Capital Analytics in DROP

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Basel II

Overview

1. Purpose of the Basel Accords: **Basel II** is the second of the Basel accords – now extended and superseded by Basel III – which are recommendations on banking laws and regulations issued by the Basel Committee on Banking Supervision (Wikipedia (2018)).
2. International Banks' Capital Requirement Standards: The Basel II Accord was published initially in June 2004 and was intended to amend international banking standards that controlled how much capital banks were required to hold to guard against financial and operational risks banks face.
3. Safeguarding Bank Solvency and Stability: These regulations aimed to ensure that the more significant the risk that the bank is exposed to, the greater the amount of capital a bank needs to hold to safeguard its solvency and its overall economic stability.
4. Adequacy Requirements for Bank Capital: Basel II attempted to achieve this establishing risk and capital management requirements to ensure that the bank has adequate capital for the risk that the bank exposes itself through its lending, investment, and trading activities.
5. Preventing the Race to Bottom: One focus was to maintain sufficient consistency of regulations so as to limit competitive inequality among internationally active banks.
6. Impact due to Financial Crisis: Basel II was implemented in the years prior to 2008, and was only to be implemented in early 2008 in most countries (Office of the Comptroller of the Currency (2007), Council of Mortgage Lenders (2011)); that years' financial crisis intervened before Basel II could become fully effective.

7. Enhancement from Basel II to III: As Basel III was negotiated, the crisis was on the top of mind and accordingly more stringent standards were contemplated and adopted in key countries including in the US and Europe.

Objective

1. Aims of the Accord: The final version aims at:
   a. Ensuring that the capital allocation is more risk sensitive
   b. Enhance the disclosure requirements which would allow the market participants to assess the capital adequacy of an institution
   c. Ensuring that credit risk, market risk, and operational risk are quantified based on data and formal techniques
   d. Attempt to align economic and regulatory capital more closely to reduce in scope for regulatory arbitrage
2. Divergence between Regulatory and Economic Capital: While the final accord has addressed the regulatory arbitrage issue at large, there are still where the regulatory capital requirements will diverge from economic capital.

The Accord in Operation: Three Pillars

1. Pillars of Basel II: Basel II uses a *three-pillar* concept:
   a. Minimum Capital Requirements (addressing risk)
   b. Supervisory Review

c. Market Discipline

2. Shortcoming of Basel I: The Basel I accord dealt with only parts of each of these pillars. For example, with respect to the first Basel II pillar, only one risk, credit risk, was dealt with in a simple manner while the market risk was an after-thought; operational risk was not dealt with at all.

The First Pillar: Minimum Capital Requirements

1. Components of the First Pillar: The first pillar deals with the maintenance of the regulatory capital calculated for three major components of risk that a bank faces; credit risk, regulatory risk, and market risk. Other risks are not considered quantifiable at this stage.
2. Credit Risk Component Capital Pillar: The credit risk component can be calculated in three different ways of varying degrees of sophistication, namely Standardized Risk Approach, Foundation IRB, Advanced IRB, and General IB2 Restriction. IRB stands for "Internal Ratings Based" Approach.
3. Operational Risk Component Capital Requirements: For operational risk, there are three different approaches – Basic Indicator Approach or BIA, Standardized Approach or TSA, and the Internal Measurement Approach (an advanced form of which is the Advanced Measurement Approach or AMA).
4. Market Risk Component Capital Requirements: For the market risk component, the preferred approach is VaR.
5. Migration from Standardized to Customized: As the Basel II recommendations are phased in by the banking industry, it will move from standardized requirements to more refined and specific requirements that have been developed for each risk category by each individual bank.

6. Advantages of such Migration: The upside for banks that do develop their own risk migration systems is that they will be rewarded with potentially lower risk capital requirements. In the future there will closer links between the concepts of economic and regulatory capital.

The Second Pillar: The Supervisory Review

1. Assessment of Diverse Risk Capital: This is a regulatory response to the first pillar, giving the regulators better tools over those previously available. It also provides a framework for dealing with systemic risk, pension risk, concentration risk, strategic risk, reputational risk, liquidity risk, and legal risk, which the accord combines under the title of residual risk.
2. Internal Capital Adequacy Assessment Process: The Internal Capital Adequacy Assessment Process (ICAAP) is a result of Pillar 2 of the Basel accords.

The Third Pillar: Market Discipline

1. The Disclosure Requirements Component Complement: This pillar aims to complement the minimum capital requirements and the supervisory review process by developing a set of disclosure requirements which will allow market participants to gauge the capital adequacy of an institution.
2. Advantages of the Disclosure: Market discipline supplements regulation as sharing of information facilitates assessment of the bank by others, including investors, analysts, customers, other banks, and ratings agencies, which leads to good governance.

3. Items of Disclosure/Reporting: The aim of Pillar 3 is to allow market discipline to operate by requiring institutions to disclose details on the scope of application, capital, risk exposures, risk assessment processes, and the capital adequacy of the institution.
4. Consistency with the Operating Objective: It should be consistent with how the senior management, including the board, assess and manage the risks of the institution.
5. Facilitating the Prudent Risk Assessment: When market participants have a sufficient understanding of the banks' activities and the controls it has in place to manage its exposures, they are better able to distinguish between the banking organizations so that they can reward those that can manage their risks prudently and penalize those that do not.
6. Frequency of the Disclosures: These disclosures are required to be made at least twice a year, except for the qualitative disclosures providing a summary of the general risk management objectives and policies which can be made annually.
7. Instituting the Disclosure Policy: Institutions are also required to create a formal policy on what will be disclosed and the controls around them along with the validation and the frequency of these disclosures.
8. Applicability at the BHC Level: In general, the disclosures under Pillar 3 apply to the top consolidated level of the banking group to which the Basel II framework applies.

Chronological Updates

1. September 2005 Update: On 30 September 2005, the four US federal banking agencies (Office of the Comptroller of the Currency, Board of Governors of the Federal Reserve System, Federal Deposit Insurance Corporation, and Office of Thrift Supervision) announced their revised plans for the US implementation of the Basel II accord. This delayed the implementation of the accord for the US banks by 12 months (Federal Reserve (2005)).
2. November 2005 Update: On 15 November 2005, the committee released a revised version of the accord, incorporating changes to the calculations for market risk, and the treatment of the

double default effects. These changes have been flagged well in advance, as part of a paper released in 2005 (Basel Committee on Banking Supervision (2005)).

3. July 2006 Update: On 4 July 2006, the committee released a comprehensive version of the accord, incorporating the June 2004 Basel II Framework, the elements of the 1988 accord that were not revised during the Basel II process, the 1996 Amendment to the capital accord to incorporate market risks, and the November 2005 paper (Basel Committee on Banking Supervision (2006)). No new elements were released in this compilation.
4. November 2007 Update: On 1 November 2007, the Office of the Comptroller of the Currency (US Department of Treasury) approved the final rule implementing the advanced approaches of the Basel II Capital Accord. This rule establishes regulatory and supervisory expectations for credit risk through the Internal Ratings Based (IRB) Approach, the operational risk through the Advanced Measurements Approach (AMA), and articulates enhanced standards for supervisory review of capital adequacy and public disclosures for the largest US banks (Office of the Comptroller of the Currency (2007)).
5. July 2008 Update: On 16 July 2008, the federal banking and the thrift agencies (Office of the Comptroller of the Currency, Board of Governors of the Federal Reserve System, Federal Deposit Insurance Corporation, and Office of Thrift Supervision) issued a final guidance outlining the supervisory review process for the banking institutions that are implementing the new advanced capital adequacy framework (Basel II). The final guidance, relating to the supervisory review, is aimed at helping banking institutions meet certain qualification requirements in the advanced approaches rule, which took effect on 1 April 2008.
6. 16 January 2009 Update: For public consultations, a series of proposals to enhance the Basel II framework was announced by the Basel committee. It released a consultative package that includes: the revision to the Basel II market risk framework, the guidelines for computing capital for incremental risk in the trading book, and proposed enhancements to the Basel II framework (Basel Committee on Banking Supervision (2009a)).
7. 8-9 July 2009 Update: The final package of measures to enhance the three pillars of the Basel II framework and the strengthening of the 1996 rules governing the trading book capital was issued by the newly expanded Basel Committee. These measures include the enhancement to the Basel II framework, the revisions to the Basel II market risk framework, and the

guidelines for computing capital for the incremental risk in the trading book (Basel Committee on Banking Supervision (2009b)).

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Basel III

Overview

1. <u>Definition of Basel III Standard</u>: **Basel III** – or the **Third Basel Accord** or **Basel Standards** – is a global, voluntary regulatory framework on bank capital adequacy, stress testing, and market liquidity risk (Wikipedia (2018)).
2. <u>Successor to Basel I and II</u>: This third installment of Basel Accords was developed in response to the inadequacies in financial regulation revealed by the financial crisis of 2007-8.
3. <u>Strengthening the Bank Capital Requirements</u>: It is intended to improve bank capital requirements by increasing the liquidity and decreasing leverage.
4. <u>Timeline - From Introduction to Complete Implementation</u>: Basel III was agreed upon by the members of the Basel Committee for Banking Standards in November 2010, and was scheduled to be introduced from 2013 until 2015, however, implementation was repeatedly pushed to 31 March 2019 (Basel Committee on Banking Supervision (2010)).
5. <u>Enhancement to the Basel II Standard</u>: The Basel III standard aims to strengthen the requirements from the Basel II standards on a bank's minimum capital ratios.
6. <u>Requirements on Liquidity and Funding Stability</u>: In addition, it introduces requirements on liquid assets and funding stability, thereby seeking to mitigate the risk of a run on the bank.

Key Principles – Capital Requirements

1. Basel III Common Equity Rule: The original Basel III rule from 2010 required banks to find themselves with 4.5% of common equity – up from 2% in Basel II – of risk-weighted assets (RWA's).
2. Definition of the CET1 Ratio: Since 2015, a minimum Common Equity Tier 1 (CET1) ratio of 4.5% must be maintained at all times by the bank (Basel Committee on Banking Supervision (2013)). The ratio is calculated as follows:

$$\frac{CET1}{RWAs} \geq 4.5\%$$

3. Components of the Tier 1 Capital: The minimum Tier 1 Capital increases from 4% in Basel II to 6% (Basel Committee on Banking Supervision (2013)), applicable in 2015, over RWA's. This 6% is composed of 4.5% of CET1, plus an extra 1.5% of Additional Tier 1 (AT1).
4. Basel III Mandatory Capital Conservation Buffer: Furthermore, Basel III introduced two additional capital buffers; a mandatory "Capital Conservation Buffer", equivalent to 2.5% of risk-weighted assets. Considering the 4.5% CET1 capital ratio required, banks have to hold a total of 7% CET1 Capital ratio, from 2019 onwards.
5. Basel III Discretionary Counter-Cyclical Buffer: A *discretionary counter-cyclical buffer*, allowing national regulators to require upto an additional 2.5% of capital during periods of high credit growth is also required. The level of this buffer ranges from 0% to 2.5% of RWA and must be met by the CET1 Capital.

Key Principles – Leverage Ratio

1. Basel III Leverage Ratio - Motivation: Basel III introduced a new *leverage ratio*. This is a non-risk-based leverage ratio and is calculated by dividing the Tier 1 capital by the bank's

average total consolidated assets – sum of the exposures of all the assets and the non-balance sheet items (Basel Committee on Banking Supervision (2017)).

2. Basel III Leverage Ratio – Definition: The banks are expected to maintain a leverage ratio in excess of 3% under Basel III.

$$\frac{Tier1\ Capital}{Total\ Exposure} \geq 3\%$$

3. Fed Mandated Minimum Leverage Ratio: In 2013, the US Federal Reserve announced that the minimum Basel III leverage ratio would be 6% to 8% for 8 Systematically Important Financial Institution (SIFI) banks, and 5% for their insured bank holding companies (Central Banking (2013)).

Liquidity Requirements

1. Basel III Liquidity Coverage Ratio – Definition: Basel III introduced two required liquidity ratios. First, the *Liquidity Coverage Ratio* was supposed to require a bank to hold sufficiently high-quality liquid assets to cover its total net cash outflows over 30 days.
2. Basel III LCR - Expression: Mathematically it is expressed as follows:

$$LCR = \frac{High\ Quality\ Liquid\ Assets}{Total\ Net\ Liquidity\ Outflows\ over\ 30\ Days} \geq 100\%$$

3. Basel III Net Stable Funding Ratio: The Net Stable Funding Ratio was to require that the available amount of stable funding exceed the required amount of stable funding over a one-year period of extended stress (Committee on Financial Services, United States House of Representatives (2011)).

US Version of the Basel Liquidity Coverage Ratio Requirements

1. Federal Reserve's Interagency LCR: In October 2013, the Federal Reserve Board of Governors approved an inter-agency proposal for the US version of the BCBS Liquidity Coverage Ratio (LCR).
2. Application of the Federal Reserve's LCR: The ratio would apply to certain US banking organizations and other SIFI's (Federal Reserve (2013)). The comment period for the proposal closed on 31 January 2014.
3. Comparison with the BCBS LCR Requirement: The US LCR proposal came out significantly tougher than the BCBS version, especially for the larger bank holding companies.
4. Purpose of the HQLA Requirement: The proposal requires financial institutions and FSOC designated non-bank financial companies to have a stock of high-quality liquid assets (HQLA) that can be quickly liquidated to meet the liquidity needs over a short period of time.
5. Component of the Fed's LCR: The LCR consists of two parts: the numerator is the value of the HQLA, and the denominator consists of the total net cash outflow over a specified stress period – total net cash outflows minus the total net cash inflows.
6. Asset Levels fort LCR Applicability: The LCR applies to US banking operations with assets of more than $10 billion. The proposal would require the following.
7. Large Bank Holding Companies (BHC): Large BHC's refer to those with $250 billion in consolidated assets, or more in on-balance sheet foreign exposure, and to systemically important non-bank financial institutions. They have to hold enough HQLA to cover 30 days of net cash outflow. That amount would be based on the based on the peak cumulative amount within the 30-day period (Federal Reserve (2013)).

8. LCR for Regional Firms: Regional firms – those with between $50 and $250 billion in assets – would be subject to a *modified* LCR at the BHC level only. The modified LCR requires the regional firms to require holding enough HQLA to cover 21 days of net cash outflows.
9. Comparison against large BHC LCR's: These net cashflow parameters are 70% of those applicable to the large institutions and do not include the requirement to calculate the peak cumulative outflows.
10. LCR Rules for Small BHC's: Smaller BHC's – those under $50 billion – would remain subject to the prevailing qualitative supervisory framework.
11. Quality Classification of Qualifying HQLA's: The US proposal divides qualifying HQLA's into three specific categories – Level 1, Level 2A, and Level 2B. Across the categories, the combination of Level 2A and Level 2B assets cannot exceed 40% HQLA and 2B assets are limited to a maximum of 15% HQLA.
12. Level 1 HQLA - Asset Characteristics: Level 1 represents assets that ar highly liquid – generally those risk-weighted at 0% under the Basel III standardized approach to capital – and receive no haircut.
13. Entities excluded from Level 1 HQLA: Notably, the Fed chose not to include GSE issued securities in Level 1, despite industry lobbying, on the basis that they are not guaranteed by the *full faith and credit* of the US government.
14. Level 2A HQLA Risk Weights: Level 2A assets generally include assets that would be subject to a 20% risk weighting under Basel III, and includes assets such as GSE issued and guaranteed securities.
15. Level 2A HQLA Haircut: These assets would be subject to a 15% haircut, which is similar to the treatment of such securities under the BCBS version.
16. Composition of the Level 2B HQLA Assets: Level 2B assets include corporate debt and equity securities, and are subject to a 50% haircut.
17. Variation with the BCBS Treatment: The BCBS and the US versions treat equities in a similar manner, but corporate debt under BCBS version is split between 2A and 2B based on public credit ratings, unlike the US proposal.
18. Elimination of the References to Credit Rating: This treatment of the corporate debt securities is the direct impact of the Dodd-Frank Act's Section 939, which removed

references to credit ratings, and further evidences the conservative bias of the US regulators' approach to the LCR.

19. LCR Operational Implementation Plan Timeline: The proposal requires that the LCR be at least equal to or greater than 1.0, and includes a multi-year transition period that would require: 80% compliance starting 1 January 2015, 90% compliance starting 1 January 2016, and 100% compliance starting 1 January 2017.
20. LCR Operational Slippage Remediation Plan: Lastly, the proposal requires both sets of firms – large bank holding companies and regional firms – subject to the LCR requirements to submit remediation plans to the US regulators to address what actions would be taken of the LCR falls below 100% for three or more consecutive days.

Summary of Originally Proposed Changes (2010) in the Basel Committee Language

1. Quality, Consistency, and transparency of Capital: First, the quality, the consistency, and the transparency of the capital base will be raised.
    a. Tier 1 Capital => The predominant form of Tier 1 Capital must be common shares and retained earnings.
    b. Tier 2 Capital => Tier 2 is the supplementary capital; however, the instruments will be harmonized.
    c. Tier 3 Capital will be eliminated (Basel Committee on Banking Supervision (2009)).
2. Strengthening of the Capital Framework: Second, the risk coverage of the capital framework will be strengthened.
    a. Promote more integrated management of market and counterparty credit risk.
    b. Add credit valuation adjustment – risk due to deterioration in the counterparty's credit rating.

    c. Strengthen the capital requirements for counterparty credit exposures arising from bank's derivatives, repos, and securities financing transactions.
    d. Raise the capital buffers backing these exposures.
    e. Reduce procyclicality.
    f. Provide additional incentives to move OTC derivatives contracts to qualifying central counterparties – probably clearing houses. Currently, BCBS has stated that derivatives cleared with a QCCP will be risk-weighted at 2%. This rule is still to be finalized in the US.
    g. Provide incentives to strengthen risk management of counterparty credit exposures.
    h. Raise counterparty credit risk management standards by including wrong-way risk.

3. <u>Leverage Ratio Monitoring and Maintenance</u>: Third, a leverage ratio will be maintained as a supplementary measure to the Basel II risk-based framework. It is intended to achieve the following objectives:
    a. Put a floor under the buildup of the leverage in the banking sector.
    b. Introduce additional safeguards against model risk and measurement error by supplementing the risk-based measure with a simpler measure that is based on gross exposures.
4. <u>Reducing Procyclicality and Promoting Counter-cyclical Buffers</u>: Fourth, a series of measures have been introduced to promote the buildup of capital buffers during good times that can be drawn upon in periods of stress.
    a. The measures to address pro-cyclicality are:
        i. Dampen excess cyclicality of the minimum capital requirement.
        ii. Promote more forward-looking provisions.
        iii. Conserve capital to build buffers at individual banks level and at the banking sector level that can be used in periods of stress.
    b. The measures to achieve broader macro-prudential goal of protecting the banking sector from periods of excess credit growth are:
        i. Requirements to use long-term data horizons for estimation.
        ii. Downturn loss-given-default estimates, recommended in Basel II< to become mandatory.

iii. Improved calibration of the risk functions, which convert loss estimates into regulatory capital requirements.
iv. Banks must conduct stress tests that include widening credit spreads in recessionary scenarios.

c. The measures for promoting stronger provisioning practices (forward-looking provisioning) are:
i. Advocating a change in the accounting standards towards an expected loss (EL) approach – usually

$$EL\ Amount = LGD \times PD \times EAD$$

as outlined in Basel Committee on Banking Supervision (2005).

5. Required Levels of LCR and NSFR: Fifth, a global minimum liquidity standard for internationally active banks is introduced that includes a 30-day liquidity coverage ratio requirement underpinned by a longer-term structural liquidity ratio called the Net Stable Funding Ratio. In January 2012, the oversight panel of the Basel Committee on Banking Supervision issued a statement saying that regulators will allow banks to dip below their required liquidity levels, the liquidity coverage ratio, during periods of stress.
6. Extra Capital, Liquidity, and Supervisory Measures: The Committee is also reviewing the need for additional capital, liquidity, or other supervisory measures to reduce the externalities created by systemically important institutions.
7. Basel III Tiered Capital Ratio: As of September 2010, the proposed Basel III norms asked for ratios as: $7 - 9.5\%\ (4.5\% + 2.5\%\ (Conservation\ Buffer) + 0 - 2.5\%\ (Seasonal\ Buffer)\ for\ common\ equity, and\ 8.5 - 11\%\ for\ Tier\ 1\ Capital, and\ 10.5 - 13\%\ for\ total\ capital.$
8. Measuring and Controlling Large Exposures: In April 2014, BCBS released the final version of its *Supervisory Framework for Measuring and Controlling Large Exposures* (SFLE) that builds on longstanding BCBS guidance on credit measure concentrations.
9. US Banking Agency LCR Implementation: On 3 September 2014, the US Banking Agencies – Federal Reserve, Office of the Comptroller of the Currency, and Federal Deposit Insurance

Corporation – issued the final rule covering the implementation of the Liquidity Coverage Ratio (LCR).

10. Purpose of the LCR: The LCR is a short-term liquidity measure intended to ensure that banking organizations maintain a sufficient pool of liquid assets to cover net cash outflows over a 30-day stress period.
11. Disclosure of Regulatory Metrics and Qualitative Data: The 11 March 2016, the Basel Committee on Banking Supervision released the second of three proposals on public disclosure of regulatory metrics and qualitative data by banking institutions.
12. Granular Disclosure of the Market Risk Metrics: The proposal requires disclosures on market risk to be more granular for both the standardized approach as well as the regulatory approval of internal models.

US Implementation

1. US Implementation of Basel III Rules: The US Federal Reserve announced in December 2011 that it would implement substantially all of the Basel III rules.
2. Applicability across the Range of Institutions: It made clear that they would apply not only to banks, to also to all institutions with more than $50 in assets. The rules may be summarized as follows.
3. Risk-Based Capital Surcharge: The first is the *Risk Based Capital and Leverage Requirements* which includes annual capital plans, stress tests, and capital; adequacy checks, including a Tier 1 Common Risk Based Capital Ratio greater than 5%, under both expected and stressed conditions.
4. Liquidity Based Quantitative Limits: The next is market liquidity tests, based first on the US's own *Inter-agency Liquidity Risk Management Guidance* issued in March 2010 that require liquidity stress tests and set internal quantitative limits, later moving to a full Basel III regime.

5. Fed Mandated Plus Internal Stress Tests: The Federal Reserve Board itself would conduct tests annually *using three economic and financial market scenarios*. Institutions would be encouraged to use at least five scenarios reflecting improbable events, and especially those considered impossible by the management, but no standards apply yet to extreme scenarios. Only the summary of the three official Fed scenarios *including company-specific information, would be made public*, but one or more internal company-run stress tests must be run each year with summaries provided.
6. Single Counterparty Credit Limit: Single counterparty credit limits to cut *credit exposure of a covered financial firm to a single counterparty as a percentage of the firm's regulatory capital. Credit exposure between the largest financial companies would be subject to a tighter limit*.
7. Early Weakness Monitoring and Remediation: *Early remediation requirements* will be required to ensure that *financial weaknesses are addresses at an early stage*. One or more *triggers for remediation – such as capital levels, stress test results, and risk management weaknesses – in some cases calibrated to be forward-looking* would be proposed by the Board in 2012. *Required action would vary based on the severity of the situation, but could include restrictions on growth, capital distributions, executive compensation, as well as capital raising or asset sales* (Federal Reserve (2011)).
8. Currentness of the Fed Implementation: As of January 2014, the United States has been on track to implement many of the Basel III rules, despite differences in ratio requirements and calculations.

Europe Implementation

1. EU Implementation of the Accord: The implementation of the Basel III agreements in the European Union has been the new legislative package comprising Directive 2013/36/EU

(CRD IV) and Regulation (EU) No, 575/2013 on prudential requirements for credit institutions and investment firms (CRR) (European Banking Agency (2013)).

2. Replacement of the Existing Directives: The new package, approved in 2013, replace the Capital Requirements Directives (2006/48 and 2006/49) (European Commission (2014)).

Key Milestones

1. Capital Requirements:

Date	Milestone: Capital Requirement
2014	Minimum Capital Requirements: Start of the gradual phasing-in of the higher minimum capital requirements.
2015	Minimum Capital Requirements: Higher minimum capital requirements are fully implemented.
2016	Conservation Buffer: Start of the gradual phasing-in of the Conservation Buffer.
2017	Conservation Buffer: The conservation buffer is fully implemented.

2. Leverage Ratio:

Date	Milestone: Leverage Ratio
2011	Supervisory Monitoring: Developing templates to track the leverage ratio and the underlying components.

2013	Parallel I: The leverage ratio and its components will be tracked by the supervisors but not disclosed and not mandatory.
2015	Parallel II: The leverage ratio and its components will be tracked and disclosed but not mandatory.
2017	Final Adjustments: Based on the results of the parallel run period, any final adjustments are to be made to the leverage ratio.
2018	Mandatory Requirement: The leverage ratio will become a mandatory part of the Basel III requirements.

3. Liquidity Requirements:

Date	**Milestone: Liquidity Requirements**
2011	Observation Period: Developing templates and supervisory monitoring of the liquidity ratios.
2015	Introduction of the LCR: Initial introduction of the Liquidity Coverage Ratio (LCR), with a 60% requirement. This will increase by ten percentage points each year until 2019. In the EU 100% will be reached by 2018 (European Commission (2014)).
2018	Introduction of the NSFR: Introduction of the Net Stable Funding Ratio.
2019	LCR comes into Full Effect: 100% LCR is expected.

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VaR and Stress Methodology – Integration and Testing

Objectives of Risk Capital Estimation

1. Evaluation of the BHC Capital Adequacy: Evaluate the BHC's capital adequacy compared to the risk level. Risk Capital (RC) is defined as the amount of risk that the BHC is taking, measured in units equivalent of common equity. This corresponds to the BHC's available equity capital.
2. Evaluating Economic OC of Businesses: Evaluate the ROE of the BHC business units from an economic perspective. Using the analysis above, risk capital may be defined as the amount of equity the business unit needs, based on its risk level. This enables prioritization of businesses based on ROE.

BHC Risk Capital – Principles

1. Principle behind the BHC Risk Capital Framework: 99.97% confidence interval over a 1Y time horizon. This is consistent with a AA level of financial strength.
2. Focus on Unexpected Losses: Expected Losses covered by current prices or reserves.
3. Comprehensive Coverage of Risk Types: Credit risk, operational risk, market risk, etc.
4. Horizon Constant level of Risk: A constant level of risk over the year for most activities is assumed. BHC must maintain its business activities during the crisis.
5. Full Inclusion of Tail Risk: This must include high correlations and lack of liquidity during a crisis.
6. Avoidance of Pro-cyclicality: Pro-cyclicality occurs when the reported risk goes up as the crisis occurs.

Market Risk Capital – Coverage and History

1. Focus on Market Risk: This includes counter-party exposure on derivatives (CVA), credit spread risk on AFS, and defined-benefit pension plans. The interest rate component of AFS is typically covered by a separate ALM model.
2. VaR as a Measure of Capital: Prior to 2008, VaR was typically used to measure risk capital. This failed in 2008, since both volatility and correlations increase during a crisis.
3. Drying up of Trading Liquidity: Liquidity dried up for certain market factors, e.g., credit securitizations, while others such as G10 Spot FX remained highly liquid.
4. Dramatic Increase of Asset Correlation: In key markets, prices moved in a sustained direction, not randomly. Credit spreads widened during 2008 as firms de-leveraged to meet margin calls. Scaling daily volatility under the assumption of i.i.d. would not describe the actual annual change.

Enhanced Risk Capital Framework

1. Components of VaR-Stress Framework: The VaR-Stress integrates the strengths of these components. The first is VaR, which is often fed in annualized.
2. GSST - Extreme Systemic Stress Scenarios: Extreme stress scenarios (GSST) with assigned likelihoods are based on:
    a. Two statistical stress scenarios, based on 90 years of historical data, and
    b. Three hypothetical stress scenarios, typically specified by the BHC economist.
3. BSST – Business Specific Stress Tests: This captures the material and complex risk not included in GSST or VaR.
4. Credit Related Default Risk Stresses: Default risk is included for credit-related stresses. For trading and counter-party risk exposure, separate calculation is added to credit with capital. For AFS and Pensions, the spread shocks in VaR-stress are grossed up to include default risk.
5. Liquidity Horizons of 1Y: Initially, the assumptions are that all liquidity horizons are for one year. The stress scenarios are defined in terms of annual change in market prices.

6. Enhancements to incorporate Reduced Volatility Horizon: Refinement allows a few businesses to use a reduced liquidity horizon, e.g., the worst being 2 months, rather than a year. This enables the use of liquidity adjusted stresses.

Step #1 – VaR at 99.97% at 1Y Horizon

1. Steps in Calculating VaR:
   - Simulate Changes in market factors – e.g., currently more than 400,000 factors are used.
   - Calculate the resulting simulated change in the portfolio value.
   - Derive the 1D 99% VaR from the probability distribution of portfolio values.
2. Adjustment for Lon Term Factors: VaR is then adjusted to reflect long-term factors. Use of long-term average volatilities and correlations instead of current values ensures that the estimated risk does not decline when the market volatility declines.
3. Scaling 1D VaR to 99.97%: The 1D VaR is then scaled from 99% at 1Y to 99.97%. The losses are assumed to follow a normal distribution, which results in scaling by inverse normal of 0.9997 divided by the inverse normal of 0.99, as well as a multiplication by $\sqrt{252}$ days.

Step #2 – Global Systemic Stress Testing (GSST)

1. Representation of Extreme Stress Events: GSST tests ensure that the extreme stress events are represented. Extreme events are poorly predicted by extrapolating everyday price changes. Stressed co-movements are much higher than everyday Pearson correlations.
2. Challenges with the Stress Testing Approach: There are a couple of challenges with using stress testing as a foundation for Risk Capital.
3. Defined Probability for Stress Tests: Stress tests typically do not have a defined probability. One alternative is to set a stress based on judgement or an observed historical shock.

However, this approach provides no statistical foundation to justify the 99.97% result. Thus, the historical data is used to provide a statistical foundation.

4. Stresses across Multiple Market Factors: Stress tests have to provide stresses for many market factors at the same time. The alternative to this is to stress each market factor separately to its extreme outcome – this, however, ignores the benefit of diversification. One solution is to start with a known baseline market factor, then represent other market factors conditional on the outcome of the baseline. Often, a BHC's baseline variable is the credit risk.

Credit Risk – The Anchor Set for GSST

1. Market Characterization of Crisis Periods: Crisis periods are characterized by a surge in credit spreads and a large drop in equity prices, e.g., the Great Depression and the 2008 Liquidity Crisis. In both cases, huge bank losses and a loss of liquidity led to many bank failures.
2. Credit as the Dominant Risk Factor: Credit risk is the dominant risk factor all major banks. A BHC's core risks are highly correlated with credit markets.
    a. Trading accounts reflect a heavy focus on fixed-income trading.
    b. Under-writing activities – especially leveraged finance – are highly correlated with credit markets.
    c. Investment portfolios often have a spread dimension, e.g., municipals.
    d. CVA PnL is heavily driven by credit spreads.
    e. Equity investment losses on FV basis are highly correlated with credit spreads.
    f. Default losses in loan portfolios are moderately correlated with credit events.

Historical Credit Spread Studies

1. Spread Changes from 1925-2011: Examination and analysis of the spread changes from 1925 to 2011 reveals several patterns. Estimating the 99.97% confidence interval for credit spread reveals that the distribution is fat-tailed, i.e., a t-distribution with 5 degrees of freedom fits the tail well. The estimated shock at 99.97% confidence corresponds to 2x the observed shocks in 2008.
2. Analysis of Historical Time Series: Analyzing the historical time series of credit spreads with that of the other market factors enables the identification of the 10 largest annual changes in credit spreads. Examination of changes in other classes of market factors is also carried out.

Scenario Design – Analyzing Patterns

1. Inflationary and Deflationary Foundation Patterns: *Two different patterns* can be noted with these largest credit-spread events – *inflationary* and *deflationary*. One can base these two foundational scenarios on the risk factor moves identified by each pattern.
2. Deflationary Systemic Stress Shock:
    a. Credit Spreads – UP
    b. Equity Markets – DOWN
    c. Yield Curve Level – DOWN
    d. Commodities – DOWN
    e. Energy - DOWN
3. Inflationary Systemic Stress Shock:
    a. Credit Spreads – UP
    b. Equity Markets – DOWN
    c. Yield Curve Level – UP
    d. Commodities – UP
    e. Energy – UP

Top 10 Credit Spread Events

1. Top Credit Spread Events Table:

Event Number	Date	Baa Spread Change (bp)	S&P 500 Annual Return (%)	5Y Treasury Absolute Change (bp)	10Y – 3M Treasury Absolute Change (bp)
1	Nov 2008	371	-39.5	-197	+129
2	Apr 1932	332	-61.4	+42	+96
3	Jan 1975	221	-29.7	+183	-53
4	Apr 1938	180	-40.5	-17	+30
5	Aug 1982	161	-2.7	-256	+520
6	Apr 1980	147	+4.5	+259	-135
7	Nov 1970	140	-7.0	-106	+169
8	Jan 2001	125	-2.0	-172	-148
9	Apr 1931	113	-39.4	-11	N/A
10	Dec 1966	94	-13.1	+28	+28

Event Number	FX Rate	WTI Spot % Return from 1946	S&P GSCI Non-energy Commodity Index	Inflationary, Deflationary, or Neither
1	+7.8%	-55.0	-28.5%	Deflationary
2	N/A	+33.8	N/A	Neither
3	-8.5%	+159.0	+49.2%	Inflationary
4	N/A	-4.2	N/A	Neither
5	-0.8%	-6.0	-7.8%	Deflationary
6	-1.0%	+149.0	+4.1%	Inflationary
7	N/A	-1.0	+3.9%	Neither

8	8.1%	+9.0	+3.2%	Neither
9	N/A	-45.4	N/A	Neither
10	N/A	+2.0	N/A	Neither

2. Notes on the above Table:
   - The FX rate is specified as USD/EUR from Feb 1999. Prior to the German DM/USD is used. FX did not float until after the Bretton-Woods system, and is represented by N/A in the table for the years prior to 1973.
   - Energy price return is calculated using annual averages of crude oil purchase prices in dollars per barrel, sourced from the Energy Information Administration.

Formulating GSST Scenarios

1. 2008 Capital Baseline - Deflationary Crisis: This is the first of the two key scenarios that drive much of the VaR-stress result. This equals the conditional outcome for all prices given a 99.97% shock to credit spreads divided by 2, i.e.

$$\begin{aligned} &\mathit{Conditional}\ 99.97\%\ \mathit{Shock} \\ &\qquad = \mathit{Standalone}\ 99.97\%\ \mathit{Shock} \\ &\qquad \times \mathit{Stress\ Correlation\ with\ Credit\ Spreads} \end{aligned}$$

2. Scenario Components of Deflationary Crisis:

Market Factor	2008 Actual	Study	Extrapolated 99.97% Shock	Stress Correlation	2008 Capital Baseline Shock

Credit Spreads	Varies by Instrument	BBB credit spreads back to 1925	2x as large as 2008 Actual	1.0	Same as 2008 actual for each instrument
DM Interest Rates	-200 bp for 5Y treasury	Treasury Yields back to 1953	-320 bp	-0.50	-100 bp ~ -320 bp x 0.5 / 2
DM Equity Prices	-40%	S&P 500 back to 1948	-74%	0.84	-32% ~ -74% x 0.84 / 2

3. 1974 Capital Baseline - Inflationary Crisis: The 1974 capital baseline is the second key scenario. It is judged to be the aggregate of the 99.97% of wider spreads and rising interest rates. Individual shocks are around 80% of the estimated 99.97% shock divided by 2. However, the reverse correlation of the rates/spreads makes this scenario much less likely.
4. 1974 Capital Baseline Scenario Table:

Market Factor	**1974 Actual**	**2008 Capital Baseline Shock**	**Rationale**
Credit Spreads	56% of 2008 Actual	80% of 2008 actual for each instrument	Given t-5 distribution, this is about twice as likely as a 99.97% shock
DM Interest rates	+183 bp for 5Y treasury	+150 bp	Standalone 99.97% shock estimated at 90%. Multiply by ~80% - judgmental – then divide by 2
EM Equity Prices	-30%	-25.5%	Multiply 2008 Capital Baseline by ~80%

Step #3 – Business Specific Stress Tests

1. <u>Purpose of Business Specific Tests</u>: The purpose is to quantify material risks not quantified by GSST or VaR. Examples include exotic derivatives, merger arbitrage, and basis risks not in GSST. The cBSST or the *correlated* BSST is typically used to address deficiencies in the GSST. The iBSST or *independent* BSST is used to address the idiosyncratic risks. The loss occurs randomly, but is correlated with the GSST results.
2. <u>Guidelines to Developing Business Tests</u>: A BSST is required if risk is not accurately captured by VaR or GSST. It would typically be proposed by risk managers, and agreed to with the business. The update process is monthly, and the updates will be done as the potions change. Typically, certain materiality tests may be app-lied. For instance, if the correlation is zero, the loss amount may be estimated as 5% of the business GSST loss amount with a lower floor – say $25 million loss amount. If the correlation is high, the floor may be set at a smaller amount, e.g., $5 million. The probability is set to 1-in-50 year confidence level for linear risks. The defeasance period is treated to be a maximum of one year. This is based on conservative period to defease the exposure in a stressed environment.

VaR-Stress integrates VaR and Stress Results

1. <u>Annualized VaR</u>:
   a. VaR is simulated as a Normal Random variable.
   b. VaR is computed based on through-the-cycle volatilities, not current volatilities, to avoid pro-cyclicality.
   c. VaR is scaled to be half of the 99.97% 1Y c.i.
   d. The VaR based outcome is assumed to be uncorrelated with the stress results. Therefore, it represents idiosyncratic risk.
2. <u>Systemic Stresses (GSST)</u>:
      a. In 88% of the simulations, there is no stress loss.

b. In 12% of simulated outcomes, one of 6 GSST scenarios is randomly selected – at 2% probability for each scenario.
c. Each position is revalued using the assumptions corresponding to the selected GSST scenario.
3. Business Specific Stress Tests BSST:
   a. BSST represents the 1-in-50 downside losses for linear risks. For non-linear risks, the BSST loss is the 99.97% loss divided by 2.
   b. Each iBSST is simulated separately as a binomial variable with a given probability.
   c. Each cBSST is specified by the Market Risk Manager for each of the GSST scenarios.
4. Total Loss in a Path: In each scenario, the total loss outcome is the sum of the VaR PnL, the GSST PnL, and the BSST outcome(s).
5. The VaR Stress Capital Estimate: The VaR-stress equals the average loss in the 98th percentile tail. The 98th percentile tail is the average of the worst 200 outcomes out of 10,000 simulated scenarios.
6. Risk Capital Estimated at 99.97%: The loss is then scaled by 2x to estimate the risk capital at 99.97%.

Illustration of VaR-Stress Process

1. Generate a simple annualized VaR distribution.
2. Compute the gain or loss from the six stress scenarios.
3. Generate the 6 annualized VaR distribution centered the six stress scenarios using the initial distribution.
4. Finally, generate the fat annualized tail distribution.

Allocation of Total Risk Capital to each Business

1. Allocating the VaR-stress Capital: The total VaR-stress RC is allocated among the businesses. This uses the large diversification benefit among the businesses. The following are the objectives of an allocation methodology:
    a. Simple and stable over time.
    b. Diversified RC for each business should be proportional to the business' standalone risk.
    c. The business allocations have to add up to the total VaR-stress outcome.
2. Pro-rata and Contributory Allocation Approaches:
    a. In the pro-rata approach, the business capital allocation fraction equals the standalone business RC divided by the sum of the standalone RC of all the other businesses. The concern with this approach is that this does not adjust for the different correlations and the level of systemic risk.
    b. In the contributory approach, the business capital equals the incremental marginal impact of each business to the total risk capital. However, this can lead to negative allocations. Further, the allocated capital can also be unstable across time.
3. Beta Approach for Capital Allocation: To address the above issues, a *beta* approach is used for the allocation to the businesses.
    a. The beta measures the level of systemic risk for a business.
    b. Beta has three values – high, medium, or low.
    c. The RC allocated to each business is the product of the business beta and the business standalone RC.
    d. Betas may be calibrated each quarter such that the sum of business capital equals the total VaR-stress capital.
4. Determination of the Betas: First, estimation of the systemic risk of each business is required.
    a. First, correlation between each business revenue and a suitable credit spread index must be performed.
    b. The core of the BHC risk is credit, so a high correlation with credit means that the business adds directly to the BHC's core risk.

c. The historical correlation must be adjusted judgmentally to reflect structural business risks and potential loss of liquidity in a crisis.

5. Beta Table for Historical Correlation: Each quarter, x is re-calibrated so that the sum of the RC is the total BHC RC.

Historical Correlation Beta Bucket	Starting Beta (say, 2010 beta)	Final Business Beta
High	80%	80%
Medium	36%	2x
Low	18%	x

6. Allocation for CVA and AFS: For CVA and AFS exposure, the allocation is very simple. The VaR-stress result is driven entirely by shocks to credit spreads. The sum of business is very close to the total. The businesses simply add up to the total.
7. Example - Trading/AFS Beta Classification Table:

Product	Business	Trading Beta	AFS Beta
Advisory	Advisory	Low	High
CAI	CAI	Medium	High
Commodities	Commodities Houston	Low	High
Credit	Credit Trading	Medium	High
	Distressed	Medium	High
	EM Credit Trading	Medium	High
	Credit Macro Hedge	Hedge	Hedge
	PECD	High	High
	Short Term	Medium	High
	GSSG West	High	High
EM ABF	EM ABF	Medium	High
Equities	Cash	Low	High
	Converts	High	High
	Equity Derivative	Medium	High

Equity Under-writing	Equity Under-writing	Low	High
Fixed Income Under-writing	EM Bonds	Medium	High
	EM Primary Loans	Medium	High
	IG Bonds	Medium	High
	IG Primary Loans	Medium	High
	Leveraged Finance	High	High
	Other FI Under-writing	Medium	High
	Project Finance	Medium	High
FX Local Markets	G10 FX	Low	High
	Local Markets	Low	High
G10 Rates	G10 Rates	Medium	High
G10 Risk Treasury RV Finance	FIMA	Low	High
	Finance	Low	High
	Risk Treasury	Low	Medium
GTS	GTS	Low	High
GWM	GWM	Low	High
Hybrids	Hybrids	Medium	High
Municipals	Municipals	Medium	High
OS&B	OS&B	OS&B	OS&B
Other Global Markets	Other Global Markets	Low	High
Prime Finance	Prime Finance	Low	High
Securitized Markets	Securitized Markets	High	High

8. Notes on Sample Table:
   a. Certain businesses, such as Consumer Banking and other Corporate Lines, may not receive a beta treatment.
   b. Betas for some activities may be not be differentiated across its component businesses.
   c. Hedge means a beta of -1 because these hedges should produce a profit in a crisis.

Conclusion

1. Risk Capital Estimation as a Fundamental Activity: Risk capital estimation is based ongoing, fundamental risk management systems. It must integrate both normal VaR and stress tests.
2. Avoiding Double Counting of Losses: The systemic and business specific stress losses and VaR capture different aspects of risk, and can be statistically combined.
3. Understandable by Business Units: Stress based risk capital is simple to understand. Allocation to businesses is based on their own risks.
4. Ongoing Performance Review and Enhancement: The core stress scenarios (2007/2008) have been refined over time with additional research. The three hypothetical stress scenarios – conditioned on the current state of the economy – are periodically updated by the senior economist in collaboration with senior risk management. Business specific risks are reviewed and updated by trading risk managers in a systematic way. Trading risk managers must also meet monthly to review VaR PnL attribution to identify any material risk not captured in VaR, or any adjustments that may need to be made to the GSST scenarios. Liquidity-adjusted stresses must be applied to as many areas as possible.

GSST Stress Scenario Definitions

1. Variable/Market Factor:
    a. Macro-economic Variables
        i. GDP
        ii. Unemployment
        iii. House Prices (Case/Shiller) – Note a
    b. Market Factors
        i. IR Level – Note b, Note c
        ii. IR Slope – Note b, Note c

iii. Credit Spread including Municipals – Note d
iv. Spot FX – USD vs all other currencies – Note e
v. Equity and equity indexes
vi. Private equity – Note f
vii. Hedge funds – Note h
viii. ABX Index 07-1 AAA
ix. Energy – WTI, 1MFt
x. Natural Gas – NYMEX, 3Mft
xi. Copper Spot
xii. Gold Spot
xiii. Corn 3MFt
xiv. Other Commodities
xv. Equity Implied Volatilities VIX
xvi. Implied Volatilities – Other – Note g

c. Other
   i. Wholesale LGD
   ii. Likelihood of Scenario

2. Variable/Market Factor Description:

Variable/Market Factor	**DM or EM**	**Type of Change**	**Unit**
GDP	Both	1	ppt
Unemployment	Both	2	ppt
House Prices	Both	3	pct
IR Level	DM/EM Low Vol EM High Vol	4	bp
IR Slope	DM/EM Low Vol EM High Vol	4	bp
Credit Spread	Both	5	pct
Spot FX	DM/EM Low Vol EM High Vol	3	pct

Equity	DM EM	3	pct
Private Equity	DM EM	3	pct
Hedge Funds	Both	3	pct
ABX	Both	3	pct
Energy	Both	3	pct
Natural Gas	Both	3	pct
Copper	Both	3	pct
Gold	Both	3	pct
Corn	Both	3	pct
Other Commodities	Both	3	pct
VIX	Both	6	Vol points
Implied Volatilities – Other		3	pct
Wholesale LGD	Both		pct
Likelihood			

3. Definition of Monthly Scenarios - Hypothetical:

Variable/Market Factor	Dollar Decline	Lost Decade	IR Shock	Deep Downturn
GDP	-0.8	-0.8	-1.5	-1.6
Unemployment	1.7	1.8	2.0	2.3
House Prices	-7.7	-13.3	-16.0	-17.2
IR Level	86 86	-64 50	175 275	-134 100
IR Slope	-124 -124	-42 -54	-50 -50	-102 -109
Credit Spread	30	25	40	50
Spot FX	-7 -10	4.8 4.8	3.0 6.0	12.0 24.0

Equity	-15.1 -18.9	-17.0 -21.3	-25.0 -35.0	-30.2 -37.8
Private Equity	-12.1 -15.1	-13.6 -17.0	-20.0 -28.0	-24.2 -30.2
Hedge Funds	-6.1	-6.8	-10.0	-12.1
ABX	-17.0	-10.0	-10.8	-25.0
Energy	59.6	-14.9	20.0	-36.2
Natural Gas	55.6	-15.6	18.5	-31.1
Copper	51.9	-20.0	17.3	-40.0
Gold	45.6	-8.3	20.0	-16.7
Corn	33.1	-11.7	11.0	-23.3
Other Commodities	30	-10	10	-20
VIX	37.9	42.6	67.5	75.6
Implied Volatilities – Other	21.5	16.0	30.0	33.5
Wholesale LGD	35	35	50	50
Likelihood	1-in-50	1-in-50	1-in-50	1-in-50

4. Capital Baseline Scenarios:

Variable/Market Factor	**Historical Scenarios**		**Baseline Scenarios**	
	1974	**2008**	**1974**	**2008**
GDP	-2.3	-5.0	N/A	N/A
Unemployment	3.7	4.0	N/A	N/A
House Prices	-5.0	-20.0	N/A	N/A
IR Level	183 112	-200 200	150 112	-100 200
IR Slope	-53 -122	129 -218	-100 -174	100 -218
Credit Spread	56	100	90	100
Spot FX	-8	8	-8	8

	-8	24	-8	24
Equity	-30 -40	-40 -55	-25.5 -35.5	-32 -40
Private Equity	-24 -32	-32 -44	N/A N/A	N/A N/A
Hedge Funds	-12	-16	N/A	N/A
ABX	-15	-55	-20	-40
Energy	160.0	-55.0	112.0	-32.0
Natural Gas	90.9	-20.0	89.0	-28.0
Copper	84.7	-53.0	83.0	-16.0
Gold	72.0	2.0	73.0	-15.0
Corn	54.1	-14.0	53.0	-21.0
Other Commodities	49.0	-29.0	48.0	-18.0
VIX	75.0	100.0	63.8	80.0
Implied Volatilities – Other	45.0	50.0	40.0	25.0
Wholesale LGD	50.0	50.0	50.0	50.0
Likelihood	1-in-50	1-in-50	N/A	N/A

5. Notes on the Listings Above:
    a. Represents 18-month decline. The peak-to-trough would be significantly greater.
    b. The yield curve is based off of the local currency sovereign. The level refers to the parallel shift to the entire curve.
    c. The slope pivots at the 5Y tenor. There is an interest rate floor at 0 bp for the short term, 25 bp for 5Y, and 50 p for 10Y to avoid negative rates.
    d. The percentage change in the credit spread ids against a fixed baseline.
    e. Negative FX % implies a USD depreciation.
    f. PE risk capital is already defined and therefore no capital baseline stress is provided.
    g. Volatility shock applies to Commodities, FX, and Rates.
    h. Capital baseline shocks are usually set using baselines determined by an Alternate Asset Investment Team, say -35%.

i. The baseline scenarios are the ones usually driving the risk capital.

6. Details on Types of Change:
   a. 1 => Scenario GDP growth – Q/Q – 4
   b. 2 => Peak vs Current Level
   c. 3 => Change vs Current – Q/Q – 4
   d. 4 => Change vs. 4Q forward
   e. 5 => Change as a % of calendar 2008 spread widening
   f. 6 => Volatility point change as % change of calendar 2008 volatility point change – 39 volatility points for 1M ATM

Integrated VaR and Stress Testing Risk Capital Methodology

Executive Summary

1. Integrated VaR and Stress Testing Model: The integrated VaR and Stress Testing (iVAST) model is designed to estimate the amount of risk-adjusted capital (Risk Capital) needed to support the BHC's trading and mark-to-market (MTM) exposures and spread risk associated with AFS, CVA, and Pensions, at a high confidence level.
2. Major Objectives of the Model: The model intends to satisfy the following criteria as much as possible. First, it measures potential losses over one year period in a severely adverse scenario, notionally equivalent to 99.97^{th} percentile of the model loss distribution.
3. Constant Level of Risk Assumption: It is consistent with a constant level of risk assumption, i.e., assumes that the businesses will maintain the same risk exposure over a one-year period, and will not materially increase or reduce their risk-taking as market conditions change.
4. Full Inclusion of "Tail Events": It is fully inclusive of *tail events*, including the non-normal behavior of the individual market factors, high correlation during the stress periods, and illiquidity as the markets crash.
5. Stable Level of Risk Capital: It aims to provide an approximately stable level of risk capital over the economic cycle, avoiding the potentially volatile capital associated with, for example, a VaR model calibrated to recent data.
6. Drawbacks of a Purely Statistical Model: Before iVAST, BHC's had often relied on a purely statistical (VaR-based) model for estimating Risk Capital (RC).
7. Need for Enhanced Capital Models: During the 2007/2008 financial crisis, typical BHC losses well exceeded the RC levels estimated by the statistical models and it became necessary to develop and enhanced method for estimating Market Risk Capital.
8. Combining VaR and Stress Outputs: iVAST was developed to address this limitation by combining outputs from VaR with those from stress tests generating scenario dependent losses.

9. Components of the Stress P&L: The stress P&L's consists of the Global Systemic Stress Test (GSST) P&L, correlated Business Specific Stress Test (cBSST) P&L, and idiosyncratic Business Specific Stress Test (iBSST) P&L.
10. Correlation Assumption Among the Components: Illustration of the P&L aggregation is shown below representing the perfect correlation assumption between the GSST and the cBSST P&L's, and the independence assumption of iBSST P&L's.
11. Illustration of the Aggregation Logic:

VaR P&L		**GSST P&L**		**cBSST P&L**		**iBSST P&L**		**Aggregated P&L**	
1	V_1	1	G_1	1	cB_1	1	0	1	$V_1 + G_1 + cB_1$
2	V_2	2	G_1	2	cB_1	2	0	2	$V_2 + G_1 + cB_1$
3	V_3	3	G_1	3	cB_1	3	iB	3	$V_3 + G_1 + cB_1 + iB$
…	…	…	…	…	…	…	…	…	…
200	V_{200}	200	G_1	200	cB_1	200	0	200	$V_{200} + G_1 + cB_1$
201	V_{201}	201	G_2	201	cB_1	201	iB	201	$V_{201} + G_2 + cB_2 + iB$
…	…	…	…	…	…	…	…	…	…
400	V_{400}	400	G_2	400	cB_2	400	0	400	$V_{400} + G_2 + cB_2$
…	…	…	…	…	…	…	…	…	…
1000	V_{1000}	1000	G_5	1000	cB_5	1000	0	1000	$V_{1000} + G_5 + cB_5$
1001	V_{1001}	1001	0	1001	0	1001	0	1001	V_{1001}
…	…	…	…	…	…	…	…	…	…
5893	V_{5893}	5893	0	5893	0	5893	iB	5893	$V_{5893} + iB$
…	…	…	…	…	…	…	…	…	…
10000	V_{10000}	10000	0	10000	0	10000	0	10000	V_{10000}

Model Scope, Purpose, and Functional Soundness

1. Model Purpose: The intended use of the model is to calculate the Risk Capital with one-year time horizon, through-the-cycle view, and at 99.97 percentile confidence level.

2. Requirements: This meets the usage requirements that the model must be capable of calculating stand-alone and marginal RC at a level defined by, for e.g., group, product, business, and risk type.
3. Scope of the Model: The scope of the model is defined by the characteristics of the assets covered.
4. Nature of the Assets Covered: That is, the model intends to cover all the assets that have price risk, which is defined as meeting one of the following criteria:
    a. BHC intends to sell the asset prior to maturity, i.e., most trading assets.
    b. Asset is funded by short-term debt, and hence will be market-to-market.
    c. Losses would impact equity due to accounting treatment.
5. Model Inputs and Test Data: The model inputs and the data used for testing in the later sections of this chapter are deemed to be sufficient for establishing the functional soundness of the model.
6. Model Assumptions and Framework: The model calculates the risk capital based on the assumption that the businesses maintain their asset composition during the one-year time horizon, which is a common assumption in Risk – or Economic – Capital Calculation Framework in the industry.
7. Model Outputs: The model generates outputs in three different perspectives.
8. Standalone Perspective: Under the standalone perspective, RC is calculated for each entity (Business, for example) without any diversification benefit. This approach ignores any off-setting correlation between the businesses. For this reason, the sum of the stand-alone RC for all BHC businesses is higher than the RC of Citi on a standalone basis.
9. Marginal-To-Firm Perspective: Under the marginal-to-firm perspective, the sum of all the BHC businesses will be equal to the standalone RC of the BHC. This view provides details on which businesses contribute or off-set firm-level RC.
10. Importance of the Marginal-To-Firm Perspective: given that the current audience for the model outputs being group-level or business-level managers, this perspective may not be used extensively. However, this has an important theoretical meaning because it is computed from a contributory perspective – similar to CVaR – including the diversification of each business' risk against other businesses.

11. Marginal-To-Group Perspective: Under the marginal-to-group perspective, the sum of the individual RC's of the businesses of the group will be equal to the standalone RC for the group. This view provides details on which businesses contribute to or offset group-level RC.
12. Downstream Consumers of the RC: There are two downstream usages of the outputs – which are the desk – or sub-business – level allocation and the country level allocation.
13. Desk Level Allocation of RC: For the desk – or the sub-business – level allocation, the model outputs at the business level are allocated to the desk – or the sub-business – level by multiplying the business-level number by a constant assigned to each desk or sub-business.
14. Country-Level Allocation of RC: For the country-level allocation, the model outputs at the regional level are allocated at the country level based on a distribution of the VaR.

Functional Soundness Governance

1. Model Design/Development Stakeholders: Typical contributions of the stakeholders during the design/development of the model include the following:
    a. Market Risk Management defines the scope and the requirement
    b. Risk Analytics develops and implements the model incorporating inputs such as VaR, GSST, and BSST.
    c. Model Risk Management validated the model.
2. Model Operation/Maintenance Stakeholders: Contributions of the stakeholders during the operation/maintenance of the model include the following:
    a. Risk Analytics calibrates the model parameters periodically and provides it to Risk IT
    b. Risk IT generates the model inputs
    c. Risk Reporting/Finance distribute/monitor the model output
    d. Model Risk Management conducts an on-going performance assessment on a regular basis
3. Monthly Model Review and Reporting: Trading Book Metrics holds the following two monthly meetings to review the iVAST model and its inputs. Attendees include Risk

Analytics, Risk Architecture including Risk Capital and Stress Testing Methodology, Business Line Risk Management, Model Risk Management, and Risk Reporting, with:

   a. Top Risk/BSST/Risk not-in-VaR reviews covering the risk identification, documentation, and historical trend to cover these risks and their contributions to risk capital
   b. GSST, BSST, and iVAST discussions

   On a monthly basis the iVAST results are published in the Addendum of the ICG Risk Management Committee Package distributed to the business and the regulators.

4. Working Group for Methodology Enhancements: A working group is formed involving Capital Optimization and Finance to discuss enhancements and re-calibration of the iVAST desk or sub-business level allocation – beta allocation – methodology, in preparation for rolling out the Corporate Capital Allocation Framework.

Basis behind the Modeling Approach

1. Description of the Applicable Modeling Approaches (MA): As stated, the model's objective is to calculate the RC over a one-year time horizon at 99.97% confidence level. Assuming no data restrictions, the preferred approach modeling would be to estimate the market factors' possible movements over one-year time horizon and use a VaR type P&L simulation approach to estimate the 99.97% loss number.
2. Approach Modifications under Data Limitations: With data limitations, one alternative is to utilize the VaR by scaling the results considering time horizon difference, confidence level difference, etc. Another approach is to combine scenario-based approach with a VaR-type simulation approach.
3. Preferred Modeling Approach: Estimating potential loss for a portfolio at 99.97% confidence level in one-year time horizon is tantamount to estimating the third worst-case scenario in a 10,000 year history. One of the main challenges with the preferred approach like the VaR simulation approach is the availability of data to capture extreme tail events with sufficient fidelity.

4. Phase 1 Risk Capital Model: Previously, RC was typically estimated by extrapolating the one-day 99% confidence-level VaR results:
    a. The 99% daily VaR was extrapolated to 99.97% assuming a normal distribution;
    b. The one-day VaR was extrapolated to one-year, assuming that the P&L each day was an independent random draw from an identical distribution, i.e., i.i.d. assumption.
5. Lack of Liquidity in the Credit Markets: Neither of these assumptions was valid during the 2008 crisis. For example, during that year market liquidity for some credit-sensitive assets materially decreased, and instead of the credit spreads following a random walk during that year, they widened almost every day as leveraged firms sold credit-sensitive assets to meet margin calls and/or minimum capital requirements.
6. Phase 2 Risk Capital Model: To address the data limitations and the issue of extrapolating the VaR model results, the methodology of combining the scenario based approach with the simulation based approach was devised and has been adopted in the model.
7. Advantages of the Approach: The approach takes the strengths of the two models such as the ability to evaluate a wide range of loss cases of the simulation based approach and to incorporate specific severe market events of the scenario based approach. Details of the modeling approach are described in the later sections.

Technical Soundness Considerations

1. Model Data, Development, and Specification: In this section the details of the technical specifications and the model implementation are described.
2. Model Objective: The technical objectives of the model are as follows.
3. Pro-cyclical GSST and BSST Loss Distributions: Combine VaR adjusted for through-the-cycle view, GSST, and BSST to produce the P&L distribution.
4. Conditional Business Tail Expected Shortfall: Calculate the expected shortfall defined as a conditional expectation of the loss distribution at its tail region.
5. Firm-Conditional Business Tail Loss: Calculate the expected shortfall of a business conditional on the tail region loss cases of the firm.

6. Group-Conditional Business Tail Loss: Calculate the expected shortfall of a business conditional on the tail region loss cases of the group the business belongs to.
7. Rationale behind the Model Objectives: The first technical objective serves as the functional requirement of producing a through-the-cycle P&L distribution while capturing extreme loss events. The second technical objective is to calculate the standalone RC. The third and the fourth technical objectives are to calculate the marginal RC's of a business to the firm and the group it belongs to, respectively.
8. Model Inputs: The model inputs fall into three categories – VaR P&L, Stress P&L, and grouping/mapping. The abstract data structures of the model inputs are described below.
9. VaR P&L: VaR P&L input has 10,000 P&L's by Account Level, Factor Sensitivity (FS) type, Region, and Risk Type.
10. Spot to Through-the-Cycle Volatilities: As the VaR P&L's are based on the volatilities measured from the recent three years data, they are considered as point-in-time measures. To convert them into through-the-cycle ones, the P&L's are scaled by volatility adjustments.
11. Updating Through-the-Cycle Volatilities: The volatility adjustments are provided to the model as input and defined at the individual FS types. The adjustment is calculated as the ratio of long-term volatility to the volatility used in VaR for the representative market factor in each FS type. The long term volatilities are update typically quarterly using the entire history available.
12. Stress P&L's: Stress P&L's have 3 components: GSST P&L, cBSST P&L, and iBSST P&L.
13. GSST Scenario Sequence P&L Treatment: GSST P&L input has P&L by business (e.g., Consumer Cards, Consumer Other, etc.), Region (e.g., ASIA, EMEA, etc.), Risk Type (AFS, Trading, etc.), and GSST scenario with probability assigned at each scenario. GSST is expected to measure unexpected financial impact under various historical and hypothetical systemic stress scenarios.
14. Determination of the GSST Scenarios: GSST scenarios are defined as a specific combination of the market and the macro-economic shocks designed to adversely impact the firm's financials. GSST scenarios are assumed to be mutually exclusive.
15. Correlated BSST Scenario P&L Treatment: cBSST P&L input has P&L by Business, Region, Risk Type, GSST scenario, and cBSST scenario. cBSST for each of the specific portfolio is

deigned to capture the risks that are assumed to be perfectly correlated to one of the GSST scenarios but are not captured by GSST due to lack of granularity or insufficient large stress moves.

16. Independent BSST Scenario P&L Treatment: iBSST P&L input has P&L by Business, Region, Risk Type, and the corresponding iBSST scenario with the associated probability. iBSST is designed to capture the effects of risks with low correlation to the GSST scenarios and missing from the VaR scenarios. An iBSST scenario is assumed to be independent from the other iBSST scenarios as well as the other GSST/cBSST scenarios.
17. Grouping/Mapping: As the model produces RC numbers at the bucket level defined by Group (BHC-GCG, BHC-ICG, etc.), Product (Consumer, Advisory, etc.), Business, Region, and Risk Type, there are several grouping/mapping inputs:
    - Business to Account-level mapping
    - Group, Product, and Business grouping
    - RBC code to Risk Type mapping to map VaR P&L to one of the Risk Types
    - Region in VaR P&L to Region in iVAST mapping
18. Model Outputs: The model generates RC for each business and its various aggregates. The outputs are reported in three different perspectives.
19. Standalone versus Marginal Risk Capital: First, in the standalone perspective, the RC is calculated without the diversification benefit. Second, in the marginal-to-firm perspective, RC at a business is the contribution to the firm-level RC. Marginal-to-group is the last perspective, in which the RC at the business level is the contribution to the group level RC.
20. Marginal to Higher Aggregation Granularities: Additionally, details such as Marginal-to-Regional BHC, contributory VaR to RC by business, region (ASIA, EMEA, GLOBAL, and NA), and risk type (AFS, ALL, CVA, IDR, Pension, Trading, etc.) are produced.
21. Additional RC-Related Outputs: The model produces details such as:
    - Marginal to Global BHC
    - Marginal to Regional BHC
    - Marginal to Global Group
    - Marginal to Regional Group Standalone
    - Contributory VaR to Standalone

- Contributory GSST to Standalone
- Contributory BSST to Standalone
- 1-day VaR
- 1974 Baseline – Total
- 2008 Baseline – Total
- Deep Downturn – Total
- Interest Rate Shock – Total
- Lost Decade – Total
- Worst iBSST
- 1974 Baseline – GSST
- 2008 Baseline – GSST
- Deep Downturn – GSST
- Interest Rate Shock – GSST
- Lost Decade – GSST
- 1974 Baseline – cBSST
- 2008 Baseline – cBSST
- Deep Downturn – cBSST
- Interest Rate Shock – cBSST
- Lost Decade – cBSST
- Contributory cBSST to Standalone
- Contributory iBSST to Standalone

22. 3M Average versus 1M Snapshot: A set of outputs can be either a three month average ("regular") view or a single month snapshot.
23. Aggregating VaR and Stress P&L: The model generates P&L distribution by aggregating the P&L's from VaR L_{VaR} with stress P&L's of GSST L_{GSST}, cBSST L_{cBSST}, and iBSST L_{iBSST}. That is, the aggregated P&L L_{iVAST} is the scaled sum as shown below.
24. Master VaR and Stress Combiner:

$$L_{iVAST} = k_{VaR} \cdot L_{VaR} + k_{STRESS} \cdot L_{STRESS}$$

where

$$L_{STRESS} = L_{GSST} + L_{cBSST} + L_{iBSST}$$

25. The Correlation and the Scale Parameters: Scaling factors k_{VaR} and k_{STRESS} and the correlation assumptions are used in addition to the above equations, as explained later.
26. VaR P&L per Market Factor: The VaR model generates P&L's for each Factor Sensitivity (FS) type by simulating the underlying market factors.
27. Through-the-Cycle P&L Conversion: As the VaR calculation is based on the point-in-time market factor volatilities at time t, the simulated P&L's from factor i $l_{VaR,i}(t)$ are multiplied by the volatility adjustment $vol\_adj_i(t)$ to be converted into the through-the-cycle values.
28. Snapshot P&L across Market Factors: $vol\_adj_i(t)$ is estimated using the ratio of long-term volatility used in the VaR calculation at time t and the VaR P&L's are adjusted and aggregated as shown below:

$$l_{VaR}(t) = \sum_{FS\ type\ i} vol\_adj_i(t) \cdot l_{VaR,i}(t)$$

29. Smoothening of the Consolidated P&L's: To reduce the fluctuation in the RC from portfolio change over time, L_{VaR} as of time t is defined as the sum of the current $l_{VaR}(t)$ and two previous month end $l_{VaR}(t-1)$ and $l_{VaR}(t-2)$ divided by $\sqrt{3}$ as shown below.

$$L_{VaR} := \frac{1}{\sqrt{3}}[l_{VaR}(t) + l_{VaR}(t-1) + l_{VaR}(t-2)]$$

30. One day $l_{VaR}(t)$ Snapshot: The summation in the above equation is done by assuming that the random variables are independent. Note that the L_{VaR} defined above represents one day P&L. Further adjustment of one-day to one-year time horizon is done in k_{VaR}.

31. One Month $l_{VaR}(t)$ Snapshot: For a single-month snapshot, L_{VaR} is defined alternatively as

$$L_{VaR} := l_{VaR}(t)$$

32. 3M Annual Stress P&L Snapshot: Similar to the VaR P&L, the stress P&L's except iBSST P&L are defined as the average of the recent 3 month's values to reduce the time varying portfolio effect:

$$L_{GSST} := \frac{1}{3}[L_{GSST}(t) + L_{GSST}(t-1) + L_{GSST}(t-2)]$$

$$L_{cBSST} := \frac{1}{3}[L_{cBSST}(t) + L_{cBSST}(t-1) + L_{cBSST}(t-2)]$$

$$L_{iBSST} := L_{iBSST}(t)$$

33. Time Horizon for Stress P&L: Note that the stress P&L's are already estimated for a one-year time horizon. As a result, average rather than the summation divided by $\sqrt{3}$ is used.
34. Single Month Annual Stress P&L Snapshot: For a single month snapshot, the stress losses are defined alternatively as:

$$L_{GSST} := L_{GSST}(t)$$

$$L_{cBSST} := L_{cBSST}(t)$$

$$L_{iBSST} := L_{iBSST}(t)$$

35. Rationale behind the k_{VaR} Estimation: The role of k_{VaR} is to adjust for the time horizon mismatch and make the expected shortfall at 2% comparable to the P&L at 0.03% confidence level.

36. Definition of, and Expression for, k_{VaR}: Denoting the value of a random variable x and a confidence p as $percentile\ (x, p)$ k_{VaR} is derived using the equation below.

37. EDS and L_{VaR} Horizon Scaling:

$$k_{VaR} \cdot \mathbb{E}\left[L_{VaR,1D} | L_{VaR,1D} \leq percentile\left(L_{VaR,1D}, 2\%\right)\right] = percentile\left(L_{VaR,1Y}, 0.03\%\right)$$

where $L_{VaR,1Y}$ represents a random variable of VaR P&L over one-year time horizon, and $L_{VaR,1D}$ is the one-day P&L defined in

$$L_{VaR,1D} := \frac{1}{\sqrt{3}}\left[l_{VaR}(t) + l_{VaR}(t-1) + l_{VaR}(t-2)\right]$$

38. 1D To 1Y L_{VaR} Horizon Scaling: Assumption of a normal distribution for $L_{VaR,1D}$ such that

$$L_{VaR,1D} \sim (0, \sigma)$$

along with the independent and identically distributed assumption of daily P&L leads to

$$L_{VaR,1D} \sim \left(0, \sqrt{260}\sigma\right)$$

39. Explicit Expression for k_{VaR} Estimate: Then k_{VaR} is calculated as

$$k_{VaR} = \frac{percentile\left(L_{VaR,1Y}, 0.03\%\right)}{\mathbb{E}\left[L_{VaR,1D} | L_{VaR,1D} \leq percentile\left(L_{VaR,1D}, 2\%\right)\right]} = \sqrt{260} \times \frac{\Phi^{-1}(0.0003)}{\frac{1}{2\%}\int_{-\infty}^{\Phi^{-1}(0.02)} x\phi(x)dx}$$

where $\Phi(\cdot)$ denotes the inverse cumulative distribution function and $\phi(\cdot)$ the probability density function of the standard normal distribution. This results in

$$k_{VaR} = 22.8$$

40. Formulation of the k_{STRESS} Estimator: k_{STRESS} is similarly defined as

$$k_{STRESS} \cdot \mathbb{E}[L_{STRESS} \mid L_{STRESS} \leq percentile(L_{STRESS}, 2\%)] = percentile(L_{STRESS}, 0.03\%)$$

41. Explicit Expression for k_{STRESS} Estimate: Assuming a Student's t distribution with degree of freedom ν for L_{STRESS}, k_{STRESS} is calculated as

$$k_{STRESS} = \frac{\mathrm{T}^{-1}(0.0003;\ \nu)}{\frac{1}{2\%}\int_{-\infty}^{\mathrm{T}^{-1}(0.02;\ \nu)} x t(x;\ \nu) dx}$$

where $t(x;\ \nu)$ and $\mathrm{T}^{-1}(x;\ \nu)$ respectively denote the Student's t density and the inverse cumulative distribution function given ν degrees of freedom, which is currently set to 5. This results in

$$k_{STRESS} = 2.0$$

42. Correlations among L_{VaR}, L_{GSST}, L_{cBSST}, and L_{iBSST}:

$$L_{iVAST} = k_{VaR} \cdot L_{VaR} + k_{STRESS} \cdot L_{STRESS}$$

and

$$L_{STRESS} = L_{GSST} + L_{cBSST} + L_{iBSST}$$

require correlation assumptions among L_{VaR}, L_{GSST}, L_{cBSST}, and L_{iBSST}

43. PDF for the GSST Distribution: Hence its probability density function $f_{GSST}(x)$ is defined as

$$f_{GSST}(x) = \sum_{s=1}^{N_{GSST}} \delta(x - L_{GSST,s})p_{GSST,s} + \left[1 - \sum_{s=1}^{N_{GSST}} p_{GSST,s}\right]\delta(x)$$

where $\delta(\cdot)$ denotes the Dirac delta function and $p_{GSST,s}$ is the probability of a the GSST scenario s.

44. <u>GSST P&L in Scenario s</u>: GSST P&L in scenario s, $L_{GSST,s}$, is defined as

$$L_{GSST,s} = \sum_{b,r,rt} l_{GSST,s,b,r,rt}$$

where $l_{GSST,s,b,r,rt}$ represents the P&L for Business s, Region r, and Risk Type rt under the GSST scenario s.

45. <u>cBSST 100% correlated with GSST</u>: cBSST P&L is defined to be perfectly correlated with the GSST P&L. That is, a cBSST P&L associated with a GSST scenario is assumed to happen at the same time as GSST P&L for the scenario.

46. <u>PDF for the BSST Distribution</u>: Its probability density function $f_{cBSST}(x)$ is defined as

$$f_{cBSST}(x) = \sum_{s=1}^{N_{GSST}} \delta(x - L_{cBSST,s})p_{GSST,s} + \left[1 - \sum_{s=1}^{N_{GSST}} p_{GSST,s}\right]\delta(x)$$

where

$$L_{cBSST,s} = \sum_{b,r,rt,\tilde{s}} l_{cBSST,s,b,r,rt,\tilde{s}}$$

with s representing the GSST scenario and $\tilde{s}$ the cBSST scenario associated with the GSST scenario.

47. Complete Independence of iBSST P&L's: iBSST P&L $l_{iBSST,s,b,r,rt}$ defined for Business b, Region r, Risk Type rt, and iBSST scenario s is independent from the rest including the other iBSST P&L $l_{iBSST,s\prime,b\prime,r\prime,rt\prime}$ if

$$s \neq s'$$

48. i.i.d. Aggregates over Distinct $l_{iBSST,s,b,r,rt}$: $L_{iBSST,s}$ is the sum of the independent random variables $l_{iBSST,s,b,r,rt}$ as shown in

$$L_{iBSST,s} = \sum_{b,r,rt} l_{iBSST,s,b,r,rt}$$

49. Standalone Risk Capital: With the various P&L's defined above, the standalone risk capital $RC_{b,r,rt}$ is calculated from the aggregated loss $L_{iVAST,b,r,rt}$ relevant for Business b, Region r, and Risk Type rt.

$$RC_{b,r,rt} = -\mathbb{E}\left[L_{iVAST,b,r,rt} \mid L_{iVAST,b,r,rt} \leq percentile\left(L_{iVAST,b,r,rt}, 2\%\right)\right]$$

50. Marginal Risk Capital: The marginal risk capital $MRC_{b,r,rt,MARGINAL}$ is calculated from $L_{iVAST,b,r,rt}$ relevant for Business b, Region r, and Risk Type rt considering the aggregated loss of a bigger organization or category $L_{iVAST,MARGINAL}$. For example, *marginal* can be entire form or a group such as ICG. It also uses conditional expectation as

$$MRC_{b,r,rt,MARGINAL} = -\mathbb{E}\left[L_{iVAST,b,r,rt} \mid L_{iVAST,MARGINAL} \leq percentile\left(L_{iVAST,MARGINAL}, 2\%\right)\right]$$

51. Details of the Model Inputs - Observability, Proxies, and Overrides: The model's main inputs are VaR P&L, GSST, cBSST, and iBSST losses. VaR P&L comes from the VaR model.

GSST losses and associated probabilities are defined by the Corporate Stress Testing and Economics groups. cBSST and iBSST losses and associated probabilities are defined by Risk Manager. These three inputs are considered as upstream model inputs.

52. Evidence that the Assumptions are Reasonable: The scaling factor k_{VaR} is set based on the assumption that distribution of the VaR P&L is normal. Various historical evidences support other distributions with fatter tails, which is captured by k_{STRESS} calculated based on assumption that the stress P&L follows the Student's t-distriburion with 5 degrees of freedom.

Model Performance Testing and Outcomes Analysis

1. Evidence that the Out of Sample Tests using Historical Data shows that the past Performance of the Model meets the Standard. For risk models, does the Model pass Back-testing? Because of the nature of the model estimating the risk capital at 99.97%, back-testing is not feasible. However, the model's structure and inputs are designed based on the firm's experience in the past financial crisis.
2. Sensitivity of the Model Results to Changes in Underlying Variables: The sensitivities of the input data are examined by comparing standalone RC numbers focusing on

$$Group = BHC - ICG$$

   which has the largest group level RC.
3. Effect of the GSST: GSST P&L L_{GSST} defined in

$$L_{GSST} := \frac{1}{3}[L_{GSST}(t) + L_{GSST}(t-1) + L_{GSST}(t-2)]$$

   is examined by individual GSST scenarios and businesses.

4. Sensitivity of the GSST P&L: Sensitivity of the GSST P&L is tested by setting it to zero. As RC is driven by the 2% tail losses, it would have been affected mostly by the 1974 Baseline scenario. Typically, however, a smaller reduction is observed due to the independence assumption among VaR P&L, GSST P&L, and iBSST P&L making some of the other GSST scenarios fall into the 2% tail loss.
5. Effect of BSST: As was done for GSST, the sensitivity of BSST (iBSST + cBSST) can be tested by setting both the cBSST and the iBSST to zero.
6. cBSST vs. GSST Tail Domination: As cBSST is perfectly correlated with GSST, the question of which scenario would dominate can be answered by looking at the combined amount of cBSST and GSST.
7. Baseline vs Scenario Sensitivities: Excluding specific Baseline Events vs. Stress Scenarios reveal the corresponding contributors, the effect of which may be magnified due to the amplifying factor k_{STRESS}.
8. Effect of GSST and BSST: When both GSST and BSST (cBSST + iBSST) are set to zero, the RC reductions are slightly less than the sum of the cases

$$GSST = 0$$

and

$$BSST = 0$$

9. Effect of k_{STRESS}: If, instead of Student t a normal distribution assumption is used for k_{STRESS} – which now makes it

$$k_{STRESS} = 1.4$$

the fall in RC can be steep.

10. k_{STRESS} under $T-5$ Distribution: If, however, the t distribution has more than 3 degrees of freedom, e.g., 5, then

$$k_{STRESS} = 2.8$$

and results in a sharp increase in RC.

11. Effect of VaR: By setting

$$VaR = 0$$

it can be shown that the RC capital reduction is typically small both at the BHC level as well as the Business level.

12. Effect of Volatility Adjustments: As described before, the volatility adjustment of

$$l_{VaR}(t) = \sum_{FS\ type\ i} vol\_adj_i(t) \cdot l_{VaR,i}(t)$$

is needed to convert the point-in-time VaR into through-the-cycle VaR.

13. Effect of No Volatility Adjustment: The effect is tested by setting all of the volatility adjustments to 1, i.e., no volatility adjustment, as shown in the table below. As will be expected, the expected RC changes given the effect of VaR P&L will be small.

14. Base Case Volatility Adjustment:

FS Type i	$\boldsymbol{vol\_adj_i(t-2)}$	$\boldsymbol{vol\_adj_i(t-1)}$	$\boldsymbol{vol\_adj_i(t)}$
CMDL	0.68	0.64	0.64
CMVG	0.92	0.91	0.91
CSVG	1.00	1.00	1.00
EBID	1.13	1.12	1.12
EBSY	1.13	1.12	1.12

ECVG	1.13	1.12	1.12
EQDL	1.13	1.12	1.12
EQVG	0.94	0.91	0.93
FXDL	0.99	0.87	0.87
FXRR	0.83	0.82	0.82
FXST	0.83	0.82	0.82
FXVG	0.83	0.82	0.82
IDIO	1.04	0.99	0.95
IRDL	1.24	1.24	1.24
IRVG	1.24	1.24	1.24
ISDL	1.07	0.99	0.95
LODL	1.06	1.06	1.06
OMDL	2.62	2.41	2.41
OSDL	2.62	2.41	2.41
PPDL	1.00	1.00	1.00

15. Standalone RC ($MM) without Volatility Adjustment:

Group	**Product**	**Business**	**New RC w/o Volatility Adjustment**	**Base Case RC**	**Base Case - New**
BHC - ICG	Advisory	Advisory	0	0	0
	CAI	CAI	12	11	-1
	Commodities	Commodities Houston	557	405	-152
	Credit	Credit Trading	374	374	1
		Distressed	212	216	5
		EM Credit Trading	448	445	-3

		Credit Macro Hedge	0	0	0
		PECD	2363	2363	0
		Short Term	24	24	0
		GSSG West	0	0	0
	EM ABF	EM ABF	0	0	0
	Equities	Cash	205	203	-2
		Converts	93	94	1
		Equity Derivatives	336	327	-9
	Equity Under-writing	Equity Under-writing	50	50	0
	Fixed Income Under-writing	EM Bonds	0	0	0
		EM Primary Loans	0	0	0
		IG Bonds	124	124	0
		IG Primary Loans	0	0	0
		Leveraged Finance	0	0	0
		Other FI Under-writing	77	75	-1
		Project Finance	0	0	0
	FX Local Markets	G10 FX	669	666	-3
		Local Markets	1748	1769	21

	G10 Rates	G10 Rates	2057	2081	24
	G10 Risk Treasury RV Finance	FIMA	0	0	0
		Finance	142	147	5
		Risk Treasury	1624	1639	15
	GTS	GTS	98	98	0
	GWM	GWM	52	53	1
	Hybrids	Hybrids	400	417	17
	Municipals	Municipals	2403	2398	-4
	Nikko Investments	Nikko Investments	0	0	0
	OS&B	OS&B	29	27	-1
	Other Global Markets	Other Global Markets	166	166	0
	Prime Finance	Prime Finance	31	31	0
	Securitized Markets	Securitized Markets	3126	3176	51
BHC-ICG Total			**11575**	**11665**	**89**

16. Effect of VaR and GSST: The table below shows the RC results when both the VaR and the GSST P&L are set to zero. Without VaR and GSST, RC is expected to be driven by cBSST. As seen before, the worst case cBSST at the ICG level is $865MM loss in the 2008 Baseline scenario, which after considering k_{STRESS} explains the majority of $1.8b RC.
17. Standalone RC ($MM) with Zero VaR and GSST P&L:

Group	**Product**	**Business**	**New RC w/o Volatility Adjustment**	**Base Case RC**	**Base Case - New**
BHC - ICG	Advisory	Advisory	0	0	0

	CAI	CAI	0	11	11
	Commodities	Commodities Houston	149	405	256
	Credit	Credit Trading	16	374	358
		Distressed	82	216	135
		EM Credit Trading	161	445	284
		Credit Macro Hedge	0	0	0
		PECD	1010	2363	1352
		Short Term	0	24	24
		GSSG West	0	0	0
	EM ABF	EM ABF	0	0	0
	Equities	Cash	106	203	97
		Converts	17	94	77
		Equity Derivatives	230	327	98
	Equity Under-writing	Equity Under-writing	0	50	50
	Fixed Income Under-writing	EM Bonds	0	0	0
		EM Primary Loans	0	0	0
		IG Bonds	0	124	124
		IG Primary Loans	0	0	0
		Leveraged Finance	0	0	0

		Other FI Under-writing	0	75	75
		Project Finance	0	0	0
	FX Local Markets	G10 FX	424	666	242
		Local Markets	208	1769	1561
	G10 Rates	G10 Rates	364	2081	1717
	G10 Risk Treasury RV Finance	FIMA	0	0	0
		Finance	0	147	147
		Risk Treasury	0	1639	1639
	GTS	GTS	0	98	98
	GWM	GWM	0	53	53
	Hybrids	Hybrids	40	417	377
	Municipals	Municipals	169	2398	2229
	Nikko Investments	Nikko Investments	0	0	0
	OS&B	OS&B	0	27	27
	Other Global Markets	Other Global Markets	0	166	166
	Prime Finance	Prime Finance	0	31	31
	Securitized Markets	Securitized Markets	155	3176	3021
BHC-ICG Total			**1811**	**11665**	**9854**

18. Effect of VaR and BSST: On setting the VaR and the BSST to zero, the RC should be completely be determined by the worst case of the GSST P&L. At the ICG level, the worst

GSST loss is $4821MM coming out of the 1974 Baseline scenario and the RC of $9642MM matches the $4821MM multiplied by k_{STRESS}. At a business level, for example, EM Credit Trading RC of $252MM matches the Interest Rate Shock scenario loss of $126MM multiplied by k_{STRESS}.

19. Standalone RC ($MM) with Zero VaR and BSST P&L:

Group	**Product**	**Business**	**New RC w/o Volatility Adjustment**	**Base Case RC**	**Base Case - New**
BHC - ICG	Advisory	Advisory	0	0	0
	CAI	CAI	0	11	11
	Commodities	Commodities Houston	0	405	405
	Credit	Credit Trading	337	374	37
		Distressed	63	216	154
		EM Credit Trading	252	445	192
		Credit Macro Hedge	0	0	0
		PECD	1351	2363	1012
		Short Term	22	24	3
		GSSG West	0	0	0
	EM ABF	EM ABF	0	0	0
	Equities	Cash	179	203	25
		Converts	67	94	27
		Equity Derivatives	0	327	327

	Equity Under-writing	Equity Under-writing	50	50	0
	Fixed Income Under-writing	EM Bonds	0	0	0
		EM Primary Loans	0	0	0
		IG Bonds	124	124	0
		IG Primary Loans	0	0	0
		Leveraged Finance	0	0	0
		Other FI Under-writing	0	75	75
		Project Finance	0	0	0
	FX Local Markets	G10 FX	613	666	53
		Local Markets	1708	1769	61
	G10 Rates	G10 Rates	1536	2081	545
	G10 Risk Treasury RV Finance	FIMA	0	0	0
		Finance	112	147	35
		Risk Treasury	1602	1639	37
	GTS	GTS	98	98	0
	GWM	GWM	50	53	2
	Hybrids	Hybrids	262	417	155
	Municipals	Municipals	2339	2398	60

	Nikko Investments	Nikko Investments	0	0	0
	OS&B	OS&B	21	27	6
	Other Global Markets	Other Global Markets	166	166	0
	Prime Finance	Prime Finance	30	31	1
	Securitized Markets	Securitized Markets	2939	3176	237
BHC-ICG Total			**9642**	**11665**	**2023**

20. Tests that indicate that the Numerical Error converges sufficiently, and is small for the Recommended Parameters: The model is subject to simulation noise. The effect is tested by running the model with 10 different ransom seeds and looking at 3 specific metrics – firm-level standalone RC, ICG level standalone RC, and ICG marginal to firm. The results in the Table below show the sufficiently small effect of the simulation noise.
21. Simulation Noise: All numbers in $MM.

Seed	BHC Standalone RC	ICG Standalone RC	ICG Marginal to BHC
Seed1	17505	11663	11553
Seed2	17600	11751	11656
Seed3	17483	11680	11564
Seed4	17657	11659	11566
Seed5	17407	11596	11496
Seed6	17598	11702	11597
Seed7	17443	11619	11526
Seed8	17506	11592	11497
Seed9	17422	11576	11494
Seed10	17517	11647	11542
Average	**17514**	**11649**	**11549**

Standard Error	**82**	**54**	**51**
Standard Error/Average	**0.47%**	**0.47%**	**0.44%**

22. Other Measures: As a basic sanity check on the marginal RC calculation, the sum of the ICG businesses marginal RC's to the ICG is compared against ICG standalone RC. As shown in the table below, the sum $11,655MM matches the ICG standalone RC seen earlier.

23. Marginal RC ($MM) to BHC-ICG:

Group	Product	Business	Marginal RC to ICG
BHC - ICG	Advisory	Advisory	0
	CAI	CAI	1
	Commodities	Commodities Houston	-1078
	Credit	Credit Trading	316
		Distressed	47
		EM Credit Trading	301
		Credit Macro Hedge	-242
		PECD	2148
		Short Term	9
		GSSG West	0
	EM ABF	EM ABF	0
	Equities	Cash	152
		Converts	77
		Equity Derivatives	-869

	Equity Under-writing	Equity Under-writing	38
	Fixed Income Under-writing	EM Bonds	0
		EM Primary Loans	0
		IG Bonds	122
		IG Primary Loans	0
		Leveraged Finance	0
		Other FI Under-writing	-1
		Project Finance	0
	FX Local Markets	G10 FX	292
		Local Markets	1600
	G10 Rates	G10 Rates	1917
	G10 Risk Treasury RV Finance	FIMA	0
		Finance	-6
		Risk Treasury	1247
	GTS	GTS	96
	GWM	GWM	47
	Hybrids	Hybrids	30
	Municipals	Municipals	2256

	Nikko Investments	Nikko Investments	0
	OS&B	OS&B	5
	Other Global Markets	Other Global Markets	51
	Prime Finance	Prime Finance	22
	Securitized Markets	Securitized Markets	2795
Total			**11665**

24. Performance Metrics Definition and Rationale: Ongoing performance monitoring should focus on period-over-period changes of the model output as the model is expected to produce relatively stable capital numbers.

Integrated VaR and Stress Testing Risk Capital Methodology Validation

Brief Description of the Purpose of this Model

1. Enhanced Estimate of Risk Capital: The purpose of the model is to provide a better method to estimate the economic risk capital – ERC – that is used to review the performance of the businesses within the BHC.
2. Coverage - Assets with Price Risk: The model intends to cover all assets that have price risk, including trading assets, CVA, and AFS assets.
3. Stress Tests and Statistical P&L Combination: It combines the stress tests and the statistical P&L calculations as an enhancement to the current RC model that is based solely on the statistical approach.
4. Annual Losses at 99.97% Confidence: The new RC model will satisfy the following criteria as much as possible. First, it will measure the potential losses over the next year under a severely adverse scenario, notionally equivalent to the 99.97th percentile of the model loss distribution.
5. Assumption - Constant Level of Risk: Second, it must be consistent with a constant level of risk assumption, i.e., it assumes that the businesses will maintain the same level of risk exposure over the next year, and will not materially increase or reduce their risk taking as market conditions change.
6. Identifying Assets with Price Risk: Third, it must clearly identify assets subject to *price risk* – those whose valuation and impact on book equity depends primarily on market observed prices as opposed to, for example, assets which are valued primarily based on their contractual status, assets such as defaulted loans in the banking book.

7. Full Inclusion of Tail Events: Fourth, it must provide a full inclusion of *tail events* including non-normal behavior of individual market factors, high correlation during stress periods, and illiquidity as markets crash.
8. Non Pro-cyclical Risk Capital: Provides an approximately stable level of risk capital over the economic cycle, avoiding the potentially volatile risk capital associated with, for example, a VaR model calibrated to recent data or a credit loss calibrated to market implied PD's.

General Modeling Approach

1. iVAST Losses from Stress Scenarios: The iVAST losses of a portfolio are driven by the stress losses calculated based on a set of carefully specified stress scenarios.
2. VaR/Stress Component Loss Correlation: Also included is the contribution of VaR P&L's directly from Market Risk. These two components are not correlated.
3. Estimation of the Stress Loss Distribution: On top of the VaR P&Ls, stress losses are simulated based on loss levels calculated from business stress tests and the associated probabilities of the stress scenarios.
4. Types of Stress Scenarios: There are three types of stress tests – the Global Systemic Stress Tests (GSST), the idiosyncratic Business Specific Stress Tests (iBSST), and the correlated Business Specific Stress Tests (cBSST).
5. Correlation between Stress Test Scenarios: The GSST is fully correlated with the associated cBSST, and uncorrelated with all iBSSTs.
6. 98% Loss to 99.97% VaR: Extrapolation treatment is needed to translate iVAST losses at a practical confidence level, e.g., 98%, to that required by the RC at 99.97%. This is achieved by assuming a certain tail distribution of the losses.
7. Breakdown of the Risk Capital: The RC breakdown by businesses is calculated in two flavors – the standalone and the marginal – and both are reported by the model.

Approximations or Algorithms

1. Lack of History – Expert Call: For RC calculations, it is necessary to incorporate some expert judgements due to lack of historical data.
2. Stress Scenario Probability and Averaging Horizon: In the iVAST model, the probability for each stress scenario to occur is set to a fixed value, say, 2%. The stress loss is the average over the 3 months' stress tests.
3. Correlation between GSST and cBSST: The correlation factor of cBSST severity with the GSST severity is based on the risk managers' judgement.
4. VaR/Stress Loss Tail Distribution: The scaling factors for the VaR P&Ls and the stress losses are determined by the tail distributions applied to them – normal distribution for VaR P&Ls and Student-t distribution with 5 degrees of freedom for stress losses.

Brief Description of the Main Assumptions Underlying the Model

1. Losses under Normal Market Conditions: Losses under the normal market conditions handled by the statistical risk model, losses under extreme market conditions handled by global systemic stress tests – combined with the correlated business specific stress tests – and the idiosyncratic stress tests are considered uncorrelated.
2. Tail of the Loss Distribution: Based on historical data analysis, the tails of the VaR P&L's and the stress losses can be described with a normal distribution and a Student's t-distribution with 5 degrees of freedom, respectively, to reasonably capture the fat tail behavior of the financial market.
3. Stress Event Losses and Probabilities: The losses and probabilities of stress events can be quantified using expert judgement.
4. Completeness of Historical Stress Logic: The existing stress test scenarios based on historical data and business judgement provide a reasonably comprehensive coverage of possible stress situations.

5. cBSST/GSST Correlation Severity Judgement: The risk manager's judgement on the corr4elation factor of severity between cBSST and GSST is reasonable.
6. Probabilities of the Stress Scenarios: The probabilities of the systemic stress scenarios are all set to 2%.
7. Expected Shortfall Confidence Level: Expected shortfall is measured at a judgmental percentile corresponding to

$$\alpha = 2\%$$

General Review

1. Importance of Stress Testing Capital: As Basel II requires that the stress testing processes be implemented to assess a bank's capital adequacy, the incorporation of stress tests in regulatory capital and economic risk capital is becoming an industry standard.
2. Better Estimate of Risk Capital: The iVAST model attempts to combine the statistical model and stress testing in order to better estimate the economic risk capital in risk management.
3. Advantages of Statistical/Scenario Approach: This model has the advantages from both approaches, although the stress test losses are more judgmental and conditional on particular stress scenarios.
4. Challenges with Simulating Stress Scenarios: Alternative approaches may include the attempts to simulate the stress scenarios, but this seems not quite feasible owing to insufficient historical data of extreme events at such confidence level.
5. RC Estimation using Stress Tests: This model shifts the focus in RC estimation from statistical analysis to stress tests, which is a revolutionary change.
6. Stress Impact on RC Numbers: Consequently, the RC level can be much larger than before, capturing the historically worst market scenario, but it also becomes much more judgmental.
7. Best Historical Estimate of Losses: The RC can be understood as the best estimate of capital loss based on existing historical scenarios, and the RC may be adjusted accordingly as new market data becomes available.

8. Extrapolation from 2% to 0.03%: The basic reason for the iVAST model be considered *judgmental* is essentially due to stress loss extrapolation from 2% probability down to 0.03% probability.
9. iVAST Stress Loss Factor Scaling: In iVAST the stress loss is scaled by a factor of 2.0, consistent with the tail behavior suggested by the Student's t-distribution with 5 degrees of freedom.
10. Evidence for Stress Loss Distribution: This is based on judgement, although historical analysis on some corporate bonds suggests that the spreads fit the t-distribution better than other distributions. For further improvement of the model, one may focus on how to extrapolate the stress loss to a very low probability.

Alternative Approaches

1. Simulation of Extreme Loss Scenarios: For alternative approaches, one may consider simulating the extreme stress scenarios. But as indicated above, this is an extremely hard task due to the lack of historical data for extreme events. The covariance and the tail distribution may have to be based on pure assumptions.
2. Maintaining Total Portfolio Loss Constraint: An easier approach may be to simulate the stress losses using a loss distribution, but the constraint that the total portfolio loss should be a sum of the sub-portfolio losses may be hard to maintain, and one may still be unable to benefit from the richness of the losses by simulation.
3. iVAST Simplicity, Feasibility, and Transparency: Considering simplicity, feasibility, and transparency, the iVAST model seems to be a best choice.

Limitations of the General Modeling Framework

1. Expert Judgement Stress Scenario Specification: The RC depends highly on a small set of stress scenarios – even a single one. Specification of stress scenarios and their associated probabilities relies on expert judgement.
2. RC as a Loss Guide: The RC estimated from iVAST can be treated as judgmental to a certain extent, and it may serve as a guide for the risk of unexpected capital loss of a business rather than an accurate measure.
3. Parameters Determining the RC Estimate: In iVAST, the RC estimation depends on the choices of the following model parameters:
    a. The set of stress scenarios and their associated probabilities
    b. The distribution type of the stress loss tail
    c. The correlation factors for the cBSST severity
4. GSST/cBSST Impact on RC: For example, it is observed that the RC depends largely on the worst GSST scenario – plus cBSST.
5. Duration of the GSST Scenarios: It is, therefore, natural to ask if the existing GSST scenarios can reach the depth of the stress losses for a larger period of time.
6. Equivalence of 98% to 99.97%: It also makes sense to investigate the representation power of the stress scenario at 98% ES to capture the stress losses at 99.97% VaR.

Limitations of any Particular Algorithms or Approximations

Monte Carlo Simulation in iVAST has certain statistical error, though it may be much less significant than the impact of the possible uncertainty in model parameters.

Error Analysis/Convergence Testing

The focus here is on the Monte Carlo error and the investigation is on how the error depends on the number of simulations.

Cases Used in Testing

The hierarchical RC's calculated from iVAST are reviewed. The properties of the iVAST loss distribution are reviewed. Comparison against a pure statistical model is conducted. The impact of through-the-cycle VaR Correction is reviewed. Contributions of VaR, FSST, and BSST (cBSST and iBSST) to RC are compared.

Stress Testing

iVAST is a statistical model, and there is no conceivable situation under which the model would fail. Thus, the performance of the model under a wide range of probabilities for the stress events must be tested.

Benchmarking

In this test, the cutoff rang for expected shortfall calculation at the same level of stress probability is maintained, and the behavior of the RC over a wide range of probabilities is examined.

Sensitivity Analysis

The sensitivity of RC on several model parameters is tested – probabilities associated with the stress scenarios, choice of the GSST scenarios, and tail distribution of the stress losses using a very fat tail distribution, and a normal distribution without a tail.

Conclusions

1. Monte Carlo Error Convergence Analysis: The convergence analysis shows that the Monte Carlo error is proportional to $\frac{1}{\sqrt{n_{SIM}}}$, fully as expected, and that 5,000 simulations are sufficient for the RC estimation.
2. Non-normality of Loss Distribution: The loss distribution shows highly non-normal behavior, and different responses of businesses to the stress scenarios can be distinguished in the model.
3. Impact of the Stress RC: Analysis of the RC shows that the stress scenarios play a far more important role in RC estimation than the statistical scenarios, and it is observed that the single worst GSST scenario largely determines the RC level. This is reasonable, as the RC is intended to capture the losses under extreme market conditions.
4. Through-the-Cycle VaR Impact: Through-the-cycle VaR correction displays a relatively small correction to the RC.
5. Risk Capital Stress Probability Dependence: The benchmarking test observes the dependency between the RC and the stress probabilities with alpha taken at the probability level. The RC shows the same behavior as k_{STRESS}, meaning that the RC has a major dependence on the stress tests.
6. RC Sensitivity to Stress Probabilities: Sensitivity analysis shows that the RC is not sensitive to the stress probabilities, given that the ES range is kept constant.
7. Asymptotic Nature of the Risk Capital: The RC decreases as expected on reducing the size of the scenario set gradually by removing the most severe stress scenarios, but it seems to show asymptotic behavior, which may support the estimate of the RC level.
8. Stress Loss under Fat Tail: The RC is sensitive to the choice of the fat tail distribution of the stress losses. But the two cases corresponding to a very fat tail or no fat tail at all seem to set up the upper and the lower bounds for the RC.

Model Description

1. Parameters Determining the RC Estimation: The economic risk capital RC is defined as the amount the BHC needs to absorb as unexpected loses over a certain time horizon at a given confidence level. Typically, the time horizon is set as one year, and the confidence level is 99.97%. Historically, the RC has been estimated by scaling up the VaR numbers of the businesses that are used for regulatory capital reporting. During the crisis of 2007/08, it was that this old RC method was not adequate to fully explain the losses of the BHC.
2. Combining Statistical and Stress Scenarios: The iVAST risk capital methodology tries to combine the outputs from an objectively calibrated statistical risk model and the stress tests quantified using expert judgement.
3. Advantages of Calibrated Statistical Model: This way, it takes advantage of the strengths of the statistical approach:
    a. Infinitely many objective scenarios to examine a wide range of potential portfolio weaknesses
    b. Testable through back-testing to check how well VaR captures the risks
    c. Risks easily aggregated
4. Advantages of Stress Testing Approach:
    a. Can incorporate *severe but plausible* events that may be missed by the statistical models due to its weaknesses
    b. No limit for creating stress scenarios, not constrained by history
    c. In probing extreme events, reveals possible negative convexity on the portfolio
5. Motivation behind the VaR-Stress Model: In view of the large losses taken by the BHC's during the 2007/08 financial crisis that well exceeded the risk capital levels calculated using the statistical model that relies on a short distribution window, it became necessary to develop an RC model to further incorporate the stress testing results. The model is developed to satisfy, as much as possible, all the following criteria.
6. Horizon – 1Y; Confidence Level – 99.97%: Measure potential losses over the next year in a severely adverse scenario, notionally equivalent to 99.97^{th} percentile of the model loss distribution.

7. Constant Level of Risk Assumption: Be consistent with a constant level of risk assumption, i.e., assume that the businesses will maintain the risk exposure over the next year, and will not materially increase or reduce risk-taking as the market conditions change.
8. Assets Subject to Price Risk: Clearly identify assets subject to *price risk*, i.e., those whose valuation and impact on book equity depends primarily on market observed prices – as opposed, for example, assets which are primarily valued based on contractual status, such as defaulted loans in the banking book.
9. Full Inclusion of Tail Events: Full inclusion of *tail events*, including non-normal behavior of individual market factors, high correlation during stress periods, and illiquidity as markets crash.
10. Stable Level of Risk Capital: Provides an approximately stable level of risk capital over the economic cycle, avoiding the potentially volatile risk capital associated with, for example, a VaR model calibrated to recent data, or a credit loss calibrated to market implied PD's.
11. VaR-Stress Model - Asset Coverage: The iVAST model should cover all types of assets subject to price risk deemed by policy. For example, it could cover the following assets.
12. Market Sensitive Trading Book Assets: All market sensitivities of assets in the Trading Book – as opposed to some earlier treatments where the risk capital of these assets may have been driven by scaled VaR.
13. Market Sensitive CVA Book Assets: All market sensitivities of the CVA asset, excluding spread sensitivity of the CVA liability. Alternative risk capital on these assets could have been driven by exposures computed by Counterparty Credit Systems, run against, for example, a Wholesale Credit Risk Capital Model.
14. Credit Spread Sensitive AFS Assets: The credit spread sensitivity of the AFS assets – but not the interest rate sensitivity of these assets, which can run in the AM Risk Capital model. In the past, risk capital on these assets has often been calculated by a combination of the Wholesale Credit and the ALM Risk Capital Models.
15. Challenges with RC Bask-Testing: As it is technically difficult to conduct back-testing on risk capital, this RC analysis can be viewed as a guide of the long term risk at a very high confidence level, rather than as an accurate measure of it.

Error Analysis/Convergence Testing

1. Theoretical Estimate of Monte Carlo Errors: This section looks at the Monte Carlo errors associated with the number of random scenarios. Assuming normality for the P&L's, the 99% VaR from 5,000 scenarios has a theoretical Monte Carlo error of 2.27%, which is verified by the actual tests – the values are a bit larger at 3-4% due to the level of convexity in factor sensitivities.
2. Expected Errors for Order Statistics: The method is to take the 1% - or the worst 50th – order statistics as the VaR. If the same approach were applied to RC, one would look at the 0.03% - the worst 1.5th – order statistics of 5,000 scenarios, and the expected relative error would be

$$Error = \sqrt{\frac{q(1-q)}{N}}\frac{1}{\xi_q\, f(\xi_q)} = \sqrt{\frac{0.0003 \times 0.9997}{5000}}\frac{1}{3.4316 \times n(3.4316)} = 6.45\%$$

3. Switchover to Reliable Boundaries: As the worst 1.5th order statistics is not very easy to determine, and the deviations from normality may have a significant contribution to the error, the iVAST model uses the average of the worst 2% losses scaled to the 99.97% confidence level and one-year time horizon under certain tail distribution assumptions.
4. Incorporation of the Stratified Sampling Technique: In addition, in order to reduce the Monte Carlo error, the model uses the stratified sampling technique described in Glasserman (2004). For each of the systemic stress scenarios, the model generates exactly $p_j \times 5000$ losses, which are randomly applied to the VaR P&L's. For idiosyncratic stress scenarios, the losses are simulated based on the occurrence probabilities.
5. Worst 2% Loss Based RC: The following tables show the calculation of RC as the average of the worst 2% losses for VaR P&L's and iVAST losses:
   a. VaR

# Simulations	5000	2500	1000	500	200

RC Mean	-6,253,009,548	-6,234,234,689	-6,199,657,677	-6,149,090,147	-5,948,655,763
RC Standard Deviation		67,928,449	175,936,388	317,966,277	520,161,055
RC Relative Error		1.09%	2.84%	5.17%	8.74%

b. iVAST

# Simulations	5000	2500	1000	500	200
RC Mean	-37,866,247,762	-37,840,358,352	-37,755,167,543	-37,633,183,821	-37,222,513,191
RC Standard Deviation		26,238,965	418,067,983	513,304,310	1,054,178,288
RC Relative Error		0.07%	1.11%	1.36%	2.83%

6. Errors for Small Simulation Sets: Starting from 5,000 iVAST simulations. And slicing the data into exclusive parts of equal sizes for statistical analysis, one doesn't have relative error for 5,000 scenarios, but one can estimate from the tendency for other simulation sizes.
7. Monte Carlo Error Inverse Square Root Law: It is observed that as the number of simulations increases, the Monte Carlo error tends to reduce. The behavior fits the inverse square root law very nicely.
8. VaR vs. Stress Errors: From the above tables, one may notice that the errors for VaR P&Ls are larger than for other iVAST losses. This is because, in the iVAST calculation, the number of GSST events are always kept constant, i.e., the number of expected number of events, and GSST contributes to iVAST losses much more than the VaR P&Ls, which is obvious by comparing RC means for VaR and for iVAST in the above tables.
9. Simulation Size vs. Error Regression: The relative Monte Carlo error can be estimated by extrapolation. The focus here is on the data points, except that with 2500 simulations, since in that analysis, only two data points contribute to the error. A pretty good fir can be found using the straight line

$$Error \approx \frac{0.35}{\sqrt{n_{SIM}}}$$

10. Estimation of the Monte Carlo Error: Using the above expression, the relative error for 5,000 simulations would be 0.50%, which is very good for a Monte Carlo method. This is because stratified sampling (Glasserman (2004)) is applied to reduce the Monte Carlo error, resulting in the elimination of the randomness of the stress losses. This result indicates that the choice of 5,000 scenarios is sufficient.
11. Handling Uncertainty in Parameter Estimation: On top of the random error from the Monte Carlo simulation, one must bear in mind that the systematic uncertainty in terms of the choice of the parameters of the model could be much more significant. As expert judgement is difficult to validate objectively, a set of sensitivity tests will be needed to be run to identify important model parameters.

Conclusion

The convergence analysis shows that the Monte Carlo error is proportional to $\frac{1}{\sqrt{n_{SIM}}}$, fully as expected, and that 5,000 simulations are sufficient for RC estimation.

Benchmarking

Given the current state of data availability, this model is a straightforward approach to estimating the risk capital. Thus, the BHC level RC from iVAST is in line with the trading losses experienced during the worst stress scenario, the 2007/08 financial crisis. The basic idea behind this model to incorporate stress testing is widely recognized, in accordance with the recommendation by the Basel II Accord (Kupiec (2000), Bank for International Settlements

(2005)). However, it is important to emphasize that there could be great variations in implementation details, including choices of the stress scenarios.

References

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- Kupiec, P. H. (2000): Stress Tests and Risk Capital *Risk* **2 (4)** 27-39

Trading Risk Capital Beta Allocation

Allocation Methodology

1. Goal of the Capital Allocator: The goal is to allocate the *trading marginal to trading total* into each of the business and the hedge desks.
2. Current Approach - Desk Level Beta: Each desk is assigned a beta, where the allocated RC is the product of the desk standalone RC times a beta.
3. Low/High Betas and their Calibration: The betas are calibrated such that the sum of the allocated RC equals the marginal.
   a. Desks with high beta:

$$\beta_H = 0.8$$

   b. Desks with low and medium beta:

$$\beta_M = 2\beta_L$$

   c. Calibration:

$$\beta_M \sum_{i \in Medium} RC_i + \beta_L \sum_{j \in Low} RC_j + \beta_H \sum_{k \in High} RC_k = RC_T$$

where $RC_{i/j/k}$ is the standalone of business $i/j/k$, and RC_T is the total RC to be allocated.

4. Proposed Approach - Separating Hedge Trades: The first step is to separate out the hedge trades. The allocation to the hedge is the Trading hedge desks marginal to the Trading total. Trading Total minus Marginal to Trading Hedge Desks are allocated as below.
5. The Differential Component Allocation Approach: Separately allocate the VaR + GSST + cBSST component vs. the iBSST component. The [VaR + GSST + cBSST] allocation follows a two beta – high vs. low – approach with

$$\beta_H = 2\beta_L$$

VaR and GSST receive low or high beta depending on the business liquidity, whereas cBSST always receives high beta. iBSST allocation is pro-rata to standalone worst iBSST of each business.

Allocation Approach and Available Inputs

1. Trading Desk Marginal to Total: Since there is no VaR, GSST, and BSST contributions of Trading Marginal to Trading Total, the Trading Standalone is first allocated to each business. The allocation is then scaled such that the sum adds up to the Trading Marginal to Trading Total less the Trading Hedge Desks Marginal to Trading Total.
2. Decomposition of Trading Desk Standalone: The following data elements are expected to be typically be available in a monthly VaR-stress run – trading standalone broken down to marginal contribution from VaR, iBSST, cBSST, and GSST.

$$RC_{Trading\ Standalone} = RC_{Marginal,GSST} + RC_{Marginal,VaR} + RC_{Marginal,cBSST} + RC_{Marginal,iBSST}$$

$RC_{Trading\ Standalone}$ refers to the Trading desk standalone minus the hedge. The RHS refers to the marginal contributions to the trading standalone from VaR, GSST, cBSST, and iBSST – less the hedges.

3. <u>Decomposing the Business/Desk Standalone</u>: Business/Desk standalone broken down to marginal contribution from VaR, iBSST, cBSST, and GSST.

$$RC_{Trading\ Standalone,i} = RC_{Marginal,GSST,i} + RC_{Marginal,VaR,i} + RC_{Marginal,cBSST,i} + RC_{Marginal,iBSST,i}$$

$RC_{Trading\ Standalone,i}$ is the standalone for desk i. The RHS refers to the marginal contributions to desk i from VaR, GSST, cBSST, and iBSST – less the hedges.

4. <u>iBSST Capital Allocation using Worst</u>: PnL of the worst iBSST for the trading desk $PnL_{Worst,iBSST}$ and for each business desk $PnL_{Worst,iBSST,i}$

Allocation Algorithm for each Component

1. <u>VaR, GSST, and cBSST Components</u>:
    a. Parent Value to be allocated => $RC_{Marginal,GSST} + RC_{Marginal,VaR} + RC_{Marginal,cBSST}$
    b. Inputs => $RC_{Marginal,GSST,i}$, $RC_{Marginal,VaR,i}$, and $RC_{Marginal,cBSST,i}$
    c. Allocation Algorithm =>

$$\beta_L = \frac{RC_{Marginal,GSST} + RC_{Marginal,VaR} + RC_{Marginal,cBSST}}{[\sum_{i \in L}\left(RC_{Marginal,GSST,i} + RC_{Marginal,VaR,i} + RC_{Marginal,cBSST,i}\right) + 2 \times \sum_{i \in H}\left(RC_{Marginal,GSST,i} + RC_{Marginal}\right.}$$

$$\beta_M = 2\beta_L$$

$$RC_{ALLOCATION,VaR+GSST+cBSST,i} = \beta_{L/H} \times \left(RC_{Marginal,GSST,i} + RC_{Marginal,VaR,i}\right) + \beta_H \times RC_{Marginal,cBSST,i}$$

2. <u>iBSST Components</u>:
    a. Parent Value to be allocated => $RC_{Marginal,iBSST}$
    b. Inputs => $PnL_{Worst,iBSST,i}$
    c. Allocation Algorithm =>

$$RC_{ALLOCATION,iBSST,i} = \frac{PnL_{Worst,iBSST,i}}{\sum_{i \notin Hedge} PnL_{Worst,iBSST,i}} \times RC_{Marginal,iBSST,i}$$

3. <u>Trading Marginal to Group Scaling</u>: Scale to the Trading Marginal contribution to the Group ex. Hedge.

$$Allocation\ for\ non-hedge\ Desk\ i = \frac{Trading\ Marginal\ to\ Group - Trading\ Hedges\ Marginal\ to\ Group}{Trading\ Standalone} \times \left(RC_{ALLOCATION,VaR+GSST+cBSST,i} + RC_{ALLOCATION,iBSST,i}\right)$$

$$Allocation\ for\ Hedge = Trading\ Hedges\ Marginal\ to\ Group$$

Two-Beta Allocation of Trading Capital

Executive Summary

1. <u>Two-Beta Capital Allocation – Definition</u>: The new two-beta capital allocation intends to enhance the current approach in order to better reflect the long-term business strategy, and recognize revenue contributions from Trading Book businesses with different risk exposures and liquidity profiles.
2. <u>Stakeholders of the Allocation Scheme</u>: Typically, these schemes have been developed by Market Risk Management, Risk Capital Groups, and Finance. Trading Book Risk Management often adopts a different approach with Capital Optimization in mind, which leads to a working group of members from Corporate Finance and Trading Capital Optimization.

Summary of Capital Allocation Approaches

1. <u>Simple Pro-rata Allocation Scheme</u>: The simple pro-rata scheme provides uniform diversification benefits allocated across businesses. The diversified RC is equal to the standalone RC multiplied by *one floating factor* for all businesses.
2. <u>Issues with the above Allocation Scheme</u>: The scheme does not take into account the different levels of correlation and systemic risk in each business. Thus, businesses that are relatively well diversified are not rewarded, and businesses have little incentive to not add to existing BHC risk concentrations.
3. <u>3-Beta with fixed High-Beta Allocation Scheme</u>: This provides uniform diversification benefits allocated within the bets group, but differentiated by group. The diversified RC is equal to the standalone RC multiplied by 3 different factors for:

a. 80% fixed for high-beta.
b. Weighted floating factors for medium and low (2 to 1).

4. Issues with the Allocation Scheme:
   a. Variation and fluctuation levered for low and medium, with fixed for the high somewhat contributed by full revaluation – see the example below.
   b. Capital allocation to the low and the medium businesses can be negative or above 100% on the business level – the allocation is done on a sub-business level.
5. Contributory Marginal Allocation Scheme:
   a. Here, the diversification benefits are allocated purely by correlation.
   b. The diversified RC is equal to the standalone RC multiplied by the floating factors calibrated from period to period, and varied by business.
6. Issues with the Allocation Scheme:
   a. Here, the variation and the fluctuation in the RC are beyond the control of any individual business, and are handled by managing risk exposures.
   b. This approach can lead to negative diversified RC that is difficult to interpret, and can lead to distorted return incentives.
7. Rationale for the New Approach: The new approach uses calibrated 2-beta approach or the weighted pro-rata approaches. Details of the description follow.

Enhanced Approach for the Allocation

1. Two-Beta Factor Allocation Approach:
   a.

$$Diversified\ Business\ RC = \beta \times Standalone\ RC$$

   b.

$$\beta_H = \beta_L \times 2$$

c. β's are calculated so that the sum of the products is equal to the Total Trading VaR Stress Risk Capital

d. Concentrated and illiquid exposures, i.e., the BSST's in low beta businesses are adequately accounted for.

2. General Principles of the Scheme:

    a. Capital allocations are done on the sub-business level – e.g. Credit Flow Trading under Capital Markets.

    b. Diversified RC should be driven primarily by the factors that the business can control and lower, and ne proportional to the standalone risk of the businesses to ensure simple and transparent linkage.

    c. Barring significant changes in the business and the exposure mixes, diversified RC should be relatively stable over time.

    d. Diversified RC should be positive, with the exception of risk mitigation hedges.

    e. A process should exist to continuously benchmark the allocated RC to a marginal contribution and ensure that any unallocated RC nets to zero over long-term diversification at the Trading Level.

    f. Businesses are split into two buckets:

        - High-beta businesses are characterized by structural credit risk exposures that are difficult to hedge
        - Low-beta businesses are characterized by credit-risk exposures that are easily hedgeable and by non-credit credit risk factors.

Incorporating BSST's

1. Handling the Illiquid BSST Risk: To cover the illiquid risk presented by the BSSTs, especially those in the low-beta businesses, allocation to BSST is done separately, as shown below.

2. Liquidity Impact on the Turnover: Although test runs show low impact from the BSST, the step is necessary to handle the cases where certain risks show low turn-over in the quarterly Volcker RENTD review.
3. Step 1 - Separating iBSST out of VaR-Stress: The global trading VaR-stress – technically the trading VaR-stress contribution to the group, excluding selected businesses, are split into two parts – the contributory iBSST, and the contributory GSST/VaR + cBSST.
4. Step 2 - Use of Worst iBSST Outcome: Allocate contributory iBSST to business by worst iBSST amounts.
5. Step 3 - Differential Allocation of Stress Capital: Allocate contributory GSST/VaR and cBSST by their contributions to the business level standalone, assign high-beta to illiquid businesses and all cBSST, low-beta to liquid businesses excluding cBSST.
6. Migration of cBSST to GSST: Historically, the cBSST's get migrated to GSST when the latter improves coverage on the granular levels. A potential issue arises when that happens with a low-beta business. Unless VaR-stress is enhanced to cover lower and more flexible business hierarchy, these BSST's cannot migrate.

Old vs New Capital Allocations

1. Elimination of Negative Beta Adjustments: As shown below, the medium and the low betas were negative, which is unacceptable. The new approach fixes this problem.

All Numbers in $MM	Standalone	Marginal Contribution	Old 3-Beta	New 2-beta	Marginal / Standalone %	3 Beta %	2 Beta %
Commodities	458	(304)	(12)	95	-66	-3	+21
Credit Structured	0	(250)	(250)	(250)	N/A	N/A	N/A
Credit Flow	261	(331)	(13)	55	-127	-5	+21
Distressed	277	102	(14)	116	+37	-5	+42

EM Credit Trading	435	89	(22)	181	+21	-5	+42
PECD	2369	2355	1895	989	+99	+80	+42
Short Term	27	12	(1)	6	+45	-5	+21
Cash	280	123	(7)	58	+44	-3	+21
Coverts	72	(23)	58	30	-32	+80	+42
Equity Derivatives	156	(2051)	(8)	33	-1316	-5	+21
G10 FX	357	(263)	(9)	74	-74	-3	+21
Liquid Markets	826	195	(21)	172	+24	-3	+21
Finance	408	55	(10)	85	+13	-3	+21
MT	730	328	(19)	152	+45	-3	+21
G10 Rates	685	(47)	(35)	143	-7	-5	+21
Hybrids	258	(95)	(13)	54	-37	-5	+21
Munis	1467	1063	(75)	612	+72	-5	+42
Prime Finance	12	4	(0)	3	+34	-3	+21
GSM	3042	2914	2434	1269	+96	+80	+42
Total	**12120**	**3877**	**3877**	**3877**	**-**	**-**	**-**

2. Recognizing Diversification and Stabilizing Allocations: In the time-frame considered below, there are no extreme marginal contributions, resulting from liquidity adjusted GSST and more risk taking. The new approach allocates less capital to high beta businesses but reflect the trading level benefits while stabilizing allocations.

All Numbers in $MM	**Standalone**	**Marginal Contribution**	**Old 3-Beta**	**New 2-Beta**	**Marginal / Standalone %**	**3 Beta %**	**2 Beta %**
Commodities	1384	310	313	476	+22	+23	+34
Credit Structured	0	(166)	(166)	(166)	N/A	N/A	N/A
Credit Flow	314	86	142	108	+27	+45	+34

Distressed	263	5	119	181	+2	+45	+69
EM Credit Trading	773	675	350	532	+87	+45	+69
PECD	1689	1569	1359	1168	+92	+80	+69
Short Term	37	24	17	13	+66	+45	+34
Cash	594	437	134	204	+73	+23	+34
Coverts	80	63	64	55	+79	+80	+69
Equity Derivatives	425	(1161)	192	146	-273	+45	+34
G10 FX	307	(483)	69	106	-158	+23	+34
Liquid Markets	1063	78	240	366	+7	+23	+34
Finance	242	86	55	83	+36	+23	+34
MT	1483	264	335	510	+18	+23	+34
G10 Rates	2520	1667	1139	867	+66	+45	+34
Hybrids	530	415	240	182	+78	+45	+34
Munis	730	612	330	502	+84	+45	+69
Prime Finance	27	(6)	6	9	-20	+23	+34
GSM	3600	3341	2880	2476	+93	+80	+69
Total	**16702**	**7818**	**7818**	**7818**	**-**	**-**	**-**

Alternate Approaches Considered in the Past

1. Balance Sheet Projection using PPNR: Balance sheet projection schemes using PPNR were contemplated to account for stress time revenue flow and trading behavior such as hedge roll-over, etc.
2. Dynamic Reassessment of Beta Bucketing: Attempts were made to form dynamic re-assessment of beta bucketing calibrated to marginal contribution through clustering.
3. Combinations of Fix/Float Bucketing: Different combinations of fix/float beta bucketing were explored.

Allocation Technical Details

1. Proposed Approach – Separating Hedge Trades: The first step would be to separate the hedges. In the treatment below, Group refers to the Trading Group Total.
    a. Allocation to the Hedge => Trading Desks Marginal to Group
    b. The *"Trading Marginal to Group"* – *"Trading Hedge Desks Marginal to Group"* are allocated as shown below.
2. Proposed Approach – Differential Component Allocation: Separate allocate the VaR + GSST component and the BSST component.
    a. *VaR* + *GSST* Allocation => A two-beta (high vs. low) approach, with

$$\beta_H = \beta_L \times 2$$

    b. Correlated BSST Allocation => Pro-rata to cBSST contribution from each business in a driving scenario – e.g., 2008.
    c. Idiosyncratic BSST Allocation => Pro-rata to standalone worst iBSST of each business.

Allocation Approach and Available Inputs

1. Trading Marginal to Total: Since there is no VaR, GSST, and BSST contribution of Trading Marginal to Trading Total:
    a. Trading standalone – or hedge – of each business is first allocated. One approximation here is that the Trading Standalone may contain the impact of the hedge.

b. The same allocation percentage of the Trading Marginal is applied to Trading Total. The trading standalone is broken down to marginal contribution from VaR, iBSST, cBSST, and GSST.

$$RC_{Trading\ Standalone} = RC_{GSST} + RC_{VaR} + RC_{cBSST} + RC_{iBSST}$$

where the RHS refers to the marginal contributions from VaR, GSST, cBSST, and iBSST.

2. Decomposing the Desk/Business Standalone: The business standalone is broken down to contributions from VaR, iBSST, cBSST, and GSST.

$$RC_{Standalone,i} = RC_{GSST,i} + RC_{VaR,i} + RC_{cBSST,i} + RC_{iBSST,i}$$

where the RHS refers to the contributions to desk i from VaR, GSST, cBSST, and iBSST.

3. Allocation for iBSST and cBSST:
   a. PnL of worst iBSST for trading $PnL_{Worst,iBSST}$ and for each business desk $PnL_{Worst,iBSST,i}$ are required.
   b. The cBSST PnL for each of the 5 scenarios is required:

$$PnL_{cBSST,s} = \sum_j PnL_{cBSST,s,j}$$

Allocation Algorithm for each Component

1. Enhanced Two-beta Allocation Table:

Component	***Parent*** **Value to be allocated**	Inputs
VaR + GSST	$RC_{GSST} + RC_{VaR}$	$RC_{GSST,i} + RC_{VaR,i}$

cBSST	RC_{cBSST}	$PnL_{cBSST,s,j}$
iBSST	RC_{iBSST}	$PnL_{Worst,iBSST,i}$

2. Allocation Algorithm:

$$RC_{ALLOCATION,VaR+GSST,i} = \left(RC_{GSST,i} + RC_{VaR,i}\right) \times \left[\frac{w_i\left(RC_{GSST} + RC_{VaR}\right)}{\sum_{j \notin Hedge} w_j\left(RC_{GSST,j} + RC_{VaR,j}\right)}\right]$$

$$w_i = 1$$

if i is a low beta desk, and 2 if i is a high beta desk. The term in the square brackets is the *beta*.

$$RC_{ALLOCATION,cBSST,i} = RC_{cBSST} \times \left[\frac{PnL_{cBSST,s,i}}{\sum_{j \notin Hedge} PnL_{cBSST,s,j}}\right]$$

s is a representative scenario such as 2008.

$$RC_{ALLOCATION,iBSST,i} = RC_{iBSST} \times \left[\frac{PnL_{Worst,iBSST,i}}{\sum_{j \notin Hedge} PnL_{Worst,iBSST,j}}\right]$$

3. Trading Marginal to Group Scaling: Scale to the Trading Marginal contribution to the Group ex. Hedge.

$$\begin{aligned} &Allocation\ for\ non-hedge\ Desk\ i \\ &= \frac{Trading\ Marginal\ to\ Group - Trading\ Hedges\ Marginal\ to\ Group}{Trading\ Standalone} \\ &\times \left(RC_{ALLOCATION,VaR+GSST,i} + RC_{ALLOCATION,cBSST,i} + RC_{ALLOCATION,iBSST,i}\right) \end{aligned}$$

$$Allocation\ for\ Hedge = \ Trading\ Hedges\ Marginal\ to\ Group$$

Reporting Flow

Overview

1. <u>Risk Source Inputs for VaR, GSST, cBSST, and iBSST</u>: GSST by PAA and capital units, VaR by FS type and capital unit, BSST P&L by FS type and business/sub-business/region/LV, allocated to capital unit.
2. <u>Simulation Input for iBSST</u>: Random numbers used to determine the iBSST P&L.
3. <u>Firm/Business Level Standalone Output</u>: Average of the top 2% of a capital entity.
4. <u>Firm/Business Level Marginal Output</u>: Average of the top 2% of a capital entity, but based on the sorted P&L for a *high* capital segment – e.g., marginal from any sub-business, from VaR, from Commodity Vega, from Municipal rate exposure etc.
5. <u>Beta Based on the Children of a Capital Segment</u>: The beta ration is based on the selections of a capital segment and the entities below it, of the standalone of the *high* capital segment against the summation of the weighted – either 1x or 2x in the two floating beta scheme – standalones of the *low* capital entities.

P&L Data Repository

1. <u>Top Capital Segment – possibly the BHC – sorted to generate the BHC wide Capital</u>: The following components need to be available:
    a. The 10,000 P&Ls
    b. The Marginal Contribution
    c. The Standalone VaR-Stress top 2% P&L’s

d. Risk Dimension made up of Risk Source + Risk Factor or PAA, e.g., GSST/Rates^Delta/Gamma, cBSST/Rates^Delta/Gamma, VaR/IDL.USD.SOV, …, iBSST/Specific Type
e. Business Dimension down to Capital Unit; Aggregation by business management segment, LV, region, etc.

2. <u>Sub-Capital Entity P&L sorted to generate Standalone VaR-Stress Capital</u>:
    a. The 10,000 P&Ls
    b. The sub-types, e.g., all rates
    c. The sub-businesses, e.g., Equity Derivatives,
    d. Standalone VaR-Stress top 2% P&Ls

Reporting

1. <u>Use of Risk Capital Analytics</u>: Reporting of the standalone, the marginal, and the allocated Capital numbers should leverage the BHC Risk Capital reporting tool.
2. <u>Additional Dimensions Required for Reporting</u>: While many dimensions may already be present, the following are the additional dimensions that need to be made available.
    a. VaR/stress business hierarchy, such as *risk type*, i.e., *CVA*, *AFS*, *Trading*, and the *Product/Business* levels, which will need to be mapped with the capital unit.
    b. *Risk Source*, i.e., *VaR, GSST, BSST, etc.*
    c. GSST PAA that are mapped to VaR FS type. If the GSST PAA's are at a higher level, the VaR P&L's can also be mapped to the GSST PAA.
    d. All iBSST specific types.
    e. Beta Status, i.e., high, medium, or low.
3. <u>Customized Grouping of Capital Entity Nodes</u>: A customized level can be established by pulling businesses from the Capital Segments or groups of Capital Units. A customized set may also be achieved using a filter.

4. Additional Calculated VaR-Stress Metrics Needed: IN addition to the previously calculated values, additional VaR-Stress metrics such as the beta allocated and the marginal contributions – which is not the same as CVaR – are also required.
5. VaR-Stress Beta Calculation Scheme: Between a *high* capital segment and the capital entities below it, beta is calculated from the standalone of all the capital entities, and is based on the *high/low* capital entity designations.

Enhanced Business Hierarchy for VaR Stress Estimation

Business Hierarchy Decisions

1. Typical vs. Desired VaR-Stress Infrastructure: A few considerations must be noted between the typical VaR-Stress estimation infrastructure and a desired one.
2. Simulation Level Tied to Reporting: Is the level of simulation tied to the level of reporting?
    a. Typical – YES. The granularity needs to be defined right at the invocation of the computation.
    b. Target State – NO. A given capital estimate can be broken down to granular level capital units.
3. Accommodating a Custom Business Hierarchy: Can a custom business hierarchy be used?
    a. Typical – NO.
    b. Target State – YES, using capital segments.
4. Granularity of the Simulations Done: What are the levels of simulation?
    a. Typical – Often at the Group/Product/Business/Region/Risk Type level, e.g., ICG + FXLM + G10 + FX + GLOBAL + Trading.
    b. Target State – At the lowest level, simulations are done at Capital Unit + Risk Type Level, i.e., the Capital Unit Key. At higher levels, capital can be aggregated at Capital Segment + Risk Type.
5. Handling of the Calculation Geography: Is the geography based simulation required?
    a. Typical – YES. Reporting depends on simulation.
    b. Target State – NO. Capital Unit level Simulation allows reporting through Managed Geography.
6. Separation of Simulation and Geography: Given that in the target state the reporting and the simulation requirements can be de-coupled, one can re-define the levels at which the results will be allocated.

7. Typical VaR Stress Simulation Levels: Traditionally, the VaR/Stress systems have provided results at the following levels:
    a. Marginal to Global BHC
    b. Marginal to Regional BHC
    c. Marginal to Global Group
    d. Marginal to Regional Group
    e. Standalone
8. Elimination of the Regional Runs: It is recommended to eliminate the regional runs. This will reduce the number of simulations required, and hence the computation time. Geographic details for reporting can be derived using capital units.
9. Estimation of Marginal to BHC: The Marginal to BHC will continue to be needed, and an individual group will need to define if the Marginal to Group – e.g., ICG, GCB, CORPORATE, etc. – will need to be maintained. For the purposes of this discussion it is assumed that they are persisted.
10. Capital Unit/Segment Standalone: The standalone results come in two varieties:
    a. Capital Unit Key => Capital Unit + Risk Type
    b. Result at the Capital Segment Level
11. Business Level Aggregation of Results: Finally, the relevant level for business allocation results needs to be identified. Two candidate proposals could be:
    a. Marginal to Product
    b. Marginal to Product and Marginal to Business
12. Example – Marginal to Business Standalone: The allocation results will tentatively look like:
    a. Marginal to BHC
    b. Marginal to Group
    c. Marginal to Product
    d. Marginal to Business
    e. Marginal to Standalone
    f. Standalone Capital Segment L1

…

    g. Standalone Capital Segment Ln

Considerations when Picking Business Reporting Options

1. Capital Allocation at Business Level: The ultimate goal is to ensure that results are run and allocated at a level that is relevant to risk management of a given business.
2. Periodic Refresh of Business Hierarchy: The Business Hierarchy mapped to Capital Segments will have to be loaded each period by the Risk Reporting Team. This will require maintenance of the references by the team against the Hierarchy Standard.
3. Capital Segment/Unit Hierarchy Shuffle: It is worth noting that the Hierarchy Standard tends to change less frequently at the higher levels of Capital Segments than the lower. Hence, if there is a desire to map below a pre-set Capital Segment level, it is likely that the Business Hierarchy will change more frequently.
4. Incorporation of Volcker Rules Results: Often there may be a need to include Volcker rules results. This needs to be clarified whether it is a reporting or a simulation requirement.

Comparison of Hierarchies

Problem Statement

1. Hierarchy Support for Volcker Requirements: The hierarchy used by a typical BHC in support of Volcker to represent the business structure of the trading desks is different from that of the Capital Segment hierarchy.
2. Capital Segment/Market Risk Hierarchy: While the BHC hierarchy appears to be based on the Capital Segment tree, there are noticeable differences. These differences include, but are not limited to:
    a. Re-grouping of Capital Segments
    b. Removing Levels
    c. Merging the Capital Segments with Managed Geography

Principles and Goals

1. Transparency and Accuracy Goals: First goal is to have transparent and accurate data.
2. Identification of the Single Structural Scope: The next is to agree on a clearly defined and communicated structure for reporting, where both the Finance and the Risk values must be present side-by-side with the understanding that they represent the same structural scope.
3. Uniformity across Operational Components Hierarchy: This single structure must include the needs of Business, Finance, Risk, and HR.
4. Purpose of the BHC Working Group: The working group will:
    a. Put forth a proposal to merge the Volcker and the Capital Segment into a single common hierarchy.

    b. When the working group cannot agree on how this can be done for a particular section, that piece must be tabled to a broader group for determination.
    c. Put controls in place to prevent divergent representations of the business organization into the future.
5. Single Structure Truth for the BHC: It is essential to have the senior management agree on a single structural truth for reporting the BHC's business organizations. This truth should be used for all internal reporting including FP&A decks, business presentations, HR, and Volcker reporting.

Need for Defining a Structural Truth

1. Problems with Inconsistent Management Hierarchies: It is a major risk to the firm to have hierarchies that are fundamentally inconsistent. By definition, both the Capital Segment Hierarchy and the Volcker Hierarchy reflect how the businesses are managed. Due to this, the firm ends up communicating different ways in which the firm manages the business depending on the reports and the regulators involved.
2. Cost Impact from Inconsistent Hierarchies: The granularity of the reporting requirements has increased at a time when the focus on the data quality is greater than ever.
    a. There is an increased risk of higher volume of errors if the scope is misaligned.
    b. Structural wastes resource times across functions investigating differences, comparing and contrasting various structures.
    c. Time and money is wasted creating and managing accommodating processes or adding user provisioning to add various views.
3. Implementing Reporting and Booking Policy: New challenges arise as one strives to implement quality PPL, Reporting, and Booking Model Policy.
4. Impact on Strategy and Information Flows: Core capabilities often refer to accurate decision making information. How does one build strategic and accurate information flows if there is ambiguity on the reporting structural foundation?

5. Aligning Finance and Risk Hierarchies: Finance Data and the related Risk Data need to be aligned in the same structure to provide meaningful reporting and insight.
6. Impact of Additional BHC Policy: BHC Policy dictates the use of Enterprise Standards and prohibits the use of alternate views.

Current Definitions – Capital Segment

1. Definition of a Capital Segment: A capital segment is a complete BHC business entity with identifiable management, business, and marketing strategy, income, expenses, assets, and funding. A capital segment may also represent middle and back office service units.
2. Purpose of the Capital Segment: The capital segment hierarchy is the BHC's line of business structure and reflects the relationship between the different business entities, e.g., Total Markets and Securities Services is a child of ICG. The Capital Segment hierarchy serves the organizational foundation for reporting and performance measurement. The hierarchy of the Manager's responsibilities – currently reflected in the HR Organization Tree – must align with the Capital Segment Hierarchy. This single structure must meet the needs of Business, Finance, Risk, and HR.

Current Definitions – Volcker

1. Verification of Compliance with Volcker: Typically, BHC's review their global business activities to identify the business units that engage in activities subject to the provisions of the Volcker Rule related to the Proprietary Trading and the status of the activities thereunder. Units of the BHC that engage in trading activities subject to the Volcker Proprietary Provisions have been designated by the Volcker Rule Office as *Trading Desks*. Any business that seeks to engage in new activities, or change its existing activities, must review such activities for compliance with the provisions of the Volcker Rule related to proprietary

trading under applicable new or changed activity approval procedures and with Legal. All such determinations are subject to review by the Volcker Rule Office.

2. <u>Volcker Proprietary Trading Provisions Mandate</u>: Each *Trading Desk* must operate under an approved mandate – a *Trading Mandate* – and related procedures maintained by the Volcker Rule Office designed to monitor and reasonably ensure compliance with the Volcker Rule. The Trading Mandates address the specific requirements and limitations of the relevant exemption (s) and/or exclusion (s) under the Volcker Proprietary Trading Provisions, pursuant to which the trading desks conduct their activities and contain additional details regarding the application of monitoring and controls regarding these activities.

Example – Capital Markets Origination Business

The Capital Markets Origination (CMO) business is often shown in the Core Capabilities response of the Market Risk Chapter, as in the Volcker and the RMC reporting, as belonging to *Markets*. The Enterprise Standard Firm Hierarchy might place the CMO not in *Markets* but in *Total Banking* where it is reported as part of the BHC's earning releases. Could both of these be correct? In which case, there are two truths, not one.