

# Damage vs. Risk Perception: Why Do House Prices Recover After Hurricanes?

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# Motivation

- Floods increase in frequency and magnitude and are the most costly among natural disasters in the US
  - Cost of damages: \$170 billion for Katrina, \$74 billion for Sandy, \$131 billion for Harvey
- Floods cause house prices to decline immediately
  - Change in risk perception
  - Direct damage
- Mixed findings in the literature:
  - Negative persistent effects on property values: Gibson & Mullins (JEEM 2020), Ortega & Taspinar (JUE 2018)
  - Temporary effects: Zhang (RSUE 2016), Atreya et al. (LE 2013), Bin & Landry (JEEM 2013) [◀ more](#)

# Research Question

- How do house prices evolve after hurricanes?
- Which factors explain the house price recovery after hurricanes?
  - Do home-buyers forget about floods?
  - Do home-buyers internalize floodplain risk designation?
  - Does renovation and rebuilding explain the house price recovery?

# Hypotheses

- Price effect is transitory:
  - If hurricanes do not change risk perception, the impacts of hurricanes will reflect the costs of damage which is typically repaired
  
- Price effect is permanent:
  - If hurricanes permanently change risk perception, the impacts of hurricanes on house prices will be permanent

# This Paper

- Provide explanations for the house price decline followed by recovery after hurricanes:
  - Combine house prices, damage assessment, and building permit data
  - Determine the extent of remodeling and rebuilding
- Test for change in risk perception:
  - Compare flood insurance take-up in affected and non-affected areas within floodplain, outside of floodplain
- Utilize Hurricane Sandy as a quasi-experiment to study house price dynamics:
  - Study the 16 affected counties in New Jersey over 20 years  
Sandy and NJ
  - Examine damaged and non-damaged properties in floodplain
  - Similarly, damaged and non-damaged properties out of floodplain

# Preview of Findings

- No persistent penalty for damaged floodplain properties
- The drop in house prices is largely driven by direct damage:
  - Severely-damaged properties face an immediately sharp decline (31%) in price, and take longer to recover
  - Less-severely-damaged properties face a smaller decline (12%) and recover faster
- House price rebound is explained by housing renovation and rebuilding
- Extent of spending on renovating and rebuilding is associated with extent of damage
  - The most significant spending on rebuilding and renovating on properties with major damage

- Temporary effects of floods, hurricanes on property values:
  - Hallstrom & Smith (2005); Atreya et al. (2013); Bin & Landry (2013); Zhang (2016)
- Negative persistent effects of floods, hurricanes on property values:
  - Ortega & Taspinar (2018), Gibson & Mullins (2020)

**My Contributions:** Explain house price drop followed by price recovery empirically

- Isolate the price effects due to direct damages
- Link damaged properties to building permits
- Use flood insurance take-up rates to show risk perception does not change

## 4 main sources of data:

- Floodplain maps
  - Historical floodplain map: FEMA Q3 Flood data, National Flood Hazard Layer (NFHL) Inventory Table
  - Current floodplain map: NFHL
  - Final data includes 83% of all communities in 16 counties
- Historical Damage Assessment data from FEMA
  - Damaged properties and to what extent: very minor, minor, major, destroyed
  - Assessment is conducted using high-resolution post-event imagery
- Housing price data are from Zillow Transaction and Assessment Dataset (ZTRAX) [◀ more details](#)
- Building permits from NJ DCA (2010-2019) [◀ more details](#)

- New Jersey statewide parcel map [← more details](#)
- 2010 TigerLine shapefile (block group and tract boundaries)
- New Jersey Coastline
  - From Department of Environmental Protection, version 20090116
- Flood insurance data from Open FEMA

- To study the effect of Sandy on house prices in floodplains, I apply DiD estimation:

$$\log(P_{ibt}) = \alpha + \beta \text{Damage}_i \times \text{Post}S_t + \gamma \text{Damage}_i \quad (1) \\ + \theta \mathbf{X}_{it} + \lambda_{gt} + \alpha_b + \epsilon_{ibt}$$

- $\log(P_{ibt})$ : log price house  $i$  in block group  $b$ , sold in year  $t$
- $\text{Damage} = 1$  if house  $i$  damaged
- $\text{Post}S = 1$  if sold after Sandy
- $\mathbf{X}_{it}$ : controls for housing characteristics
- $\lambda_{gt}$ : year fixed effects vary by distance to the coastline
- $g = \{\text{WaterFront}_i, \text{Walking}_i, \text{Biking}_i, \text{Driving}_i\}$
- $\alpha_b$ : block group fixed effects
- $\epsilon_{ibt}$ : error term

- To assess the validity of the parallel trend assumption, I estimate the event study coefficients  $\beta_t$ :

$$\log(P_{ibt}) = \sum_{\substack{y=2000 \\ y \neq 2011}}^{2019} \beta_t 1[t = y] \times \text{Damage}_i + \theta \mathbf{X}_{it} \quad (2) \\ + \lambda_{gt} + \alpha_b + \epsilon_{ibt}$$

- Key identification assumption: in the absence of Sandy, damaged and non-damaged properties would have had same trend in prices

# Estimation Results

$$\text{Equation: } \log(P_{ibt}) = \alpha + \beta \text{Damage}_i \times \text{PostS}_t + \gamma \text{Damage}_i + \theta \mathbf{X}_{it} + \lambda_{gt} + \alpha_b + \epsilon_{ibt}$$

Table: Effect of Hurricane Sandy on House Prices in Floodplain

	(1)	(2)	(3)	(4)
	ln_houseprice	ln_houseprice	ln_houseprice	ln_houseprice
Damage x PostSandy	0.088*** (0.019)	0.087*** (0.018)	0.087*** (0.018)	0.091*** (0.018)
Damage	0.002 (0.021)	0.005 (0.020)	0.005 (0.020)	-0.000 (0.023)
House Age		-0.004*** (0.000)	-0.004*** (0.000)	-0.004*** (0.000)
Lot Size			0.006 (0.003)	0.002 (0.003)
Constant	5.532*** (0.035)	5.631*** (0.035)	5.628*** (0.035)	5.530*** (0.039)
Observations	95979	95979	95979	95979
FE	Block group	Block group	Block group	Tract
Year x Distance FE	Yes	Yes	Yes	Yes
R-squared	0.633	0.644	0.645	0.595

Standard errors in parentheses. Standard errors are clustered at census block group level.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

# Estimation Results

$$\text{Equation: } \log(P_{ibt}) = \alpha + \beta \text{Damage}_i \times \text{PostS}_t + \gamma \text{Damage}_i \\ + \theta \mathbf{X}_{it} + \lambda_{gt} + \alpha_b + \epsilon_{ibt}$$

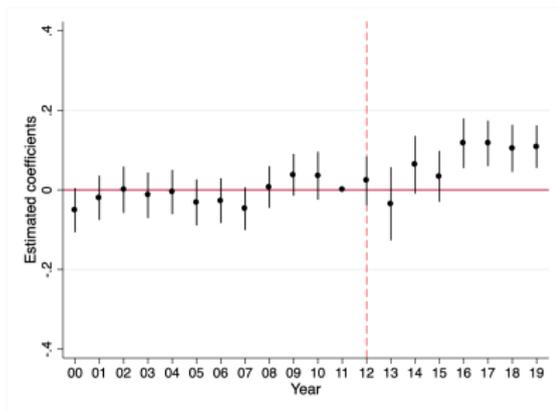
Table: Effect of Hurricane Sandy on House Prices out of Floodplain

	(1)	(2)	(3)	(4)
	ln_houseprice	ln_houseprice	ln_houseprice	ln_houseprice
Damage x PostSandy	0.012 (0.033)	0.019 (0.034)	0.021 (0.034)	0.017 (0.034)
Damage	0.087 (0.054)	0.067 (0.051)	0.067 (0.051)	0.108* (0.043)
House Age		-0.005*** (0.000)	-0.005*** (0.000)	-0.005*** (0.000)
Lot Size			0.010*** (0.001)	0.010*** (0.002)
Constant	5.221*** (0.104)	5.388*** (0.092)	5.386*** (0.092)	5.363*** (0.105)
Observations	940117	940117	940117	940117
FE	Block group	Block group	Block group	Tract
Year x Distance FE	Yes	Yes	Yes	Yes
R-squared	0.616	0.634	0.634	0.574

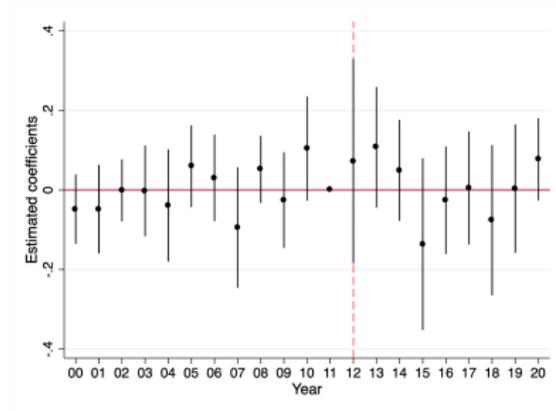
Standard errors in parentheses. Standard errors are clustered at census block group level.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

# Event Study Estimation



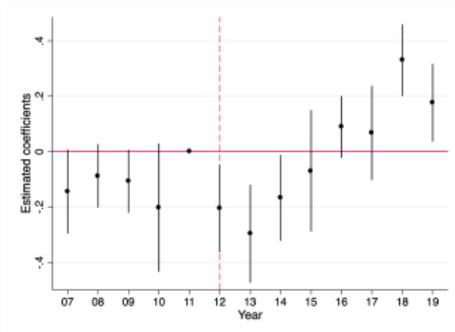
(a) Floodplain



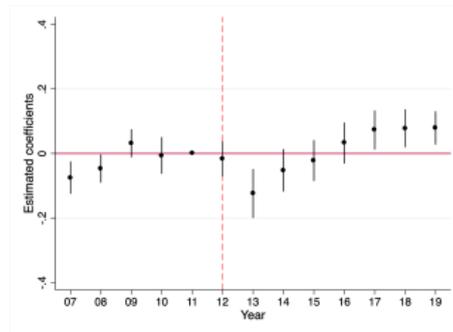
(b) Non-Floodplain

**Figure:** Event study, effects of Hurricane Sandy on prices of damaged properties in floodplain, out of floodplain

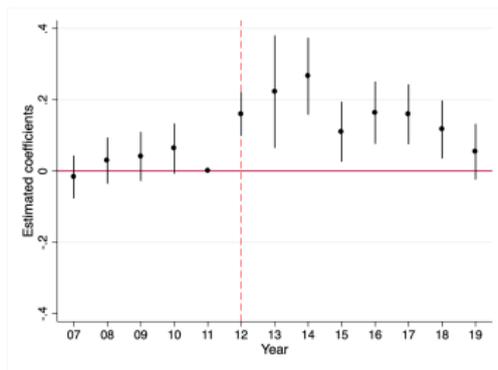
# Heterogeneous Effects of Hurricane Sandy in Floodplain



(a) Major vs. Non-Damaged

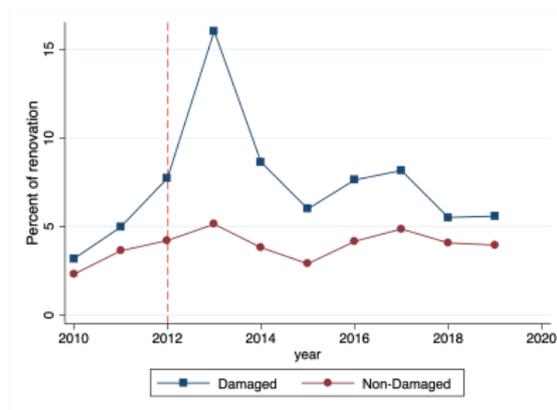


(b) Minor vs. Non-Damaged

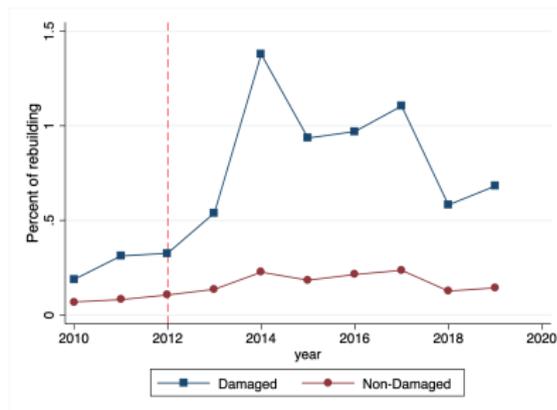


(c) Very Minor vs. Non-Damaged

# Renovation and Rebuilding After Hurricane Sandy



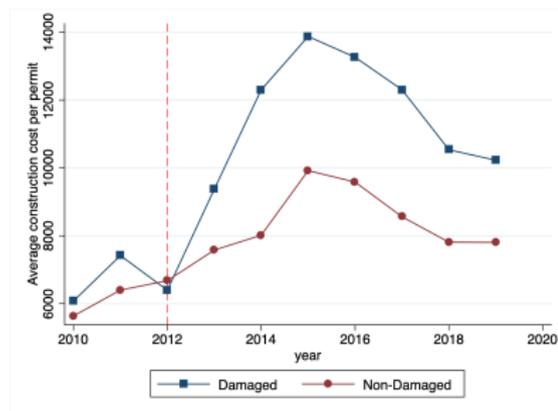
(a) Percent Renovated



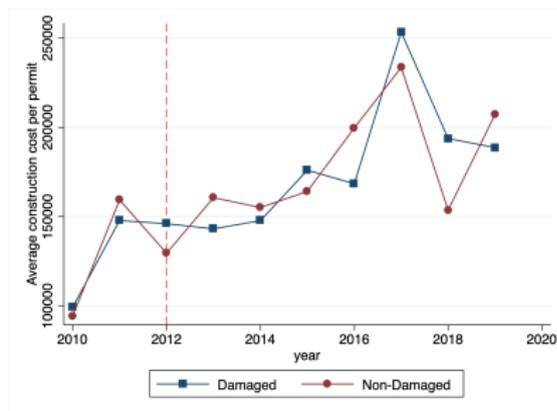
(b) Percent Rebuilt

Figure: Percent of Property Renovated and Rebuilt in Floodplain

# Average Spending on Renovation and Rebuilding



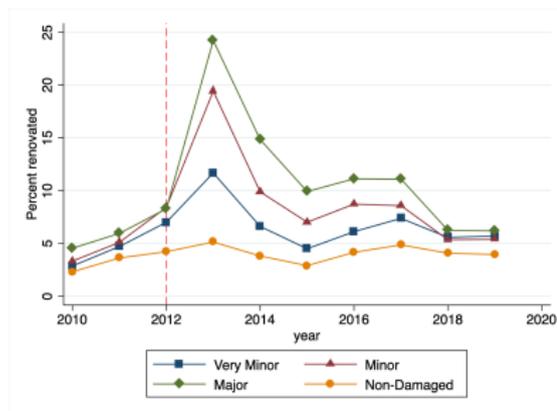
(a) Average Spending on Renovation



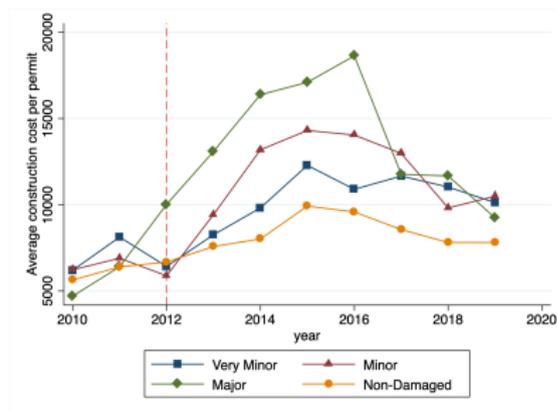
(b) Average Spending on Rebuilding

Figure: Average Renovation Spending and Rebuilding Spending

# Renovation by Extent of Damage



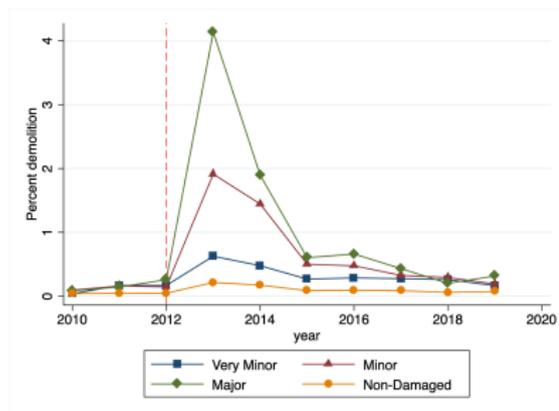
(a) Percent Renovated



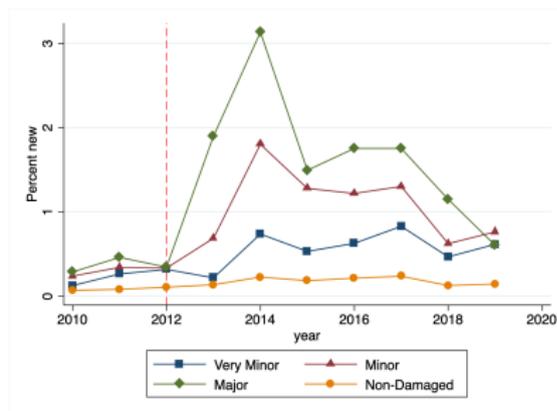
(b) Average Spending on Renovation

Figure: Percent of Property Renovated and Average Renovation Spending

# Demolishing and Rebuilding by Extent of Damage



(a) Percent Demolished



(b) Percent Rebuilt

Figure: Percent of Property Demolished and Rebuilt

# Spending on Remodeling and Rebuilding

Estimation of the construction spending on damaged properties relative to non-damaged properties:

$$\begin{aligned} \text{Spending}_{izt} = & \alpha + \beta \text{Damage}_i \times \text{Post}S_t + \gamma \text{Damage}_i \quad (3) \\ & + \theta \text{Age}_{it} + \alpha_z + \alpha_t + \epsilon_{izt} \end{aligned}$$

and

$$\begin{aligned} \text{Spending}_{izt} = & \kappa_1 \text{VeryMinor}_i + \kappa_2 \text{Minor}_i + \kappa_3 \text{Major}_i \quad (4) \\ & + \eta_1 \text{VeryMinor}_i \times \text{Post}S_t + \eta_2 \text{Minor}_i \times \text{Post}S_t \\ & + \eta_3 \text{Major}_i \times \text{Post}S_t + \theta \text{Age}_{it} + \alpha + \alpha_z + \alpha_t + \epsilon_{izt} \end{aligned}$$

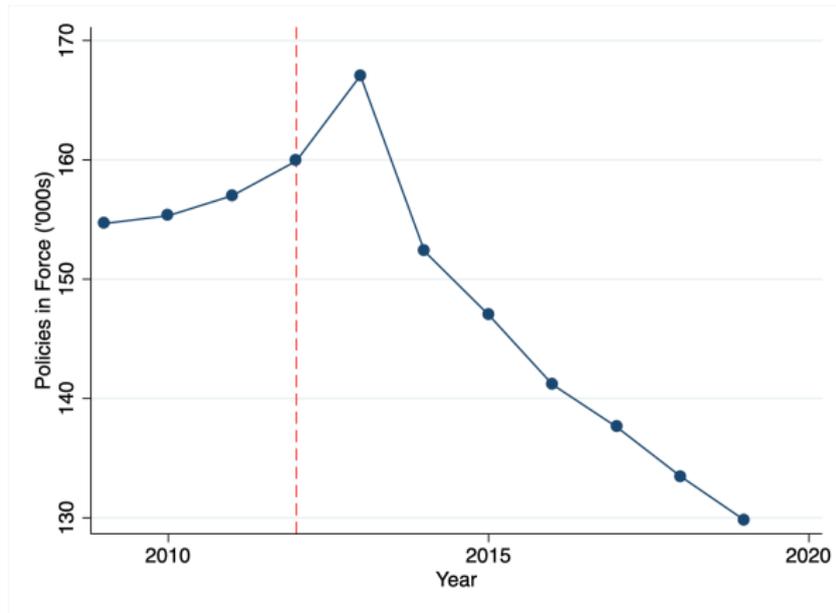
where:

- $\text{Spending}_{izt}$ : spending on renovation or rebuilding of house  $i$  in zip code  $z$  at year  $t$
- $\alpha_z, \alpha_t$ : zip code and year fixed effects

# Estimation Results: Construction Spending

	Floodplain		Non-Floodplain
	(1) Spending	(2) Spending	(3) Spending
Damage x PostSandy	10381*** (1275)		-2499 (3639)
Damage	-2014* (922)		5795 (3618)
VeryMinor		-1863 (1363)	
Minor		-2718* (1099)	
Major		1035 (2660)	
VeryMinor x PostSandy		6226** (1937)	
Minor x PostSandy		11440*** (1404)	
Major x PostSandy		22192*** (4726)	
Observations	112,491	112,491	871,858
FE	zip code	zip code	zip code
Year FE	Yes	Yes	Yes
R-squared	0.060	0.061	0.036

# Flood Insurance Take-up



**Figure:** Number of Flood Insurance Policies in Force in New Jersey by Year

**Note:** This graph only shows the number of flood insurance are effective for one-to-four families

# Flood Insurance Take-up

- To study the effect of Sandy on flood insurance take-up, I apply DiD estimation:

$$\begin{aligned} TotalPolicy_{it} = & \alpha + \beta Affect_i \times PostS_t + \gamma Affect_i \quad (5) \\ & + \theta PricePer\$1000Coverage_{it} + \alpha_t + \epsilon_{it} \end{aligned}$$

- $TotalPolicy_{it}$ : total number of flood insurance of census tract  $i$  in year  $t$
- $Affect = 1$  if census tract  $i$  has at least 1 house damaged during Sandy
- $PostS = 1$  if year  $> 2012$
- $PricePer\$1000Coverage$ : Average cost per every \$1000 coverage
- $\epsilon_{it}$ : error term

# Flood Insurance Take-up Estimation Results

Table: Effect of Hurricane Sandy on Flood Insurance Take-up

	(1)	(2)
	TotalPolicy	TotalPolicy
Affect x PostSandy	-30.729 (17.226)	7.529*** (1.759)
Affect	319.912*** (13.678)	25.912*** (1.401)
PricePer\$1000Coverage	-15.469*** (1.048)	-1.522*** (0.327)
Constant	146.414*** (14.005)	14.419*** (1.404)
Observations	10645	15206
Year FE	Yes	Yes
R-squared	0.141	0.083

Standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

# Percent of Single Family Houses Sold

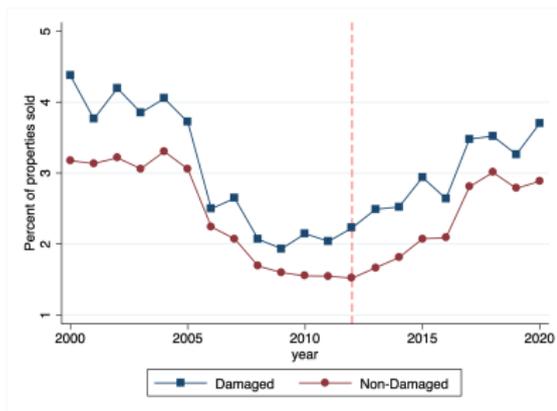
- Concerns:
  - Homeowners of damaged properties might worry about future floods (increase risk perception)
    - more damaged properties are sold after Hurricane Sandy
  - Damaged properties might be more difficult to sell without price concessions
- Percent of single family houses sold is calculated:

$$PercentSold_{ijt} = 100\% \frac{TotalTransactions_{ijt}}{TotalParcels_{ij}} \quad (6)$$

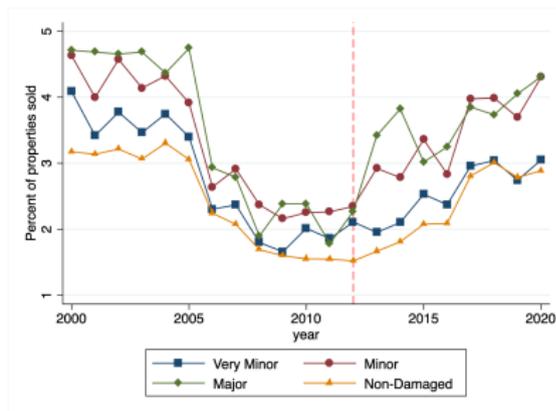
where

- $i = \{\text{damaged, non-damaged}\}$
- $j = \{\text{floodplain, non-floodplain}\}$

# Percent of Single Family Houses Sold by Year



(a) Floodplain



(b) By Extent of Damage

Figure: Percent of Single Family Houses Sold by Year

- Concern:
  - Properties sold before and after Hurricane Sandy are different properties
    - affect the estimation results
- Address: use repeat sales sample
  - A property must be sold at least twice.
  - Among transactions, one transaction must occur before Sandy and one transaction must occur after Sandy

- I apply difference-in-differences estimation on repeat sales sample:

$$\log(P_{it}) = \alpha_i + \delta \text{Damage}_i \times \text{Post}S_t + \theta \text{HouseAge}_{it} + \alpha_t + \epsilon_{it} \quad (7)$$

and

$$\begin{aligned} \log(P_{it}) = & \alpha_i + \delta_1 \text{VeryMinor}_i \times \text{Post}S_t + \delta_2 \text{Minor}_i \times \text{Post}S_t \\ & + \delta_3 \text{Major}_i \times \text{Post}S_t + \theta \text{HouseAge}_{it} + \alpha_t + \epsilon_{it} \end{aligned} \quad (8)$$

# Repeat Sales Estimation Results

**Table:** Effect of Hurricane Sandy on House Prices using Repeat Sales Sample

	Floodplain		Non-Floodplain
	(1) log(HousePrice)	(2) log(HousePrice)	(3) log(HousePrice)
Damage x PostSandy	0.151*** (0.025)		-0.001 (0.057)
VeryMinor x PostSandy		0.161*** (0.032)	
Minor x PostSandy		0.139*** (0.026)	
Major x PostSandy		0.180* (0.071)	
Observations	38,389	38,389	382,458
FE	Property	Property	Property
Year FE	Yes	Yes	Yes
R-squared	0.816	0.816	0.798

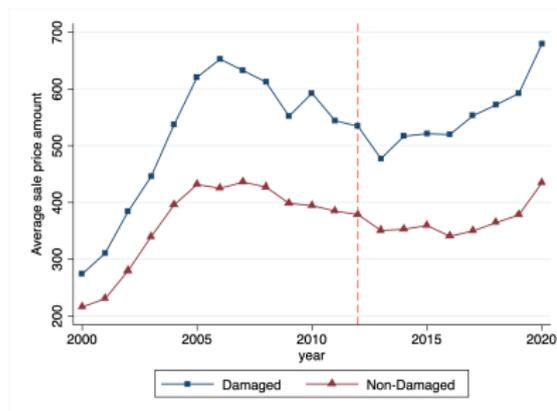
Standard errors in parentheses. Standard errors are clustered at census block group level.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

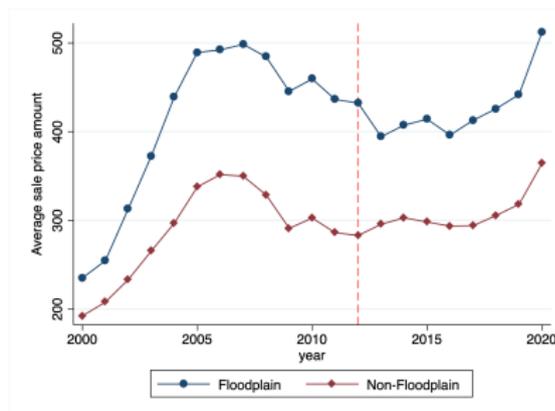
# Conclusions

- There is no persistent penalty for damaged properties in floodplains
  - Hurricanes do not permanently heighten individuals risk perception
- The immediate decline in housing prices is most likely due to direct damages
- My findings are supported by both full sample and repeat sales sample
- Remodeling and rebuilding explain the recovery in house prices

# Appendices: Average House Prices



(a) Floodplain Properties



(b) All Properties

Figure: Average House Prices by Year

# Number of Damaged Properties

Table: Number of Damaged Properties

	Extent of Damage	Number of Properties
<b>All</b>	VeryMinor	33,155
	Minor	26,926
	Major	3,587
	Total	63,668
<b>Floodplain</b>	VeryMinor	26,185
	Minor	25,197
	Major	3,481
<b>Non-Floodplain</b>	VeryMinor	6,958
	Minor	1,724
	Major	105

# Summary Statistics

Table: Summary Statistics

	Floodplain		Non-Floodplain	
	Damaged	Non-Damaged	Damaged	Non-Damaged
House Price (thousands)	527.54 (365.92)	361.10 (317.38)	411.36 (337.30)	295.07 (209.25)
log(Price)	6.02 (0.76)	5.54 (0.89)	5.72 (0.81)	5.45 (0.74)
House Age	33.84 (32.08)	43.76 (32.17)	52.59 (35.19)	45.94 (31.88)
Distance to Beach (yards)	276.40 (262.08)	3,687.75 (6,785.62)	755.21 (1,440.36)	7,688.09 (7,320.48)
Lot Size	0.44 (3.92)	0.39 (1.69)	0.36 (3.21)	0.37 (1.38)
Bedrooms	3.69 (1.17)	3.27 (0.99)	3.24 (1.25)	3.20 (1.43)
Bathrooms	2.27 (1.04)	2.44 (1.09)	2.53 (1.22)	2.49 (1.05)
Observations	30537	65442	2349	937768

**Table:** Summary Statistics Before and After Hurricane Sandy

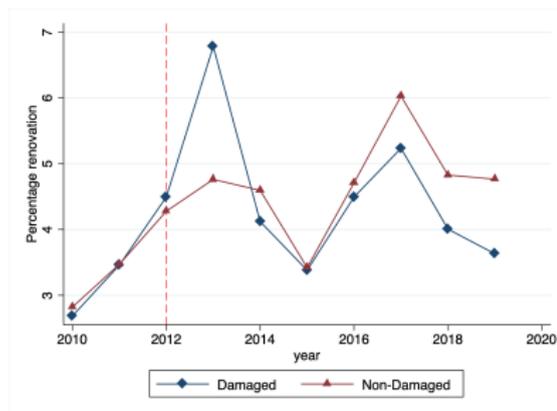
<b>Panel A:</b>	Damaged			Non-Damaged		
<b>Floodplain</b>	Before	After	Difference	Before	After	Difference
House Price	499.18 (349.71)	573.60 (386.44)	<b>74.42</b> (4.39)	354.20 (311.64)	372.32 (326.19)	<b>18.12</b> (2.58)
log(Price)	5.97 (0.74)	6.09 (0.79)	<b>0.13</b> (0.09)	5.53 (0.86)	5.55 (0.93)	<b>0.02</b> (0.07)
Observations	18901	11636		40520	24922	
<b>Panel B:</b>	Damaged			Non-Damaged		
<b>Non-Floodplain</b>	Before	After	Difference	Before	After	Difference
House Price	405.49 (337.62)	420.63 (336.78)	<b>15.14</b> (14.27)	284.57 (198.56)	312.91 (225.16)	<b>28.24</b> (0.46)
log(Price)	5.70 (0.80)	5.74 (0.82)	<b>0.04</b> (0.03)	5.43 (0.71)	5.49 (0.78)	<b>0.06</b> (0.001)
Observations	1438	911		590363	347405	

Table: Summary Statistics: Flood Insurance Policies In Force

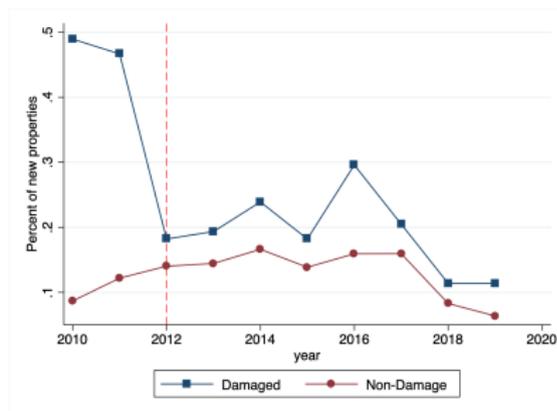
	(1)	(2)
	Floodplain	Non-Floodplain
Number of Policies	118.05 (388.8)	18.46 (33.18)
Price per \$1000 Coverage	7.73 (3.588)	2.03 (1.056)
Number of Parcels	229.48 (582.4)	1172.05 (663.8)
Year Built	1980.46 (13.07)	1983.18 (12.69)
Share Insured	0.32 (0.264)	0.03 (0.0746)
Share Adapted	0.08 (0.132)	0.01 (0.0383)
Observations	9,474	14,828



# Renovation and Rebuilding out of Floodplain



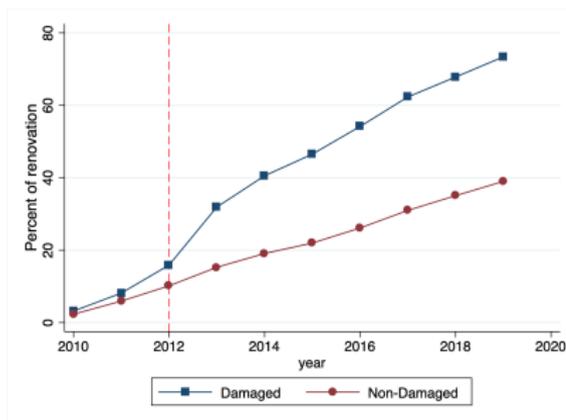
(a) Percent Renovated



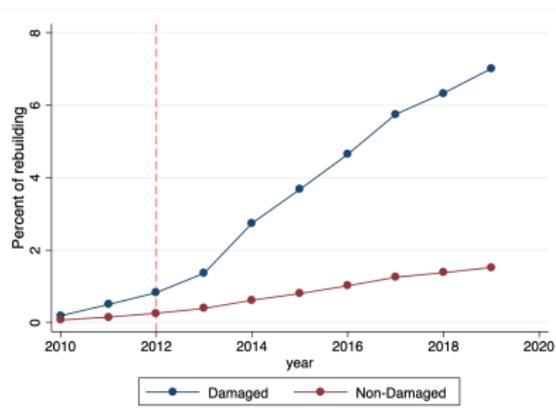
(b) Percent Rebuilt

Figure: Percent of Property Renovated and Rebuilt out of Floodplain

# Cumulative Renovation and Rebuilding in Floodplain



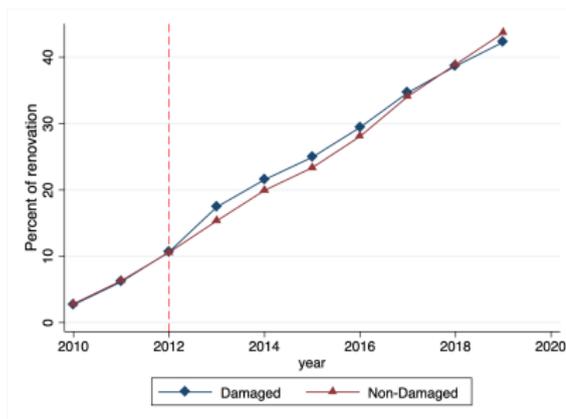
(a) Cumulative Renovation



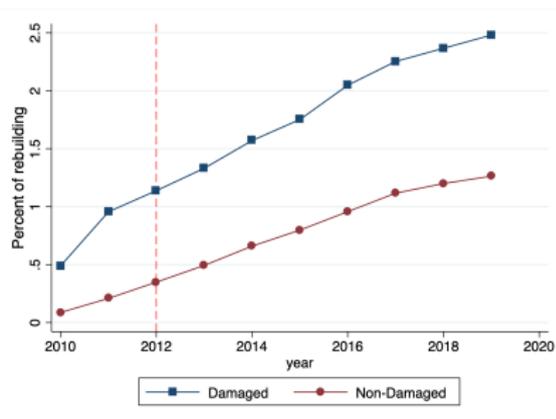
(b) Cumulative Rebuilding

Figure: Cumulative Renovating and Rebuilding in Floodplain.

# Cumulative Renovation and Rebuilding out of Floodplain



(a) Cumulative Renovation



(b) Cumulative Rebuilding

Figure: Cumulative Renovating and Rebuilding out of Floodplain.

# Percent of Single Family Houses Sold by Year

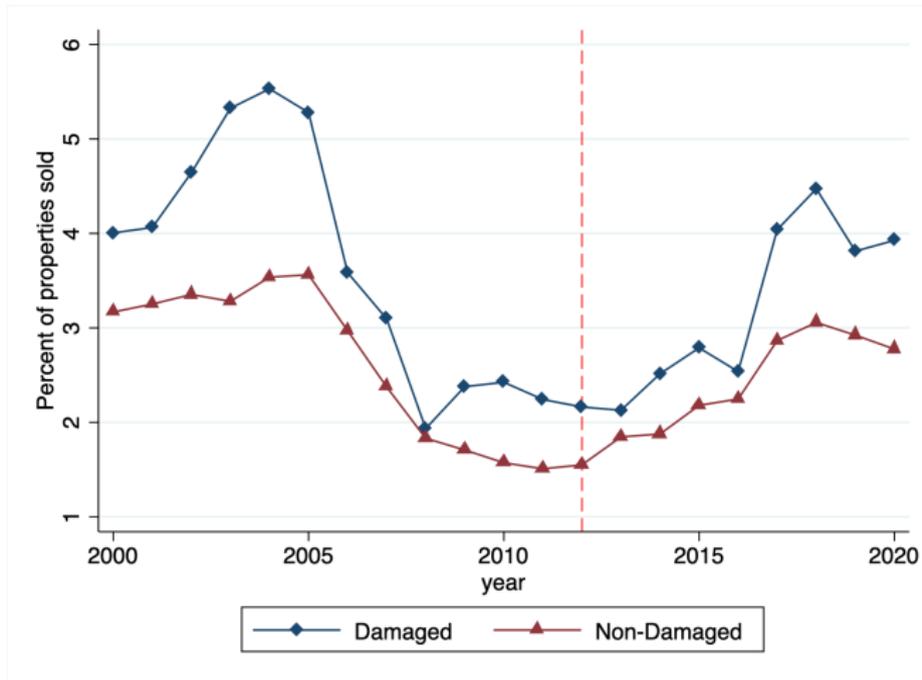


Figure: Percent of Single Family Houses Sold by Year out of Floodplain

# Estimation Results

Table: Effect of Hurricane Sandy on House Prices (Triple Differences)

	(1)	(2)	(3)	(4)
	log(Price)	log(Price)	log(Price)	log(Price)
Damage × Floodplain × PostSandy	0.101** (0.037)	0.090* (0.037)	0.093* (0.038)	0.098** (0.038)
Damage × PostSandy	0.004 (0.033)	0.014 (0.034)	0.001 (0.035)	0.009 (0.035)
Damage × Floodplain	-0.054 (0.050)	-0.048 (0.047)	-0.037 (0.049)	-0.072 (0.046)
Floodplain × PostSandy	-0.028* (0.012)	-0.033** (0.012)	-0.047*** (0.011)	-0.043*** (0.012)
Damage	0.076 (0.048)	0.067 (0.045)	0.080 (0.045)	0.115** (0.041)
Floodplain	0.030* (0.014)	0.024 (0.013)	0.053*** (0.015)	0.041* (0.019)
Observations	1036096	1036096	1036096	1036096
FE	Block group	Block group	Block group	Tract
Year × Distance FE	Yes	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

- Zillow's Transaction and Assessment Database:
  - Includes sales transactions from 2000-2019
  - Tax account identifiers, geo-coordinates, tax year, tax amount
  - Property characteristics: year built, bedrooms, bathrooms, fireplace, kitchen, etc.,
  - **Limitation:** property characteristics only capture one time at the most recent tax year (2019)
- Eliminate if transaction is family transfer, or foreclosure
- Only keep transactions for single family residential
- Trim 1% top and bottom price to remove outliers
- Trim 1% bottom year built to remove unreasonably low year built (i.e 1288)

# Building Permits Data

- Monthly report to DCA by municipalities
- Individual permit record:
  - Property tax block and tax lot number
  - Status (permit/certificate), date issue
  - Permit types: New, Addition, Alteration, Demolition
  - Fee relates to permits
  - Construction cost: value of construction involved in the permit reported by the applicant
- Restrict sample to 1 & 2 family houses only
- Merge each permit to each parcel with its flood damage and floodplain status

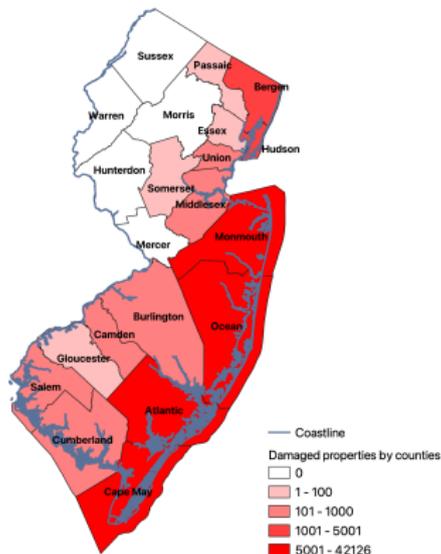
◀ back

- Biggert-Waters 2012 Act:
  - Phases out subsidies for new owners of “grandfathered” houses, properties experienced severe repetitive loss
  - From 2013, premium of those properties increases by 25% annually till it reaches the full risk rate
  - Established the minimum deductible for flood claims
- Homeowner Flood Insurance Affordability Act:
  - Extend the rate increase to all subsidized “grandfathered” properties
  - Premium increase between 5%-18% annually
- According to the National Association of Realtors:
  - Every \$500 increase in premium translates to \$10,000 reduction in property's value

# New Jersey and Extent of Sandy Damage by County



(a) New Jersey



(b) Extent of Damage

Figure: New Jersey and Extent of Sandy Damage by County



# Extended Data

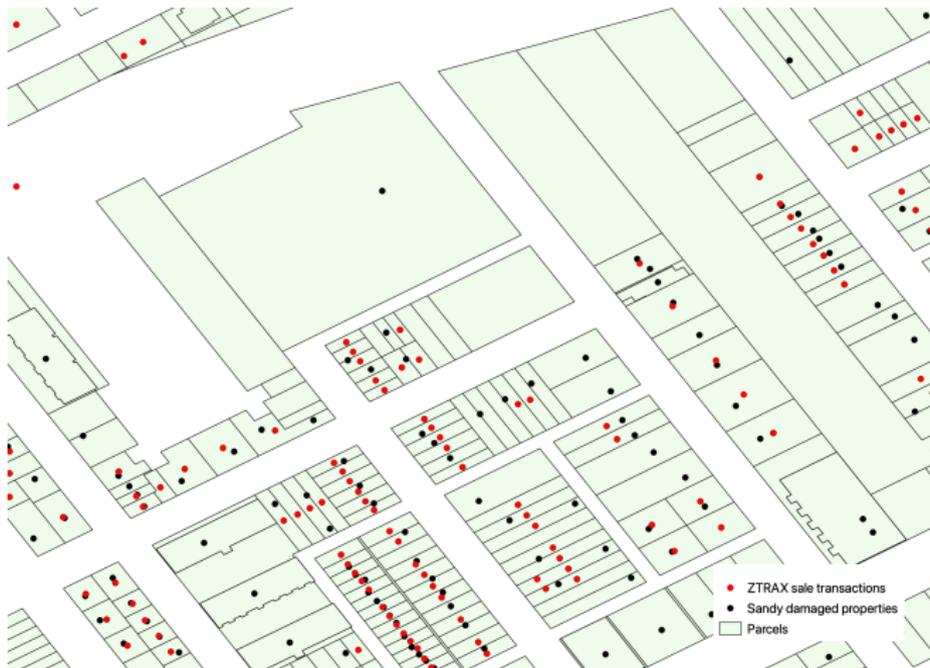


Figure: Merging ZTRAX and Damage Assessment Databases