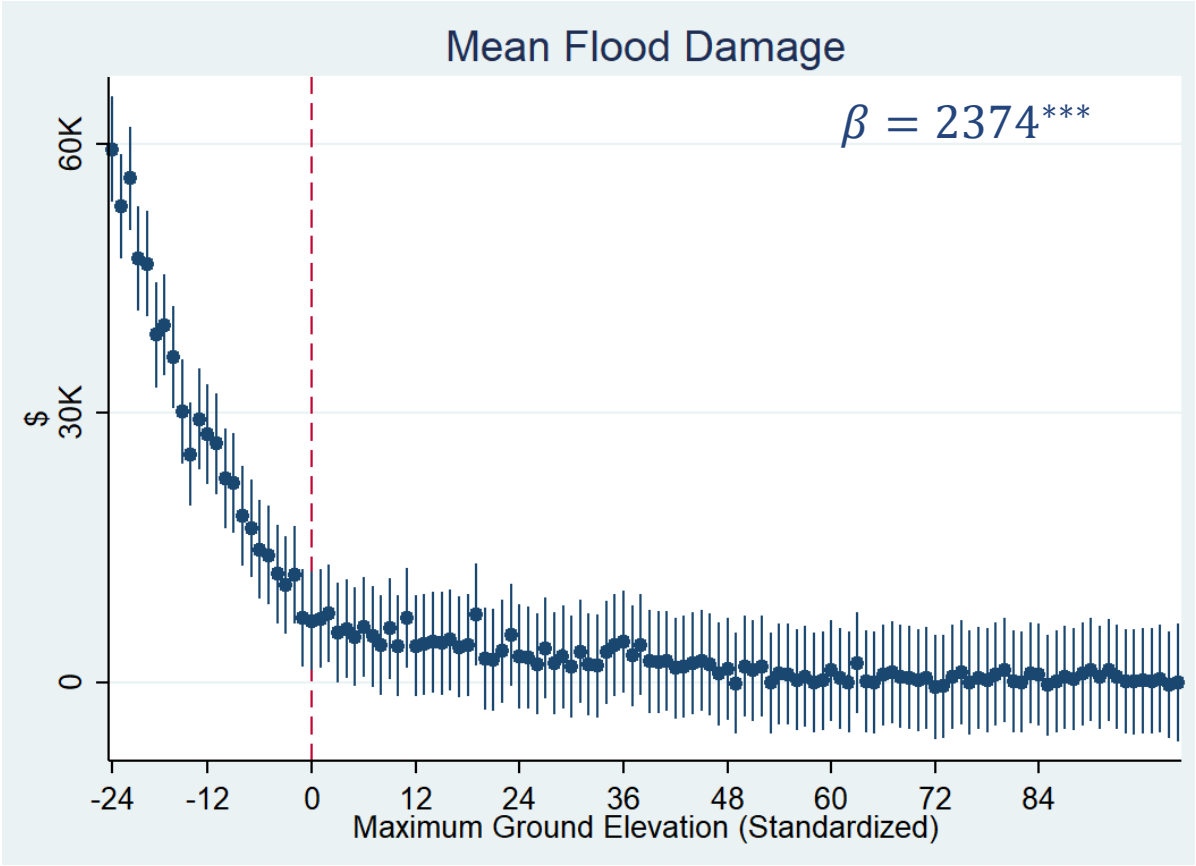
Elevation and Flood Damage

Theoretical Effect



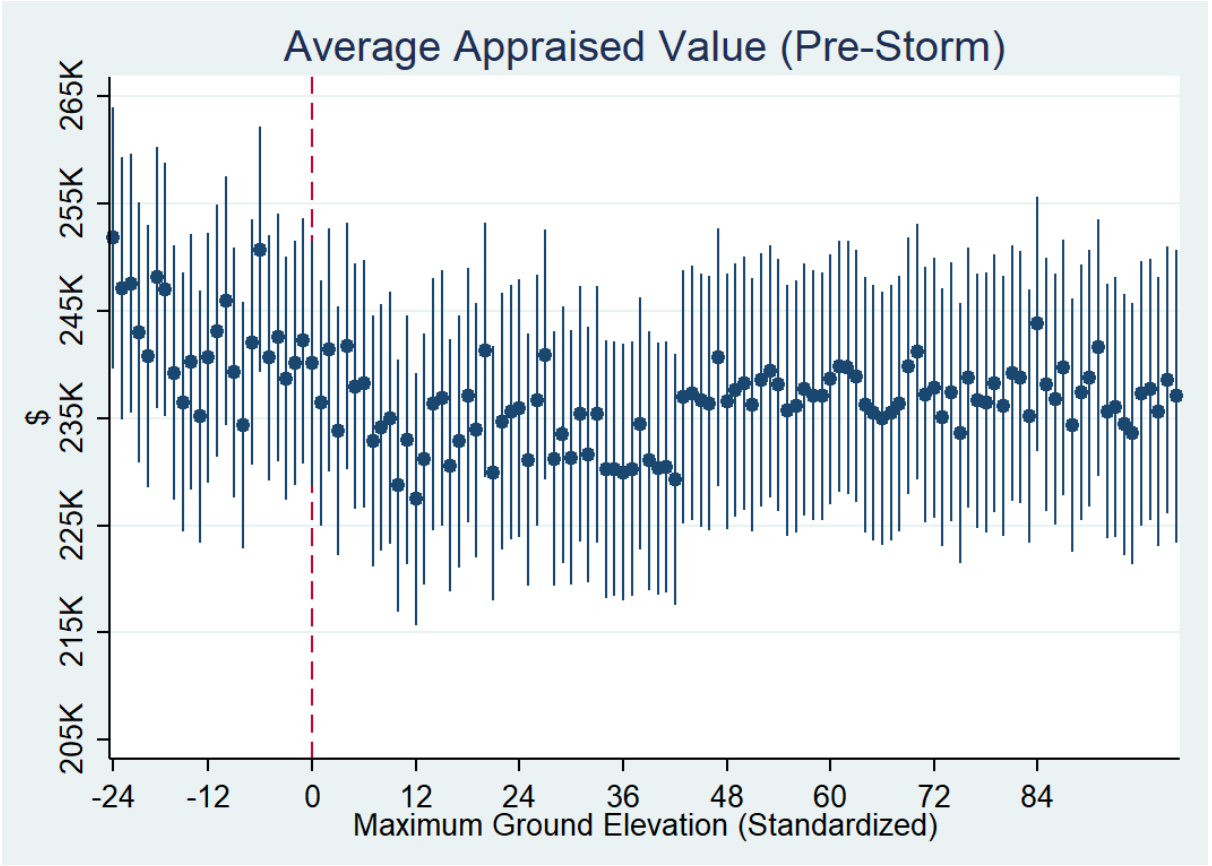
Damage and Elevation

- Ground Elevation Standardized
  - Addicks: $r_i = Elevation_i - 110$
  - Barker (Harris): $r_i = Elevation_i - 102$
  - Barker (Fort Bend): $r_i = Elevation_i - 103.5$
- Slope Change
  - $2374 per Inch to $0 at $r = 0$



Elevation and Other Characteristics

- No Slope Change in Pre-Storm Characteristics
  - Appraised Value
  - SQFT
  - Year Built
  - Days Since Last Sale



Results

Impacts of $100K Wealth Shocks

Results

Listing Propensity

	List 2017 (Post-Storm)	List 2017 (Post-Storm)	List 2018	List 2019	List 2020
2SLS Estimate	0.06**	0.04***	0.10*	0.15	0.16
Covariates		X	X	X	X
Bandwidth	(-17.3 – 57.5)	(-17.3 – 57.5)	(-22.6 – 32.4)	(-19.7 – 25.7)	(-20.7 – 27.2)

Notes: Covariates include square footage of the structure, average appraised value between 2012 through 2016, and year built. Neighborhood-level fixed effects are controlled for in all specifications. Robust Bias-Corrected standard errors are clustered at the watershed-county level. The sample of properties lying above the standardized maximum ground elevation of 0 are included in the control-mean calculation. Estimates are preliminary.

Results

Sale Propensity

	Sale 2017 (Post-Storm)	Sale 2017 (Post-Storm)	Sale 2018	Sale 2019	Sale 2020
2SLS Estimate	0.05**	0.03*	0.11	0.15	0.08
Covariates		X	X	X	X
Bandwidth	(-15.3 – 65.0)	(-15.3 – 65.0)	(-21.7 – 89.8)	(-23.8 – 98.8)	(-20.7 – 27.2)

Notes: Covariates include square footage of the structure, average appraised value between 2012 through 2016, and year built. Neighborhood-level fixed effects are controlled for in all specifications. Robust Bias-Corrected standard errors are clustered at the watershed-county level. The sample of properties lying above the standardized maximum ground elevation of 0 are included in the control-mean calculation. Estimates are preliminary.

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Takeaways

- Damage Induces Mobility
- Effects Persist for Multiple Years

Next Steps

1. **Distance Moved (Quality of Neighborhood)**
2. **Physical Health (Mortality)**
3. **Financial Health (Bankruptcy)**
4. **Labor Market (Employment and Earnings)**
5. **Household Composition (Marriage/Divorce/Fertility)**

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Thank you

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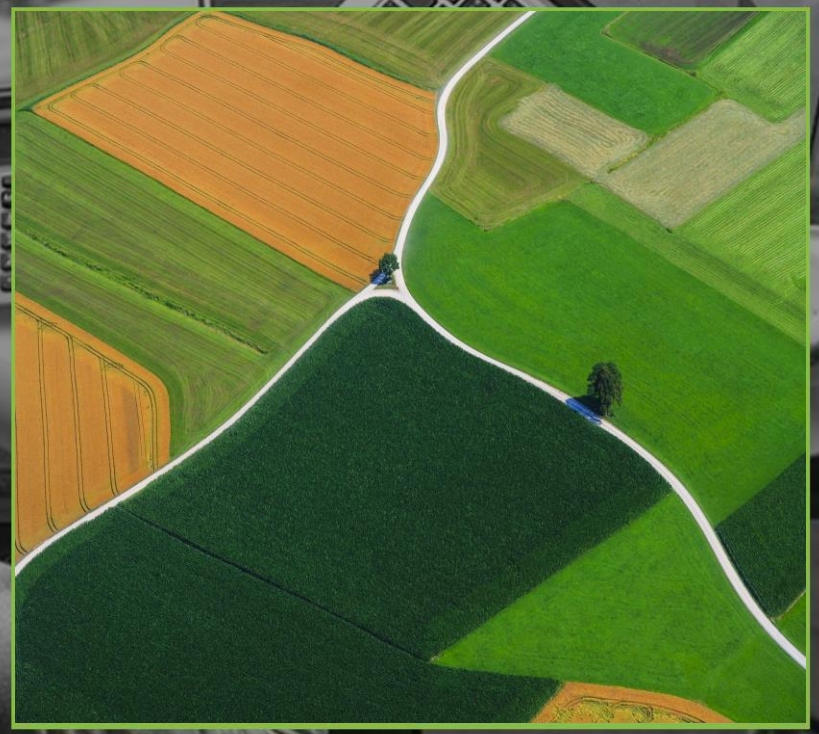
The Fork in the Road: The Diverging Policy Pathways to Rural vs. Urban Energy Security in the U.S.



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Cara Clase, Ph.D. Candidate

University of Delaware – Biden School of Public Policy & Administration

When a household is unable to afford or access a sufficient amount of energy to meet their basic needs, its members are experiencing **energy insecurity**.

Dimension	Fuel Poverty	Energy Poverty	Energy Insecurity
Factors	**Affordability** & Efficiency	Affordability, Efficiency, Accessibility & Safety	Affordability, Efficiency, Accessibility, Safety, **Behavioral Patterns and Social Impact**
Focus	Heating Systems, Prices, & Housing Insulation	Type of Energy Received, **Indoor Pollution, & Stable Energy Infrastructure**	How the affordability and access of energy affects the **health, mental, and socio-economic outcomes** of those experiencing energy insecurity
Geography/Target	Cold Climates (e.g. UK, Ireland, New Zealand)	Developing Countries	Hot and cold climates; Developed and Developing Countries; Interest in individual experiences and biographies
Relevant Works	Isherwood and Hancock (1979), Boardman (1991), Hills (2011)	Reddy (2001), Bouzarovski et al. (2012), Li et al. (2014)	Hernández (2016), Bouzarovski (2018)

IMPORTANCE OF SUSTAINABILITY

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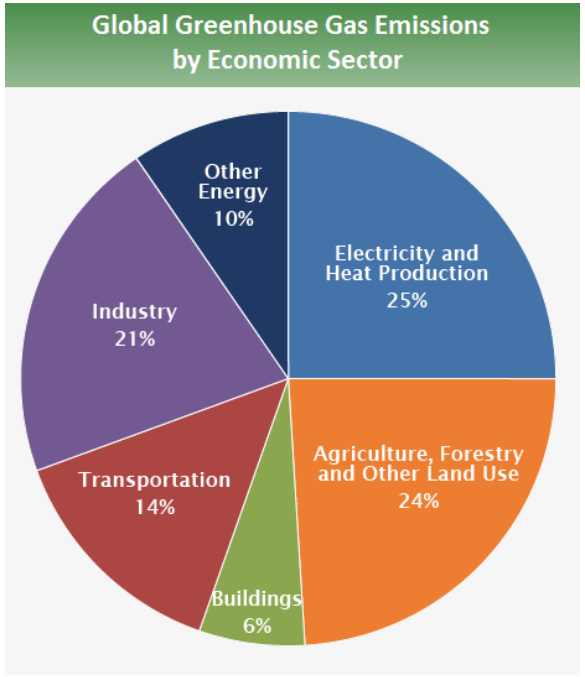
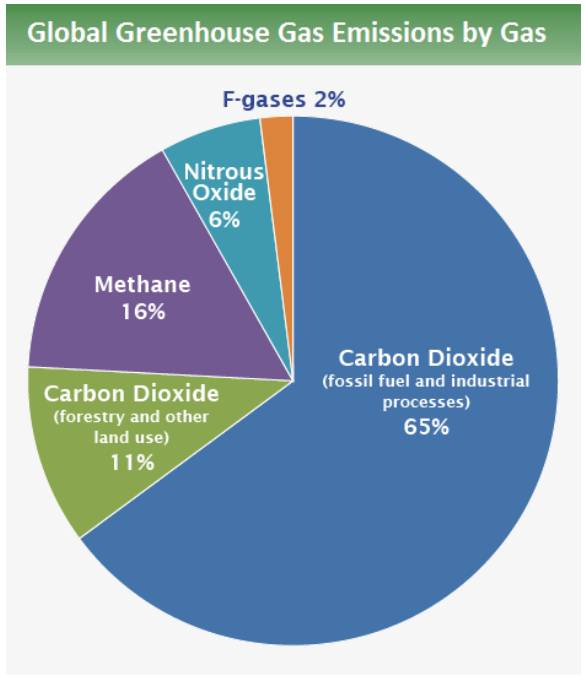
“Sustainability”

- Energy that “meets the needs of the present without compromising the ability of future generations to meet their own.” (UN World Commission on Environment and Development, 1987)

Fossil fuels…

- Make up 92% of U.S. energy (eia.gov, 2021)
- Have high price volatility (e.g. Oil Embargo of 1970s)
- Contribute towards 65% of GHG emissions in the U.S.
- Can be unsafe forms of energy (e.g. indoor pollution)





25%

Fossil fuels would **only** be the most efficient path to energy access for **25%** of energy poor households.

International Energy Agency, 2019

Policy Timeline

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THE OIL EMBARGO (1973)

350% increase in oil prices.

PROJECT FUEL (1975)

One of the first weatherization programs in the U.S.

EIA and DOE EST. 1977

Energy Information Administration and Department of Energy established. First RECS distributed in 1978

RURAL ENERGY FOR AMERICA PROGRAM EST. 2008

Provides loans and grant funding to rural small businesses and agricultural producers to make renewable systems and energy efficiency improvements.

EMERGENCY ENERGY CONSERVATION SERVICES PROGRAM EST. 1974

- U.S. creates revolving fund to programs dedicated to energy cost relief.
- Implemented through the Economic Opportunity and Community Partnership Act.
- Energy Policy and Conservation Acts implemented in 1975 and 76.

WEATHERIZATION ASSISTANCE PROGRAM EST. 1976

- Department of Energy
- Eligibility: At or below 200% of the FPL, receive Aid to Families with Dependent Children, and/or receive supplemental security income.

LOW INCOME HOME ENERGY ASSISTANCE EST. 1981

- Department of Health and Human Services.
- Created by the Omnibus Budget Reconciliation Act of 1981.
- Eligibility: At or below 150% FPL or makes 60% or less of state median income.

LOW INCOME HOUSING TAX CREDIT EST. 1986

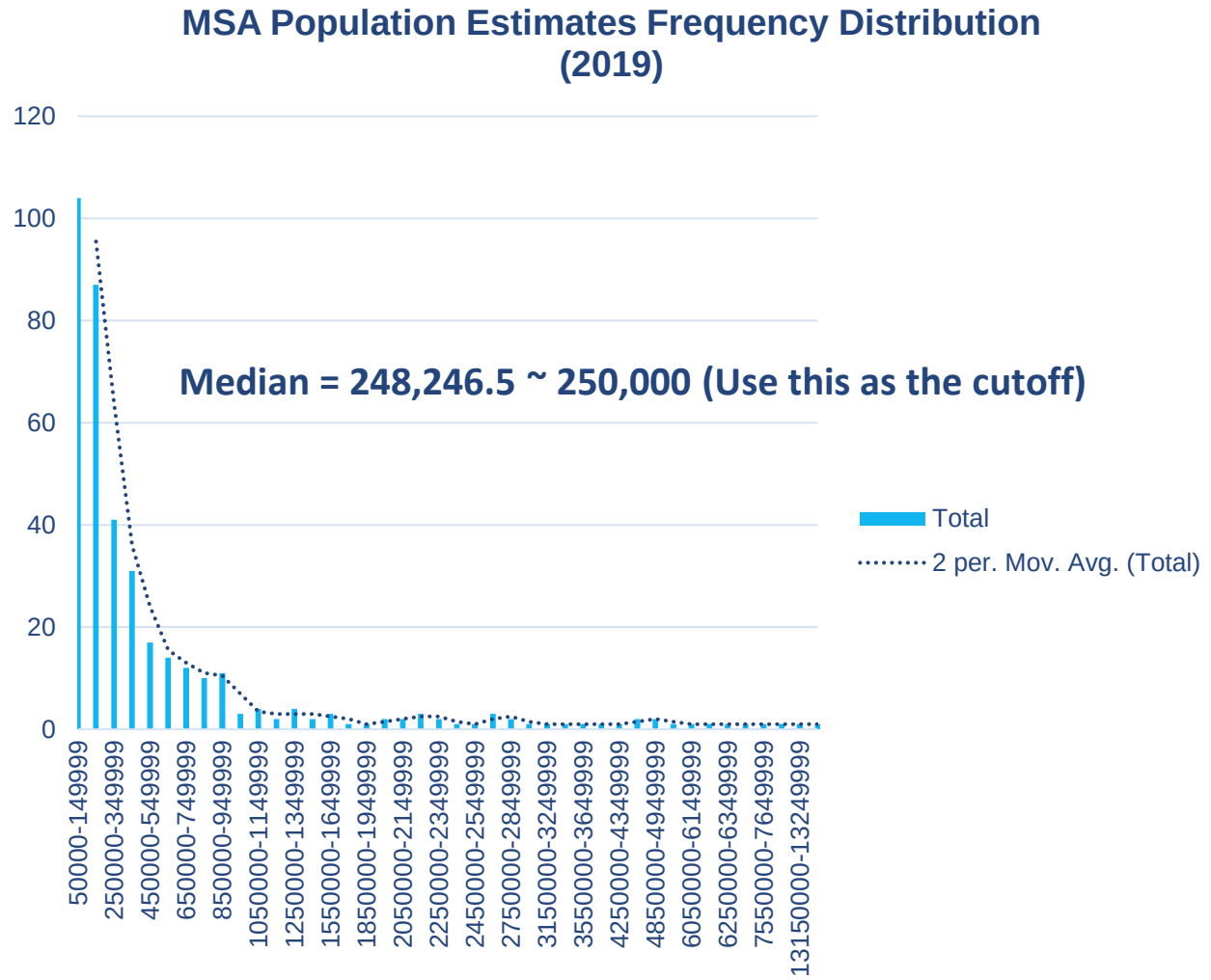
- Under Tax Reform Act of 1986.
- Internal Revenue Service
- Eligibility: Either 40% of units must be for tenants making less than 60% of Area Median Income (AMI) or 20% of units for tenants making less than 50% of AMI.

RURAL ENERGY SAVINGS PROGRAM EST. 2014 FARM BILL

Provides 0% loans to rural utilities and cooperatives for energy efficiency financing programs and/or electrification and renewable energy projects.

Rural vs. Urban

- **Urban**: Metropolitan Areas
  - “densely-settled”, “broad labor market[s]”, “50,000 or more people”. (USDA, 2019)
  - Metropolitan Statistical Areas Median Population ~ 250,000 (USDA, 2019)
- **Rural**: Non-Metro Areas
  - Rural-Urban Commuting Area Codes 4-10
  - Metro areas 400+ sq miles with 35 people per sq mile or less. (Health Resources & Services Administration, 2022)



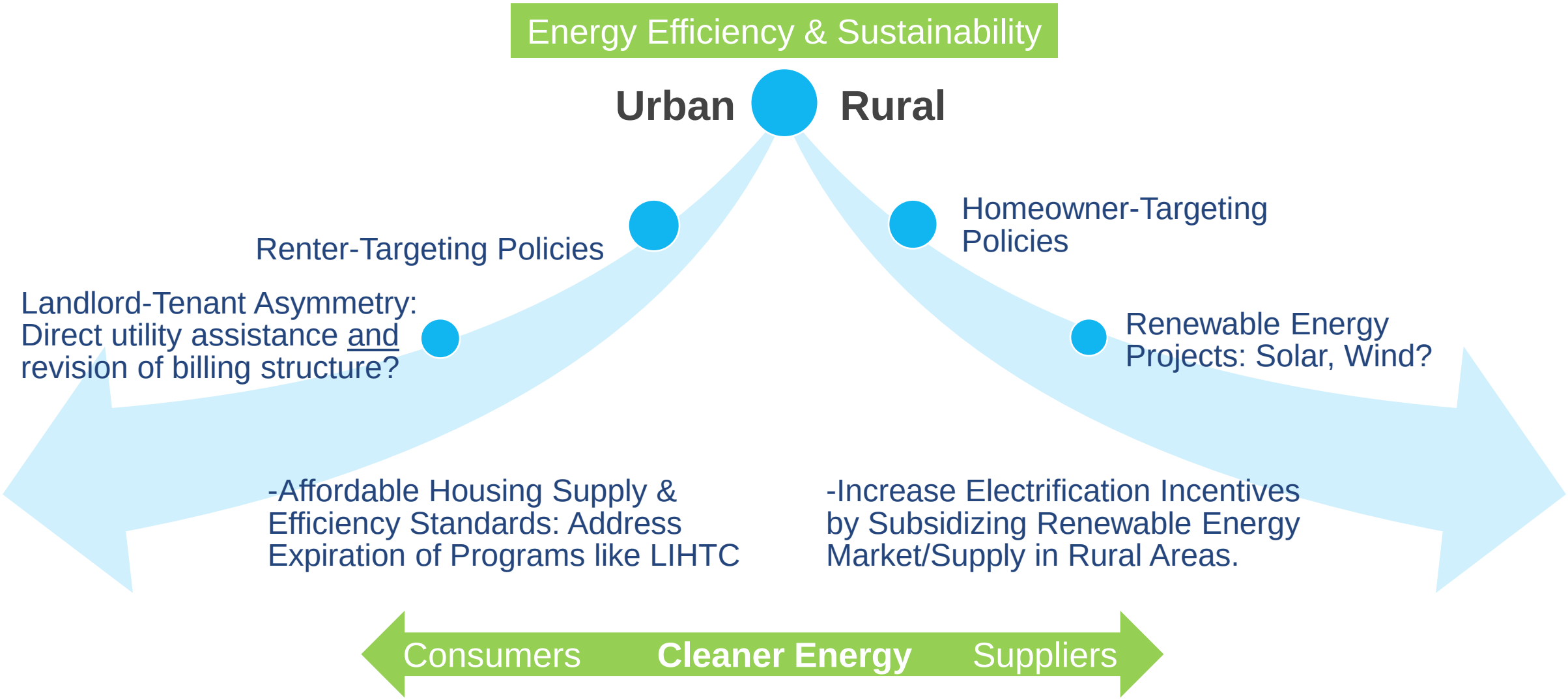
Factors

	Demographics	Asymmetric Interests	Infrastructure	Policy Motive
RURAL	Homeowners: 81.1% (Rural Housing Coalition, 2021)	Distributors vs. Residents (Harrison & Popke, 2011)	• Electrification & Market Failures	More **Need** • Higher Poverty Rate • Limited Transportation & Infrastructural Options
URBAN	59.8% Homeownership Rate. Strong renter presence.	Landlords vs. Tenants (Hernández, 2016)	• Outdated Infrastructure • Housing Quality Disparities (e.g. Redlining to Older Housing with Poor Insulation and Older Energy Systems)	Bigger **Impact** • Denser Population means more people impacted

Common Thread: Low-income households of urban and rural areas are vulnerable to high energy burdens.

- Urban, Low-Income Households: **2** times higher than average household. (Drehobl et al., 2020)
- Rural, Low-Income Households: **3** times higher.

Policy Pathways



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Thank you

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Sea Level Rise and Impact on Home Prices: Rural Vs. Non-Rural Counties in Coastal Florida

Ajita Atreya

Impact of Sea Level Rise Risk on Housing Has Been Making Headlines!

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Florida Sees Signals of a Climate-Driven Housing Crisis

Home sales in areas most vulnerable to sea-level rise began falling around 2013, researchers found. Now, prices are following a similar downward path.

Aug 30, 2021, 05:57pm EDT | 854 views

Is Your Home Value At Risk From Climate Change? Recent Research Finds A Link

NEGLECTED NO MORE:
HOUSING MARKETS, MORTGAGE LENDING, AND SEA LEVEL RISE

Benjamin J. Keys
Philip Mulder

Rising sea levels are taking down housing values

BY ED LEEFELDT
SEPTEMBER 4, 2018 / 5:30 AM / MONEYWATCH

Disaster on the Horizon: The Price Effect of Sea Level Rise *

Asaf Bernstein† Matthew Gustafson‡ Ryan Lewis§

…Do We See Any Price Effect of Sea Level Rise Risk on Home Prices?

Research Overview

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Key Objectives:

- To determine if coastal buyers pay less for homes exposed to SLR risk by pricing in future expectations
- To examine if different buyer types have varying levels of awareness/appetite for SLR risk and discount SLR risk differently
- To determine if Hurricane Irma in 2017 had any impact on home prices

Study Area, Data & Methods:

Study Area

- **35 coastline counties in Florida**

Data

- **Public Records**
- **NOAA**
- **FEMA**
- **Census Bureau**
- **University of Florida**

Method

- **Hedonic Regression**

Key Findings

- Homes exposed to the risk of rising sea level are sold for less, but the price discount is limited to homes also located in FEMA designated 100-year floodplains

- Both owner-occupied and non-owner-occupied homes are discounted if exposed to the risk of rising seas levels that are also located in FEMA-designated 100-year floodplains

- After Hurricane Irma in 2017, homes exposed to the risk of rising sea levels (both in and out of FEMA-designated 100-year floodplain) were discounted significantly*

*Homebuyers may pay less for homes damaged by hurricanes. Unfortunately, we do not have data on damages. However, we control for the condition of the house at the time of the purchase

Background

- In the United States, roughly 40% of the population resides in a coastal county. When buyers shop for housing in a coastal area, they get information about the “existing risk” via FEMA flood maps and their willingness to pay for the risk depends on how they perceive the risk which varies due to the:
  - Direct and indirect experiences (e.g., pronounced risk perception in areas directly hit by flood)
  - Media highlights, more dire risk projections, etc.

- The “existing risk” is accounted for in the form of lower real estate valuation, especially in the wake of a hurricane. But, in many coastal areas, the riskiest properties are the most desirable due to their amenity value

- With changing climate, one of the long-run risks facing the coastal housing market is the risk of Sea Level Rise (SLR) which a forward-looking buyer may perceive as “high risk” and may reduce their willingness to pay
  - One of the many risks that the housing market face is the speculative behavior from buyers and sellers (Shiller 2014)

Literature Review – Projected SLR and Price Effects

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Author/Journal	Study Area	Data	Major Findings
Baldauf, Garlappi & Yannelis 2021 – *Review of Financial Studies*	All U.S. sale transactions within 50km (31 miles) from coast 1997-2017	Zillow ZTRAX , SLR from NOAA / Yale Climate Opinion Map 2016	~Negative (-2.8%) relationship between home prices and homes being projected to be underwater due to 6ft SLR only in areas with above median climate change believers
Bernstein, Gustafson & Lewis 2019 – *Journal of Financial Economics*	All coastal counties (within .25 miles from coast) 2007-2016	Zillow ZTRAX, SLR from NOAA / All property types	~Approx. 7% discount in SLR projected area in non-owner-occupied housing segment
Fu & Nijman 2021 – *The Professional Geographer*	Miami Dade and Pinellas (within 5000ft (0.8 mile) from coast) 2004-2019	Property appraiser office / detached SF homes	~No substantial discount for 6ft SLR; higher discounts (up to 12%) for more exposed properties (<2ft) ~Discounts higher for primary owners in Miami but higher for non primary owners in Pinellas
Keenan, Hill & Gumber 2018 – *Environmental Research Letters*	Miami Dade County 1971 to 2017	Single family homes	~High elevation home appreciate more than low-elevation; paper does not identify the effect as relating to future SLR expectations
Murfin & Spiegel 2020 – *Review of Financial Studies*	All coastal states (within 30km of the shoreline (18 miles) 2012-2017	CoreLogic; Local tidally adjusted elevation and local RSLR trend to calculate SLR risk / single family homes and duplexes	~No significant price effect of SLR location even within 1.6 km (1.0 miles) of shoreline and 2015 - 2017 sample

Research Contribution

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Our study builds on literature around the willingness to pay owing to anticipated sea level rise risk. This study supplements limited *but rapidly growing* literature in three ways:

- First, our study distinguishes SLR-exposed areas (a measure of "future risk") into areas intersecting with FEMA-designated flood zones (a measure of "existing risk")
    - If there is awareness around SLR risk, all else equal, we expect reduced willingness to pay for SLR-exposed homes outside the floodplain where flood insurance is *not* required
- Second, our study teases out the differential in prices for homes exposed to SLR risk across different buyer types which likely will vary based on buyer's SLR risk awareness and their risk appetite and investment horizon
    - We expect homes bought by investors in SLR-exposed areas (outside the floodplain) to be discounted more assuming that these investors are more sophisticated in terms of their awareness of future SLR risk. However, investors may not consider long-term SLR risk if these homes are short-term investments.
- Third, our study tests the impact of Hurricane Ike in 2017 on home prices exposed to SLR risk
    - We expect discounts in SLR-exposed areas to rise after Hurricane Irma in 2017 due to heightened risk perception

Study Area: Nine Out of 35 FL Counties Studied have more than 50% Census Tracts that are Perceived as “Rural”

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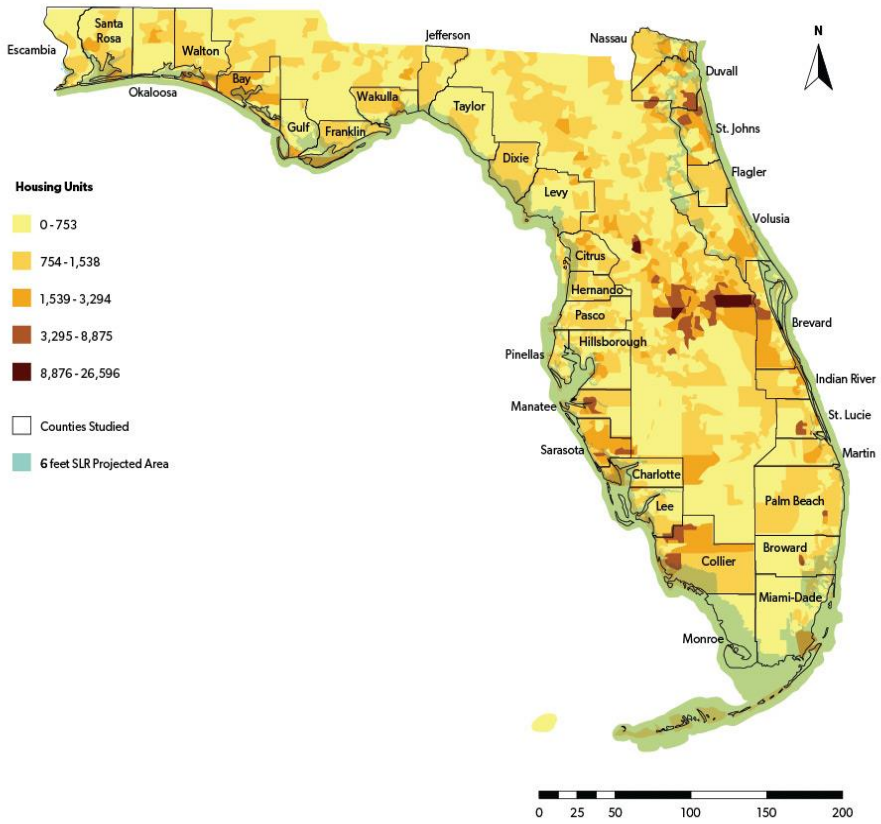
Sales within 0.25 miles of the coastline

feasible walking distance & most SLR exposure

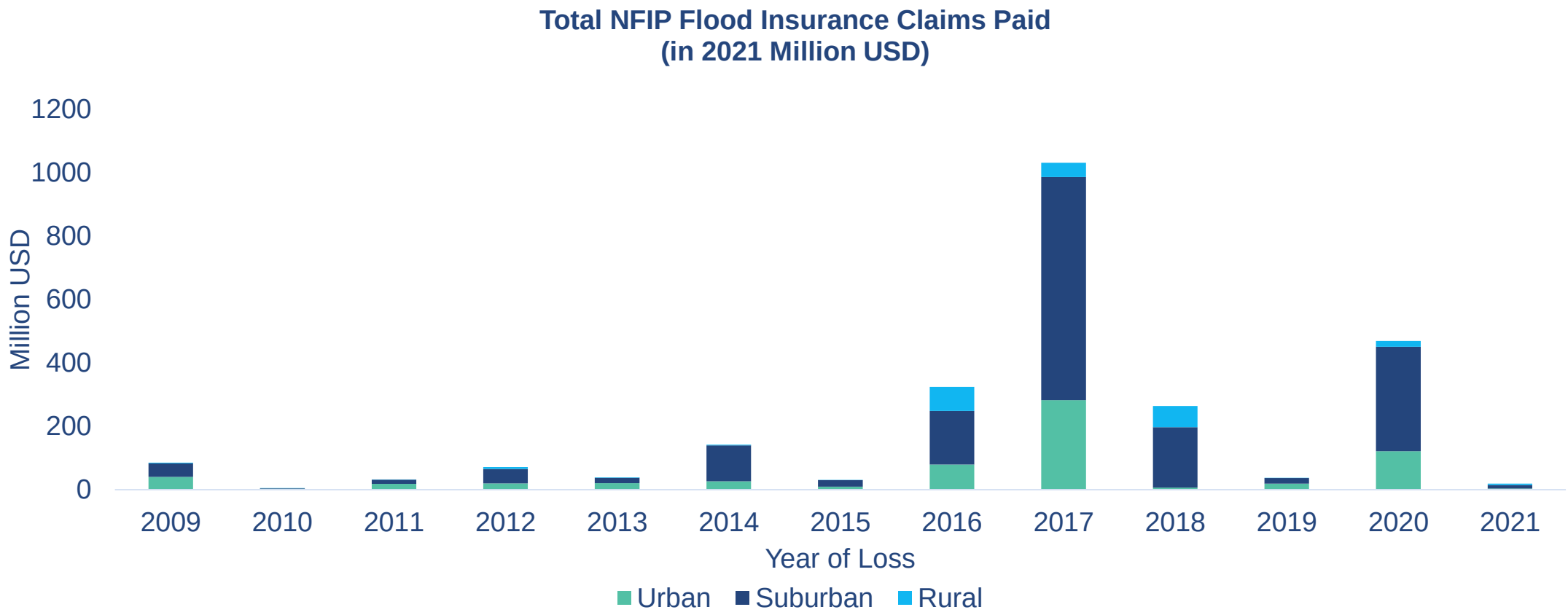
Map showing 35 coastal counties studied



County Name (Rural)	% of Census Tracts Perceived as “Rural”
Wakulla	80.0
Dixie	75.0
Jefferson	75.0
Levy	70.0
Franklin	66.7
Walton	66.7
Taylor	60.0
Citrus	57.1
Nassau	53.8

Note: Only coastal counties in FL are included, among which 238 census tracts are defined as “rural,” 2104 census tracts are defined as “suburban,” and 918 are defined as “urban.” Definitions of “urban”, “suburban”, and “rural” based on the Urbanization Perceptions Small Area Index from HUD’s 2017 American Housing Survey (AHS) neighborhood description study.

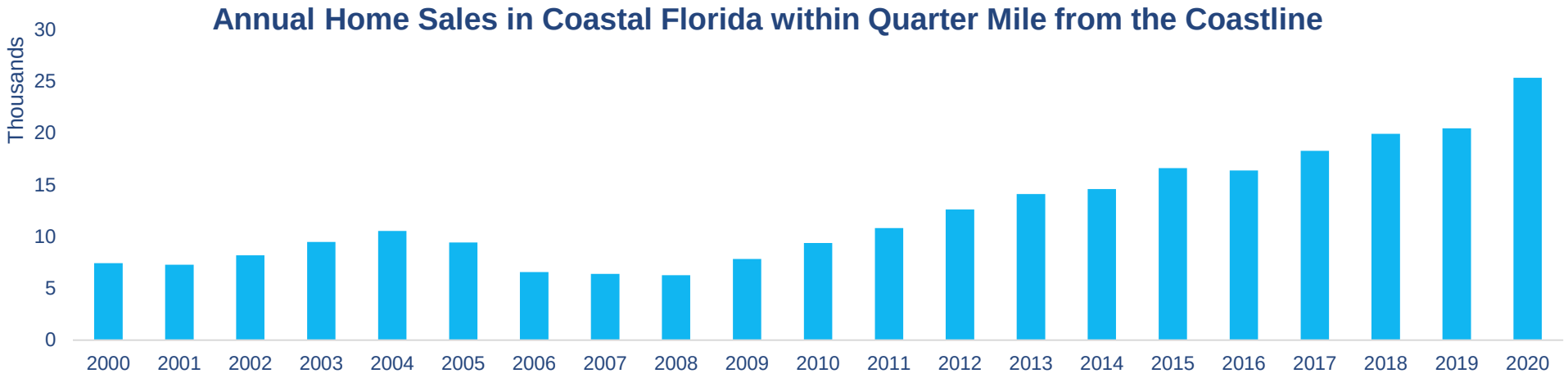
Florida Hit by Several Disasters Over the Years: Since 2009, Over 2.5 Billion Dollars in Claims were Paid Out in Coastal Florida

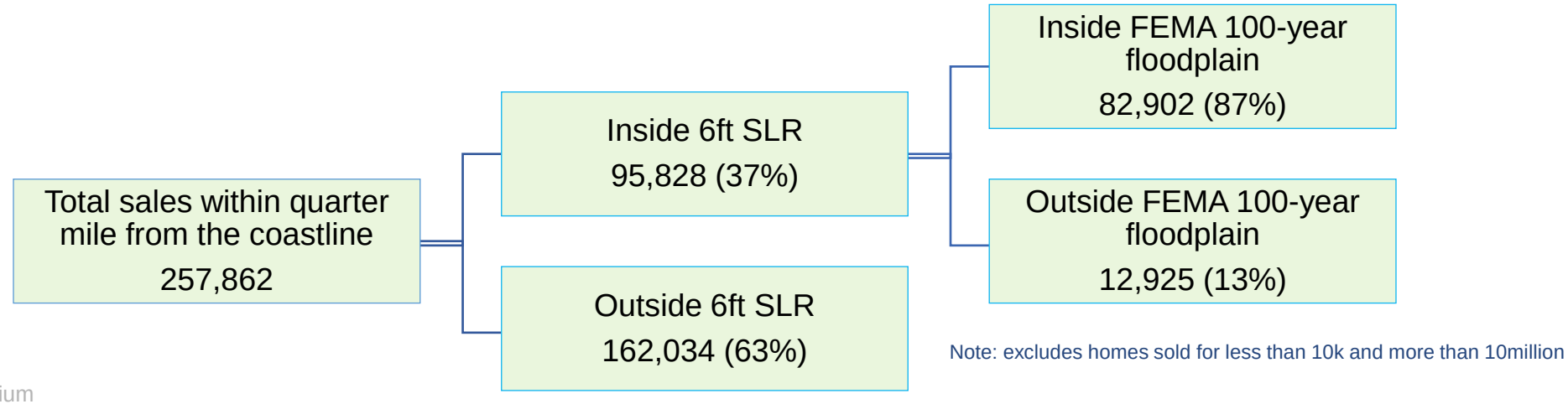


Note: Figure presents the amount of NFIP flood insurance claims by year of loss by neighborhood status. Only coastal counties in FL are included.
Source: FIMA NFIP Redacted Claims data from OpenFEMA

Data

- 4.2 million homes sold in 35 coastal counties in Florida between 2000-2020. Roughly 6-7% of the homes sold are within quarter mile of the coast





Note: excludes homes sold for less than 10k and more than 10million

Methods

We Employ Hedonic Model (Rosen 1974; Freeman 2003)

$$\log(\boldsymbol{P}_{it}) = \beta_o + \sum_{j=1}^{J}\beta_j \boldsymbol{S}_{ij} + \sum_{k=1}^{K}\beta_k \boldsymbol{L}_{ik} + \sum_{m=1}^{M}\beta_m \boldsymbol{C}_{im} + \sum_{p=1}^{P}\beta_p \boldsymbol{O}_{ip} + \boldsymbol{\beta_n(slr\_6ft)_i} + \gamma_i + \delta_t + \varepsilon_{it} \quad \text{---M1}$$

$$\log(\boldsymbol{P}_{it}) = \beta_o + \sum_{j=1}^{J}\beta_j \boldsymbol{S}_{ij} + \sum_{k=1}^{K}\beta_k \boldsymbol{L}_{ik} + \sum_{m=1}^{M}\beta_m \boldsymbol{C}_{im} + \sum_{p=1}^{P}\beta_p \boldsymbol{O}_{ip} + \boldsymbol{\beta_n(slr\_100yrFP)_i} + \boldsymbol{\beta_o(slr\_OFP)_i} + \gamma_i + \delta_t + \varepsilon_{it} \quad -M2$$

Control group: Outside SLR Exposed areas

S: Structural Attributes (# of baths, # of beds, lot size, pool availability, roof type, foundation type etc.)

L: Locational Attributes (location attributes such distance to nearest highways, golf course view, water view, elevation)

C: Distance dummy variable to coastline; within 500 feet, between 500 and 1000 feet and more than 1000 feet

O: Other controls such as type of home (condo co-op vs. single-family), type of sales (cash/mortgage), out of state buyer etc.

slr_6ft: dummy=1 if Inside 6ft SLR, homes located in these areas are projected to be underwater if the sea level rises by 6ft

slr_100yrFP: dummy=1 if Inside 6ft SLR & Inside FEMA 100-year floodplain, projected to be underwater if sea level rises by 6ft and "currently" inside FEMA's 100-year floodplain

slr_OFP: dummy=1 if Inside 6ft SLR & Outside FEMA 100-year floodplain, projected to be underwater if sea level rises by 6ft and "currently" outside FEMA's 100-year floodplain $\boldsymbol{\gamma_i}$ is the school district fixed effect and $\boldsymbol{\delta_t}$ is the year fixed effect and $\boldsymbol{\varepsilon_{it}}$ is the error term

Summary Statistics

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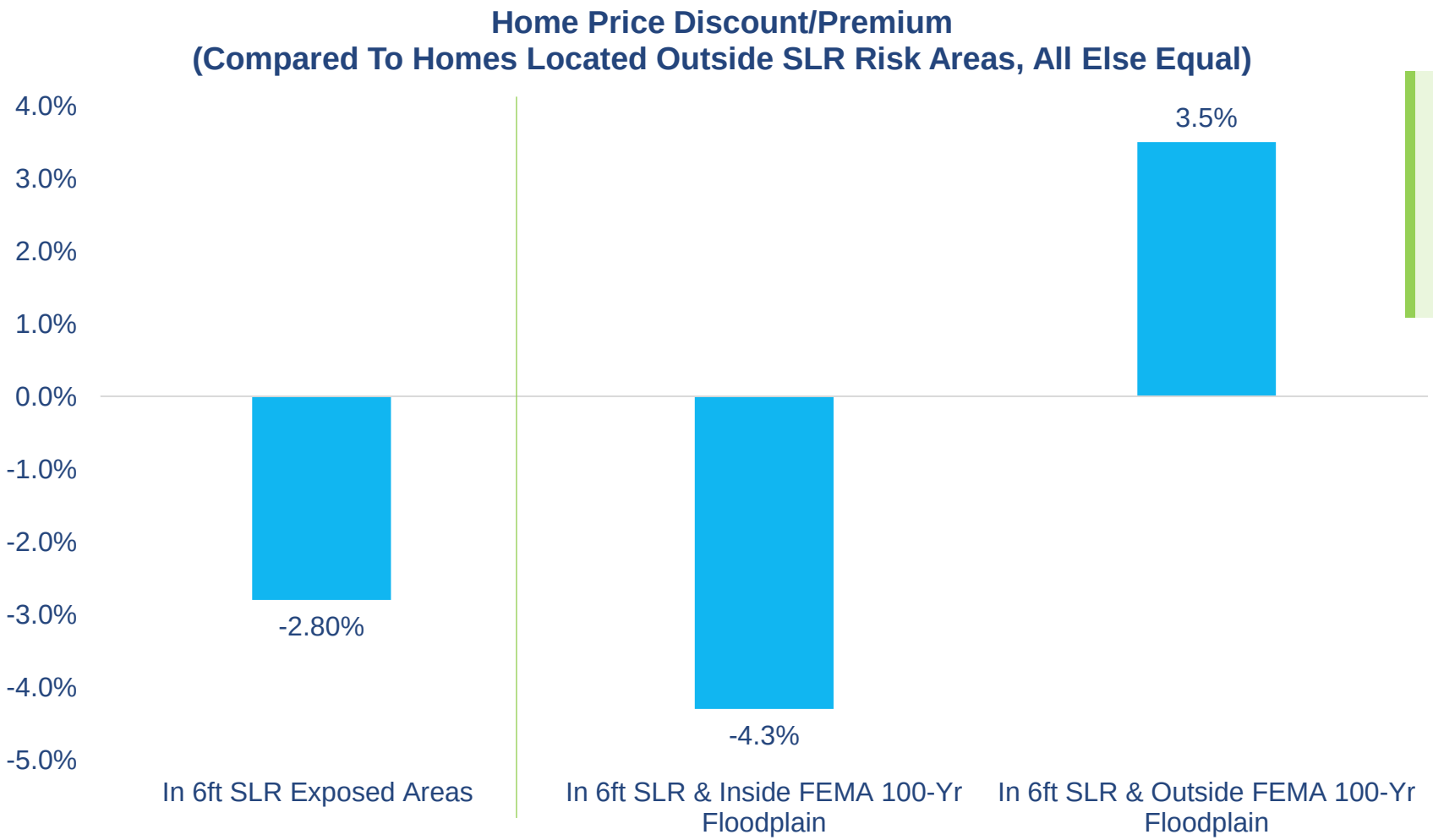
Homes Sold within quarter miles from the coast (N= 257,862)

sale price 2020$	Sale price in $2020	$845,750
coast_mile	Distance to coast	0.11 mile
oceanview	Have ocean view	2.0%
waterview	Have water view (bay, pond, lake)	1.4%
golfview	Have golf course view	8.7%
elevation	Elevation above sea Level	9.5 feet
hwy_dist (mile)	Distance to nearest highway	.56 mile
cashsales	Transacted in all cash	56%
oos_buyer	Out of State buyer	42%
new_cons	New construction	8%
con_coop	Condo/co-op	72%
manuf_home	Manufactured Home	1%
bdrms	Number of bedrooms	3.2
fullbath	Number of bathrooms	2.3
livingsqft	Living sq feet	1,637 sqft
pool	Have an indoor pool	11%
fnd_concrete	Foundation type	2%
rfcvr_concrete	Roof Cover type	3%
central_heat	Have Central Heating/Cooling	6%
cons_lux	Construction is deemed luxury	1.2%

	Share
Owner Occupied	33.1%
Non-owner occupied (Investment)	66.9%
Individual Investor	56.1%
Institutional investor	10.8%
Large investor (100+buys/year)	0.4%
Medium investor (10-99 buys/year)	2.0%
Small investor (1-9 buys/year)	8.4%

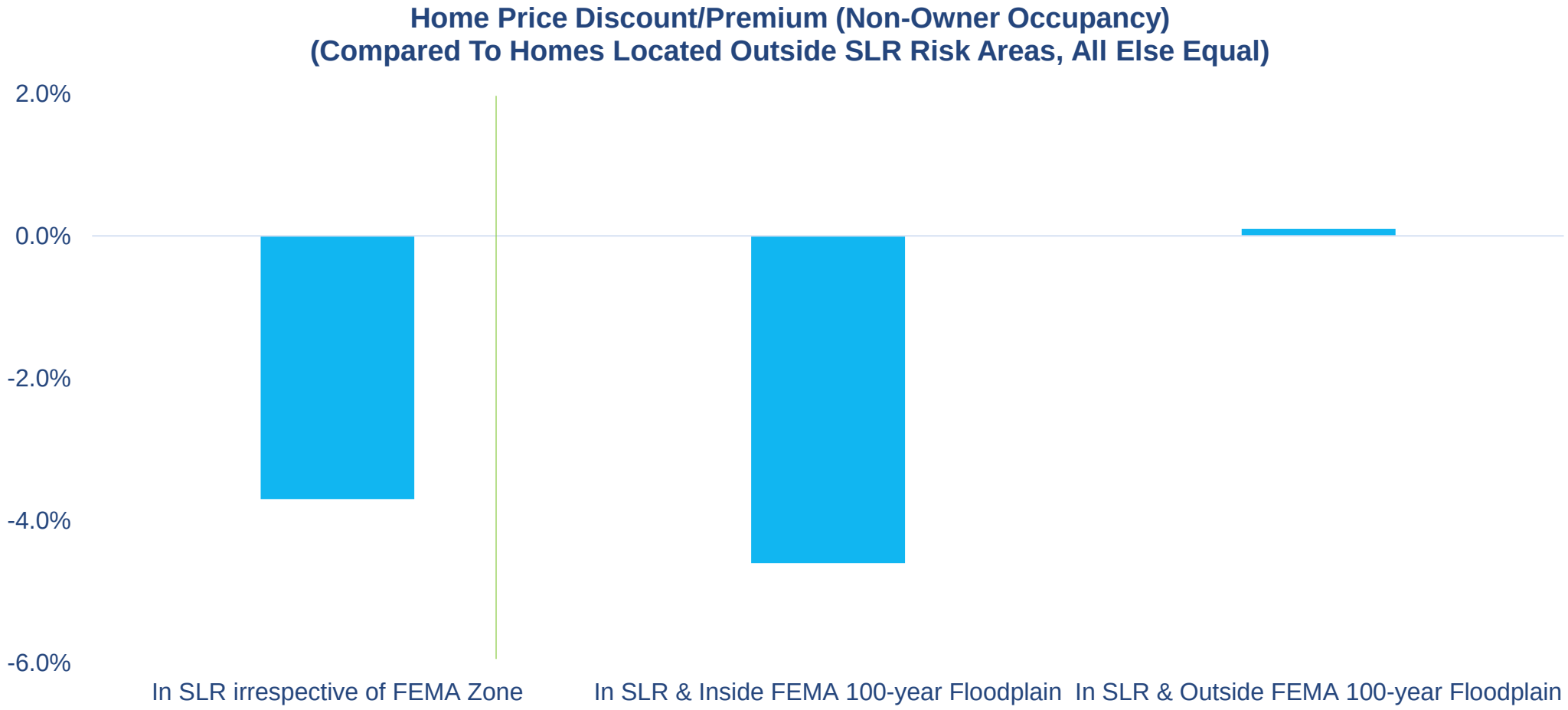
Result 1: Homes Projected to be Inundated by 6ft SLR Sell for Less; the Price Discount is However Limited to FEMA 100-Year Floodplain



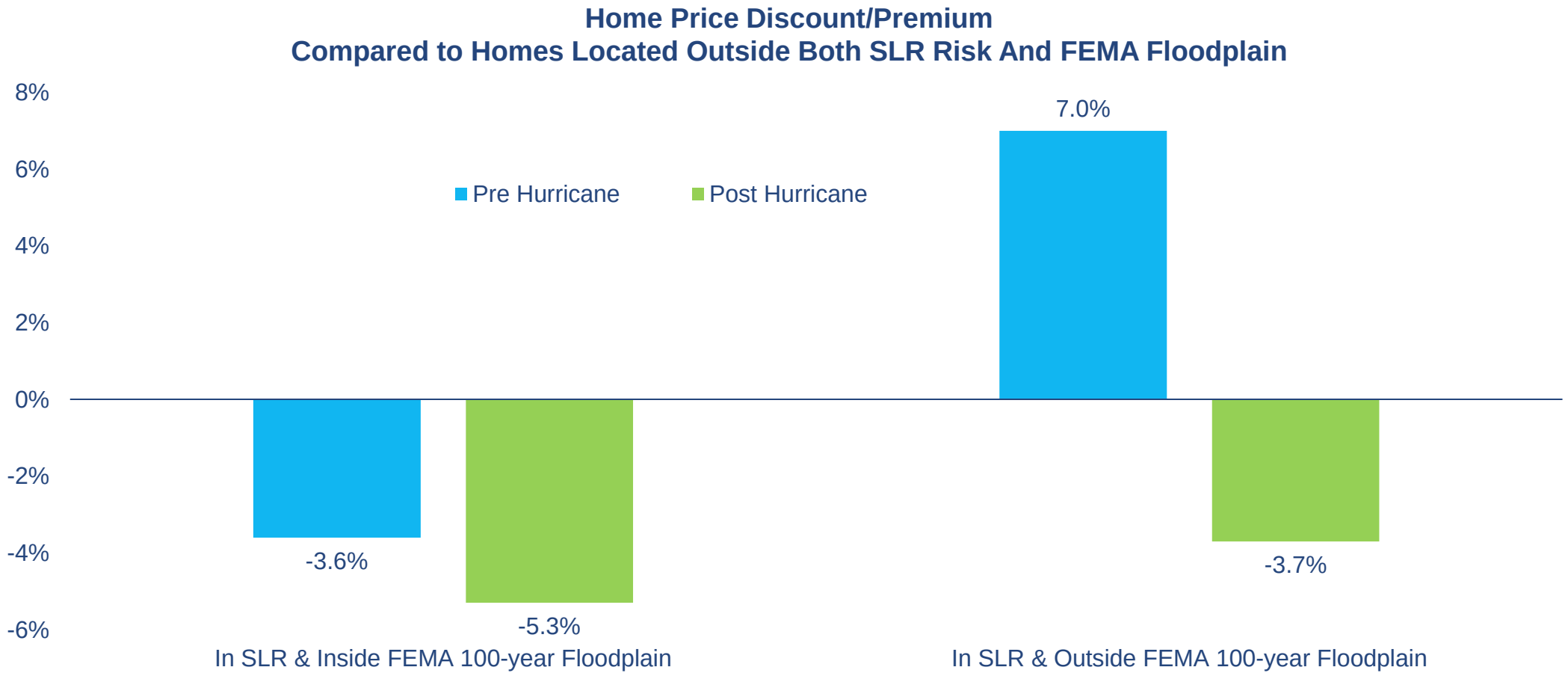
In rural counties, we find a premium of 3.6% for SLR-exposed homes in 100-year floodplain (the coefficient is weakly significant)

Result 2: Non-Owner-Occupied Homes also Sell for Less in Areas Projected to be Inundated by 6ft SLR, but the Discount is Limited to FEMA 100-Year Floodplain

RURAL RESEARCH SYMPOSIUM



Result 3: Homes in the SLR Exposed Areas Outside the Floodplain were Discounted after Hurricanes Irma in 2017



Note: includes data post 2010 to include only one significant hurricane i.e., Hurricane Irma

Conclusions

- SLR risk poses long-term challenges for the housing market and adds another layer of risk to existing flood risk. However, our research shows no evidence that SLR risk is affecting current home prices in Coastal Florida (Rural and Non-Rural Counties)
- Homes in SLR-exposed areas that did have price discounts were also located in FEMA-designated 100-year floodplains, where discounts are typical because of the flood insurance requirement, rather than in consideration of future SLR risk
- These findings are consistent with several previous studies which show that the discounts for homes located in 100-year floodplain as a result of flood Insurance payment being capitalized into home prices
- From our analysis, we conclude either *that there is a lack of awareness about SLR risk* or that *SLR risk may not be factored into pricing decisions because it is a long-term risk* and buyers are more focused on the short-term, not intending to own the home long enough for SLR to have an effect
- The absence of price adjustments now could mean decreases in home prices later, as sea levels rise, or FEMA flood maps reflect SLR which will have a significant impact on local housing markets like the ones in Florida

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Thank you

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