Virtual Seminar on Climate Economics

Federal Reserve Bank of San Francisco

Organizing Committee:

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Climate Damages

- Estimating climate damages
  - Bottom-up, data-driven empirical approaches
  - Heterogeneous impacts over space (e.g., geographic, economic) and time

  $\rightarrow$ Who will bear the costs of climate damages?
- Migration
  - Potential for relocation can alter risk exposure
  - Likely heterogeneity in ability and desire to relocate

  $\rightarrow$ What is the extent of, and impacts from, climate migration?
- Policy
  - Important role for climate adaptation policy to mitigate losses
  - Behavioral responses may significantly affect policy costs and effectiveness

  $\rightarrow$ What is the impact of climate adaptation policy?

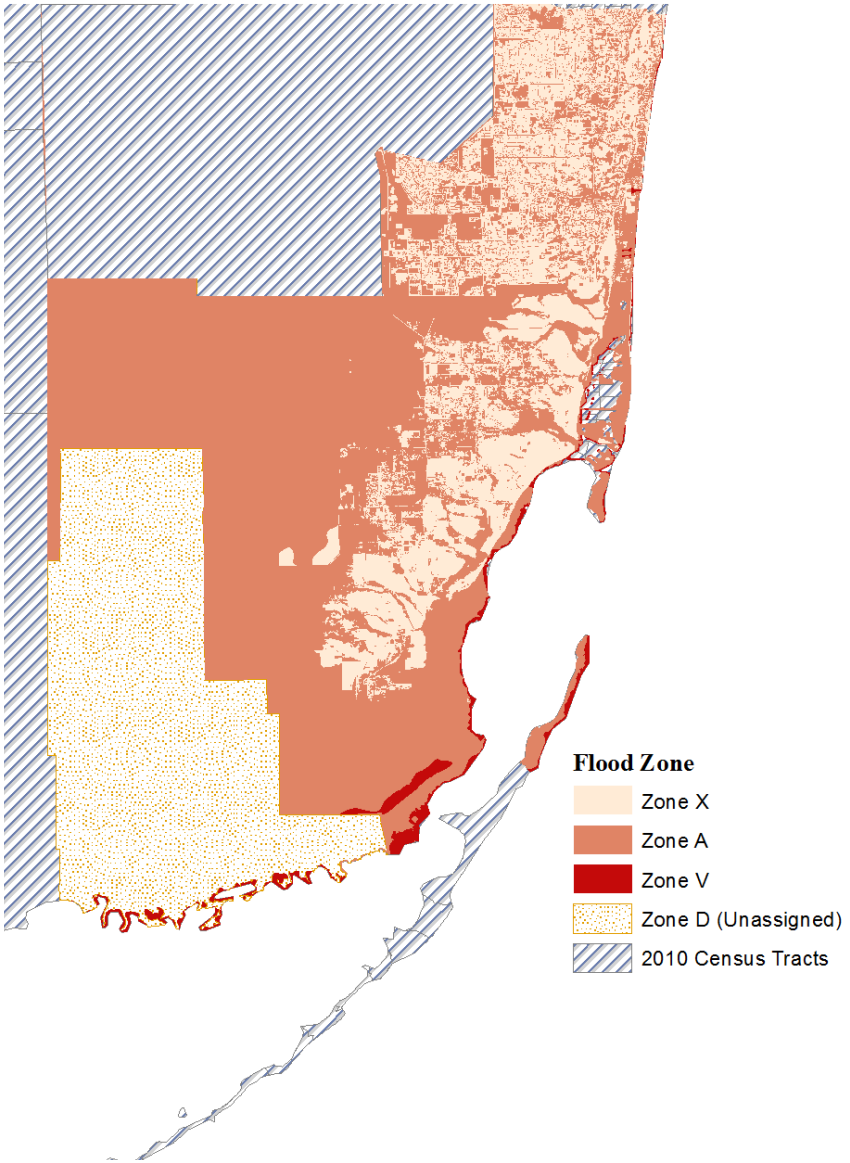
Flood Risk

- Current levels
  - Inland and coastal flooding
  - $45.9 billion in losses and 4,500 fatalities globally in 2019 (WRI, 2020)
  - $1 trillion in losses since 1980
- Future losses
  - Impacts from precipitation intensity and sea level rise
  - Expected to increase greatly with climate and socioeconomic change
    - Coastal losses could increase by a factor of 7 by 2050 (Hallegatte et al., 2013)
    - Flood loss mitigation key, including location choice
- Policy levers
  - Many policy options
    - E.g., information, insurance, zoning/codes, public mitigation, emergency response
  - Overall impacts and distributional costs vary
  - Differential behavioral responses
  - Need to understand for optimal policy mix

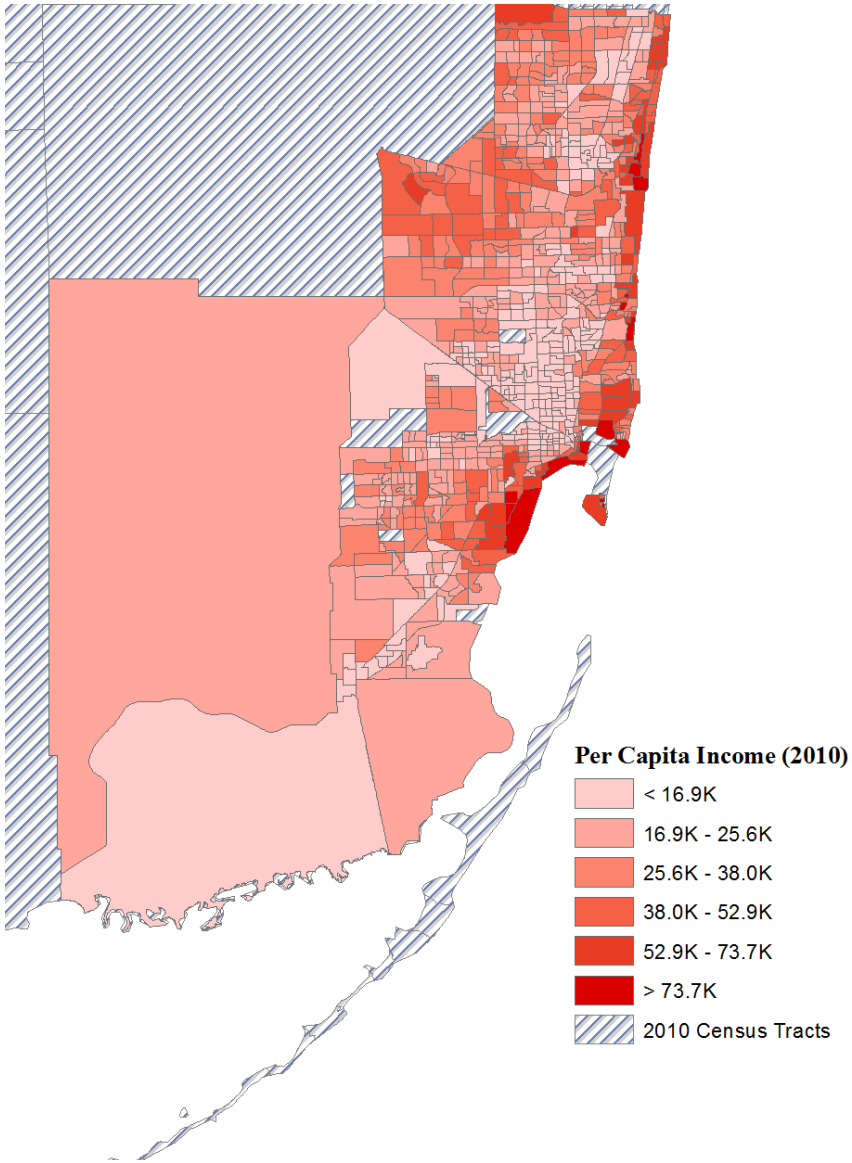
Study Motivation

- Longstanding calls for National Flood Insurance Program (NFIP) reform
  - Large fiscal imbalances driven by premium subsidies
  - Maps outdated
- Potential heterogeneous sorting by race and income across flood risk
  - Implies differential behavioral responses to policy changes
- Implications for
  - Efficiency and equity consequences of climate policy
  - Disaster and climate vulnerability

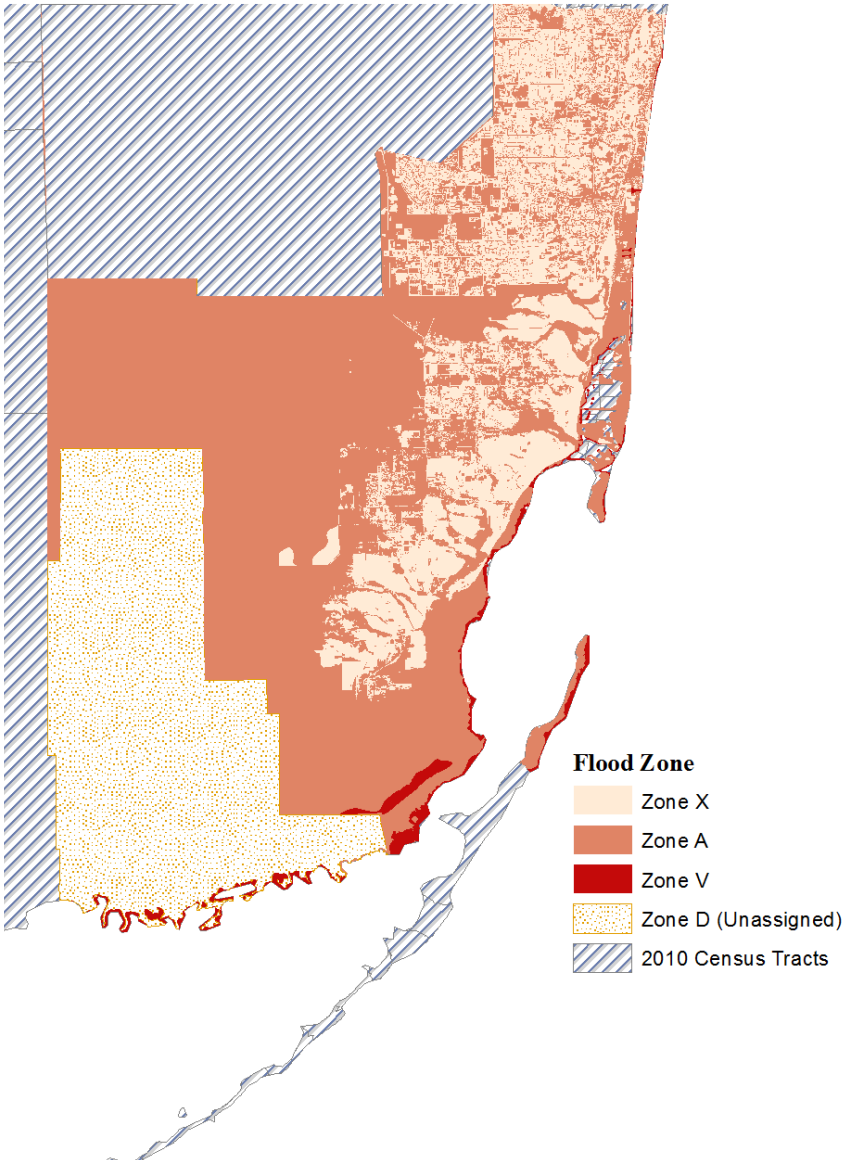
$\rightarrow$ Is there heterogeneous sorting across flood risk and, if so, what are the distributional impacts of flood insurance reform?



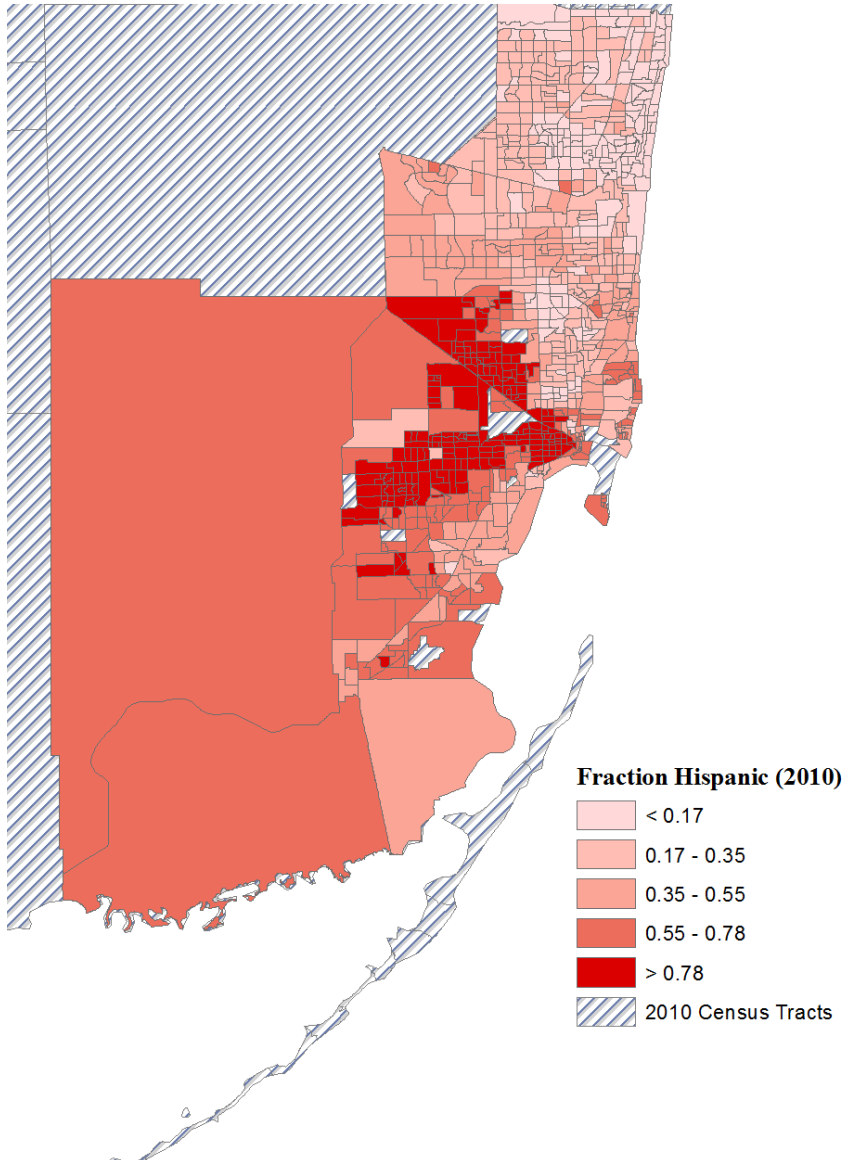
(a) Flood Zone



(b) Per Capita Income



(c) Flood Zone



(d) Fraction Hispanic

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- Potential heterogeneous sorting by race and income across flood risk
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$\rightarrow$ Is there heterogeneous sorting across flood risk and, if so, what are the distributional impacts of flood insurance reform?

What We Do

- Estimate discrete choice residential sorting model (Bayer et al., 2007, 2009; Klaiber and Phaneuf, 2010; Tra 2010)
  - Boundary discontinuity design to control for correlated amenities (Black, 1999)
  - Allows for sorting over flood risk by homebuyer race/ethnicity and income
  - Accounts for property-specific NFIP premium subsidies
- Assess counterfactual NFIP reforms (McFadden, 1999; Leggett, 2002)
  - Welfare and flood exposure impacts of subsidy removal
  - Valuation of flood map revisions
- Contributions
  - Provide evidence of heterogeneous sorting over flood risk
  - Estimates distributional impacts of hazard insurance
  - Informs understanding of the behavioral responses to climate-relevant policy reform

Preview of Results

- WTP to avoid floodplains $\sim$6% average home price among low-income White residents (5% discount rate)
- Clear evidence of heterogeneous sorting
  - Low income and minority residents more likely to sort into flood risk
  - Possible mechanisms: preferences, beliefs, choice sets, access to subsidies
- Counterfactual premium increase reduces welfare by 19% of lost subsidy
  - Fewer individuals in high risk zones
  - But higher concentration of low-income and minority groups
- Price reforms have distributional impacts
- Outdated flood maps result in large information costs to households
  - Suggestive evidence of large benefit-cost ratio from map updates

Literature

- Residential sorting to value (dis)amenities (e.g., Bayer et al., 2007; Klaiber and Phabeuf, 2010; Tra 2010)
- Hedonic literature (Rosen, 1974)
  - Flood and SLR risk (Bin and Kruse, 2006; Bin et al., 2008; Atreya and Czajkowski, 2016; Bernstein et al., 2019)
  - Flood event/salience (Hallstrom and Smith, 2005; Kousky, 2010; Bin and Landry, 2013; Gallagher, 2014)
- Disaster impact heterogeneity
  - Migration (Smith et al., 2006; Strobl, 2011)
  - Income/debt (Deryugina et al., 2014; Gallagher and Hartley, 2014; Roth Tran and Sheldon, 2017)
- Value of environmental and climate information (Pope, 2008; Ma, 2019)

Background

National Flood Insurance Program (NFIP)

- Provide public flood insurance and ensure affordability
- Develop flood hazard maps - Flood Insurance Rate Map (FIRM)
  - A zones ($\geq$1% annual freshwater flood risk)
  - V/VE zones ($\geq$1% annual saltwater flood risk)
  - X zones ($<$1% annual freshwater flood risk)
- While NFIP premiums are risk based, subsidies are available and can be large (Kousky and Shabman, 2014)
  - Houses built before community FIRM, called 'pre-FIRM'
  - Houses in communities that participate in Community Rating System
  - Houses that are grandfathered into a higher-risk zone
- Properties with federally backed or regulated mortgages in A and V zones are required to purchase flood insurance

Background

- NFIP Reform Timeline
  - 2012: Biggert-Waters Act eliminated (some) subsidies
  - 2014: Homeowner Flood Insurance Affordability Act
  - 2017: Proposed federal budget cut funding for flood map updates
  - 2018: $20.5 billion debt after $16 billion Congressional debt relief (GAO, 2017)

Data

- All residential sales in Miami CSA in 2009-2012 (Dataquick Inc.)
  - Miami-Dade, Broward, St. Lucie, Martin, Indian River, Okeechobee
  - Missing: Palm Beach (no digitized flood maps)
- Mortgage Applications Data (Home Mortgage Disclosure Act)
  - Attach homebuyer race and income to housing transactions
  - Follow Bayer et al., 2016 Merge
- NFIP Digitized Flood Insurance Rate Maps (current and 1996), Technical Manual, Community Rating System (CRS) participation
  - Map each house to a flood zone and boundary
  - Assign underlying flood risk to each house
- NFIP Technical Manual and Community Rating System discounts
- Neighborhood Attributes
  - U.S. Census, Yale University GIS Maps, Toxic Release Inventory, School quality

Final merged sample: 48,174 households Summary Statistics

Imputing Flood Insurance Premiums and Subsidies

1. Determine premium rate from NFIP Technical Manual
2. Building coverage set as (the lesser of) the loan amount or $250k
3. Incorporate CRS discounts

NFIP Premium Rate Example

		Building	Contents	Building	Contents	Building	Contents	Building	Contents	Building
BUILDING TYPE	No Basement/Enclosure	1.21 /1.11	1.52 /1.99	1.21 /1.11		1.21 /2.34		1.32 /2.46		1.32 /2.46
	With Basement	1.29 /1.64	1.52 /1.67	1.29 /1.64		1.21 /1.95		1.39 /2.40		1.39 /2.40
	With Enclosure[5]	1.29 /1.96	1.52 /1.99	1.29 /1.96		1.29 /2.44		1.39 /3.04		1.39 /3.04
	Elevated on Crawlspace	1.21 /1.11	1.52 /1.99	1.21 /1.11		1.21 /2.34		1.32 /2.46		1.32 /2.46
	Non-Elevated with Subgrade Crawlspace	1.21 /1.11	1.52 /1.67	1.21 /1.11		1.21 /2.34		1.32 /2.46		1.32 /2.46
	Manufactured (Mobile) Home[6]	1.21 /1.11	1.52 /1.99					1.32 /2.46		1.32 /2.46
CONTENTS LOCATION	Basement & Above[7]				1.52 /1.67		1.52 /1.67		2.59 /4.12	
	Enclosure & Above[8]				1.52 /1.99		1.52 /1.99		2.59 /4.93	
	Lowest Floor Only – Above Ground Level				1.52 /1.99		1.52 /1.99		2.59 /2.16	
	Lowest Floor Above Ground Level and Higher Floors				1.52 /1.39		1.52 /1.39		2.59 /1.85	
	Above Ground Level – More Than 1 Full Floor				.35 / .12		.35 / .12		.24 / .12	
	Manufactured (Mobile) Home[6]								2.59 /2.16	

Imputing Flood Insurance Premiums and Subsidies

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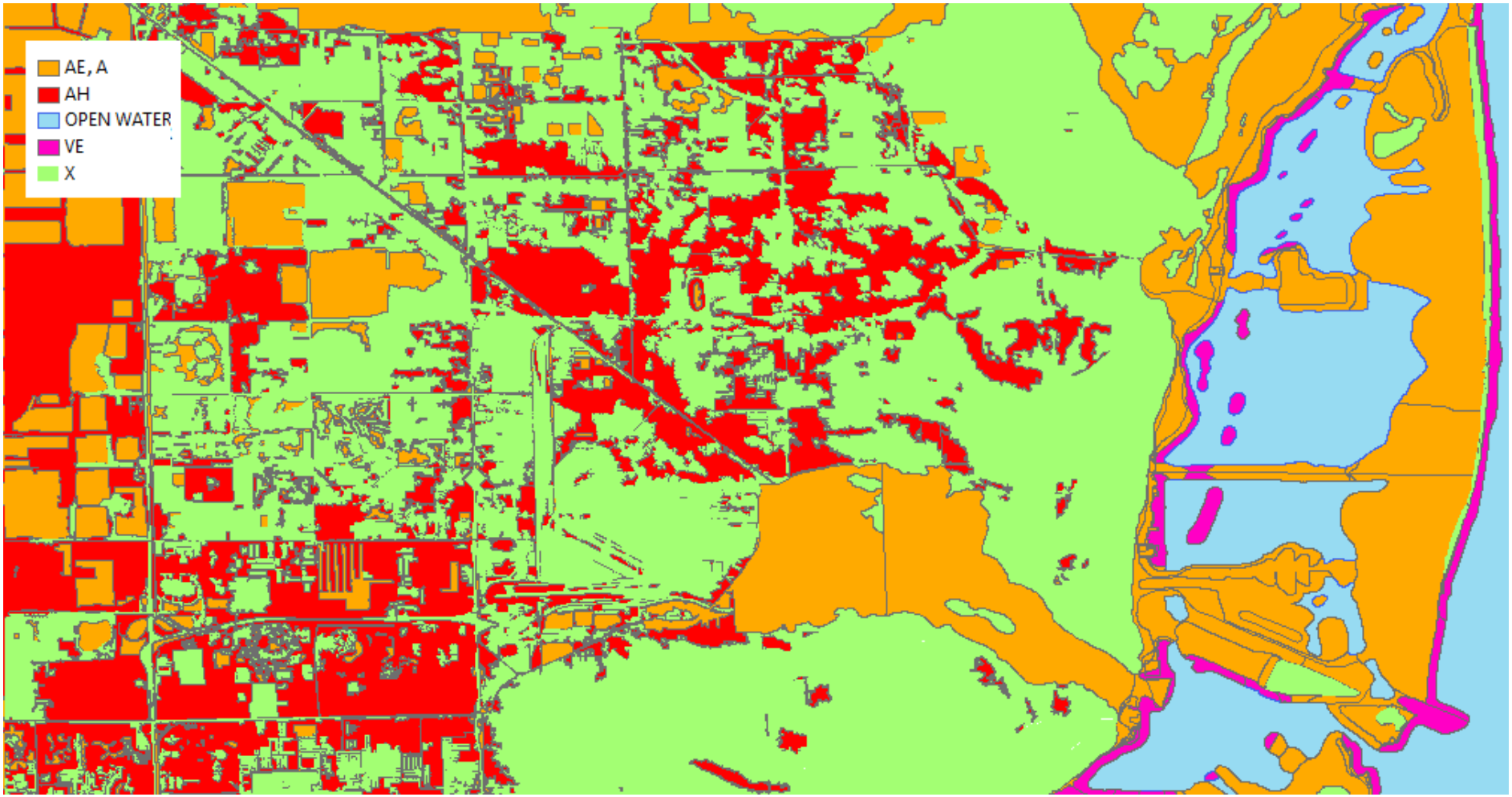
Details

Miami Flood Zones



Flood Risk and Insurance Summary Statistics ($)

A. Coverage and Annual Insurance Premium (in $'s)

Variable	Mean	Median	St. Dev.	Min.	Max.
Total Coverage (in $'s)	159,664	154,982	67,910	5,000	250,000
Full Premium (IP)	2,113	808	3,808	0	28,668
Discounted IP (pre-FIRM)	1,138	779	2,053	0	23,491
Discounted IP (pre-FIRM + CRS)	984	714	1,728	0	18,793

B. Insurance Premium Discounts

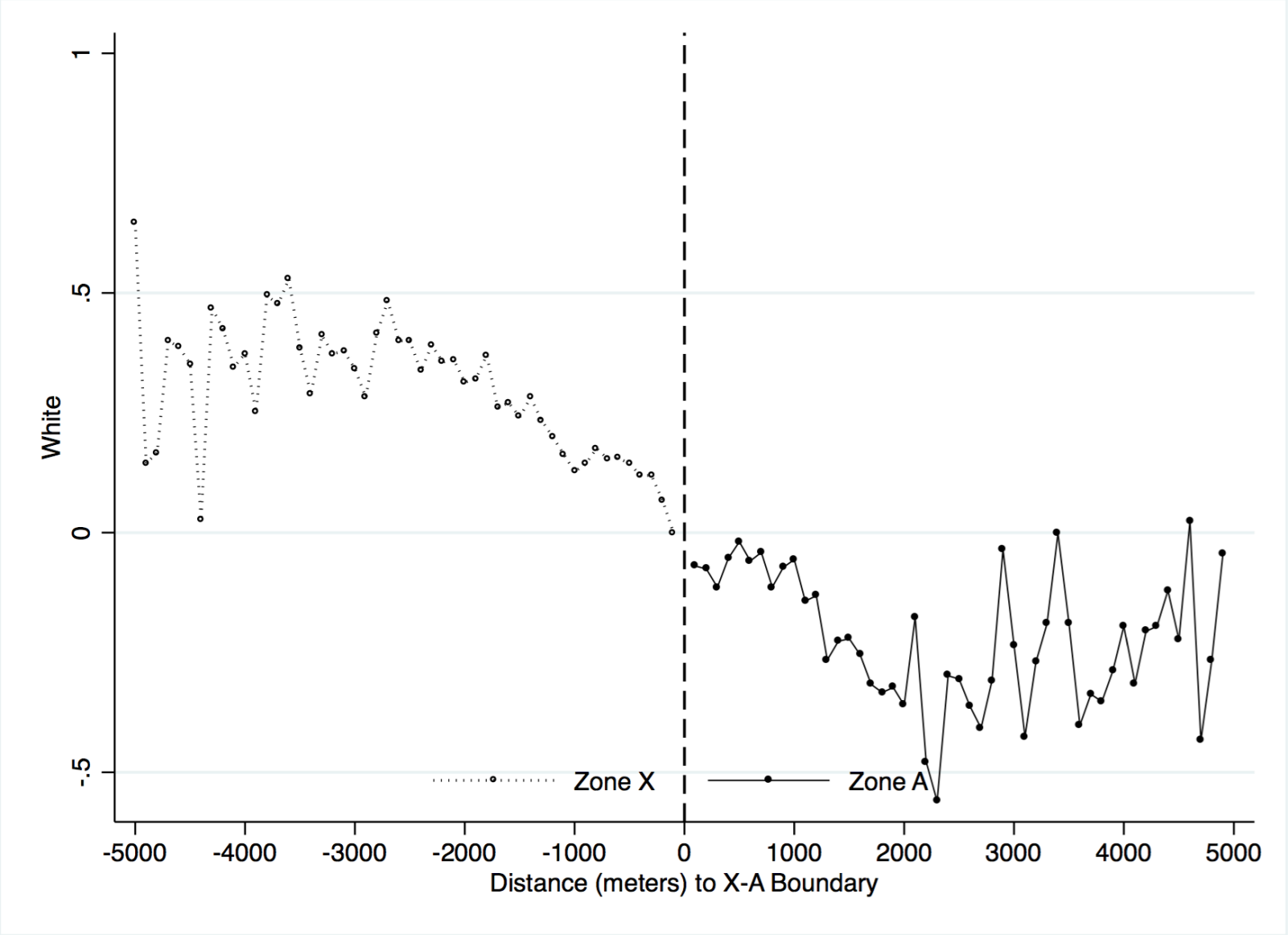
Variable	Mean	Median	St. Dev.	Min.	Max.
Total Subsidy (in $'s)	1,129	50	3,082	0	26,115
Total Subsidy (as %)	19.55	10.00	23.89	0.00	95.32
CRS Discount Rate (%)	12.02	10.00	6.18	0.00	25.00

Stylized Facts

To motivate heterogeneous sorting and identification:

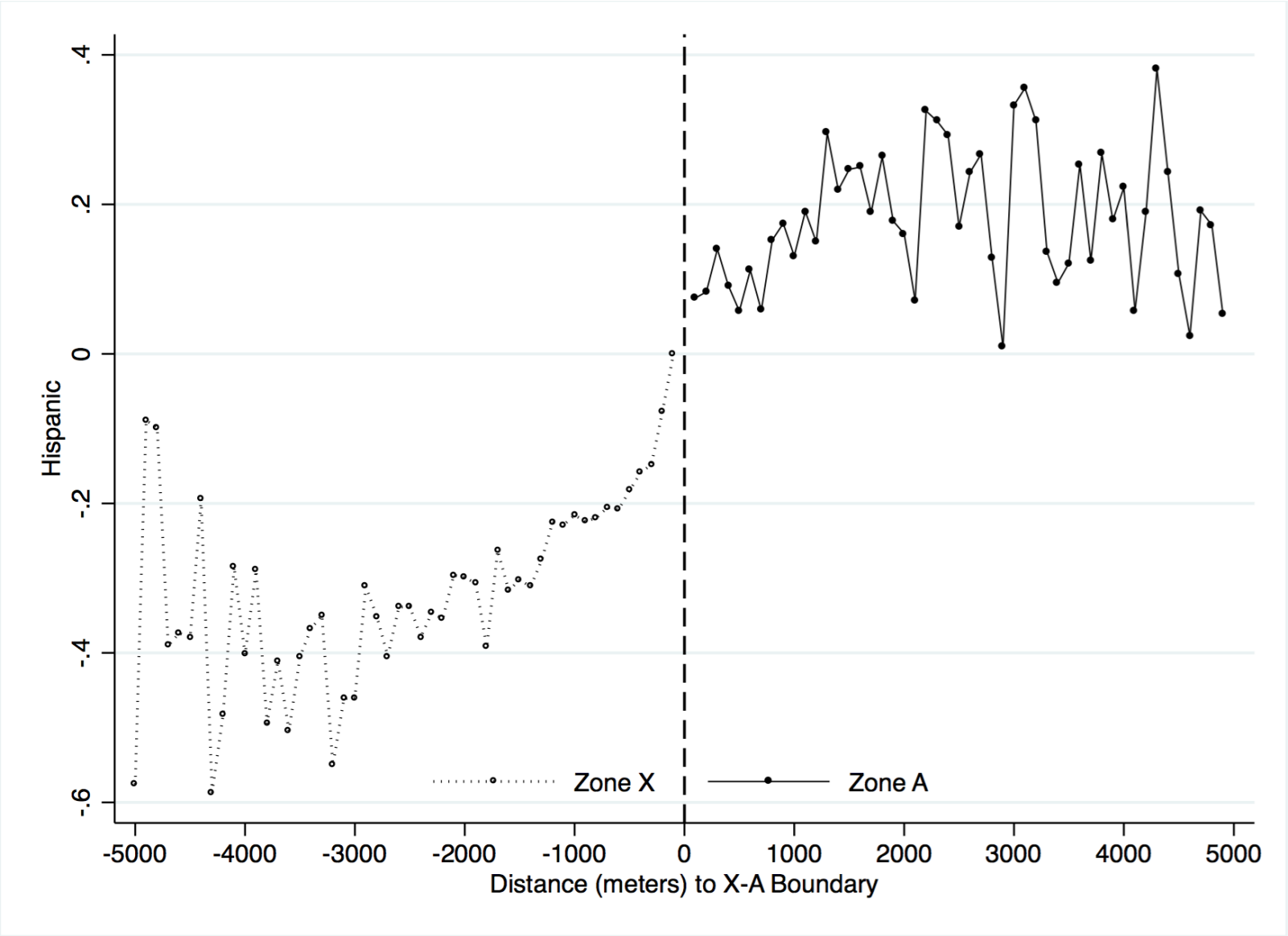
1. Sociodemographic attributes are different across flood zones
2. Hedonic results

% White Against Distance to X-A Flood Boundaries



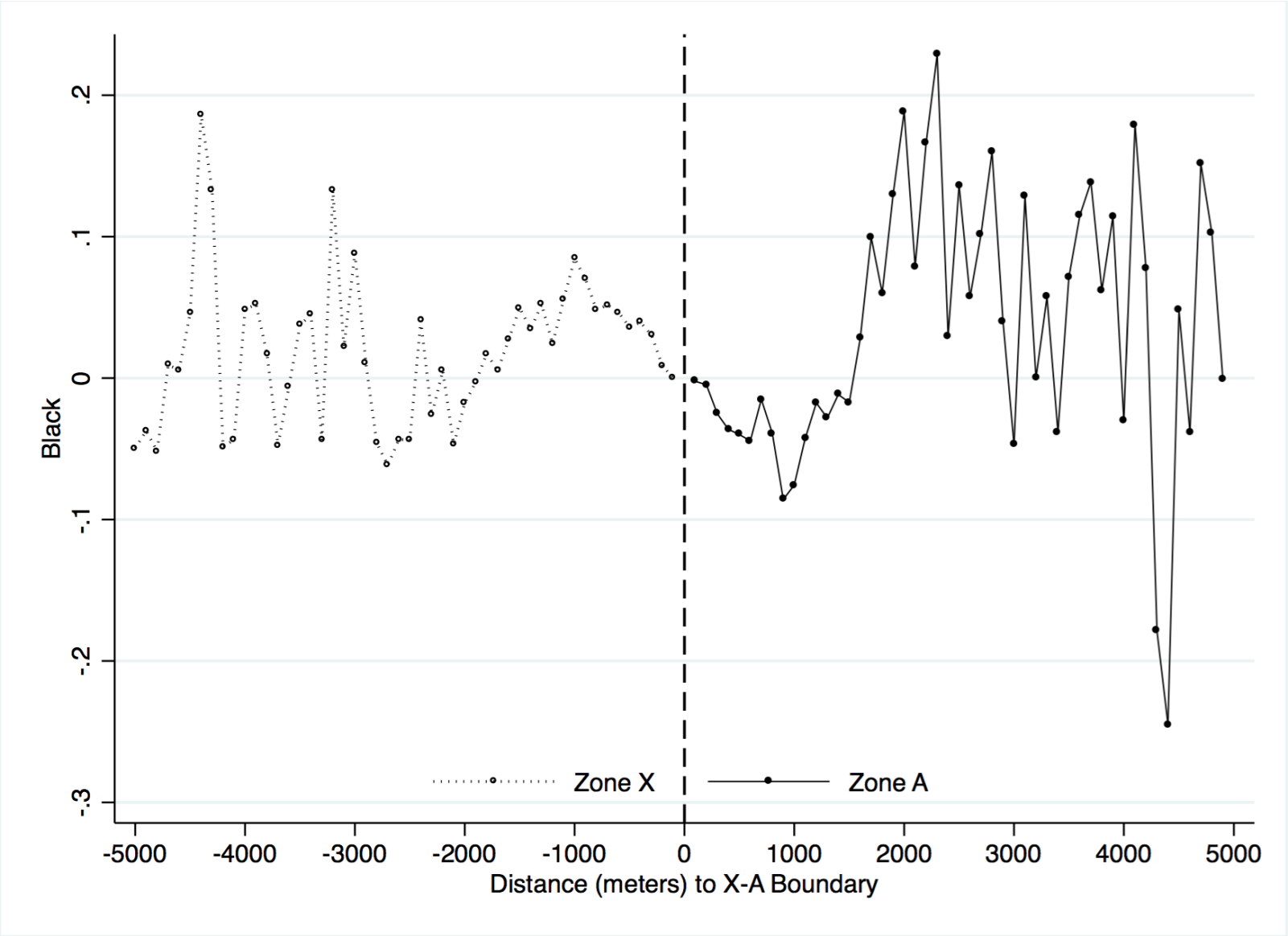
Note: Averages are relative to the estimate at 100-meters on the X side of the boundary.

% **Hispanic** Against Distance to X-A Flood Boundaries



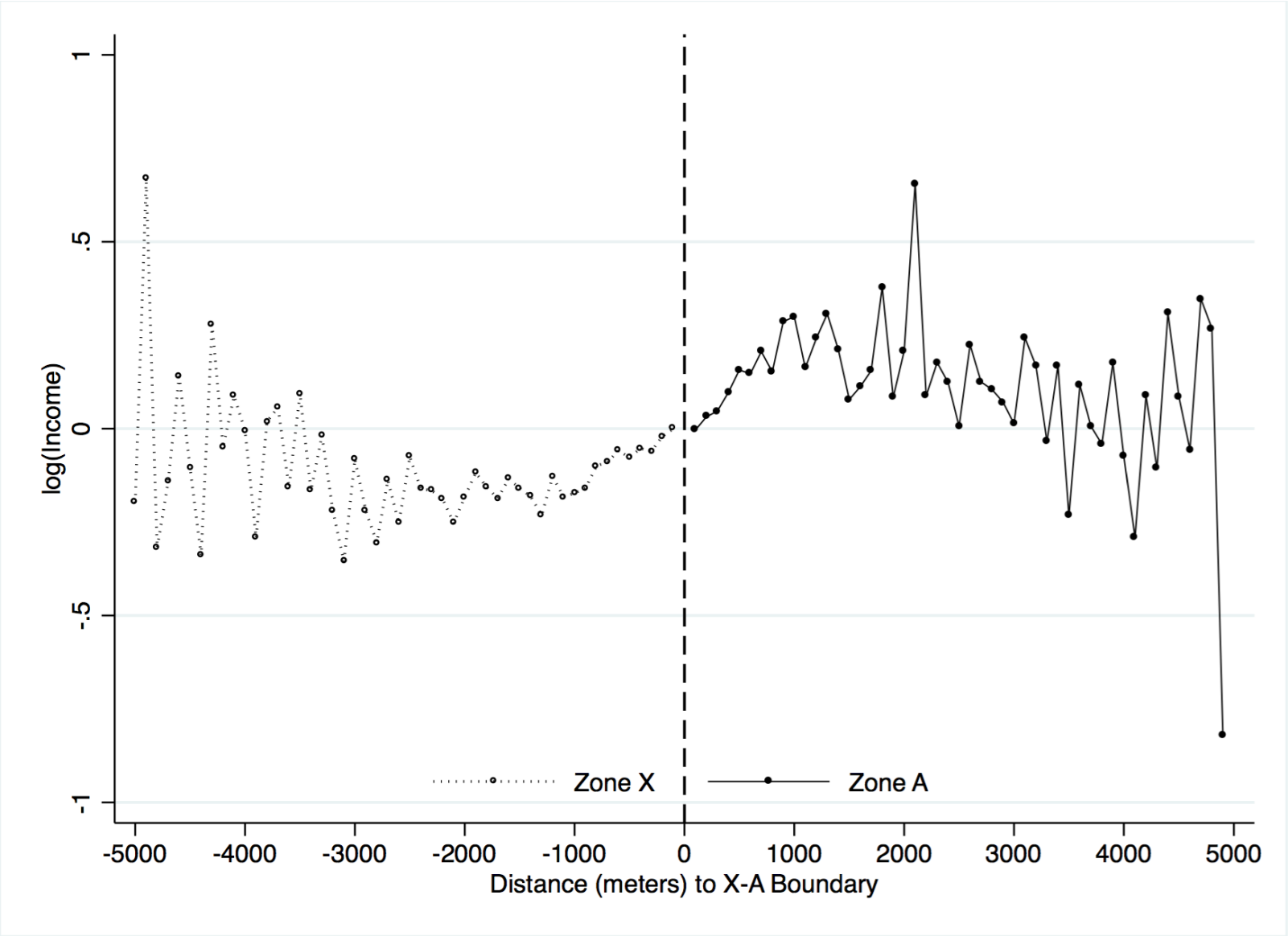
Note: Averages are relative to the estimate at 100-meters on the X side of the boundary.

% Black Against Distance to X-A Flood Boundaries



Note: Averages are relative to the estimate at 100-meters on the X side of the boundary.

Log Income Against Distance to X-A Flood Boundaries



Note: Averages are relative to the estimate at 100-meters on the X side of the boundary.

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Panel A. Progression of Controls

Dep. Var.:		Add Flood Controls		BDD (<1km)
Annual Rent	(1)	(2)	(3)	(4)
SFHA	-2,203***	-1,642***	-1,120***	-658.6***
	(80.15)	(91.70)	(85.84)	(100.1)
Elevation		-477.8***	-168.0***	-263.8***
		(33.89)	(31.81)	(47.82)
Relative BFE		460.6***	904.5***	1,081***
		(16.47)	(16.30)	(22.21)
Distance to Coast:				
<0.1km			14,392***	11,022***
			(268.4)	(400.5)
<0.5km			11,854***	7,948***
			(177.5)	(295.2)
<1km			9,908***	6,663***
			(192.9)	(263.0)
<2km			6,000***	5,022***
			(148.5)	(199.5)
<3km			3,521***	2,539***
			(141.9)	(177.7)
<4km			2,269***	808.2***
			(152.6)	(196.2)
<5km			2,161***	255.3
			(150.6)	(186.3)
Observations	48,174	48,174	48,174	31,601

Panel B. Alternative Specifications

	Other BDD Distance Buffers			Ignore Price Supports
Sample Restriction:	<800m	<500m	<300m	None
SFHA	-657.6***	-542.7***	-681.6***	-18.84
	(103.5)	(113.9)	(126.0)	(83.21)
Observations	29,044	23,194	17,594	48,174

Model

- Discrete choice residential sorting model (Bayer et al., 2007, 2009; Klaiber and Phaneuf, 2010; Tra 2010)
  - Boundary discontinuity design to control for correlated amenities (Black, 1999)
  - Allows for sorting over flood risk by homebuyer race/ethnicity and income
  - Accounts for property-specific NFIP premium subsidies
- Residence choice: Combination of Census tract, flood zone pricing characteristics, and distance from coast
- Households pick a choice to maximize utility based on preferences for neighborhood attributes and cost of living
  - Allow for heterogeneity by race/ethnicity and income quintiles
- Assuming distribution for idiosyncratic tastes, parameters estimated using ML

Identification Concerns

Unobserved neighborhood factors correlated with flood risk/zones

- Set of covariates including distance to coast bins and elevation
- Boundary discontinuity design utilizing choices within 1km of boundary

Neighborhood costs correlated with unobserved neighborhood quality

- Stage 1: Estimate choice-specific fixed-effects (Berry, 1994) and heterogeneous taste parameters
- Stage 2: Decompose choice-specific fixed-effects by choice attributes and instrument for price
  - Construct price instruments based on share of developed land over 5 km away (Bayer and Timmins, 2007)

Flood Zone Sorting ($/year)

	Flood Zone		Income (in $1,000's)	
Base Group	est.	s.e.	mean	s.d.
White, Quintile 1	-710.49	218.11	30.28	5.89
Relative to Base Group	est.	s.e.		
Black	229.25	29.40	53.85	57.17
Hispanic	91.74	20.96	86.50	134.08
Quintile 2	-15.94	24.12	45.69	4.30
Quintile 3	-31.00	24.60	63.90	6.39
Quintile 4	-62.65	25.43	94.74	12.59
Quintile 5	-198.03	27.12	235.17	245.23

Additional Preferences

Sorting Mechanisms

- Tastes (Banzhaf and Walsh, 2008)
- Access to information (Hausman and Stolper, 2019)
- Beliefs (Bakkensen and Barrage, 2018)
- Housing discrimination (US HUD, 2002; Christensen and Timmins, 2018)
- Learning (Ma, 2019)

Policy Counterfactual

NFIP subsidy elimination

- Pre-FIRM
- CRS
- Grandfathering

Welfare impact of such a change calculated (McFadden, 1999)

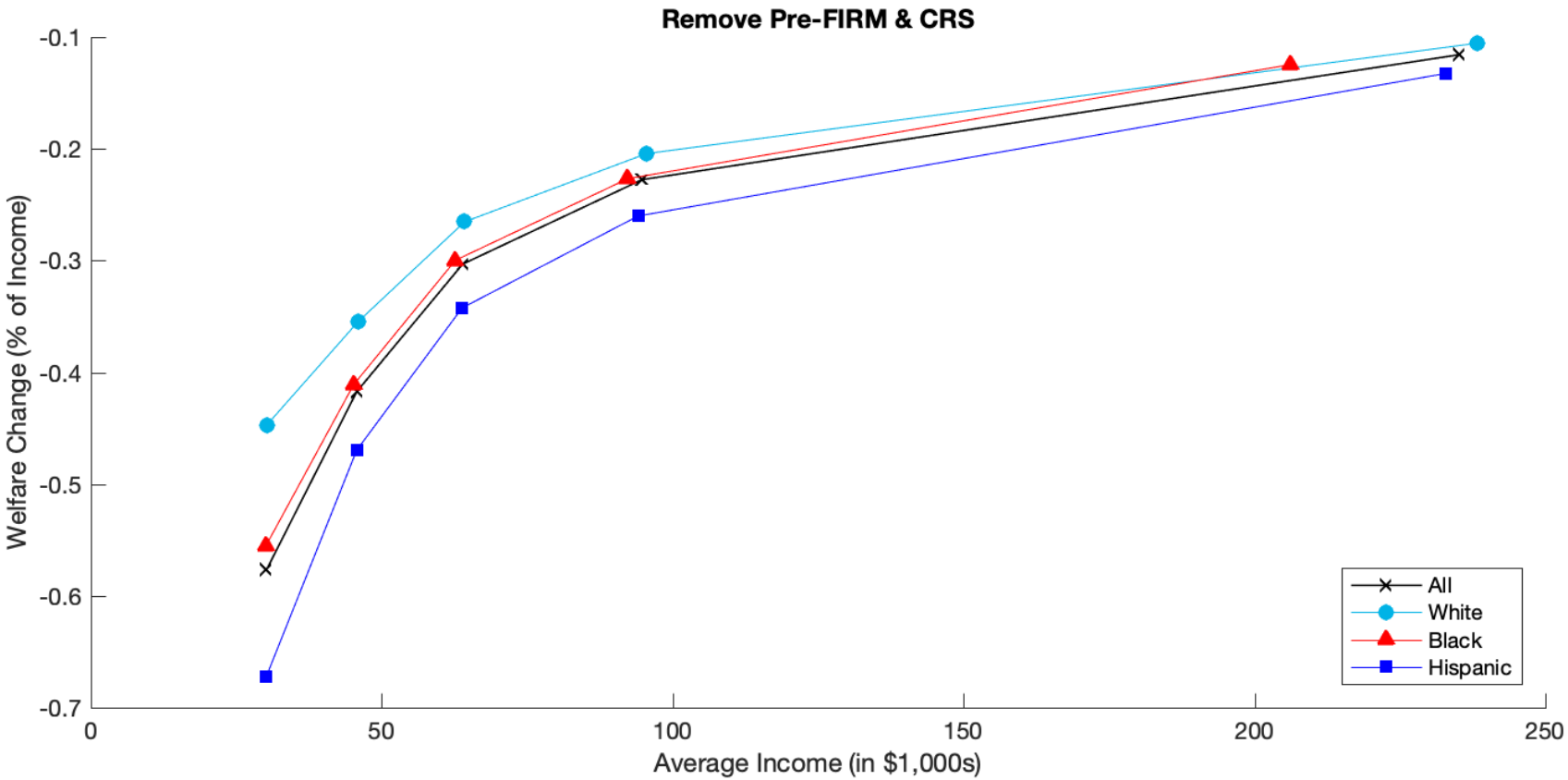
- Partial equilibrium compensating variation

Assess heterogeneous impacts on household

- Welfare
- Flood risk exposure

Welfare changes include only losses to those directly affected by policy

Subsidy Removal Impact as a Percentage of Income

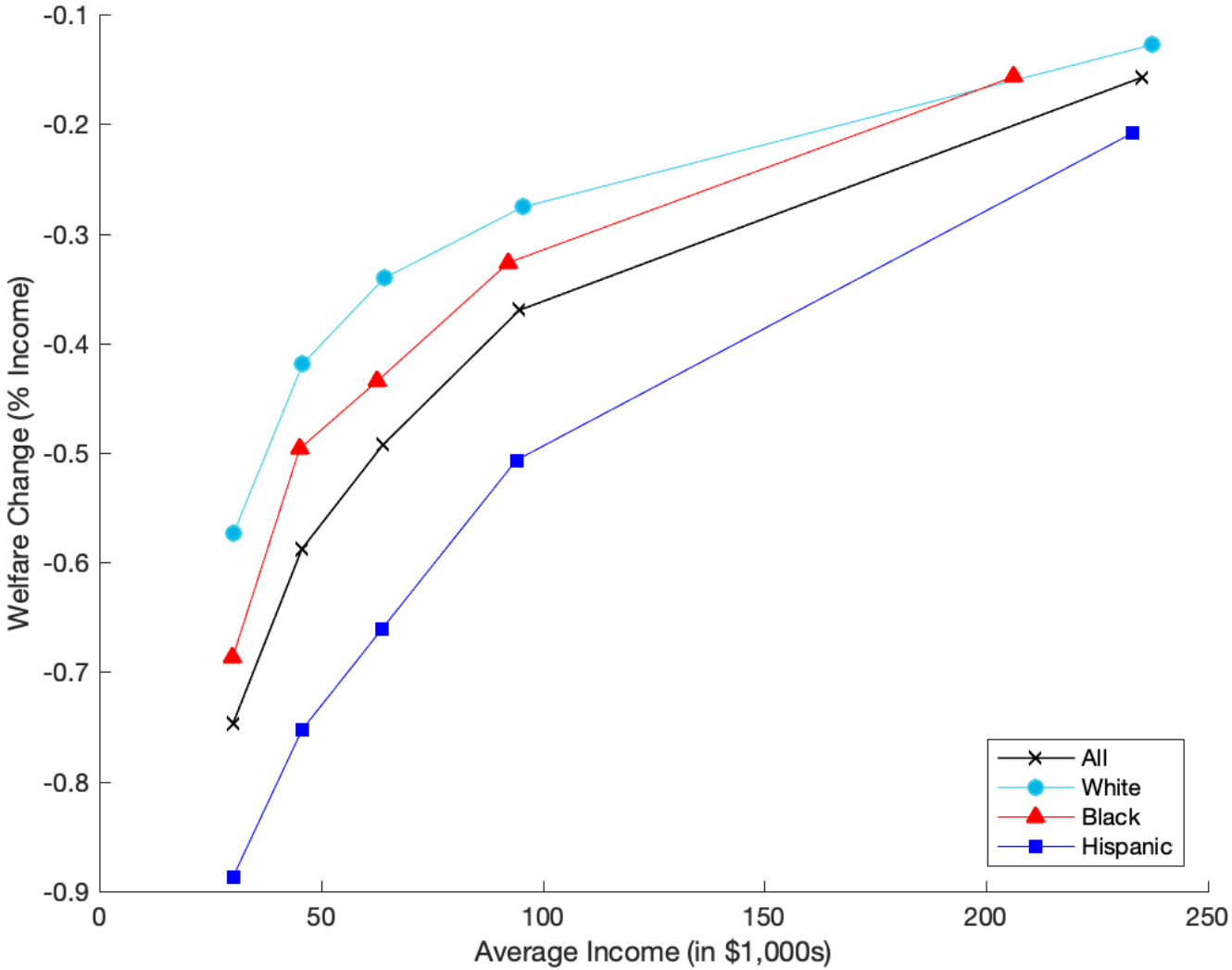


% Change in Race/Income Distribution by Zone

All	Zone X	Zone A	Zone V
White	11.55	-11.74	-54.36
Black	2.24	-2.32	-2.01
Hispanic	13.86	-14.27	-29.86

All	Zone X	Zone A	Zone V
Q1	4.70	-4.87	-4.03
Q2	4.89	-5.06	-4.90
Q3	4.84	-4.98	-10.11
Q4	5.52	-5.64	-19.45
Q5	7.71	-7.77	-47.75

Grandfathering Removal Impact as a Percentage of Income



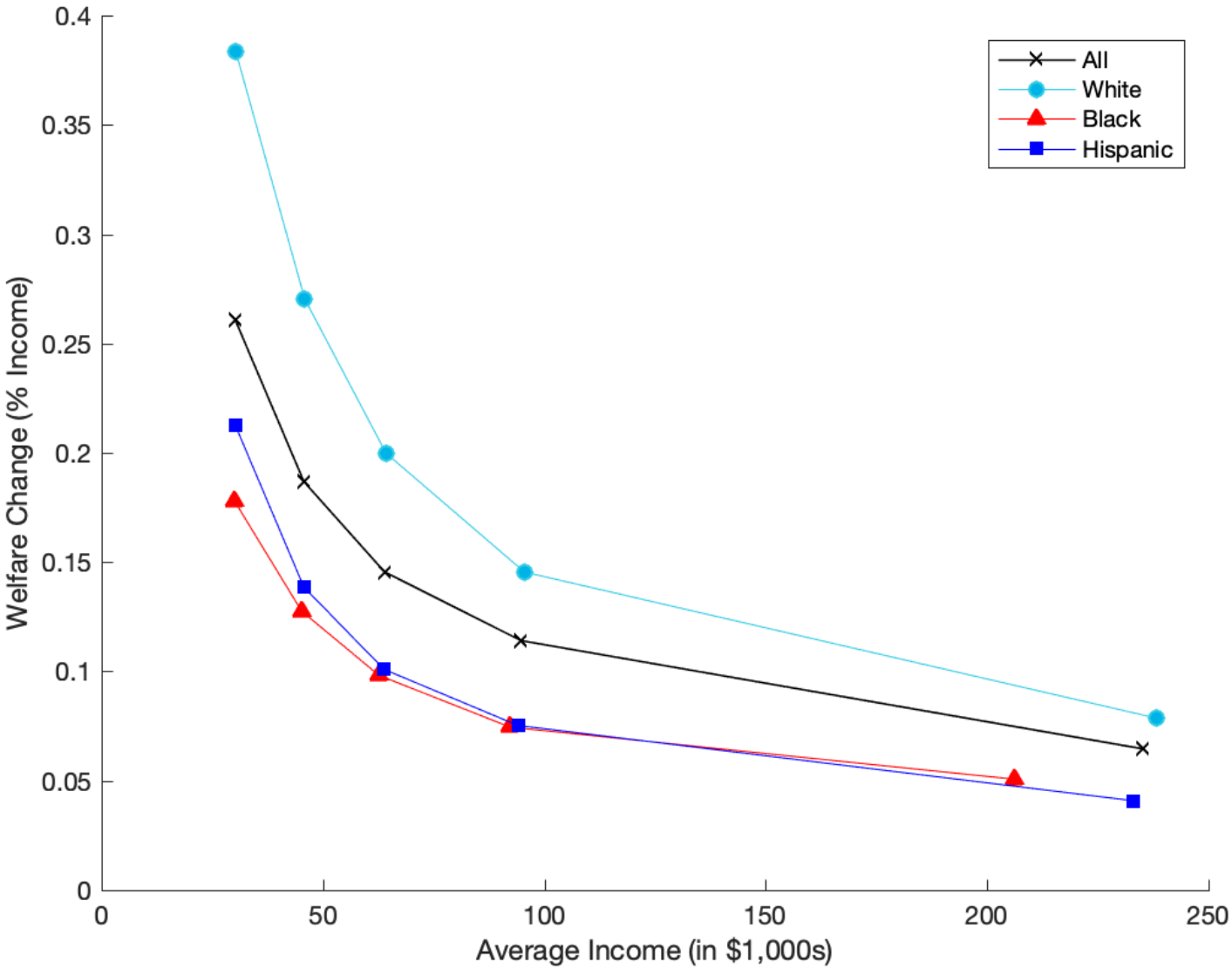
Zone Transition

Policy Counterfactual

Flood Map Updates

- Welfare impact calculated as value of information (Leggett, 2002)
  - Partial equilibrium compensating variation
- Assess heterogeneous welfare impacts on household
- Compare aggregated benefits with costs

Flood Map Update Benefits as a Percentage Income



Aggregate Impacts of Policy Reforms

Summing across households in Miami-Dade, Port St. Lucie, Ft. Lauderdale CSA

- Not equal to changes in total welfare
  - Depends on uptake, benefits, and specific map changes Uptake

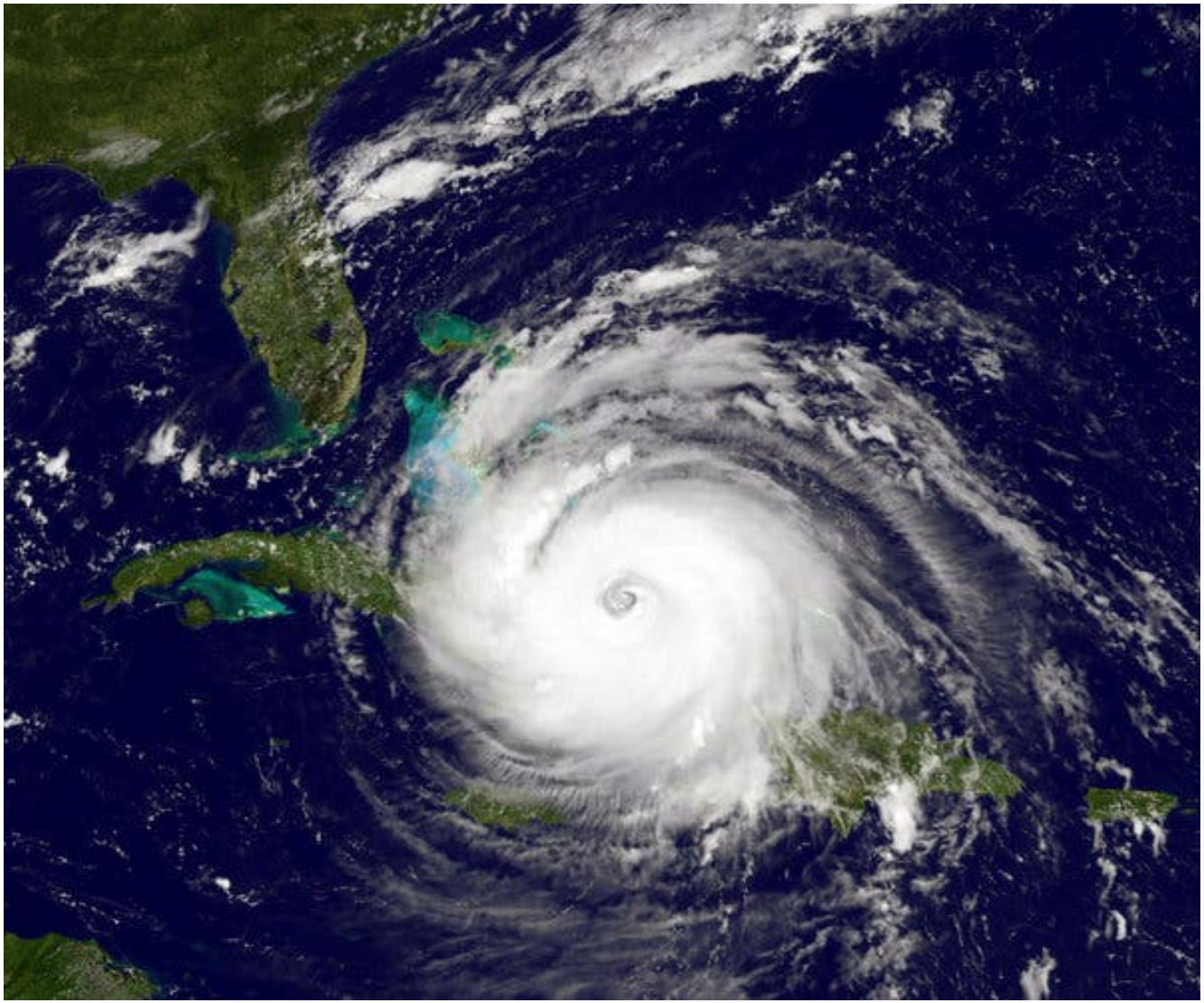
	Aggregate Impacts ($ millions/year)
Remove Pre-FIRM & CRS subsidies	-$143.5
Remove Grandfathering	-$209.7
Value of Map Revisions	$243.5

- Benefits likely outweigh costs of reforms
  - Costs significantly mitigated by behavioral response
  - $774 million/year costs if no resorting occurred
- Significant distributional costs to current households
  - Public outcry of affordability from 2012 Biggert-Waters Act
  - Future reform attempts would need to consider

Policy Implications for Managing Climate Risk

- Individuals avoid climate risk
  - $\sim$6% home price discount for flood risk
- Clear heterogeneous sorting over flood risk
  - Low income and minority residents more likely to sort into flood risk
- Policy reforms likely have large benefits relative to costs
  - Fewer individuals in high risk zones
  - Outdated flood maps result in large information costs
    - ⋆ Especially to vulnerable households
- Behavioral responses key in assessing policy impacts
  - Future reforms likely bring distributional consequences
  - Higher concentration of low-income and minority groups in high risk areas
  - Important in understand policy process of reforms
  - Migration is an important (but costly) channel to mitigate climate risks
- Critical to manage climate risk now and in the future

Thank you



(NYTimes, 2017)