

# Climate Change Credit Risk Triptych\*

Summary of Climate Stress Test Findings

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## **Overview - Climate Change Credit Risk Triptych Papers:**

In These Climate Risk Triptych Papers, We Present Three 'Empirical' Assessments of Future Potential Climate Impacts on Wholesale Credit Losses:

- Paper One: 'Smooth' NGFS Climate Scenarios Imply Minimal Credit Losses:
  - Highlight key Climate Stress Test ('CST') industry discussion points
  - Compare NGFS US GDP scenarios with CCAR Severely Adverse stress test
  - Apply Z-Risk Engine (Use Moody's CreditEdge 37k EDFs 1990-22) to project credit loss rates to 2050 for NGFS and CCAR severely adverse scenarios
- Paper Two: Climate Change Volatility Effects Imply Higher Credit Losses:
  - Apply NGFS Global Mean Temperature ('GMT') scenarios using an illustrative GMT-to-Volatility 'model' to simulate (1000 sims) climate impacts on **industry/region systematic factors** on climate induced credit losses to 2050
  - NGFS GMT-to-Vol model is illustrative multi-factor credit model predicting losses is empirical
  - Assess credit losses for an illustrative US benchmark C&I portfolio expected, 95% and 99% 'tail' credit losses
- Paper Three: Climate Change Macro Volatility Effects Imply Higher Credit Losses:
  - Apply NGFS Global Mean Temperature ('GMT') scenarios ad in paper two to simulate (1000 sims) climate impacts on **US macro-economic factors and indirect industries/regions** on climate induced credit losses to 2050
  - Assess credit losses for an illustrative US benchmark C&I portfolio, expected, 95% and 99% 'tail' credit losses
  - Compare expected, 95% and 99% 'tail' credit loss results from papers One and Two

### Z-Risk Engine

Key Industry Climate Risk Stress Test Discussion Points

Z-Risk Engine

In These Climate Risk Triptych Papers, We Consider These Key Climate Stress Test Discussion Points:

- 1. Use of *deterministic scenarios* in the NGFS approach that have only *limited empirical foundations*
- 2. Application of IAM-Style, 'trend-like' scenarios which don't consider **unexpected** economic shocks which are the usual driver of systematic credit risks
- **3.** Lack of incorporation of more **extreme**, **'near-catastrophic'** future climate 'states of the world'
- 4. 'Top-down' ('IAM') approaches support only a limited ability to assess granular, detailed Industry/region credit risk drivers
- **5.** Developing more detailed **climate narratives** could support improved economic logic in assessing climate credit stresses

## Empirical Climate Risk Assessments Use Z-Risk Engine to Assess Projected Future Credit Risk Losses

All Three Triptych Papers Utilize the ZRE Multi-Factor Credit Risk Approach:

- These assessments predict climate-driven wholesale credit losses for an *illustrative benchmark US C&I* credit portfolio for 20 industries and 2 regional factors (see Appendix for C&I portfolio details)
- We run deterministic scenarios with macro-economic factor and 'bridge' models integrated with industry/region credit factors to assess various NGFS vs CCAR ('Severely Adverse') scenarios
- We assess future 2050 systematic credit losses in various NGFS scenarios using a GMT-to-Volatility\* illustrative assumption ('model') to drive simulations of the industry/region credit factors for the C&I benchmark portfolio
- We assess future 2050 systematic credit losses in various NGFS scenarios using a **GMT-to-Volatility\*** *illustrative assumption ('model')* to drive *simulations of the macro-economic credit factors* for the C&I benchmark portfolio to 2050
- The ZRE macro-factor 'bridge' models and industry/region credit factor models are all estimated from Moody's CreditEdge EDFs for 1990-2022

\* 'GMT' represents Global Mean Temperature projections, sourced from the NGFS scenarios

1990-22 Credit Losses Exhibit Substantial Systematic Credit Cycles - NGFS Scenarios Vary However, Only in Small Changes to Trend GDP Growth Rates

## See Triptych Paper One for the Details

#### Annualized US C&I Charge-Off Loss Rates (%)



Source: Board of Governors of the Federal Reserve System

#### **Annual US GDP Growth Rates in NGFS Scenarios**

Table 2: Annual USA GDP Growth Rates in NGFS Scenarios\* \*\* \*\*\*

	Time Period				
NGFS Scenario	2023- 2030	2030- 2040	2040- 2050		
Current Policies	5.86%	4.36%	4.03%		
Below 2°C	5.85%	4.36%	4.06%		
Delayed Transition	5.85%	4.35%	4.06%		
Divergent Net Zero	5.86%	4.38%	4.08%		
Nationally Determined Contributions (NDCs)	5.86%	4.36%	4.04%		
Net Zero 2050	5.86%	4.37%	4.07%		

 Real-GDP growth from 2022 GCAM.3\_NGFS model. Converted to nominal-GDP growth by adding annual inflation of 2 per cent.

\*\* Data Source: 1662723618051-V3.2%20NGFS%20Phase%203.zip.

\*\*\* We use NGFS USA GDP to be consistent with the FRB C&I Loan Loss Index we use for benchmarking.

Source: NGFS



## Historical Macro Factor 'Z' Paths and Macro-Factor 'Bridge' Model Variables and Coefficients That Drive Paper One Findings – Paper One

- 'Bridge' model arises from pooled least-squares regressions of Industry/Region Zs and MEVs
- NGFS scenarios 'bridge' model uses GDP only
- CCAR scenarios 'bridge' models use equities (ZE), credit spreads (ZS) and GDP (ZG)
- 20 industry segments (Z) and NA corps/FIs to support benchmarking to US C&I Loan Loss Index
- Estimated 1990:Q3 to 2022:Q2
- Next slide shows the systematic impact of NGFS vs CCAR factors using the 'Bridge' models below



<sup>1990-21</sup> Historical 'Z' Macro Factors

Source: Moody's CreditEdge, FRB, and Z-Risk Engine

			CCAR	NGFS	
Variable Type	Variable*	Parameter	Estimate	Estimate	
Dependent	Δz				
	Z (-1)	mr	-0.05	-0.08	
	ΔZ (-1)	m <sub>m</sub>	0.11	0.16	
Fuelenatory	∆ZE	b(0)	0.39	0.00	
	ΔZE(-1)	b(1)	0.03	0.00	
Explanatory	∆zs	c(0)	0.23	0.00	
	ΔZS(-1)	c(1)	0.03	0.00	
	∆ZG	d(0)	0.02	0.10	
	∆ZG(-1)	d(1)	0.02	0.05	
Goodness of Fit	R <sup>2</sup>		0.53	0.09	

\*Z denotes an industry or region, Z index. ZE, ZS, and ZG represent the Macro Zs for equity prices, spreads, and GDP, respectively. As the NGFS scenarios available do not include credit spreads and equities, for running the NGFS scenarios we only use the Macro Z GDP variable, so the table above has zero coefficients on spreads and equities as they are excluded.

Source: Moody's CreditEdge, FRB,, NGFS and Z-Risk Engine

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### CCAR/NGFS Macro-Factor 'Bridge' Models

## Estimated CCAR Stress Scenario Driven by Unexpected Economic Shocks -NGFS Scenarios Exhibit Minimal Systematic Future Credit Risks – Paper One



Source: Moody's CreditEdge, FRB, NGFS and Z-Risk Engine



See Triptych Paper One for Details

### **Estimated Credit Factor Paths:**

- CCAR Severely Adverse Scenario and Two NGFS Scenarios
- Figure plots future macro-factor paths in standardized 'Z' terms (zero mean, unit variance) with standard deviation on the vertical axis
- CCAR scenario red line shows a negative 'shock' of roughly 3 standard deviations

### **Estimated Credit Losses:**

- NGFS scenarios show minimal increases in systematic credit loss rates
- CCAR scenario, red line shows substantial increase in projected credit loss rates
- See **Triptych Paper One** for details on the models utilized

Z-Risk Engine

Source: Moody's CreditEdge, FRB, NGFS and Z-Risk Engine

## To Assess Future Climate Systematic Credit Impacts We Utilize NGFS Scenario GMT Paths to Derive an Illustrative GMT-to-Volatility Multiplier

### See Triptych Paper Two for the Detailed Analysis:

- Credit Volatility Multipliers derived from simplified, illustrative GMT-to-Vol 'model' for each NGFS scenario
- The Credit Multipliers increasingly boost future volatility of the credit factors in the credit loss simulations



Source: NGFS

Source: NGFS and Z-Risk Engine

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## 2050 Credit Losses from GMT Climate Multipliers: **ZRE INDUSTRY/REGION** Credit Factor Simulation Results – Expected & Tail Results – **See Paper Two**

### Estimated 2050 Credit Losses:

- GMT-to-Vol assumption
- 20 Industry/NA Region simulations (1000)
- Multi-factor credit model empirically derived from 37k EDFs
- NGFS Compared to 'No Climate Effects' (no vol increase)
- Representative C&I portfolio, industry weights & risk grade assumptions in Appendix

Estimated Credit Losses (%) 7 6 5 4 3 2 1 0 95% 99% 95% 99% Expected 95% 99% Expected 95% 99% Expected Expected Value Value Value Value No Climate NGFS NGFS NGFS Effects Net Zero 2050 **Delayed Transition Current Policies** Source: Moody's CreditEdge, NGFS and Z-Risk Engine

#### Est 2050 Credit Losses for US C&I Portfolio: NGFS Scenarios vs 'No Climate' Effects

	Credit Losses 2050						
	Relative to Limit				Relative to Baseline		
Statistic	No Climate Effects Baseline	NGFS Net Zero 2050	NGFS Delayed Transition	NGFS Current Policies	NGFS Net Zero 2050	NGFS Delayed Transition	NGFS Current Policies
99th Percentile	4.28%	5.34%	6.43%	7.16%	1.25	1.50	1.67
95th Percentile	1.88%	2.24%	2.39%	2.84%	1.19	1.27	1.51
Expected Value	0.60%	0.68%	0.71%	0.80%	1.13	1.18	1.34

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Source: Moody's CreditEdge, NGFS and Z-Risk Engine

FOR COMPARISION 'GREAT RECESSION' OBSERVED C&I CREDIT LOSSES WERE ABOUT 2.3% COMPARED TO A LONG-RUN AVERAGE OF 0.72%



### Est 2050 Credit Losses for US C&I Portfolio: NGFS Scenarios vs 'No Climate' Effects

## 2050 Credit Losses from GMT Climate Multipliers: **ZRE MACRO** Credit Factor Simulation Results – Expected & Tail Results - **See Paper Three**

### Estimated 2050 Credit Losses:

- GMT-to-Vol assumption
- Macro Factor Simulations (1000): Credit Spreads, Equities and GDP
- Macro-Factor 'Bridge' Model includes Industry/Region effects indirectly
- NGFS GMT Compared to 'No Climate Effects' (no vol increase)
- Representative C&I portfolio, industry weights & risk grade assumptions in Appendix



Source: Moody's CreditEdge, FRB, NGFS and Z-Risk Engine

### Est 2050 Credit Losses for US C&I Portfolio: NGFS Scenarios vs 'No Climate'

	Credit Losses 2050						
	Relative to Limit				Relative to Baseline		
Statistic	No Climate Effects Baseline	NGFS Net Zero 2050	NGFS Delayed Transition	NGFS Current Policies	NGFS Net Zero 2050	NGFS Delayed Transition	NGFS Current Policies
99th Percentile	3.25%	4.03%	4.48%	5.38%	1.24	1.38	1.65
95th Percentile	1.91%	2.32%	2.54%	2.96%	1.21	1.33	1.55
Expected Value	0.69%	0.79%	0.84%	0.95%	1.14	1.22	1.37

Source: Moody's CreditEdge, FRB, NGFS and Z-Risk Engine

FOR COMPARISION 'GREAT RECESSION' OBSERVED C&I CREDIT LOSSES WERE ABOUT 2.3% COMPARED TO A LONG-RUN AVERAGE OF 0.72%

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## 2050 Projected Climate Credit Losses – Industry/Region Factor Simulation Volatility vs Macro-Factor Simulation Volatility

See Triptych Paper Two and Three for the Details:

- 'IRMC' is the ZRE 'Industry Region Monte Carlo' approach (paper Two)
- 'MMC' is the ZRE 'Macro Monte Carlo' approach (Paper Three)

#### **C&I Loss Volatilities Under Alternative Climate Scenarios Under Two ZRE Approaches**



Source: Moody's CreditEdge, FRB, NGFS, and Z-Risk Engine

## Appendix: Risk and Industry Mix Attributes of the Illustrative C&I Benchmark Portfolio Used in the Three 'Empirical' Assessments of Climate Risk

### Benchmark C&I Portfolio Applied in all Three Triptych Papers

#### TTC Risk Attribute Assumptions for C&I Benchmark Portfolio

#### Industry Sector Composition – Benchmark Portfolio

	Entity	Facility	Primary	Primary	Expected	1-Qtr				
Weight	Grade	Туре	Region	Industries	Utilization	ΡΟττς	LGDTTC	CCFTTC	FCF	
1.00/	^	RCF			10%	0.01%	35%	75%	1.00	
10%	А	TL			100%		35%	100%		
250/		RCF	RCF			20%	0.020/	30%	45%	1 00
25% BBB	TL		All Industries	100%	0.03%	30%	100%	1.00		
45% BB	RCF	North America		30%	0.14%	30%	45%	1.00		
	TL			100%		30%	100%			
1 5 0/	D	RCF			30%	0.070/	25%	45%	1.00	
15%	в	TL			100%	0.97%	25%	100%		
5% CCC	RCF			50%	6 9 4 9/	20%	45%	1 00		
		TL			100%	0.84%	20%	100%	1.00	
100%	All	All		All	63%	0.56%	23%	73%	1.00	

Source: Z-Risk Analysis and Assumptions

		Associated Region
Weight	C&I Industry	Grouping
1%	Aerospace and Defense	North America Corps
5%	Banking	North America FIs
5%	Basic Industries	North America Corps
	Business and Consumer	North America Corps
20%	Services	
	Chemicals and Plastic	North America Corps
2%	Products	
10%	Construction	North America Corps
2%	Consumer Products	North America Corps
	Finance, Insurance, and Real	North America FIs
10%	Estate	
5%	Hotels and Leisure	North America Corps
3%	Machinery and Equipment	North America Corps
5%	Media	North America Corps
5%	Medical	North America Corps
1%	Mining	North America Corps
5%	Motor Vehicles and Parts	North America Corps
3%	Oil and Gas	North America Corps
6%	Retail and Wholesale Trade	North America Corps
4%	Metals	North America Corps
4%	Technology	North America Corps
3%	Transportation	North America Corps
1%	Utilities	North America Corps
100%	All	All

Source: Z-Risk Analysis and Assumptions



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## Climate Change Credit Risk Triptych Summary:

- Modeling Wholesale Credit Risk Impacts from Climate Change :
  - NGFS Scenarios tend to be 'smooth' implying limited systematic credit risk impacts
  - The Z-Risk Engine Multi-Factor model was applied to an illustrative US C&I credit portfolio to assess 2050 expected, 95% and 99% tail credit losses
  - NGFS Global Mean Temperature scenarios were applied in an illustrative GMT-to-Vol 'model'
  - Empirical credit factor simulations of industry/region and MEV factor models show higher tail credit risk losses
- Complementing Current Scenario-Based NGFS Climate Stress Test Approaches:
  - Enhanced ystematic credit multi-factor models provide a better credit 'empirical foundation'
  - Market-based, PIT credit models (derived from EDFs) can provide more accurate assessment of potential future climate-driven systematic 'shocks'
  - Detailed industry/region dedicated sector models support **better risk differentiation** than top-down scenario approaches
  - 'Tail' credit loss assessments provide a richer foundation for assessing **more 'extreme' climate scenarios** and assessment of **'climate uncertainty'**
- In both Papers Two and Three, More Severe Climate Scenarios Imply Generally Higher Volatility and Therefore Higher Tail Credit Losses
- The Approach Presented in the Triptych Papers Can Be Integrated With Current Climate Mitigation and 'Carbon Transition' Approaches Being Developed for Climate Stress Tests

### Z-Risk Engine