Stress Testing and Macro-prudential Regulation:
A Trans-Atlantic Assessment

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Bank Stress Testing: A Stochastic Simulation Framework to Assess Banks' Financial Fragility

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Executive Summary

- We present a **stochastic model to develop multi-period forecasting scenarios** to stress test banks' capital adequacy with respect to all the relevant risk factors that may affect capital, liquidity and regulatory requirements, and that is capable of measuring the overall degree of a bank's financial fragility
- **Stochastic simulation is an effective way of representing all the elements of complexity** (conditions of non-linearity, time and cross-dependence relationships, feedback mechanisms) that cannot be reproduced using traditional deterministic analysis techniques.
- The **application of the model is very flexible and characterized by multi-level deployment**, allowing the user to choose the degree of complexity and analytical detail to be considered in its implementation, depending on the scope of the analysis and the available information, time, tools, etc.
- The **stochastic methodology proposed is based on a simplified reduced model** that, within a theoretically sound framework, provides a manageable stress-testing approach that considers only those essential variables and key risk drivers that are truly relevant for assessing a bank's capital adequacy. In fact, excessive detail and cumbersome modeling structures do not improve the accuracy and relevance of results, but often obscure the causal relationships between inputs and outputs and increase operational risk of errors.
- The use of stochastic simulation models leads the way to more appropriate and effective solutions to quantify **default risk and liquidity risk forward-looking measures, expressed in probabilistic terms**; traditional deterministic models simply do not allow an equally satisfactory determination of solutions.
- We present the results of a **simple stress test exercise performed on the G-SIBs banks** in order to show a real application of the proposed methodology and compare the results with those from the supervisory stress test performed on US banks by the Federal Reserve (published in March 2014) and those from the EBA/ECB stress test on EU banks (published in October 2014). The exercise and the assumptions made here must be considered only as an example of how the approach can be implemented, and not as the only and/or best application.
- We also present a small **back-testing comparative analysis** of the model covering three well-known cases of default/financial distress: **Lehman Brothers, Merrill Lynch Northern Rock.**

It is better to be roughly right than precisely wrong.

John Maynard Keynes

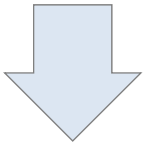
It is far easier to figure out if something is fragile than to predict the occurrence of an event that may harm it. [...] Sensitivity to harm from volatility is tractable, more so than forecasting the event that would cause the harm.

Nassim Nicholas Taleb

Analytical Framework

Stress Testing Scope and Aim

Current stress testing methodologies are designed to indicate the potential capital impact of one specific predetermined scenario, but they fail to adequately measure banks' degree of forward-looking financial fragility, providing poor indications in this regard, especially when the cost in terms of time and effort required is considered.



- Within our framework **we define stress testing as an analytical technique designed to assess a bank's overall capital and liquidity degree of fragility against "all" potential future adverse scenarios** and not just one specific adverse scenario or risk factor.
- Therefore the stress testing model proposed is aimed at a **forward-looking assessment of the overall capital adequacy** of a bank in relation to a preset level of risk.
- It can be considered an effective and handy tool to **support supervisory authorities and/or banks' management** in assessing a bank's adequate capital endowment

- The consideration of **only one deterministic adverse scenario** (or at best a very limited number, 2, 3… scenarios) limits the exercise's results to one specific set of stressed assumptions.
  - ⇒ *This approach does not provide any information about the assigned probabilities, thus strongly reducing the practical use and interpretation of the results. According to Berkowitz (1999), when we leave stress testing in a statistical purgatory «We have some loss numbers, but who is to say whether we should be concerned about them?»*

- The **reliance on macroeconomic variables as stress drivers** (GDP, interest rate, exchange rate, inflation rate, etc.) that must then be converted into bank-specific micro risk factor impacts (impairments, net interest income, regulatory requirement, etc.) by recurring to satellite models.
  - ⇒ *Most of the recent financial crises (including the latest) were not preceded (and therefore not caused) by a relevant macroeconomic downturn; often quite the opposite is true, i.e., endogenous financial instability causes a downturn in the real economy.*
  - ⇒ *Within a single-adverse-scenario approach, the macro scenario definition has the scope to facilitate the stress test storytelling rationale for supervisory communication purposes, but does not help in assessing the effective degree of a bank's/financial system's fragility.*

- The **total stress test capital impact is determined by adding up, through a building block framework**, the impacts of the different risk factors, each of which is estimated through specific and independent silo-based satellite models.
  - ⇒ *This approach disregards the potential bias arising from a risk integration where the different risks are not simultaneously considered within a single simulation framework and does not adequately manage the non-linearity, path dependence, feedback and cross-correlation phenomena that strongly affect capital in "tail" extreme events and multi-period exercises.*

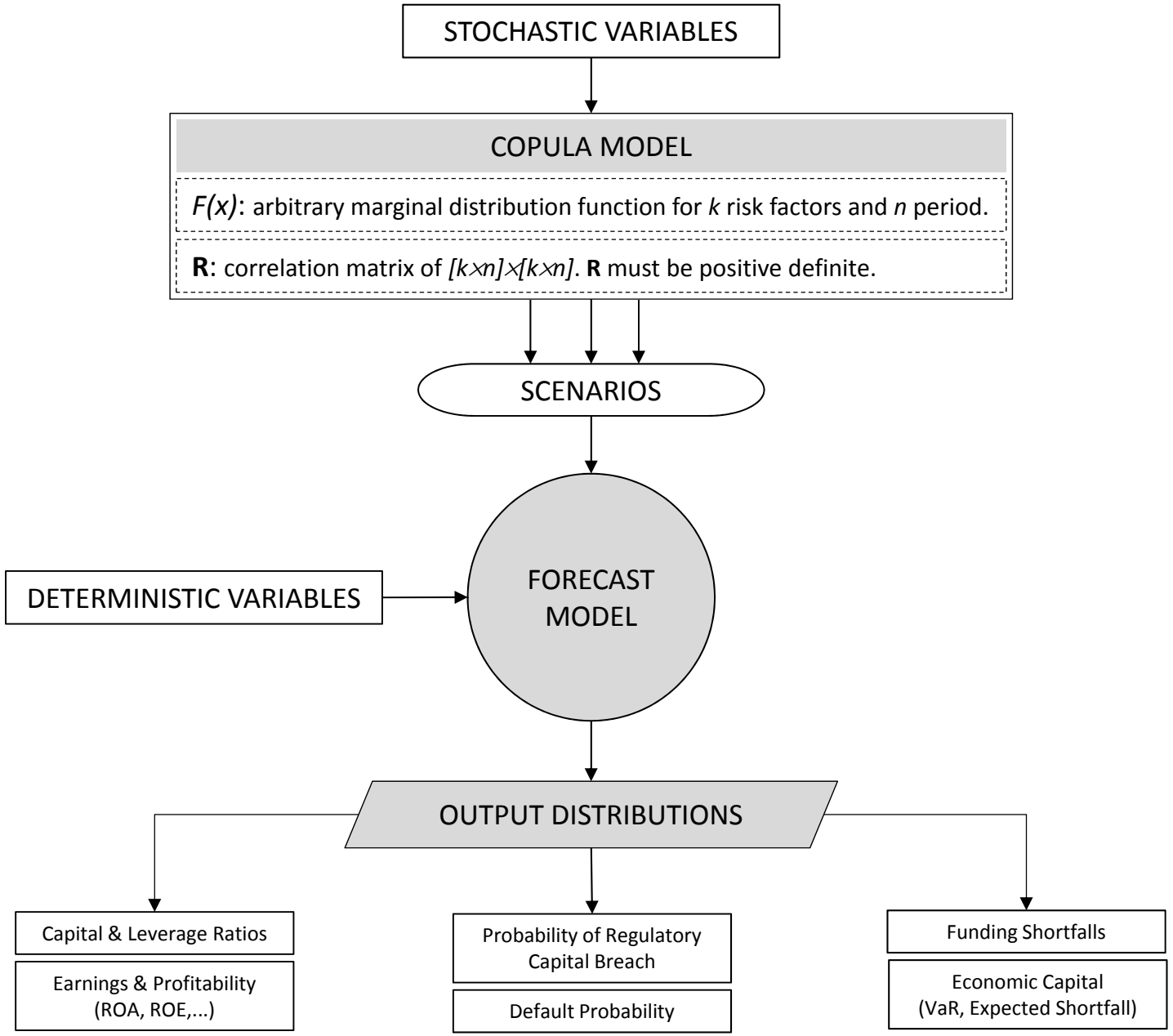
- The **satellite models are often applied with a bottom-up approach**, **i.e. using a highly granular data level** (single client, single exposure, single asset, etc.) to estimate the stress impacts and then adding up all the individual impacts.
  - ⇒ *The highly granular data level employed and the consequent use of the linked modeling systems makes stress testing exercises extremely laborious and time-consuming, limiting, as a matter of fact, the number of scenarios considered and forcing a reliance on banks' internal models and calculations.*
  - ⇒ *This approach implicitly requires a static balance sheet and portfolio composition, an unrealistic assumption in a multi-period exercise .*

- In **supervisory stress tests, the exercise is performed by the banks and not directly by supervisors**, leaving open the risk of **moral hazard** in stress test development and affecting the comparability of the results (the application of the same set of assumptions with different models does not ensure a coherent stress test exercise across all of the banks involved).
  - ⇒ *Supervisory stress testing should be performed directly by the competent authority; by adopting an efficacious and handy approach that does not constrain them to depend on banks for calculations.*

New Stress-Testing Approach: Key Features

- **Multi-period stochastic forecasting model:** a forecasting model to develop multiple scenario projections for income statement, balance sheet and regulatory capital ratios, capable of managing all of the relevant bank's value and risk drivers in order to consistently ensure:
  (1) A dividend/capital retention policy that reflects regulatory capital constraints and stress test aims.
  (2) The balancing of total assets and total liabilities in a multi-period context, so that the financial surplus/deficit generated in each period is always properly matched to a corresponding (liquidity/debt) balance sheet item.
  (3) The setting of rules and constraints to ensure a good level of intrinsic consistency and correctly manage potential conditions of non-linearity
- **Forecast variables expressed in probabilistic terms**: the variables that represent the main risk factors for capital adequacy are modeled as stochastic variables, and defined through specific probability distribution functions in order to establish their future potential values, setting correlations among them. The severity of the stress test can be scaled by properly setting the distribution functions of stochastic variables.
- **Stochastic simulation through Monte Carlo Method:** this technique allows us to solve the stochastic forecast model in the simplest and most flexible way. The stochastic model can be constructed using a copula-based approach, with which it is possible to express the joint distribution of random variables as a function of the marginal distributions. (analytical solutions would be too complex and tied to specific functional relationships of the model and probability functions assumed).
- **A top-down comprehensive view:** the simulation process set-up utilizes a high level of data aggregation, in order to simplify calculation and guarantee an immediate view of the causal relations between input assumptions and results.
- **ERM modeling for risk integration:** the impact of all risk factors is determined simultaneously, consistently with the evolution of all of the economics within a single simulation framework.

New Stress-Testing Approach: Analytical Framework



New Stress-Testing Approach: Risk Factor Modeling ⇢

Risk Factor	Types and Models to Project Losses	P&L Risk Factor Variables		Balance Sheet Risk Factor Variables		RWAs Risk Factor Variables	
		Basic Modeling	Breakdown Modeling	Basic Modeling	Breakdown Modeling	Basic Modeling	Analytical Modeling
PILLAR 1							
CREDIT RISK	• Accounting-based loss approach	• Net adjustments for impairment on loans	• Net adjustments portfolio (A, B,…)	• Net charge off (NCO) • Reserve for loan losses	• Breakdown for NCOs and reserve for portfolio	• Credit risk coefficient (% net loans) • Change of Credit risk RWA in relative terms	• Basel I type • Standard approach • Advance/foundation IRB
	• Expected loss approach (PD, LGD, EAD/CCF)	• Impairment flows on new defaulted assets • Impairment Flow on old defaulted assets	• Breakdown impairment flow for portfolio	• Non-performing loans • NPLs Write-off, Pay-downs, Returned to accruing • Reserve for loan losses	• Breakdown for NPLs, Write-off, Pay-downs, Returned to accruing and Reserve for Portfolio		
MARKET & COUNTERPARTY RISK	• Simulation of mark-to-market losses • Simulation of losses in AFS, HTM portfolio • Simulation of FX and interest rate risk effects on trading book • Counterparty credit losses associated with deterioration of counterparties creditworthiness	• Gain/losses from market value of trading position • Net adjustment for impairment on financial assets	• Gain/losses portfolio (A, B, …) • Impairment portfolio (A, B, …)	• Financial Assets • AOCI (Accumulated other comprehensive income)	• Breakdown for financial assets (HFT, HTM, AFS…, etc)	• Market risk coefficient (% financial assets) • Change of market risk RWA in relative terms	• Change in value at risk (VaR)
OPERATIONAL RISK	• Losses generated by operational-risk events	• Non-recurring losses	• Non-Recurring Losses Event A • Non-Recurring Losses Event B • […]			• Percentage of net revenues • Change of operational risk RWA in relative terms	• Standard approach • Change in value at risk (VaR)

Risk Factor	Types and Models to Project Losses	P&L Risk Factor Variables		Balance Sheet Risk Factor Variables		RWAs Risk Factor Variables	
		Basic Modeling	Breakdown Modeling	Basic Modeling	Breakdown Modeling	Basic Modeling	Analytical Modeling
PILLAR 2							
INTEREST RATE RISK ON BANKING BOOK	• Simulation of economic impact on interest rate risk on banking book	• Interest rate loans • Interest rate deposits • Wholesale funding costs • […]	• Risk free rate • Spread loan portfolio (A, B, …) • Interest rate deposits (A, B, …) • Wholesale funding costs (A, B,…) • […]				
REPUTATIONAL RISK	• Simulation of reputational event-risk	• Commissions • Funding costs • Non-interest expenses	• Interest rate deposits (A, B,…) • Wholesale funding costs (A, B,…) • […] • Marketing expenses • Administrative expenses • […]	• Deposits • Wholesale debt • […]	• Deposits (A, B,…) • Wholesale debt (A, B, …)		
STRATEGIC AND BUSINESS RISK	• Simulation of economic impact of strategic and business risk variables	• Commissions • Non-interest expenses	• Commission • Administrative expenses • Personal expenses • […]	• Loans • Deposits • Wholesale debt • IT investment • […]	• Loans (A, B, …) • Deposits (A, B, …) • Wholesale debt (A, B, …) • IT investment • […]		

PROBABILITY OF REGULATORY CAPITAL RATIO BREACH

On the basis of the capital ratio probability distribution simulated we can determine the estimated cumulated probability of triggering a preset threshold (probability of breach), such as the minimum regulatory capital ratio or the target capital ratio.

$$P_1 = P(CET1_1 < mCET1_1)$$
$$P_2 = P(CET1_1 < mCET1_1) + P(CET1_2 < mCET1_2 | CET1_1 > mCET1_1)$$
.....
$$P_n = P(CET1_1 < mCET1_1) + P(CET1_2 < mCET1_2 | CET1_1 > mCET1_1) + \cdots$$
$$+P(CET1_n < mCET1_n | CET1_1 > mCET1_1, \ldots, CET1_{n-1} > mCET1_{n-1})$$

where $mCET1$ is the CET1 Capital ratio threshold.

Marginal and annual probabilities of breach can also be estimated.

	Y1	Y2	Y3
MINIMUM	5.44%	4.53%	4.20%
1% PERCENTILE	5.50%	4.53%	5.84%
2% PERCENTILE	5.80%	4.61%	5.88%
3% PERCENTILE	5.93%	4.64%	6.12%
4% PERCENTILE	5.95%	4.85%	6.37%
5% PERCENTILE	6.13%	4.87%	6.59%
10% PERCENTILE	6.55%	5.08%	6.64%
20% PERCENTILE	6.77%	5.50%	6.77%
30% PERCENTILE	7.27%	5.63%	7.03%
40% PERCENTILE	7.37%	5.74%	7.25%
50% PERCENTILE	7.58%	6.11%	7.39%
60% PERCENTILE	7.74%	6.48%	7.43%
70% PERCENTILE	7.95%	6.81%	7.45%
80% PERCENTILE	8.26%	6.95%	7.80%
90% PERCENTILE	8.58%	7.12%	8.29%
95% PERCENTILE	8.62%	7.14%	8.50%
96% PERCENTILE	8.88%	7.17%	8.57%
97% PERCENTILE	9.09%	7.38%	8.88%
98% PERCENTILE	9.30%	7.45%	9.10%
99% PERCENTILE	9.31%	7.50%	9.37%
MAXIMUM	9.57%	8.36%	10.60%

PROBABILITY OF DEFAULT ESTIMATION

The bank's probability of default estimate is given by the frequency of scenarios in which the event of default occurs. Two different definitions of default events can be adopted:

⇒ ***Accounting-Based***
default occurs when the relevant capital adequacy ratio (CET1 or leverage ratio) falls below a predefined threshold: $PD_t = P(Capital\ Ratio_t < Threshold_t)$

⇒ ***Value-Based:***
default occurs when the equity value (determined through a DCF valuation model) falls below zero (like in the Merton approach): $PD_t = P(Equity\ Value_t < 0)$

ECONOMIC CAPITAL DISTRIBUTION (VALUE AT RISK, EXPECTED SHORTFALL)

The net losses probability distribution generated by the simulation allows us to obtain an estimate of economic capital for various time horizons and at any desired confidence level. Setting, x_t=$Net\ Income_t$, we can define the cumulated losses as:

$$Cumulative\ Total\ Loss_t = \begin{cases} 0 & \textbf{if } f(x_t) \geq 0 \\ -f(x_t) & \textbf{if } f(x_t) < 0 \end{cases} \quad \text{where } f(x_t) = \sum_{i=1}^{t} x_t$$

$$VaR_{perc}(or)ES_{perc} = (Cumulative\ Total\ Loss_t)_{perc}$$

	Y1	Y2	Y3
40% PERCENTILE	0	0	0
50% PERCENTILE	0	1,134	2,658
60% PERCENTILE	3,529	6,322	8,543
70% PERCENTILE	10,628	15,539	16,010
80% PERCENTILE	19,038	27,955	31,072
90% PERCENTILE	30,640	45,900	51,087
95% PERCENTILE	41,200	61,052	69,136
96% PERCENTILE	43,902	65,165	74,830
97% PERCENTILE	47,519	70,294	82,766
98% PERCENTILE	53,294	76,156	93,321
99% PERCENTILE	60,837	87,598	109,350
MAXIMUM	85,567	126,678	145,807

Since within the simulation we determine the distribution functions of all risk factors impacts (impairment on loans, losses on financial assets, etc.), we can also break down economic capital into the main risk factors (credit risk, market risk, …).

POTENTIAL FUNDING SHORTFALLS: A FORWARD-LOOKING LIQUIDITY RISK PROXY

The determination of liquidity indicator distribution functions permits us to estimate the bank's liquidity risk in probabilistic terms, thus providing in a single modeling framework the possibility of assessing the likelihood that critical liquidity conditions may occur jointly with the corresponding capital adequacy conditions, taking into account the interaction between the two phenomena.

HEURISTIC MEASURE OF TAIL RISK

This indicator captures fragility arising from non-linear conditions in the tails of risk distributions. The stress testing approach proposed is well suited to the application of this indicator, since its outputs are probability distributions.

Stress Testing Exercise: Implementation

WARNING: The stress test exercise performed has been developed exclusively as an exemplification for illustrative purposes and does not represent to any extent a valuation on the capital adequacy of the banks considered. Therefore the assumptions described here below are intended solely for this explanatory aim, must be considered as only one possible sensible set of assumptions and do not by any means represent the only or the best implementation paradigm of the stochastic simulation model proposed. For stress tests that more efficaciously measure financial fragility and default risk, more evolved implementation paradigms can easily be adopted, using a broader and more accurate set of data if available.

Stress Testing Exercise: General Features

- We applied the stochastic simulation framework proposed to perform a stress test exercise on a sample of the **29 international banks belonging to the G-SIBs group.**
- We **compared the stochastic simulation results with the results of the 2014 supervisory stress test** conducted for the US banks by the FED and for the EU banks by the EBA/ECB.
- The exercise includes two sets of simulations of increasing severity: the "**Stress[-]**" simulation is characterized by a lower severity, while the "**Stress[+]**" simulation presents a higher severity.
- The specific set of assumptions adopted for **this exercise must be considered strictly as an example of application of the stochastic simulation methodology proposed** and absolutely **not as the only or best way to implement the approach**. We intentionally kept modeling and assumptions as simple as possible to facilitate the description of the basic characteristic of the approach.
- The **data source is the Bloomberg** data base; the lack of publicly available data for some key variables (such as PDs and LGDs) necessitated the **use of some rough proxy estimates and benchmark data**; both issues may have affected the results.
- To eliminate bias due to derivative netting and guarantee a fair comparison within the sample, **we reported gross derivative exposures** for all banks (according to IFRS accounting standards adopted by most of the banks in the sample, except US and Japanese banks), thus market risk stress impacts have been simulated on gross exposures. This resulted in an adjustment of derivative exposures for banks reporting according to US GAAP, which allows for a *Master Netting Agreement*.
- In order to allow better comparison among the banks considered in the analysis, **the sample has been clustered into four groups, according to their business model**: **IB** = Investment Banks, **IBU** = Investment Banking-Oriented Universal Banks, **CB** = Commercial Banks, **CBU** = Commercial Banking-Oriented Universal Banks.

Stress Testing Exercise: Forecasting System

Projecting Income Statement

+ Interest Income
– Interest Expense
= Net Interest Income
+ Net Commission Income
+ Net Financial and Trading Income
+ Other Operating Income (Expense)
= Net Revenues
+ Net Adjustments for Impairment on Loans
– Non-Interest Expense
= Operating Income
+ Other Non Operating Income (Losses)
= Pretax Income
– Taxes
= Income (Loss) before Extraordinary Items
+ Extraordinary Income (Loss)
– Income Applicable to Minority Interests
= Net Income

Projecting Balance Sheet

Net Loans
+ Gross Performing Loans
+ Gross Non-Performing Loans
– Reserve for Loan Losses
Financial Assets
Goodwill
Other Intangibles
Other Assets
= Total Assets

Customers Deposits
Financial Liabilities
Other Liabilities
Preferred Equity
Minority Interest
Shareholders' Equity
= Total Liabilities

Projecting Regulatory Capital

Equity Book Value = Equity Book Value$_{(t-1)}$ + Net Income$_{(t)}$ – Dividend$_{(t)}$ – Intangible Assets
= Tangible Common Equity
– Common Equity Tier 1 Adjustments
= Common Equity Tier 1

Stress Testing Exercise: Main Assumptions

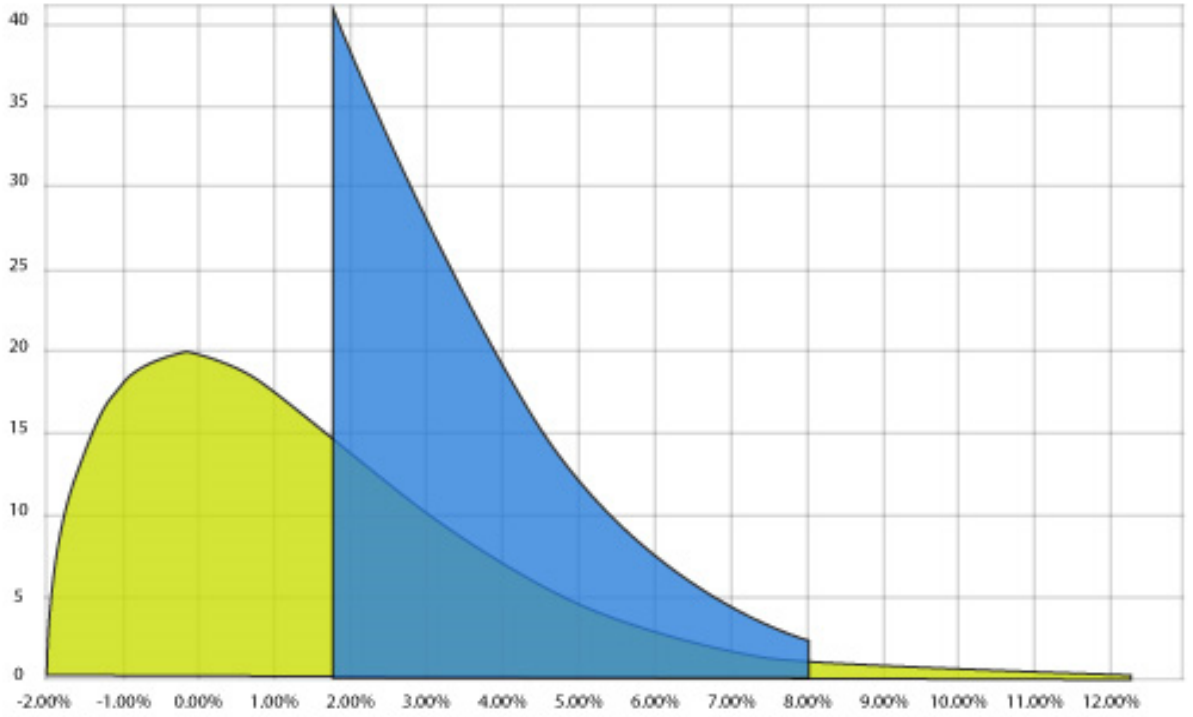
- The simulations were performed considering **fourteen stochastic variables**, covering all the main banks' risk factors. Stochastic variable modeling was done according to a standard set of rules applied uniformly to all the banks in the sample.
  - ⇒ **Credit risk**: we adopted the expected loss approach, through which yearly loan loss provisions are estimated as a function of three components: PD, LGD and EAD
  - ⇒ **Market risk**: modeled in through the item "trading and counterparty gains/losses", in which we included mark-to market losses, realized and unrealized losses on securities (AFS/HTM) and counterparty default losses
  - ⇒ **Operational risk**: this risk factor has been modeled directly making use of the corresponding regulatory requirement record reported by the banks (considered as maximum losses due to operational risk events).
- The severity has been scaled by properly setting the variability of the key risk factors, through **parameterization of the extreme values of the distribution functions** on the basis of the following data set:
  - ⇒ **Bank's track record** (latest five years).
  - ⇒ **Industry track record**, based on a peer group sample made up of 73 banks from different geographic areas comparable with the G-SIB banks.
  - ⇒ **Benchmark risk parameters** (PD and LGD) based on Hardy D. C. and Schmieder C., "Rules of Thumb for Bank Solvency Stress Testing", IMF Working Paper No. 13/232, 2013.
- For the most relevant stochastic variables we adopted **truncated distribution functions**, in order to concentrate the generation of random scenarios within the defined stress test range, restricting samples drawn from the distribution to values between a specified pair of percentiles.
- The **correlation coefficients** are based on historical cross-section empirical analysis, derived from 2007-2012 data, a period characterized by severe stress for the banking industry (Spearman Rank Correlation has been used as correlation measure). The remaining correlation coefficients have been set according to theoretical assumptions aimed at replicating interdependence relationships under stressed conditions.

Stress Testing Exercise: Stochastic Variables Modelling

		NATIVE DISTRIBUTION PARAMETER SETTING			TRUNCATED DISTRIBUTION PARAMETER SETTING	
STOCHASTIC VARIABLES	**DISTRIBUTION**	**MINIMUM**	**MEAN**	**MAXIMUM**	**TRUNCATION MIN**	**TRUNCATION MAX**
Interest Received on Earning Asset Forecast Method: *Interest Rate*	Beta (4, 4)	Stress[-] = LastHistValue - 2*Mean.Dev(Last 5y Company Data) Stress[+] = LastHistValue - 3*Mean.Dev(Last 5y Company Data)	☒	Stress[-] = LastHistValue + 2*Mean.Dev(Last 5y Company Data) Stress[+] = LastHistValue + 3*Mean.Dev(Last 5y Company Data)	☒	☒
Interest Paid on Interest-Bearing Liabilities Forecast Method: *Interest Rate*	Beta (4, 4)	Stress[-] = LastHistValue - 2*Mean.Dev(Last 5y Company Data) Stress[+] = LastHistValue - 3*Mean.Dev(Last 5y Company Data)	☒	Stress[-] = LastHistValue + 2*Mean.Dev(Last 5y Company Data) Stress[+] = LastHistValue + 3*Mean.Dev(Last 5y Company Data)	☒	☒
Net Commission Income Forecast Method: *Perc. Net Risk Assets*	Beta (4, 4)	Stress[-] = LastHistValue - 2*Mean.Dev(Last 5y Company Data) Stress[+] = LastHistValue - 3*Mean.Dev(Last 5y Company Data)	☒	Stress[-] = LastHistValue + 2*Mean.Dev(Last 5y Company Data) Stress[+] = LastHistValue + 3*Mean.Dev(Last 5y Company Data)	☒	☒
Net Financial and Trading Income Forecast Method: *Perc. Financial Assets*	Logistic	Percentile_1%(PeerGroup) = -4.26%	Mean(Last5y Company Data)	☒	Stress[-] = Mean - 2*Mean.Dev Stress[+] = Mean - 3*Mean.Dev *(Worst scenario)*	Max(Last 5y Company Data) *(Best scenario)*
Default Rate Forecast Method: *Perc. Performing Loans*	Weibull (1.5)	☒	Mean(Last5y Company Data)	Percentile_99% = 8.4%	Stress[-] = 0.7% Stress[+] = 1.7% *(Best scenario)*	Stress[-] = Mean + 4.3% Stress[+] = Mean + 6.7% *(Worst scenario)*
LGD (Loss Given Default) Forecast Method: *Perc. Defaulted Credit*	Beta (4, 4)	Stress[-] = 26% Stress[+] = 30%	☒	Stress[-] = 41% Stress[+] = 54%	☒	☒
NPL Payments Rate Forecast Method: *Perc. Non Performing Loans*	Beta (2, 6)	Min(PeerGroup Last 5y) = 5.1%	☒	Max(PeerGroup Last 5y) = 36.2%	☒	☒
NPL Charge Off Rate Forecast Method: *Perc. Non Performing Loans*	Beta (2, 6)	Min(PeerGroup Last 5y) = 6.7%	☒	Max(PeerGroup Last 5y) = 44.4%	☒	☒
Non-Interest Expense Forecast Method: *Perc. Earning Assets*	Beta (4, 4)	Mean - Mean.Dev(Last 5y Company Data)	LastHistValue	☒	☒	☒
Customers Deposits Forecast Method: *Growth Rate*	Beta (4, 4)	Growth Rate = -3%	☒	World GDP Growth Consensus Estimate	☒	☒
Performing Loans Forecast Method: *Growth Rate*	Beta (4, 4)	Growth Rate = -3%	☒	World GDP Growth Consensus Estimate	☒	☒
Financial Assets Forecast Method: *Growth Rate*	Logistic	Growth Rate = -2.13%	0.00%	☒	☒	☒
Other Non Operating Income (Losses) Forecast Method: *Value*	Beta (5, 1)	Max Loss as Economic Capital linked to Operational Risk	☒	0	Percentile_5%(Native Distribution) *(Only for Stress[-])*	☒

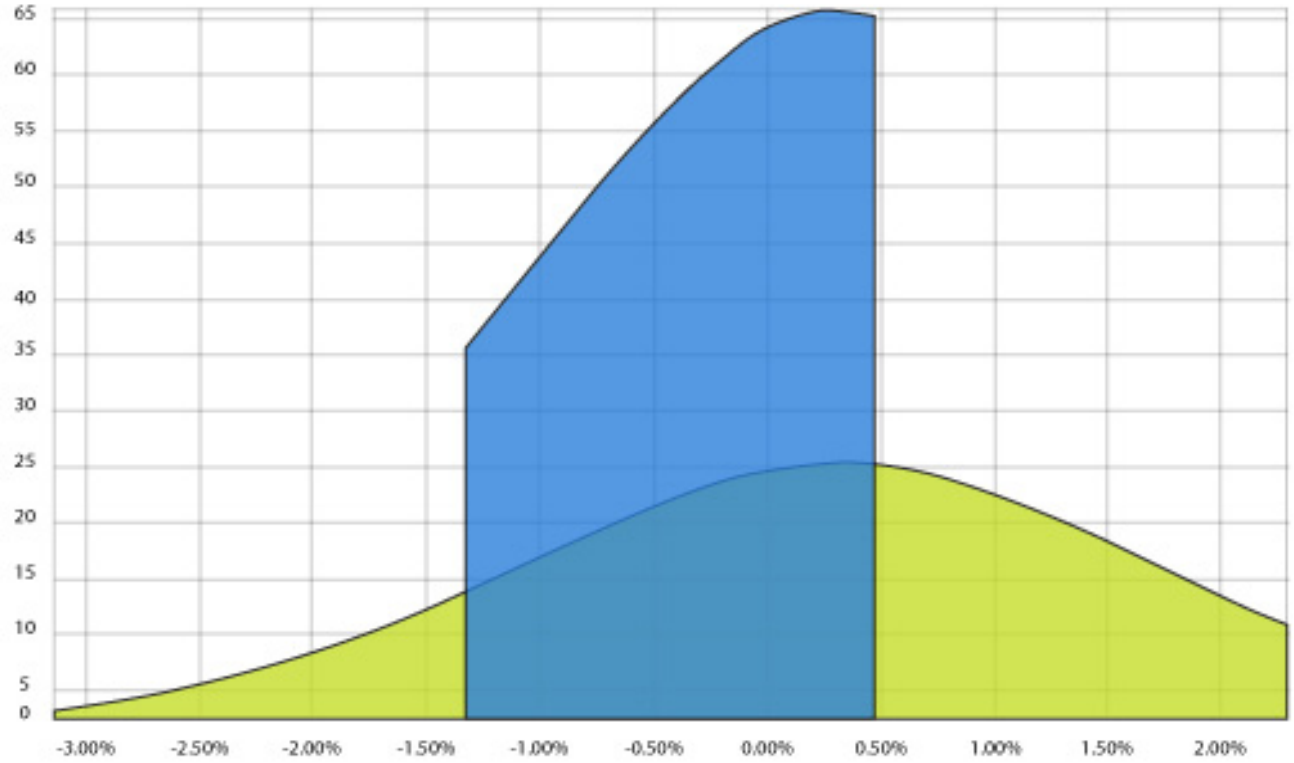
Loans Portfolio Default Rate in Stress[+] Scenario

NATIVE DISTRIBUTION – WEIBULL (1.5) (Baseline Scenarios)	
Mean	Last5y Company Data = 1.34%
Maximum (Percentile_99%)	Benchmark stressed parameters = 8.4%
TRUNCATED DISTRIBUTION (Stressed Scenarios)	
Minimum	1,7% (benchmark stressed parameters) ⇒ [Best Scenario]
Maximum	Native Mean (1.34%) + (8.4% - 1.7%) = 8,04% ⇒ [Worst Scenario]



Net Financial & Trading Income (Perc. Financial Assets) in Stress[+] Scenario

NATIVE DISTRIBUTION – WEIBULL (1.5) (Baseline Scenarios)	
Minimum (Percentile_1%)	Sector Peer Group = -4,26%
Mean	Mean(Last5y Company Data) = 0,31%
TRUNCATED DISTRIBUTION (Stressed Scenarios)	
Minimum	Native Mean (0.31%) – 3×M.Dev(Sector Peer Group) = -1,33% ⇒ [Worst Scenario]
Maximum	Max (Last 5y Company Data) = 0.48% ⇒ [Best Scenario]



Stress Testing Exercise: Results and Analysis

DISCLAIMER: The analyses carried out and the results presented here are exclusively technical in nature and intended for the sole purpose of exemplifying scientific research supporting the description of the stress testing analysis method proposed. They thus in no way constitute a judgment of the reliability, risk and value of the banks analyzed, nor a recommendation to acquire or cede investments in said banks' stocks. The authors accept no liability whatsoever for any direct or consequential loss arising from the use of this document or its contents. The information contained in this report, including any expression of opinion, has been obtained from or is based upon sources believed to be reliable, but is not guaranteed as to accuracy or completeness, although the authors consider it to be fair and not misleading..

- The stochastic simulation **stress test shows considerable differences in degree of financial fragility** among the banks in the sample (measured in terms of CET1 probability of breach).

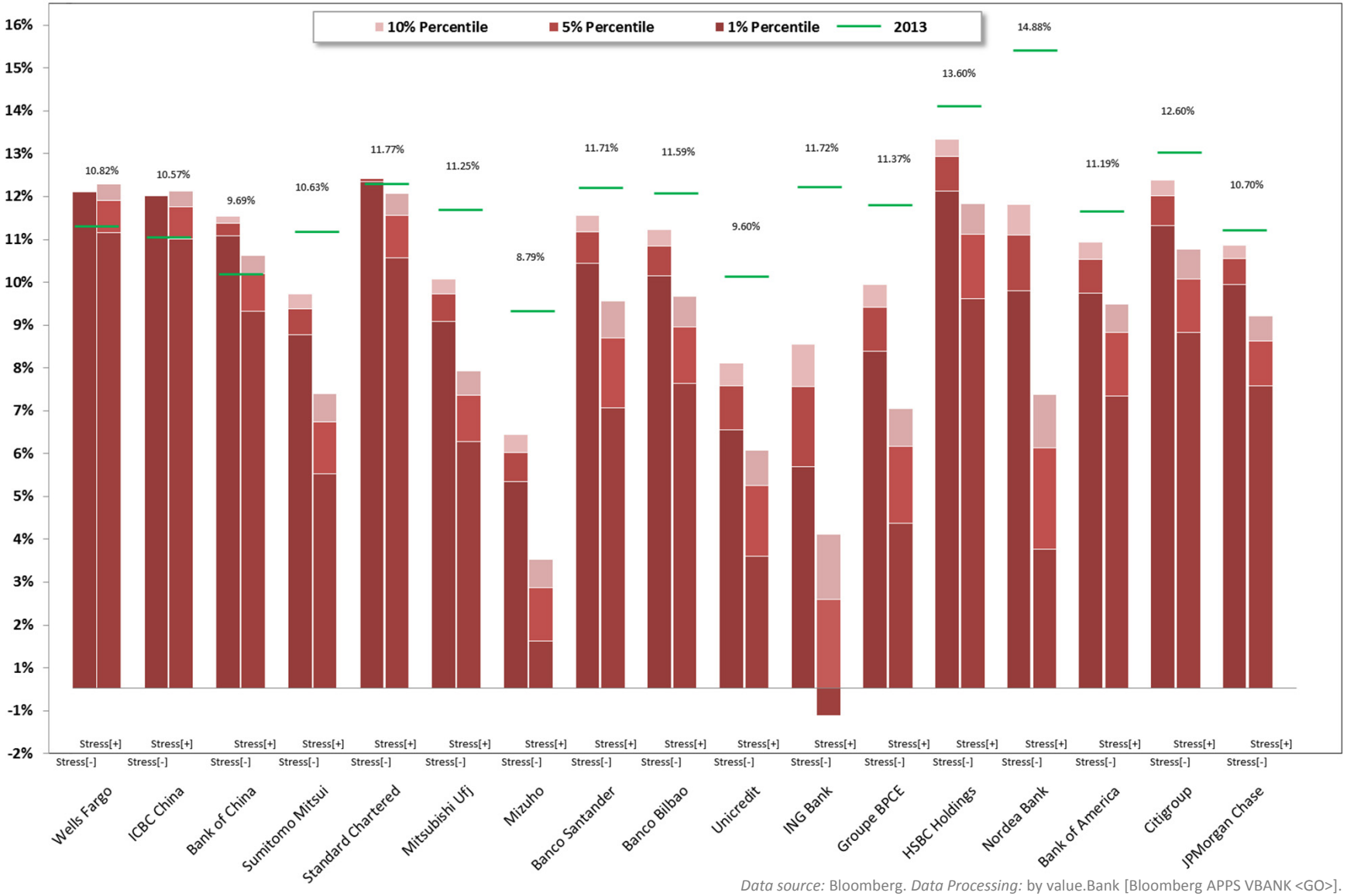
- **A sharp increase in infringement probabilities between Stress[-] and Stress[+] denotes relevant non-linear risk conditions** in the distribution tail.

- **IB and IBU banks show on average higher probabilities of infringement** than CB and CBU banks.

- Some of the **main elements that explain these differences** are:
  - ⇒ **Current capital base level**: banks with higher capital buffers in 2013 came through the stress test better. This explain part of the differences in resilience, but neither element is decisive in determining the bank's fragility ranking.
  - ⇒ **Interest income margin**: banks with the highest net interest income are the most resilient.
  - ⇒ **Leverage**: banks with the highest leverage are among the most vulnerable.
  - ⇒ **Market risk exposures**: banks characterized by significant financial asset portfolios (IB and IBU) tend to be more vulnerable to stressed conditions.

Stressed CET1 ratio 2015 vs. CET1 ratio 2013: CB & CBU ⇢

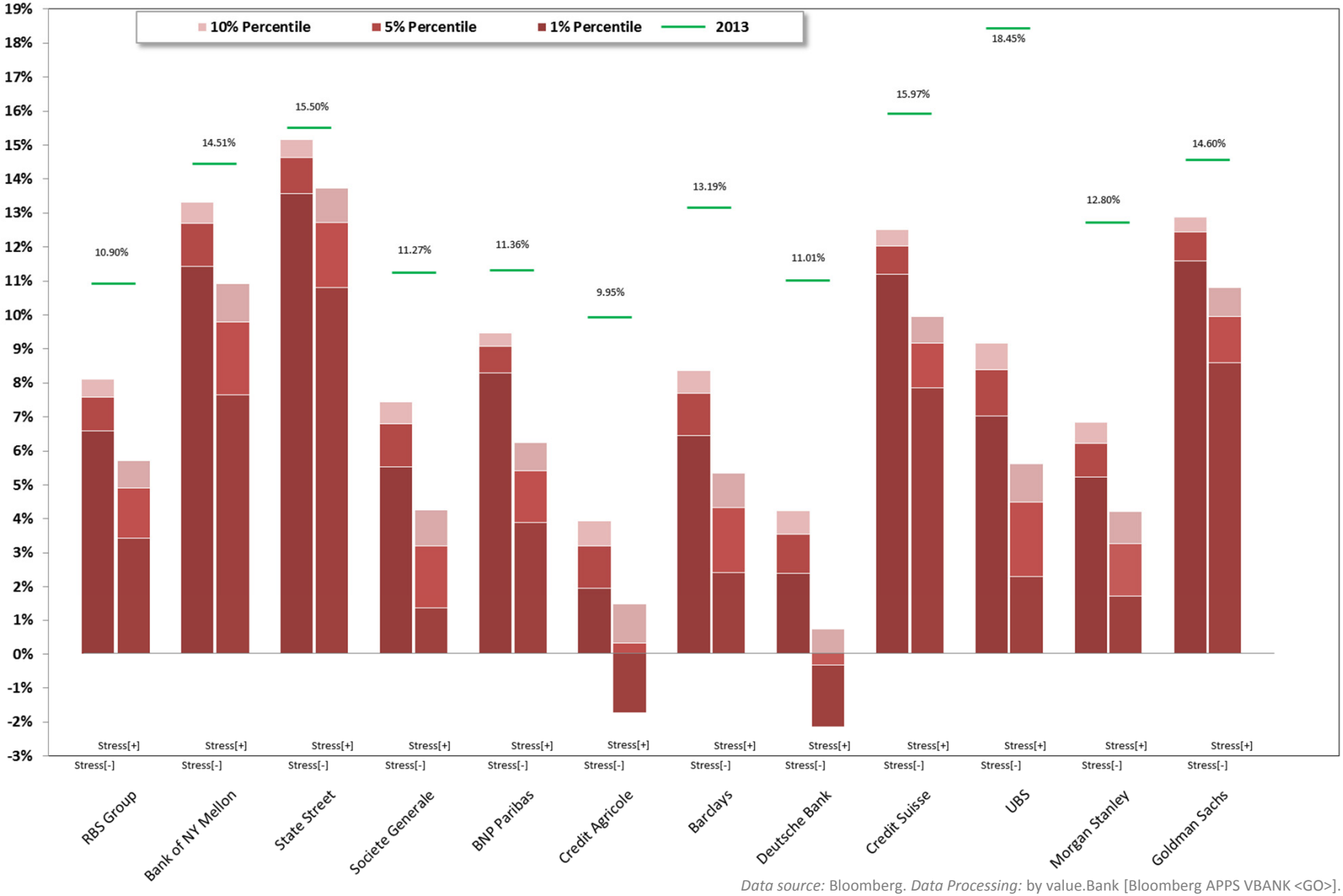
The graphs report CET1 ratios resulting from the stress test stochastic simulation performed for the group of **Commercial Banks (CB) & Commercial Banking-Oriented Universal Banks (CBU)**: histograms show first, fifth and tenth percentiles recorded; last historical (2013) CET1 ratios are indicated by a green dash, providing a reference point to understand the impact of the stress test; records are shown for 2015 and for both Stress[-] and Stress[+] simulations.



Data source: Bloomberg. *Data Processing:* by value.Bank [Bloomberg APPS VBANK <GO>].

(follows) Stressed CET1 ratio 2015 vs. CET1 ratio 2013: IB & IBU

The graphs report CET1 ratios resulting from the stress test stochastic simulation performed for the group of **Investment Banks (IB) & Investment Banking-Oriented Universal Banks (IBU)**: histograms show first, fifth and tenth percentiles recorded; last historical (2013) CET1 ratios are indicated by a green dash, providing a reference point to understand the impact of the stress test; records are shown for 2015 and for both Stress[-] and Stress[+] simulations.



Data source: Bloomberg. *Data Processing:* by value.Bank [Bloomberg APPS VBANK <GO>].

CET1 Ratio Probability of Breach: CB & CBU ⇢

			2015			2016		
			8%	7%	4.5%	8%	7%	4.5%
CB	WELLS FARGO & CO	Stress [-]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
		Stress [+]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
	ICBC CHINA	Stress [-]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
		Stress [+]	0.003%	0.000%	0.000%	0.005%	0.000%	0.000%
	BANK OF CHINA LTD-H	Stress [-]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
		Stress [+]	0.387%	0.017%	0.000%	0.693%	0.057%	0.000%
	SUMITOMO MITSUI FINANCIAL GR	Stress [-]	0.380%	0.003%	0.000%	3.007%	0.230%	0.000%
		Stress [+]	34.170%	14.253%	0.531%	62.480%	38.693%	4.911%
	STANDARD CHARTERED PLC	Stress [-]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
		Stress [+]	0.030%	0.003%	0.000%	0.070%	0.007%	0.000%
	MITSUBISHI UFJ FINANCIAL GRO	Stress [-]	0.133%	0.000%	0.000%	2.157%	0.143%	0.000%
		Stress [+]	23.307%	8.220%	0.108%	54.937%	31.373%	2.924%
	MIZUHO FINANCIAL GROUP INC	Stress [-]	78.507%	40.097%	0.364%	94.163%	71.603%	6.111%
		Stress [+]	98.143%	88.687%	31.540%	99.907%	98.570%	37.810%
CB	**AVERAGE**	**Stress [-]**	**11.289%**	**5.729%**	**0.052%**	**14.190%**	**10.282%**	**0.873%**
		Stress [+]	**22.291%**	**15.883%**	**4.597%**	**31.156%**	**24.100%**	**6.521%**
CBU	BANCO SANTANDER SA	Stress [-]	0.001%	0.000%	0.000%	0.030%	0.003%	0.000%
		Stress [+]	5.930%	2.143%	0.111%	13.953%	6.220%	0.621%
	BANCO BILBAO VIZCAYA ARGENTA	Stress [-]	0.007%	0.000%	0.000%	0.070%	0.030%	0.000%
		Stress [+]	4.147%	1.200%	0.014%	11.430%	4.463%	0.228%
	UNICREDIT SPA	Stress [-]	18.200%	4.803%	0.014%	29.103%	10.717%	0.231%
		Stress [+]	56.100%	33.820%	4.817%	74.923%	55.440%	15.593%
	ING BANK	Stress [-]	9.593%	4.817%	0.418%	21.293%	12.927%	2.831%
		Stress [+]	44.947%	35.157%	15.353%	65.713%	56.387%	34.243%
	GROUPE BPCE	Stress [-]	1.293%	0.193%	0.000%	4.747%	1.197%	0.011%
		Stress [+]	30.427%	16.660%	2.127%	55.407%	38.250%	10.047%
	HSBC HOLDINGS PLC	Stress [-]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
		Stress [+]	0.390%	0.073%	0.001%	1.583%	0.540%	0.021%
	NORDEA BANK AB	Stress [-]	0.137%	0.020%	0.000%	1.670%	0.513%	0.004%
		Stress [+]	20.130%	12.237%	2.740%	47.890%	35.917%	13.897%
	BANK OF AMERICA CORP	Stress [-]	0.013%	0.000%	0.000%	0.147%	0.027%	0.000%
		Stress [+]	5.207%	1.307%	0.014%	12.800%	5.130%	0.214%
	CITIGROUP INC	Stress [-]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
		Stress [+]	0.957%	0.223%	0.000%	4.460%	1.263%	0.058%
	JPMORGAN CHASE & CO	Stress [-]	0.000%	0.000%	0.000%	0.013%	0.000%	0.000%
		Stress [+]	6.600%	1.367%	0.004%	15.233%	4.990%	0.108%
CBU	**AVERAGE**	**Stress [-]**	**2.924%**	**0.983%**	**0.043%**	**5.707%**	**2.541%**	**0.308%**
		Stress [+]	**17.484%**	**10.419%**	**2.518%**	**30.339%**	**20.860%**	**7.503%**

(follows) CET1 Ratio Probability of Breach: IB & IBU

			2015			2016		
			8%	7%	4.5%	8%	7%	4.5%
IBU	ROYAL BANK OF SCOTLAND GROUP	Stress [-]	9.190%	2.097%	0.000%	25.333%	9.207%	0.221%
		Stress [+]	50.640%	29.887%	3.930%	78.973%	60.780%	17.940%
	BANK OF NEW YORK MELLON CORP	Stress [-]	0.000%	0.000%	0.000%	0.027%	0.002%	0.000%
		Stress [+]	1.680%	0.763%	0.044%	5.187%	2.943%	0.414%
	STATE STREET CORP	Stress [-]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
		Stress [+]	0.087%	0.020%	0.000%	0.360%	0.103%	0.010%
	SOCIETE GENERALE	Stress [-]	17.413%	6.417%	0.171%	40.103%	22.023%	2.091%
		Stress [+]	57.547%	42.110%	12.747%	81.560%	69.767%	35.550%
	BNP PARIBAS	Stress [-]	0.530%	0.010%	0.000%	4.993%	0.747%	0.000%
		Stress [+]	36.953%	20.817%	2.433%	66.530%	47.310%	12.403%
	CREDIT AGRICOLE SA	Stress [-]	75.850%	58.803%	15.513%	94.643%	86.070%	44.803%
		Stress [+]	84.243%	71.253%	40.117%	95.997%	90.037%	67.293%
	BARCLAYS PLC	Stress [-]	7.090%	2.180%	0.021%	19.620%	9.603%	0.781%
		Stress [+]	41.333%	27.860%	6.450%	68.997%	56.577%	19.760%
	DEUTSCHE BANK AG-REGISTERED	Stress [-]	72.957%	53.617%	12.283%	94.737%	86.570%	45.453%
		Stress [+]	91.453%	83.383%	51.967%	99.133%	97.647%	85.027%
	CREDIT SUISSE GROUP AG-REG	Stress [-]	0.000%	0.000%	0.000%	0.047%	0.000%	0.000%
		Stress [+]	1.750%	0.443%	0.008%	17.423%	8.713%	0.748%
	UBS AG-REG	Stress [-]	0.334%	0.967%	0.021%	37.660%	23.790%	4.004%
		Stress [+]	32.247%	21.960%	5.661%	79.517%	70.033%	40.961%
IBU	**AVERAGE**	**Stress [-]**	**18.336%**	**12.409%**	**2.801%**	**31.716%**	**23.801%**	**9.735%**
		Stress [+]	**39.793%**	**29.850%**	**12.336%**	**59.368%**	**50.391%**	**28.011%**
IB	MORGAN STANLEY	Stress [-]	25.993%	1.460%	0.141%	66.660%	22.410%	8.784%
		Stress [+]	59.273%	43.047%	13.188%	88.077%	78.363%	45.514%
	GOLDMAN SACHS GROUP INC	Stress [-]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
		Stress [+]	0.700%	0.097%	0.000%	4.943%	1.897%	0.054%
IB	**AVERAGE**	**Stress [-]**	**12.997%**	**0.730%**	**0.071%**	**33.330%**	**11.205%**	**4.392%**
		Stress [+]	**29.987%**	**21.572%**	**6.594%**	**46.510%**	**40.130%**	**22.784%**
AVERAGE ENTIRE SAMPLE		**Stress [-]**	**11.386%**	**4.963%**	**0.742%**	**21.236%**	**11.957%**	**3.827%**
		Stress [+]	**27.389%**	**19.431%**	**6.511%**	**41.843%**	**33.870%**	**16.205%**

Data source: Bloomberg. *Data Processing:* by value.Bank [Bloomberg APPS VBANK <GO>].

Stochastic Simulations Stress Test vs. FED & EBA/ECB Stress Test

- The most **appropriate way to compare the severity and the impact of the two stress tests is to look at the income statement gross and net losses rather than the CET1 drop**, because of potential differences in the way CET1 capital is calculated (phasing-in of Basel 3 rules and/or application of other rules on capital).

	STOCHASTIC SIMULATIONS VS. FED STRESS TEST				STOCHASTIC SIMULATIONS VS. EBA/ECB STRESS TEST		
	FED		STHOCHASTIC SIMULATION		EBA/ECB	STHOCHASTIC SIMULATION	
	Adverse Scenario	Severely Adverse Scenario	Stress[-]	Stress[+]	Adverse Scenario + AQR	Stress[-]	Stress[+]
» Gross Loss Rate on Net Risk Assets_2013	-2.31%	-2.75%	-1.09% (Per_95) -1.43% (Per_99)	-2.13% (Per_95) -2.62% (Per_99)	-2.04%	-1.99% (Per_95) -2.47% (Per_99)	-3.62% (Per_95) -4.38% (Per_99)
» Net Loss Rate on Net Risk Assets_2013	-0.44%	-1.43%	-0.32% (Per_95) -0.64% (Per_99)	-1.21% (Per_95) -1.69% (Per_99)	-0.33%	-1.23% (Per_95) -1.67% (Per_99)	-2.67% (Per_95) -3.46% (Per_99)

- Overall, the stochastic simulation stress test exercise provided results that were generally **in line with those obtained from the FED stress test**, albeit with some differences on a few banks.
- **Stress[-]** stochastic simulation has a **similar gross impact to EBA/ECB stress test**, while the **Stress[+]** simulation shows a **notably higher gross impact**. But **shifting from gross losses to net losses, the EBA/ECB stress test highlights a sharp decrease in its impact** (more than 80%), reducing the loss rates to very low levels.
- **Comparing the total cumulated gross loss rate on net risk assets of the two regulatory stress test**, we note that the FED exercise reports a gross loss rate of 2.75% in the severely adverse scenario, against 2.04% in the EBA/ECB stress test, notwithstanding the fact that the FED stress test covers only two years of adverse scenario while EBA/ECB covers three years plus AQR and join-up effects. In terms of total cumulated net losses, the **FED exercise reports a 1.46% net loss rate**, **against 0.33% in the EBA/ECB stress test**, about one-fourth of the FEDnet loss rate.

2015 Stochastic Simulation vs. 2015 FED Stress Test ⇢

Cumulative Losses 2014-2016 (two years of adverse scenario)

Data source: Bloomberg, Federal Reserve.
Data Processing: by value.Bank [Bloomberg APPS VBANK <GO>].

		DODD-FRANK ACT STRESS TEST (2015)		STHOCHASTIC SIMULATION (2015)			
		Adverse Scenario	Severely Adverse Scenario	Stress[-]		Stress[+]	
				95% Conf.	99% Conf.	95% Conf.	99% Conf.
Bank of America	Cumulative Gross Losses from Credit, Market & Other	-71,000	-82,200	-33,012	-42,572	-63,449	-78,301
	Gross Loss Rate on Net Risk Assets 2013	*-2.45%*	*-2.83%*	*-1.14%*	*-1.47%*	*-2.19%*	*-2.70%*
	Economic Capital (Cumulative Net Total Losses)	-14,800	-50,900	-6,965	-23,251	-40,137	-55,808
	Net Loss Rate on Net Risk Assets 2013	*-0.51%*	*-1.76%*	*-0.24%*	*-0.80%*	*-1.38%*	*-1.92%*
	Risk Weighted Assets	1,371,700	1,319,500	1,351,834	1,363,188	1,352,483	1,363,616
	Common Equity Tier 1 Ratio	8.70%	5.90%	10.04%	9.25%	8.03%	6.60%
Bank of New York Mellon	Cumulative Gross Losses from Credit, Market & Other	-5,700	-2,500	-3,118	-3,954	-6,394	-7,826
	Gross Loss Rate on Net Risk Assets 2013	*-1.60%*	*-0.70%*	*-0.88%*	*-1.11%*	*-1.80%*	*-2.20%*
	Economic Capital (Cumulative Net Total Losses)	5,600	5,900	-992	-2,637	-5,040	-7,587
	Net Loss Rate on Net Risk Assets 2013	*1.58%*	*1.66%*	*-0.28%*	*-0.74%*	*-1.42%*	*-2.13%*
	Risk Weighted Assets	122,800	118,000	123,923	125,382	123,629	124,994
	Common Equity Tier 1 Ratio	13.60%	13.10%	12.70%	11.44%	9.45%	7.38%
Citigroup	Cumulative Gross Losses from Credit, Market & Other	-68,700	-78,900	-29,853	-48,439	-67,461	-81,457
	Gross Loss Rate on Net Risk Assets 2013	*-2.60%*	*-2.98%*	*-1.13%*	*-1.83%*	*-2.55%*	*-3.08%*
	Economic Capital (Cumulative Net Total Losses)	-22,700	-46,300	-7,340	-16,227	-34,635	-48,506
	Net Loss Rate on Net Risk Assets 2013	*-0.86%*	*-1.75%*	*-0.28%*	*-0.61%*	*-1.31%*	*-1.83%*
	Risk Weighted Assets	1,134,100	1,100,200	1,143,720	1,154,272	1,139,551	1,149,750
	Common Equity Tier 1 Ratio	9.70%	7.20%	11.52%	10.83%	9.24%	8.04%
Goldman Sachs	Cumulative Gross Losses from Credit, Market & Other	-20,100	-27,900	-2,731	-3,132	-7,634	-13,585
	Gross Loss Rate on Net Risk Assets 2013	*-1.44%*	*-2.00%*	*-0.20%*	*-0.22%*	*-0.55%*	*-0.98%*
	Economic Capital (Cumulative Net Total Losses)	-15,400	-23,000	-5,458	-9,490	-18,792	-24,816
	Net Loss Rate on Net Risk Assets 2013	*-1.11%*	*-1.65%*	*-0.39%*	*-0.68%*	*-1.35%*	*-1.78%*
	Risk Weighted Assets	456,400	456,100	476,262	481,856	475,325	481,338
	Common Equity Tier 1 Ratio	9.60%	6.90%	12.44%	11.58%	9.62%	8.30%
JPMorgan Chase	Cumulative Gross Losses from Credit, Market & Other	-72,500	-93,000	-45,937	-55,868	-82,685	-98,744
	Gross Loss Rate on Net Risk Assets 2013	*-2.03%*	*-2.60%*	*-1.28%*	*-1.56%*	*-2.31%*	*-2.76%*
	Economic Capital (Cumulative Net Total Losses)	-4,300	-44,200	-1,785	-10,988	-35,243	-49,772
	Net Loss Rate on Net Risk Assets 2013	*-0.12%*	*-1.24%*	*-0.05%*	*-0.31%*	*-0.99%*	*-1.39%*
	Risk Weighted Assets	1,499,400	1,457,800	1,490,633	1,505,541	1,485,583	1,501,013
	Common Equity Tier 1 Ratio	8.70%	6.30%	10.06%	9.45%	7.84%	6.83%

(follows) 2015 Stochastic Simulation vs. 2015 FED Stress Test

Cumulative Losses 2014-2016 (two years of adverse scenario)

Data source: Bloomberg, Federal Reserve.
Data Processing: by value.Bank [Bloomberg APPS VBANK <GO>].

		DODD-FRANK ACT STRESS TEST (2015)		STHOCHASTIC SIMULATION (2015)			
		Adverse Scenario	Severely Adverse Scenario	Stress[-]		Stress[+]	
				95% Conf.	99% Conf.	95% Conf.	99% Conf.
Morgan Stanley	Cumulative Gross Losses from Credit, Market & Other	-14,300	-17,800	-6,735	-10,065	-19,029	-24,679
	Gross Loss Rate on Net Risk Assets 2013	*-0.96%*	*-1.19%*	*-0.45%*	*-0.67%*	*-1.27%*	*-1.65%*
	Economic Capital (Cumulative Net Total Losses)	-12,700	-17,500	-22,872	-27,031	-34,974	-40,950
	Net Loss Rate on Net Risk Assets 2013	*-0.85%*	*-1.17%*	*-1.53%*	*-1.81%*	*-2.34%*	*-2.74%*
	Risk Weighted Assets	410,300	409,800	448,753	455,279	449,188	455,303
	Common Equity Tier 1 Ratio	8.90%	6.10%	6.23%	5.24%	3.14%	1.64%
State Street	Cumulative Gross Losses from Credit, Market & Other	-6,500	-4,700	-3,274	-3,711	-4,868	-5,599
	Gross Loss Rate on Net Risk Assets 2013	*-2.86%*	*-2.06%*	*-1.44%*	*-1.63%*	*-2.14%*	*-2.46%*
	Economic Capital (Cumulative Net Total Losses)	1,000	100	0	-821	-1,932	-3,595
	Net Loss Rate on Net Risk Assets 2013	*0.44%*	*0.04%*	*0.00%*	*-0.36%*	*-0.85%*	*-1.58%*
	Risk Weighted Assets	86,000	83,000	87,032	87,963	86,898	87,849
	Common Equity Tier 1 Ratio	13.90%	13.30%	14.63%	13.57%	12.29%	10.45%
Wells Fargo	Cumulative Gross Losses from Credit, Market & Other	-67,500	-81,800	-29,449	-34,694	-49,788	-60,490
	Gross Loss Rate on Net Risk Assets 2013	*-4.35%*	*-5.27%*	*-1.90%*	*-2.23%*	*-3.21%*	*-3.90%*
	Economic Capital (Cumulative Net Total Losses)	420	-31,100	0	0	0	-7,718
	Net Loss Rate on Net Risk Assets 2013	*0.03%*	*-2.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.50%*
	Risk Weighted Assets	1,199,300	1,161,600	1,156,657	1,164,479	1,148,301	1,156,019
	Common Equity Tier 1 Ratio	10.00%	8.20%	11.61%	11.61%	11.02%	10.28%
TOTAL	**Cumulative Gross Losses from Credit, Market & Other**	**-326,300**	**-388,800**	**-154,109**	**-202,435**	**-301,308**	**-370,681**
	Gross Loss Rate on Net Risk Assets 2013	***-2.31%***	***-2.75%***	***-1.09%***	***-1.43%***	***-2.13%***	***-2.62%***
	Median(Gross Loss Rate on Net Risk Assets 2013)	***-2.24%***	***-2.33%***	***-1.13%***	***-1.52%***	***-2.16%***	***-2.58%***
	Economic Capital (Cumulative Net Total Losses)	**-62,880**	**-207,000**	**-45,412**	**-90,445**	**-170,753**	**-238,752**
	Net Loss Rate on Net Risk Assets 2013	***-0.44%***	***-1.46%***	***-0.32%***	***-0.64%***	***-1.21%***	***-1.69%***
	Median(Net Loss Rate on Net Risk Assets 2013)	***-0.32%***	***-1.44%***	***-0.26%***	***-0.65%***	***-1.33%***	***-1.81%***
	Median(CET1 Ratio)	**9.65%**	**7.05%**	**11.61%**	**11.21%**	**9.35%**	**7.71%**

2016 Stochastic Simulation vs. 2016 EBA/ECB Stress Test ⇢

Cumulative Losses 2014-2016 (three years of adverse scenario)

Data source: Bloomberg, EBA and ECB.
Data Processing: by value.Bank [Bloomberg APPS VBANK <GO>].

		EU-WIDE STRESS TEST	STHOCHASTIC SIMULATION (2016)			
		Advers Scenario + AQR (2016)	Stress[-]		Stress[+]	
			95% Conf.	99% Conf.	95% Conf.	99% Conf.
Banco Bilbao	Cumulative Losses from Credit, Market & Other	-19,660	-13,643	-16,240	-22,737	-28,099
	Gross Loss Rate on Net Risk Assets 2013	*-3.42%*	*-2.37%*	*-2.82%*	*-3.95%*	*-4.89%*
	Economic Capital (Cumulative Net Total Losses)	1,719	-5,066	-8,177	-14,885	-19,795
	Net Loss Rate on Net Risk Assets 2013	*0.30%*	*-0.88%*	*-1.42%*	*-2.59%*	*-3.44%*
	Risk Weighted Assets	381,341	329,150	332,470	325,608	328,855
	CET1 ratio	9.00%	10.09%	9.20%	7.20%	5.67%
Banco Santander	Cumulative Losses from Credit, Market & Other	-41,131	-28,945	-35,385	-49,998	-60,728
	Gross Loss Rate on Net Risk Assets 2013	*-3.78%*	*-2.66%*	*-3.25%*	*-4.59%*	*-5.57%*
	Economic Capital (Cumulative Net Total Losses)	-414	-922	-6,672	-21,332	-31,124
	Net Loss Rate on Net Risk Assets 2013	*-0.04%*	*-0.08%*	*-0.61%*	*-1.96%*	*-2.86%*
	Risk Weighted Assets	540,248	558,446	568,305	551,426	561,542
	CET1 ratio	8.90%	10.30%	9.47%	6.88%	5.06%
BNP Paribas	Cumulative Losses from Credit, Market & Other	-33,890	-28,253	-37,776	-63,232	-76,687
	Gross Loss Rate on Net Risk Assets 2013	*-1.90%*	*-1.58%*	*-2.11%*	*-3.54%*	*-4.29%*
	Economic Capital (Cumulative Net Total Losses)	-10,427	-12,973	-18,875	-43,132	-54,012
	Net Loss Rate on Net Risk Assets 2013	*-0.58%*	*-0.73%*	*-1.06%*	*-2.41%*	*-3.02%*
	Risk Weighted Assets	684,617	644,980	652,439	643,524	651,180
	Common Equity Tier 1 ratio	8.10%	8.01%	7.13%	3.30%	1.57%
Credit Agricole (*)	Cumulative Losses from Credit, Market & Other	-28,810	-27,927	-34,075	-48,168	-58,080
	Gross Loss Rate on Net Risk Assets 2013	*-1.92%*	*-1.86%*	*-2.27%*	*-3.20%*	*-3.86%*
	Economic Capital (Cumulative Net Total Losses)	-7,354	-25,269	-30,975	-38,416	-46,844
	Net Loss Rate on Net Risk Assets 2013	*-0.49%*	*-1.68%*	*-2.06%*	*-2.55%*	*-3.11%*
	Risk Weighted Assets	621,404	426,723	434,291	424,345	431,813
	Common Equity Tier 1 ratio	8.80%	1.22%	-0.19%	-2.02%	-4.12%
Deutsche Bank	Cumulative Losses from Credit, Market & Other	-15,520	-27,078	-33,754	-49,144	-59,613
	Gross Loss Rate on Net Risk Assets 2013	*-0.97%*	*-1.70%*	*-2.11%*	*-3.08%*	*-3.73%*
	Economic Capital (Cumulative Net Total Losses)	3,193	-33,170	-39,341	-54,589	-63,576
	Net Loss Rate on Net Risk Assets 2013	*0.20%*	*-2.08%*	*-2.46%*	*-3.42%*	*-3.98%*
	Risk Weighted Assets	478,072	460,779	467,678	460,074	467,706
	Common Equity Tier 1 ratio	8.90%	1.22%	-0.18%	-3.64%	-5.71%

(*) The stochastic simulations refer to Credit Agricole S.A. The EBA/ECB analysis is conducted on Credit Agricole Group.

Cumulative Losses 2014-2016 (three years of adverse scenario)

Data source: Bloomberg, EBA and ECB.
Data Processing: by value.Bank [Bloomberg APPS VBANK <GO>].

		EU-WIDE STRESS TEST	STHOCHASTIC SIMULATION (2016)			
		Advers Scenario + AQR (2016)	Stress[-]		Stress[+]	
			95% Conf.	99% Conf.	95% Conf.	99% Conf.
Groupe BPCE	Cumulative Losses from Credit, Market & Other	-18,817	-28,488	-33,901	-48,333	-56,608
	Gross Loss Rate on Net Risk Assets 2013	*-1.68%*	*-2.54%*	*-3.02%*	*-4.31%*	*-5.04%*
	Economic Capital (Cumulative Net Total Losses)	-8,028	-9,285	-14,054	-27,928	-35,414
	Net Loss Rate on Net Risk Assets 2013	*-0.72%*	*-0.83%*	*-1.25%*	*-2.49%*	*-3.16%*
	Risk Weighted Assets	458,147	419,778	425,063	414,274	419,865
	Common Equity Tier 1 ratio	7.00%	8.07%	6.89%	3.54%	1.67%
ING Bank	Cumulative Losses from Credit, Market & Other	-13,561	-21,583	-25,561	-38,347	-45,042
	Gross Loss Rate on Net Risk Assets 2013	*-1.26%*	*-2.00%*	*-2.37%*	*-3.55%*	*-4.17%*
	Economic Capital (Cumulative Net Total Losses)	-361	-16,561	-23,613	-27,739	-47,562
	Net Loss Rate on Net Risk Assets 2013	*-0.03%*	*-1.53%*	*-2.19%*	*-2.57%*	*-4.40%*
	Risk Weighted Assets	344,106	319,374	323,436	314,509	318,763
	Common Equity Tier 1 ratio	8.70%	5.36%	3.08%	-1.53%	-4.81%
Societe Generale	Cumulative Losses from Credit, Market & Other	-20,316	-19,659	-25,302	-37,639	-46,137
	Gross Loss Rate on Net Risk Assets 2013	*-1.65%*	*-1.60%*	*-2.06%*	*-3.06%*	*-3.76%*
	Economic Capital (Cumulative Net Total Losses)	-5,333	-15,220	-20,571	-32,866	-40,550
	Net Loss Rate on Net Risk Assets 2013	*-0.43%*	*-1.24%*	*-1.67%*	*-2.67%*	*-3.30%*
	Risk Weighted Assets	377,059	398,276	403,831	397,298	402,800
	Common Equity Tier 1 ratio	8.10%	5.29%	3.91%	0.71%	-1.31%
Unicredit	Cumulative Losses from Credit, Market & Other	-29,151	-20,095	-25,294	-34,582	-42,910
	Gross Loss Rate on Net Risk Assets 2013	*-3.47%*	*-2.39%*	*-3.01%*	*-4.11%*	*-5.11%*
	Economic Capital (Cumulative Net Total Losses)	-8,634	-14,188	-18,975	-28,358	-35,610
	Net Loss Rate on Net Risk Assets 2013	*-1.03%*	*-1.69%*	*-2.26%*	*-3.37%*	*-4.24%*
	Risk Weighted Assets	433,431	425,190	429,623	420,727	425,457
	Common Equity Tier 1 ratio	6.80%	6.45%	5.33%	3.05%	1.27%
TOTAL	**Cumulative Losses from Credit, Market & Other**	**-220,856**	**-215,671**	**-267,288**	**-392,180**	**-473,904**
	Gross Loss Rate on Net Risk Assets 2013	***-2.04%***	***-1.99%***	***-2.47%***	***-3.62%***	***-4.38%***
	Median(Gross Loss Rate on Net Risk Assets 2013)	***-1.90%***	***-2.00%***	***-2.37%***	***-3.55%***	***-4.29%***
	Economic Capital (Cumulative Net Total Losses)	**-35,639**	**-132,654**	**-181,253**	**-289,245**	**-374,487**
	Net Loss Rate on Net Risk Assets 2013	***-0.33%***	***-1.23%***	***-1.67%***	***-2.67%***	***-3.46%***
	Median(Net Loss Rate on Net Risk Assets 2013)	***-0.43%***	***-1.24%***	***-1.67%***	***-2.57%***	***-3.30%***
	Median(CET1 Ratio)	**8.40%**	**6.45%**	**5.33%**	**3.05%**	**1.27%**

Relationship Between Stress Test Risk and Market Valuation

The analysis **relates the bank fragility** estimated in our stress test analyses and in the analyses conducted by the EBA/ECB and by the FED in 2014, with **respect to the current market valuation** (October 2015), measured using a multiple on tangible assets. We should expect a **negative relation between the riskiness assessed in the 2014 stress test and the subsequent market value dynamic**.

STOCHASTIC SIMULATION G-SIB BANKS

	2015 CET1 Ratio Probability of Breach (7%)	Market Cap/ Tangible Assets
Wells Fargo	0.00%	16.15%
ICBC China	0.00%	7.20%
Standard Chartered	0.00%	4.14%
Bank of China	0.02%	6.67%
State Street	0.02%	11.39%
HSBC Holdings	0.07%	6.04%
Goldman Sachs	0.10%	9.87%
Citigroup	0.22%	8.97%
Credit Suisse	0.44%	4.73%
Bank of NY Mellon	0.76%	13.03%
Banco Bilbao	1.20%	7.48%
Bank of America	1.31%	8.29%
JPMorgan Chase	1.37%	9.98%
Banco Santander	2.14%	5.66%
Mitsubishi Ufj	8.22%	3.89%
Nordea Bank	12.24%	6.16%
Sumitomo Mitsui	14.25%	3.66%
BNP Paribas	20.82%	3.27%
UBS	21.96%	8.20%
Barclays	27.86%	3.56%
RBS Group	29.89%	3.96%
Unicredit	33.82%	4.15%
Societe Generale	42.11%	2.58%
Morgan Stanley	43.05%	7.79%
Credit Agricole	71.25%	2.03%
Deutsche Bank	83.38%	2.27%
Mizuho	88.69%	3.20%
SPEARMAN RANK CORRELATION		**-0.65**

Low Risk / High Risk

EURO-AREA G-SIB BANKS

STOCHASTIC SIMULATION

	2015 CET1 Ratio Probability of Breach (7%)	Market Cap/ Tangible Assets
Banco Bilbao	1.20%	7.48%
Banco Santander	2.14%	5.66%
BNP Paribas	20.82%	3.27%
Unicredit	33.82%	4.15%
Societe Generale	42.11%	2.58%
Credit Agricole	71.25%	2.27%
Deutsche Bank	83.38%	2.03%
SPEARMAN RANK CORRELATION		**-0.92**

Low Risk / High Risk

EBA/ECB STRESS TEST

	Decrease in CET1 Ratio from 2013 to 2016	Market Cap/ Tangible Assets
Credit Agricole	1.15%	2.27%
Deutsche Bank	2.11%	2.03%
Banco Bilbao	2.59%	7.48%
Unicredit	2.80%	4.15%
Banco Santander	2.81%	5.66%
Societe Generale	3.17%	2.58%
BNP Paribas	3.26%	3.27%
SPEARMAN RANK CORRELATION		**0.36**

Low Risk / High Risk

US G-SIB BANKS

STOCHASTIC SIMULATION

	2015 CET1 Ratio Probability of Breach (7%)	Market Cap/ Tangible Assets
Wells Fargo	0.00%	16.15%
State Street	0.02%	11.39%
Goldman Sachs	0.10%	9.87%
Citigroup	0.22%	8.97%
Bank of NY Mellon	0.76%	13.03%
Bank of America	1.31%	8.29%
JPMorgan Chase	1.37%	9.98%
Morgan Stanley	43.05%	7.79%
SPEARMAN RANK CORRELATION		**-0.67**

Low Risk / High Risk

FED STRESS TEST

	Decrease in CET1 Ratio from 2013 to 2015	Market Cap/ Tangible Assets
Bank of NY Mellon	1.00%	13.03%
State Street	2.20%	11.39%
Wells Fargo	2.40%	16.15%
JPMorgan Chase	4.20%	9.98%
Bank of America	5.20%	8.29%
Citigroup	5.50%	8.97%
Morgan Stanley	6.50%	7.79%
Goldman Sachs	7.30%	9.87%
SPEARMAN RANK CORRELATION		**-0.76**

Low Risk / High Risk

Backtesting Comparative Analysis (Lehman, Merrill Lynch, Northern Rock)

- *The event of default (tangible common equity ≤ 0) has been defined in a very narrow way; since in the real world a bank would default long before reaching a zero capital level, a simulation run with a broader definition of default would have highlighted much higher PDs*
- *For all banks considered, PDs measured by other models publicly available at the time showed very low values either in 2007 or 2008 analysis*
- *PDs implied in CDS in 2007 did not catch the high risk of default that occurred the following year; in 2008 they increased significantly (but at that time all banks experienced a generalized relevant increase in CDS)*
- *PDs estimated through the simulative approach show a high level of default risk for all banks as early as the 2007 analysis, in particular with reference to 2 and 3 yrs PDs, with a relevant increase in the 2008 analysis*

31-Jan-07		STHOCHASTIC SIMULATION	MERTON MODEL	CREDIT DEFAULT SWAP	RATING	
(about 2 years before default)		Tangible Common Equity Default Frequency (*)	Moody's KMV PD	Implied PD	S&P Implied PD	Moody's Implied PD
LEHMAN BROTHERS	1-Yr	1.08%	0.03%	0.12%	0.06%	0.08%
	2-Yr	9.93%	N/A	0.33%	0.11%	0.25%
	3-Yr	22.08%	N/A	0.67%	0.24%	0.55%
MERRILL LYNCH	1-Yr	2.24%	0.01%	0.09%	0.03%	0.05%
	2-Yr	7.68%	N/A	0.27%	0.10%	0.15%
	3-Yr	14.29%	N/A	0.52%	0.20%	0.22%
NORTHERN ROCK	1-Yr	3.50%	N/A	0.77%	0.03%	N/A
	2-Yr	16.84%	N/A	1.74%	0.10%	N/A
	3-Yr	31.09%	N/A	3.01%	0.20%	N/A

31-Jan-08		STHOCHASTIC SIMULATION	MERTON MODEL	CREDIT DEFAULT SWAP	RATING	
(year of default)		Tangible Common Equity Default Frequency (*)	Moody's KMV PD	Implied PD	S&P Implied PD	Moody's Implied PD
LEHMAN BROTHERS	1-Yr	2.09%	0.07%	3.08%	0.06%	0.08%
	2-Yr	10.35%	N/A	5.85%	0.11%	0.25%
	3-Yr	20.26%	N/A	8.33%	0.24%	0.55%
MERRILL LYNCH	1-Yr	6.62%	0.07%	3.23%	0.03%	0.05%
	2-Yr	22.70%	N/A	5.89%	0.10%	0.15%
	3-Yr	39.31%	N/A	7.99%	0.20%	0.22%
NORTHERN ROCK	1-Yr	34.86%	N/A	6.89%	0.03%	N/A
	2-Yr	74.10%	N/A	12.63%	0.10%	N/A
	3-Yr	92.25%	N/A	17.10%	0.20%	N/A

(*) *Tangible Common Equity ≤ 0*

Lehman Brothers defaulted on 15-9-2008 (Chapter 11); **Merrill Lynch** was saved through bail out by Bank of America on 14 9-2008 (completed in January 2009); **Northern Rock** has been bailed out by the British government on 22-2-2008 (the bank has been taken over by Virgin Money in 2012).

Source: Montesi G., Nicastro P. and Papiro G., *Stress Testing: A Stochastic Simulation Model and a Comparison with 2014 EBA/ECB Exercise*, Bancaria, No. 2, 2015.

To predict banks' financial fragility we need not try to forecast specific exceptional adverse events and calculate the corresponding losses, nor is it necessary to adopt an overly complex and analytically detailed modeling apparatus which, in the attempt to ensure a presumed "high fidelity" in terms of calculation accuracy, ends up disregarding some of the most relevant phenomena for assessing a bank's resilience.

STOCHASTIC SIMULATION APPROACH ADVANTAGES

- It is significantly **less complex and expensive in terms of time and implementation effort** than current stress test practices; the exercise presented shows how even with a very simplified and easy-to-apply modeling, results can be obtained that in our opinion are significant and useful.
- The **flexibility** of the approach allows for different levels of complexity/analyticity, depending on data set availability and the purpose of the analysis.
- The **ERM model framework** allows for sound management, even in extreme tail conditions, of risk integration and inter-risk diversification and non-linear and path-dependent phenomena
- This makes it well suited both for internal bank use in RAF and ICAAP processes, and primarily for supervisory authorities in SREP and supervisory stress test processes, **allowing supervisors to perform stress test exercises themselves**, so as to speed up and simplify the process, ensuring an effective comparability of results across institutions.

- **The most relevant advantage** of the simulative methodology we propose is that by considering the impacts related to an extremely high number of potential different adverse future scenarios, **it generates results expressed in probabilistic terms**, that is the most direct and appropriate way to assess banks' minimum capital endowment.
- This leads the way to a different, more advanced **bank-specific approach for setting minimum regulatory capital requirements**:
  (1) Supervisors, according to their systemic risk appetite, set a **common level of confidence** (probability threshold equal for all banks) **in bank resiliency** (e.g. 99.5% of capital losses absorption capacity) and severity of stress test.
  (2) Through the stochastic simulation framework, applied with a common standard set of rules to all banks, **supervisors generate for each bank the specific economic capital distribution** function (net cumulated losses)
  (3) Supervisors can then **pick up the economic capital percentile** of the distribution function corresponding to the common level of confidence set that quantifies the regulatory bank's specific minimum capital endowment.
  (4) Once the capital requirement has been set, **it could also be expressed in terms of a ratio,** in order to provide a requirement in relative terms between one supervisory assessment and another; and in our opinion in this regard it would be better to consider an un-weighted risk base (as for the leverage ratio) rather than a RWA-based ratio.
- With this approach **under a common risk appetite level**, the regulatory minimum capital requirements would be established on **a bank-specific basis according to its risk profile and financial fragility degree**.