Econometric Applications in Bank Stress Testing

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The views expressed in this paper are those of the author and not necessarily those of Bank of Greece.

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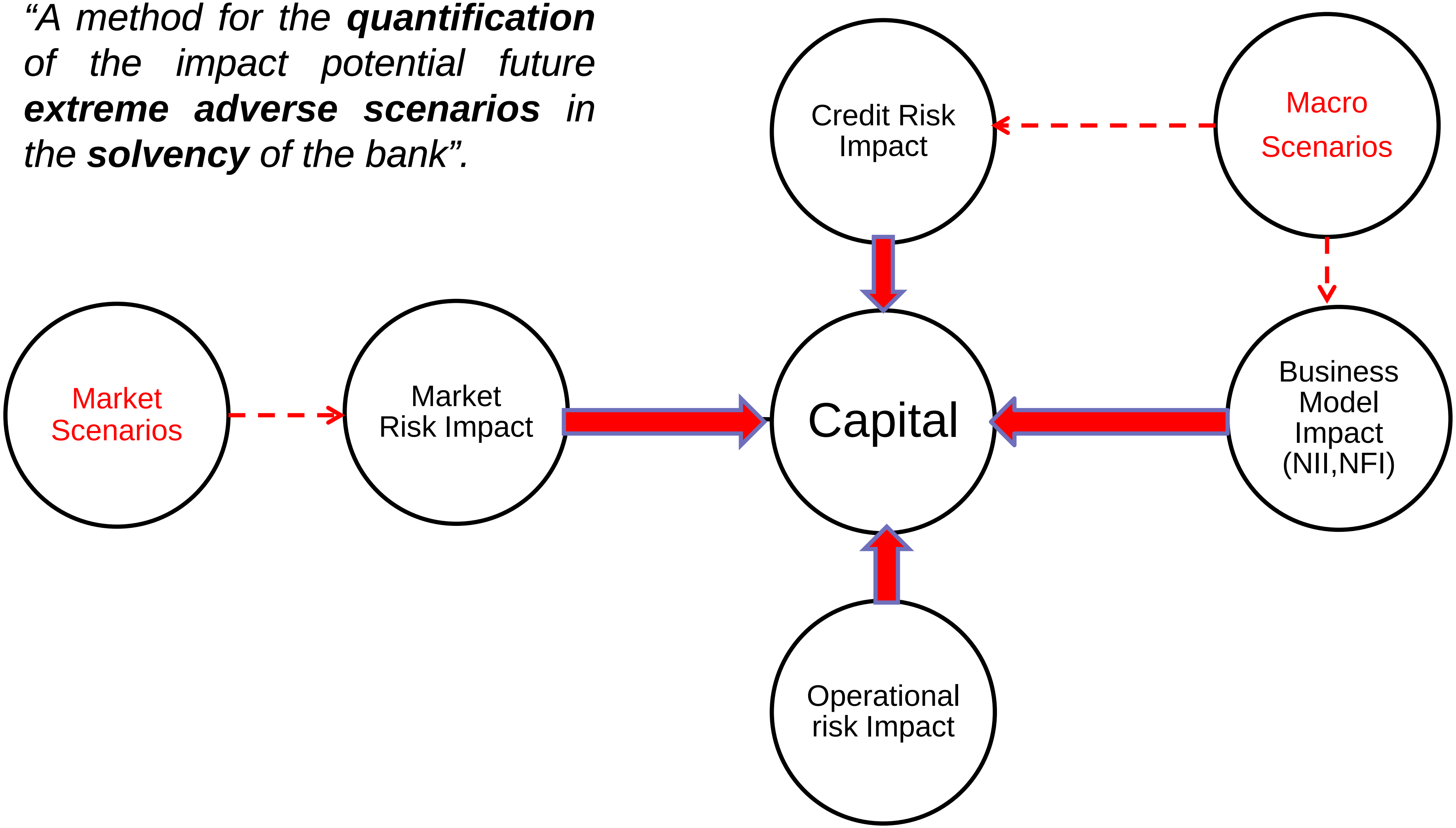
Stress Test overview.

*“A method for the **quantification** of the impact potential future **extreme adverse scenarios** in the **solvency** of the bank”.*



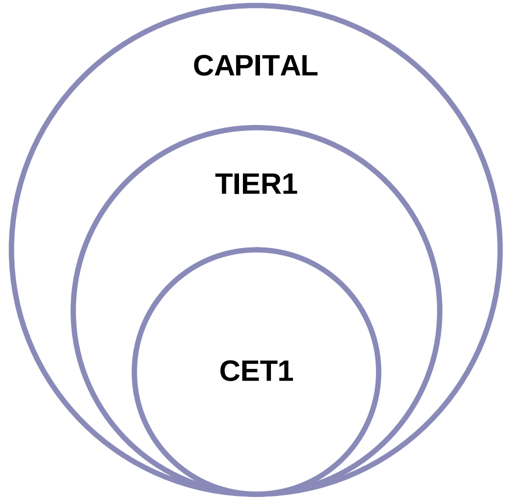
Stress Test Scenarios – ECB assessment 2015

	Baseline scenario			Adverse scenario		
	2015	2016	2017	2015	2016	2017
Real GDP annual growth (%)	-2.3	-1.3	2.7	-3.3	-3.9	0.3
HICP inflation – annual rate (%)	-0.4	1.5	0.9	-0.7	0.6	-1.0
Unemployment rate (end-of-year, %)	26.9	27.1	25.7	27.3	28.1	27.5
House price growth (annual average, %)	-7.5	-5.0	-1.0	-7.8	-8.8	-7.8
Prime commercial property price growth (%)	-3.4	-1.2	1.1	-3.6	-3.4	-2.1

	Adverse scenario		
Average annual deviation from baseline level	2015	2016	2017
Short-term interest rate (3-month Euribor)	40	80	80
10-year Greek government bond yield	204	390	170
Greek stock prices (ASE Composite Index)	-10.5	-20.1	-8.8

Bank Solvency – Regulatory Capital.

•**Regulatory capital** is the available amount for loss absorption. It is classified qualitatively based on its loss absorption ranking.



•Capital is a relative measure for banks. Therefore Basel III introduced capital ratios based on Risk Weighted Assets (RWA) which measure the degree of viability of a banking institution.

Bank Solvency – Capital ratios.

•**Common Equity Tier 1 Ratio**: $CET1\% = \frac{CET1\ capital}{RWA}$

•**Tier 1 Ratio**: $\mathrm{TIER1\%} = \frac{TIER1\ capital}{RWA}$

•**Capital Adequacy Ratio**: $CAR\% = \frac{Capital}{RWA}$

•Stress testing exercises usualy define **capital ratio thresholds**.

•If the loss of capital leads to fall below threshold the bank is called either to a **capital increase (recapitalization)** or **other capital actions** in order to restore its viability.

Timeline of stress tests and recapitalizations.

- **Dec 2012: 1st stress test (BOG)**
- **April 2013: 1st recapitalization**
- **Mar 2014: 2nd stress test (BOG)**
- **Apr 2014: 2nd recapitalization**
- **Oct 2014: 3rd stress test (ECB)**
- **Oct 2015: 4th stress test (SSM)**
- **Nov-Dec 2015: 3rd recapitalization**

1st Recapitalization

Piraeus:	8.4 bn
NBG:	9.8 bn
Eurobank	5.8 bn
Alpha:	4.6 bn

2nd Recapitalization

Piraeus	1.8 bn
NBG	2.5 bn
Eurobank	2.8 bn
Alpha	1.2 bn

3rd Recapitalization

Piraeus	4.6 bn
NBG	4.5 bn
Eurobank	2.0 bn
Alpha	2.6 bn

Why the ECB conducted the CA exercise in 2015?.

- The sharp deterioration of the operating environment in 2015 had a significant impact on the solvency and liquidity position of Greek banks.
- Against this backdrop, “a buffer of up to €25billion has been envisaged under the Program to address potential bank recapitalization needs.
- As a result, a Comprehensive Assessment (CA) has been conducted by the ECB, based on end of June 2015 data and comprising both
  1. **an asset quality review** (AQR) and
  2. **a stress test** with baseline and adverse scenarios.
- The CRD IV CET1 capital definition has been used with phase-in rules. The minimum capital hurdles for the baseline and adverse scenarios are 9.5% and 8%, respectively.

Asset Quality Review.

Phase 1

Portfolio selection

Phase 2

1 Processes, policies and accounting review (PP&A) *[Note: not relevant for this exercise apart from CVA workblock]*

- CVA challenger model adjust-ments

2 Loan tape creation and data integrity validation (DIV)

3 Sampling

4 Credit file review (CFR)

6 Projection of findings of credit file review

7 Collective provisioning

5 Collateral and real estate valuation

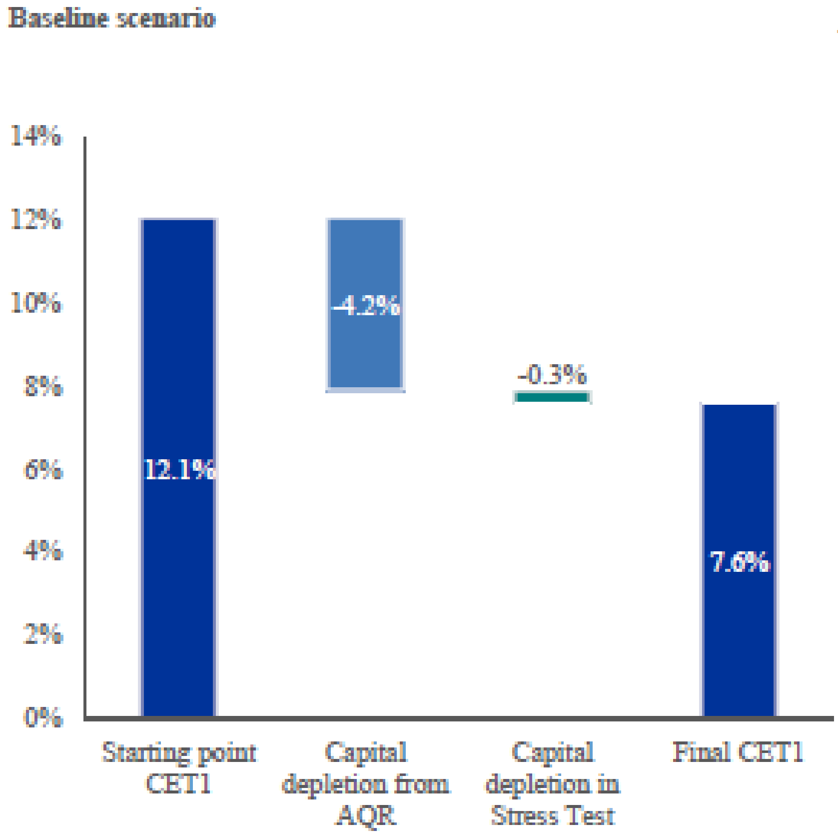
8 Level 3 fair value exposures review *[Note: not relevant for this exercise]*

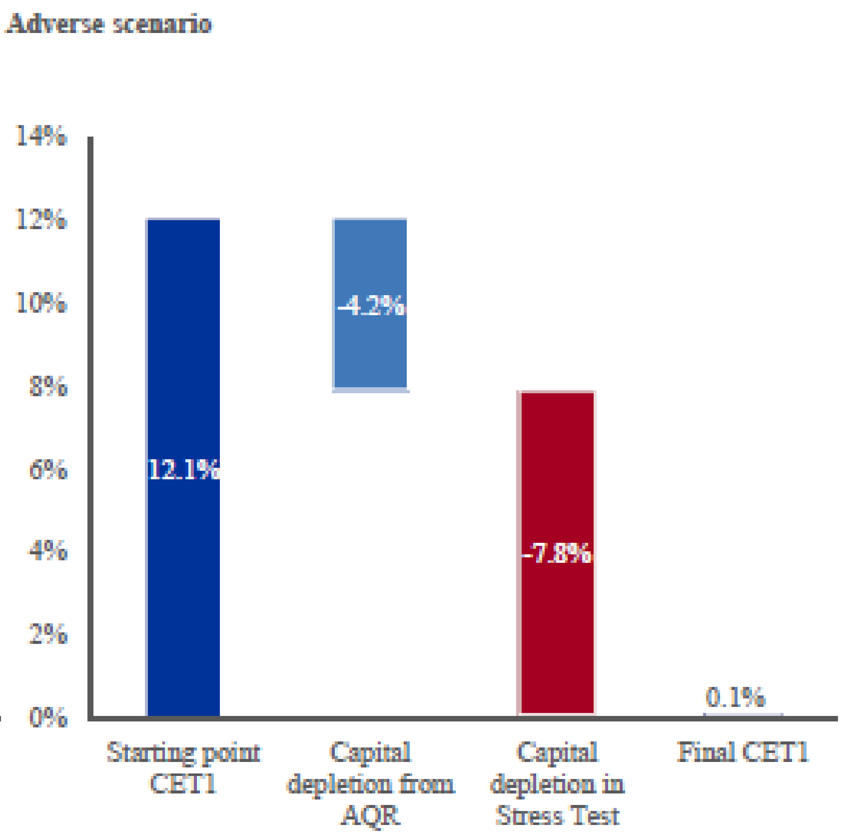
- i. Level 3 revaluation of non-derivative assets
- ii. Core processes review
- iii. Derivative pricing model review

9 Determination of AQR-adjusted CET1 for use in ECB stress test and definition of remediation activities for banks following the CA

Summary of all work blocks

Comprehensive Assessment CETI impact.





Comprehensive Assessment – Results per bank.

Bank Name	CET1 ratio starting point pre AQR	CET1 ratio starting point post AQR	CET1 ratio baseline scenario	CET1 ratio adverse scenario	Capital shortfall baseline scenario (€ billion)	Capital shortfall adverse scenario (€ billion)
Alpha Bank, S.A.	12.7%	9.6%	9.6%	2.1%	0.26	2.74
Eurobank Ergasias, S.A.	13.7%	8.6%	8.7%	1.3%	0.34	2.12
National Bank of Greece, S.A.	11.6%	8.1%	7.3%	-0.2%	1.58	4.60
Piraeus Bank, S.A.	10.8%	5.5%	5.2%	-2.3%	2.21	4.93
System wide	12.1%	7.9%	7.6%	0.1%	4.39	14.40

Credit Risk models.

- Credit Risk: Key components
  - Probability of Default (PD): Probability that the counterparty default on its loan (%).
  - Loss Given Default (LGD): Percentage of loss incurred if the counterparty defaults on its loan (%).
  - Exposure at Default (EAD): Amount of loan to the counterparty.
- Expected Loss (EL)=PD*LGD*EAD.
- For example, PD=1%, LGD=20%, EAD=1000 Euros ⟹

  EL = 2 Euros.
- Bank will deduct from its capital the shortfall between projected Expected Losses and its stock of provisions.

  Capital Impact = EL - Provisions

Probability of Default-PD.

- Migration Matrix is a basic tool of credit risk monitoring

	A1	A2	B1	B2	C1	C2	D1	D2	Default
A1	**90.63%**	8.04%	0.00%	0.00%	1.04%	0.00%	0.00%	0.00%	**0.29%**
A2	1.53%	**85.38%**	10.64%	0.14%	0.00%	0.14%	0.00%	0.00%	**2.18%**
B1	0.14%	2.99%	**86.60%**	5.69%	0.35%	0.14%	0.00%	0.07%	**4.03%**
B2	0.00%	0.00%	3.75%	**85.08%**	4.09%	1.02%	0.08%	0.31%	**5.67%**
C1	0.00%	0.00%	0.66%	7.57%	**71.38%**	10.69%	1.64%	0.99%	**7.07%**
C2	0.00%	0.19%	0.38%	0.77%	7.31%	**75.38%**	8.08%	1.73%	**6.15%**
D1	0.00%	0.00%	0.00%	0.00%	1.64%	14.10%	**61.20%**	10.38%	**12.67%**
D2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	**75.00%**	**25.00%**

Probability of Default-PD.

- Model Default Probability (PD) as a function of loss drivers

$$PD = f\left(\beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \dots + \beta_n\chi_n\right)$$

- e.g

$$f\left(PD_{t+1}\right) = \beta_1 + f\left(PD_t\right) + \beta_2 GDP_t + \beta_3 UNR_t + \beta_4 INT_t + \beta_5 IFL_t + \varepsilon_t$$

- where

GDP: Gross Domestic Product Growth

UNR: Unemployment Rate

INT: Interest Rates

INF: Inflation

Loss Given Default-LGD.

$$LGD = 1 - \frac{\sum_{t=1}^{T} \frac{Collateral.Flows - Liquidation.costs}{(1+r)^{t}}}{EAD}$$

- Model LGD as a linear function of loss drivers

$$LGD = \beta_0 + \beta_1 \chi_1 + \beta_2 \chi_2 + ... + \beta_n \chi_n + \varepsilon$$

- LGD main loss drivers.
  - Borrower creditworthiness (default rates)
  - Real Estate Prices
  - GDP growth
  - Industry sector and size of the company
  - LTV (Loan –to –Value) ratio

Loss Given Default-LGD.

- LGD is not a normal distribution. So practitioners map a Beta distribution onto the LGD data.

$$f(x) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \chi^{\alpha-1}(1-\chi)^{\beta-1}$$

- Where $\Gamma(\beta)$ Euler's gamma function and moments

$$\mu = \frac{\alpha}{\alpha+\beta} \qquad \sigma = \sqrt{\frac{\alpha\beta}{(\alpha+\beta)^2(1+\alpha+\beta)}}$$

- Bounded between 0 and 1 and can be estimated using ML or method of moments

Exposure At Default - EAD.

- EAD = Drawn + CCF*(Limit-Drawn)
- CCF (Credit Conversion Factor) is the proportion of the undrawn but committed amount likely to be drawn prior to default. Also called Loan Equivalency Factor (LEQ).

$$0 \leq CCF \leq 1$$

- EAD modeling focus on estimating CCF factor which can be backed out from the above relationship

$$CCF = \frac{EAD - Drawn}{Limit - Drawn}$$

Market Risk.

- Stress scenarios contain a large number of shocks to a large number of instruments.
- Banks themselves have an even larger group of underlying instruments on which derivatives are based.
- In the case of derivatives factors may be based on Delta or Vega sensitivities whereas the position may be positive or negative.

$$MarketLosses = \alpha + \sum_{i=1} \beta_i \left(Position_i\right)\left(Factor_i\right)\left(Shock_i\right) + \varepsilon$$

- This equation provides the basis on which to perform linear regression to find the coefficients and assess the strength of the relationship

Operational Risk

- **Operational risk** is the risk of losses caused by inadequate or failed internal processes, people and systems, or from external events.
- One of the most dramatic and well-documented derivatives losses was the collapse in 1995 of Barings, Britain's oldest merchant bank (200 years!).
- One person (Nick Leeson), based in Singapore managed to circumvent internal systems over an extended period of time to hatch and hide his trading schemes. It ultimately resulted in over $1.2bn of losses.

Operational Risk Models

- Operational Risk events are separated into two main categories.
  - Low Frequency – High Severity events (e.g conduct risk fines)
  - High Frequency – Low Severity events (e.g power failure)

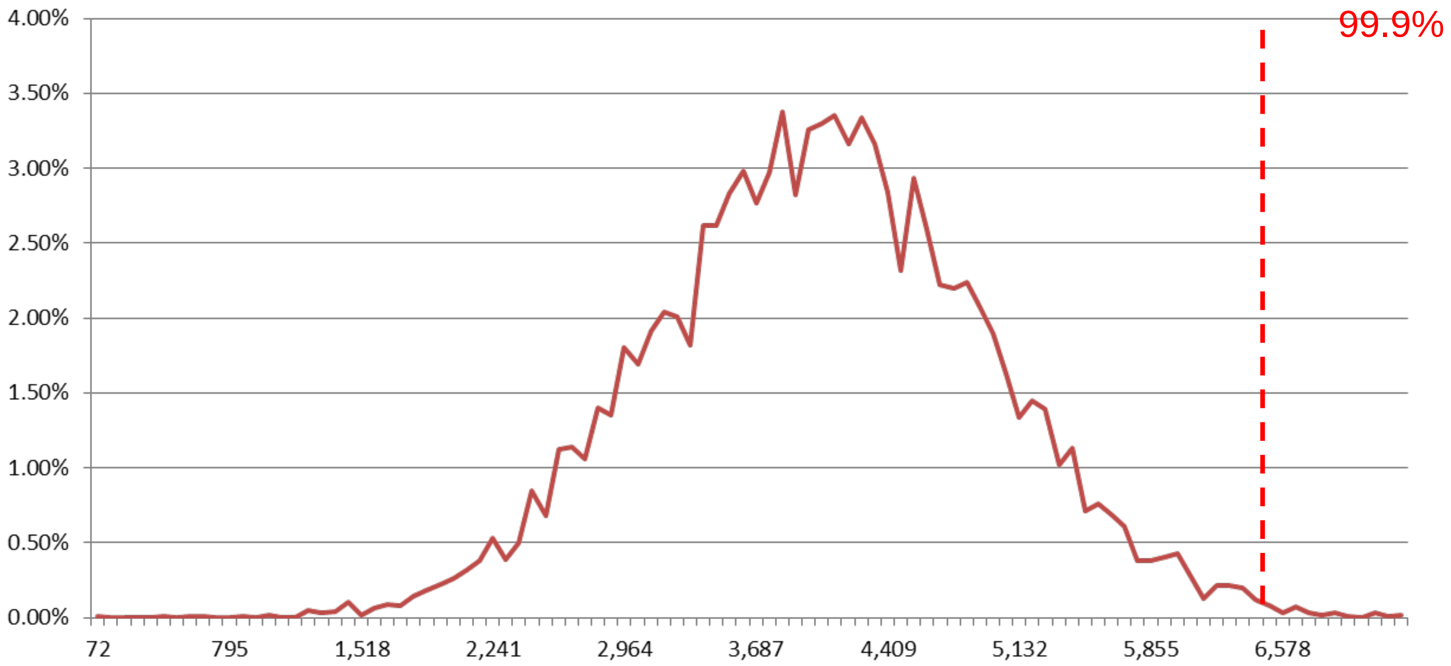
- Loss Frequency: The number of loss events during a period. Distributions frequently used:
  - Binomial Distribution.
  - Poisson Distribution.
  - Negative Binomial Distribution.

Operational Risk Models

- Loss Severity: The impact of the event in terms of financial loss. Distributions frequently used:
  - Log-normal distribution.
  - Gamma distribution.
  - Two parameter hyperbolic density distribution.
- Based on the assumption that loss frequency and loss severity are independent the compound distribution can be derived with Monte Carlo simulation.
  1. Take random draw from frequency distribution (e.g **n** events).
  2. Take **n** random draws from the severity distribution.
  3. Sum the **n** simulated losses to obtain a total loss.
  4. Repeat thousand of times this procedure to obtain the losses distribution.

Operational Risk Models

- Example: Average loss 200.000 euro per event with standard deviation of 20.000 euro (loss impact) and 20 expected events per year (loss frequency). Based on 10.000 simulations the distribution is.



Income models.

- Income generated by banks during the stress test horizon is an important part of each stress testing exercise as it acts as a counterweigh to projected losses.
- The dynamics of Net Interest Income and Fee & Commission income are usually modeled using dynamic panel data econometric frameworks (Arellano & Bond, 1991).

$$NIM_{it} = \alpha_{it} + \beta NIM_{it-1} + \gamma_{it} X' + \varepsilon_{it}$$

- Covariates (X) usually used are
  - GDP growth.
  - Interest Rate Differential.
  - Stock market volumes.

Loan Flow Models.

- Econometric models are useful in modeling bank loan flow paths which can be derived conditional on some macro-financial scenarios.
- The dynamics of loan flows are usually modelled using dynamic panel data econometric frameworks.

$$L_{it} = \alpha_{it} + \beta L_{it-1} + \gamma_{it} \mathrm{X}' + \varepsilon_{it}$$

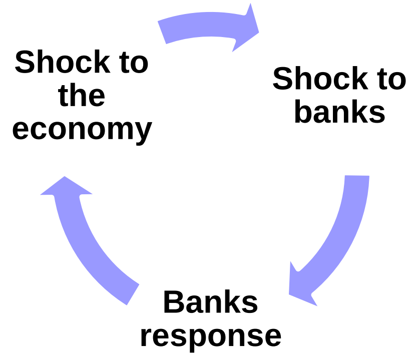
- Covariates (X) usually used are
  - Consumption - Investment
  - GDP growth.
  - Interest Rates.
  - Company stock market values.

Contagion Models.

- Interbank market was one of the main victims of the financial crisis that started in 2007.
- The crisis led to a general loss of trust among market participants and resulted in severe market disruptions.
- In scenario analysis it is assumed that banks experiencing a capital shortfall cannot repay their interbank obligations. This could trigger a chain of second round default effect in their counterparties.
- Methodologies used to model such type of effects include network model or bilateral matrix simulations.

Second Round Effect Models.

- In an adverse scenario emergence banks might pro-actively raise their capital buffers by deleveraging, issuing equities or change their portfolio allocation.
- The banks response to an adverse scenario creates second-round effects on the macroeconomic environment and amplifies the impact of the shocks that initial hit only the banking sector.



- VAR methodologies usually applied for modeling such type of effects.

Static vs Dynamic stress testing

- Static balance sheet assumption: When the crisis arrives according to specified scenario the bank retains over the stress testing period the same structure in asset and liabilities.
- This hypothesis may depart from reality given that upon the arrival of a crisis banks tend to deleverage in the asset side and change their funding mixture in the liability side.
- Therefore most recent stress testing exercises are moving to a dynamic balance sheet framework where the balance sheet structure evolve over time.

Q&As