



# Scenario-Based Stress Testing for Regulatory and Strategic Planning Purposes

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**“Risk Management and Regulation in Banks and Other Financial Institutions**

**How to Achieve Economic Stability?”**

Israel, Jerusalem, June 13-15, 2016

# Agenda

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- 1. Introduction**
- 2. New Generation of Regulatory Stress Tests:  
CCAR vs. EBA Stress Tests**
- 3. Stress Testing as the New Capital Standard**
- 4. A New Framework for Scenario Analysis:  
*Staterix* Approach**
- 5. Conclusions**

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# 1 Introduction

# Introduction

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- **Are current regulatory stress tests useful?**
  - ✓ Thousands of daily stress tests at the risk factor level, historical scenarios... (infrastructure, analysis of limit breaches,...)
  - ✓ Viewed as regulatory constraints: not used in practice to improve risk management.
  - ✓ New EBA stress tests: many shortcomings
- **Need for a new framework:**
  - ✓ CCAR (Comprehensive Capital Assessment Review)
  - ✓ Next generation of stress testing fully incorporated in the business, capital and liquidity planning process of the bank
- **First, some brief historical perspective.**

# Introduction

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- **The October 1987 crash, in many respects, marked the birth of Value at Risk (VaR) as a key risk management tool in financial firms.**
  - ✓ By 1989, Dennis Weatherstone, J.P. Morgan then chairman, called for a "4:15 Report", which combined all of the firm's market risk in one place. That report should contain information sufficient to answer the question "***How much could JPM lose if tomorrow turns out to be a relatively bad day?***"
  - ✓ By 1996, they had published their methodology and the detail of the parametrisation of their risk models: RiskMetrics.
  - ✓ The 1996 Market Risk Amendment to Basel I led to the universal adoption and consecration of VaR by banks worldwide to manage market risk and derive regulatory capital against market risk.

# Introduction

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- **However, each time there is a turmoil in financial markets, the limitations of VaR and other risk metrics are revealed:**
  - ✓ VaR is a static measure assuming liquid markets, and calibrated in pre-crisis regime underestimating volatilities and correlations that prevail during extreme market conditions.
  - ✓ August 1998 (LTCM) and the GFC (2007-2009) are illustrations of these shortcomings of VaR especially when such financial crises are accompanied by a drying up of market liquidity and the occurrence of large tail events.
- **No later than August 2007, the Chief Financial Officer of Goldman Sachs, David Viniar, commented to the *Financial Times*:**
  - ✓ “We are seeing things that were 25-standard deviation moves, several days in a row”.
  - ✓ To provide some context, assuming a normal distribution, a 7.26-sigma daily loss would be expected to occur once every 13.7 billion or so years. That is roughly the estimated age of the universe.

# Introduction

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- **Models are powerful tools, but they involve simplifications. They are static in nature and cannot capture the full extent of risk in all its dimensions (disruption in liquidity, strong non-linearities, jump in volatilities and correlations), potential interactions, systemic interconnections and “think the unthinkable”.**
- **This is where stress testing and scenario analysis comes into play!**
  - ✓ First, it became a policy recommendation by the Derivatives Policy Group in 1995 (stress testing at the risk factor level):
    - Parallel yield curve shift of plus or minus 100 bps
    - Yield curve twist of plus or minus 25 bps
    - Equity index changes of plus or minus 10 percent
    - Currency changes of plus or minus 6 percent.
    - Volatility changes of plus or minus 20 percent.

# Introduction

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- **Then, with the 1996 Basel Amendment to Market Risk stress testing became a regulatory requirement. Banks should subject their portfolio to a series of historical scenarios, such as:**

- ✓ The 1987 equity crash
- ✓ The European Exchange Rate Mechanism (ERM) crises of 1992 and 1993, or
- ✓ The fall in the bond markets in the first quarter of 1994.

- **But it wasn't effective in August 1998 when LTCM failed:**

*"We recognize that stress testing is a developing discipline, but it is clear that adequate testing was not done with respect to the financial conditions that precipitated Long-Term Capital's problems. Effective risk management in a financial institution requires not only modeling, but models that can test the full range of financial transactions across all kinds of adverse market developments. Whether such models existed and, if so, whether they were not effective, are issues that we need to address."*

William McDonough, President of the Federal Reserve Bank of New York before the Committee on Banking and Financial Services, U.S. House of Representatives, October 1, 1998



# Introduction

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- **Ten years later, during the GFC, McDonough's remark still applied: stress tests were still static and not realistic:**
  - ✓ Look at the immediate impact on static portfolios of the cumulative shocks of scenarios which, in real life, unfold over a period of time with management intervention.
  - ✓ Cannot capture liquidity risk which requires a dynamic framework.
- **The GFC showed the need for a holistic testing framework that helps an institution to understand the balance sheet impact of stresses on revenues, losses, and capital adequacy of a whole range of risks and risk interactions, e.g., liquidity and market risk.**

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# 2

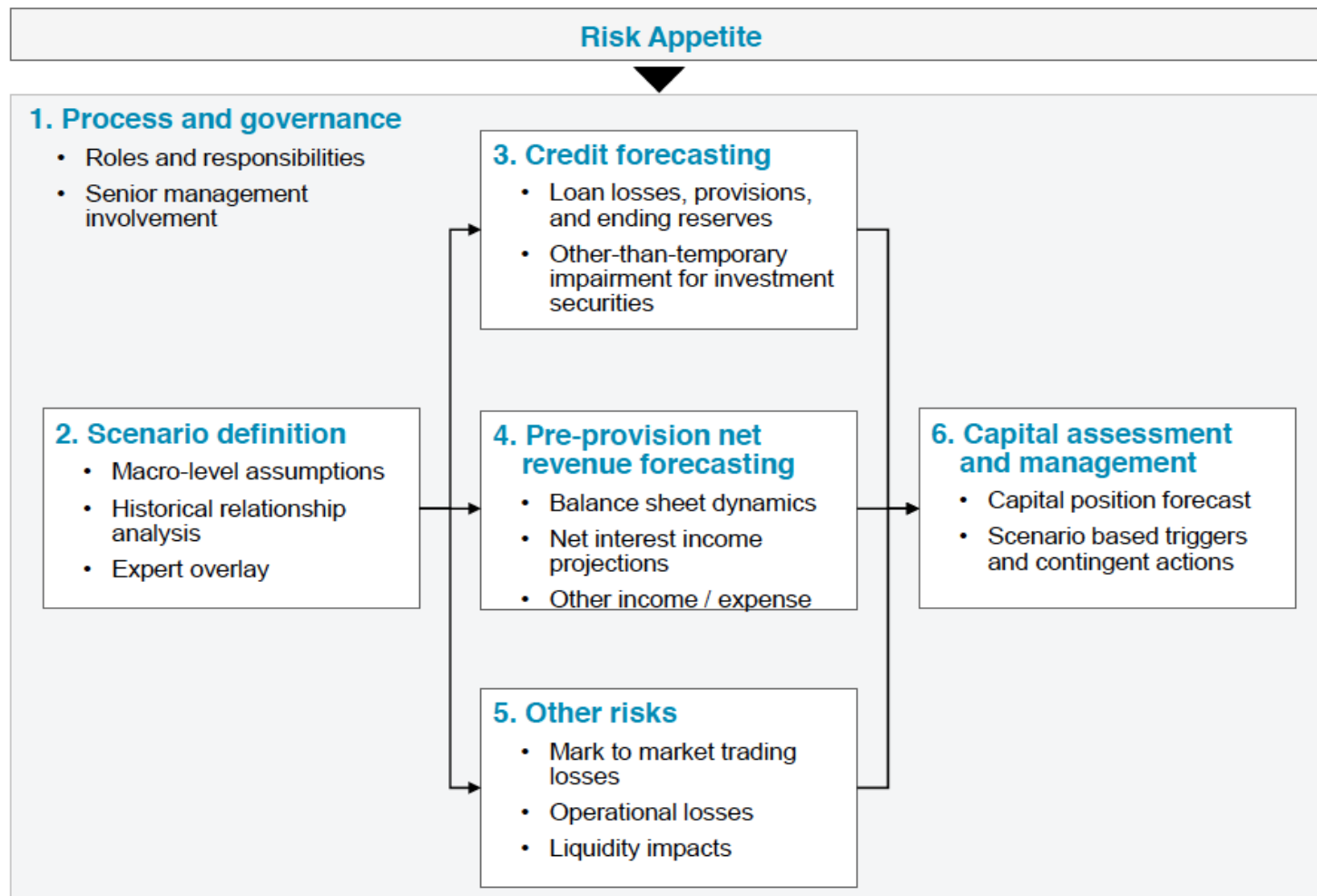
## **New Generation of Stress Tests: CCAR vs. EBA Stress Tests**

# New Generation of Stress Tests

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- **After the GFC, regulators in the U.S., with the Dodd-Frank Act, undertook a “cultural revolution” by instituting:**
  - ✓ a top-down approach with macroeconomic scenarios unfolding over several quarters;
  - ✓ a focus on the effect of macroeconomic downturns on a series of risk including credit risk, market risk, operational risk, business revenues and liquidity risk;
  - ✓ a very demanding approach since risk drivers are not stationary and it requires to adjust along the scenarios PDs, EADs, LGDs, ratings, credit spreads, collateral calls, ...
  - ✓ a “realistic” approach that allows for active management of the portfolios;
  - ✓ a framework that is fully incorporated into the business, capital and liquidity planning process of the bank.
- **In addition, the stress tests look not only at each bank in isolation but across all institutions in order to collect systemic information showing how a major common scenario would affect the largest banks collectively.**

# Key Components of a Bank Stress Testing Program



Source: Oliver Wyman

# DFAST and CCAR

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- **The Dodd-Frank Act (DFA) makes stress testing mandatory for all U.S. banks with assets over \$10 bn and nonbank financial companies designated by the FSOC (Financial Stability Oversight Council).**
- **The Federal Reserve Board (FRB) conducts two complementary exercises: DFAST and CCAR.**
- **DFAST (Dodd-Frank Act Stress Testing)**
  - **Large banks with assets over \$50bn of assets should run DFAST twice a year.**
  - **Banks with assets between \$10 and \$50bn (mid-sized banks) should run DFAST at least once a year.**
  - **The Fed designs 3 scenarios for the annual exercise: baseline, adverse and severely adverse over a 9-quarter planning horizon.**
  - **For the mid-cycle DFAST exercise, large BHCs should run 3 internally generated scenarios (baseline, adverse and severely adverse).**
  - **In addition, large trading institutions must estimate losses under the “Global Market Shock” and “Largest Counterparty Default”.**
  - **Standardized capital action assumptions: dividend distribution as previous year, scheduled dividend, interest, and principal payments are assumed to be paid, stock repurchase not allowed and no issuance of new common stock, preferred stock or other instrument.**

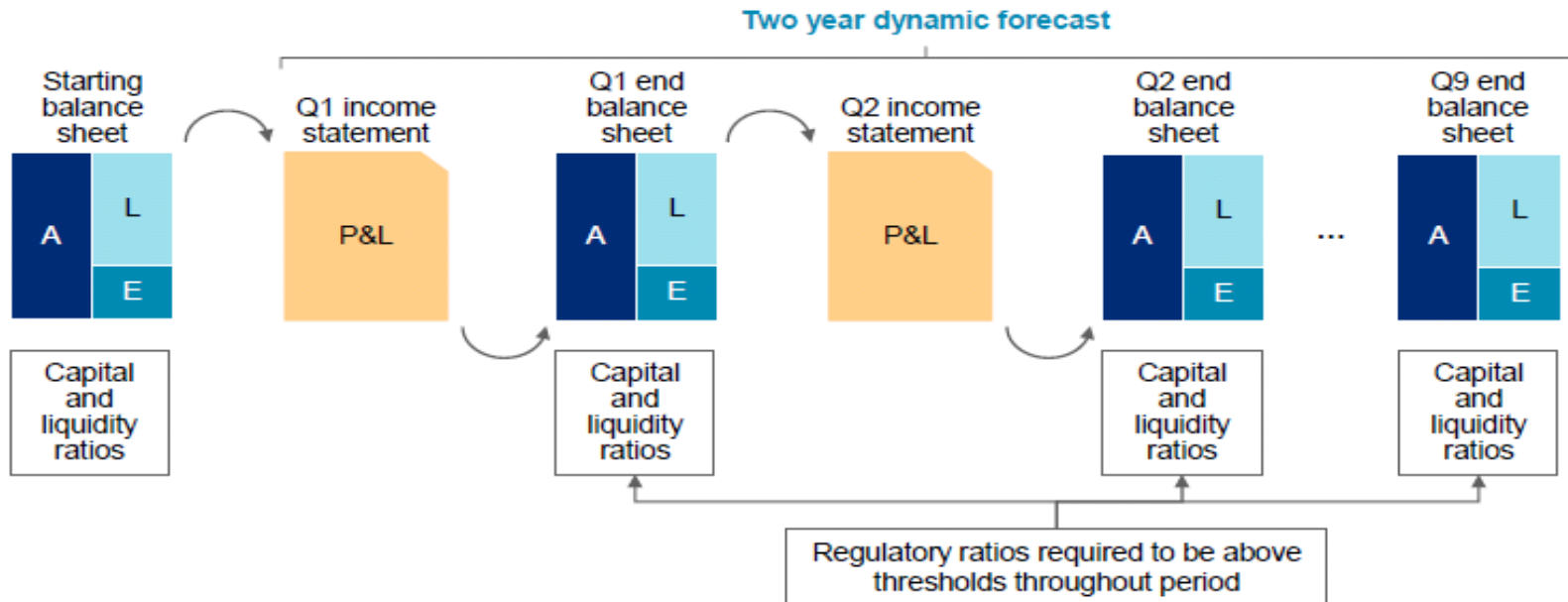
# DFAST and CCAR

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- **CCAR (Comprehensive Capital Analysis and Review)**
  - Annual exercise with the 3 supervisory scenarios and 2 internally generated scenarios (BHC baseline and BHC adverse) appropriate for the business model and portfolios of the bank.
  - BHC to present a capital plan that describes all planned actions (e.g., dividend increases, share repurchases, major acquisitions) over a 9-quarter planning horizon.
  - Banks must maintain a Tier 1 capital ratio of at least 5% throughout the planning period.
  - The Fed's qualitative assessment of the capital plan revolves around the adequacy of the internal processes.
- **31 BHCs participated in the 2015 CCAR exercise. Deutsche Bank was the only new BHC participating in CCAR/DFAST 2015. 9 participants are in the LISCC (Large Institution Supervision Coordinating Committee) for which the Fed has heightened expectations for capital planning process.**
- **2 new banks participate in 2016: BankWest (BNP Paribas) and TD.**
- **Foreign banks (IHC – legal entities) will also be subject to stress testing requirements starting in 2017.**

# DFAST and CCAR

Concretely, stress testing involves dynamic projections of revenue, income/losses, balance sheet, and regulatory ratios – a huge challenge!



- P&L link to balance sheet: how will components of P&L change?
- Volumes and margins: what will the impact on new volume and renewals and be?
- Balance sheet evolution
  - How will the structure (term, mix and availability) of liabilities evolve?
  - How can asset and liability changes be modeled?

Source: Oliver Wyman --

# The Macroeconomic Scenarios

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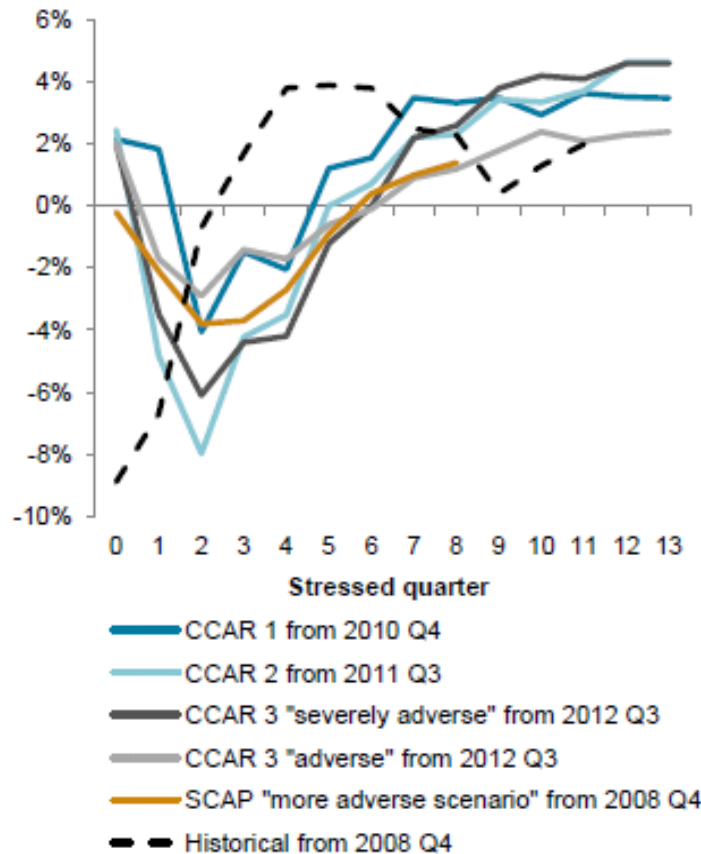
- **A typical macroeconomic scenario should include a recessionary economy characterized by:**
  - Declines in gross domestic product and employment
  - Declines in equity prices, credit quality and house prices
  - Consider different severities: baseline scenario, adverse scenario and severely adverse scenario
  - Recession is followed by a recovery
- **The macroeconomic scenario is specified via trajectories of 28 key economic and market variables over the nine quarters comprising the capital planning period.**
  - The typical macroeconomic stress scenario portrays a recessionary economy characterized by declines in gross domestic product and employment as well as declines in equity prices, credit quality and house prices.
  - The typical scenario displayed a V-shape with the economy initially contracting and then recovering towards the end of the 9-quarter capital planning period
  - The V-shape is important because it determines that the most pressing time for the banks' capital adequacy ratios may be an intermediate point within the capital planning period when the capital ratios reach their minimum levels prior to the healing effects of the ensuing economic recovery
  - Banks should forecast the evolution of the risk drivers (beyond the 28 provided by the Fed)



# Comparing U.S. stress testing scenarios: SCAP (2009), CCAR (2011 to 2013)

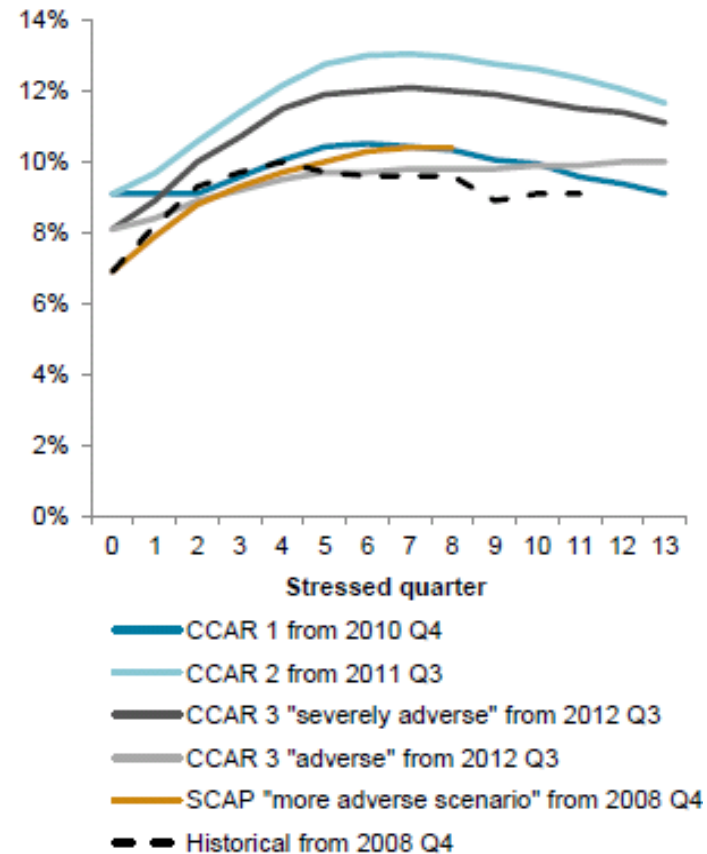
## Real GDP growth

Stress-test scenarios vs. recent historical observations



## Unemployment rate

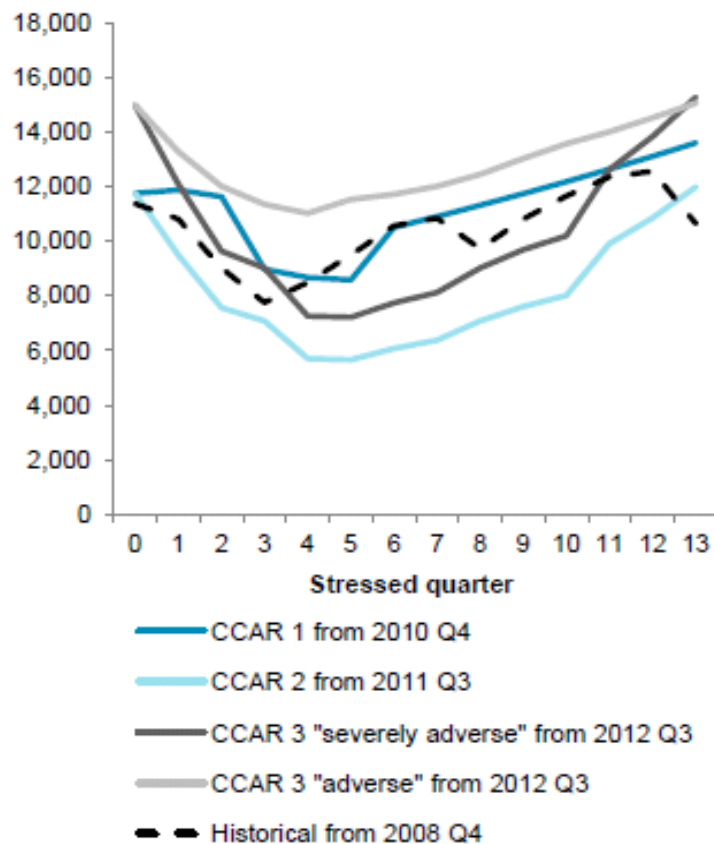
Stress-test scenarios vs. recent historical observations



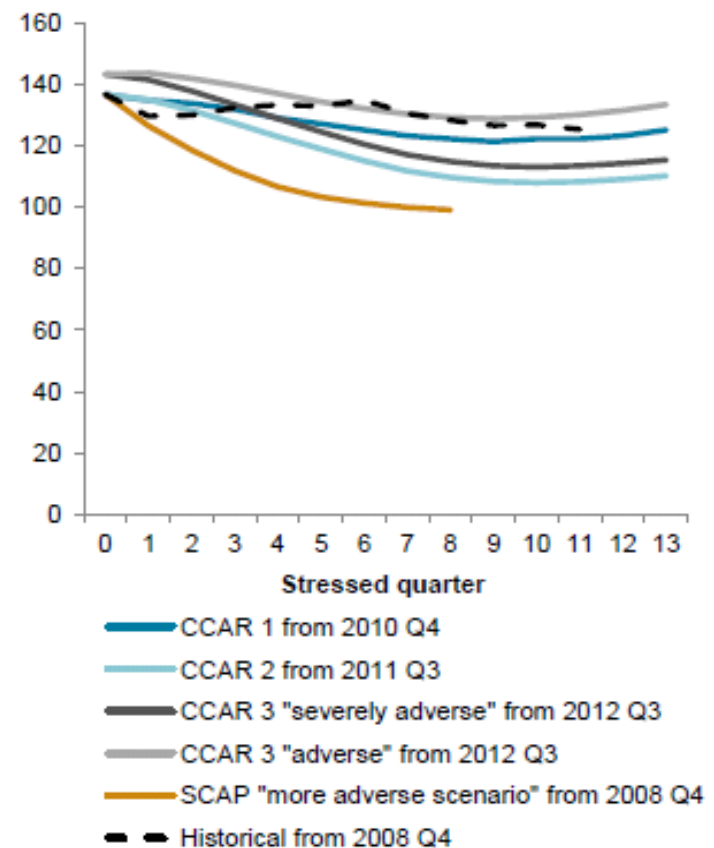
Source: Fed, The Supervisory Capital Assessment Program: Design and Implementation, 24 April 2009; Fed, Comprehensive Capital Analysis and Review: Objectives and Overview, 18 March, 2011; Fed, "Comprehensive Capital Review" document and "Capital Plan review" 22 November 2011; Fed, "2013 Supervisory Scenarios" 15 November 2012; Datastream © Oliver Wyman

# Comparing U.S. stress testing scenarios: SCAP (2009), CCAR (2011 to 2013) (cont'd)

**Dow Jones total stock market index level**  
Stress-test scenarios vs. recent historical observations



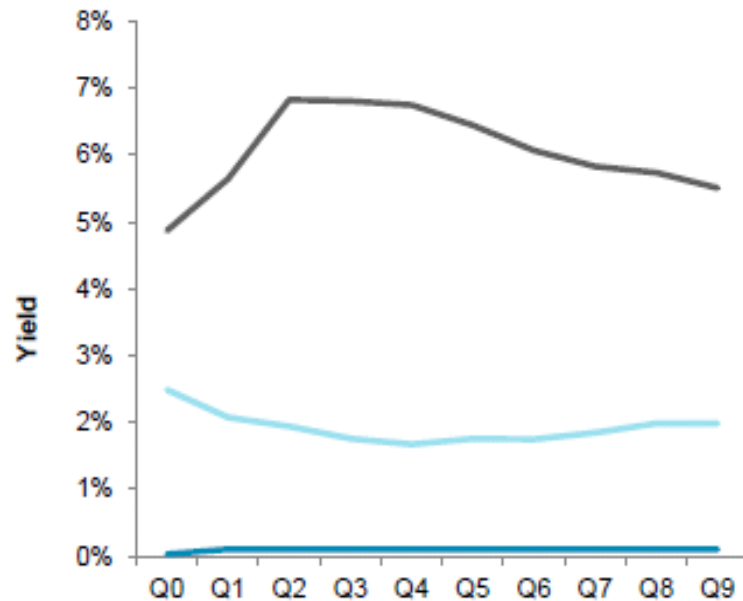
**House Price index**  
Stress-test scenarios vs. recent historical observations



Source: Fed, The Supervisory Capital Assessment Program: Design and Implementation, 24 April 2009; Fed, Comprehensive Capital Analysis and Review: Objectives and Overview, 18 March, 2011; Fed, "Comprehensive Capital Review" document and "Capital Plan review" 22 November 2011; Fed, "2013 Supervisory Scenarios" 15 November 2012; Datastream © Oliver Wyman

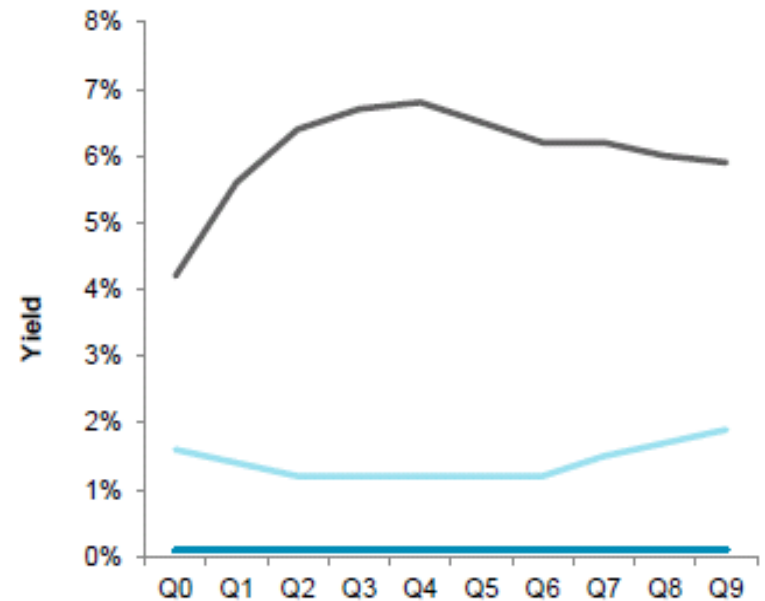
# Interest rates and spreads

**Interest rate environment**  
2012 CCAR supervisory stress test



— 3-month Treasury yield  
— 10-year Treasury yield  
— BBB corporate yield

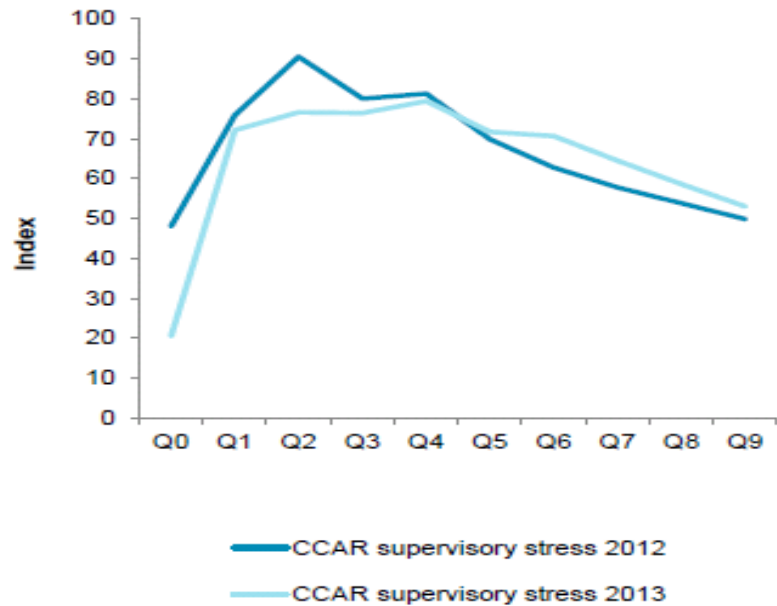
**Interest rate environment**  
2013 CCAR supervisory stress test



— 3-month Treasury yield  
— 10-year Treasury yield  
— BBB corporate yield

# VIX

**Market Volatility Index (VIX)**  
2012 vs. 2013 CCAR supervisory stress test

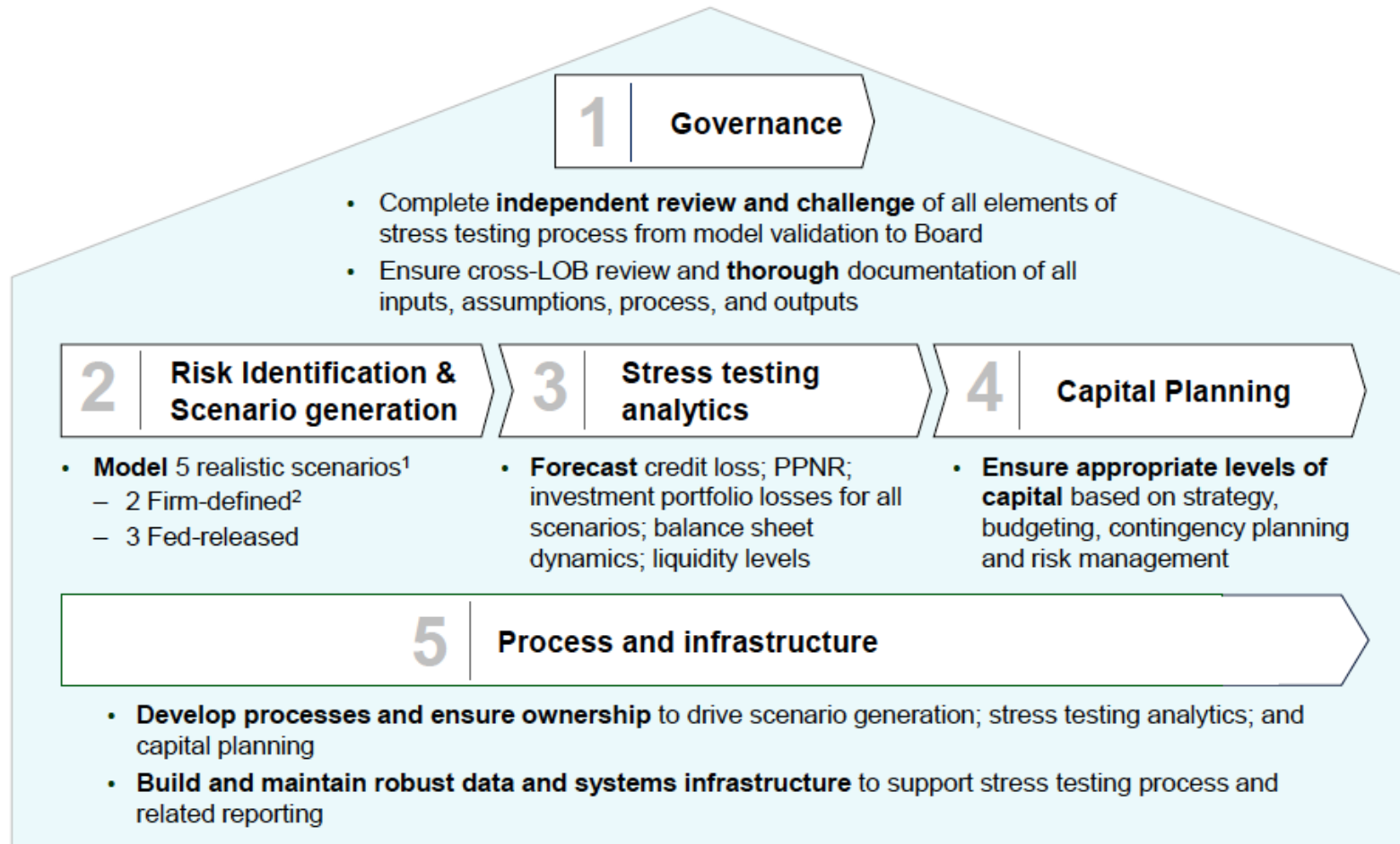


# The Fed Macroeconomic Scenarios

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- The **baseline scenario** is defined as a set of conditions that affect the U.S. economy or the financial condition of a covered company and that reflect the consensus views of the economic and financial outlook. It should reflect the views of the macroeconomic outlook expressed by professional forecasters, government agencies, and other public-sector organizations as of the beginning of the annual stress-test cycle.
- The **adverse scenario** is defined as a set of conditions that affect the U.S. economy or the financial condition of a covered company that are more adverse than those associated with the baseline scenario and may include trading or other additional risk components. The adverse scenario will, at a minimum, include the paths of economic variables that are generally consistent with mild to moderate recessions.
- The **severely adverse scenario** is defined as a set of conditions that affect the U.S. economy or the financial condition of a covered company and that overall are more severe than those associated with the adverse scenario and may include trading or other additional components. The severely adverse scenario will, at a minimum, include the paths of economic variables that are generally consistent with the paths observed during severe post-war U.S. recessions.
- In November of each year, the Federal Reserve specifies the macroeconomic scenario to be used for the annual stress test of banks' profit and losses over the nine calendar quarters following September 30th. The results of those stress tests are publicly reported by the Federal Reserve and by the BHCs in March. At mid-year, each BHC specifies the macroeconomic and market scenarios to be used to project its own profit and losses over the nine calendar quarters following March 31st. The results of those calculations are publicly reported by the BHC in September.

# CCAR Stress Testing Components



Source: Oliver Wyman

# EBA Stress Test 2016

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- **European banks with assets of EUR 30 bn and above must run EBA Stress Test 2016.**
- **Stress test is run at the consolidated level of the banking group (insurance activities are excluded).**
- **2 supervisory macroeconomic scenarios covering the 3-year period 2016 – 2018:**
  - ✓ **Baseline scenario**
  - ✓ **Adverse scenario**
- **Risk coverage:**
  - ✓ **Credit risk including securitization**
  - ✓ **Market risk and counterparty credit risk (CCR)**
  - ✓ **Funding risk (ALM - NII)**
  - ✓ **Operational risk, including conduct risk (e.g., lawsuits for misconduct issues).**

# EBA Stress Test 2016

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- **Methodology different for market risk, credit risk and ALM: no contingent dynamic management actions allowed**
  - ✓ **Market risk**
    - Assess the immediate impact of a one-time global market shock to a broad range of risk factors on MTM value of trading positions including hedges – no dynamic approach.
    - No portfolio management actions allowed in response to the stress scenario (e.g., portfolio rebalancing or liquidation).
    - Full revaluation is required.
    - For CCR it is assumed that the 2 most vulnerable of the largest 10 counterparties default.
  - ✓ **Credit risk**
    - Assess the impact of macro-scenarios on both capital (via credit losses due to credit migration and defaults) and credit risk exposures over the 3-year horizon.
    - Assumption: “dynamic” approach under static balance sheet
      - Defaulted assets (current and in the future) are not replaced: total exposure (defaulted and non-defaulted assets) kept at a constant level.
      - Initial residual maturity is kept constant for all assets throughout the 3-year planning horizon.
      - Need to estimate the relationship between the macroeconomic variables and exposures, point-in-time PDs and LGDs and rating transition matrices.



# EBA Stress Test 2016

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- **Methodology different for market risk, credit risk and ALM**
  - ✓ **ALM**
    - Assess the impact of macroeconomic scenarios on net interest income (NII) over the 3-year planning horizon.
    - “Semi-Dynamic” approach under the constraint of a semi-static balance sheet: assets and liabilities that mature should be replaced with identical instruments in terms of type, maturity, credit quality except for the yield (reference rate and margin) linked to the macroeconomic factors.
- **Conduct risk and other operational risks**
  - ✓ **Qualitative approach to estimating future conduct risk losses.**
  - ✓ **Regulatory approach (Basel III) to estimating operational risk losses.**

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# 3 Stress Testing as the New Capital Standard

# Risk Appetite and Capital Requirements should be Function of the Stress Testing Results

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According to William Dudley in 2011, a planning process should include:

*"description of risk appetite and capital target, robust internal controls, incorporation of stress testing and stress-test results into the decision process, good governance with respect to the role of senior management and the board of directors and well-articulated capital distribution policies that describe how decisions are made relative to expectations of future outcomes"*

William Dudley, President and CEO of the Federal Reserve Bank of New York

# Stress testing in the spirit of CCAR is becoming the capital standard for large banks

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- **Stress testing requires that institutions to be sufficiently capitalized (and “liquid”) to survive extreme macroeconomic scenarios over a given period of time (9 quarters for CCAR but could be longer for strategic planning purpose).**
- **A number of key advantages of dynamic stress testing as a tool to determine aggregate capital :**
  - **ST related to specific tangible scenarios that can be easily understood by non-specialists,**
  - **The capability to rapidly and accurately determine risk exposures under various market environments,**
  - **Not just losses but also revenues and expenses, as well as difficult to quantify risks such as operational risk, compliance risk, reputational risk**
  - **Dynamic and path dependent projections,**
  - **Should outline capital contingency actions to remedy any current or prospective deficiencies in their capital position**
  - **Provides regulator with a measure of systemic risk in the system as well as standalone performance of banks on a like-for-like basis.**

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# 4

## **A New Framework for Scenario Analysis: *Straterix* Approach**

# Overview of the Scenario Analysis Framework

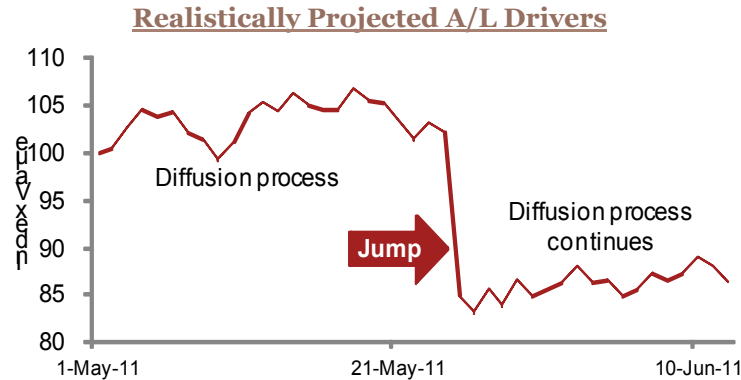
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- **The objectives of the overall framework are to allow the bank to:**
  - ✓ Evaluate its capital planning process on stress scenarios;
  - ✓ Consistently incorporate funding and liquidity considerations;
  - ✓ Identify early warning signals for adverse performance on key metrics (reverse stress testing);
  - ✓ Design, ahead of time, contingency plans based on cost/risk trade-offs;
  - ✓ Incorporate stress scenarios into risk appetite statements and risk limit policies.
- **The above objectives require a comprehensive set of multiple scenarios in addition to the supervisory imposed ones (baseline, adverse, severely adverse).**
- **The framework should capture the initial impact of a shock and the snowball effect it has caused.**
- **The proposed framework should allow to generate adverse “internal” scenarios.**

# Construction of Portfolio Outcomes

**Phase 1**

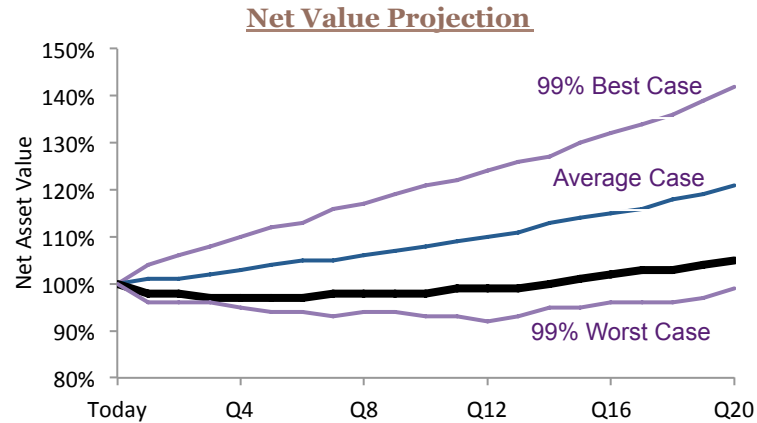
- | Risk Drivers   |
|--|
| <ul style="list-style-type: none"> <li>• Macro</li> <li>• Market</li> <li>• Credit</li> </ul>                  |
| Shock Events   |
| <ul style="list-style-type: none"> <li>• Macro</li> <li>• Geopolitical</li> <li>• Natural Disasters</li> </ul> |



**Phase 2**

- | Portfolio  |
|--|
| <ul style="list-style-type: none"> <li>• Industry/ Sector</li> <li>• Ratings</li> <li>• Maturities</li> <li>• Coupons</li> <li>• Hedges</li> </ul> |

Evaluate portfolios on these scenarios



- Reverse Stress Testing
- Contingency Planning
- Portfolio Optimization
- Includes all Asset Classes and Liability Types
- Serves ALM Needs

# Probabilities and Severities

Shock Event Names (Hist proxy date)	China Event 30/09/2015			European Crisis 01/08/2011			Financial Crisis 15/09/2008			Oil Shock Up 30/06/2008			Oil Shock Down 31/01/2015		
Probability of Events: Low, Average and High	2,00%	3,00%	5,00%	1,50%	3,00%	5,00%	2,50%	3,50%	8,00%	10,00%	20,00%	30,00%	5,00%	10,00%	20,00%
Risk Driver Names	Min Impact	Historical Average	Max Impact	Min Impact	Historical Average	Max Impact	Min Impact	Historical Average	Max Impact	Min Impact	Historical Average	Max Impact	Min Impact	Historical Average	Max Impact
Dow Jones Total Stock Market Index	-3,86%	-4,29%	-19,33%	-1,50%	-10,00%	-19,33%	-5,00%	-6,30%	-19,33%	-5,00%	-6,30%	-19,33%	-1,00%	-4,00%	-19,33%
Market Volatility Index (VIX)	11,33%	30,00%	85,26%	20,00%	30,00%	60,00%	40,00%	64,58%	100,00%	5,00%	15,00%	30,00%	8,82%	15,00%	36,49%
US Unemployment Rate Total in	2,00%	3,00%	10,00%	2,00%	3,00%	10,00%	10,00%	12,00%	18,00%	1,00%	4,00%	6,00%	1,00%	3,00%	5,00%
Oil Prices	-5,00%	-15,00%	-30,00%	-3,00%	-6,00%	-15,00%	-20,00%	-30,00%	-40,00%	20,00%	30,00%	50,00%	-15,00%	-23,00%	-45,00%
3-month Treasury rate	0,00%	0,00%	10,00%	0,00%	0,00%	10,00%	-10,00%	-30,00%	-50,00%	2,00%	7,00%	30,00%	0,00%	0,00%	-10,00%
5-year Treasury yield	-3,00%	-5,00%	-15,00%	-3,00%	-13,00%	-40,00%	-4,00%	-6,00%	-20,00%	0,00%	10,00%	15,00%	0,00%	-18,00%	-25,00%
10-year Treasury yield	-2,00%	-7,00%	-20,00%	-6,00%	-26,00%	-40,00%	-2,00%	-6,00%	-20,00%	0,00%	6,00%	10,00%	0,00%	-16,00%	-25,00%
BBB corporate yield	1,00%	3,00%	10,00%	0,00%	-3,00%	-7,00%	2,00%	10,00%	20,00%	0,00%	2,00%	20,00%	0,00%	-4,00%	-10,00%
Euro Area Real GDP Growth	0,00%	11,00%	15,00%	-60,00%	-100,00%	-150,00%	-50,00%	-100,00%	-200,00%	-50,00%	-100,00%	-150,00%	5,00%	13,00%	20,00%
Real GDP growth rate	0,00%	-40,00%	-60,00%	0,00%	-70,00%	-100,00%	-100,00%	-200,00%	-400,00%	0,00%	-50,00%	-100,00%	0,00%	2,00%	5,00%
France CDS	-2,00%	-7,00%	-20,00%	10,00%	40,00%	50,00%	5,00%	30,00%	100,00%	0,00%	11,00%	50,00%	0,00%	-6,00%	-15,00%
CDS for Fin-AA	0,00%	2,00%	20,00%	2,00%	18,00%	30,00%	15,00%	45,00%	60,00%	0,00%	20,00%	30,00%	-2,00%	-6,00%	-10,00%
CDS for Fin-A	0,00%	2,00%	10,00%	2,00%	20,00%	25,00%	10,00%	30,00%	50,00%	5,00%	15,00%	35,00%	-2,00%	-6,00%	-15,00%
CDS for Fin-BBB	0,00%	1,00%	10,00%	2,00%	18,00%	25,00%	5,00%	30,00%	50,00%	10,00%	20,00%	50,00%	-2,00%	-6,00%	-10,00%
Industrials CDS -AA	1,50%	4,00%	10,00%	4,00%	28,00%	35,00%	5,00%	25,00%	50,00%	5,00%	10,00%	50,00%	-4,00%	-7,00%	-15,00%
Industrials CDS - A	0,00%	1,50%	10,00%	2,00%	21,00%	30,00%	10,00%	40,00%	60,00%	4,00%	9,00%	25,00%	0,00%	-5,00%	-10,00%
Industrials CDS - BBB	0,00%	6,00%	20,00%	1,00%	20,00%	30,00%	10,00%	35,00%	60,00%	5,00%	10,00%	30,00%	0,00%	-7,00%	-10,00%
Industrials CDS - HY	0,00%	3,00%	5,00%	0,00%	2,00%	10,00%	-1,00%	-7,00%	-20,00%	0,00%	-4,00%	-7,00%	0,00%	1,50%	5,00%
Oil CDS - AA	n/a	n/a	n/a	4,00%	22,00%	30,00%	10,00%	35,00%	40,00%	2,00%	12,00%	35,00%	n/a	n/a	n/a
Oil CDS - A	n/a	n/a	n/a	2,00%	15,00%	30,00%	2,00%	4,00%	20,00%	0,00%	-4,00%	-20,00%	n/a	n/a	n/a
Oil CDS - BBB	n/a	n/a	n/a	2,00%	25,00%	30,00%	2,00%	25,00%	60,00%	0,00%	-10,00%	-30,00%	n/a	n/a	n/a
Oil CDS - HY	-1,00%	-2,00%	-5,00%	-1,00%	-4,00%	-8,00%	-1,00%	-8,00%	-20,00%	-1,00%	-4,00%	-10,00%	1,00%	2,00%	5,00%
Wheat Prices	2,00%	3,00%	5,00%	-1,00%	-5,00%	-20,00%	-3,00%	-15,00%	-20,00%	-3,00%	-10,00%	-20,00%	-2,00%	-5,00%	-15,00%



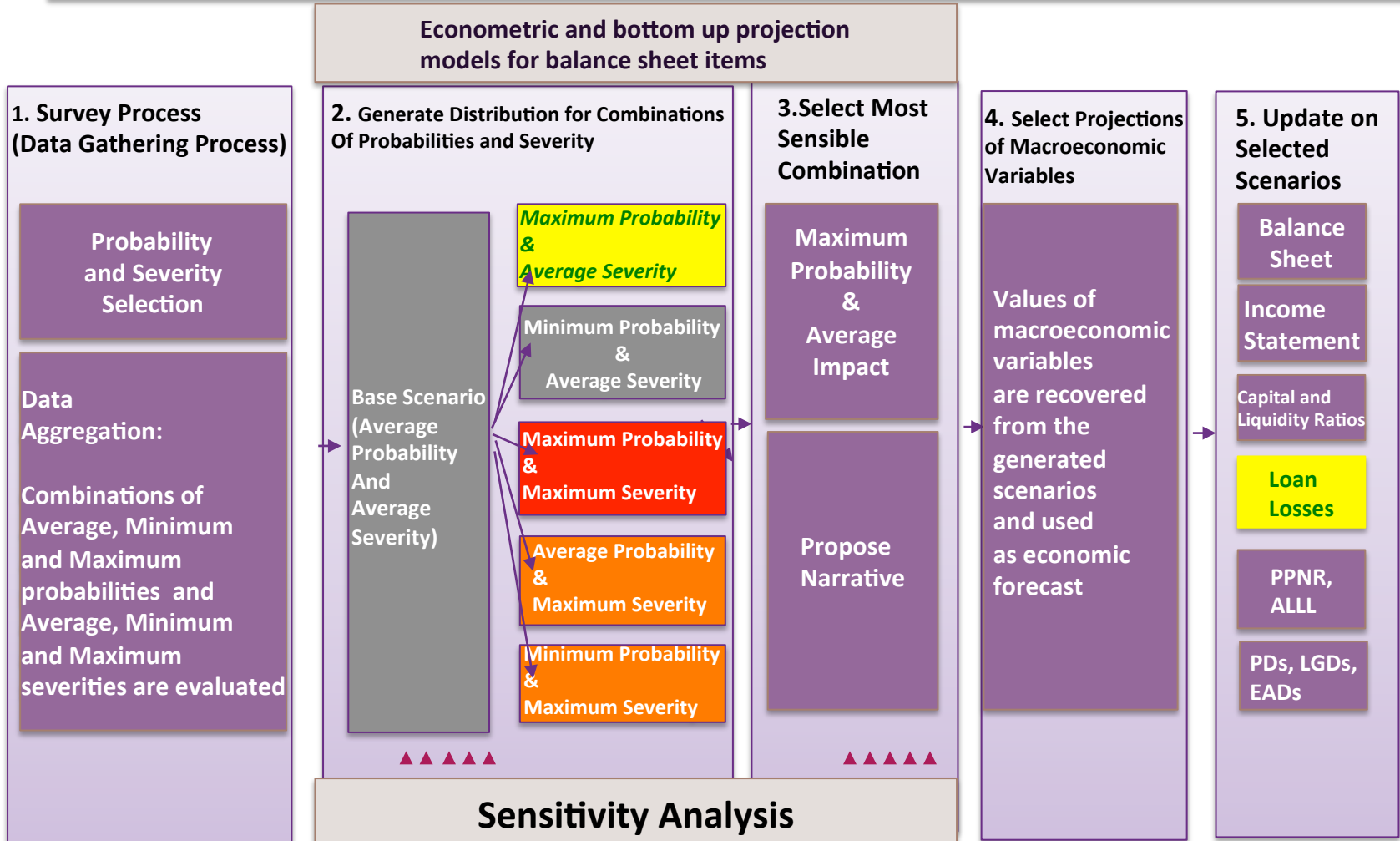
# Probabilities and Severities Calibration Process

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- 1. Business leaders select potential shock events that would form stress scenarios, their probabilities and severities (impact on risk drivers).**
- 2. Their opinions are statistically analyzed in conjunction with historical observations.**
- 3. As a result, the table of full ranges is formed, from the lowest (Min) values for probability and severity to average and then the highest (Max), for each shock and each risk driver.**

# Scenario Generation Process – Flowchart

## End to End Process



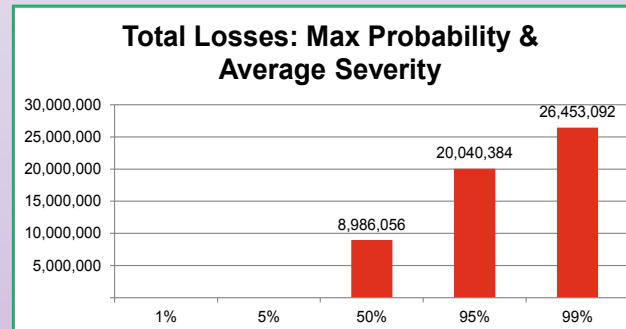
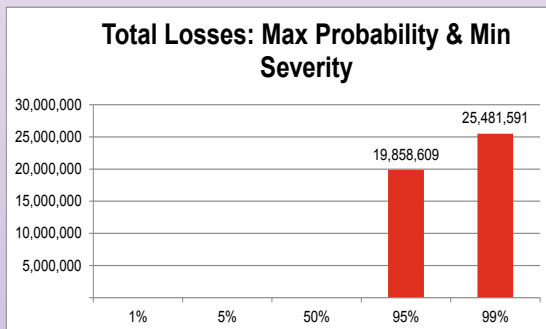
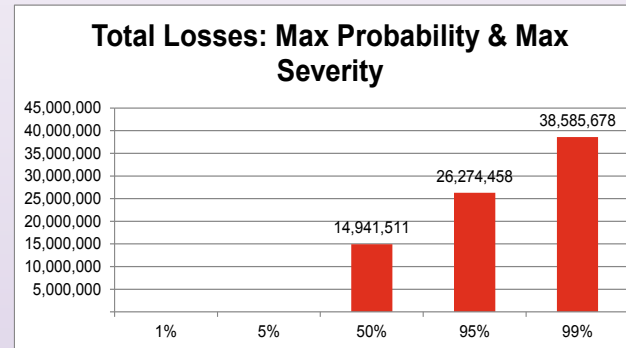
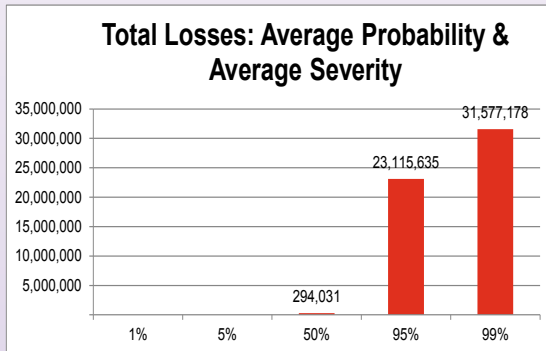
# Selection of Appropriate Combination

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- 1. For each combination of these values (Max probability – Max severity, Max probability – Average severity, etc.) the new set of scenarios is generated (jump-diffusion Monte-Carlo engine)**
- 2. In the study we performed at Natixis, limited to a well diversified loan portfolio, the key performance indicator (e.g., cumulative credit loss over a 3-year period) was chosen as the selection criteria for sensitivity analysis**
- 3. The results of such analysis are in the histograms below**
- 4. The most reasonable combination is chosen based on the 50<sup>th</sup> percentile and should reflect business intuition**

# Sensitivity Analysis

Compare the distributions for combinations of probabilities and severity (impacts)



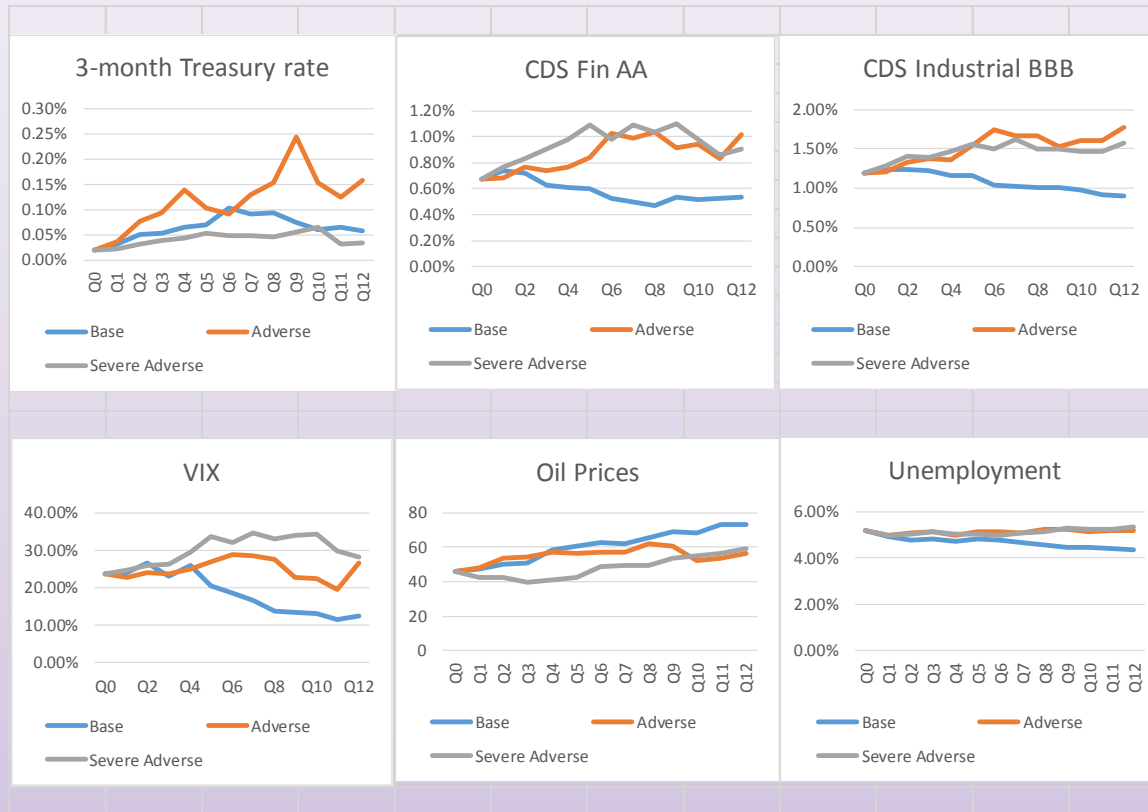
# Discovery of Stress Scenarios

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- 1. Using the set of scenarios and loan portfolio outcomes, select the specific scenario numbers corresponding to:**
  - **50<sup>th</sup> percentile – to be used and base case**
  - **5<sup>th</sup> percentile – to be used as adverse scenario**
  - **1<sup>st</sup> percentile to be used as severely adverse scenario**
- 2. Collect the values of risk drivers on these selected scenarios**
- 3. Average a few paths surrounding the respective percentiles to form a robust image of adverse environments**
- 4. Find the scenarios where the values for Fed variables are close to respectively Base, Adverse and Severely Adverse scenarios and obtain the values for internal variables on these scenarios**
- 5. Analyze the outcomes and build scenario narratives**

# Scenario Quantification

## Extract macroeconomic variables



From this selected distribution, we obtain the values of the macro variables that produced the adverse and severely adverse outcomes

# Insights Derived from the Scenario Analysis

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- **Sensitivity to the short-term rate should disappear when liabilities are added**
- **Exposure to increased credit spreads (warning signals for rising PDs) and market volatility (warning signals for rising LGD) might be mitigated by the diversification effect if other asset classes benefit from the same condition**
- **Exposure to low oil prices overweighs the exposure to high ones**
- **Lack of sensitivity to unemployment might change if retail asset classes or other portfolios are incorporated**

# Step 1 – Select Internal Variables

Description / Date	Dow Jones Total Stock Market Index	Market Volatility Index (VIX)	US Unemployment Rate Total in	Oil Prices	3-month Treasury rate	CDS Fin AA, 5Y	CDS INDUST BBB, 5Y	CDS INDUST HY, 5Y	Funded-Comm Ratio
...									
2009Q2	8592.99864	26.35%	9.30%	69.271	0.18%	1.53%	1.79%	1.32%	72.94%
2009Q3	9626.16636	25.61%	9.60%	68.147	0.12%	0.91%	1.35%	1.49%	71.04%
2009Q4	10437.2109	21.68%	9.90%	75.257	0.05%	1.02%	1.29%	1.57%	69.18%
2010Q1	10677.5187	17.59%	9.80%	79.931	0.15%	0.98%	1.18%	1.62%	68.20%
2010Q2	10159.2673	34.54%	9.60%	75.659	0.12%	1.52%	1.38%	1.61%	66.19%
2010Q3	10591.2418	23.70%	9.50%	78.417	0.15%	1.22%	1.32%	1.72%	69.12%
2010Q4	11469.963	17.75%	9.60%	92.255	0.14%	1.41%	1.21%	1.77%	61.96%
2011Q1	12081.4765	17.74%	9.00%	114.67	0.10%	1.24%	1.19%	1.84%	59.78%
2011Q2	12097.3095	16.52%	9.10%	113.9	0.04%	1.26%	1.18%	1.85%	57.99%
2011Q3	11164.7491	42.96%	9.00%	109.91	0.01%	2.12%	1.84%	1.73%	57.85%
...									
2013Q4	16107.6736	13.72%	7.00%	110.76	0.07%	0.89%	1.04%	2.26%	46.70%
2014Q1	16308.6276	13.88%	6.70%	107.75	0.05%	0.71%	1.03%	2.32%	45.03%
2014Q2	16843.7548	11.57%	6.20%	111.97	0.04%	0.60%	0.95%	2.38%	45.70%
2014Q3	17098.1414	16.31%	6.10%	98.57	0.02%	0.59%	0.97%	2.32%	48.63%
2014Q4	17766.2391	19.20%	5.70%	63.135	0.03%	0.63%	0.94%	2.31%	48.02%
2015Q1	17931.745	15.29%	5.57%	56.939	0.03%	0.62%	0.85%	2.36%	47.17%
2015Q2	17927.2191	18.23%	5.40%	63.753	0.02%	0.66%	0.97%	2.35%	45.73%
2015Q3	16329.1514	23.62%	5.17%	48.54	0.02%	0.80%	1.25%	2.23%	48.47%

	Total Funded	Total Commitment	Funded-Comm Ratio
<b>(Intercept)</b>	-0.3243	3.7226	-0.9310
<b>Dow Jones Total Stock Market Index</b>			-0.2925
<b>Market Volatility Index (VIX)</b>		0.0387	
<b>US Unemployment Rate Total in</b>	-0.2487	-0.4171	
<b>Oil Prices</b>	-0.2253	-0.1270	
<b>3-month Treasury rate</b>	-0.0184	-0.0175	
<b>Euro Area Real GDP Growth</b>			1.4779
<b>Real GDP growth rate</b>	1.2076	0.5178	
<b>CDS Fin AA, 5Y</b>		-0.0974	
<b>CDS INDUST BBB, 5Y</b>	-0.4619	-0.2050	-0.0994
<b>CDS INDUST HY, 5Y</b>	-1.7082	-0.8226	-0.6740
<b>Wheat Price</b>	0.1835	0.1751	

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# Step 2 – Select Scenarios Closest to Fed (Base)

OCC DFAST 10-50 Scenario Variables: Base Scenario

Variable Name	Actual As of 12/31	Projected								
		PQ1 (3/31)	PQ2 (6/30)	PQ3 (9/30)	PQ4 (12/31)	PQ5 (3/31)	PQ6 (6/30)	PQ7 (9/30)	PQ8 (12/31)	PQ9 (3/31)
Dow Jones Total Stock Market Index	17,728	17,961	18,189	18,428	18,671	18,918	19,165	19,414	19,664	19,918
Market Volatility Index (VIX)	23.62%	23.50%	25.19%	24.95%	25.55%	25.67%	26.15%	26.15%	26.39%	26.51%
US Unemployment Rate Total in	5.17%	4.98%	4.98%	4.98%	4.89%	4.89%	4.89%	4.89%	4.89%	4.89%
3-month Treasury rate	0.02%	0.03%	0.05%	0.06%	0.07%	0.08%	0.09%	0.09%	0.10%	0.11%
5-year Treasury yield	1.49%	1.61%	1.79%	1.91%	2.03%	2.15%	2.21%	2.26%	2.32%	2.38%
10-year Treasury yield	2.17%	2.30%	2.37%	2.43%	2.56%	2.63%	2.70%	2.76%	2.76%	2.83%
BBB corporate yield	5.34%	5.45%	5.66%	5.77%	5.87%	5.98%	6.19%	6.19%	6.30%	6.41%
Euro Area Real GDP Growth	1.96%	2.08%	2.08%	2.08%	2.21%	2.08%	2.08%	2.08%	2.08%	2.08%
Real GDP growth rate	2.31%	2.90%	2.90%	2.90%	2.90%	2.90%	2.70%	2.70%	2.60%	2.60%
Oil Prices	45.93	49.50	54.70	52.99	53.64	56.27	59.17	63.79	65.52	67.69
CDS Fin AA, 5Y	0.67%	0.80%	0.84%	0.78%	0.66%	0.55%	0.50%	0.51%	0.58%	0.64%
CDS INDUST BBB, 5Y	1.20%	1.43%	1.36%	1.33%	1.04%	0.98%	0.90%	0.80%	0.84%	0.82%
CDS INDUST HY, 5Y	2.22%	2.15%	2.11%	2.06%	2.06%	2.06%	2.07%	2.08%	1.99%	1.93%
Wheat Price	648	665	678	652	610	568	504	507	536	567
Total Funded	13,745	13,530	14,275	15,038	16,849	17,562	17,346	17,617	18,674	19,709
Total Commitment	28,273	27,954	28,997	29,759	31,332	32,165	31,635	31,244	32,312	32,913
Funded-Comm Ratio	48%	48%	48%	50%	51%	52%	52%	52%	53%	54%

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# Step 2 – Select Scenarios Closest to Fed (Adverse)

OCC DFAST 10-50 Scenario Variables: Adverse Scenario

Variable Name	Actual As of 12/31	Projected								
		PQ1 (3/31)	PQ2 (6/30)	PQ3 (9/30)	PQ4 (12/31)	PQ5 (3/31)	PQ6 (6/30)	PQ7 (9/30)	PQ8 (12/31)	PQ9 (3/31)
Dow Jones Total Stock Market Index	17,728	16,970	16,427	16,107	15,854	15,649	15,518	15,440	15,456	15,663
Market Volatility Index (VIX)	23.62%	21.54%	21.28%	19.73%	18.52%	17.74%	17.13%	16.78%	16.53%	16.61%
US Unemployment Rate Total in	5.17%	5.31%	5.45%	5.52%	5.52%	5.59%	5.59%	5.59%	5.59%	5.59%
3-month Treasury rate	0.02%	0.02%	0.03%	0.03%	0.04%	0.04%	0.04%	0.05%	0.05%	0.05%
5-year Treasury yield	1.49%	1.61%	1.73%	1.81%	1.93%	2.01%	2.09%	2.13%	2.21%	2.21%
10-year Treasury yield	2.17%	2.32%	2.42%	2.52%	2.62%	2.73%	2.78%	2.88%	2.93%	2.93%
BBB corporate yield	5.34%	5.42%	5.65%	5.72%	5.72%	5.80%	5.80%	5.87%	5.87%	5.87%
Euro Area Real GDP Growth	1.96%	-0.50%	0.40%	1.10%	1.70%	2.10%	2.10%	2.10%	2.00%	2.00%
Real GDP growth rate	2.31%	0.30%	0.80%	1.20%	1.70%	1.80%	1.80%	1.90%	2.00%	2.20%
Oil Prices	45.93	51.16	48.22	47.66	48.97	51.11	49.88	49.09	52.09	49.49
CDS Fin AA, 5Y	0.67%	0.86%	0.92%	0.93%	0.78%	0.72%	0.58%	0.65%	0.68%	0.55%
CDS INDUST BBB, 5Y	1.20%	1.40%	1.44%	1.40%	1.27%	1.20%	0.99%	0.94%	0.89%	0.91%
CDS INDUST HY, 5Y	2.22%	2.22%	2.10%	2.03%	1.96%	1.94%	2.01%	1.99%	1.96%	1.98%
Wheat Price	648	625	638	693	778	813	818	812	869	817
Total Funded	13,745	12,417	13,486	14,915	17,249	18,454	19,211	19,808	21,191	20,852
Total Commitment	28,273	26,408	27,419	29,127	31,946	32,815	33,998	34,238	35,869	35,409
Funded-Comm Ratio	48%	47%	48%	49%	51%	52%	54%	54%	54%	54%

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# Step 2 – Select Scenarios Closest to Fed (Severely Adverse)

OCC DFAST 10-50 Scenario Variables: Severe;y Adverse Scenario

Variable Name	Actual As of 12/31	Projected								
		PQ1 (3/31)	PQ2 (6/30)	PQ3 (9/30)	PQ4 (12/31)	PQ5 (3/31)	PQ6 (6/30)	PQ7 (9/30)	PQ8 (12/31)	PQ9 (3/31)
Dow Jones Total Stock Market Index	17,728	15,448	13,167	10,887	8,606	9,087	9,607	10,481	11,521	12,895
Market Volatility Index (VIX)	23.62%	29.74%	35.86%	41.98%	48.10%	38.40%	30.70%	25.50%	21.60%	18.70%
US Unemployment Rate Total in	5.17%	6.25%	7.33%	8.42%	9.50%	9.90%	10.00%	10.10%	10.00%	9.90%
3-month Treasury rate	0.02%	0.04%	0.06%	0.08%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%
5-year Treasury yield	1.49%	1.20%	0.90%	0.60%	0.40%	0.50%	0.60%	0.80%	0.90%	1.10%
10-year Treasury yield	2.17%	1.97%	1.70%	1.50%	1.30%	1.50%	1.50%	1.60%	1.80%	1.90%
BBB corporate yield	5.34%	5.60%	5.80%	6.05%	6.30%	6.20%	6.00%	5.80%	5.60%	5.50%
Euro Area Real GDP Growth	1.96%	1.50%	0.50%	-0.50%	-1.50%	-0.10%	1.00%	1.70%	2.10%	2.20%
Real GDP growth rate	2.31%	1.50%	-0.50%	-2.00%	-3.20%	-1.50%	1.20%	1.20%	3.00%	3.00%
Oil Prices	45.93	50.01	53.38	56.97	56.49	53.81	54.19	51.83	51.30	53.77
CDS Fin AA, 5Y	0.67%	0.71%	0.80%	0.88%	0.73%	0.64%	0.52%	0.43%	0.47%	0.46%
CDS INDUST BBB, 5Y	1.20%	1.18%	1.32%	1.36%	1.19%	1.21%	1.06%	0.94%	0.97%	0.98%
CDS INDUST HY, 5Y	2.22%	2.17%	2.11%	2.04%	1.98%	1.94%	1.92%	1.95%	1.95%	1.92%
Wheat Price	648	637	623	608	636	640	615	658	671	691
Total Funded	13,745	14,196	13,847	13,862	16,100	17,605	18,403	20,030	20,842	21,121
Total Commitment	28,273	28,675	28,073	28,022	30,782	32,853	33,842	35,633	35,833	36,356
Funded-Comm Ratio	48%	48%	48%	49%	50%	51%	51%	52%	52%	52%

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# Step 3 – Balance Sheet and Income Statement Projections (Illustrative)

Scenario Summaries	Actual	Projected									Comments and Assumptions
	As of 12/31/2015	PQ1 (3/31)	PQ2 (6/30)	PQ3 (9/30)	PQ4 (12/31)	PQ5 (3/31)	PQ6 (6/30)	PQ7 (9/30)	PQ8 (12/31)	PQ9 (3/31)	
<b>Adverse Scenario</b>											
Total loan and lease net charge-offs	129	481	861	1,443	1,955	1,531	1,334	1,615	2,405	2,374	Interest Income = 116bps for loans and leases and 25bps for other assets adjusted for risk free rate changes
Pre-provision net revenue	32,762	63,292	65,183	71,963	76,350	99,199	100,032	92,650	91,774	96,627	
Interest Income	61,062	93,087	95,264	102,236	106,909	129,950	130,974	123,688	123,003	127,856	Interest Expense = 8bps of total liabilities. Half of it adjusted for interest rate changes
Interest Expense	4,719	6,214	6,501	6,692	6,979	7,170	7,361	7,456	7,648	7,648	
Non-interest income	5,164	5,164	5,164	5,164	5,164	5,164	5,164	5,164	5,164	5,164	NI = [PPNR - Loan Loss Provisions (NCO)]*(1-33% tax rate)
Non-interest expense	28,745	28,745	28,745	28,745	28,745	28,745	28,745	28,745	28,745	28,745	
Net income	21,017	23,803	30,521	33,150	34,302	44,020	44,803	51,998	64,753	68,477	Loan reserves = 70bps of loans and leases
Allowance for loan and lease losses	32,191	31,501	29,859	30,745	30,074	35,656	34,532	31,672	30,285	31,497	Total Loans and Leases plus Other Assets
Total assets	7,306,621	7,050,293	6,815,624	6,942,249	6,846,414	7,643,817	7,483,304	7,074,712	6,876,508	7,049,620	
Total Loans & Leases	4,756,505	4,500,177	4,265,508	4,392,133	4,296,298	5,093,701	4,933,188	4,524,596	4,326,392	4,499,504	
Other Assets	2,550,116	2,550,116	2,550,116	2,550,116	2,550,116	2,550,116	2,550,116	2,550,116	2,550,116	2,550,116	
Total liabilities	5,974,752	5,974,752	5,974,752	5,974,752	5,974,752	5,974,752	5,974,752	5,974,752	5,974,752	5,974,752	
Dividends, share repurchases, and sale, conversion, acquisition, or retirement of capital stock	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	
Total equity capital	1,331,869	1,075,541	840,872	967,497	871,662	1,669,065	1,508,552	1,099,960	901,756	1,074,868	Assets minus liabilities
Common equity tier 1 risk-based capital ratio	11.73%	9.91%	8.01%	9.05%	8.27%	14.18%	13.09%	10.10%	8.52%	9.90%	CET1 / RWA
Tier 1 Common Capital (CET1)	676,464	537,771	420,436	483,749	435,831	834,533	754,276	549,980	450,878	537,434	CET1=50% of Total Equity Capital
Risk Weighted Assets	5,765,564	5,428,726	5,248,031	5,345,532	5,271,739	5,885,739	5,762,144	5,447,528	5,294,911	5,428,207	RWA=77% of total assets
Tier 1 risk-based capital ratio	11.73%	9.91%	8.01%	9.05%	8.27%	14.18%	13.09%	10.10%	8.52%	9.90%	Tier 1 Capital / RWA
Tier 1 Capital	676,464	537,771	420,436	483,749	435,831	834,533	754,276	549,980	450,878	537,434	T1=CET1
Tier 1 leverage ratio	10.18%	8.48%	6.85%	7.74%	7.07%	12.13%	11.20%	8.64%	7.29%	8.47%	Tier 1 Capital / Total Assets for Leverage Ratio (=90% of total assets)
Total Assets for Leverage Ratio	6,644,839	6,345,264	6,134,062	6,248,024	6,161,773	6,879,436	6,734,973	6,367,241	6,188,857	6,344,658	
Total risk-based capital ratio	12.30%	10.50%	8.49%	9.59%	8.76%	15.03%	13.88%	10.70%	9.03%	10.49%	Total Capital / RWA
Total Capital	709,195	570,037	445,662	512,773	461,981	884,605	799,532	582,979	477,931	569,680	T1 + T2 Capital(=3% of total equity capital)

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# 5 Conclusions

# Conclusions

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- ❑ **A transparent and well documented stress testing and idiosyncratic scenario identification process is proposed that can be validated quantitatively.**
- ❑ **The internal business experts provided valuable inputs that allowed us to forecast internal variables consistently with the ones provided by the regulator.**
- ❑ **Rigorous process: for each scenario we can produce a narrative well grounded on the quantification process.**
- ❑ **This framework will allow the bank to respond quickly to queries from the regulator: “What would be the impact of a given macro-shock on the bank (capital, liquidity positions...)”**