OLIVER WYMAN

ETH *zürich*

10 Years after Lehman: how has risk management changed?
ETH Zürich – Risk Day

September 14, 2018

Til Schuermann

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There's no chance that the iPhone is going to get any significant market share. No chance.

–` Steve Ballmer, Microsoft CEO
USA Today, April 2007

Hindsight is a wonderful thing

– David Beckham

Hindsight bias makes surprises vanish

– Daniel Kahneman
(2002 Nobel laureate in economics)

My big take-away from the crisis: it's really, really, really hard to predict (ex ante) what will, let alone what might happen

- The risk manager's perennial problem

- A consequence of the efficient market hypothesis, and a recognition that the market is the best information aggregator we have
  - Can't systematically predict returns (on average, alpha = 0)
  - … but some people are better informed (and smarter?) than others

- Oddly, volatilities are (somewhat) predictable
  - E.g., GARCH models
  - But that is not helpful for predicting market disruptions

- These ideas have at least 4 Nobel prizes behind them

- It is hard to predict tail outcomes
  - It is really hard to predict far tails
  - It is nearly impossible to predict disruptions
    - And when one does happen, it is really hard to know if it's short or long duration

Let's travel back to the summer of 2006...

In the past, risk managers would frequently look towards historical precedents as an indicator for the worst case scenario stress event…

TED spread
Bps, Jan 1990-June 2006

VIX
Points, Jan 1990-June 2006

Source: FRED

In the past, risk managers would frequently look towards historical precedents as an indicator for the worst case scenario stress event…
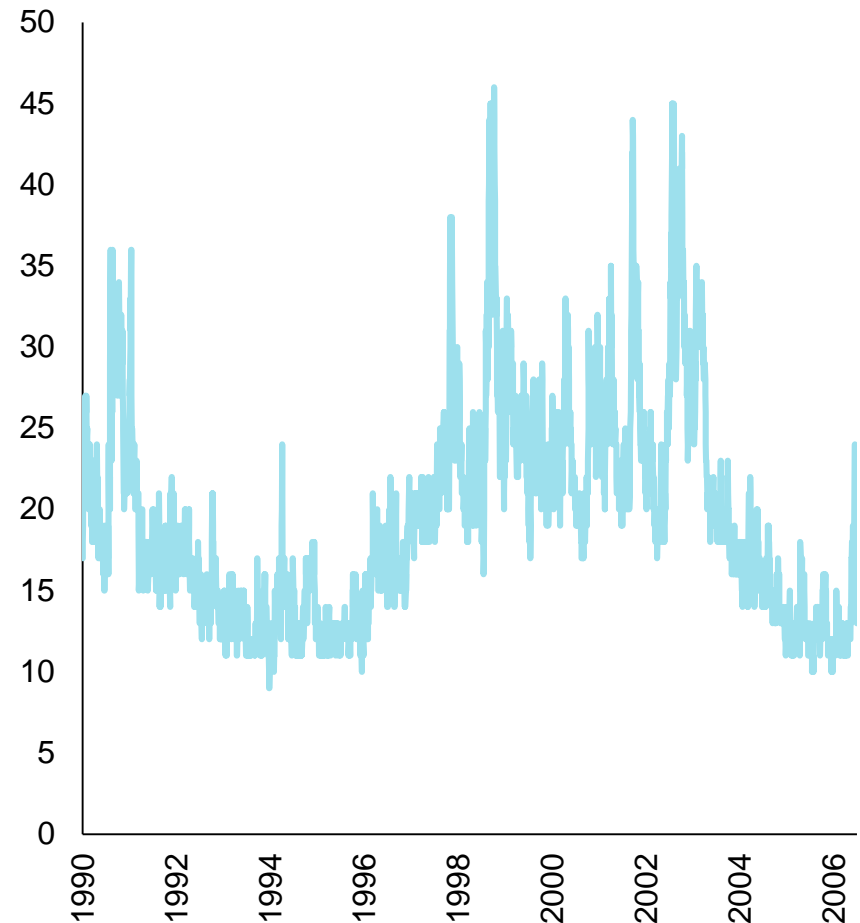
TED spread
Bps, Jan 1990-June 2006

VIX
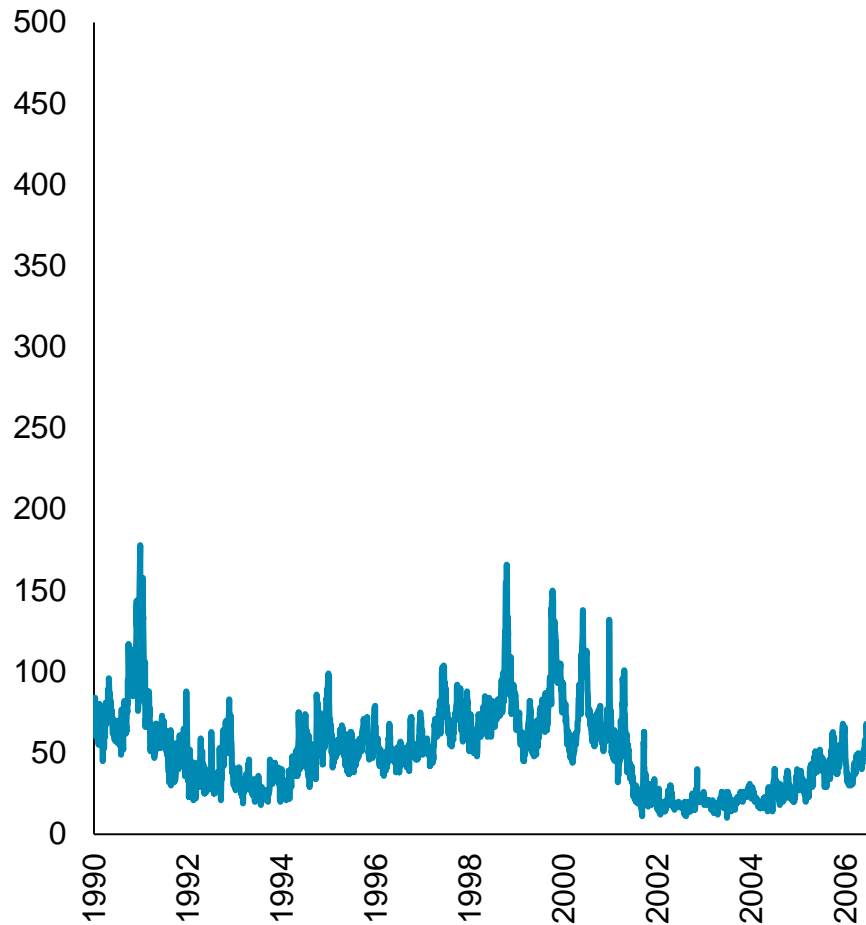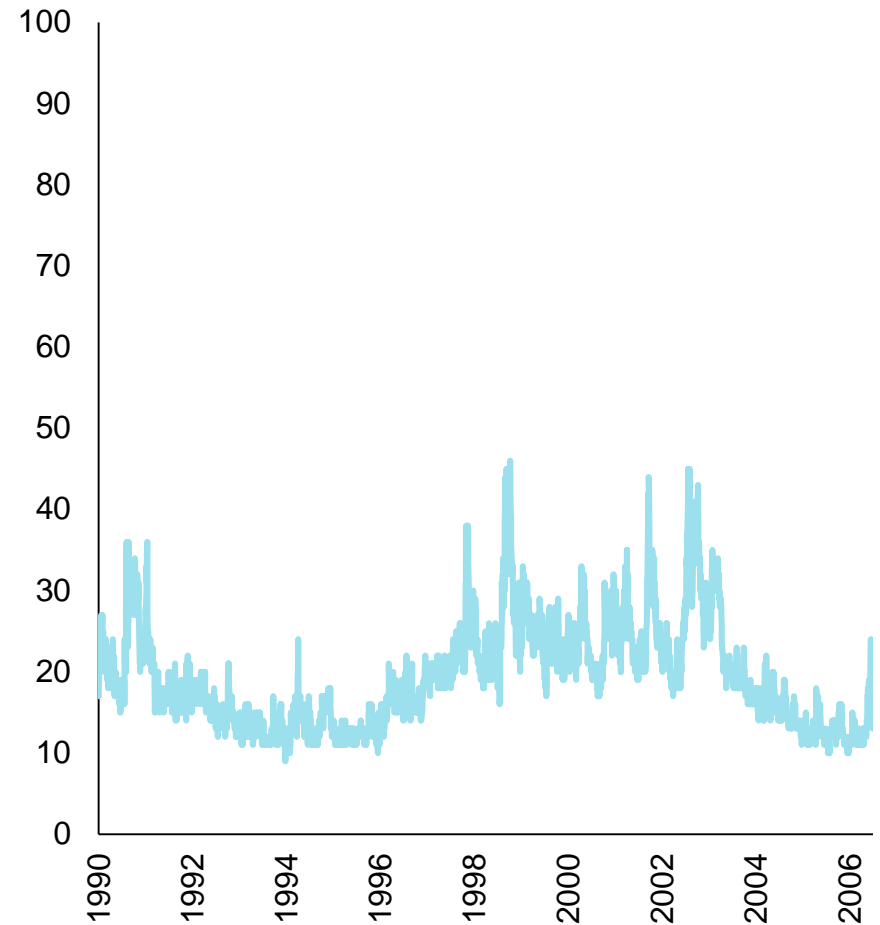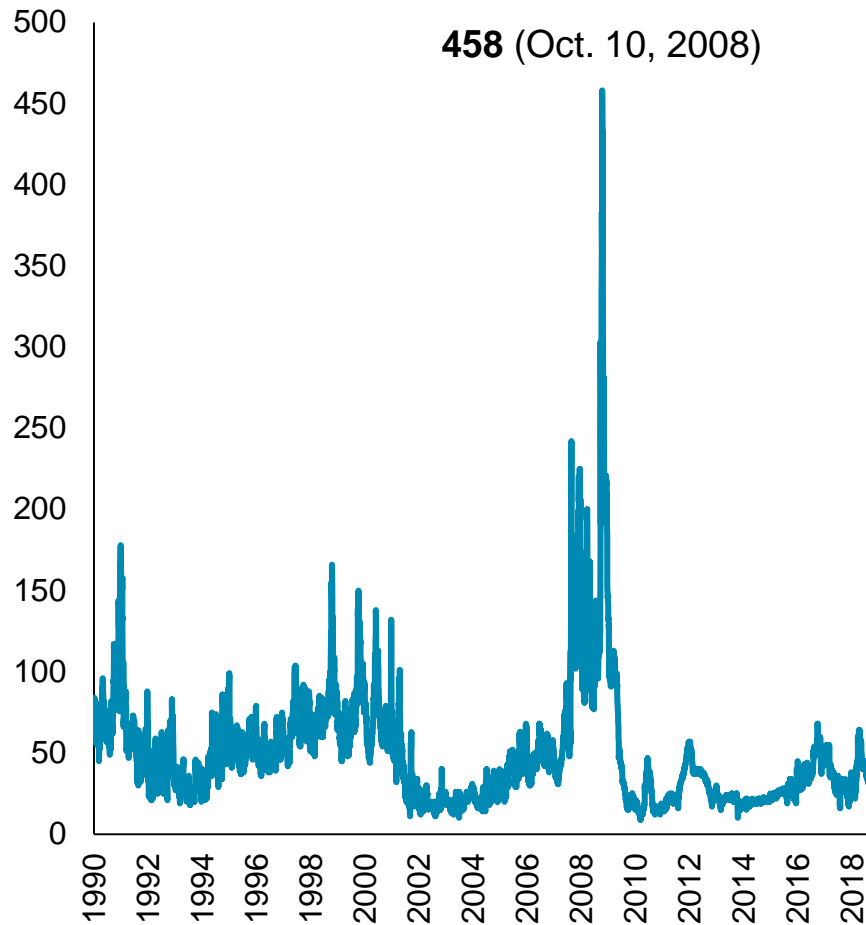Points, Jan 1990-June 2006
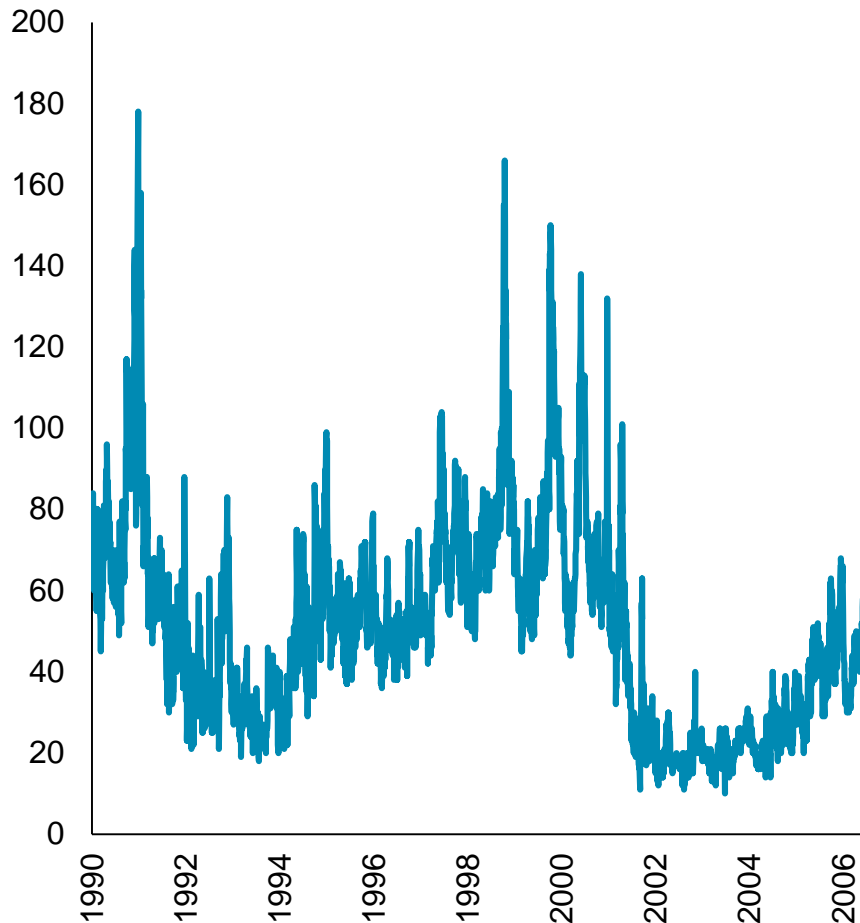
Source: FRED

…while during the crisis many of these metrics reached unprecedented levels

TED spread
Bps, Jan 1990-Aug 2018
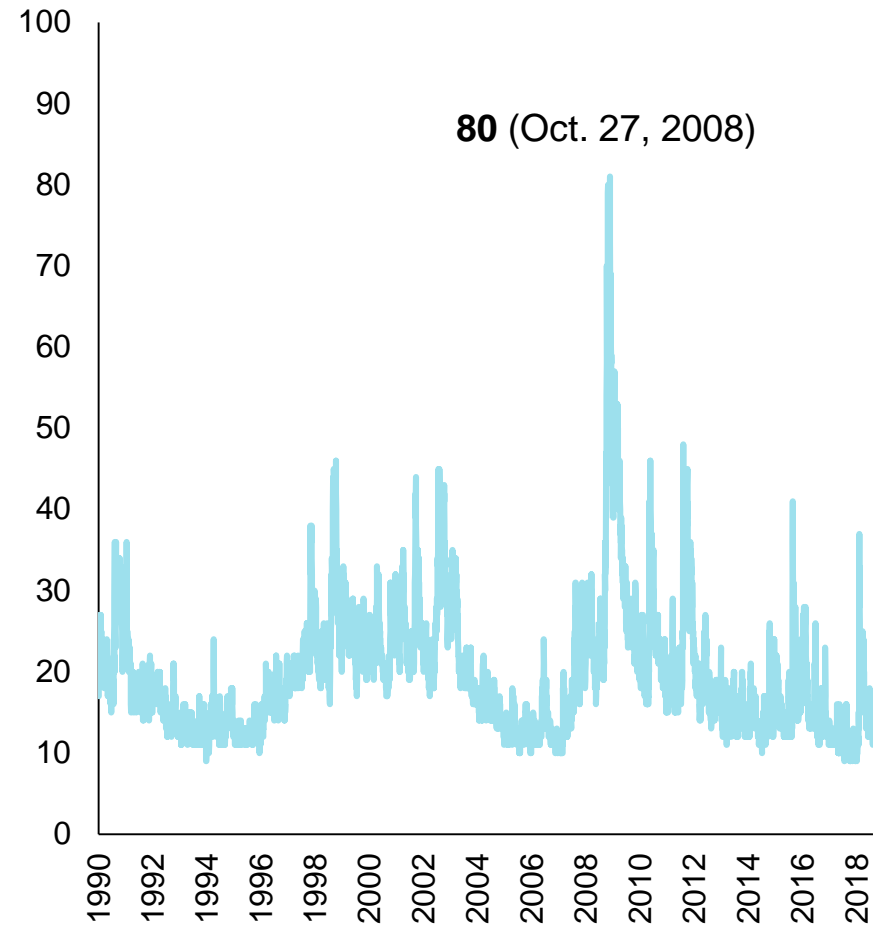
458 (Oct. 10, 2008)

VIX
Points, Jan 1990-Aug 2018

80 (Oct. 27, 2008)

Source: FRED

The real economic impact of the financial crisis has been enormous

Real GDP – domestic currency[1]
Indexed to 1999 Q1 = 100
1997 Q1 – 2018Q1

Lehman Brothers
(Sep 2008)

Northern Rock
(Sep 2007)

US bank stress test (May 2009)

Greek bonds downgraded to junk (Apr 2010)

EBA stress testing results
(Oct 2014)

Peak-to-trough
%, drop during crisis

-13% ('07 Q4 – '10 Q3)

-12% ('07 Q4 – '09 Q4)

-4% ('07 Q4 – '09 Q2)

-6% ('08 Q1 – '09 Q4)

-10% ('08 Q2 – '13 Q3)

-27% ('08 Q1 – '15 Q3)

Legend: Iceland — Ireland — US — UK — Greece — Spain
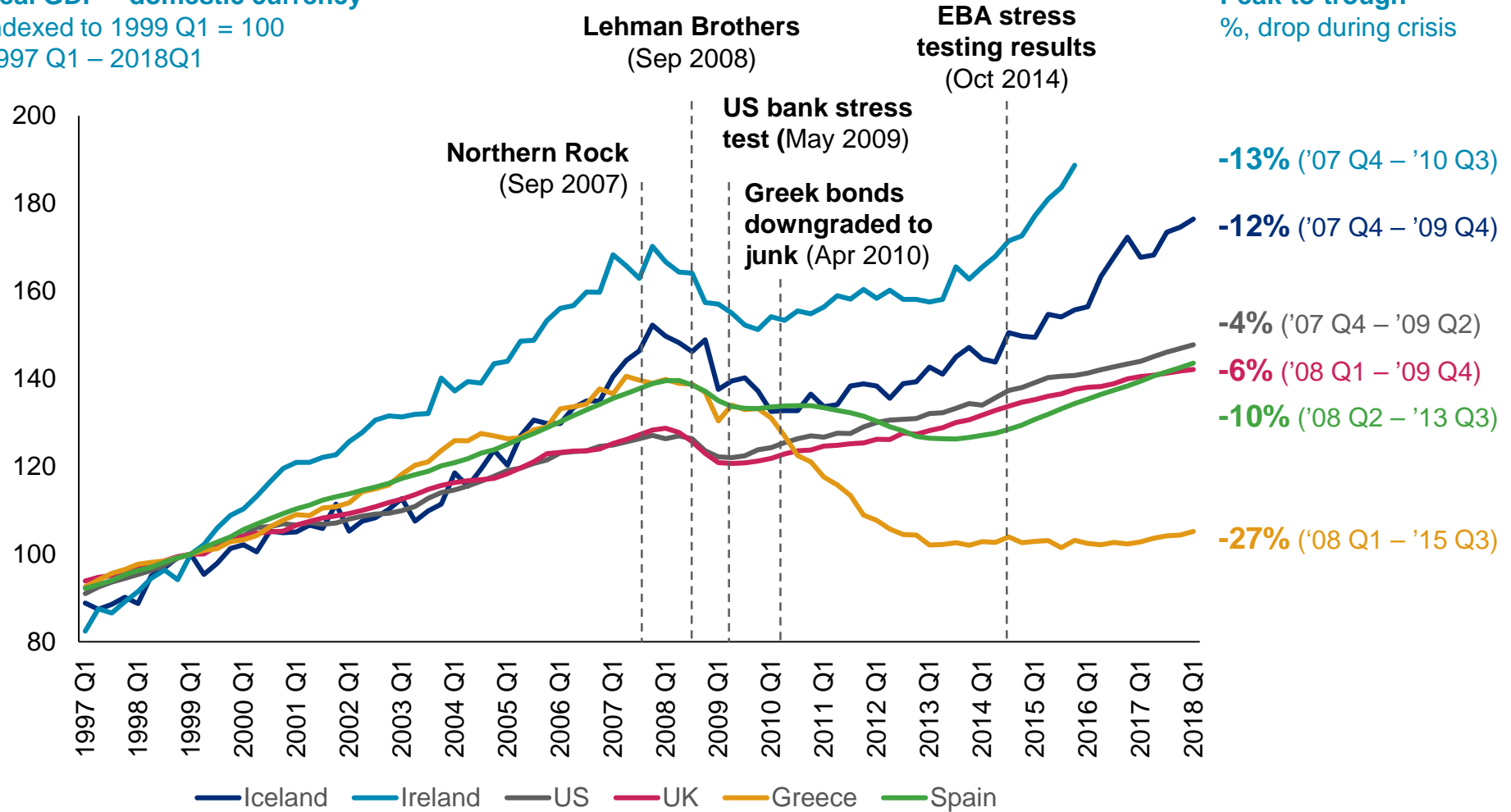
Source: Seasonally adjusted GDP data from Federal Reserve Bank of St. Louis (FRED)
1. For US, indexed GDP values inferred from annual rates
2. SCAP (Supervisory Capital Assessment Program) introduced by Federal Reserve

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Bank performance is correlated with the economy, opening the door to practical stress testing

US unemployment rate and total US bank loan losses[1]

Legend: Unemployment (LHS) — Loan losses (RHS)
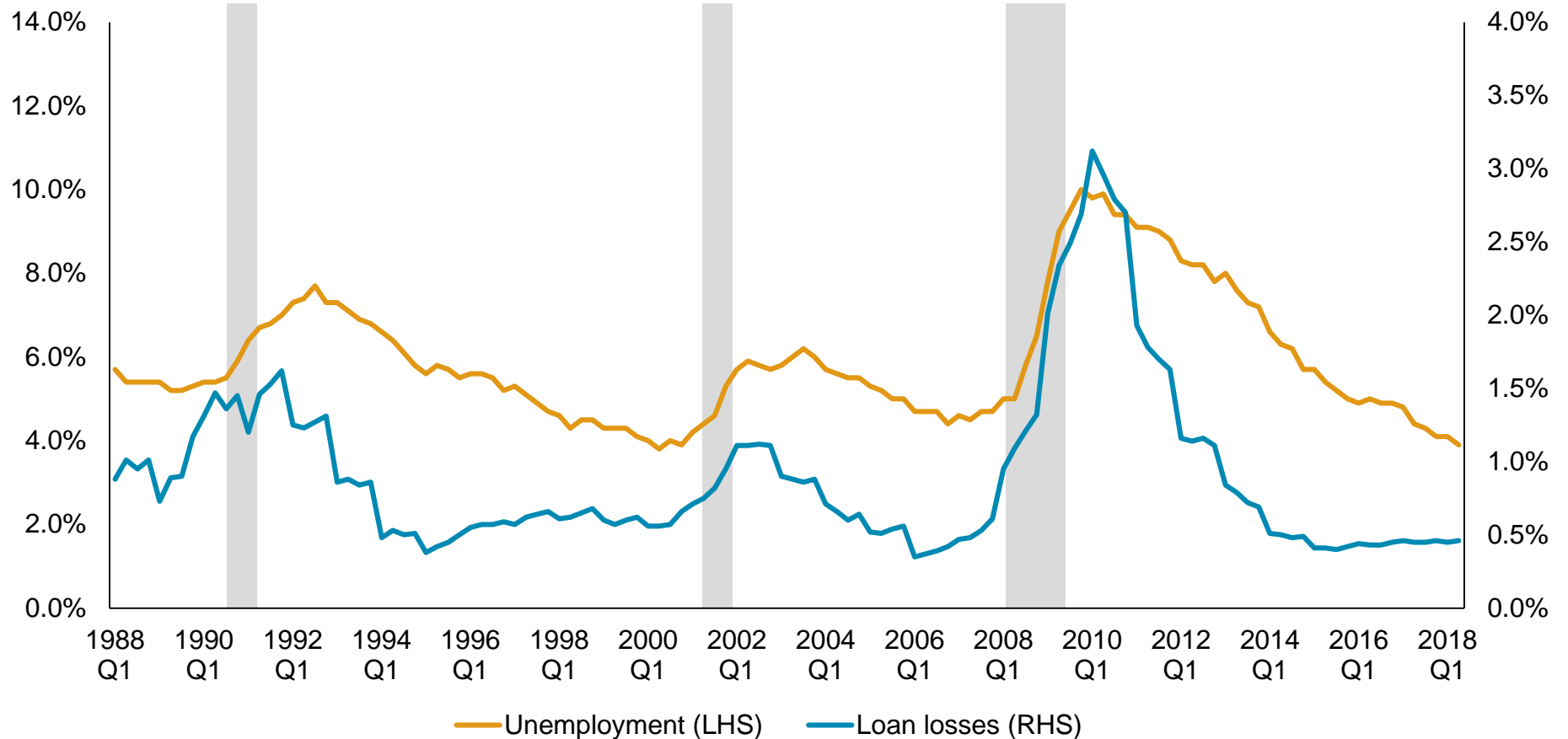
1. Total Net Loan Charge-offs to Total Loans for Banks – not seasonally adjusted (quarterly time series as sourced from FRED)

Stress testing at banks before and after the crisis

- Before the crisis, business line and product-level stress testing regimes were reasonably well-developed
  - But corporate-wide credit risk stress testing still at a developmental stage

- No firm had a fully-developed program of integrated stress testing that captured all major financial risks on a firm-wide basis

Pre-crisis

- Mostly single shock
- Product or business unit level
- Static
- Losses only
- Not usually tied to capital adequacy

2009 →

- Broad macro scenario and market stress
- Comprehensive, firm-wide
- Dynamic and path dependent
- Losses, revenues and costs
- Explicit post-stress common equity threshold

Early stress tests in U.S. and Europe

CEBS – '10
EBA – '11,'14,'16,`18

~24% GDP World

Capital shortfall:
€3.5 BN (2010)
€2.5 BN (2011)
€24.6 BN (2014) [AQR: €47.5 BN]
€5.7 BN (2016)*

USA – '09
2011–'18

~24% GDP World

Capital shortfall (2009):
$75 BN
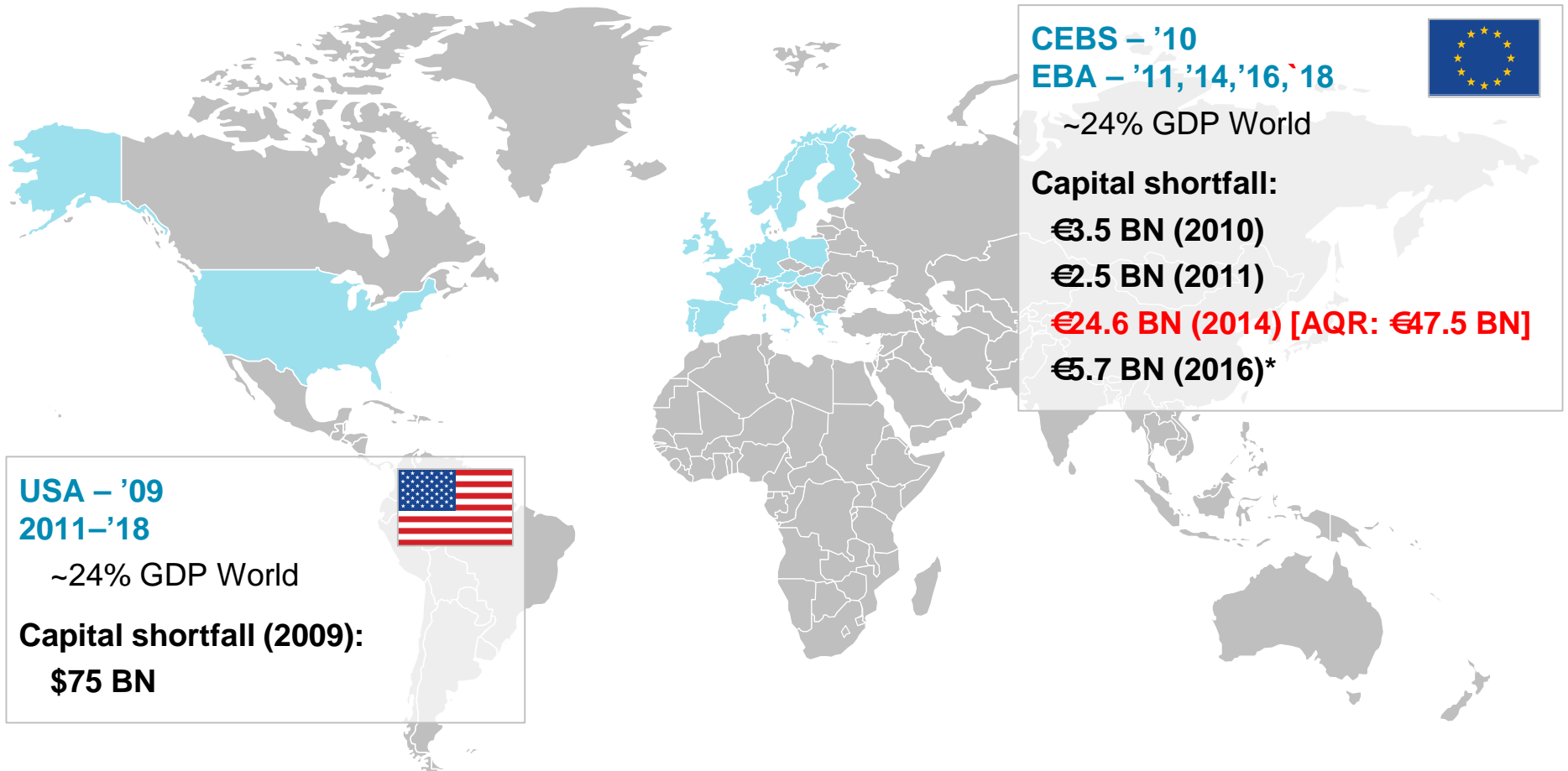
* No pass/fail threshold. Monte Paschi projected min CET1 was -2.4%

Quantification of capital shortfalls in Europe following Asset Quality Review (AQR) and stress test exercises

Ireland – '11

~2% GDP EU

Capital shortfall:

~ €24 BN

Spain – '12

~12% GDP EU

Capital shortfall:

~ €59 BN

Portugal – '11, '12

~2% GDP EU

Capital shortfall:

~ €7.8 BN ('11)

~ €7.6 BN ('12)

Slovenia – '13

~0.4% GDP EU

Capital shortfall:

~€4.8 BN

Greece – '12, '15

~2% GDP EU

Capital shortfall:

~€40.5 BN ('12)

~€14.4 BN ('15)

Cyprus – '12

~0.2% GDP EU

Capital shortfall:

~€9 BN
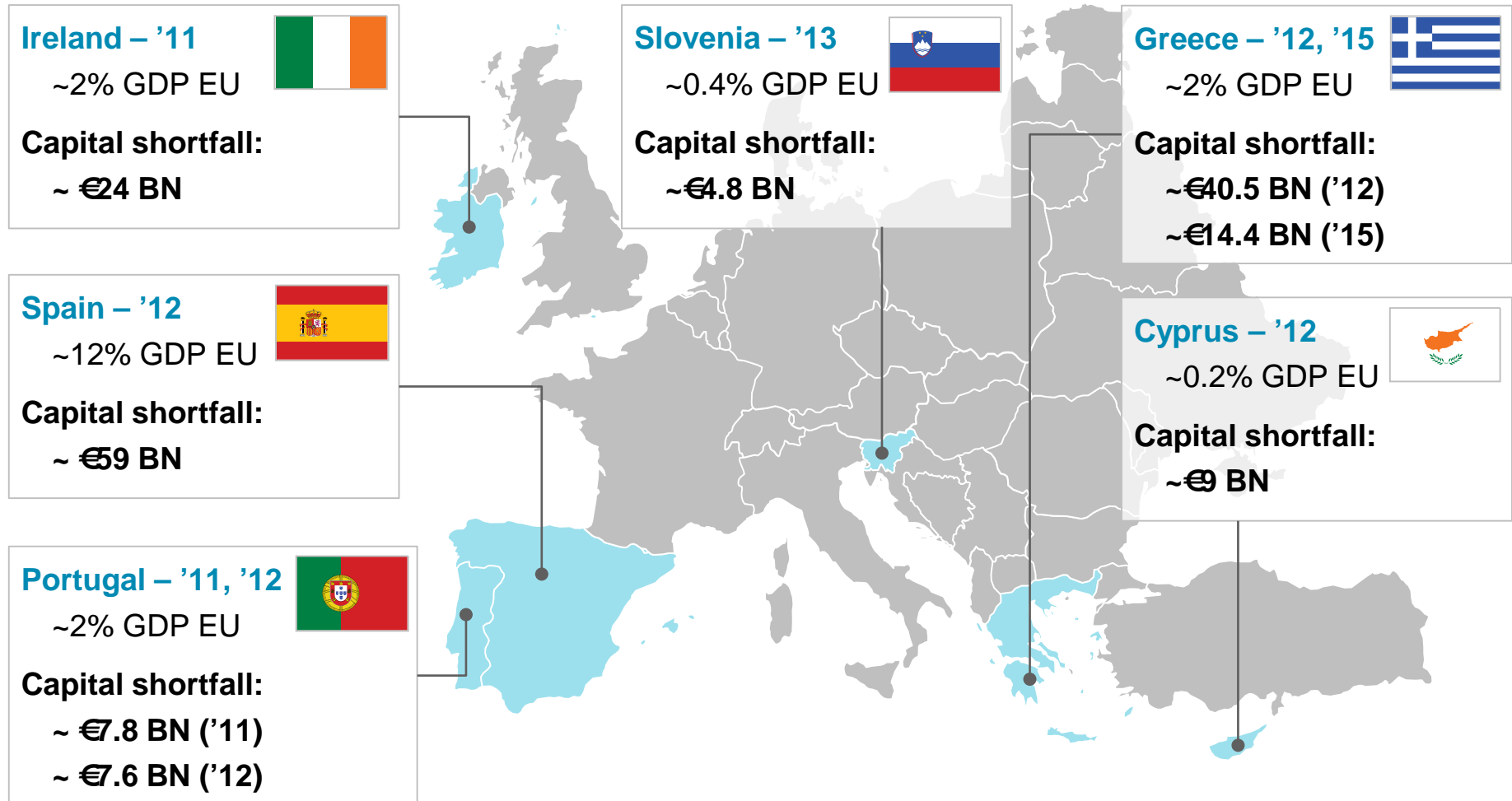
Stress testing involves mapping a view of the world (state space) to micro-outcomes (higher losses, lower revenues)

Macro

- GDP

- Unemployment

- Home price index

▼

▼
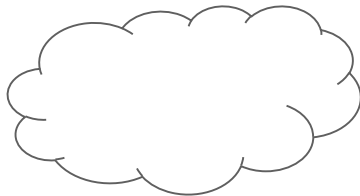
Micro

- Business lending losses

- CRE losses

- Mortgage revenue

- Trading P&L

- …

- A myriad assumptions need to be made to go from the macro-scenario to the micro-outcomes, e.g.
  - Regional real estate variables
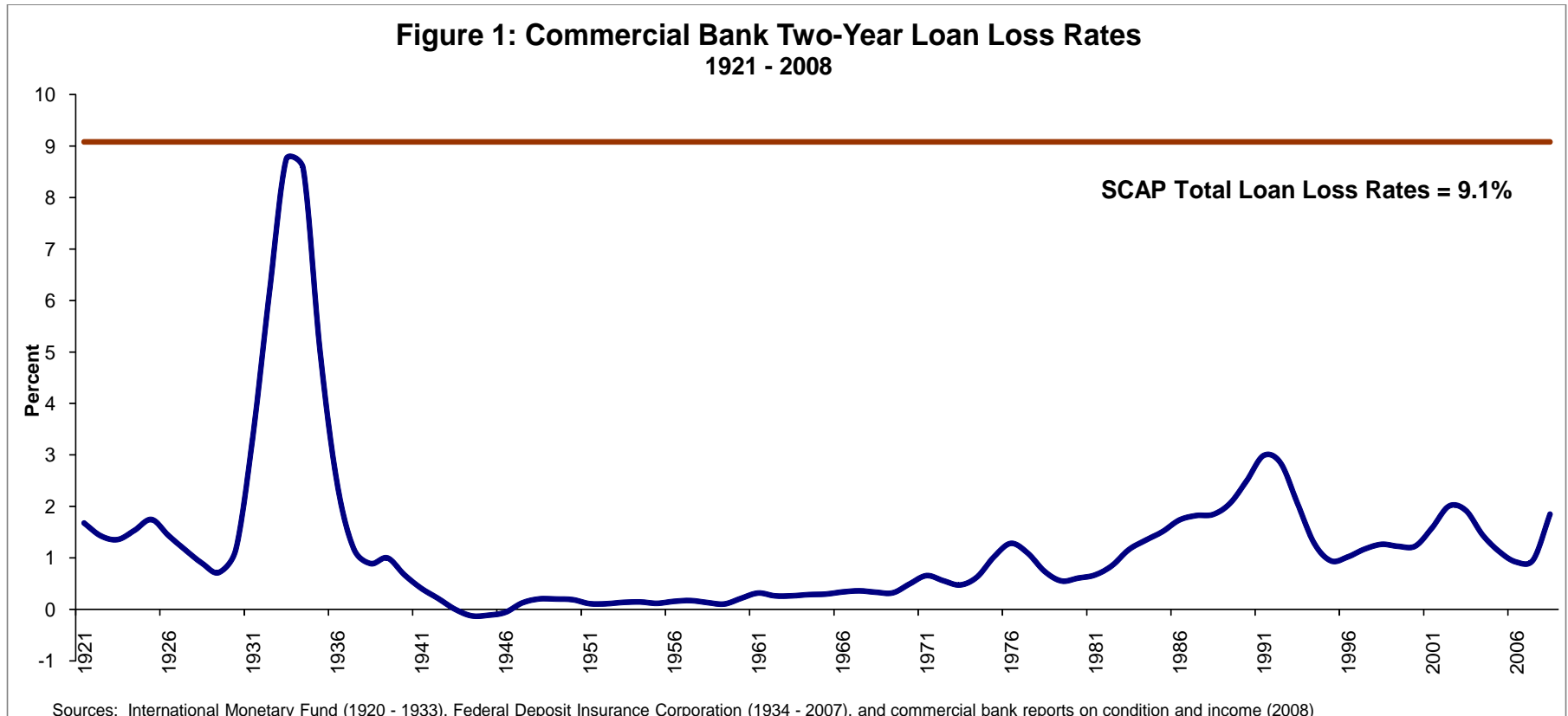 - Manheim index (used car prices)
    - US: auto sales dropped by 37% in 2008-'09 recession, Manheim index rose 4%
  - Mortgage modifications and other policy actions

- Standard linear and logistic regressions remain the workhorses for modeling
  - Consider revenue for product j driven by macro-factors (x) and firm/business specific factors (z)

$$r_{j,t+1} = \alpha_{j,[t?]} + \boldsymbol{\beta}_{j,[t?]} x_{t-k} + \boldsymbol{\gamma}_{j,[t?]} z_{j,t-k} + \varepsilon_{j,t+1}$$

  - Further heterogeneity (e.g. geography, product type, client segment,…)
  - There may be structural changes (e.g. during or just after a financial crisis), there may be non-linearities (…..)

US stress test in 2009 was credibly severe: banks had to capitalize against possible losses higher than during the Great Depression

Figure 1: Commercial Bank Two-Year Loan Loss Rates
1921 - 2008

SCAP Total Loan Loss Rates = 9.1%

Sources: International Monetary Fund (1920 - 1933), Federal Deposit Insurance Corporation (1934 - 2007), and commercial bank reports on condition and income (2008)

Source: http://www.federalreserve.gov/bankinforeg/bcreg20090507a1.pdf.

How does one design a good stress scenario? And how is it different for a bank vs. a regulator?

- It should be "stressful"
  - What is your risk appetite? How severe should the storm be that the bank or banking system should survive?
    - A bad recession, a stock market crash?
    - 2008 Financial Crisis?
    - Great Depression?
  - How much capital should they have post stress?

- It should be coherent
  - A statement about correlation or dependence structure
  - Probe and expose dependence on "natural hedges" and equilibrium relationships …
    - E.g. covered interest parity and cross-currency basis
    - E.g. convergence trades, e.g. on- and off-the-run Treasuries (LTCM in 1998)
  - … without becoming, well, incoherent

- It should be reasonably comprehensive in probing vulnerabilities
  - Bank: products, markets, clients, segments, countries, …
  - Regulator: which banks or type of banks should I target?

- Best to have many scenarios to cover range of possibilities

Example: U.S. real GDP growth and unemployment rate
SCAP (2009), CCAR (2011-2018)

Real GDP Growth (%)
Severely Adverse scenarios vs. historical observations
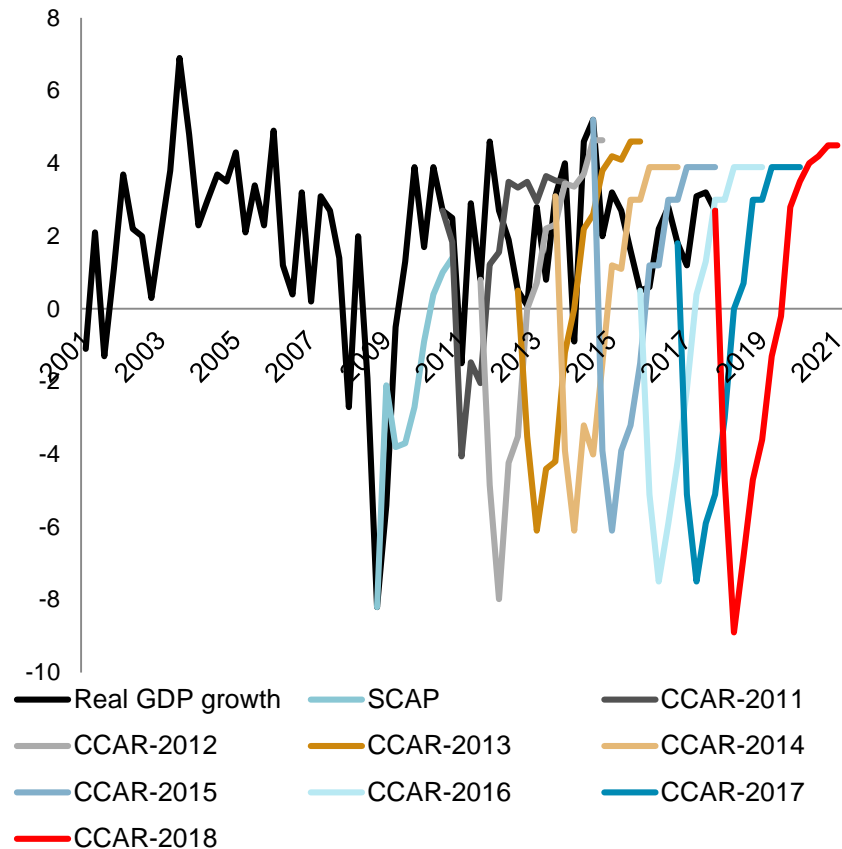
Unemployment Rate (%)
Severely Adverse scenarios vs. historical observations
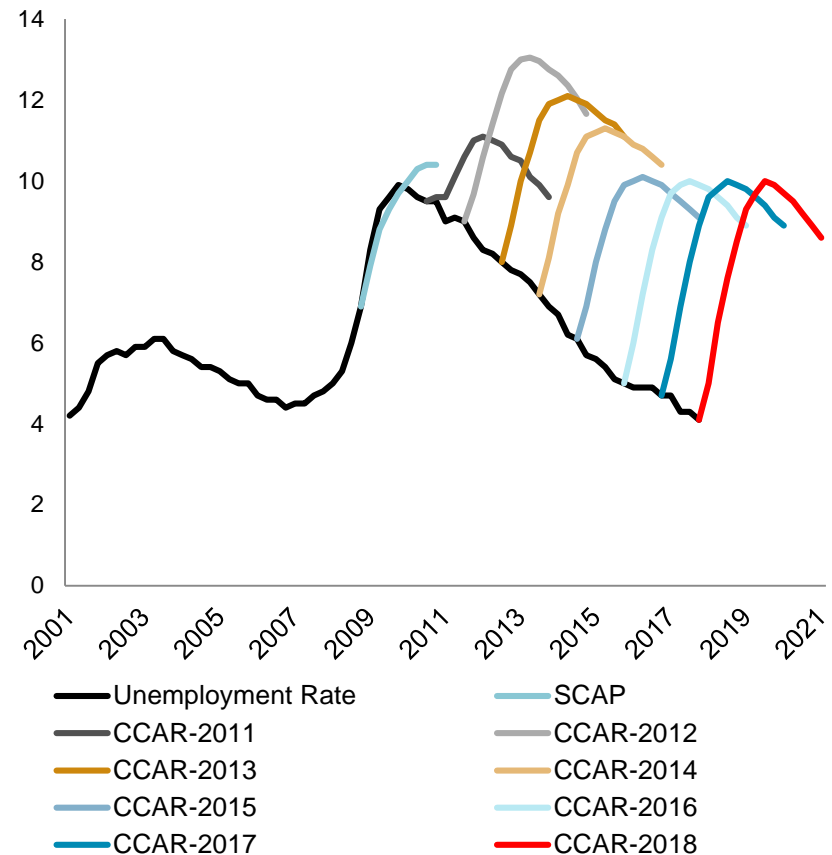
Source: Fed SCAP and CCAR-2011-2018 scenario disclosures
Note: For SCAP-2009, CCAR-2011 and CCAR-2012, only baseline and adverse scenarios were released. Therefore, adverse scenario data for these years is shown on the right-hand side graph for comparison to severely adverse scenario data for CCAR-2013-2018

Example: 3M U.S. Treasury and BBB Corporate Yield Spread
CCAR (2012-2018)

3-Month Treasury Rate (%)
Severely Adverse scenarios vs. historical observations

Legend:
- 3-month Treasury yield
- CCAR-2012
- CCAR-2013
- CCAR-2014
- CCAR-2015
- CCAR-2016
- CCAR-2017
- CCAR-2018

BBB Corporate Yield Spread (% to 10Y treasury)
Severely Adverse scenarios vs. historical observations
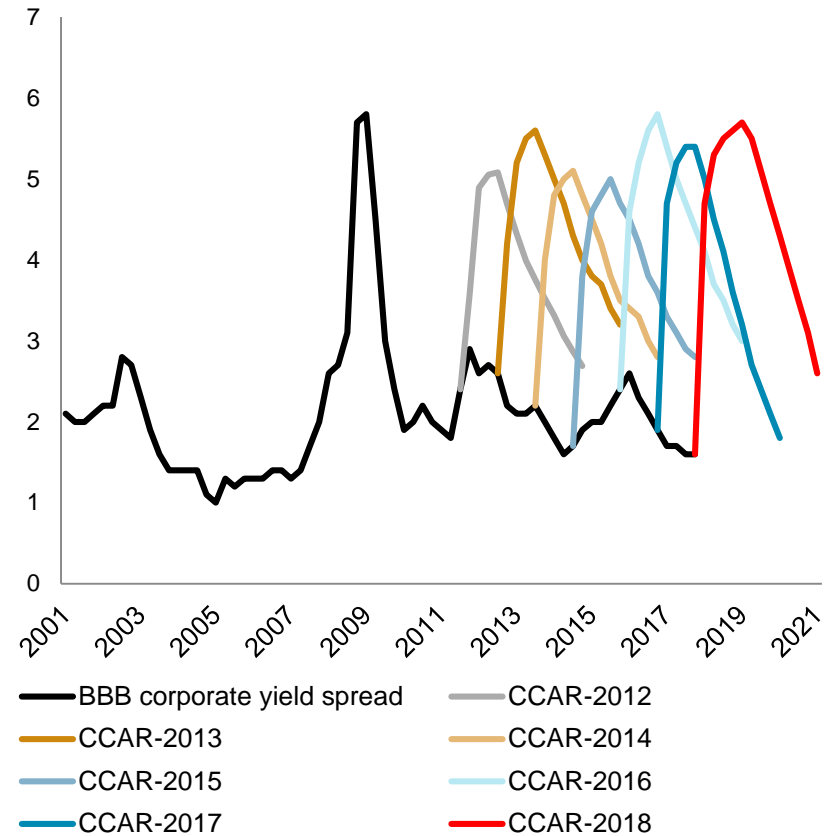
Legend:
- BBB corporate yield spread
- CCAR-2012
- CCAR-2013
- CCAR-2014
- CCAR-2015
- CCAR-2016
- CCAR-2017
- CCAR-2018

Source: Fed SCAP and CCAR-2011-2018 scenario disclosures
Note: For SCAP-2009, CCAR-2011 and CCAR-2012, only baseline and adverse scenarios were released. Therefore, adverse scenario data for these years is shown on the right-hand side graph for comparison to severely adverse scenario data for CCAR-2013-2018

Example: Dow Jones Total Stock Market Index and VIX
CCAR (2012-2018)
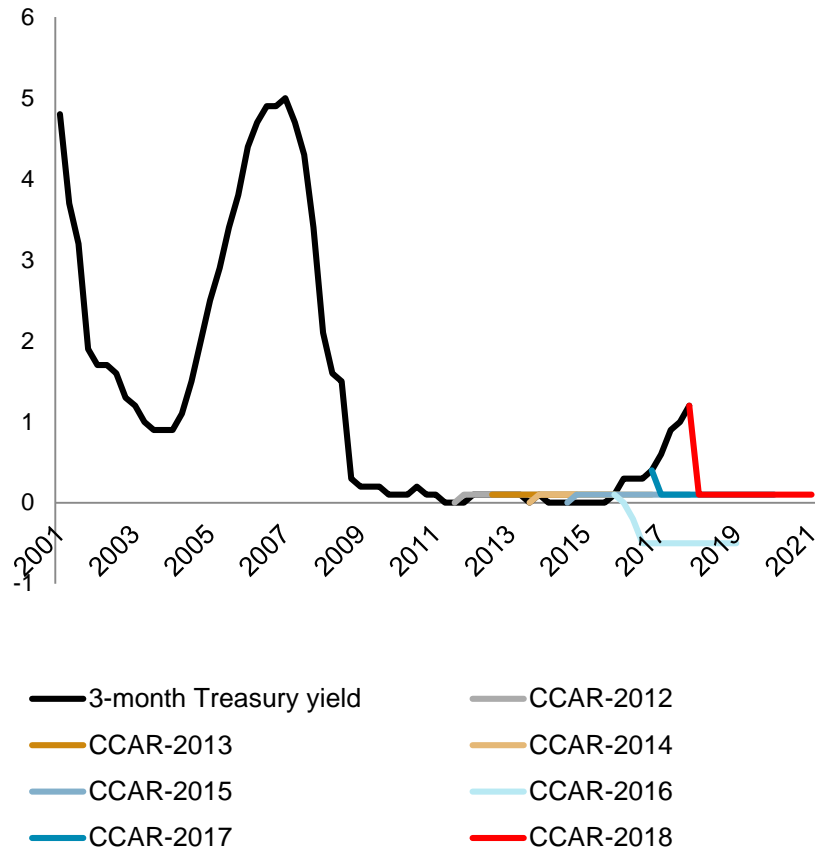

Dow Jones Total Stock Market Index (Level)
Severely Adverse scenarios vs. historical observations

Market Volatility Index (Level)
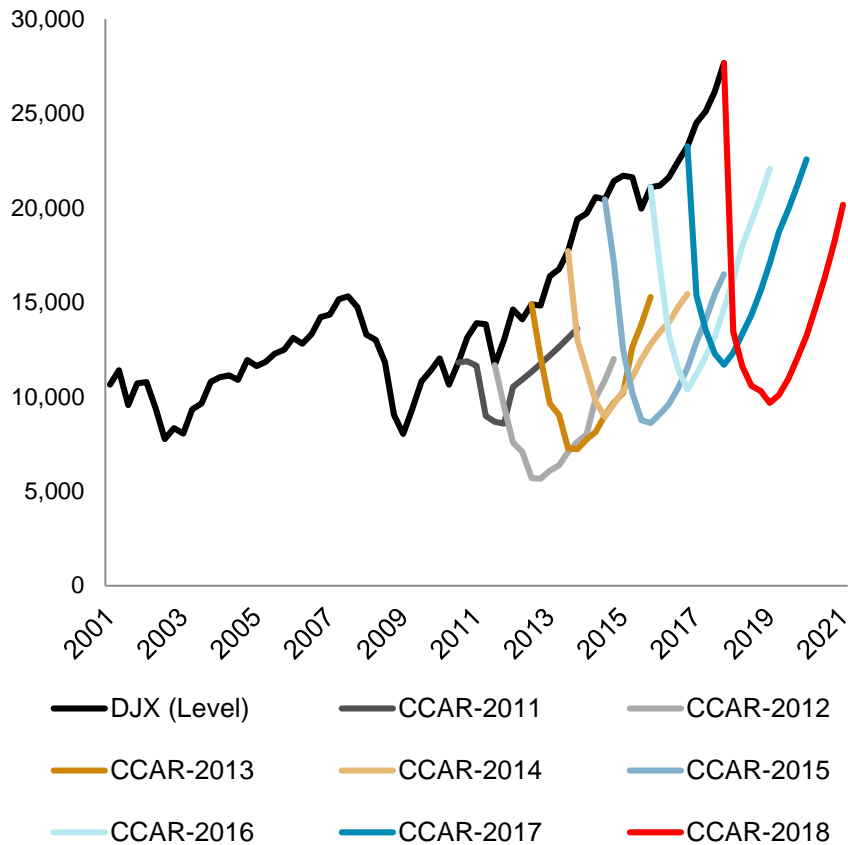Severely Adverse scenarios vs. historical observations

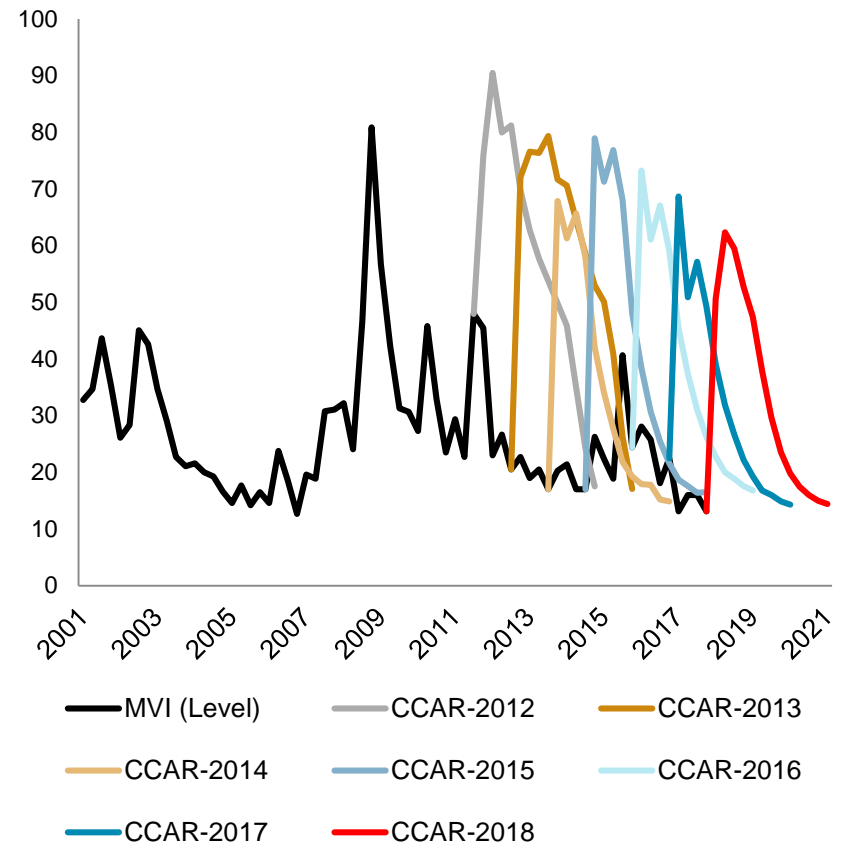Source: Fed SCAP and CCAR-2011-2018 scenario disclosures
Note: For SCAP-2009, CCAR-2011 and CCAR-2012, only baseline and adverse scenarios were released. Therefore, adverse scenario data for these years is shown on the right-hand side graph for comparison to severely adverse scenario data for CCAR-2013-2018

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There has been a veritable model explosion since the crisis

- Models of state space and risk factors
  - Formal macro-econometric models: 10-1000+ risk factors
    - Note that macro-econometric models based on equilibrium relationships; hard to generate very far from equilibrium outcomes
  - Adaptation by banks to specific exposure categories
    - Regional concentrations require regional tailoring of house price index, unemployment, etc.
  - Market risk factors for trading operations
    - Large trading firms maintain 50,000 – 400,000+ risk factors daily
      - (NB: not a post-crisis phenomenon)
    - Fed's Global Market Shock is specified to 30,000 risk factors

- Models to translate scenarios (risk factors) to outcomes
  - Banks have 50-1000+ stress testing models depending on size, complexity, business and geographic coverage
  - Temptation to fit models to last crisis – at likely cost of low robustness to future unknown shocks

We're all econometricians now!

Fortunately the explosion of models has been met with the rise of formal model risk management

Early days of model risk

- Proliferation of model use in banking: valuation, credit evaluation, risk measurement

- Growing reliance on banks' own economic capital and VaR models for capital adequacy assessment

- Derman (1996)

Model validation

- Securitization and credit derivatives drive need for complex models (copula)

- Use of banks' own models in capital regulation (Basel II)

Model Risk Management

- Banking industry investing in and developing MRM frameworks

- Regulatory reliance on modeling shifts to stress testing

Degree of sophistication in model risk management (y-axis)

OCC 2000-16 guidance on model validation

Fed/OCC 2011-07 guidance on model risk management

2000   **2011**

Brown, J., B. McGourty, and T. Schuermann (2015). "Model Risk and the Great Financial Crisis: The Rise of Modern Model Risk Management," ch. 15 in Douglas Evanoff, Andrew Haldane, and George Kaufman (eds.), *The New International Financial System: Analyzing the Cumulative Impact of Regulatory Reform*. World Scientific Studies in International Economics.

"The Formula that Killed Wall Street"
Wired, Feb. 2009

$$Pr[T_A < 1, T_B < 1] = \phi_2(\phi^{-1}(F_A(1)), \phi^{-1}(F_B(1)), \gamma)$$

WIRED

— THE —
SECRET FORMULA
That Destroyed Wall Street

$$P = \phi(A, B, \gamma)$$

PLUS

A Radically Transparent Plan to Remake the Market

ALSO IN THIS ISSUE
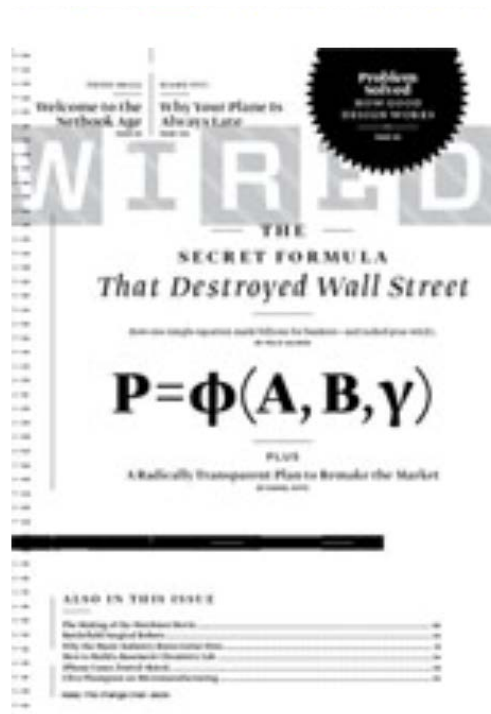
Example: model fitting error on home equity ABS exploded starting in early summer 2007
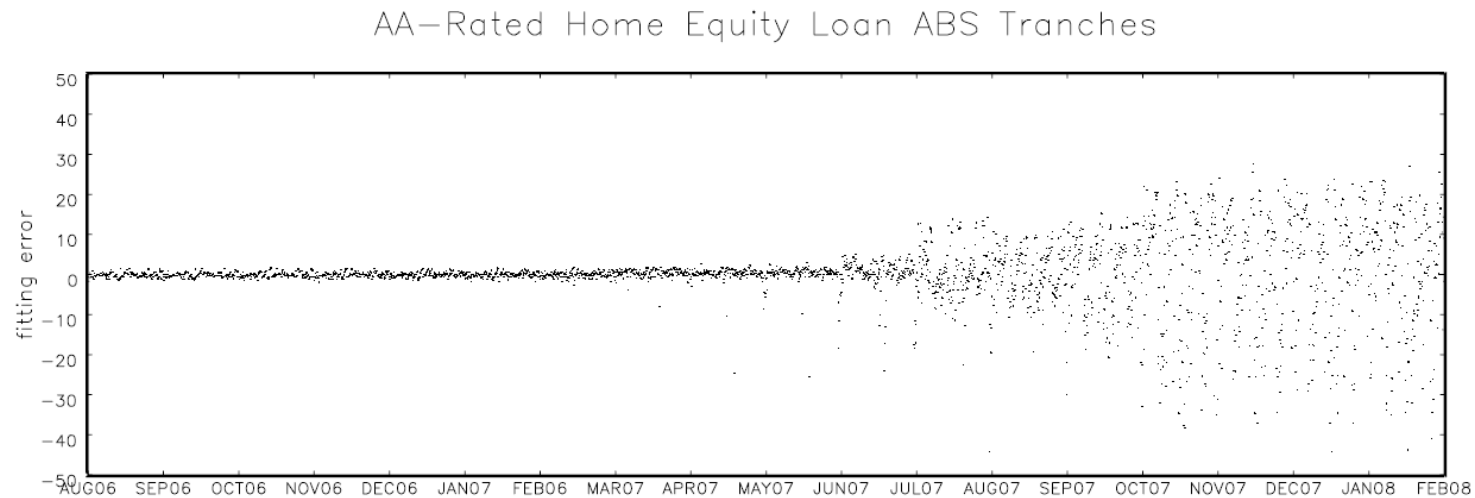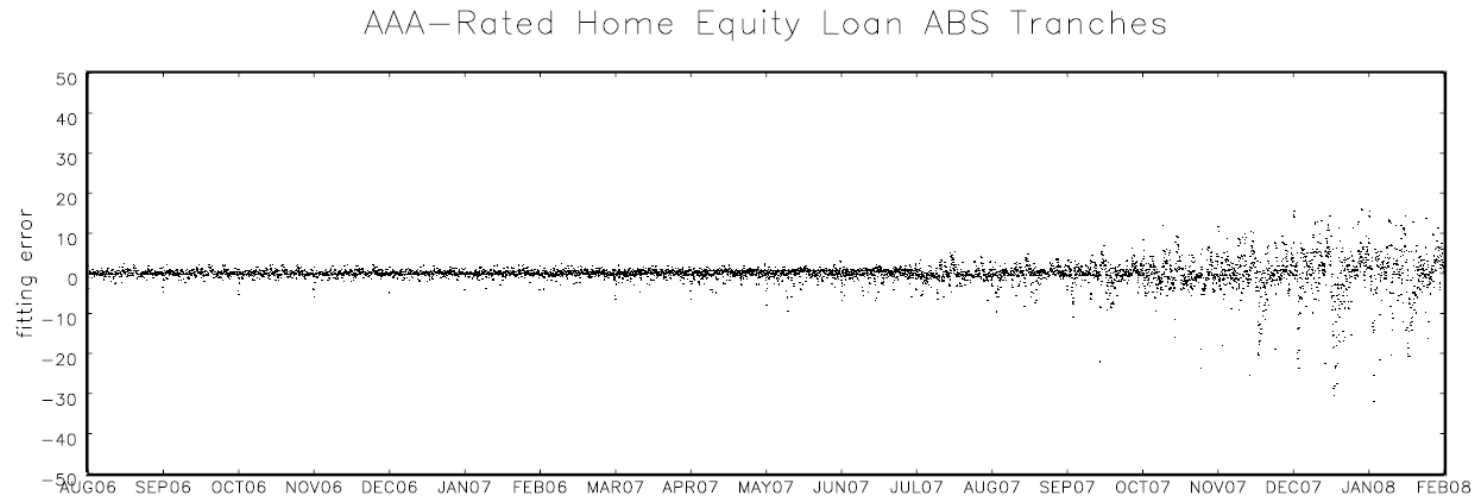
Source: Perraudin & Wu, 2008, "Determinants of Asset-backed Security Prices in Crisis Periods", Imperial College WP

But models, carefully built and monitored, are really useful for a range of applications

Performance = β ∗ Macro + α

Performance   Macro- Management-
driven   driven
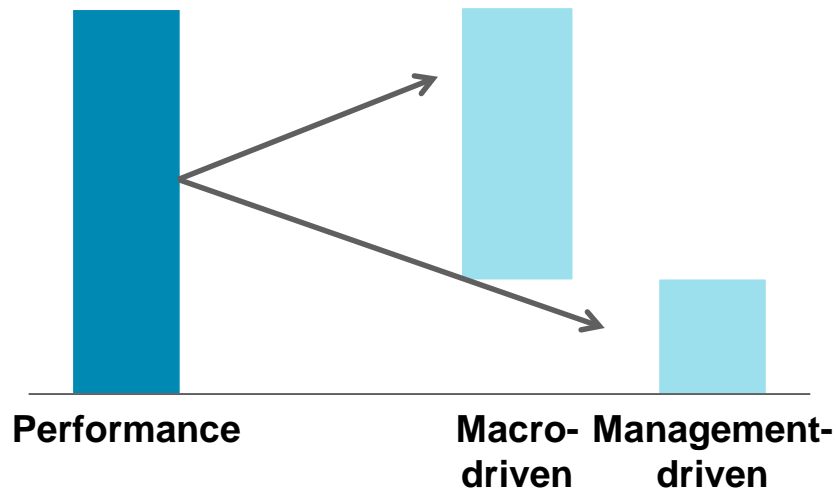
Ex-ante goal setting

- Management can set specific targets for the portion of the performance that they can impact (the alpha)
  – More robust and disciplined discussions on the contribution to performance of various strategic initiatives

Ex-post performance assessment

- Management can assess whether a deviation from plan is due to changes in market and economic conditions or due to management actions

Risk management has evolved significantly since the crisis, with increasing shift towards non-financial risks and machine learning / AI

Traditional risk management

- Quantification of **financial risk**
  - Market risk: Value at Risk (**VaR**); dynamic volatility modeling
  - Credit risk: Default rate prediction; correlated defaults with **copulas**
- Modeling mostly **focused on asset risk**
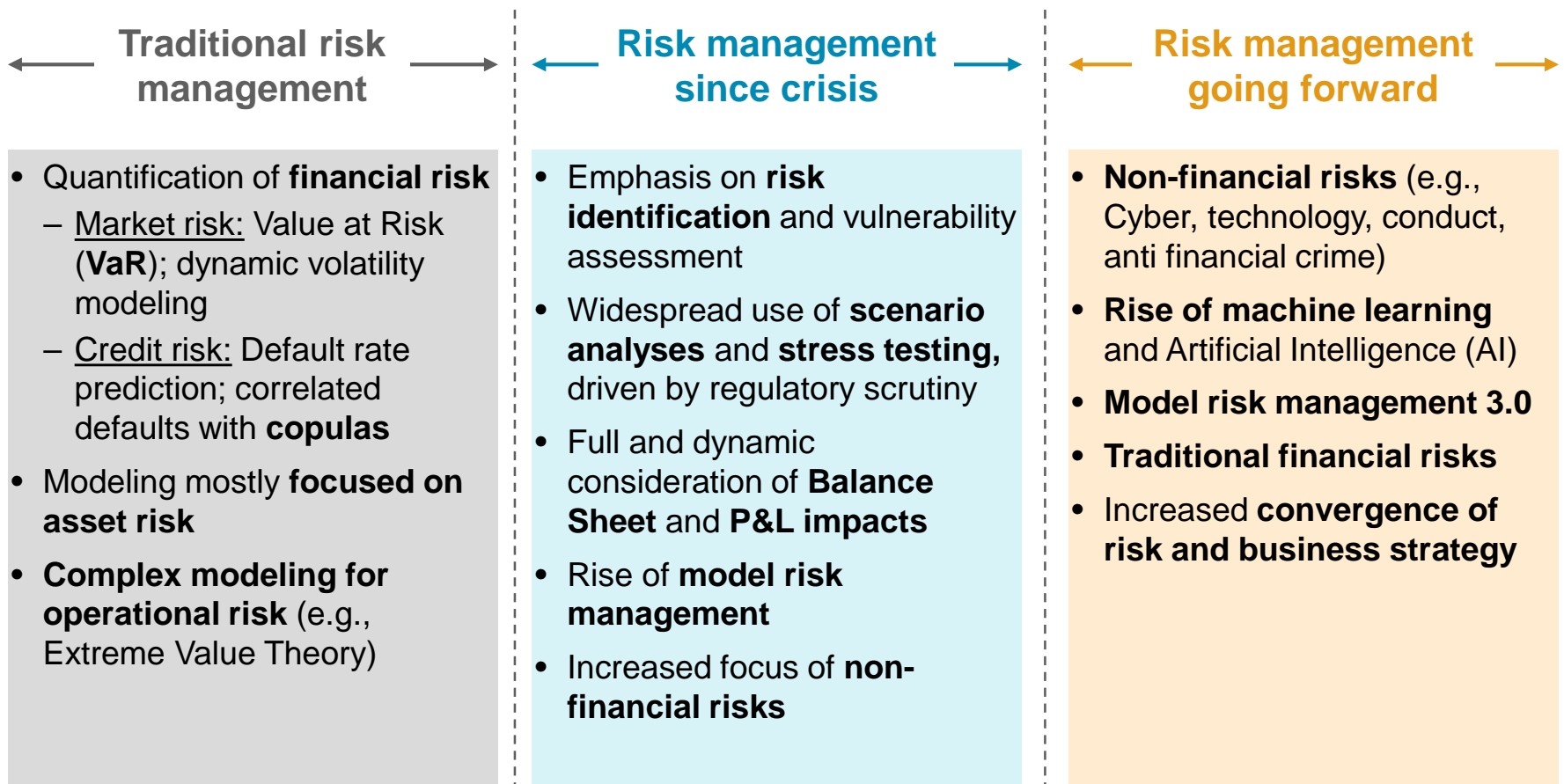- **Complex modeling for operational risk** (e.g., Extreme Value Theory)

Risk management since crisis

- Emphasis on **risk identification** and vulnerability assessment
- Widespread use of **scenario analyses** and **stress testing,** driven by regulatory scrutiny
- Full and dynamic consideration of **Balance Sheet** and **P&L impacts**
- Rise of **model risk management**
- Increased focus of **non-financial risks**

Risk management going forward

- **Non-financial risks** (e.g., Cyber, technology, conduct, anti financial crime)
- **Rise of machine learning** and Artificial Intelligence (AI)
- **Model risk management 3.0**
- **Traditional financial risks**
- Increased **convergence of risk and business strategy**

Machine learning models are entering risk and business functions

Fraud detection and anti-money laundering

Bank used ML to drive 25% to 35% decrease in false positives and 35% increase in fraud detection

Credit monitoring through sentiment and news analysis

Bank used sentiment analysis to increase Gini of SME early warning monitoring system by 20%

Portfolio optimization

BAML tested an AI-based stock-picking tool to help identify small-cap stock opportunities

Pricing

Bank developed an advanced ML-based pricing analytics platform for its term deposit portfolio pricing strategy

Recommendation engines

JP Morgan developed a predictive recommendation engine to identify clients best positioned for follow-on equity offerings

Customer advisory
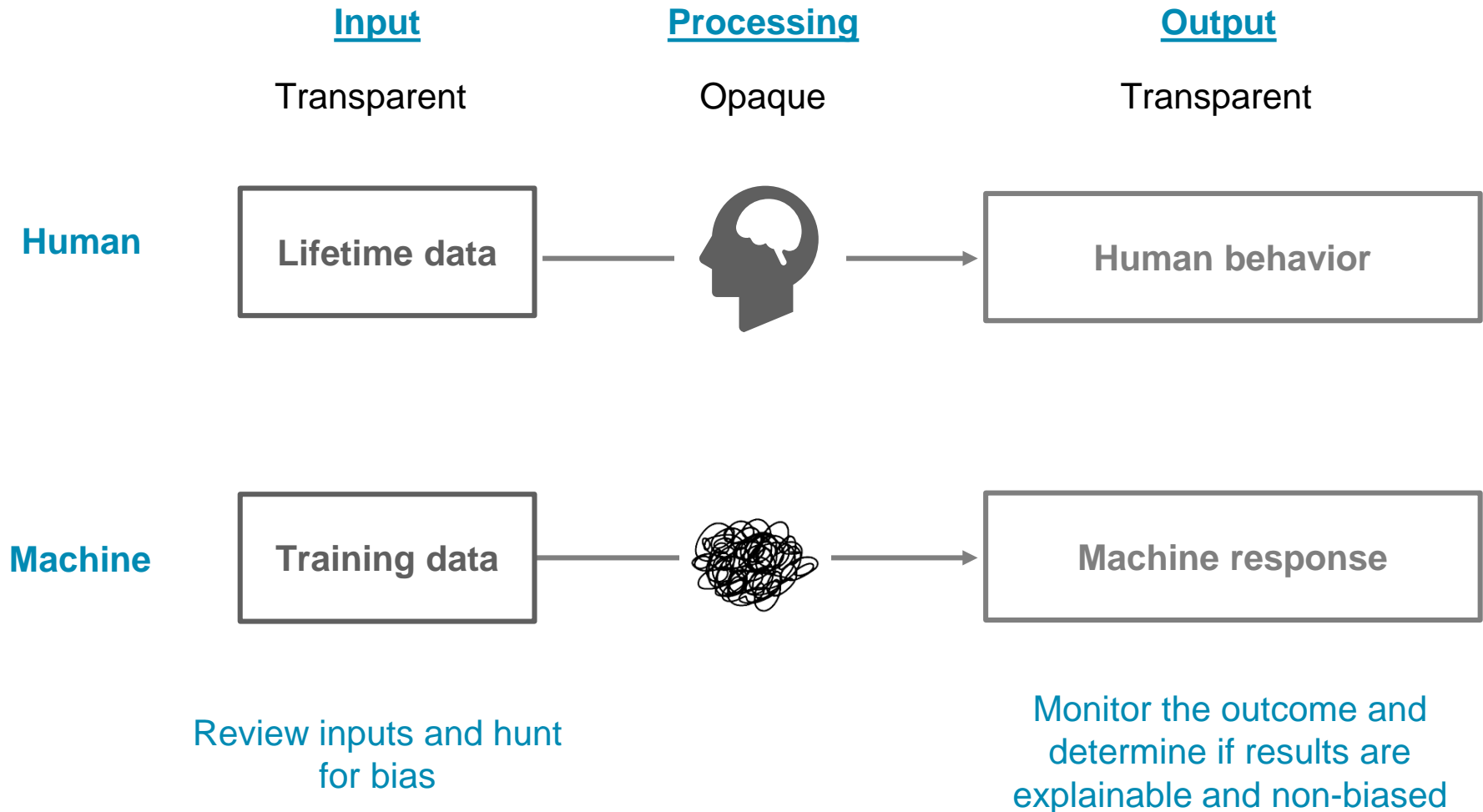
Erica by Bank of America uses ML to make account suggestions and optimize client interactions.

Source: Company disclosures

How can we get comfortable with these complex and opaque analytics?
One approach: treat machines like humans

	Input	**Processing**	**Output**
	Transparent	Opaque	Transparent

Human

Lifetime data → [brain icon] → Human behavior

Machine

Training data → [scribble icon] → Machine response

Review inputs and hunt for bias

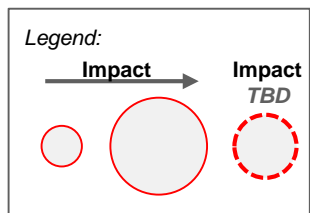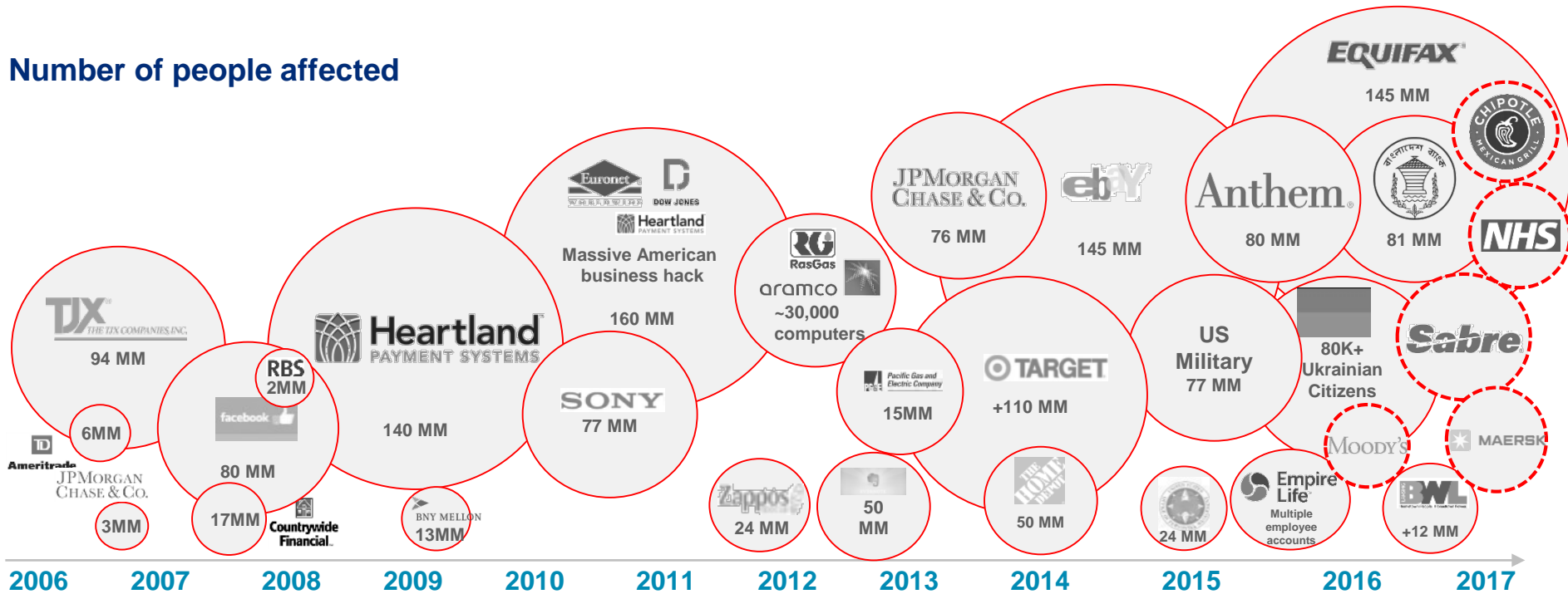Monitor the outcome and determine if results are explainable and non-biased

Cyber is in everyone's top-3 risks
WEF estimate of direct & indirect costs: $500B - $1T annually

Number of people affected

EQUIFAX
145 MM

CHIPOTLE MEXICAN GRILL

JPMorgan Chase & Co.
76 MM

ebaY
145 MM

Anthem
80 MM

81 MM

NHS

Euronet
DOW JONES
Heartland PAYMENT SYSTEMS
Massive American business hack
160 MM

RasGas
aramco
~30,000 computers

Sabre

TJX THE TJX COMPANIES, INC.
94 MM

Heartland PAYMENT SYSTEMS
140 MM

SONY
77 MM

Pacific Gas and Electric Company
15MM

TARGET
+110 MM

US Military
77 MM

80K+ Ukrainian Citizens

MAERSK

TD Ameritrade
6MM

facebook
80 MM

RBS
2MM

BNY MELLON
13MM

Zappos
24 MM

50 MM

Moody's

BWL
+12 MM

JPMorgan Chase & Co.
3MM

17MM

Countrywide Financial

THE HOME DEPOT
50 MM

24 MM

Empire Life
Multiple employee accounts

| 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |

Legend:

Impact

Impact TBD

Source: Company disclosures; Oliver Wyman analysis

What will trigger the next financial crisis?
5 predictions …. and my own

5 *Wall Street Journal* columnists made predictions on Sept. 7, 2018

1. Interest rate jump
   - After a decade of very low interest rates, are we ready for a rise?

2. Bad loan boom
   - Rise of corporate debt and record issuance of low credit quality bonds (near junk and junk)

3. Italy dumps euro

4. China cracks
   - China debt already over 250% of GDP

5. Supply chain disruption
   - Real economic global interconnectedness quickly propagates shocks

- Massive coordinated cyber attack
  - Financial and electricity infrastructure
  - What can central banks do?

Final thoughts

- The great Financial Crisis was a potent reminder that we are not immune from far tail events
  - And a potent reminder of the critical importance of effective risk management

- Post crisis reform has focused on resilience:
  - Can the banks and the banking system withstand large shocks?
  - What is "large"?
  - Which shocks?

- Do banks have enough loss absorbing capacity – capital?
  - Depends on how severe the shock, and how much capital after
  - E.g.: 2018 US stress test
    - Scenario more extreme than financial crisis
    - Banks had more capital *post* stress than US banks had YE 2006

- Host of new vulnerabilities driven by technology

- But: risk managers have a seat at the table for important strategic decisions
  - Banks are more likely to walk into risk taking with their eyes open

Thank you!

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