

Weatherproofing Your Credit Portfolio: The Impact of Natural Disaster Events on the U.S. Residential Mortgage Market

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Agenda

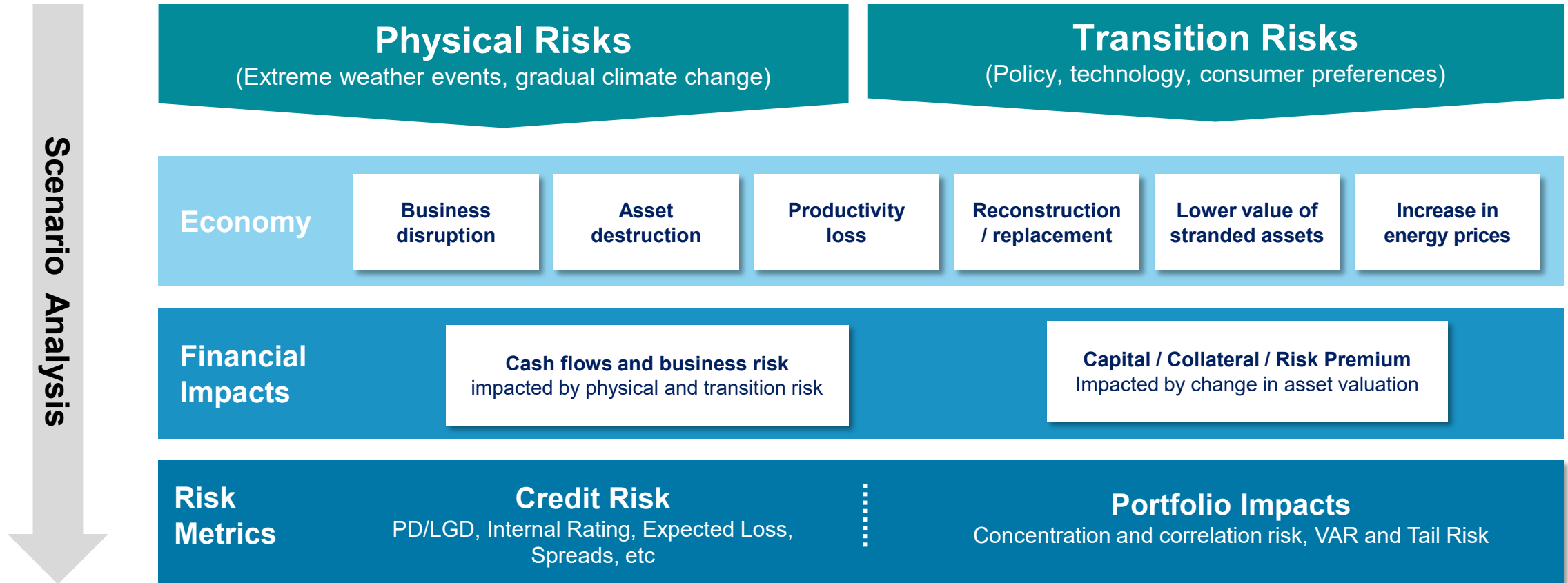
1. Introduction: A Primer on Climate Risk
2. The Role of Natural Disasters On Mortgage Defaults
3. Quantifying The Probability And Severity Of Natural Disasters
4. Simulations Of Natural Disasters In Credit Models
5. Leverage Data From Four Twenty Seven To Quantify Intrastate Differences

1

Introduction: A Primer on Climate Risk

Economic and Financial Impacts of Climate Risk

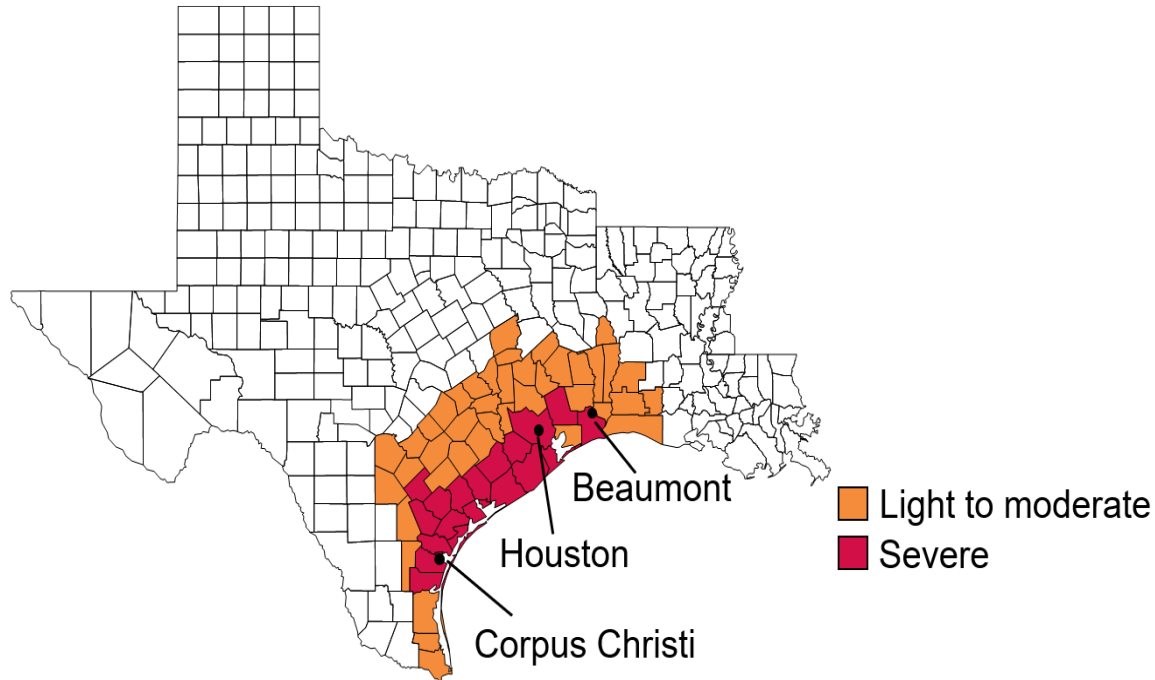
Moody's conceptual framework



Acute & Chronic Physical Risk

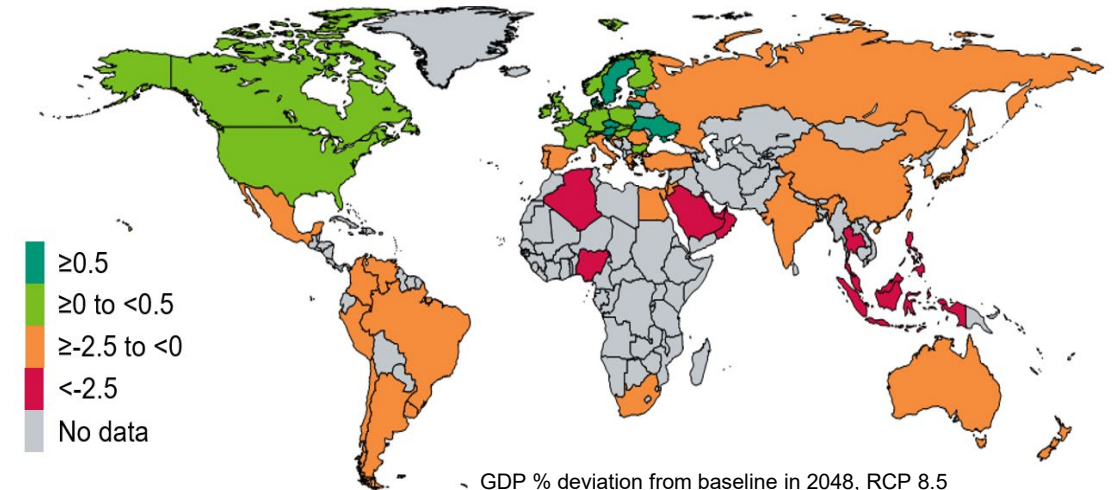
Harvey Leaves a Trail of Destruction

Real GDP impact



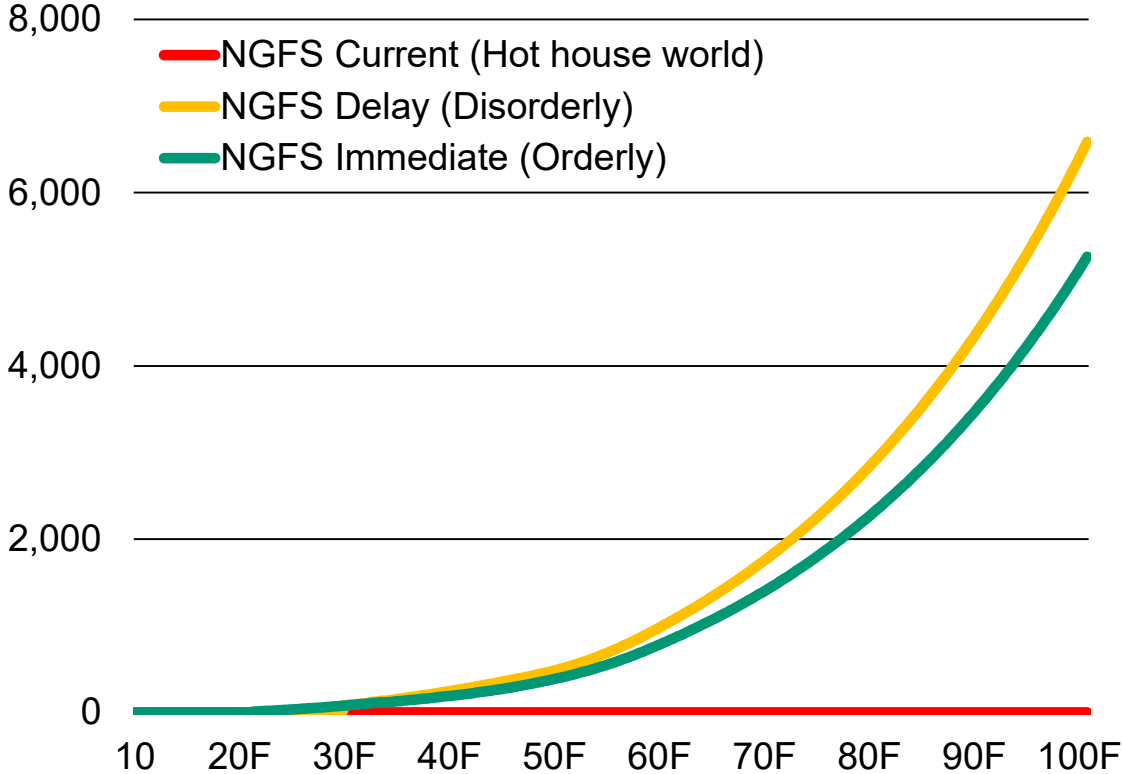
Global: Some Winners, More Losers

GDP, %change, 3° C temperature increase, RCP 8.5

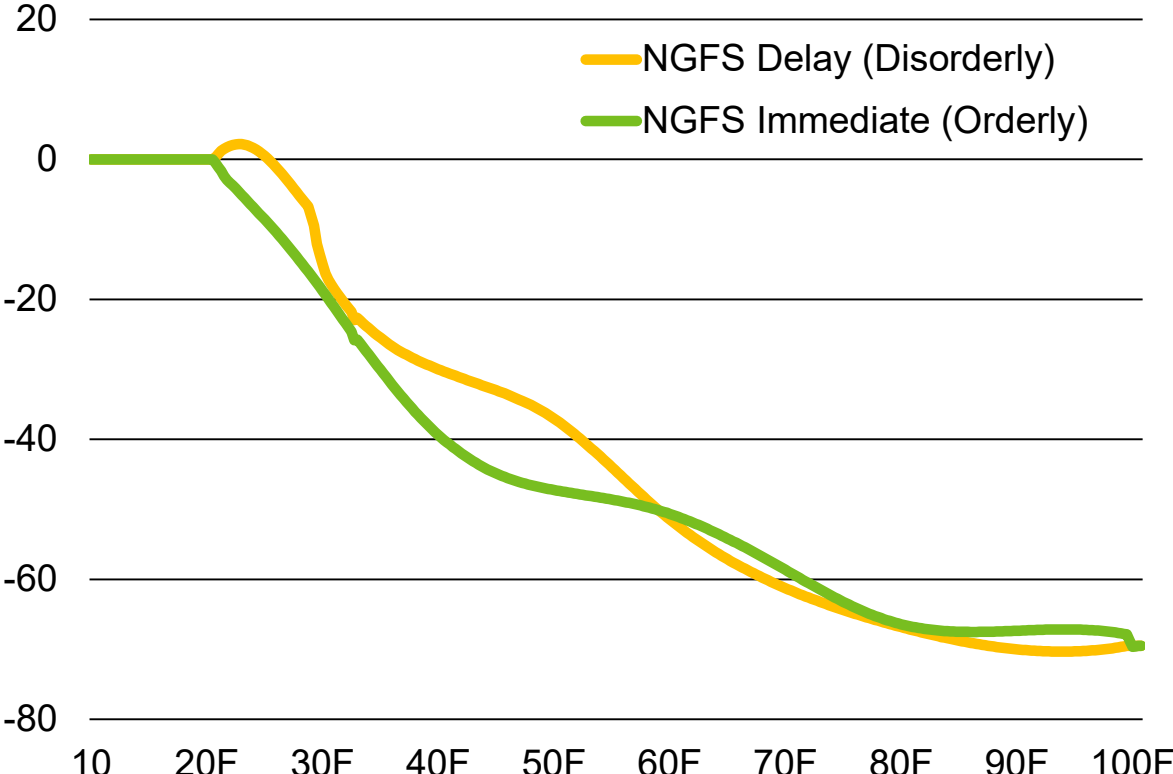


Transition Risk

Carbon tax, USD per metric ton, NSA



U.S. GPO – Mining Industry, % Deviation from Current



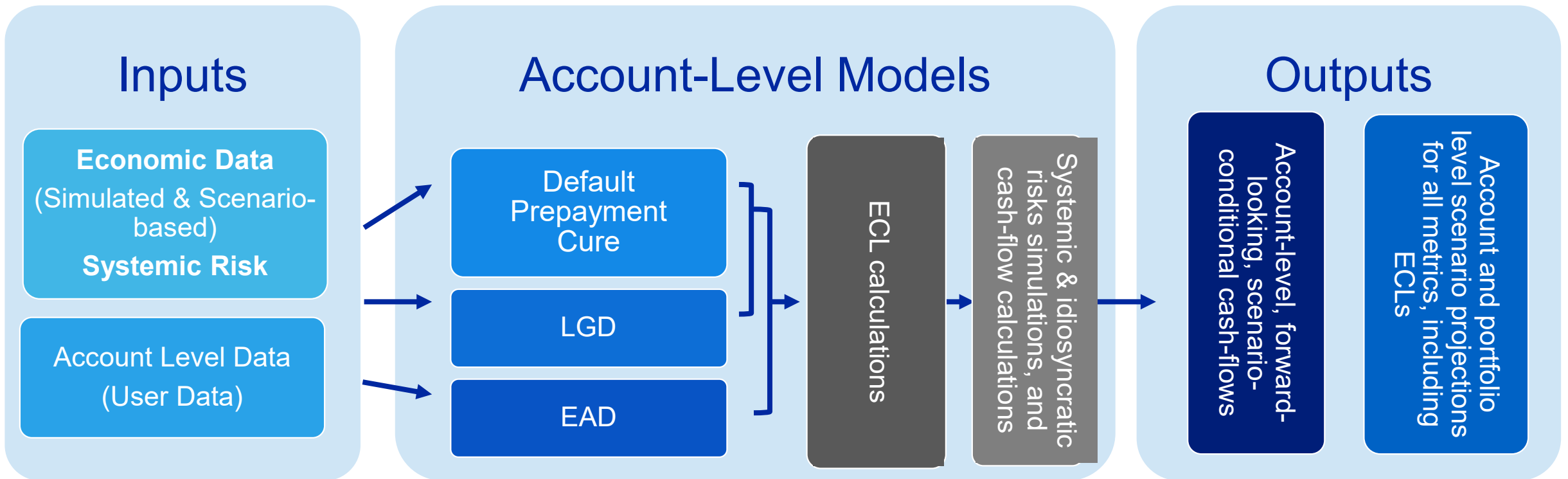
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The Role of Natural Disasters On Mortgage Defaults

Portfolio Analyzer (PA) Suite of Models

Modular structure

PA uses [account-level econometric models](#) for credit and impairment metrics across retail portfolios

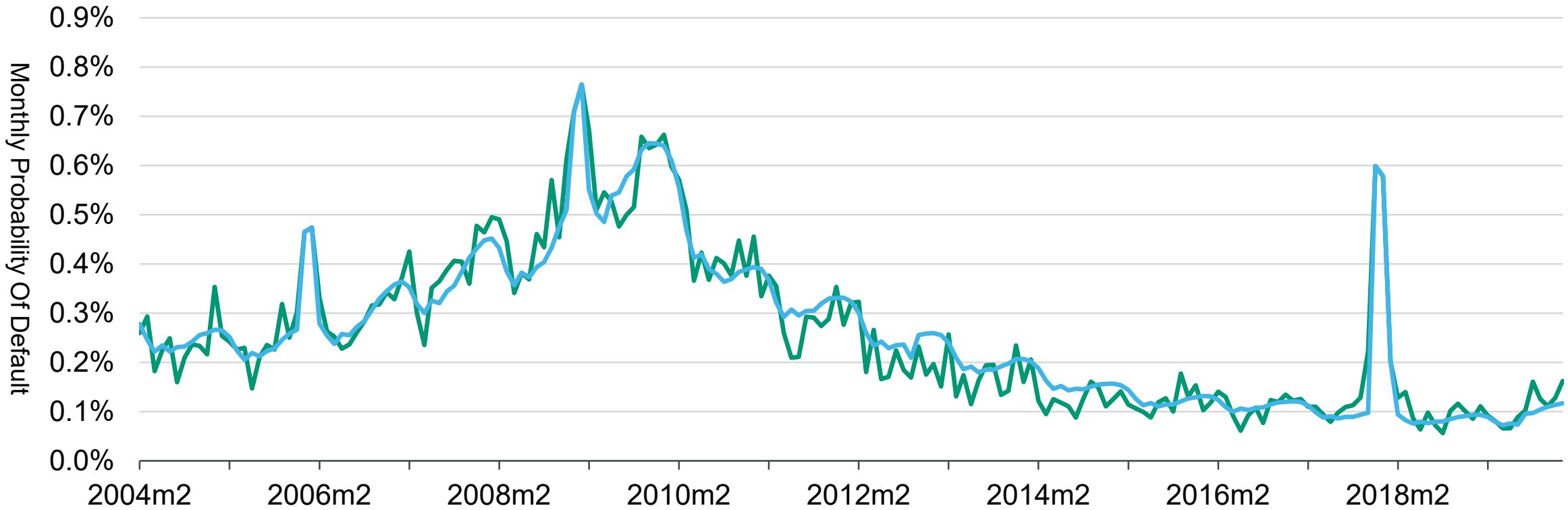


Hurricane Harvey In Texas

First lien FRM mortgage default rate

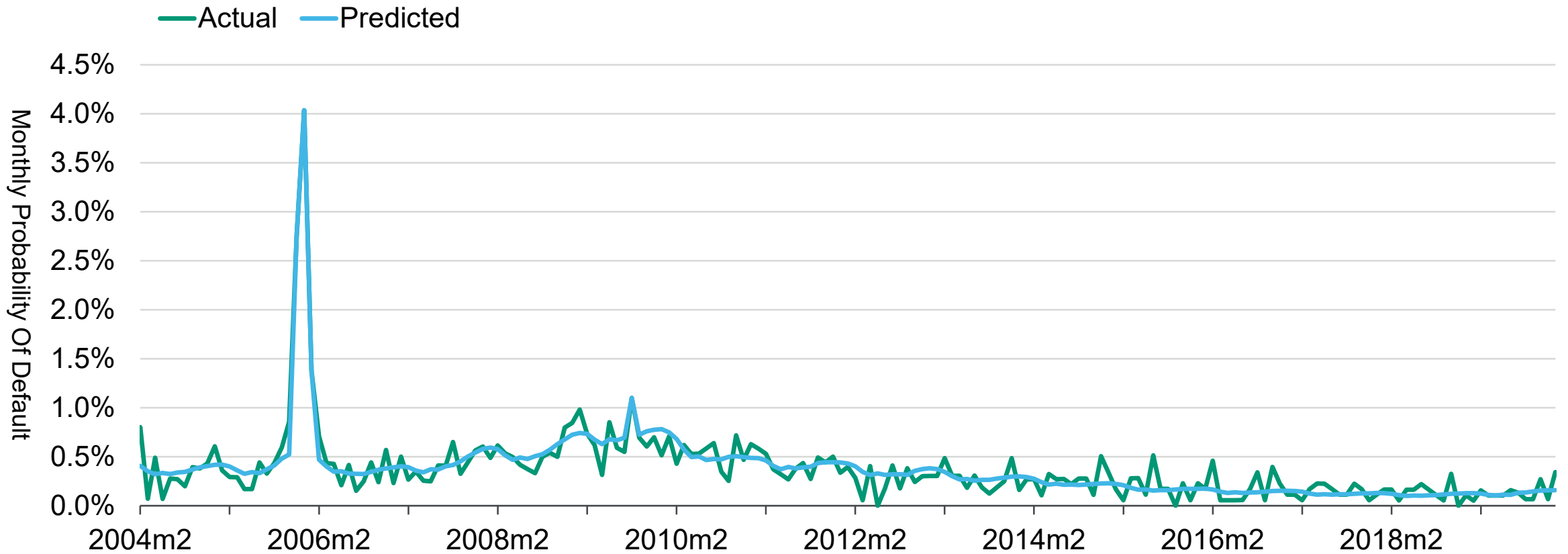


— Actual — Predicted



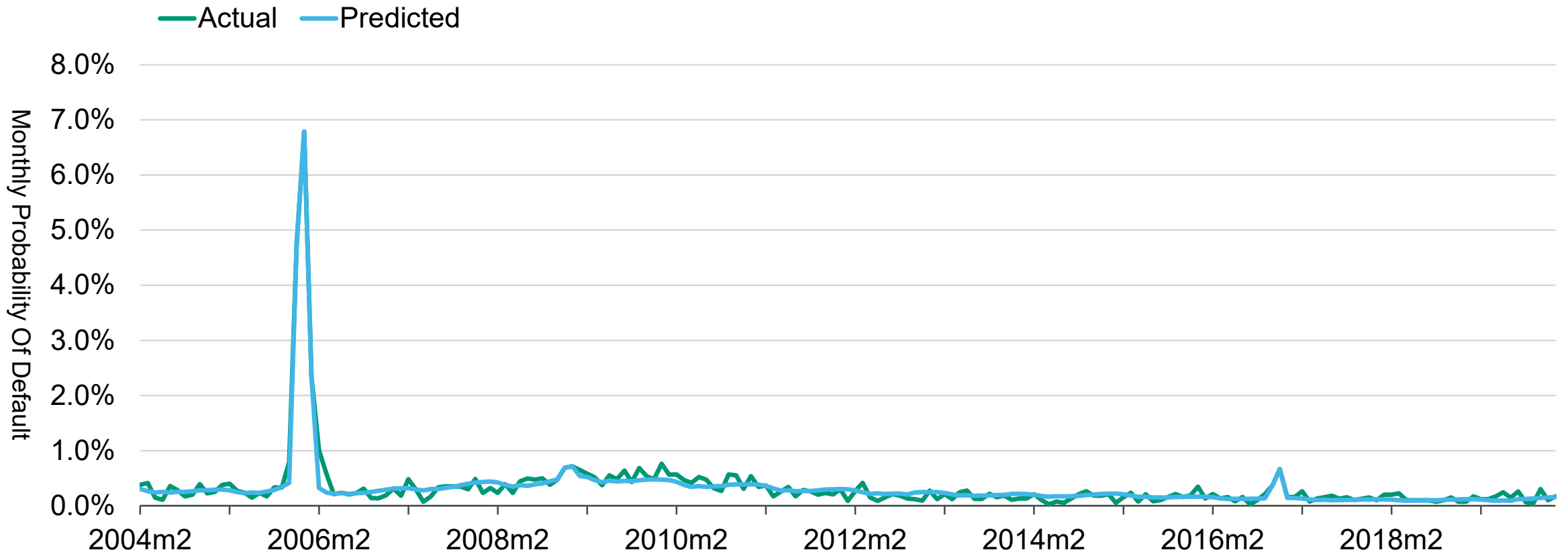
Hurricane Katrina In Mississippi

First lien FRM mortgage default rate



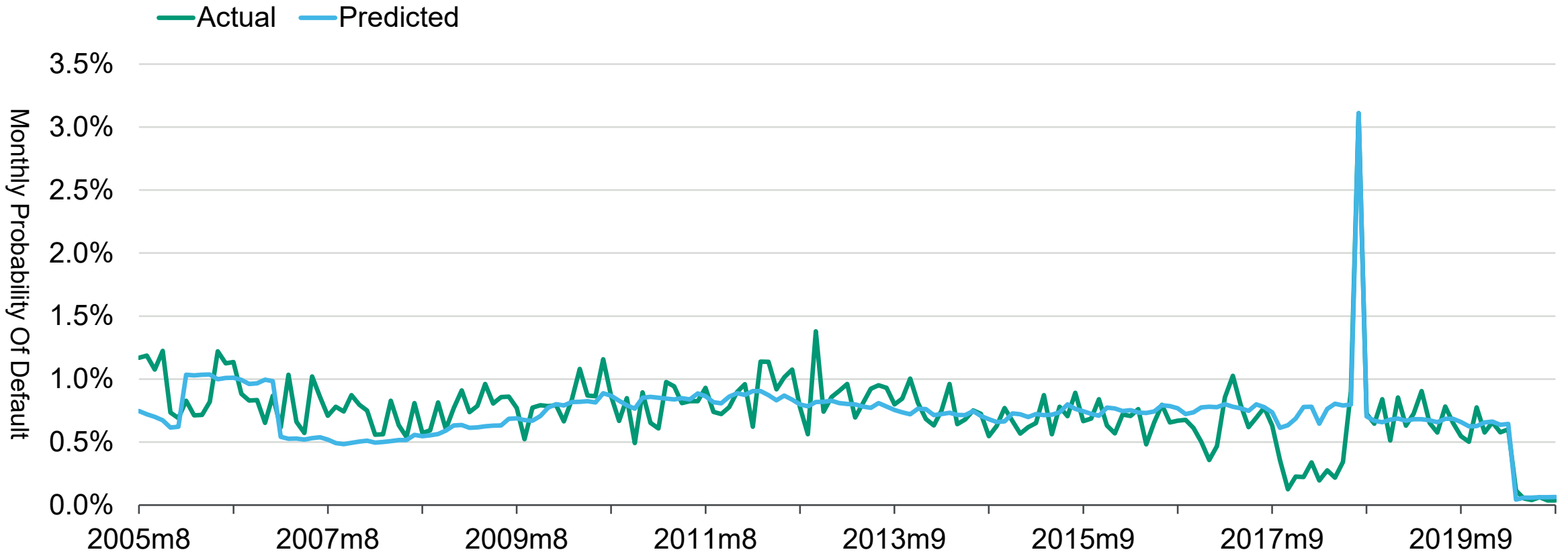
Hurricane Katrina In Louisiana

First lien FRM mortgage default rate



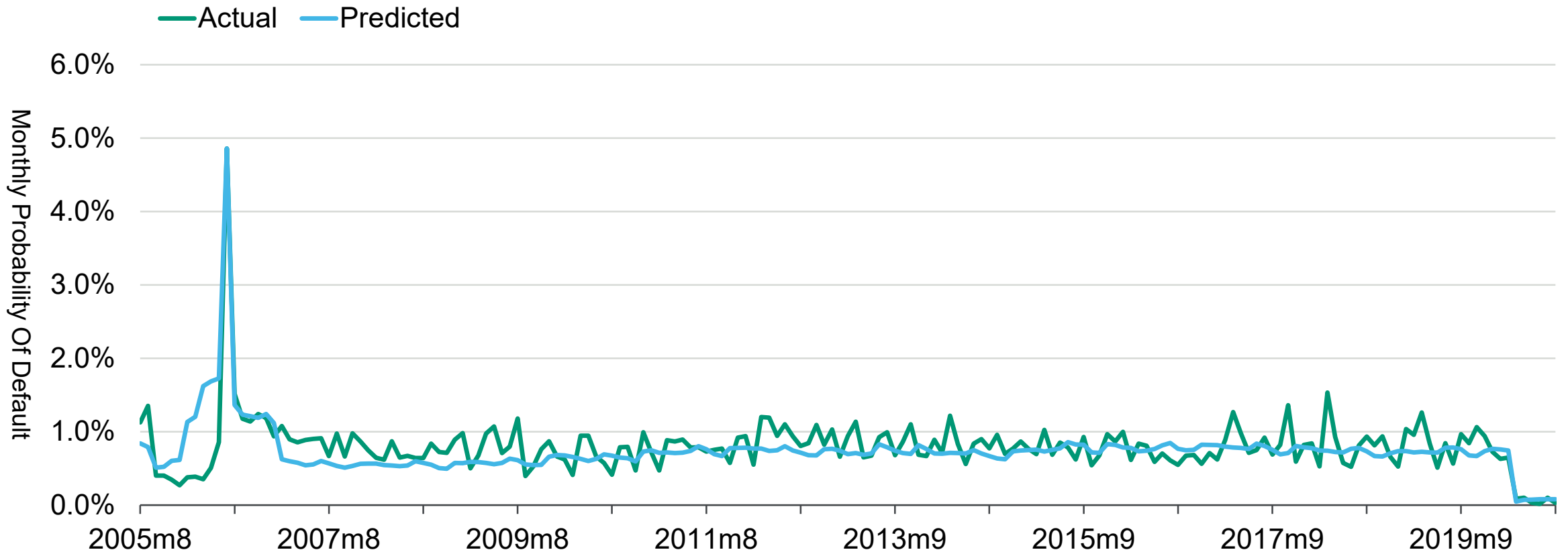
Natural Disaster Impact on Student Loans

Florida – Hurricane Irma



Natural Disaster Impact on Student Loans

Louisiana – Hurricane Katrina



National Oceanic and Atmospheric Administration (NOAA) Data

- » Close to 13,000 events for 24 different event types
- » Year, month, state, number of deaths and the estimated amount of damage to property incurred by the weather event

Event Type	
flood	lightning
hurricane_typhoon	fog
wildfire	volcanic ash
tornado_waterspout	heat
tsunami	low tide
blizzard	dense smoke
thunderstorm wind_heavy rain	drought
high wind	dust storm
hail	funnel cloud
rip current	northern lights
avalanche	seiche
landslide	other

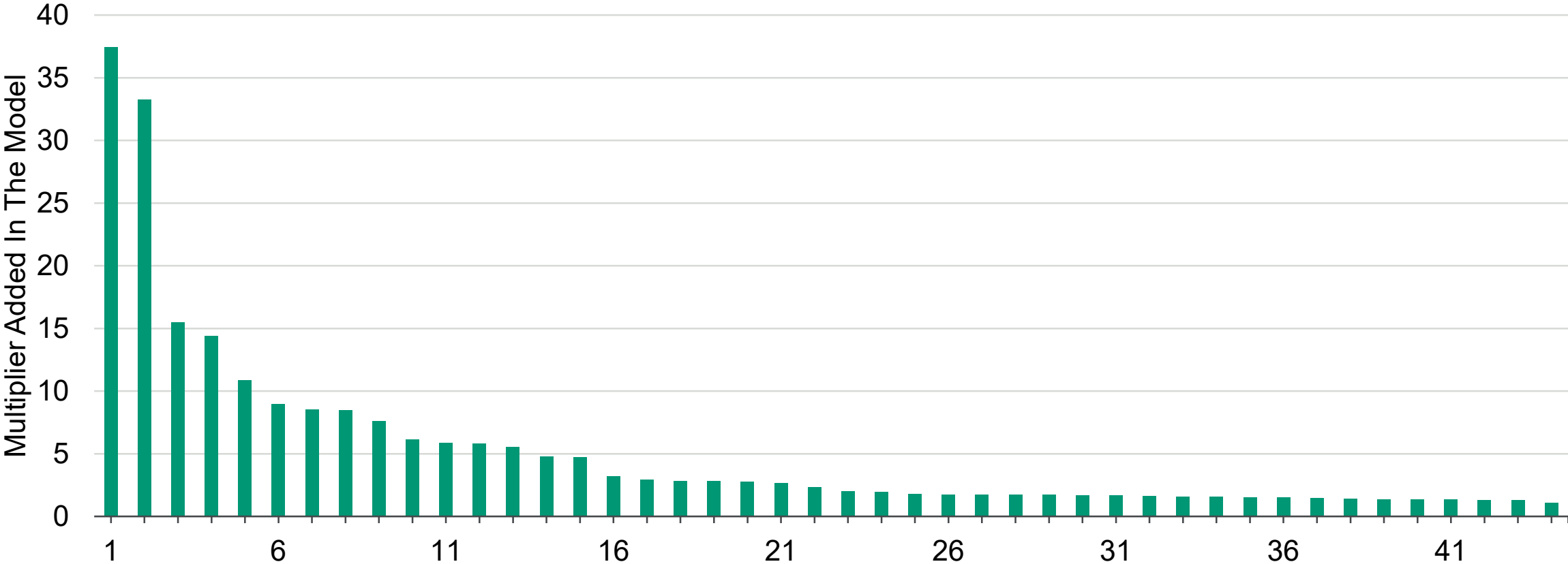
Top 9 Extreme Natural Disasters

57 natural disasters with more than \$500M estimated damage

State	Year-Month	Property Damage	Direct Deaths	Disaster
TX	201708	43,704,268,000	67	Harvey
NJ	201210	20,950,000,000	2	Sandy
PR	201709	19,018,177,000	20	Irma
CA	201811	17,000,000,000	86	Wildfire
LA	200508	16,933,030,000	816	Katrina
MS	200508	13,482,120,000	181	Katrina
FL	200409	10,562,815,000	13	Stewart
FL	200510	10,215,603,000	1	Wilma
LA	201608	8,992,219,000	12	32 inches of rainfall

44 Events Had Significant Impacts On Probability Of Default

Multipliers in first lien FRM mortgage default model



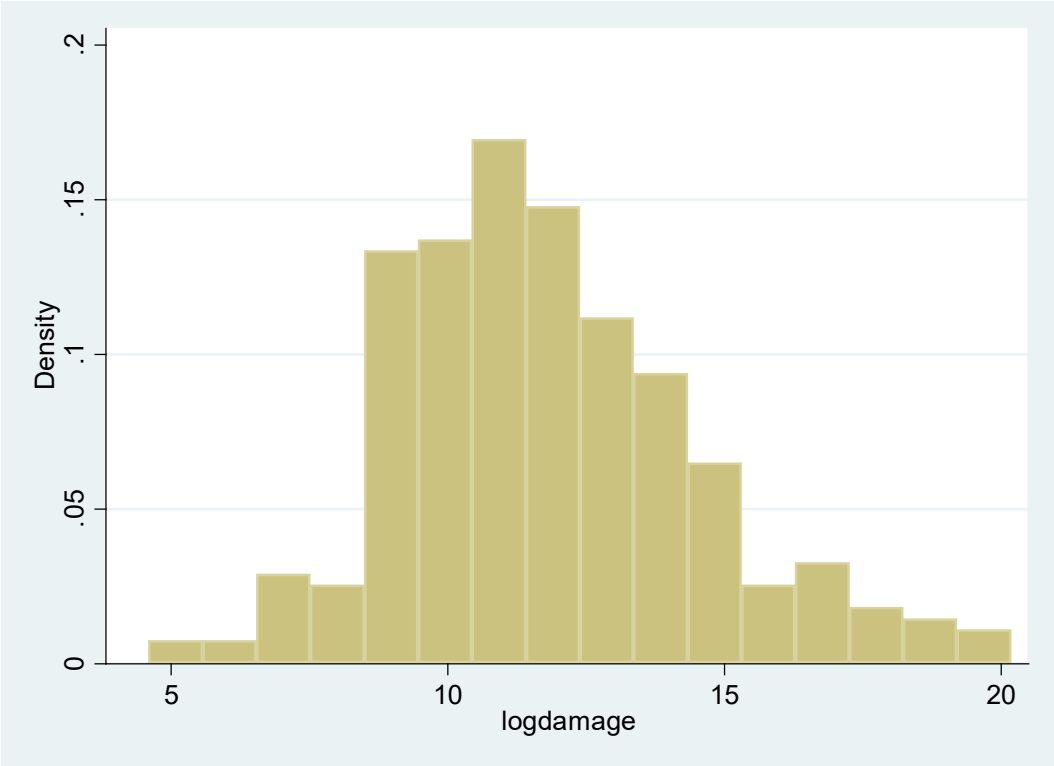
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Quantifying The Probability And Severity Of Natural Disasters

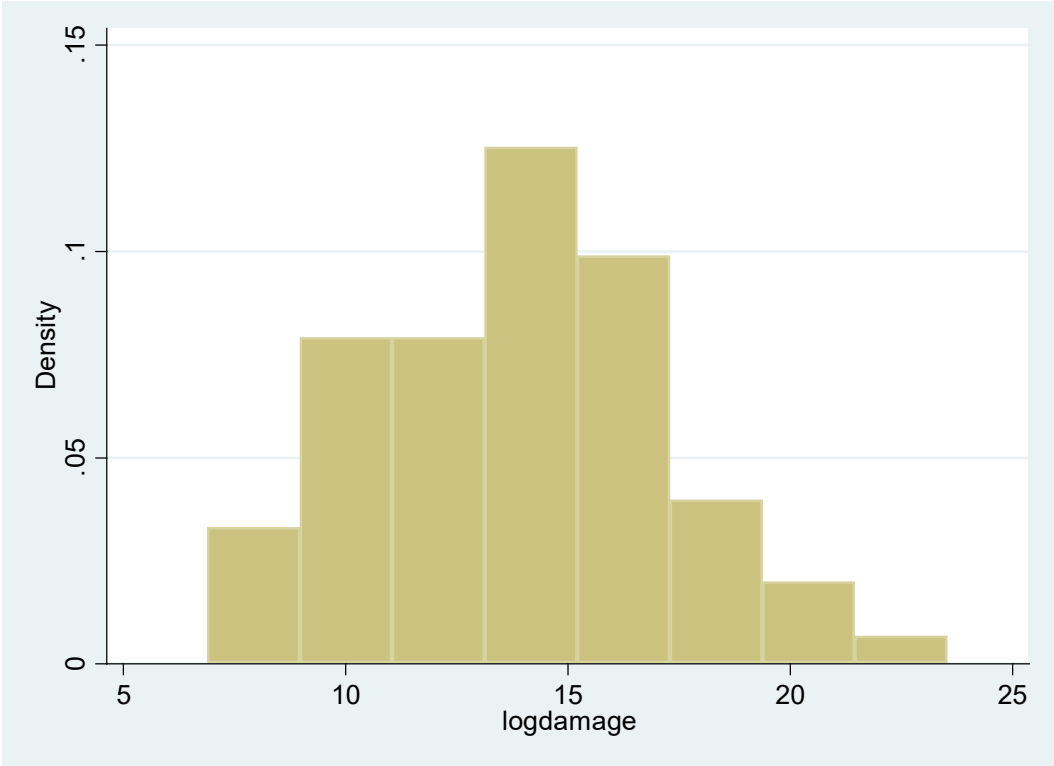
The Distribution Of Damages In California

Probability Density Function Of $\ln(\text{Property Damage})$

Wildfire



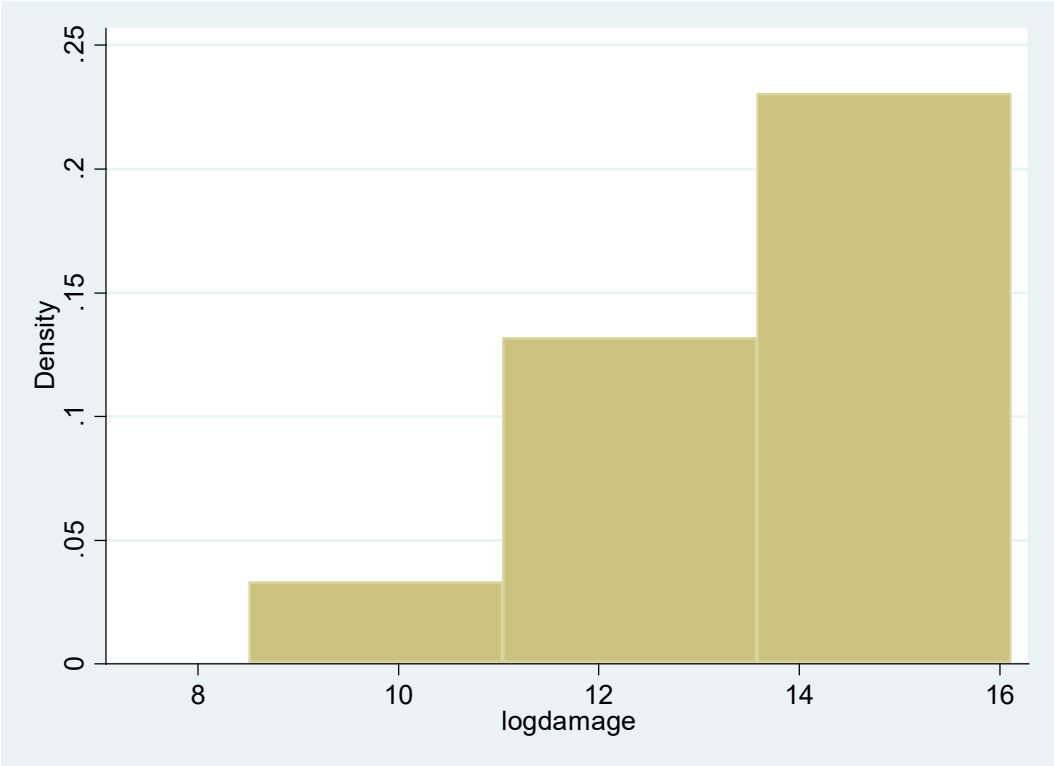
Flood, Hurricane, Tornado & Heavy Rain



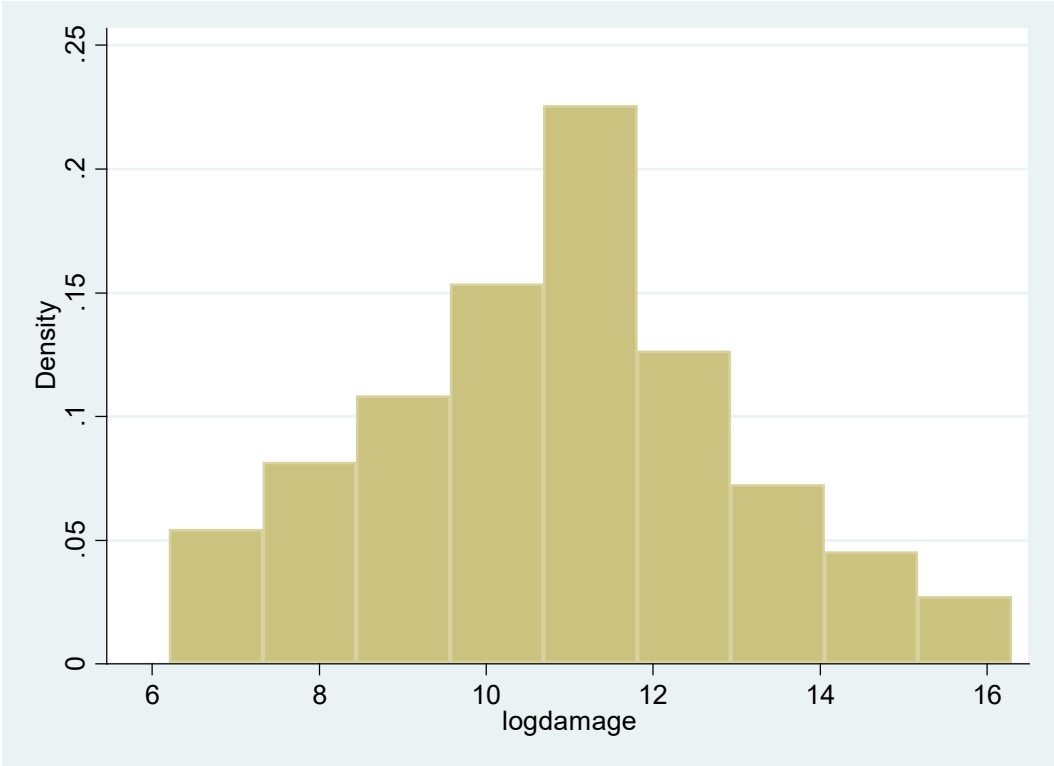
The Distribution Of Damages In Wyoming

Probability Density Function Of $\ln(\text{Property Damage})$

Wildfire



Flood, Hurricane, Tornado & Heavy Rain



Threshold Exceedances

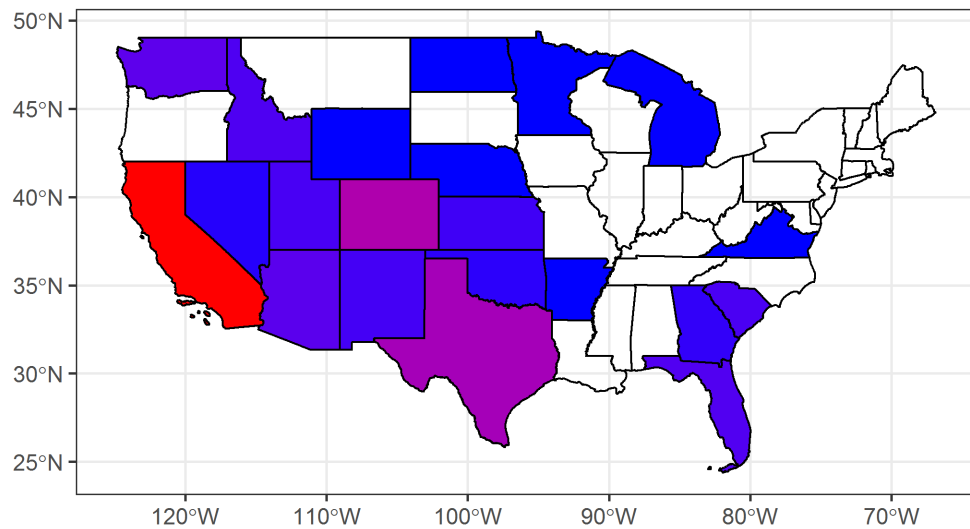
Generalized Pareto Family Distributions

$$\Pr\{X > u + y | X > u\} = \frac{1 - F(u + y)}{1 - F(u)} \quad , y > 0$$

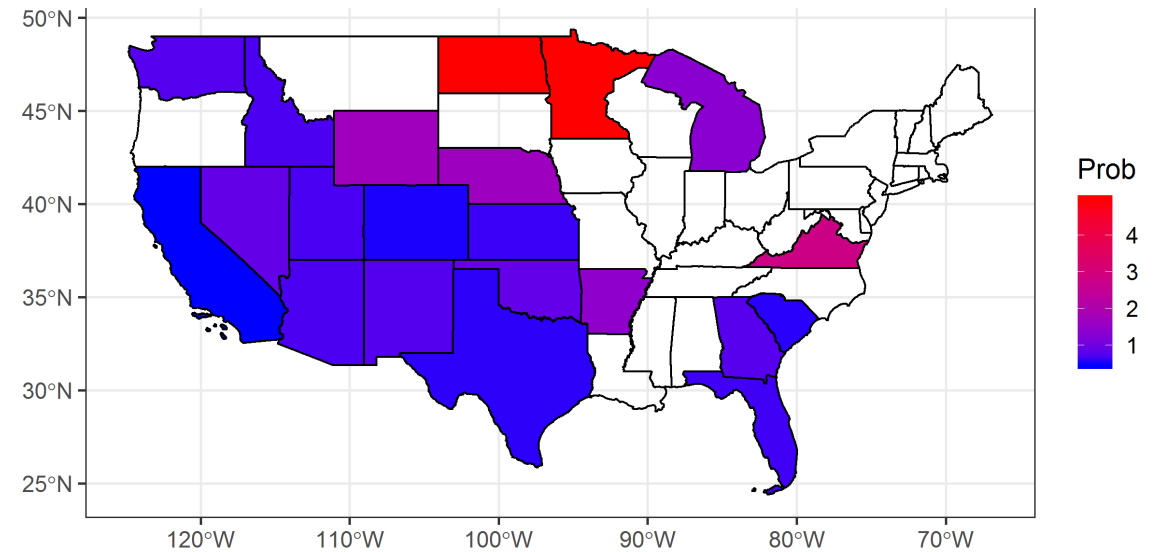
$$H(y) = 1 - \left(1 + \frac{\lambda y}{\tilde{\sigma}}\right)^{-1/\lambda} \quad \text{where } \tilde{\sigma} = \sigma + \lambda(u - \mu)$$

Distribution Parameters For Wildfires

Probability

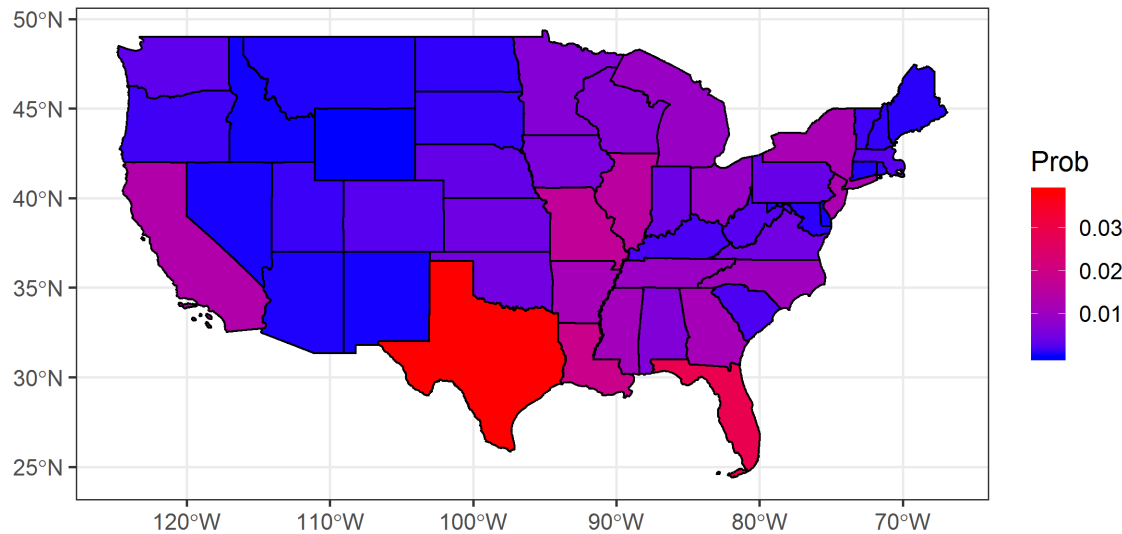


Lambda

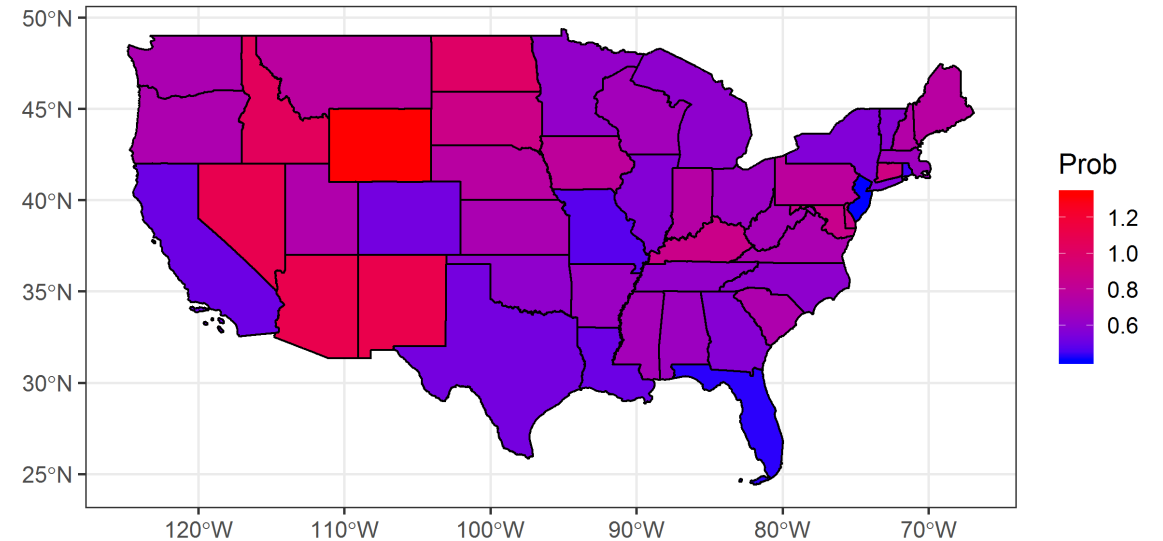


Distribution Parameters For Hurricanes, Floods, Sea Level Rise and Rainfall

Probability



Lambda



4

Simulations Of Natural Disasters In Credit Models

Use Monte Carlo Simulations To Quantify Natural Disaster Impacts

Portfolio: 2,688 loans, Total Balance: \$803M

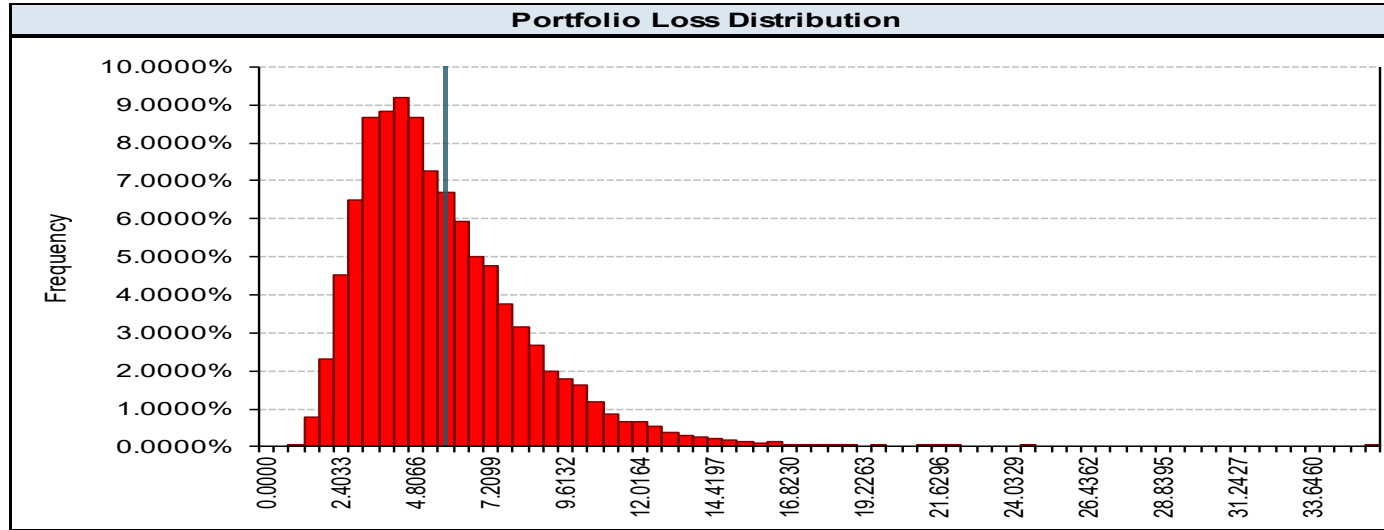
FICO	#	%	Exposure
>= 790	537	19.90	159,792,000.00
>= 750	331	12.53	100,668,000.00
>= 710	360	13.24	106,328,000.00
>= 670	356	13.31	106,868,000.00
>= 630	356	13.35	107,248,000.00
>= 590	356	13.06	104,916,000.00
>= 550	392	14.61	117,328,000.00
>= 510	0	0.00	0.00
>= 470	0	0.00	0.00
>= 430	0	0.00	0.00

Loan Size	#	%	Exposure
>= 368,500	181	8.48	68,108,000.00
>= 352,000	327	14.66	117,744,000.00
>= 335,500	247	10.53	84,544,000.00
>= 319,000	244	9.89	79,444,000.00
>= 302,500	268	10.35	83,132,000.00
>= 286,000	282	10.31	82,836,000.00
>= 269,500	256	8.86	71,148,000.00
>= 253,000	298	9.73	78,128,000.00
>= 236,500	264	8.09	64,964,000.00
>= 220,000	321	9.10	73,100,000.00

LTV	#	%	Exposure
>= 100	0	0.00	0.00
>= 95	65	3.08	24,700,000.00
>= 90	318	14.55	116,896,000.00
>= 85	322	13.95	112,000,000.00
>= 80	294	11.98	96,244,000.00
>= 75	326	12.52	100,532,000.00
>= 70	345	12.40	99,572,000.00
>= 65	356	11.88	95,428,000.00
>= 60	341	10.54	84,676,000.00
>= 55	321	9.10	73,100,000.00

Simulation Results For Loans in TX

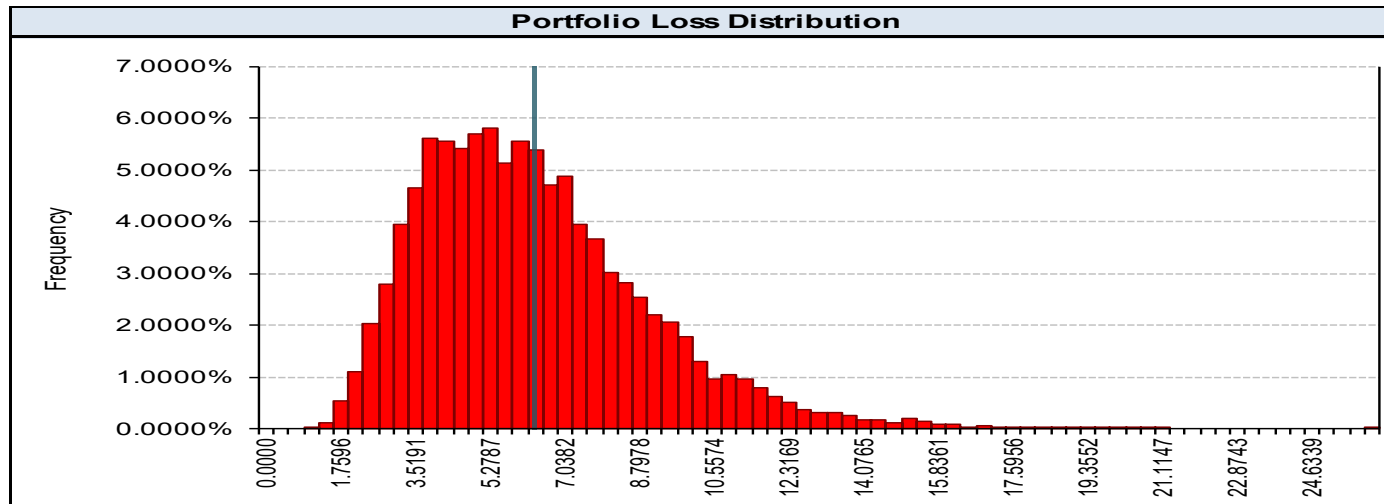
Without Natural
Disasters



Aggregate Statistics	
Number of Simulations	10,000
Mean (Portfolio EL)	5.8959%
Standard Deviation	2.6908
Interquartile Range	3.3077
Skewness	1.4992
Kurtosis	5.3347
95th / 50th Percentile	2.0578

Percentiles	
5%	2.6345
10%	3.0726
25%	3.9670
50%	5.3252
75%	7.2746
90%	9.4209
95%	10.9580

With Natural
Disasters

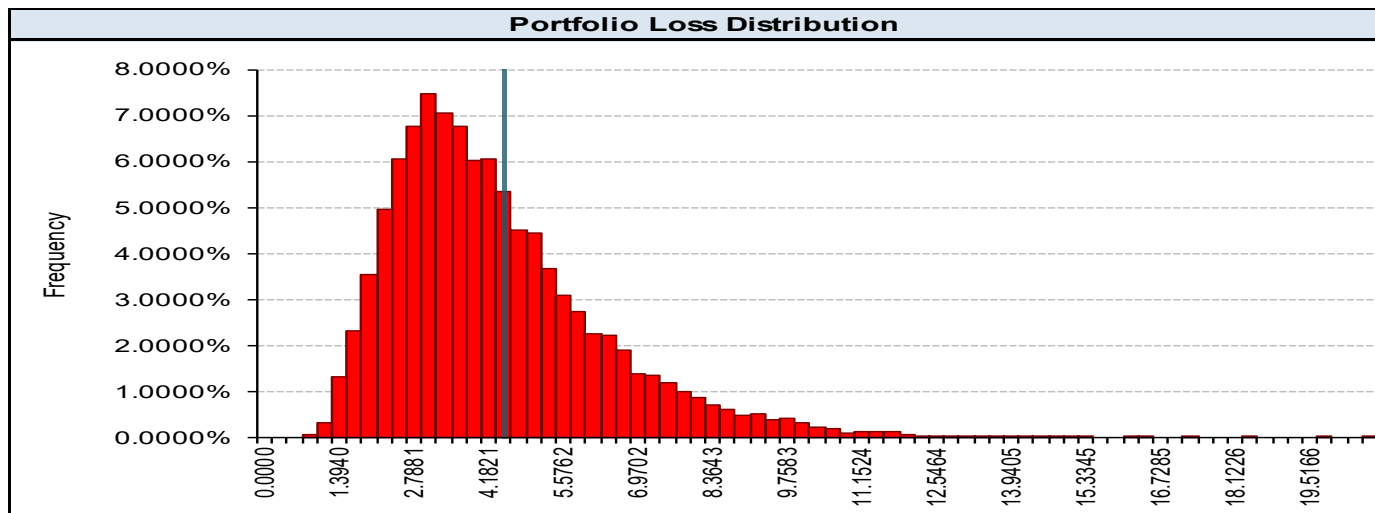


Aggregate Statistics	
Number of Simulations	10,000
Mean (Portfolio EL)	6.4705%
Standard Deviation	2.6704
Interquartile Range	3.4410
Skewness	1.0242
Kurtosis	1.7184
95th / 50th Percentile	1.8817

Percentiles	
5%	2.9795
10%	3.4734
25%	4.4881
50%	6.0788
75%	7.9291
90%	9.9837
95%	11.4384

Simulation Results For Loans in WY

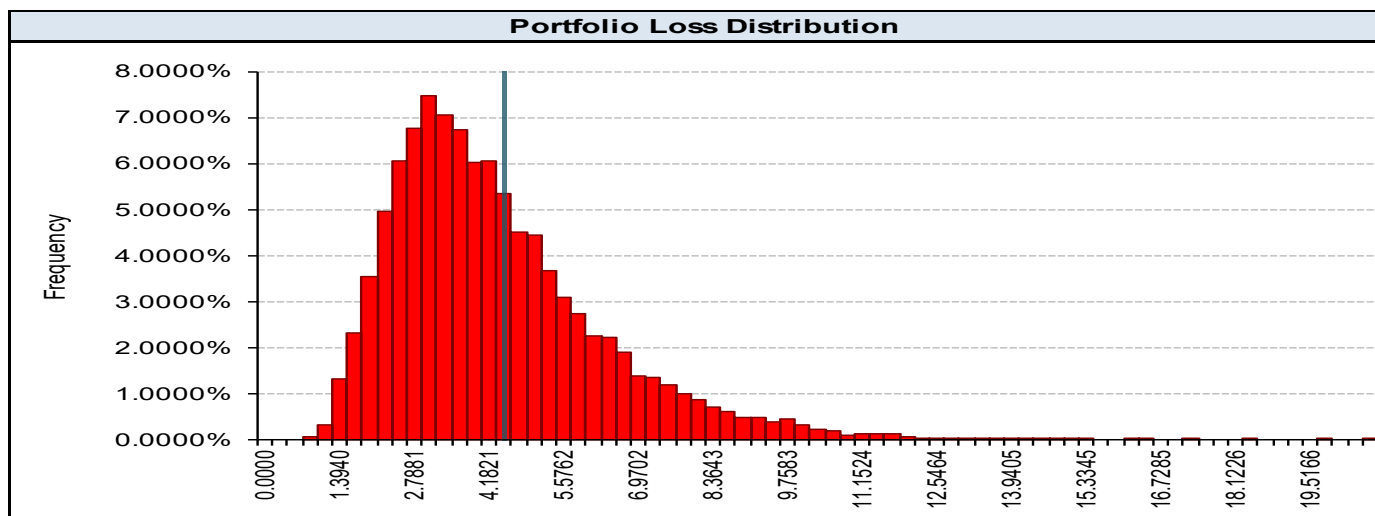
Without Natural
Disasters



Aggregate Statistics	
Number of Simulations	10,000
Mean (Portfolio EL)	4.4758%
Standard Deviation	2.0276
Interquartile Range	2.3861
Skewness	1.4464
Kurtosis	3.6947
95th / 50th Percentile	2.0704

Percentiles	
5%	2.0342
10%	2.3689
25%	3.0490
50%	4.0534
75%	5.4351
90%	7.1330
95%	8.3922

With Natural
Disasters

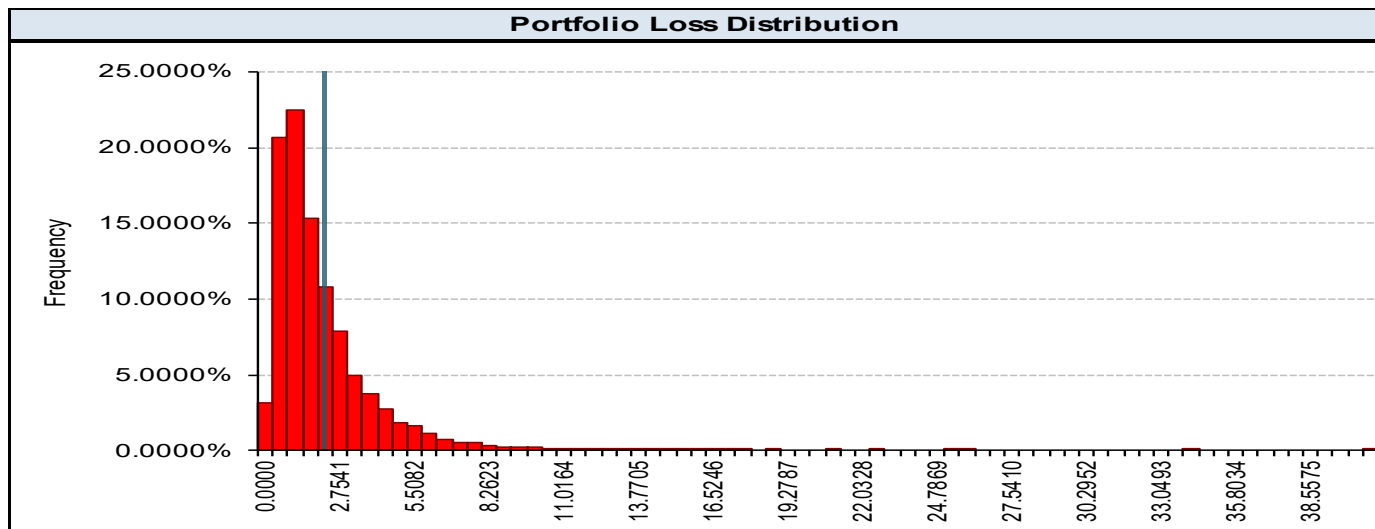


Aggregate Statistics	
Number of Simulations	10,000
Mean (Portfolio EL)	4.4757%
Standard Deviation	2.0274
Interquartile Range	2.3868
Skewness	1.4468
Kurtosis	3.6980
95th / 50th Percentile	2.0699

Percentiles	
5%	2.0342
10%	2.3689
25%	3.0490
50%	4.0544
75%	5.4358
90%	7.1301
95%	8.3922

Simulation Results For Loans in CA

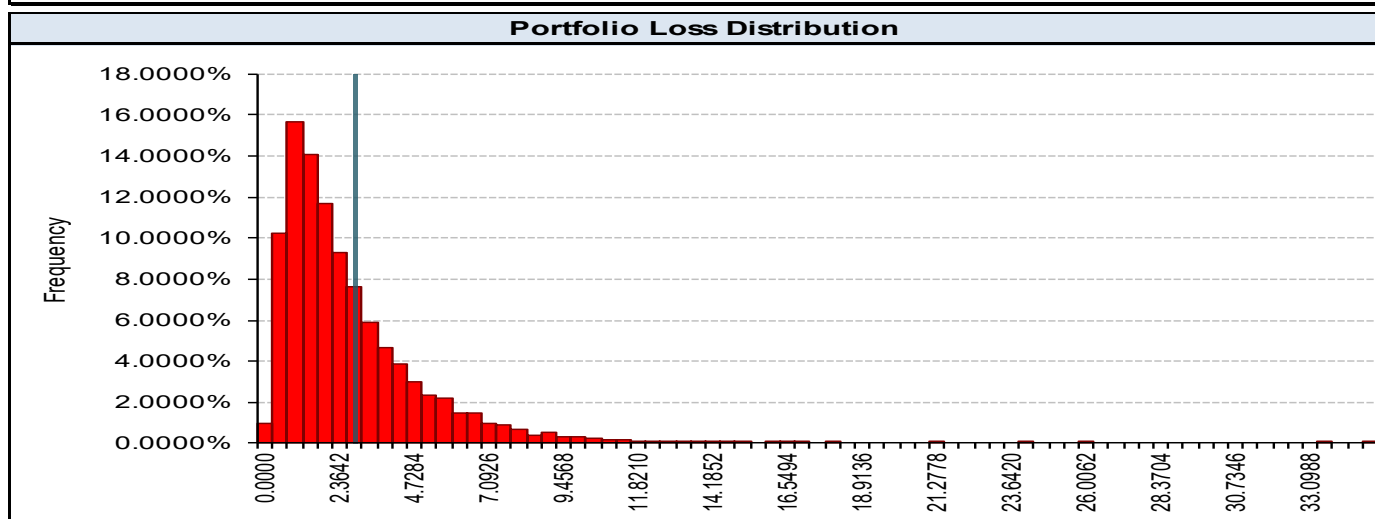
Without Natural
Disasters



Aggregate Statistics	
Number of Simulations	10,000
Mean (Portfolio EL)	2.3528%
Standard Deviation	2.0021
Interquartile Range	1.7891
Skewness	3.8773
Kurtosis	35.5313
95th / 50th Percentile	3.3797

Percentiles	
5%	0.6207
10%	0.7803
25%	1.1276
50%	1.7676
75%	2.9166
90%	4.6195
95%	5.9740

With Natural
Disasters



Aggregate Statistics	
Number of Simulations	10,000
Mean (Portfolio EL)	2.9007%
Standard Deviation	2.2573
Interquartile Range	2.3703
Skewness	2.4709
Kurtosis	13.9273
95th / 50th Percentile	3.2391

Percentiles	
5%	0.7171
10%	0.9091
25%	1.3603
50%	2.2364
75%	3.7306
90%	5.7722
95%	7.2440

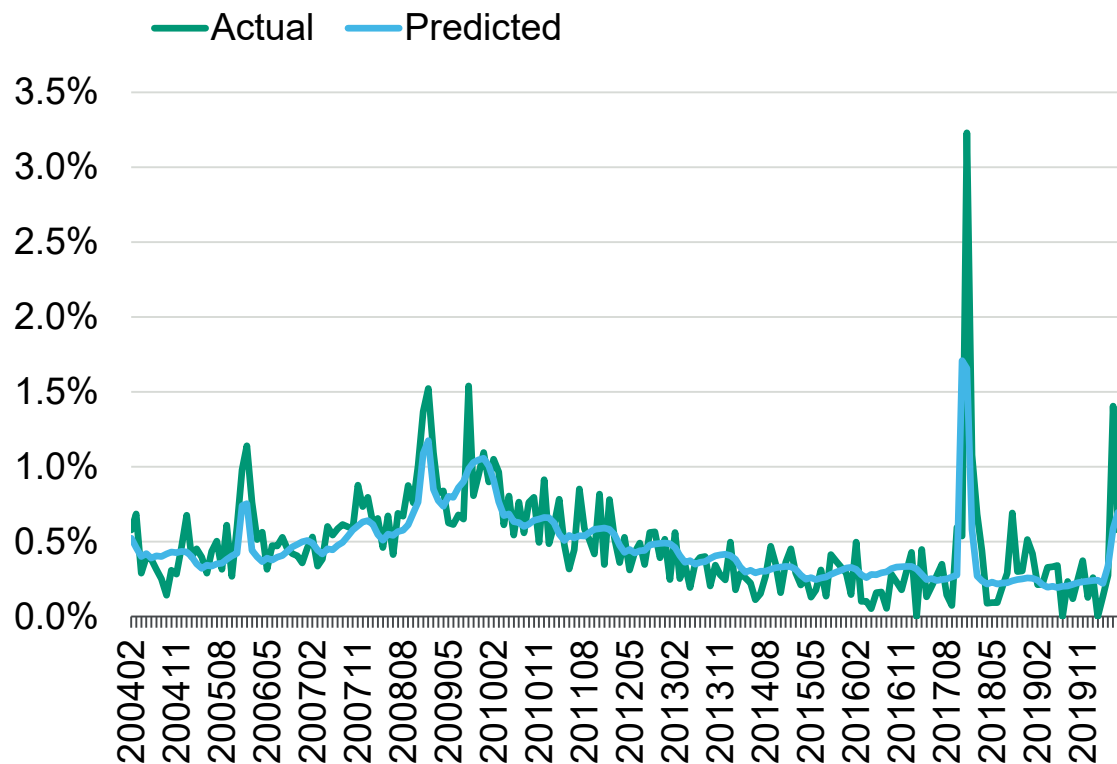
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Leverage Data From Four
Twenty Seven To Quantify
Intrastate Differences

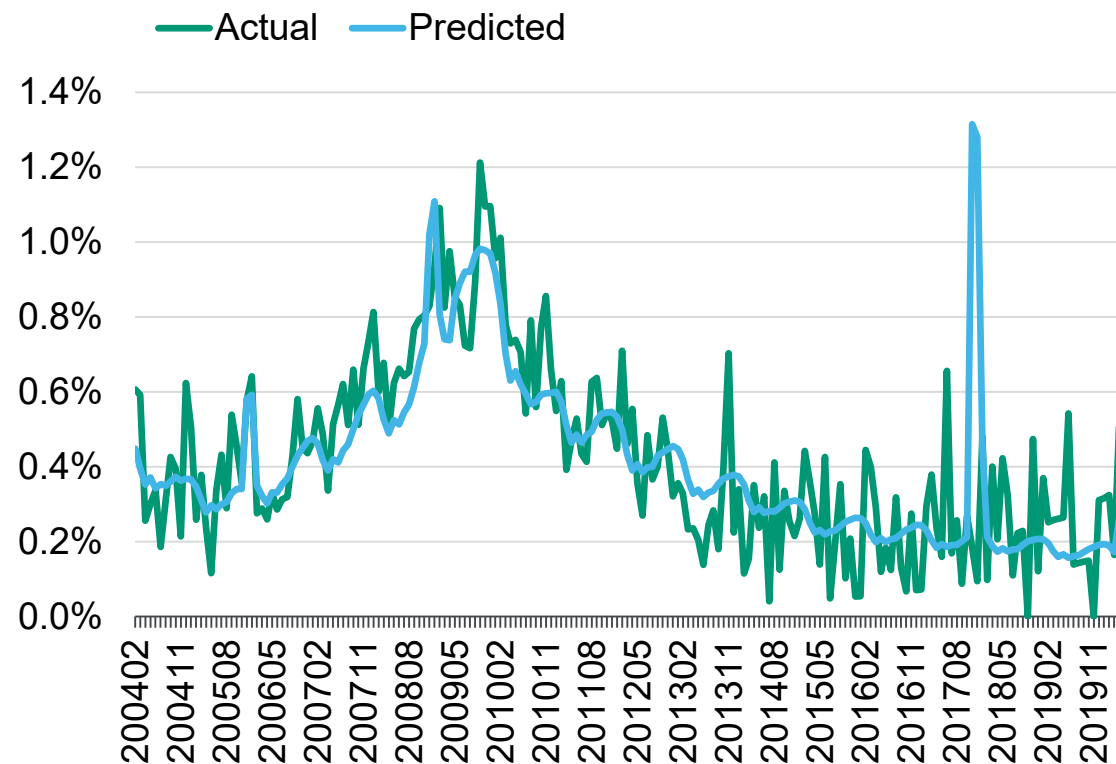
PD Model Performance For Two MSAs

Monthly Probability of Default

Houston (MHOU)



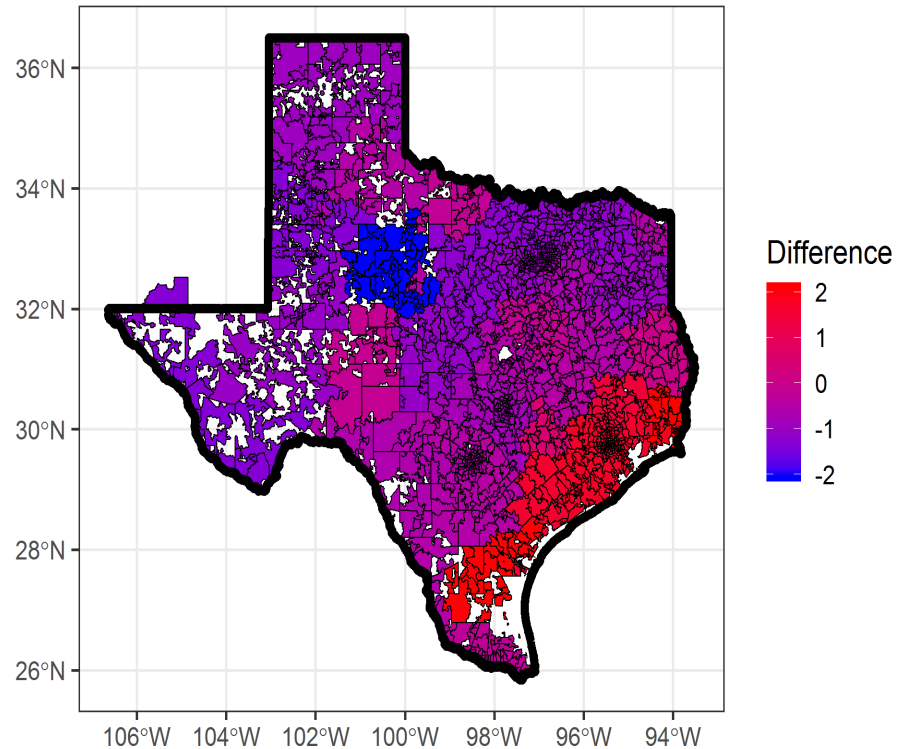
Dallas (MDAL)



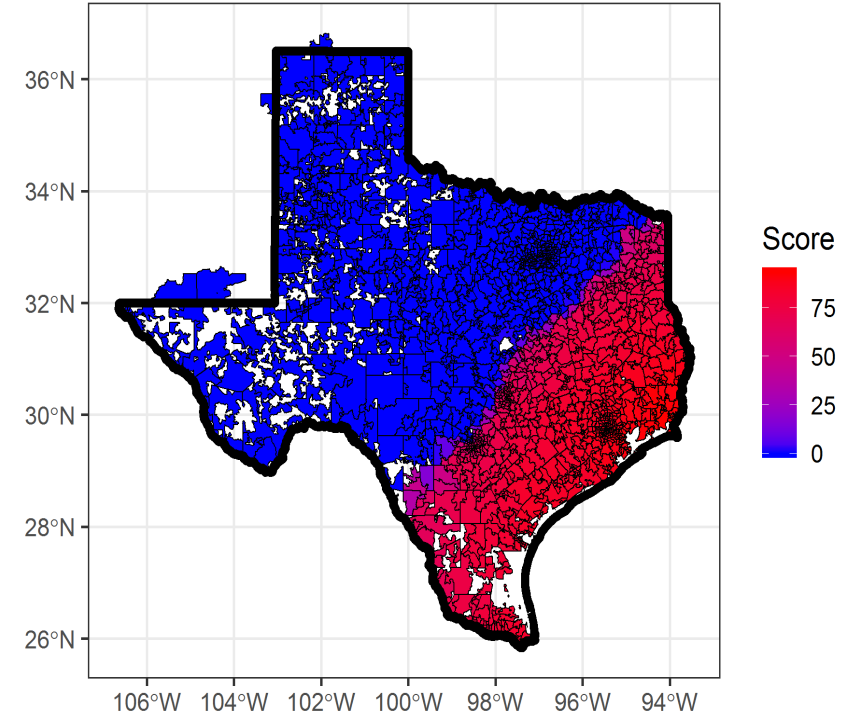
Adding Four Twenty Seven Scores

Difference = Actual PD – Predicted PD

Hurricane Harvey - MPA coefficient difference, Texas zip codes



Texas - 427 Hurricanes score, by zip codes



Local Differences Are Explained by Four Twenty Seven Scores

Galveston

Hurricane: 99

Sea Level Rise: 92

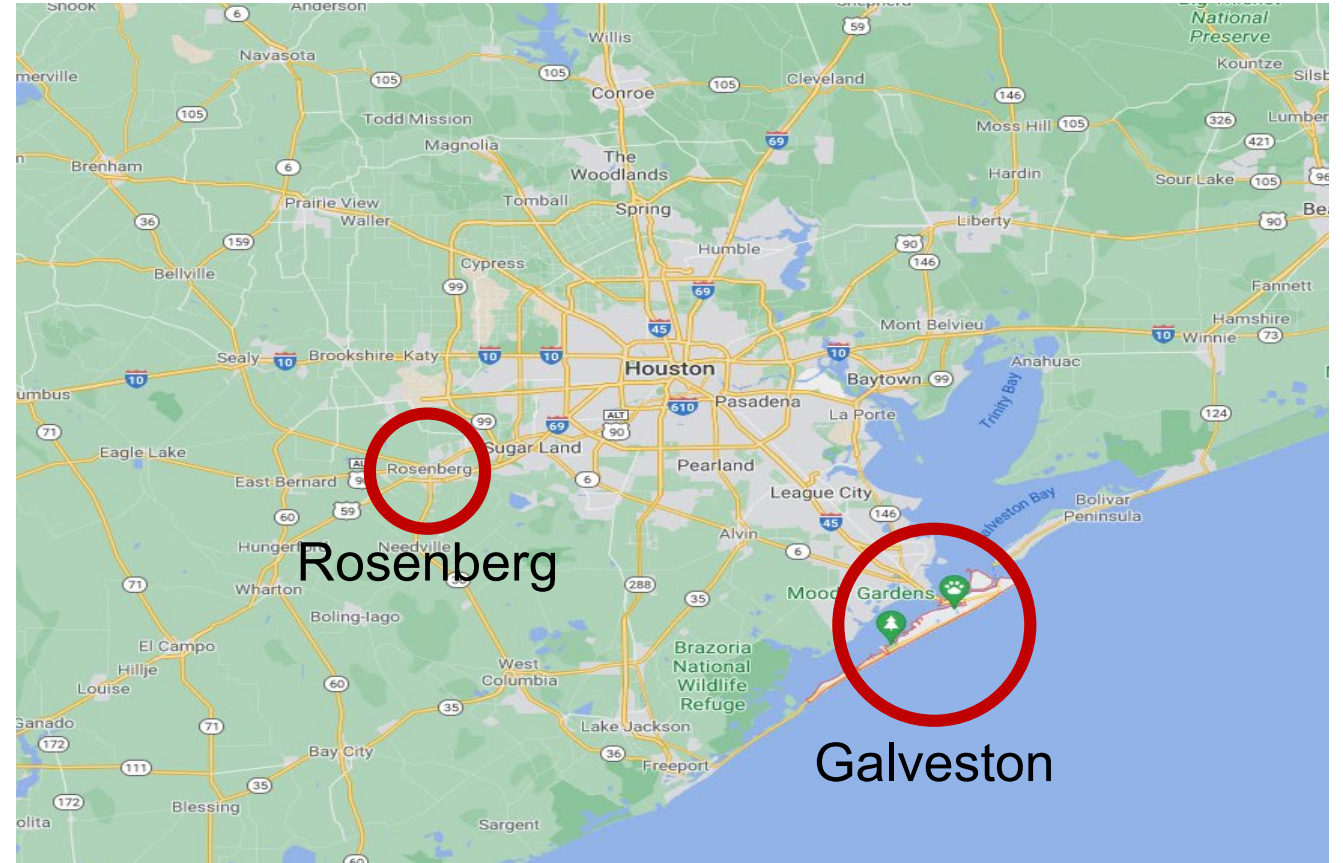
→ Implied multiplier = 338

Rosenberg

Hurricane = 52

Sea Level Rise = 55

→ Implied multiplier = 40



Questions & Answers

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