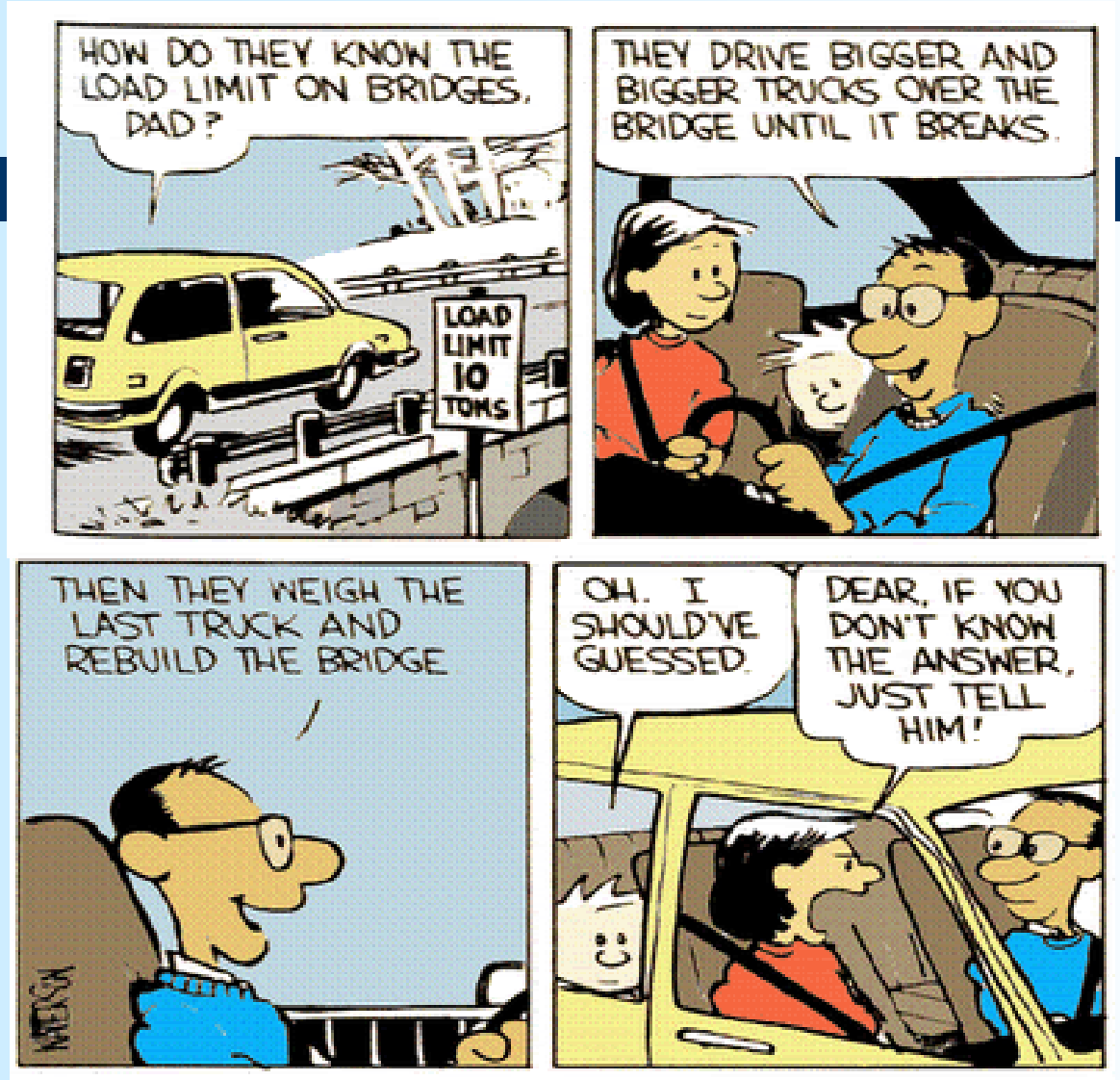
Stress Testing Methodology

Wholesale
Lending
Portfolio Loss
Estimation

One view on stress testing …



Calvin & Hobbes
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Session Objectives

1. General expectations
2. Common segmentation approaches
3. Common loss estimation approaches
4. Range of practice
5. Supervisory evaluation

Objective 1:
General Expectations

1. **General expectations for loss estimation**
2. Common segmentation approaches
3. Common loss estimation approaches
4. Range of practice
5. Supervisory evaluation

General Expectations

- Methodologies should:
  - Effectively capture risks in the credit portfolios
  - Generate credible estimates with a clear linkage to scenario conditions and supported by sound assumptions and empirical evidence
  - Be quantitative (i.e., statistically-based), where possible
    - However, in some cases, a qualitative approach or management overlay may be appropriate (e.g., due to data limitations, new products or businesses)
  - Are forward-looking taking into account latent risks
  - Are transparent and repeatable
- BHCs should understand and account for the uncertainties around the model estimates

General Expectations: Quantitative Approaches

- BHCs can use a range of quantitative approaches depending on:
  - Type and materiality of portfolio
  - Availability of data
- Models should produce loss estimates at a sufficiently granular level to identify common risk drivers and capture the effect of changing conditions
  - This can be achieved via segmentation or loan-level loss estimation
- BHCs with leading practices
  - Conduct sensitivity analysis of key variables, parameters, and assumptions
  - Use challenger / benchmarking models to compare to primary model output
  - Have a robust risk driver selection process detailing which drivers were selected and which were ultimately rejected

General Expectations: Qualitative Approaches

- Most BHCs use some form of expert judgment
  - Most commonly as a management overlay to modeled outputs
- Management overlays:
  - Account for unique risks of certain portfolios not captured by the models
  - Compensate for model and data limitations
  - Account for uncertainty in model output (model risk)
- Expert judgment should be:
  - Well supported with quantitative analysis and empirical evidence
  - Directionally conservative, except in very rare well supported cases
  - Part of a transparent, repeatable, documented process
  - Subject to effective review and challenge

General Expectations: Documentation Practices

- Loss estimation methodologies and assumptions should be clearly documented, including:
  - Conceptual framework, including its ability to properly account for both risk unique to the BHC and macroeconomic risk drivers
  - Formulaic specifications, assumptions, numerical techniques, approximations
  - Reference data set used, including any data manipulation, exclusions, or sampling
  - Portfolio segmentation process, including support for final segmentation vs. the options considered but ultimately rejected
- Documentation should delineate between model outputs, qualitative adjustments to model outputs, and purely qualitative estimates

General Expectations: Data

- Data Sources: Internal vs. External
  - BHCs should develop and use internal data to estimate losses
    - However, BHCs may lack sufficient, relevant historical data due to systems limitations, acquisitions, or new products
  - BHCs using external data should:
    - Ensure it reasonably approximates underlying portfolio risk characteristics
    - Make adjustments to modeled outputs to account for identified differences in risk characteristics and performance reflected in internal and external data
- Assessing Data Quality
  - Time Series Length – does internal data capture more than one downturn cycle?
  - Consistency – has internal data changed over time given acquisitions, rating methodology changes, portfolio changes, regulatory changes?
  - Granularity – is data parsed sufficiently to distinguish risks among portfolios?
  - Critical Mass – is data sufficient to distinguish risk drivers within a portfolio?

Objective 2: Segmentation

1. General expectations for loss estimation
2. **Common segmentation approaches**
3. Common loss estimation approaches
4. Range of practice
5. Supervisory evaluation

Segmentation

- Loss estimates should be derived at a sufficiently granular level to identify common risk drivers and capture effects of changing conditions
  - Achieved via segmentation or loan-level loss estimation
- Segmentation approaches typically depend on:
  - Type and materiality of portfolio
  - Composition and availability of data
- Segmentation typically starts at a high-level: Wholesale vs. Retail
- And then expands to more granular levels to capture exposures that react differently to risk drivers under stress conditions:
  - Wholesale → C&I vs. CRE → income producing CRE vs. construction
  - Retail → Auto vs. Mortgages → 1st lien mortgage vs. 2nd lien

Segmentation

- Segmentation should account for portfolio risk characteristics
  - Segments are homogeneous pool of loans responding (nearly) equally to exogenous (macroeconomic) risk drivers
  - A loan can move in and out of segments through time
    - The risk drivers a loan is exposed to should determine its appropriate segment
- Segmentation can be achieved via:
  - Explicit separation of data – the leading and most appropriate approach
  - Implicit separation of data via indicator variables
    - This approach is less effective, but necessary when loss data does not have critical mass
    - Indicator variables should include interaction terms when necessary

Objectives 3 & 4: Loss Estimation Methodologies

1. General expectations for loss estimation
2. Common segmentation approaches
3. **Common loss estimation approaches**
4. **Range of practice**
5. Supervisory evaluation

Common Credit Loss Estimation Methodologies

- Expected Loss Framework:
  - EL = PD X LGD X EAD
- Ratings Transition Models
  - CDI
  - Z-Factor
- Other Econometric Models
  - ARIMA Models
- Net Charge-Off Models

Expected Loss (EL) Approach

- The EL approach makes use of a firm's Probability of Default (PD) and Loss Given Default (LGD) credit risk rating models
- The obligor's "Probability of Default" (PD)
  - Estimates the probability that the obligor will "default", or become 90 days or more past due, over the next 12 months
  - PD probabilities are typically calibrated for each grade in the bank's obligor credit risk rating system
- Approaches to developing PD rating models include:
  - Structural: Considers the obligor's balance sheet foundation, capital structure and implied firm value
  - Reduced form: Considers the obligor's debt prices and credit spreads
  - Regression models: Considers borrower's financial ratios and historical default data
  - Hybrid: Bridges the reduced form and structural models

Expected Loss (EL) Approach

- The facility's "Loss Given Default" (LGD)
  - Given default by the borrower, estimates the percentage of the outstanding loan amount that will not be collected
    - Affected by type and quality of underlying collateral,
    - Other collateral characteristics such as advance rates, LTV, collateral location seniority of claim on collateral, etc
    - Guarantees,
- Can be calculated at the facility level, or at the portfolio segment level
- Expressed as 1 – (Recovery Value/Exposure at Default)

Expected Loss (EL) Approach

- A facility's "Exposure at Default" (EAD) estimates the percentage of the fully committed portion of the facility that will be drawn as of the day of default
  - Developed based on historical average drawn portions of defaulted loans relative to the committed amount
  - Best practice includes "conditioning" EAD based on macro-economic trends
  - Sufficiency of data can be a challenge
  - May be called "Utilization Given Default" (UGD)

Ratings Transition Models

- In using an EL framework for loss estimation, all EL inputs (PD, LGD and EAD) must be conditioned (“stressed”) based on historical downturns trends in macro-economic variables
- To condition PDs, a common approach uses historical transition matrices
  - Quantifies increases or decreases in PD based on trends in macro-economic variables
- Due to limited data, LGD estimation at the facility level may be limited to conservative, static measure vs. estimation of a conditioned or “stressed” LGD
  - The ability to condition LGD based on historical downward trends in macro-economic variables is a strong practice
  - Use of Weighted Average LGD estimation approach at the portfolio level is a lagging practice
- Stronger practices include use of LEQ (estimated additional drawdown as a percent of unused commitment) and credit conversion factors (CCF)

Ratings Transition Models

1st Quarter Migration Example (Hypothetical)

Initial Balance Distribution	Unfunded		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 (Default)	Final Balance Distribution	UGD Draws (UF * UGD *PD)
50.00	25.00	1	99.98%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	49.99	0.00
60.00	30.00	2	0.00%	99.97%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	59.98	0.01
75.00	37.50	3	0.00%	0.00%	99.93%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	74.95	0.02
85.00	42.50	4	0.00%	0.00%	0.00%	99.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	84.92	0.03
90.00	45.00	5	0.00%	0.00%	0.00%	0.00%	99.85%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	89.87	0.04
105.00	52.50	6	0.00%	0.00%	0.00%	0.00%	0.00%	99.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.25%	104.74	0.07
135.00	67.50	7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	99.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.40%	134.46	0.13
155.00	77.50	8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	99.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.60%	154.07	0.20
190.00	95.00	9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	99.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.75%	188.58	0.29
160.00	80.00	10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	99.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.90%	158.56	0.28
150.00	75.00	11	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	98.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.10%	148.35	0.30
145.00	72.50	12	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	98.20%	0.00%	0.00%	0.00%	0.00%	0.00%	1.80%	142.39	0.46
120.00	60.00	13	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	97.50%	0.00%	0.00%	0.00%	0.00%	2.50%	117.00	0.51
105.00	52.50	14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	93.00%	0.00%	0.00%	0.00%	7.00%	97.65	1.19
90.00	45.00	15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	87.70%	0.00%	0.00%	12.30%	78.93	1.70
70.00	35.00	16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	80.60%	0.00%	19.40%	56.42	2.02
45.00	22.50	17	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	72.00%	28.00%	32.40	1.78
		18	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	56.76	

Defaulted Balance (PD)

Ratings Transition Models

- Ultimately, LGD and information related to additional draws will be applied to determine overall loss rate and dollars (see appendices)

LGD	40%

Defaulted Balance from previous slide

NPL Losses & Payoffs before Timing Effects

Vintage	Inflows to NPL	UGD Draws	Total NPLs	Loss	Payoff
Q1	56.76	9.03	65.79	26.32	39.47
Q2	48.55	8.67	57.22	22.89	34.33
Q3	42.04	8.33	50.37	20.15	30.22
Q4	36.84	8.01	44.85	17.94	26.91

Timing Schedules

	Quarter Relative to Default			
	+0 Q	+1 Q	+2 Q	+3 Q
Charge-off Timing	50%	30%	15%	5%
Payoff Timing	30%	25%	25%	20%

Charge-offs

NPL Vintage	Total Loss	Q1	Q2	Q3	Q4
Q1	26.32	13.16	7.89	3.95	1.32
Q2	22.89		11.44	6.87	3.43
Q3	20.15			10.07	6.04
Q4	17.94				8.97

UGD

1	78%
2	73%
3	69%
4	64%
5	58%
6	52%
7	47%
8	44%
9	41%
10	39%
11	37%
12	35%
13	34%
14	32%
15	31%
16	30%
17	28%

Ratings Transition Models

- Choosing the Matrix and Linking to the Scenario
  - Various Approaches:
    - Long-term, average matrix
    - “Worst case” matrix
    - Other manual methods, including “expert judgment”
    - Direct link to macroeconomic factors via regression (CDI or Z approach)
  - Cumulative Default Index (CDI) Approach
    - Calculate a CDI for each historical matrix within a time series
    - Regress CDI against one or more macroeconomic variables to establish a relationship between CDI and macroeconomic environment
    - Use the relationship to calculate CDI for each quarter within the forecast
      - Calculated CDI points to a specific matrix that determines transitions for that quarter of the forecast, including transitions to default (PD)

Ratings Transition Models

- CDI Approach Continued…
  - Once CDI is calculated for each historical matrix, a regression can be run against various macroeconomic factors in order to determine a relationship between CDI and the macroeconomic environment

$$CDI_{t+1} = 243.93 + 0.59CDI_t - 72.14RTSCHNG_t + 329.41UNEMPCHNG_t$$

In which

t =	Current quarter
CDI =	Cumulative default measure
RTSCHNG =	Percentage change in retail sales since previous quarter
UNEMPCHNG =	Simple difference in unemployment rate since previous quarter

  - This formula can then be used to calculate CDI for each quarter of the forecast, which points to a transition matrix for each quarter

Ratings Transition Models

- Output from PD forecast model is combined with
  - LGD inputs
    - An LGD forecast model, similar to the PD forecast model, is a sound practice.
    - Data limitation may reduce input to a static, conservative input for each portfolio segment.
  - EAD inputs
    - An EAD (or UGD) forecast model, similar to the PD forecast model, is a sound practice.
    - Data limitations may reduce EAD to a static, conservative input for each portfolio segment.
- The resulting forecasted credit losses are used to determine future capital needs
- Macro-economic variables having relationships with past PD transitions (or LGD severity, or EAD), are used to describe future adverse and severely adverse economic conditions

Net Charge-Off Models

- Net charge-off (NCO) models estimate a statistical relationship between charge-off rates and macroeconomic variables
  - Top down models with PD, LGD, and EAD captured in one rate
  - Material limitations include:
    - Inability to capture variation in portfolio risk characteristic over time
    - Future loss may outpace historic
    - Lower explanatory power than models that consider distinct portfolio characteristics
  - Recommendation: best used as benchmark/challenger models
  - Particular attention should be paid to:
    - Segmentation – it is important to establish homogenous portfolios
    - Change in accounting definitions for charge-offs
    - Out-of-time backtesting

Scalar Adjustments

- Some BHCs used simple scalars to adjust portfolio loss estimates from the baseline scenario to the stress scenario
  - Important limitations include:
    - Lack of transparency in how scalars are derived
    - Lack of sensitivity to changes in portfolio composition and scenario variables
  - Recommendation: most suitable for immaterial portfolios for which the BHC lacks sufficient data to directly model loss estimates

Objective 4: Supervisory Evaluation

1. General expectations for loss estimation
2. Common segmentation approaches
3. Common loss estimation approaches
4. Range of practice
5. **Supervisory evaluation**

Supervisory Evaluation

- **Goal:** To assess BHC's ability to identify, measure, and translate risk exposures into estimates of potential loss under stress conditions
  - Is the analysis comprehensive?
  - Are all positions and business lines captured?
  - Are reference data sets complete and relevant?
  - Does the BHC use a sound approach to estimating loss forecasts?
  - Does the BHC appropriately segment portfolios to capture relevant risk drivers and unique sensitivities to the macro scenario?
  - Have the loss estimation models been validated by independent parties?
    - If yes, what was the quality of the validation?
  - Does the BHC demonstrate a strong governance structure and understanding of loss estimates?

Supervisory Evaluation

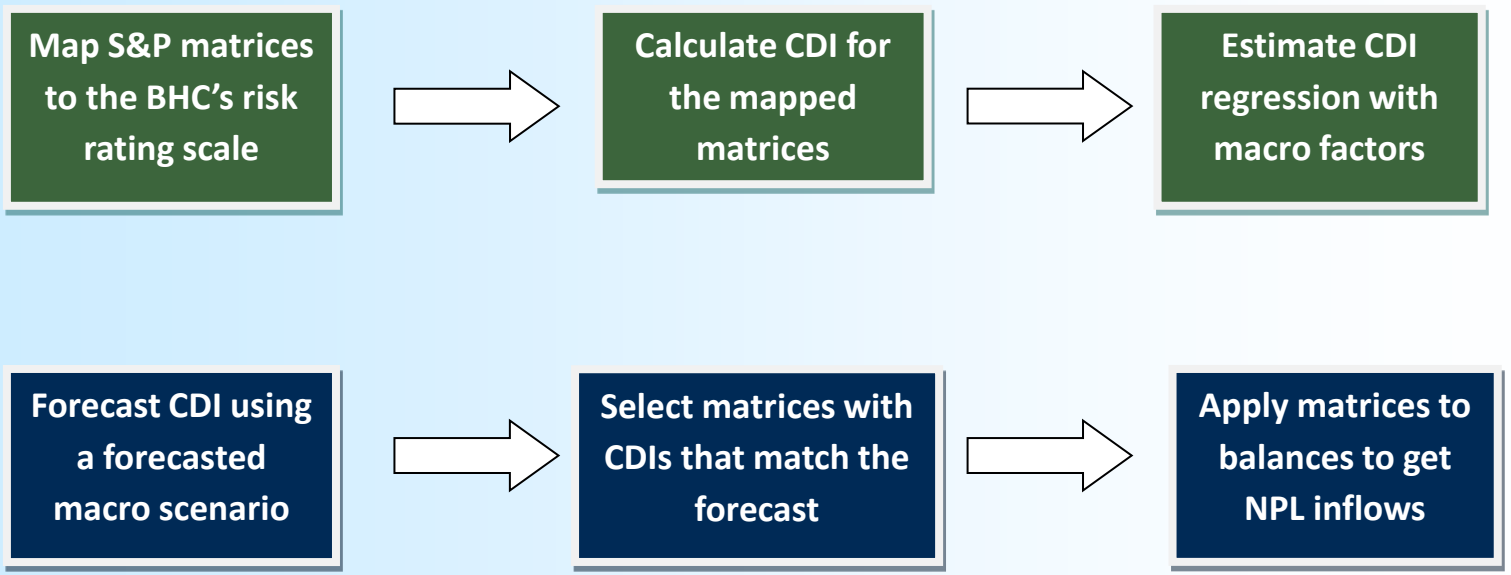
- **Goal:** To assess BHC's ability to identify, measure, and translate risk exposures into estimates of potential loss under stress conditions
  - Does the BHC have a credible process for translating raw information into results that made sense given the BHC's portfolio characteristics?
  - Are assumptions clearly outlined and appropriately conservative?
  - Do models clearly factor in the severity of the scenario and show appropriate progression of results across scenarios?
  - Are the methods used to forecast losses in line with industry best practice?
- Assess whether the broader capital planning process has clear governance and is conducted in a well-controlled manner

Supervisory Evaluation: Example

- A BHC's wholesale loss estimation model predicts inflows of nonperforming loans using Cumulative Default Index (CDI) matrices
  - The model first imports S&P corporate bond matrices, and applies an algorithm that maps the S&P bond ratings to the BHC's internal PRISM rating scale
  - CDI is calculated for these mapped matrices. Calculated CDI is then regressed against selected macroeconomic factors
  - A forecasted macroeconomic scenario is then applied to this regression, and CDI is forecasted
  - Matrices that correspond with this forecasted CDI are selected and then applied to loan balances in order to predict NPL inflows

Supervisory Evaluation: Example

- Process overview



Supervisory Evaluation: Example

- The Federal Reserve found the use of S&P corporate bond matrices lacked support and conceptual soundness, and called into question the selection process of macro factors used in the CDI regression
  - The developer selected the unemployment rate, BBB bond spread, and equity volatility as macro factors but provided no explanation as to why they were relevant to CDI
  - Estimated losses are highly dependent on the use of S&P's corporate bond matrices, rather than matrices based on the BHC's specific portfolios
    - The developer chose to use the S&P matrices because internal data dated back to 2007 only and did not cover a full credit cycle
    - The S&P matrices ***"have a long history across multiple credit cycles, and they are largely indicative of the broad credit health of the economy"***
  - However, the BHC's portfolio is regionally specific, and therefore, not representative of the broad economic spectrum

Supervisory Evaluation: Example

- In addition, weaknesses were observed in the mapping of S&P risk ratings (AAA-D), to the BHC's internal PRISM rating system (1-18+)

		To Prism Grade																
S&P to Prism Matrix		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18+
From S&P Grade	AAA	100%	0%																
	AA+	100%	0%																
	AA	100%	0%																
	AA-		100%	0%															
	A+			100%	0%														
	A				100%	0%													
	A-					100%	0%												
	BBB+						100%	0%											
	BBB							75%	25%										
	BBB-								25%	75%									
	BB+									0%	100%								
	BB											75%	25%						
	BB-												25%	75%					
	B+														75%	25%			
	B															25%	75%		
	B-																100%	0%	
	CCC/C																	100%	0%
	D																		100%

- Examiners found there was a lack of testing and justification around the mapping process. Ultimately, *qualitative judgment* was used to construct the map above, but with insufficient documentation of support

Supervisory Evaluation: Example

- To resolve these issues, a Matter Requiring Attention (MRA) was issued that required the BHC to “develop guidance on the appropriate selection, use and management of data used to develop run and test models.”
- In addition to this, “documentation should be comprehensive and transparent, include rationale and support for methodology used and assumptions chosen, and identify weaknesses and limitations.”

Questions?