Mortgage Finance and Climate Change: Securitization Dynamics in the Aftermath of Natural Disasters

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Big Questions: Climate Risk in Financial Markets

- **Who bears climate risk?**
  - Houses mostly purchased using mortgage credit. Mortgages are traded, securitized.
  - Risk sharing between borrowers and: commercial banks, non-bank lenders, Government Sponsored Enterprises (GSEs), Private Label Securitizers.
  - Questions of optimal risk-sharing
- **Who is more informed?**
  - Asymmetric observability of *current* local climate risk.
  - Ambiguity of *future* climate risk probability distributions.
- **Is climate risk priced in?**
- **Who adapts to climate risk?**
  - Political economy of climate risk sharing.
  - Large amount of policy intervention in the mortgage market.
  - Design of institutions to make the economy resilient?

A Securitization Chain

$$\text{Borrower} \xrightarrow{\text{Interest Rate}} \text{Lender} \xrightarrow{\text{Guarantee Fee}} \text{Securitizer}$$

- **A '*Market for Lemons*' in local natural disaster risk?**
- **Observing such selection** at the conforming loan limit:
  - Government Sponsored Enterprises, Fannie and Freddie use FHFA-set observable rules for purchasing mortgages and pricing securitization.
  - Sharp **discontinuity** in lenders' ability to securitize their originated mortgages at the conforming limit.
- **Natural experiment**: Conforming limits varying across counties and across time 'biting' at different arbitrary points.

Questions:

1. Do local natural disasters lead to more origination and securitization of conforming loans?
2. Are conforming loans better or worse risk?
3. How can the GSEs adapt?

Findings

1. Do local natural disasters lead to more securitization of conforming loans relative to jumbo loans?

   $\uparrow$ in volume and securitization of conforming loans relative to jumbo loans.

   Increasing adverse selection after disaster.

   Impact increases for 3 years after the event.
   Greater increase in securitization & bunching with disaster "new news".
2. Are conforming loans better or worse risk?
   Higher rates of delinquency and default.
3. How can the GSEs adapt? An asymmetric information structural model for counterfactuals.
   $\rightarrow$ **adjust guarantee fees and securitization standards.**

Billion Dollar Events

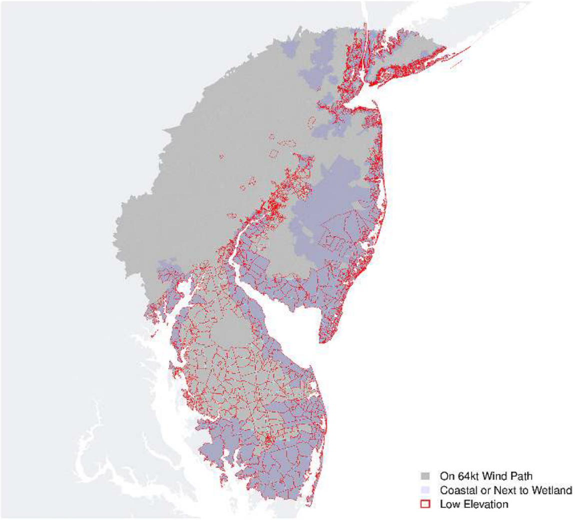
Year	Name	From	To	Category	States	Normalized PL‡ USD b$, 2018
2005	Katrina	25-Aug	30-Aug	5	FL, LA, MS, AL	$116.88
2012	Sandy	30-Oct	31-Oct	3	NY	$73.49
2008	Ike	12-Sep	14-Sep	4	TX, LA	$35.15
2005	Wilma	24-Oct	24-Oct	5	FL	$31.90
2004	Charley	13-Aug	14-Aug	4	FL, SC	$26.93
2004	Ivan	12-Sep	21-Sep	5	AL, FL	$25.89
2004	Frances	03-Sep	09-Sep	4	FL	$16.48
2005	Rita	20-Sep	24-Sep	5	LA, TX	$14.89
2004	Jeanne	15-Sep	29-Sep	3	FL	$13.57
2011	Irene	26-Aug	28-Aug	3	NC	$10.79
2008	Gustav	31-Aug	03-Sep	4	LA	$5.45
2005	Dennis	04-Jul	18-Jul	4	FL, AL	$3.54
2005	Ophelia	09-Oct	18-Oct	3	NC	$2.48
2012	Isaac	21-Aug	03-Sep	1	LA	$2.36
2008	Dolly	20-Jul	27-Jul	1	TX	$1.48

Source: Estimates from Weinkle et al (2018).

Climate data: Hurricanes, Elevation, Wetland

1. **High Resolution Storm Surge Predictions:** NOAA's hurricane model: Sea, Lake, and Overland Surges from Hurricanes (SLOSH).
2. **HUD Inspections of housing units.**
3. **NOAA's Atlantic Hurricane Data Set "HURDAT2" 1851-2018.**
   3.1 Geocoded Hurricane path with wind speed and time-varying radius.
   3.2 64kt wind radius: Saffir Simpson Scale.
4. **USGS's Elevation data: Shuttle Radar Topography Mission.**
   4.1 Satellite measurements of elevation by 30m x 30m cell.
5. **USGS's National Land Cover data base.**
   5.1 Open water, Woody wetlands, Emergent wetlands.

Treatment Area Geography: the Example of Sandy

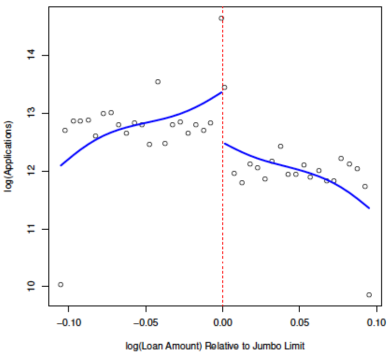


Financial data: Three Key Data Sources

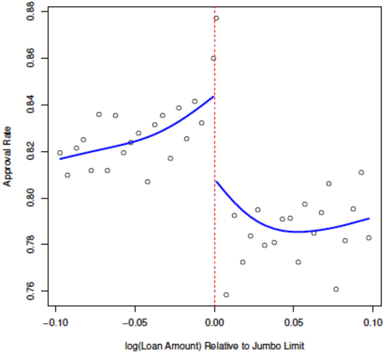
1. **McDash data set from Black Knight Financial.**
   - Data from servicers, covers about 65% of the market, since 1989.
   - FICO scores, monthly payment history, loan amortization structure (interest rate; IO, fully amortizing, balloon payment; ARM, FRM).
   - First and second mortgage: combined LTV
   - 5-digit ZIP code data.
2. **The FFIEC's Home Mortgage Disclosure Act data set**
   - Larger coverage, more granular (census tract), but no payment history.
   - Matched to lenders' balance sheets (Transmittal Sheets).
3. **Banks' Balance Sheets**
   - Quarterly Reports of Income and Condition (Bank-Level) $\rightarrow$ balance sheet liquidity, regulator, bank type.

Baseline Discontinuities: Applications and Credit Score

(a) Counts of Applications



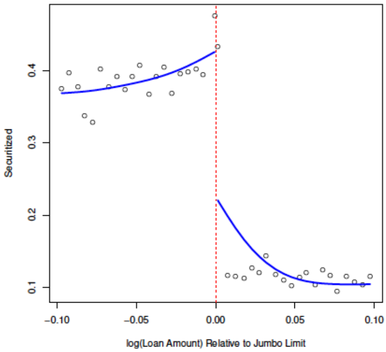
(b) Approval Rates



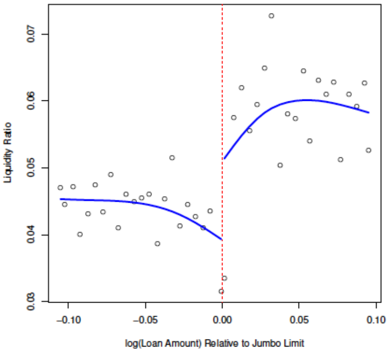
- Home Mortgage Disclosure Act data.

Baseline Discontinuities: Securitization Rates, Lender Liquidity

(c) Securitization Rates



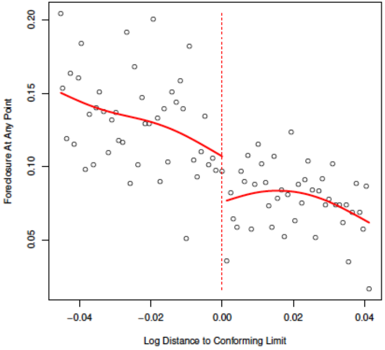
(d) Lender's Balance-Sheet Liquidity



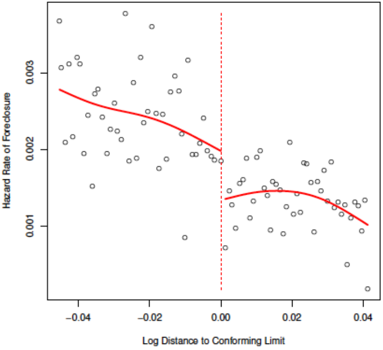
- Home Mortgage Disclosure. Reports of Income and Condition.

Baseline Discontinuities: Default, Foreclosure

(a) Foreclosure at any point after origination



(b) Hazard Rate of a Payment Incident (Delinquency, Foreclosure)



Spec #1: Discontinuity – Difference-in-Differences

- Baseline specification:

$$
\begin{aligned}
\mathit{Outcome}_{it} = \alpha \cdot \text{Below Conforming Limit}_{ijy(t,d)} &+ \gamma \text{Below Limit}_{ijy(t,d)} \times \text{Treated}_{j(i)} \\
&+ \sum_{t=-T}^{+T} \xi_t \cdot \text{Treated}_{j(i)} \times \text{Time}_{t=y-y_0(d)} \\
&+ \sum_{y=1995}^{2016} \zeta_y \cdot \text{Below Conforming Limit}_{ijy(t,d)} \times \text{Year}_{y(t)} \\
&+ \sum_{t=-T}^{+T} \delta_t \cdot \text{Below Conforming Limit}_{ijy(t,d)} \times \text{Treated}_{j(i)} \times \text{Time}_t \\
&+ \text{Year}_{y(t,d)} + \text{Disaster}_d + \text{ZIP}_{j(i)} + \varepsilon_{it}, \qquad (1)
\end{aligned}
$$

- $y(t,d)$: hurricane year; i: loan, t: year relative to the event.
- δ_t: discontinuity after a billion dollar event over and above the baseline discontinuity.
- In a 95%–105% window around the time-varying and county-specific conforming loan limit.

Two Sources of Identifying Variation

- Idiosyncratic extent of hurricane impacts conditional on the satured set of local f.e.s

  NOAA's Seasonal outlook [...] predicts the number of named tropical storms, hurricanes, and major hurricanes [...] ***But that's where the reliable long-range science stops. The ability to forecast the location and strength of a landfalling hurricane is based on a variety of factors, details that present themselves days, not months, ahead of the storm.***

- Conforming loan limits and guarantee fees are set nationally every year.

  The Federal Housing Finance Agency (FHFA) publishes annual conforming loan limits that apply to all conventional mortgages delivered to Fannie Mae.

Spec #2: Bunching – Difference-in-Differences

$$\frac{\#\,\textit{Below Limit}_{jt} - \#\,\textit{Above Limit}_{jt}}{\#\,\textit{Below Limit}_{jt} + \#\,\textit{Above Limit}_{jt}}$$
$$= \gamma^{v}\text{Treated}_j + \sum_{t=-T}^{+T} \xi_t^{v} \cdot \text{Treated}_j \times \text{Time}_t$$
$$+ \text{Year}_{y(t,d)}^{volume} + \text{Disaster}_{d}^{volume} + \text{ZIP}_{j}^{volume} + \varepsilon_{jt}^{v}, \qquad (2)$$

- $\#\,\textit{Below Limit}_{jt}$ ($\#\,\textit{Above Limit}_{jt}$): number of mortgages with loan amounts in the 10% segment below (above) the conforming limit.
- Coefficients of interest are the ξ_t^{v}, $t \geq 0$, the impact of the natural of the disaster for each postdisaster year $t = y - y_0(d)$. $t = -5, \ldots, +4$.
- Coefficients ξ_t^{v}, $t < 0$: pre-trends in the discontinuity prior to the disaster.
- Coefficient γ^{v}: the average difference in the size of the discontinuity between the treated and untreated zip codes.

Specification #1: Discontinuity Post-Disaster

	Securitized		
	±20%	±10%	±5%
	(7)	(8)	(9)
Below $\text{Limit}_{it} \times \text{Treated}_{t=-4}$	0.041**	0.040**	0.071***
	(0.019)	(0.018)	(0.022)
Below $\text{Limit}_{it} \times \text{Treated}_{t=-3}$	−0.002	−0.005	−0.016
	(0.025)	(0.025)	(0.026)
Below $\text{Limit}_{it} \times \text{Treated}_{t=-2}$	−0.017	−0.018	−0.027
	(0.024)	(0.026)	(0.024)
Below $\text{Limit}_{it} \times \text{Treated}_{t=+0}$	0.006	0.005	0.013
	(0.021)	(0.021)	(0.029)
Below $\text{Limit}_{it} \times \text{Treated}_{t=+1}$	0.018	0.017	0.042*
	(0.019)	(0.019)	(0.021)
Below $\text{Limit}_{it} \times \text{Treated}_{t=+2}$	0.045*	0.046*	0.086***
	(0.024)	(0.024)	(0.027)
Below $\text{Limit}_{it} \times \text{Treated}_{t=+3}$	0.095***	0.097***	0.120**
	(0.029)	(0.029)	(0.043)
Below $\text{Limit}_{it} \times \text{Treated}_{t=+4}$	0.154**	0.155**	0.193***
	(0.067)	(0.066)	(0.064)
Observations	1,500,360†	1,461,539†	900,765†
R^2	0.249	0.250	0.229
Adjusted R^2	0.246	0.246	0.223

Specification #1: Adverse Selection

	Credit Score	Term	Foreclosure	30 d. del.
$Below\ Limit_{it} \times Treated_{jt=-2}$	2.110	−4.268	−0.004	−0.003
	(1.493)	(3.537)	(0.009)	(0.008)
$Below\ Limit_{it} \times Treated_{jt=0}$	−0.117	2.686	0.009	0.015***
	(0.912)	(2.521)	(0.008)	(0.006)
$Below\ Limit_{it} \times Treated_{jt=+1}$	−3.371*	4.680	0.036**	0.036***
	(1.962)	(3.190)	(0.018)	(0.009)
$Below\ Limit_{it} \times Treated_{jt=+2}$	−3.745***	6.058**	0.057***	0.033***
	(1.180)	(3.070)	(0.008)	(0.009)
$Below\ Limit_{it} \times Treated_{jt=+3}$	−3.403***	3.136	0.049***	0.006
	(1.029)	(3.193)	(0.009)	(0.007)
Observations	1,072,465	1,696,513	1,697,650	1,697,650
R Squared	0.176	0.111	0.246	0.158
F Statistic	27.915	21.608	56.772	32.610

Specification #1: Adverse Selection

	60 d. del.	90 d. del.	120 d. del.	Vol. Payoff
$Below\ Limit_{it} \times Treated_{jt=-2}$	-0.001	0.000	-0.000	-0.018
	(0.009)	(0.010)	(0.008)	(0.011)
$Below\ Limit_{it} \times Treated_{jt=0}$	0.012	0.010	-0.004	-0.012**
	(0.008)	(0.007)	(0.006)	(0.006)
$Below\ Limit_{it} \times Treated_{jt=+1}$	0.039***	0.032***	0.013	-0.031***
	(0.014)	(0.013)	(0.010)	(0.009)
$Below\ Limit_{it} \times Treated_{jt=+2}$	0.046***	0.041***	0.032***	-0.026***
	(0.012)	(0.010)	(0.005)	(0.008)
$Below\ Limit_{it} \times Treated_{jt=+3}$	0.022**	0.024***	0.013**	-0.023***
	(0.010)	(0.009)	(0.006)	(0.009)
Observations	1,697,650	1,697,650	1,697,650	1,697,650
R Squared	0.198	0.192	0.175	0.168
F Statistic	42.833	41.334	36.952	35.223

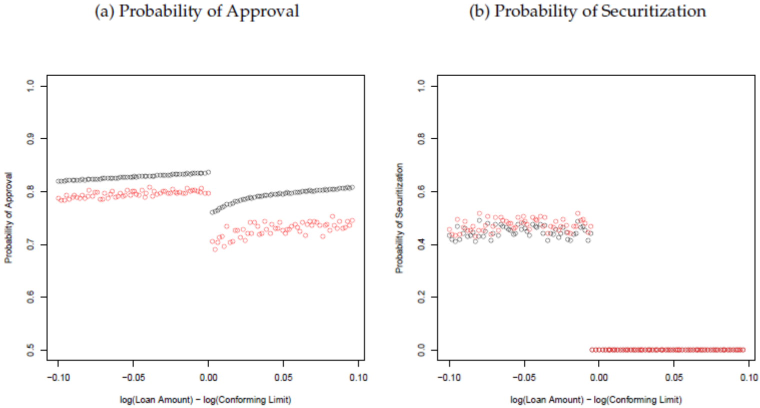
Specification #2: Bunching Post Disaster

	Dependent variable: Discontinuity in: Applications	Approvals	Originations	Securitizations
	±5%	±5%	±5%	±5%
	(1)	(2)	(3)	(4)
$Treated_{jt=-4}$	0.059	0.059	0.070	0.085
	(0.050)	(0.050)	(0.054)	(0.052)
$Treated_{jt=-3}$	0.079	0.079	0.087	0.074
	(0.049)	(0.049)	(0.056)	(0.059)
$Treated_{jt=-3}$	0.039	0.039	0.025	−0.0001
	(0.038)	(0.038)	(0.044)	(0.039)
$Treated_{jt=0}$	−0.067	−0.067	−0.071	−0.050
	(0.043)	(0.043)	(0.044)	(0.043)
$Treated_{jt=+1}$	−0.002	−0.002	0.008	−0.008
	(0.040)	(0.040)	(0.050)	(0.049)
$Treated_{jt=+2}$	0.094*	0.094*	0.093*	0.068
	(0.047)	(0.047)	(0.052)	(0.054)
$Treated_{jt=+3}$	0.161***	0.161***	0.151***	0.171***
	(0.043)	(0.043)	(0.047)	(0.046)
$Treated_{jt=+4}$	0.181***	0.181***	0.185***	0.170***
	(0.043)	(0.043)	(0.047)	(0.049)
Additional Controls	See Specification (2). Year f.e., Disaster f.e., ZIP f.e.			
Observations	173,255	173,255	173,034	171,115
R^2	0.650	0.650	0.646	0.628
Adjusted R^2	0.647	0.647	0.643	0.626
Note:	*p<0.1; **p<0.05; ***p<0.01			

Counterfactual Approach: Simulating an Increase in Disaster Risk without the GSEs' Securitization Activity

- Estimating counterfactuals requires a **model**.
- Second-degree price discrimination: lenders offer **a menu of choices.**
  - Households self-select based on their default driver ε.
  - $\rightarrow$ reproduce the observed discontinuity.
- **Simulate the impact of an increase in disaster risk** π on the equilibrium of the mortgage market.
- Disaster risk $\uparrow$ lead to little change in origination volumes in the conforming segment when the GSEs securitize, yet very large sensitivity to flood risk when we withdraw the GSE securitization option.

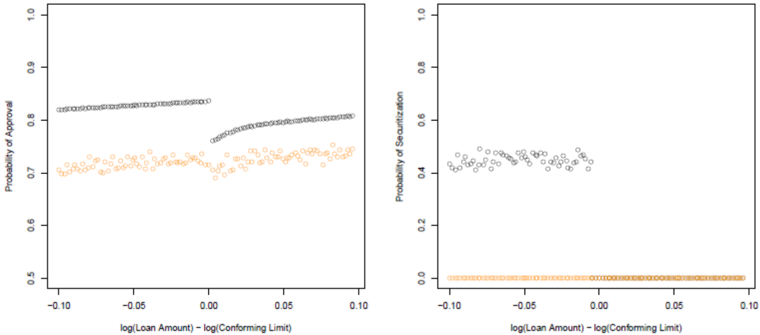
Introducing Disaster Risk (1%)



New equilibrium in red.

Counterfactual Simulation. Shutting down GSE securitization

(a) Probability of Approval (b) Probability of Securitization



Response of approval rates to the introduction of a 1% disaster risk.

New equilibrium in orange.

The GSEs Can Adapt

- **Endogenous Guarantee Fees.**

Profit-neutral guarantee fees

Disaster Risk π	0.0%	0.25%	1.0%	1.25%	1.5%
Guarantee Fee $\varphi^*(\pi)$	0.40%	0.44%	0.56%	0.59%	0.65%

$$\varphi^*(\pi) \quad \text{such that} \quad \sum_{j=1}^{J} \Pi_j^{sec}\left[\varphi^*(\pi)\right] = \sum_{j=1}^{J} \Pi_j^{sec}\left[\varphi(0)\right] \tag{3}$$

- **Transfer climate risk to private sector investors using Credit Risk Transfers.**

A Research Agenda

Questions:

- Can financial products diversify climate risk?
  - Does the packaging of climate-exposed assets reduce risk or rather lead to *Fault Lines* that endanger the stability of the mortgage market?
- Do private counterparties adapt to the rising default risk?
  - by charging higher fees, *pricing in the risk of climate shocks*?
- Is climate a *Weitzman* type tail risk or rather part of conventional volatility?
  - A "climate" equity premium puzzle?
- How do agents behave in the face of ambiguous risk?

→ Exploring each part of a general equilibrium asset pricing model.

→ Does climate risk affect the fundamental theorems of asset pricing?