Aladdin
by BlackRock

PHYSICAL RISK – MUNICIPAL BONDS

Financial Modeling Group

EMPHASIZE BOTH PHYSICAL AND TRANSITION RISK OF INVESTMENT PORTFOLIOS

> "I believe that this is the beginning of a long but rapidly accelerating transition – one that will unfold over many years and reshape asset prices of every type. We know that climate risk is investment risk. But we also believe the climate transition presents a historic investment opportunity."

Larry Fink,
2021 Annual Letter to CEOs

SCOPE – CLIMATE RISK MODEL

Aladdin Climate

- A climate risk-calculation engine, allowing users to understand exposures to climate-related risks, evaluate investment trade-offs, stress test portfolios to different climate scenarios, and report on climate-related exposures to regulators and stakeholders.
- Select common metrics across all asset class (climate adjusted value, risk score)
- Asset class: CMBS, RMBS, Muni, Corporate Equity and Debt, Sovereign

For Muni

- Climate analytics including indicative **price change** and **climate risk score** given climate scenarios
- Obligor and security level analytics are accessible through Aladdin Research as **supplementary** information in addition to the standard risk analytics

Benefit

- Productionized **scalable** solution
- Consistency of climate risk approach for the **entire portfolio**
- **Commercial** use for Aladdin and external client

FRAMEWORK TO ASSESS **PHYSICAL RISK** IN MUNIS

Rhodium Data & Forecasts

1 CLIMATE MODELING

Assess physical risks at specific geo-locations

Change in Temperature
Change in Precipitation
Sea level increase…

2 ECONOMIC IMPACT

Convert physical risks into economic impact

Change in macros, energy cost
Impact of hurricanes
Impact of crime…

+

BRS Modeling

3 FINANCIAL MODELING*

Translate economic impact to financial impact

Muni Rating Transition Model
(FMAC approved)

Establish linkage between muni probability of default and macro conditions

Muni Yield Model
(new model)

Establish linkage between muni bond yield and regional macro conditions

›

4 OBLIGOR/SECURITY LEVEL CLIMATE RISK

Apply climate overlays on economic impact -> financial impact

Change in security price, portfolio risk
Expected financial impact

Risk score (security/obligor)

*model estimation doesn't involve climate data

CLIMATE AND ECONOMIC IMPACT VARIABLES

1 CLIMATE MODELING

Damage Functions

Relationship between climate and economic variables

2 ECONOMIC IMPACT

Temperature
• Average annual temperature
• Average seasonal temperature
• Days above 90F / below 32F

Precipitation
• Total annual precipitation
• Total seasonal precipitation

Sea Level Rise
• Fraction below high tide
• Fraction below mean sea

Direct relationship between temperature change, hurricanes etc, and overall macroeconomic factors, such as unemployment rate, GDP etc.

Top down

- Unemployment rate
- Personal income
- GDP
- Total employment

Relationship between climate hazards and social and economic outcomes of interest, such as crime rate, agricultural production, labor productivity etc.

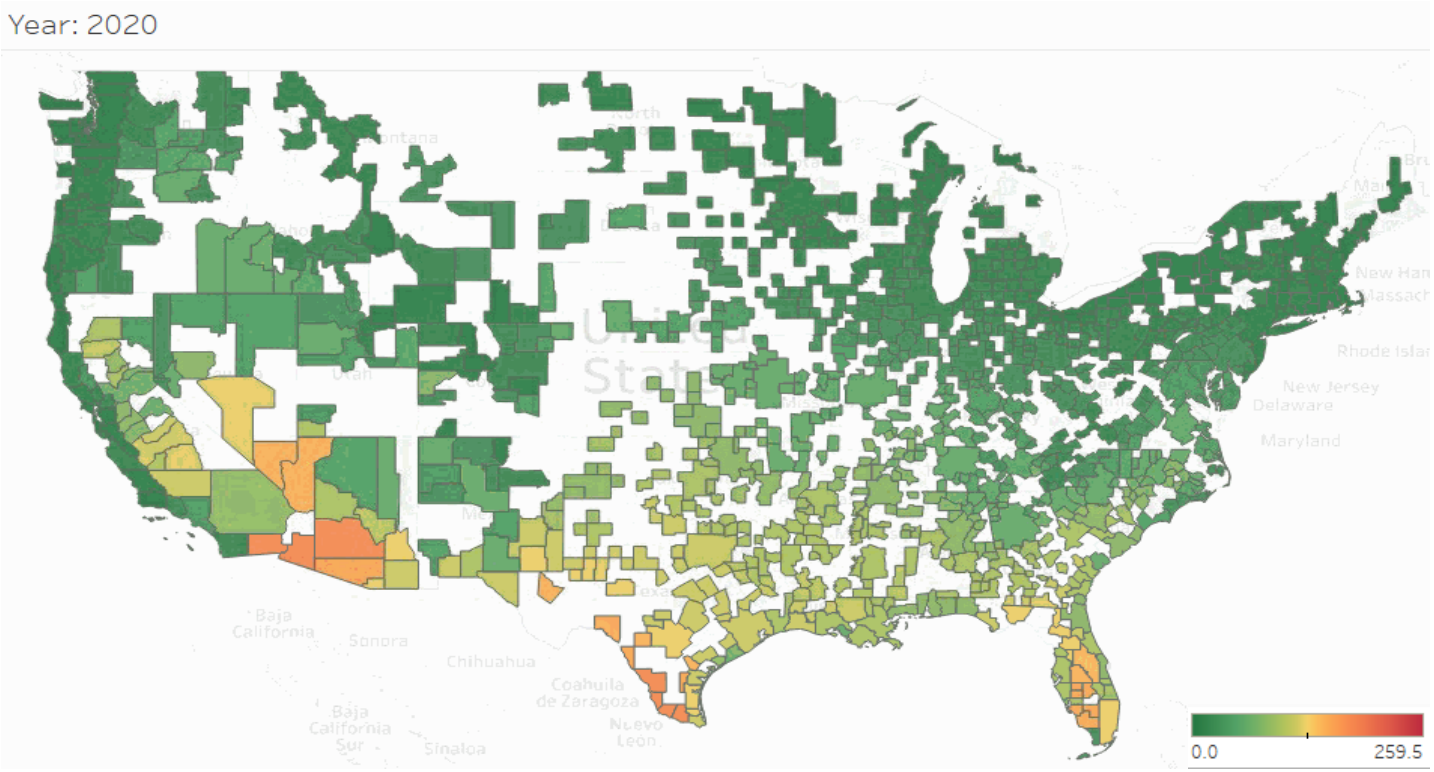
Bottom up

- Energy cost
- Agriculture loss
- Hurricane damages
- Impact of crime

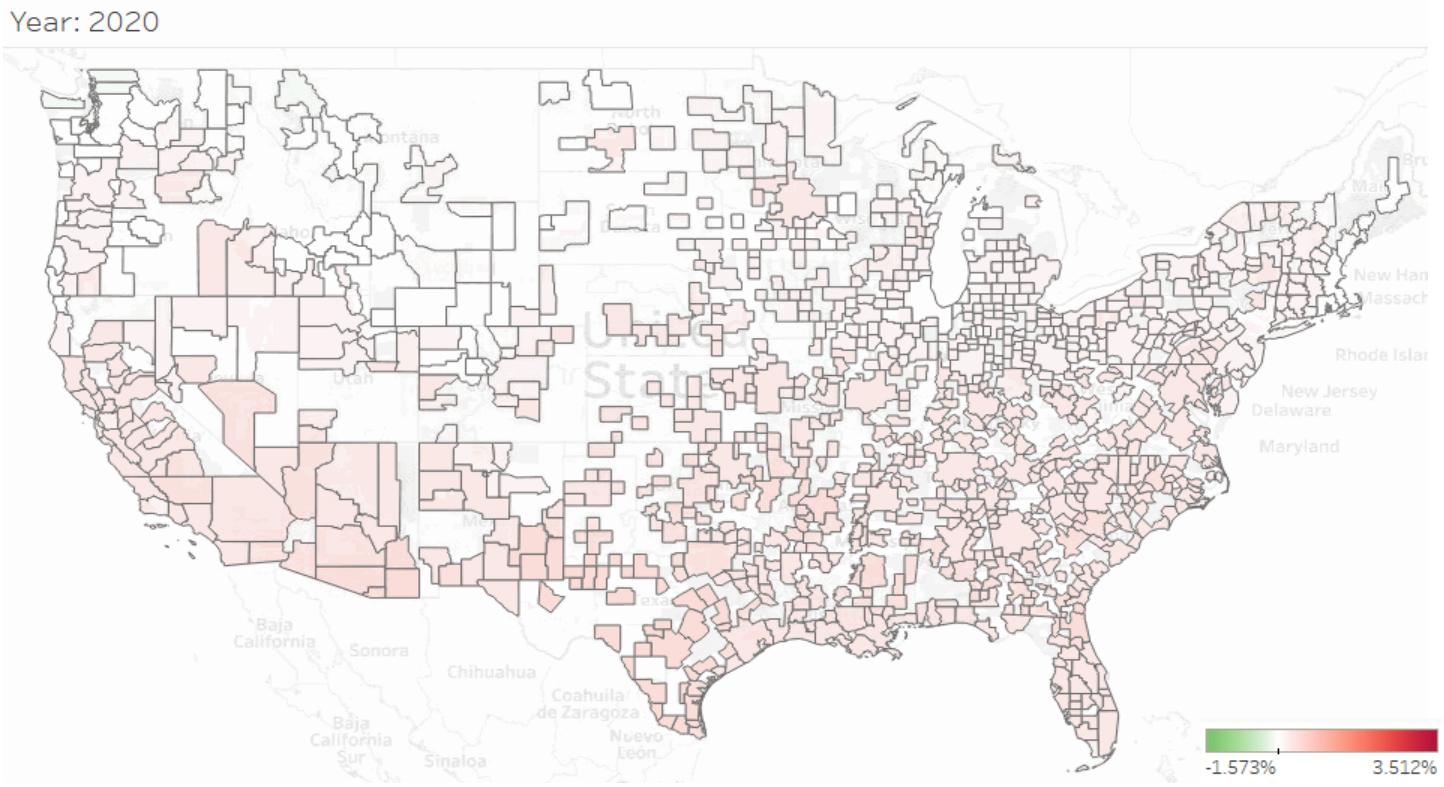
Temperature change | Hurricane activity

CLIMATE RISK – RHG DATA

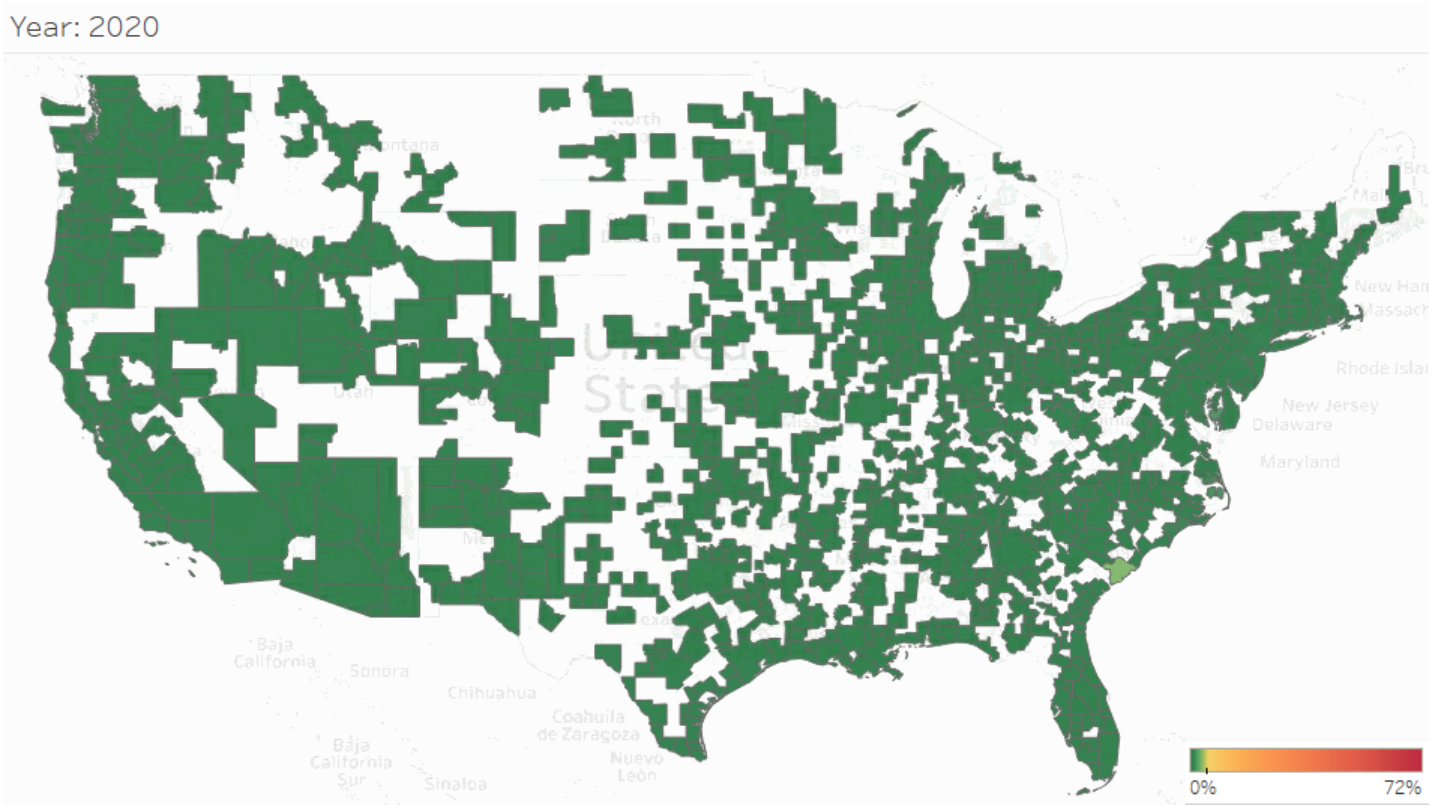
PHYSICAL RISK EXPOSURE: **DAYS OVER 90F** – HIGH EMISSION 83 PERCENTILE



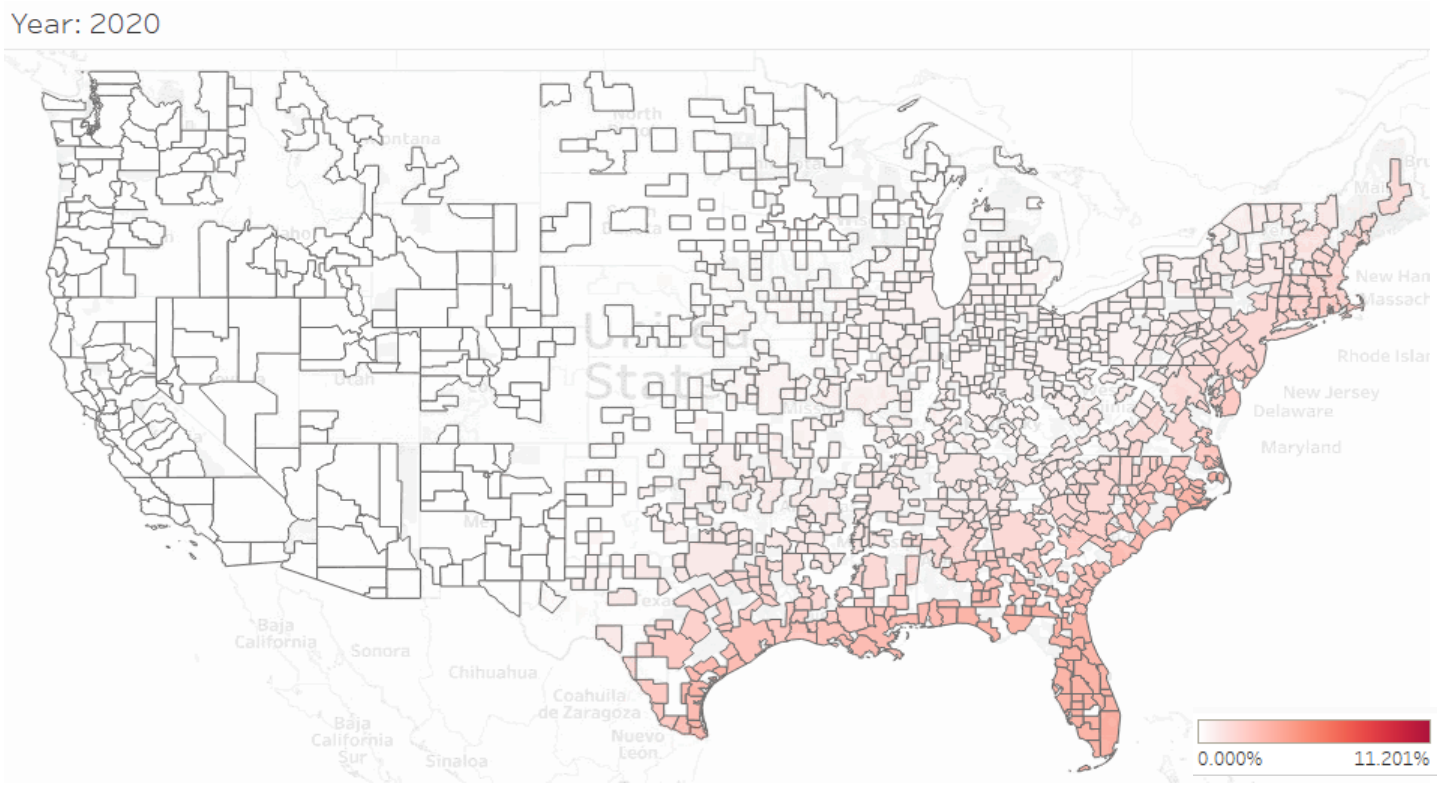
PHYSICAL RISK ECONOMIC IMPACT: CHANG IN **UNEMPLOYMENT RATE** – HIGH EMISSION 83 PERCENTILE



PHYSICAL RISK EXPOSURE: FRACTION BELOW **HIGH TIDE** – HIGH EMISSION 83 PERCENTILE

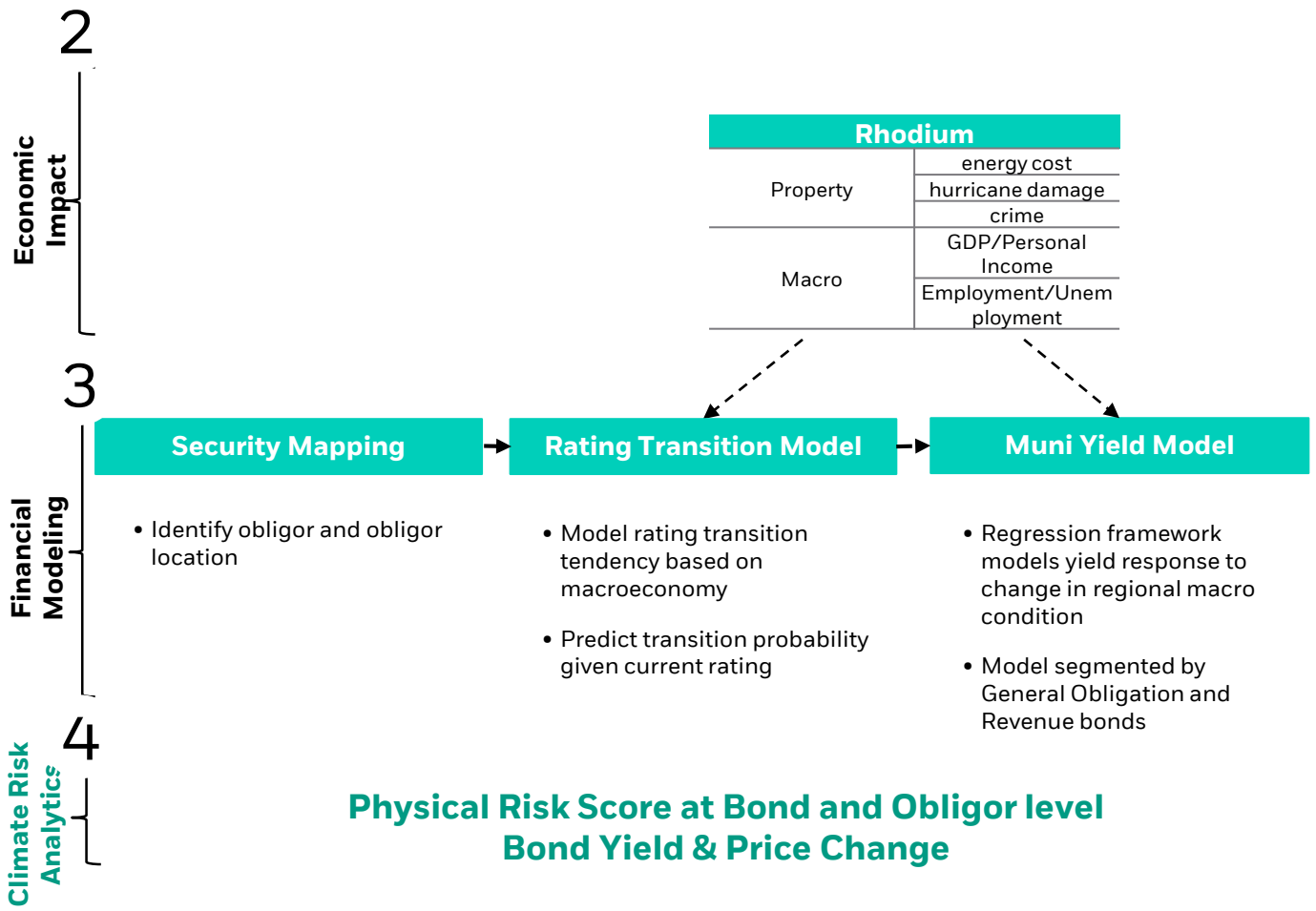


PHYSICAL RISK ECONOMIC IMPACT: CHANG IN **GDP** DUE TO HURRICANE - HIGH EMISSION 83 PERCENTILE



FINANCIAL MODELING

MODELING FRAMEWORK



RATING MIGRATION MODEL

Objective:

Project scenario-specific probability of other than temporary impairment (OTTID)

Methodology:

Parametric binomial model of rating migration with estimated probability

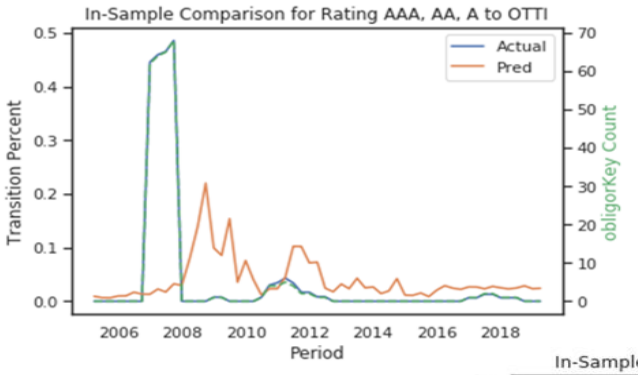
Input Variable	Down Sign	Up Sign
Unemployment	+	-
BBB muni spread	+	-
DJ stock market index	-	+
HPI	-	+
VIX	+	-
CPI Inflation	+	-
Real GDP Growth	-	+
CRE Price Index	-	+

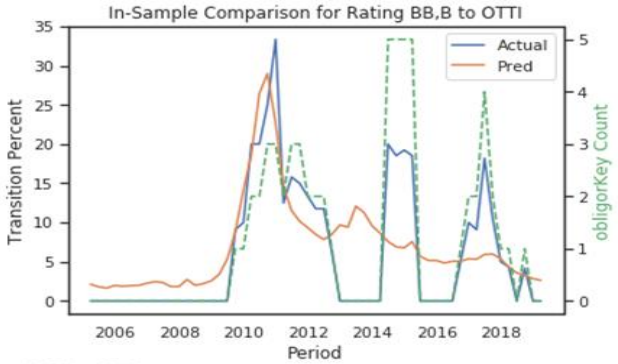
→ **Economic Overlays due to Climate Change** →

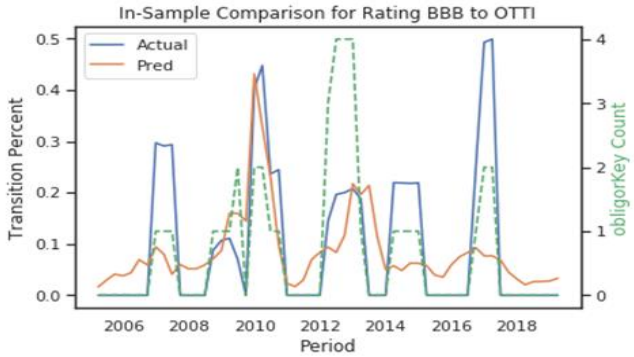
Source Rating \ Destination Rating	AAA	AA	A	BBB	BB	B	CCC	CC	C	D
AAA		D1	D2	D3+			OTTID			
AA	U1		D1	D2	D3+		OTTID			
A	U2	U1		D1	D2	D3+	OTTID			
BBB		U2	U1		D1	D2	OTTID			
BB			U2	U1		D1	OTTID			
B				U2	U1		OTTID			
CCC					U2	U1	OTTID			
CC						U2	OTTID			
C							OTTID			
D							OTTID			

→ **Climate Adjusted Probability of Transition**

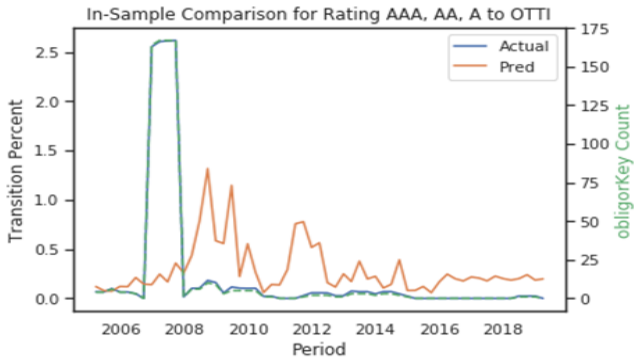
IN-SAMPLE ESTIMATION PLOTS

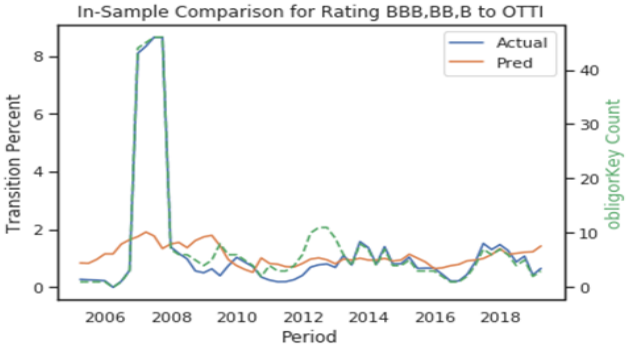






General Obligor





Revenue

LITERATURE REVIEW FOR MUNI YIELD MODEL

Municipal Yield:

Empirical Studies	Control variables	Relationship between yield and macro condition
Karpf and Mandel (2018)	• time to maturity • rating • treasury • coupon	• Real gdp growth • Population growth • Local/State debt
Poterba and Rueben (2000)	• time to maturity • rating • treasury • Issuance amount	• Per capita income • Unemployment rate
Hastle (1972) & Swartz (1989)	• term to maturity • bond offer size • treasury rate	• GDP • population

Schwert (2017): Municipal bond liquidity and default risk

- Default risk plays an outsized role relative to the observed rate of default due to a high risk premium
- The role of liquidity is not as large as one might infer from the literature given the typical participates are buy-and-hold retail investors

MUNI YIELD MODEL

Determinants of Municipal Bond Yields

- **Instrument Characteristics**
  - Term to Maturity
  - Coupon
- **Credit Market Condition**
  - Muni Callable MMD curve (AAA)
  - Credit Rating
- **Regional Macro Condition**
  - Unemployment Rate
  - Employment
  - House Price
  - GDP
  - Personal Income
- **Funding Type**
  - General Obligor (GO)
  - Revenue Bond (REV)

Data

- Muni Bond issuance data from 2005-2019 (938k deals)
- Period selected: post Crisis (09 Q2)
- Dependent variable: Issuance Yield

First Difference Panel Regression

Model yield response to macro variable by controlling unobserved time-invariant heterogeneity (tax rate, state financing condition, investor preference)

Time Series Construction

50 Sates + DC

5 rating groups: (AAA, AA, A, BBB, BB below &NR) - BRS_3LO_MSF

$$\Delta MuniBondYield_{i,t} = \Delta MuniMMD_{i,t} + \Delta TermtoMaturoty_{i,t} + \boldsymbol{\beta}^T \Delta \boldsymbol{X}_{i,t} + \gamma_i + \varepsilon$$

$$\boldsymbol{X}_{i,t} = \begin{matrix} UnemploymentRate \\ log(Employment) \\ log(GDP) \\ log(PersonalIncome) \\ log(HPI) \end{matrix}$$

- Model is segmented by GO and REV

OBLIGOR GEOLOCATION

MAPPING LOGIC

Type	Percentage	Geo Mapping
LOCAL: CITIES COUNTIES	46%	County, Sub division Admin boundary
SCHOOL DISTRICT	28%	District boundary
WATER&SEWER	8%	County, Sub division Admin boundary
DEVELOPMENT DISTRICT	6%	County, Sub division Admin boundary
HOSPITAL	2%	Multi ZIP5 boundary
MULTI-FAMILY	2%	ZIP5 boundary
UNIVERSITY	2%	University boundary
PUBLIC POWER	2%	County, Sub division Admin boundary
CORP	1%	ZIP5 boundary
STATE	1%	State boundary
AIRPORT	0%	Airport boundary

1) Issuer Sector Code in Issuer_sector.issuer_code
2) Link the issuer name to a public available set of GIS data based on issuer name
    - Levenshtein distance + Longest common substring
    - Intersection of ZIP5 and matched boundary

issuer	name	ZIP	sector0	sector1
C57777	YONKERS N Y	10701	TAX	CITIES COUNTIES

Match with County, Sub Division gov official files

issuer	name	ZIP	sector0	sector1
C49593	SCARSDALE N Y UN FREE SCH DIST	10583	TAX	SCHOOL DISTRICTS

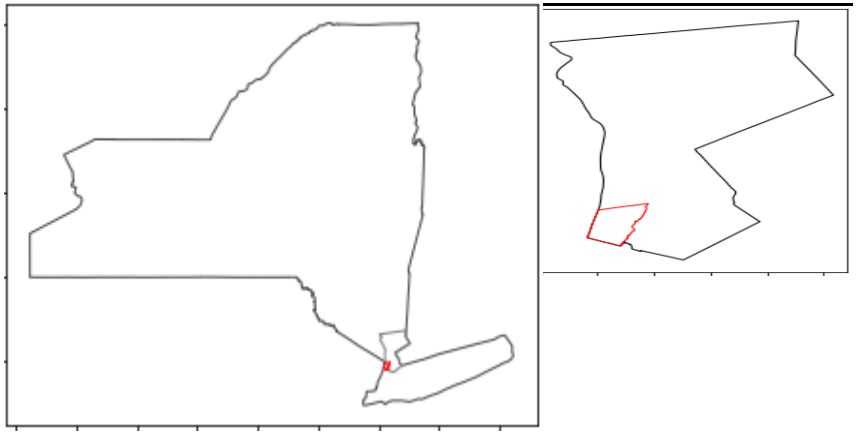
Match with School District gov official files

NY STATE EXAMPLE

Issuer: C79165 | New York State | Sector: TAX

Issuer: C44305 | Orange County | Sector: TAX

Issuer: C57777 | Yonkers City, Westchester | Sector: TAX



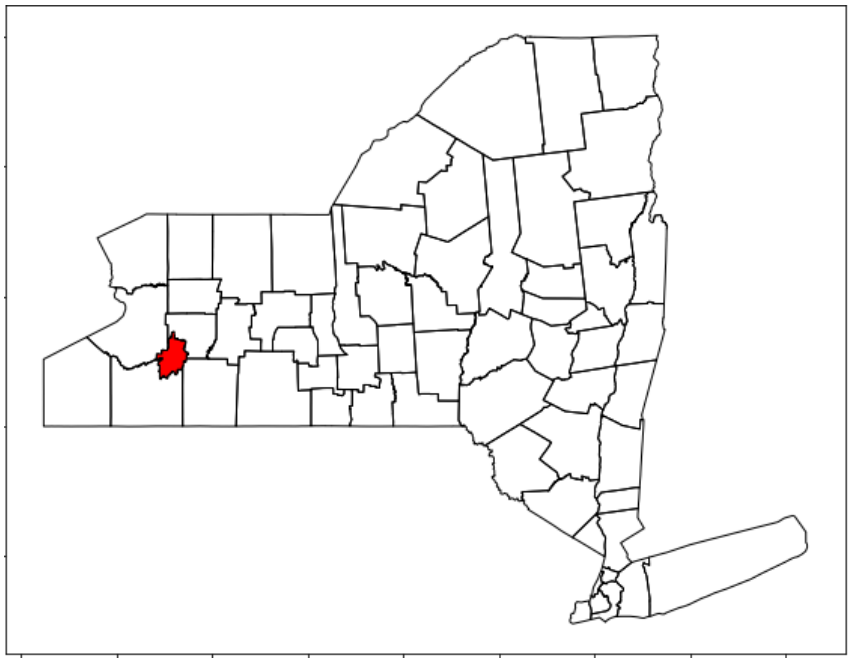
Issuer: C40911 | Monroe-Woodbury School District | Sector: TAX

MULTI-COUNTY EXPOSURE

Macro Impact Contribution Follows:

Issuer: C57835 | YORKSHIRE PIONEER N Y CENT SCH DIST | Sector: TAX

County	% Area
Cattaraugus	0.487
Wyoming	0.513

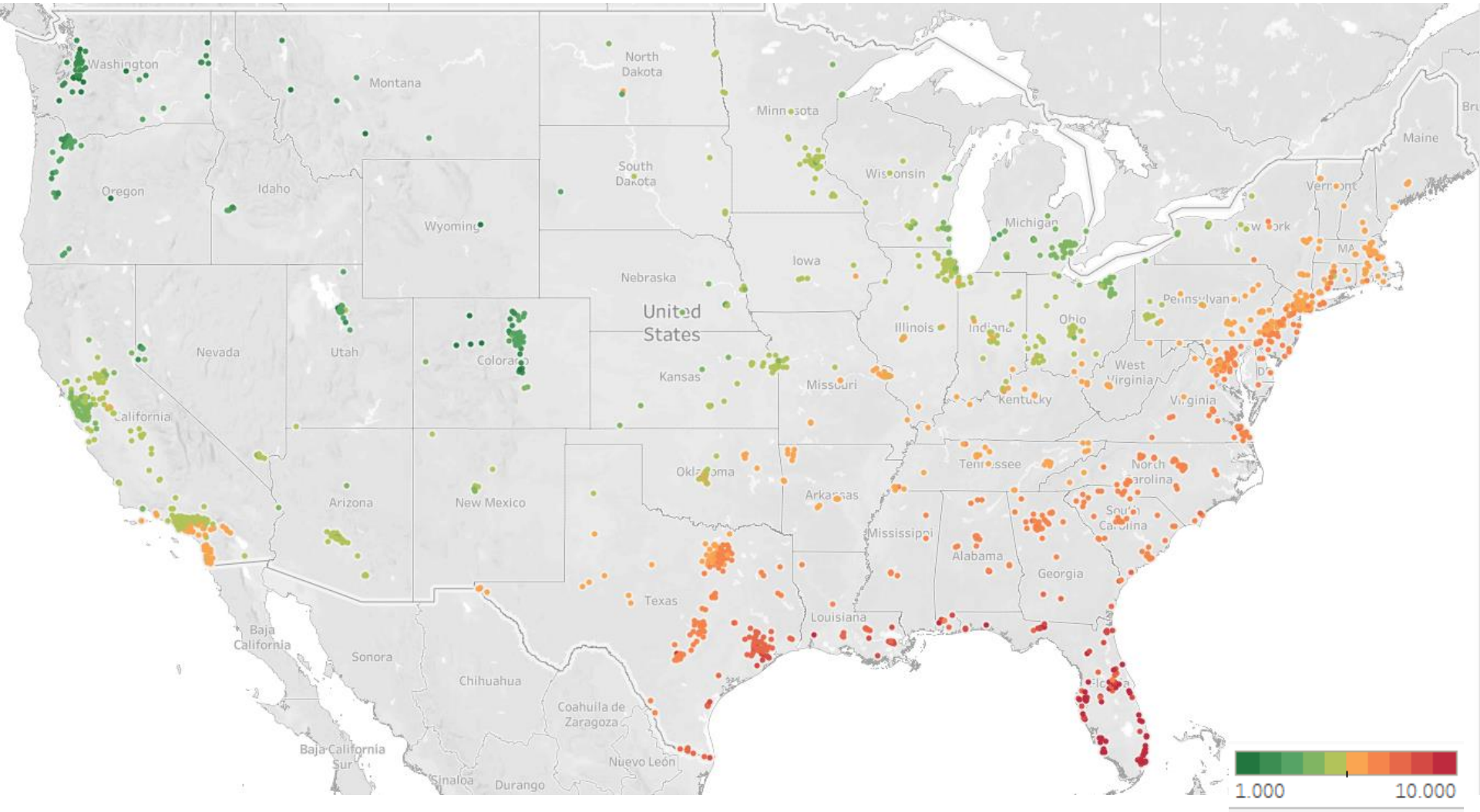


SCORING

METHODOLOGY COMPARISON

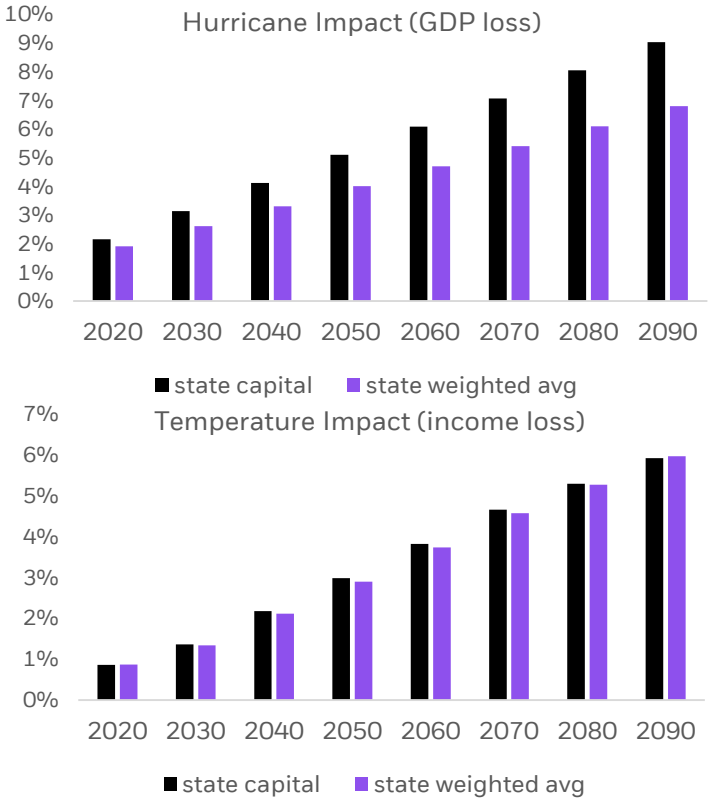
	Current	Proposed
Data Input	• Early version of Rhodium data	• Automated Rhodium data refresh via google cloud
Location Mapping	• ZIP5 to CBSA exposure (~900)	• Map obligor (state, county, city, school district etc.) geo boundary to county (~3000)
Climate Scenario	• RCP 8.5 mean	• Representative scenarios: RCP 4.5/RCP 8.5 mean and RCP 8.5 83rd (tail risk)
Economic Metric	• Economic impact: regional GDP	• Translate economic impacts (regional GDP, un/employment, personal income, HPI) into financial impact

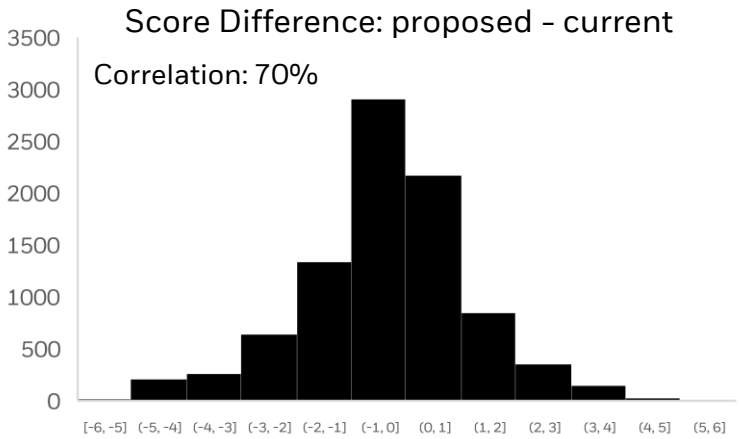
3000 OBLIGORS IN MBINDEX 10: HIGHEST RISK



OBLIGOR SCORE

MISSISSIPPI (STATE OF)	C40605	Score transfers to lower bucket Reason: mapping state obligor to state exposure diversifies climate risk
current score	9	
proposed score	7	

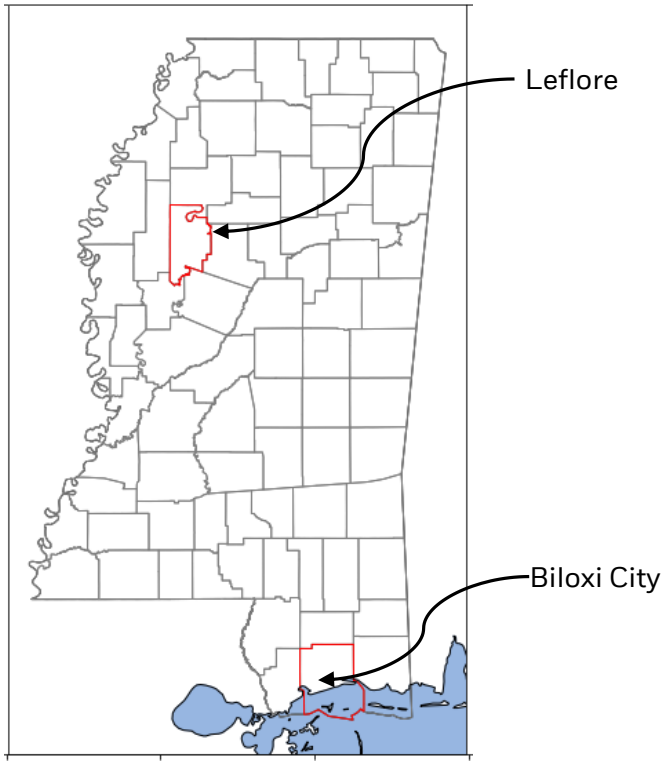


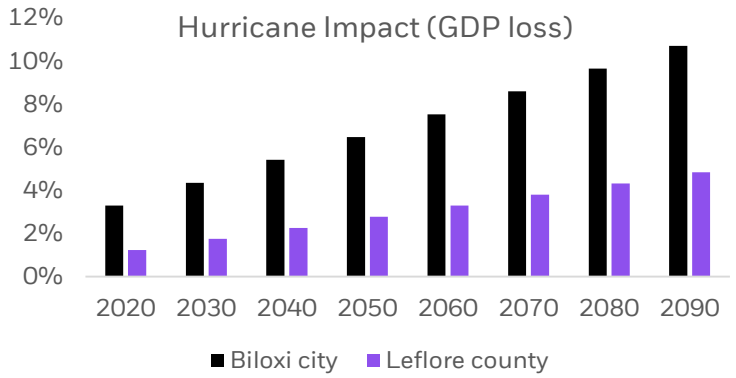


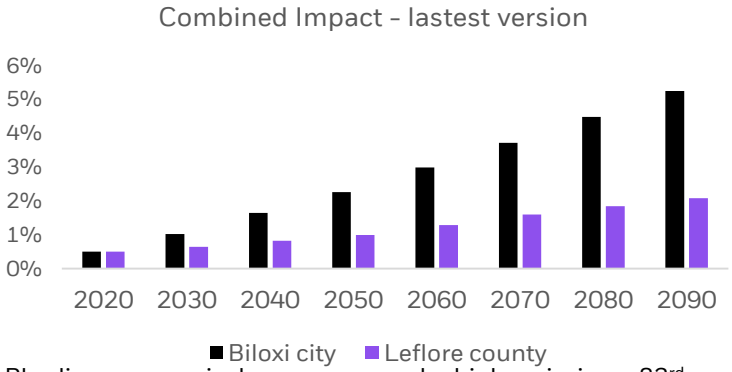
Rhodium economic damages are under high emission – 83rd percentile

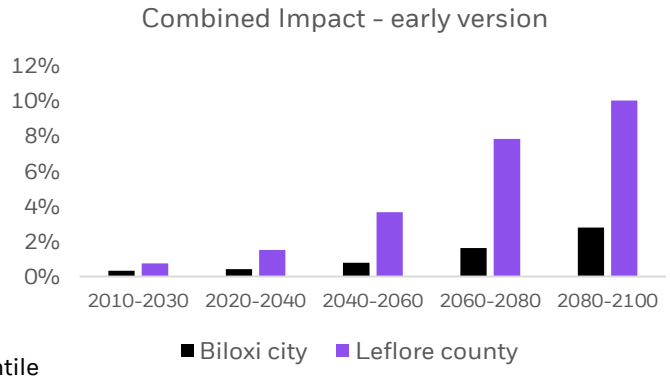
OBLIGOR SCORE

Leflore County	C36864	Score transfers to lower bucket Reason: Latest Rhodium hurricane impact provides higher accuracy
current score	10	
proposed score	7	
Biloxi city	C20117	
current score	9	
proposed score	9	









Rhodium economic damages are under high emission – 83rd percentile

IMPACT ANALYSIS

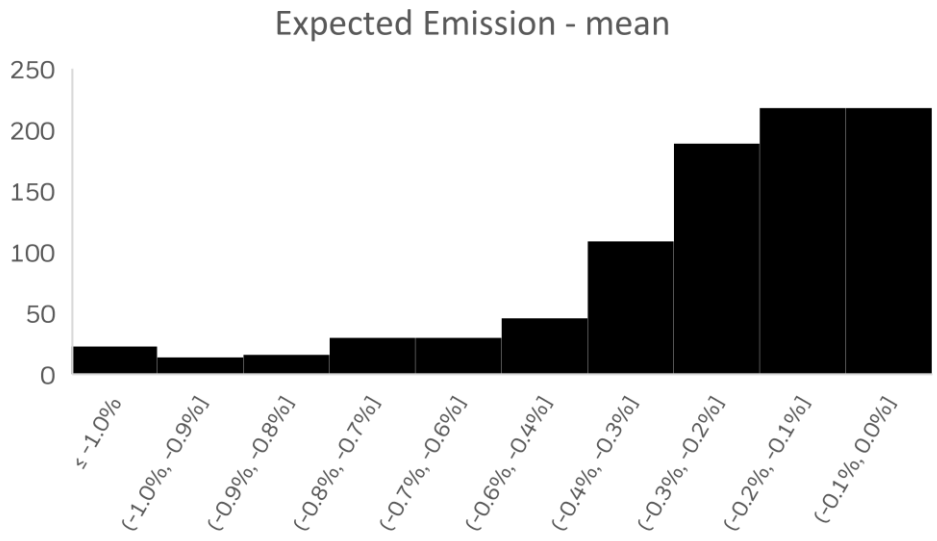
PORTFOLIO COMPARISON

Portfolio	Muni ESG	BR-NATL	BR-HYMUNI	BR-SMO-AG	BFK	MBINDEX
#of Cusip	36	461	714	1,035	280	~55,000
# of Issuer	36	210	365	388	157	~3,000
Change in value -expected emission	**-0.18%**	**-0.38%**	**-0.50%**	**-0.35%**	**-0.42%**	**-0.28%**
Change in value – high emission	**-0.27%**	**-0.56%**	**-0.73%**	**-0.51%**	**-0.63%**	**-0.41%**
Change in value – high emission 83rd	**-0.41%**	**-0.84%**	**-1.13%**	**-0.77%**	**-0.95%**	**-0.62%**
Cusip Score	5.36	6.56	7.07	6.25	6.62	5.75
Proposed Obligor Score	5.24	6.03	6.28	5.87	6.33	5.82
Existing Obligor Score	4.65	5.38	5.76	5.54	5.51	5.73
Climate Hazard (hurri/temp)	**44/56**	**52/48**	**49/51**	**49/51**	**48/52**	**48/52**
wal_to_worst	**4.90**	**6.36**	**7.65**	**7.38**	**6.59**	**5.47**

As of 29th Jan 2021

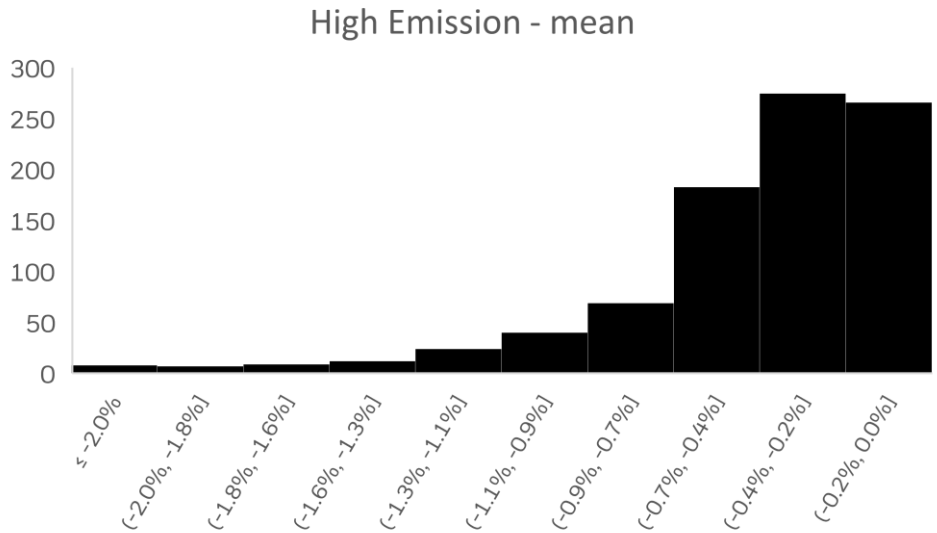
- Existing score: compare obligor climate exposure against the 900 CBSA
- Proposed score; compare obligor aggregated climate impact against all other 46,000 obligors available in Aladdin

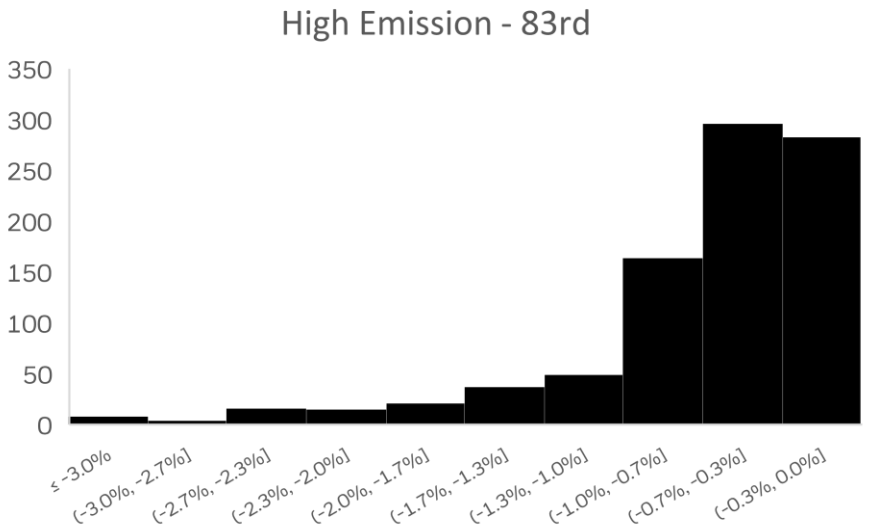
SECURITY LEVEL PRICING IMPACT



Portfolio: BR-NATL & BR-HYMUNI

Analytics data: 1/22/2021





APPENDIX

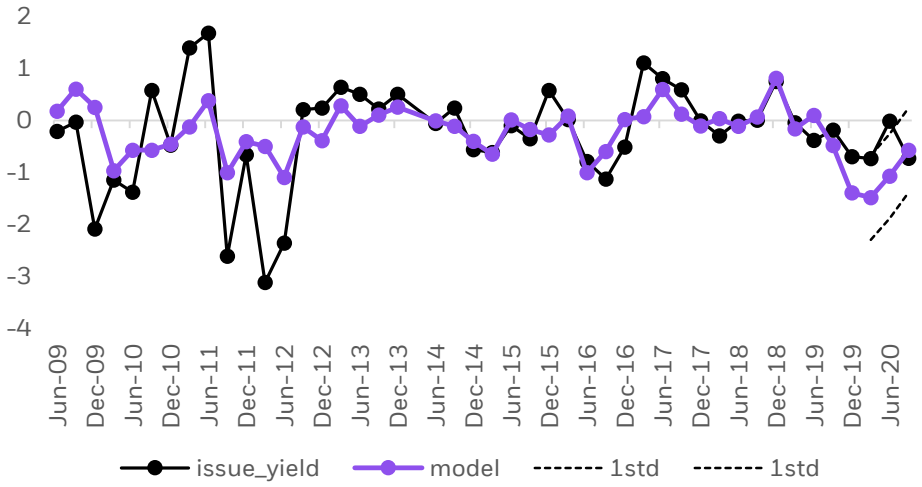
ESTIMATION RESULT

Predictor Power	Time to maturity	Muni_MMD	Coupon	Employment	GDP/Income	HPI
GO	**29%**	**30%**	**19%**	**6%**	**11%**	**5%**
REV	**29%**	**27%**	**26%**	**4%**	**13%**	**1%**

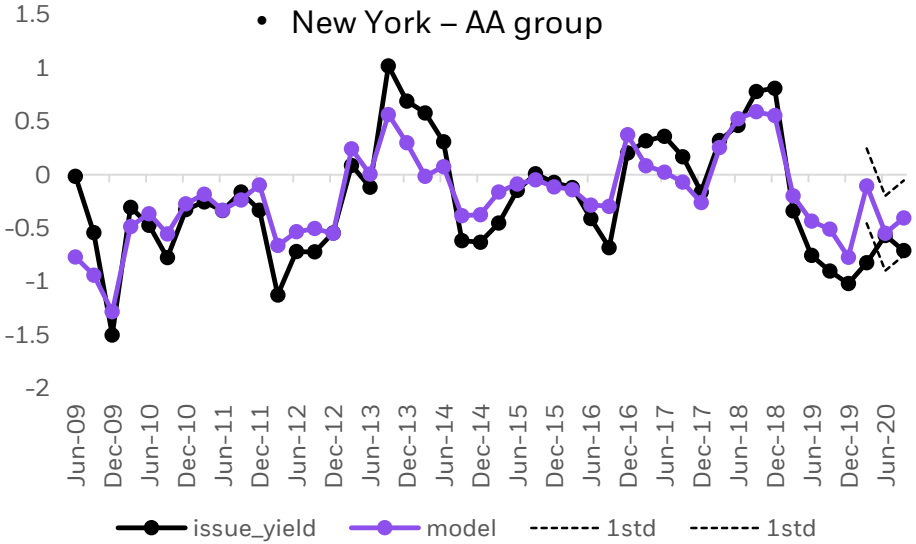
GO		coef	stderr.robust	t	P<.1 *
TimeToMaturity		0.0985	0.003	36.506	***
Muni_MMD		0.6562	0.021	31.156	***
Coupon		0.2942	0.014	21.396	
Employ	UER_lag1	-0.0326	0.006	-7.185	***
	EM_gr_lag3				
Growth	Ln_GDP	-3.4477	0.184	-15.063	***
	ln_PI				
ln_HPI_cs		-0.9323	0.251	-5.316	***
Adj. R-squared		0.68			
REV		**coef**	**stderr.robust**	**t**	**P<.1 ***
TimeToMaturity		0.0681	0.002	33.860	***
Muni_MMD		0.5354	0.022	24.311	***
Coupon		0.4439	0.016	28.543	
Employ	UER_lag1	-0.0264	0.005	-5.239	***
	EM_gr_lag3				
Growth	Ln_GDP	-3.9450	0.255	-15.481	***
	ln_PI				
ln_HPI_cs		-0.1875	0.100	-1.875	*
Adj. R-squared		0.60			

IN-SAMPLE (2009-2019) OUT-SAMPLE(2020) – GO

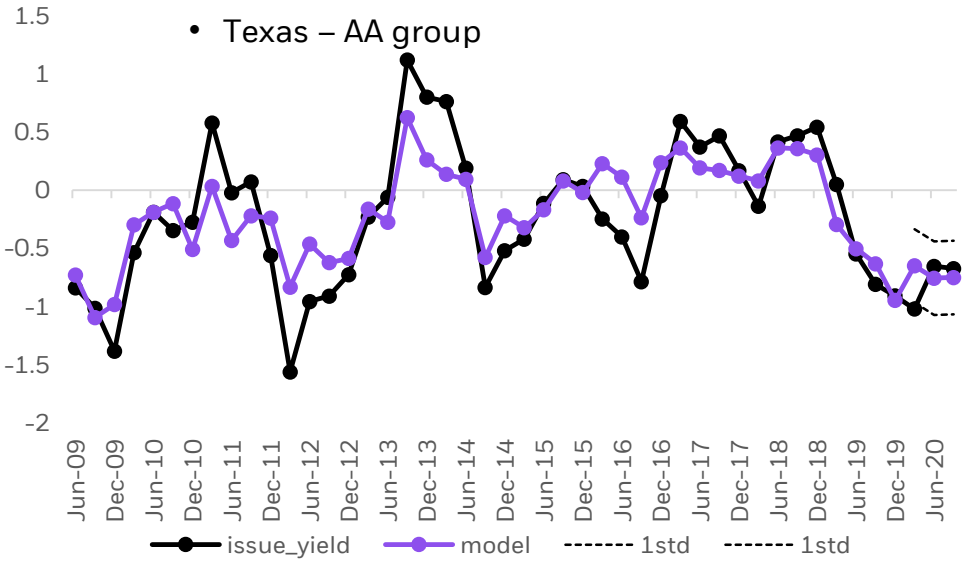
- California – AA group



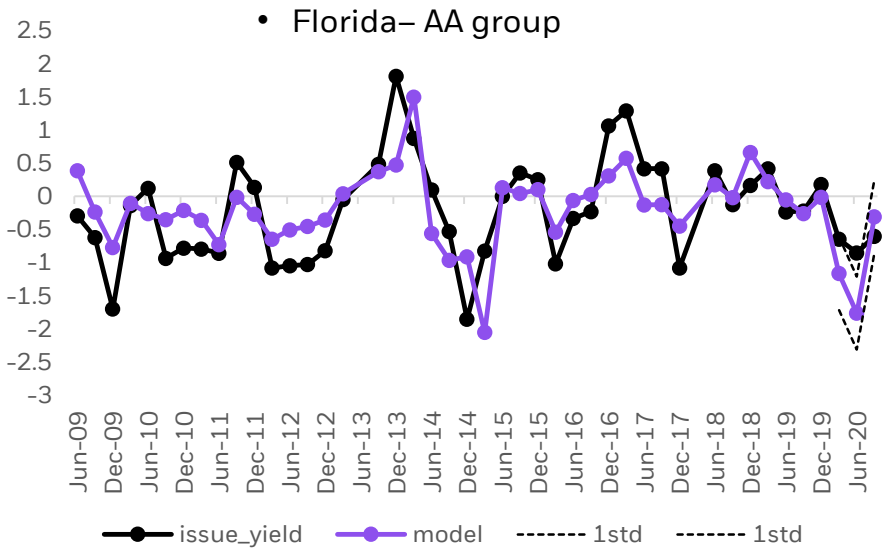
- New York – AA group



- Texas – AA group



- Florida– AA group

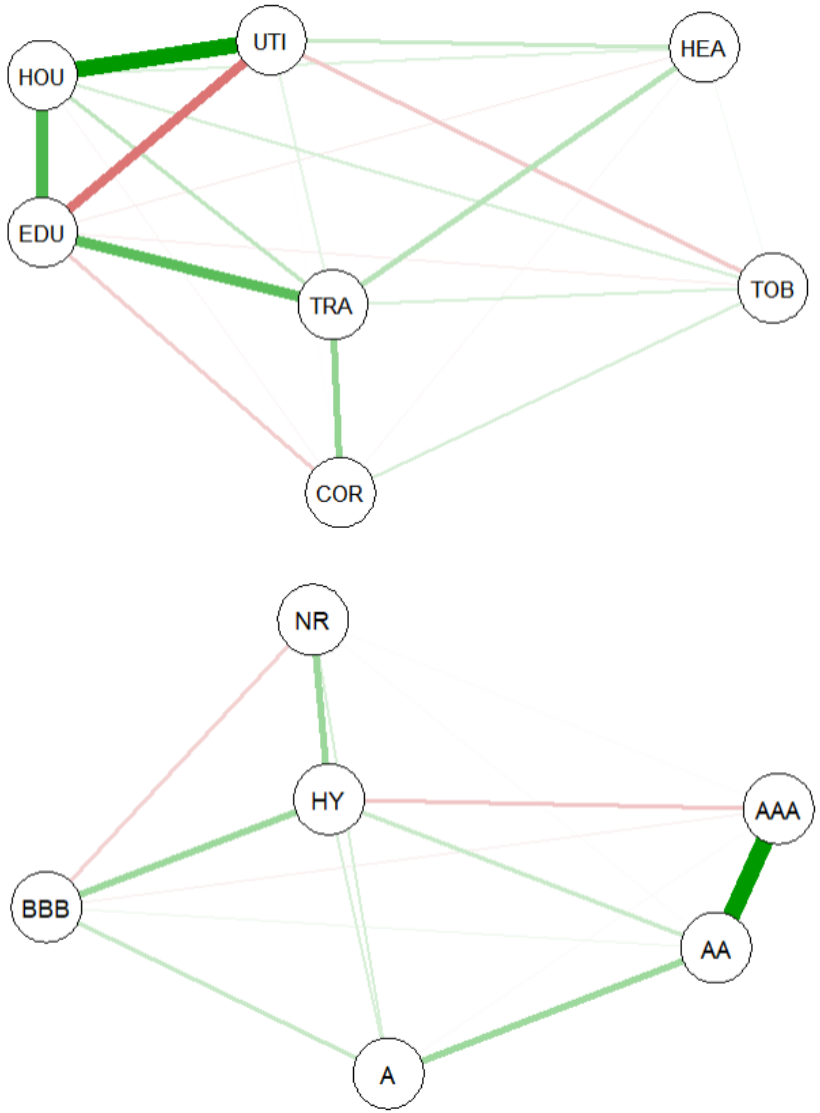


EMPIRICAL EVIDENCE

Z-Sector	Ratio	BBB&below as %population weighted by par
Housing	1.00	9%
GO	1.21	8%
Utility	1.36	7%
Education	1.40	16%
Transportation	1.51	15%
Health	1.54	31%
Corporation	2.15	64%
Tobacco	2.49	77%

Z-Rating	Ratio
AAA	1.00
AA	1.04
A	1.13
BBB	1.35
HY	1.95
NR	2.73

Partial Correlation Graph



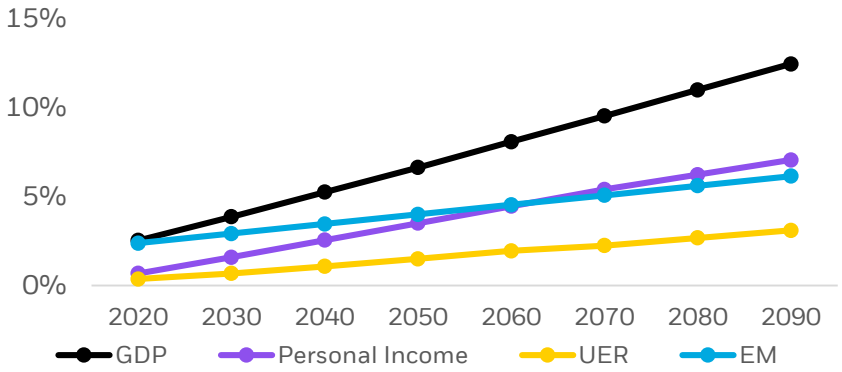
ESTIMATION RESULT – SECTOR – ALTERNATIVE MODEL

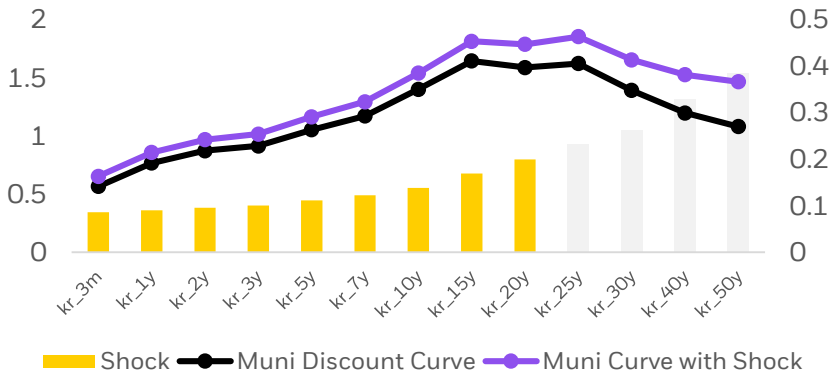
Predictor Power	Time to maturity	Muni_MMD	Coupon	Employment	GDP/Income	HPI
GO	**29%**	**30%**	**19%**	**6%**	**11%**	**5%**
REV-Hous/Educ/Util	**27%**	**21%**	**37%**	**4%**	**6%**	**5%**
REV-Trasp/Heal	**35%**	**21%**	**26%**	**6%**	**11%**	**1%**
REV-CORP/TOBA/OTHER	**33%**	**21%**	**29%**	**4%**	**13%**	**0%**

coef		GO	REV		
		All	Hous/Educ/Util	Trasp/Heal	Corp/Toba/Other
TimeToMaturity		0.0985	0.0578	0.0745	0.0765
MuniMMD		0.6562	0.4248	0.4321	0.4948
Coupon		0.2942	0.5310	0.4296	0.44051
Employ	UER_lag1	-0.0326***	-0.0206***	-0.0333***	-0.0212**
	EM_gr_lag3				
Growth	Ln_GDP	-3.4477***	-1.6022***	-3.0842***	-3.3836***
	ln_PI				
ln_HPI_cs		-0.9323***	-0.9108***	-0.2037*	
Adj. R-squared		0.68	0.64	0.59	0.58

CASE STUDY – CLIMATE RISK IMPACT ON 20 YEAR GO BY MIAMI-DADE COUNTY Under high emissions 83rd percentile

Climate macro shocks & impact on spreads





Climate adjusted analytics and risk scores

ANALYTICS	BASE ANALYTICS	ANALYTICS W/ CLIMATE CHANGE	DIFFERENCE
Price	131.17	129.61	-1.20%
Yield to Worst	1.28%	1.44%	0.16%
Eff. Duration	13.56	13.52	-0.04

ANALYTICS	RISK SCORE	CLIMATE FACRTOR	CONTRIBUTION
Security Level	10	Hurricane	65%
Obligor Level	9	Temperature	35%