Going Under Water?

Bakkensen and Barrage, 2017

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Flood Risk Belief Heterogeneity and Coastal Home Price Dynamics

Bakkensen and Barrage, 2017

Presented by Casey O'Hara, Nov. 27, 2018

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How will climate risk beliefs affect coastal housing market dynamics?

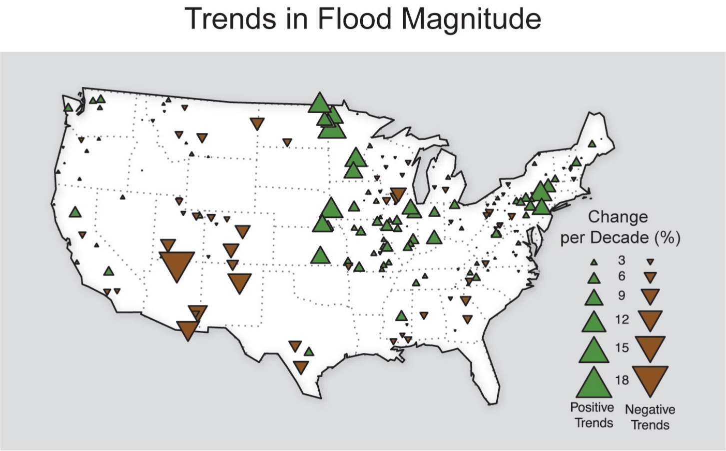
- Heterogeneity in beliefs about future value of fundamentals can lead to inflated prices, bubbles, excess volatility, credit crises, etc.
- Heterogeneous beliefs about flood risks due to sea level rise (SLR) have implications for coastal housing markets
- Standard approaches to modeling economic impacts of SLR assume homogeneous beliefs
- This likely underestimates impacts of SLR and climate change

Motivation

Flood risk

- Climate change increases precipitation and storm surge
- This leads to catastrophic events
  - Harvey (2017), Sandy (2012), Katrina (2005) etc.
- FEMA flood maps often out of date, backward-looking

Motivation


Trends in Flood Magnitude
Change
per Decade (%)
3
6
9
12
15
18
Positive
Trends
Negative
Trends

US Flood policy

1968: National Flood Insurance Program (NFIP) under Federal Emergency Management Agency (FEMA)

- 5M policies nationwide covering >\$1.2T
- \$250k property policy limit
- Limited enforcement & low risk perceptions ⇒ many homes are un- or under-insured
- Subsidies; rates not at actuarially fair levels

Takeaway: Homeowners do not internalize real risk

US Flood policy

Moves to improve NFIP

- Biggert-Waters (2012)
  - Goal: phase out subsidies and enforce actuarially fair rates
- Homeowner Flood Insurance Affordability Act (2014)
  - Partially repealed Biggert-Waters

But optimal policy will eventually be put in place (…?)

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- Dynamic housing market model with heterogeneity in risk beliefs
- Learning mechanism to allow agents to update risk beliefs
- Survey to quantify beliefs about amenity values and risk perceptions
- Simulation to estimate impacts of risk belief heterogeneity

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Housing Market Model

Dynamic housing market

Builds upon Burnside, Eichenbaum, Rebelo (2016) on booms and busts in housing markets.

- Continuum of agents (households) with linear utility, discount rate β
- Heterogeneity in home types (coastal, non-coastal), prefs for coastal amenities, and flood risk beliefs
- Each period, agents choose among:
  - buy coastal home at price P_t
  - buy non-coastal home at price P_t^{NC}
  - rent
- Home price determined by valuation of marginal buyer, indifferent among options

Dynamic housing market

- Households are heterogeneous in preferences:
  - ξ^i coastal amenity value
  - π_t^i annual flood risk belief
- Fraction k_1 of homes are "coastal" properties
- Fixed housing stock for sale: $k < 1$, where $k_1 < k < 1$ is coastal
- Rental market: $1 - k$ houses, rental rate w per period
- Flow of utility ε^h (homeowner) and ε^r (renter)
- Coastal homes have higher utility value ξ^i but incur flood damage δ with probability π_t^*.

Dynamic housing market

Home price determined by valuation of marginal buyer m_t, indifferent among options:

$$
\begin{aligned}
&-P_t + \beta(\varepsilon^h + \xi^{m_t} - \pi_t^{m_t}\delta + \mathbb{E}_t^{m_t}[P_{t+1}]) \\
&= \beta(\varepsilon^r - w) \\
&= -P_t^{NC} + \beta(\varepsilon^h + \mathbb{E}_t^{m_t}[P_{t+1}^{NC}])
\end{aligned}
$$

Dynamic housing market

Define $e^h \equiv \varepsilon^h - (\varepsilon^r - w)$ and solving for P_t results in pricing condition for coastal homes:

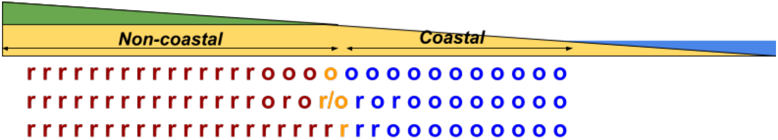
$$P_t = \beta(e^h + \xi^{m_t} - \pi_t^{m_t}\delta + \mathbb{E}_t^{m_t}[P_{t+1}])$$

- $\mathbb{E}_t^{m_t}[P_{t+1}]$ includes marginal buyer's higher order expectations of own and others' future flood risk beliefs
- For homogeneous and correct risk beliefs π_t^i, price is based on amenity value only and changes smoothly in anticipation of changes in flood risk.
- For homogeneous amenity value ξ^i, price is based on flood risk belief of marginal buyer, which likely changes dramatically after storm events.

Dynamic housing market

$$P_t = \beta(e^h + \xi^{m_t} - \pi_t^{m_t}\delta + \mathbb{E}_t^{m_t}[P_{t+1}])$$

- Divide the population into two types: fraction θ^o optimists (π_t^o) and fraction $(1-\theta^o)$ realists (π_t^r), with $\pi_t^o \leq \pi_t^r \forall t$.
- Coastal amenity independently distributed $\sim U[0, \Xi]$.
- This results in three possible cases of P_T depending on identity of marginal buyer:



Determining home price

$$P_t = \beta(e^h + \xi^{m_t} - \pi_t^{m_t}\delta + \mathbb{E}_t^{m_t}[P_{t+1}])$$

Backward induction: $t = T$

A strong flood insurance requirement at actuarially appropriate rates forces agents to internalize flood risk, regardless of risk beliefs. Policy efforts e.g. Biggert-Waters Flood Insurance Reform Act of 2012 attempt to approach such a policy.

Assume such a policy is put into place in period T, then:

$$\pi_T^o = \pi_T^r = \pi_T^*$$

Determining home price

Backward induction: $t = T - 1$

In period $T - 1$, optimists and realists hold expectations over the policy to be announced in period T:

$$\mathbb{E}^r_{T-1}[\pi^*_T] = \pi^{*,r}_T \text{ and } \mathbb{E}^o_{T-1}[\pi^*_T] = \pi^{*,o}_T$$

which affects their expectations about future home prices P_T, thus price P_{T-1}.

Backing up to period $T - 2$, expectations over prices are based on each agent's expectation of the expectations of other agents about the marginal buyer and risk beliefs for periods $T - 1$ and T. This quickly becomes a nightmare.

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Structure

- Flood risk π^L until period T_1, then increases to π^H.
- Realists know true flood risk at all times
  - thus do not update beliefs in response to flood events.
- Optimists know initial flood risk, and become Bayesian learners at time T_1
  - i.e. update prior in response to flood events.

Bayesian learning

Based on Dieckmann (2011): Optimist estimate of flood risk in time $t \geq T_1$ is

$$\pi_t^o = q_t^o(\pi^H) + (1 - q_t^o)(\pi^L)$$

And updated each period based on flood event occurrence:

$$q_{t+1}^o|_{flood=1} = \Pr(\pi^H|_{flood=1}) = \frac{q_t^o(\pi^H)}{q_t^o(\pi^H) + (1 - q_t^o)(\pi^L)}$$

$$q_{t+1}^o|_{flood=0} = \Pr(\pi^H|_{flood=0}) = \frac{q_t^o(1 - \pi^H)}{q_t^o(1 - \pi^H) + (1 - q_t^o)(1 - \pi^L)}$$

Bayesian learning

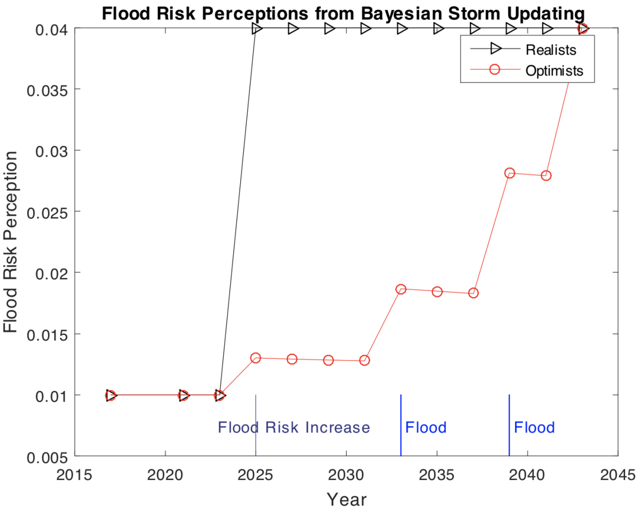

Figure 1

Higher order beliefs

Beliefs about updating beliefs

- Realists have rational expectations that optimists will update their risk beliefs due to flood events
- Optimists don't anticipate changes in their own risk beliefs

Beliefs about enforced policy rates in time T

- Realists have accurate belief about eventual policy rate:

$$\mathbb{E}_t^r[\pi_T^*] = \mathbb{E}_t^r[\pi_T^r] = \pi^*$$

- Optimist beliefs in range of:

$$\mathbb{E}_t^o[\pi_T^*] \in [\mathbb{E}_t^o[\pi_T^o], \mathbb{E}_t^o[\pi_T^r]]$$

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Motivation

Quantify heterogeneity

Need to estimate joint distribution of amenity values and flood risk beliefs

$$PREM_t^{\text{coast}} \equiv (P_t - P_t^{NC}) = \beta(\xi^{m_t} - \pi_t^{m_t}\delta + \mathbb{E}_t^m[P_{t+1} - P_{t+1}^{NC}])$$

- The $\pi_t^{m_t}\delta$ term represents marginal buyer's current risk beliefs;
- $\mathbb{E}_t^m[P_{t+1} - P_{t+1}^{NC}]$ encompasses marginal buyer's expectation of future risk as well as beliefs about the risk expectations of others

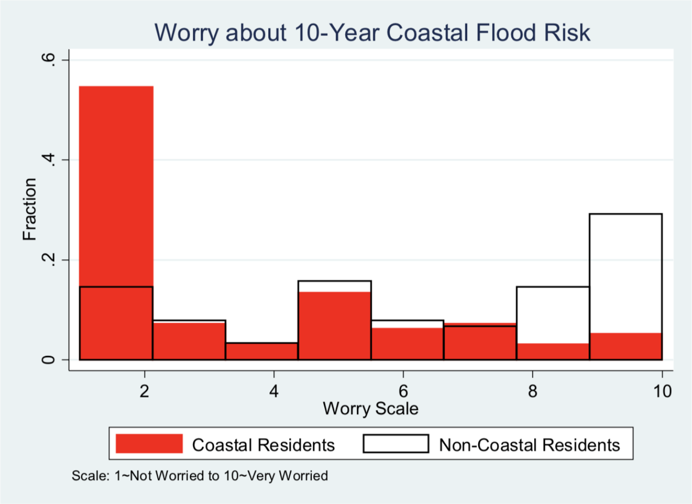
Survey

Rhode Island communities with both coastal (w/in 400’ of ocean) and non-coastal homes: $n = 187$, 52% coastal/48% non-coastal

- WTP for annual flow of coastal amenities
- Quantitative flood risk perceptions
  - likelihood of flood within 10 years
- Qualitative flood risk perceptions
  - 10-point worry scale ($1 =$ not worried, $10 =$ very worried)
- Potential confounders (could affect flood worries even without heterogeneity in risk beliefs)
  - Expectations of flood damage
  - Expectations of insurance reimbursement
  - Expectations of government aid

Flood risk perception

Coastal residents are far less worried about flood risk than non-coastal residents



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Flood risk perception

NFIP floodzone residents are far less worried about flood risk than non-floodzone residents

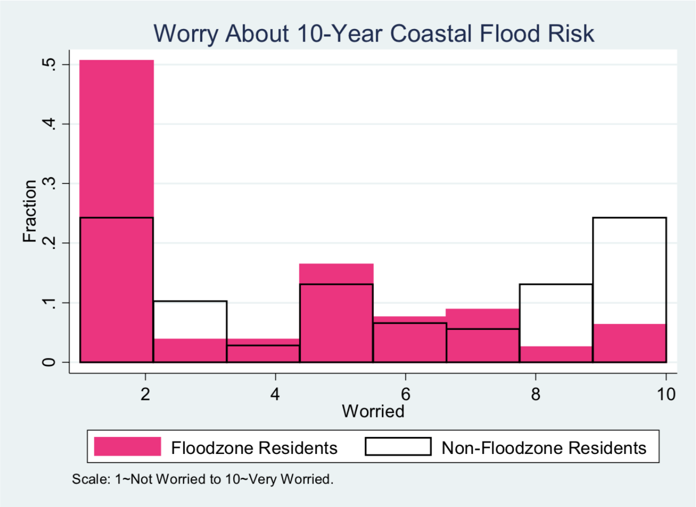
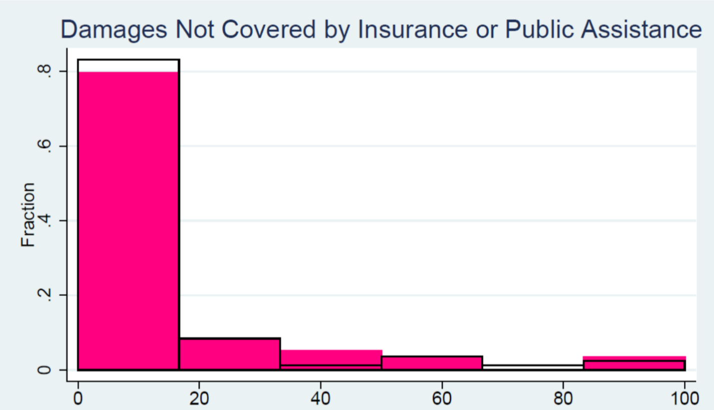


Figure 2

Flood risk perception

Are differences in apparent risk perception due to different expectations of unreimbursed damages?

Risk perceptions are not likely due to different expectations of damage as % of home value, net of expected insurance and government aid



Flood risk perception

Coastal residents underestimate flood risks vs. storm surge elevation risk models (70% of predictions below 1:1 line)

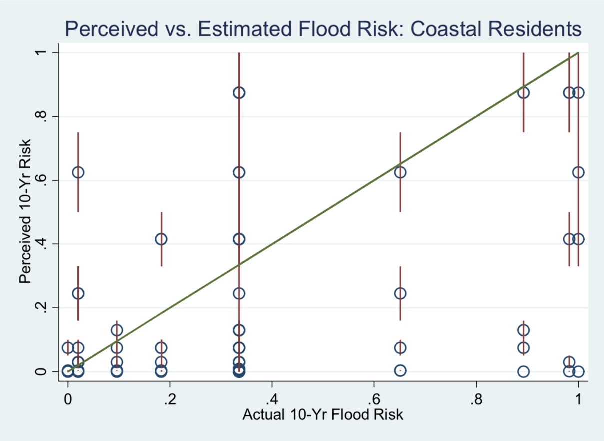
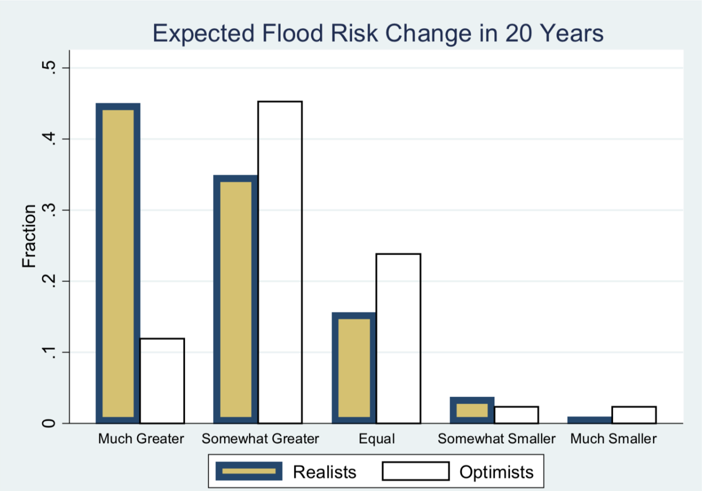


Figure 5. Note: Red lines span range of 10-year flood risk probability in respondent's answer (e.g., 5-10%) on the y-axis,

Expected flood risk change

- 1-year risk at least 1% $\Longrightarrow$ 10-year risk is 9.6%
- "Optimist" types underestimate 10-yr flood risk by $\geq$ 50%
- For this study area, optimist = risk assessment $\in$ [0%, 5%]



Coastal amenity value

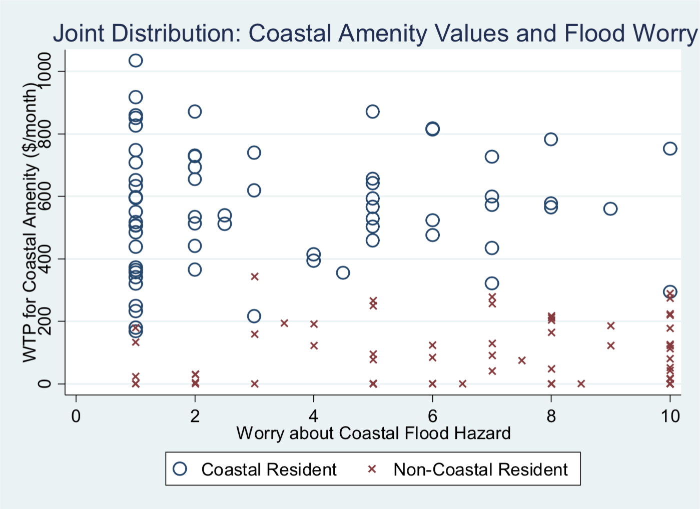


Figure 7

Simulation

Calibration

Table 3: Benchmark Model Calibration

Parameter		Value	Source
k_1	Share of coastal homes	0.134	Authors' calculation from RIGIS properties and coastline
θ^o	Share of optimists	0.35	Survey: Share estimating $\pi_{10yr}^{Flood} < 5\%$
Ξ	Max. coastal amenity ξ (\$/yr)	\$7.7k	Survey: Max WTP within 10% of med. home price
δ	Flood damages (\$)	\$65.65k	Survey: Med. damage/price $\times$ Med. price
e^h	Net value of living in own home	2.98	Match initial med. coastal home price \$410k
β	Annual discount factor	0.98	
π_L	Initial annual flood risk	1%	FEMA
π^H	New higher flood risk	4%	STORMTOOLS; elevation mapping
T_1	Flood risk increase	2023	
T	Policy reform period	2043	
$q^o_{T_1}$	Optimists' prior $\Pr(\pi = \pi^H)$ at T_1	0.1	
Flood events: 2031, 2037			

Results

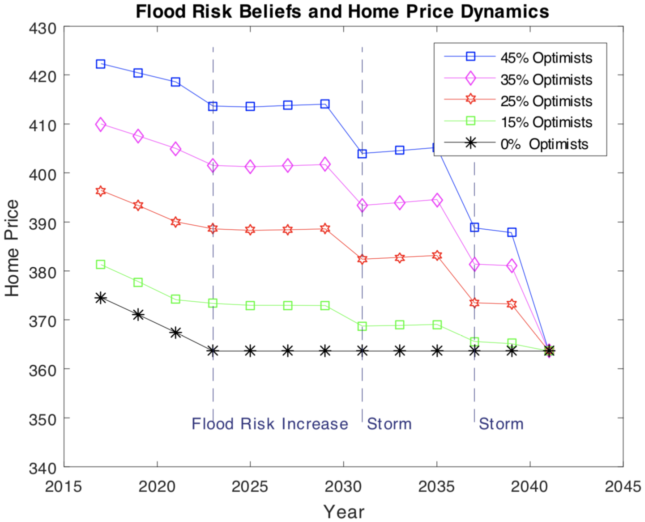


Figure 12

Results

Table 4: Benchmark Simulation Results

Scenario	Future $\%\Delta P$	Var($\%\Delta P$)
0% Optimists	-3.0%	0.19
15% Optimists	-4.8%	0.21
25% Optimists	-9.0%	0.99
35% Optimists	-12.7%	2.38
45% Optimists	-16.1%	4.11

Flood risk increase from 1% to 4% in 2023.

Risk internalization policy / belief change at T=2043.

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Welfare costs not captured in model

Welfare costs due to coastal overvaluation and volatility:

- loans based on overvalued properties could lead to defaults and further asset losses
- local tax revenues based on property value would be affected by volatility and permanent price declines

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Allocative inefficiency

Amenity value would drive allocation in absence of belief heterogeneity.

Direct allocative inefficiency occurs when realists with high coastal amenity values get priced out of the coastal housing market due to optimists overvaluing coastal homes.

Allocative inefficiency

Social planner would allocate coastal homes to those with k_1 highest amenity values:

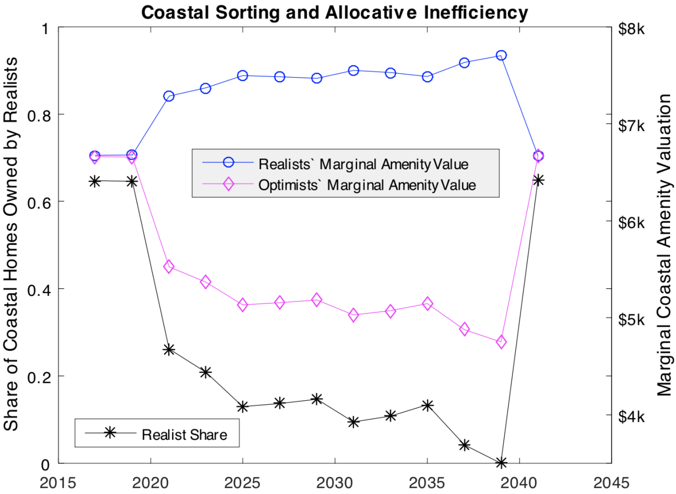
$$\bar{\xi}^{*,o} = \bar{\xi}^{*,r} = \Xi(1-k_1)$$

But allocative inefficiency occurs when marginal realist valuation exceeds marginal optimist valuation, $\bar{\xi}_t^r > \bar{\xi}^{*,r}$ and $\bar{\xi}_t^o < \bar{\xi}^{*,o}$.

$$\Delta W_t \equiv CS_t^* - CS_t = \int_{q^{*,o}}^{q_t^o} \left[\Xi - \frac{\Xi}{\theta^o} q\right] dq - \int_{q^r}^{q_t^{*,r}} \left[\Xi - \frac{\Xi}{1-\theta^o} q\right] dq$$

(q_t^i = qty of coastal housing consumed by group i in period t)

Allocative inefficiency



Figure

Allocative inefficiency

Table 7: Allocative Inefficiency Costs

Scenario	Per Household Net Costs	Scenario	Per Household Net Costs
Benchmark	\$685	$k_1 = 0.05$	\$137
$\Xi = \$4.9k$	\$609	$k_1 = 0.20$	\$862
$\Xi = \$8.5k$	\$648	$T = 2035$	\$374

Allocative inefficiency

Table 8: Further Sensitivity Analysis

Scenario	Future $\%\Delta P$	Var($\%\Delta P$)	Re-scaled
Benchmark	-12.7%	2.38	n/a
Overreaction $\gamma = 10\%$	-12.7%	3.72	n/a
Max WTP $\Xi = \$4.9k$	-23.2%	7.14	
Max WTP $\Xi = \$4.9k$	-13.2%	2.51	✓
Max WTP $\Xi = \$8.5k$	-11.23%	1.86	
Max WTP $\Xi = \$8.5k$	-12.6%	2.31	✓
Share coastal $k_1 = 0.05$	-15.3%	2.81	✓
Share coastal $k_1 = 0.20$	-12.2%	2.08	✓
Flood events: 2030 only	-12.7%	5.57	n/a
Flood events: 2040 only	-12.7%	5.40	n/a
Flood events: none	-12.7%	7.87	n/a
Policy Reform $T = 2033$	-12.8%	6.73	

Re-scaling of general own-home utility value e^h holds initial coastal home price constant at benchmark/empirical value ($410k).

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Wildfire

Wildfire

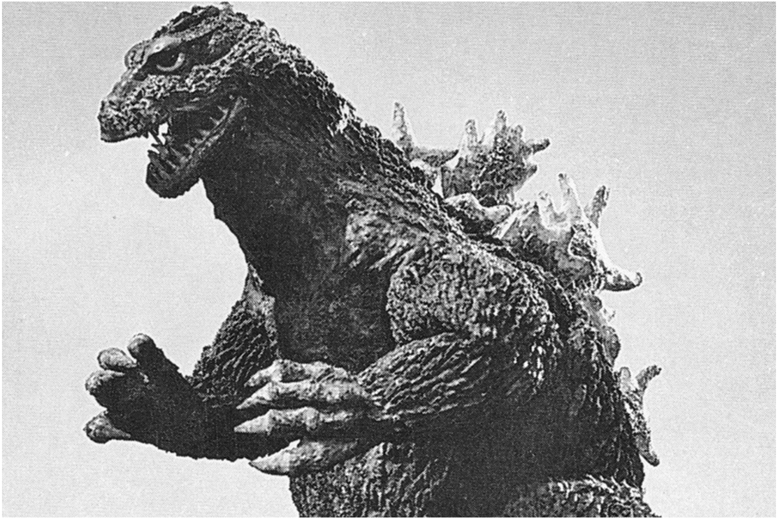
Homeowners on wildland-urban interface bear heterogeneous beliefs about fire risk, and/or do not fully believe they will be forced to internalize costs:

- Agents (home buyers) underestimate fire risk
- Agents under-insure or do not insure
- Fire fighting costs are borne by society

Other natural disasters

Other natural disasters

Other natural disasters



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Implications for flood insurance reform

Value of better flood risk information!

Impacts of flood insurance policy reform!

- Policy reform sooner reduces allocative inefficiency
- But at the cost of increased market volatility

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Implications

From Burnside, Eichenbaum, and Rebelo (2016):

- Skeptics (realists?) are correct? $\Rightarrow$ boom then bust
- Optimists are correct? $\Rightarrow$ boom not followed by bust

Table 6: Optimists' Long-Run Policy Expectations

Scenario	Future $\%\Delta P$	Var($\%\Delta P$)
$E_t^o[\pi_T^*] = E_t^o[\pi_T^o]$	- 28.3%	18.11
$E_t^o[\pi_T^*] = (\theta^o)E_t^o[\pi_T^o] + (1-\theta^o)E_t^o[\pi_T^r]$	- 12.7%	2.38
$E_t^o[\pi_T^*] = E_t^o[\pi_T^r]$	- 4.7%	0.06

Implications

- If policy reflects realist beliefs, optimists suffer losses when price crashes.
  - Arbitrage opportunity? realists could short sell in anticipation of crash
- If policy reflects optimist beliefs, optimists benefit from elevated value while imposing social costs on others
  - Political pressure to maintain elevated value could affect long-term policy
  - e.g. 2014 partial rollback of Biggert-Waters

Opportunity?

- Social or private investment in actual risk reduction?
  - Optimists could support investment in coastal engineering (bleh) or coastal protection ecosystem services (yay!) to reduce risk
- How does this affect ecosystem service valuation?

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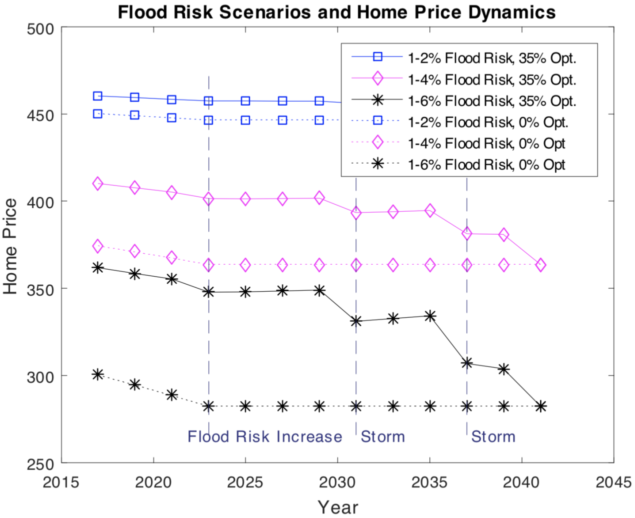

Figure 13

sensitivity analysis

Table 5: Flood Risk Sensitivity		
	Future $\%\Delta P$	
Scenario	$\pi_H = 2\%$	$\pi_H = 6\%$
0% Optimists	-0.8%	-6.3%
35% Optimists	-3.1%	-28.0%

Predicted flood risk change

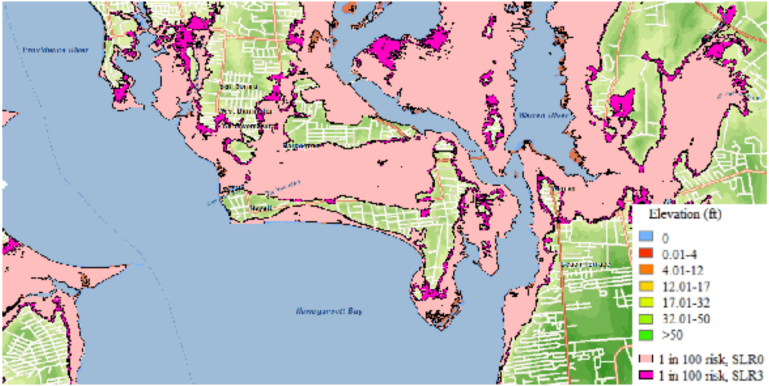

Figure 9

Predicted flood risk change

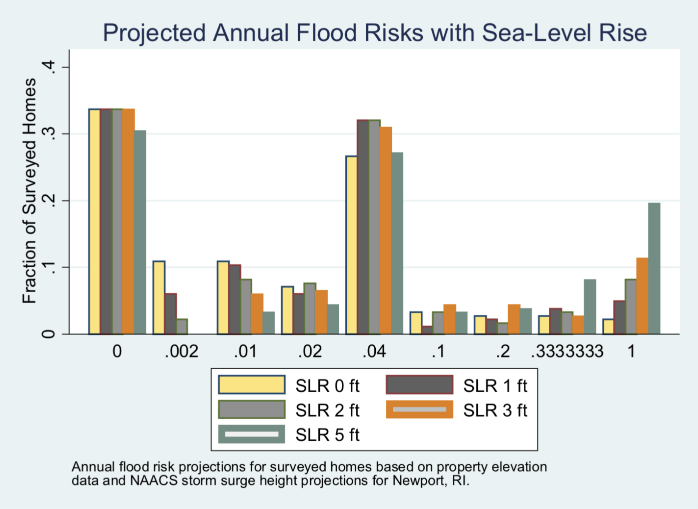

Figure 10