BANCO CENTRAL DO BRASIL

# Stress Testing at Central Banks – The case of Brazil

CEMLA Seminar:

**"PREPARACIÓN DE INFORMES DE ESTABILIDAD FINANCIERA"**

October 2009

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# Agenda

- Definition
- ST Framework
- Measuring and Scenarios
- Sensitivity tests
- Credit risk
- Market risk
- Contagion risk
- Liquidity risk
- Conclusion

# Definition

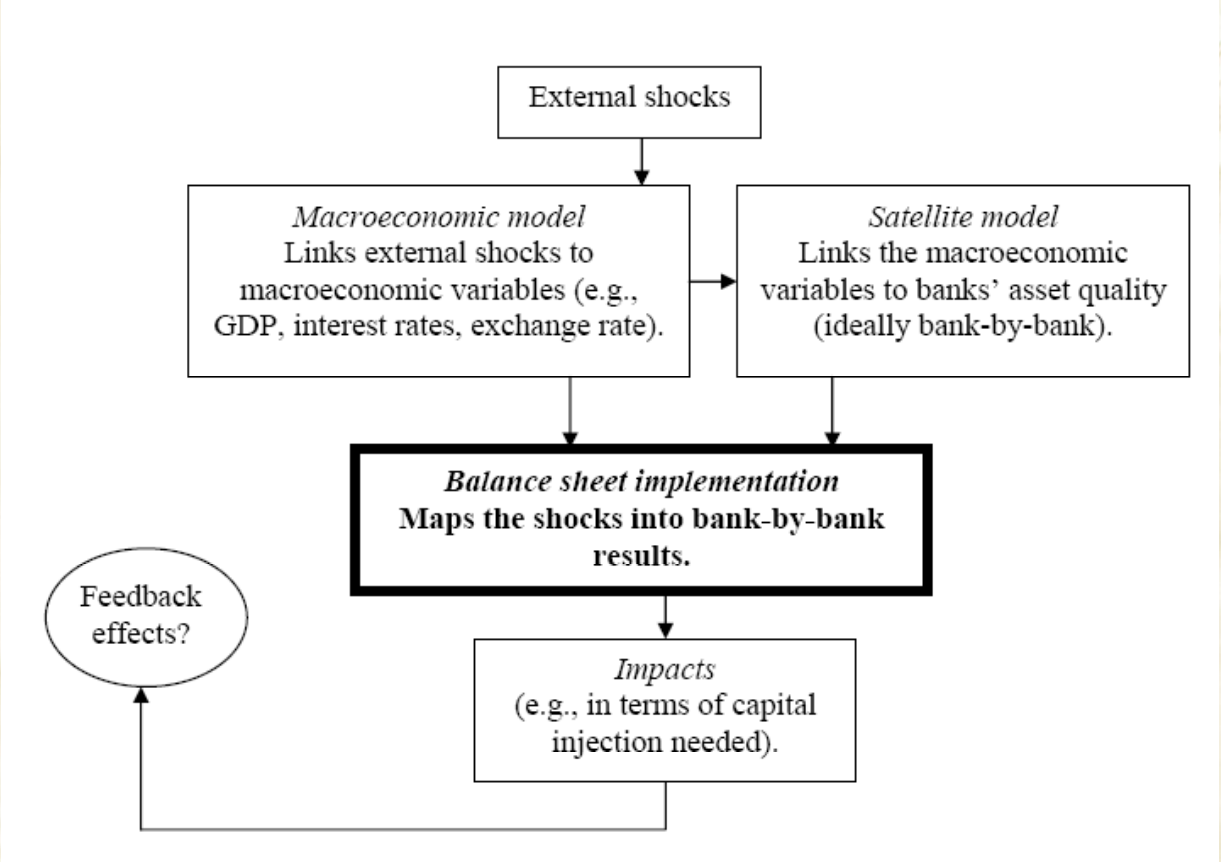
*Stress-testing refers to a range of techniques used to assess the vulnerability of whole banks, banking systems, or financial systems to "exceptional but plausible" shocks.*

*They involve testing beyond normal operational capacity, often to a breaking point, in order to observe the results.*

# Definition

- The interest in ST is a response to increased financial instability in many countries in the 1990s.
- ST has been an important component of the Financial Sector Assessment Programs (FSAPs).
- The current crisis has underscored the importance of stress testing as an essential risk management and capital planning tool.

# ST framework



# ST framework

- There are two main approaches to translating macroeconomic shocks and scenarios into financial sector variables:
  - **the "top-down" approach**, where the impact is estimated using aggregated data;
  - **the "bottom-up" approach**, where the impact is estimated using data on individual portfolios.

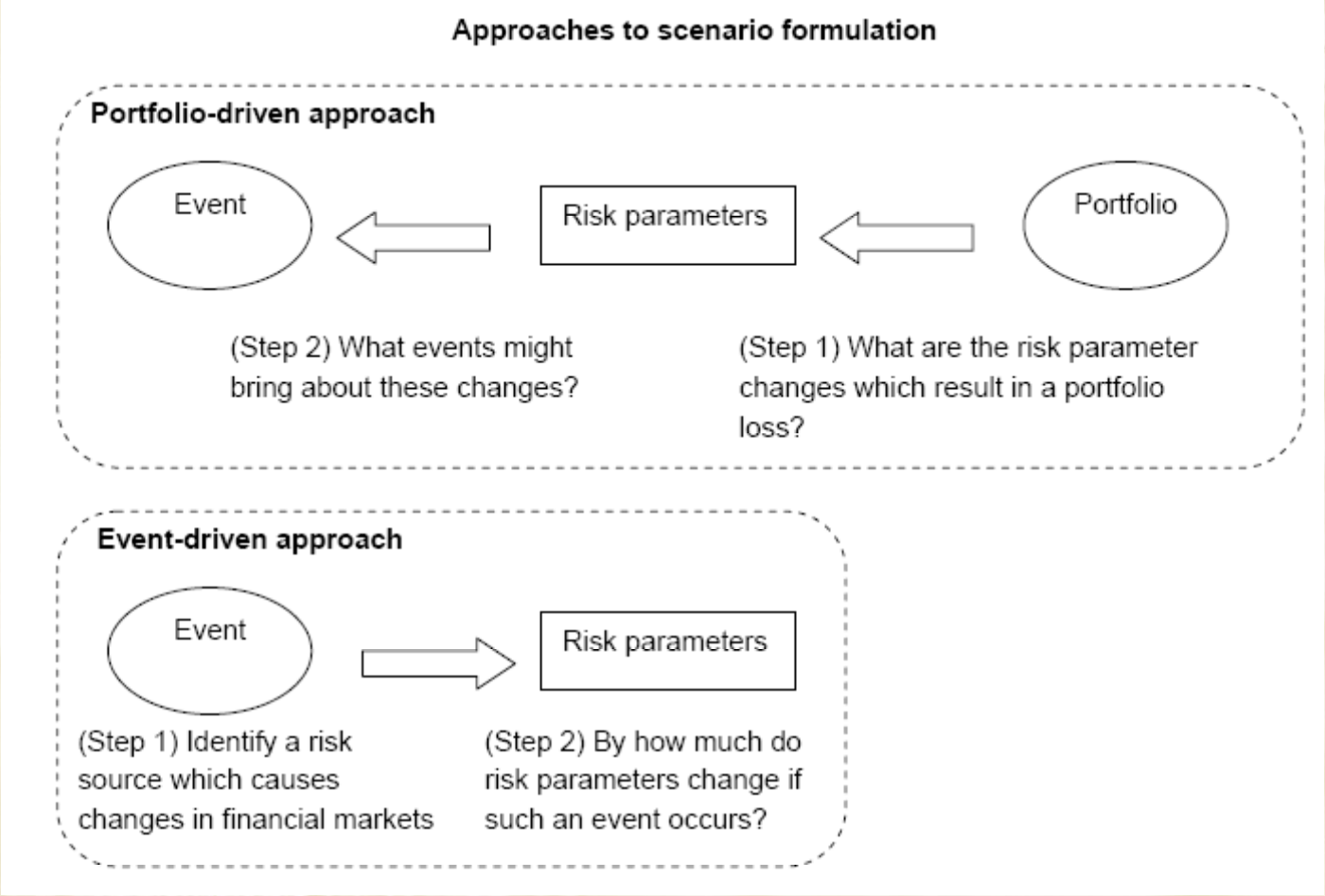
# ST framework

- There are two main approaches to performing the numerical analysis:
  - **Centralized approach:** all the calculations are done in one center (e.g., at the central bank or a supervisory agency).
  - **Decentralized approach:** the banks carry out the stress testing calculations.

# Measuring

- In order to measure the impacts of the stress tests, various variables have been used so far:
  - Capital;
  - Capitalization;
  - Capital injection needed;
  - Profits;
  - Loan losses;
  - Ratings and probabilities of default (PDs);
  - Liquidity indicators.

# Scenarios

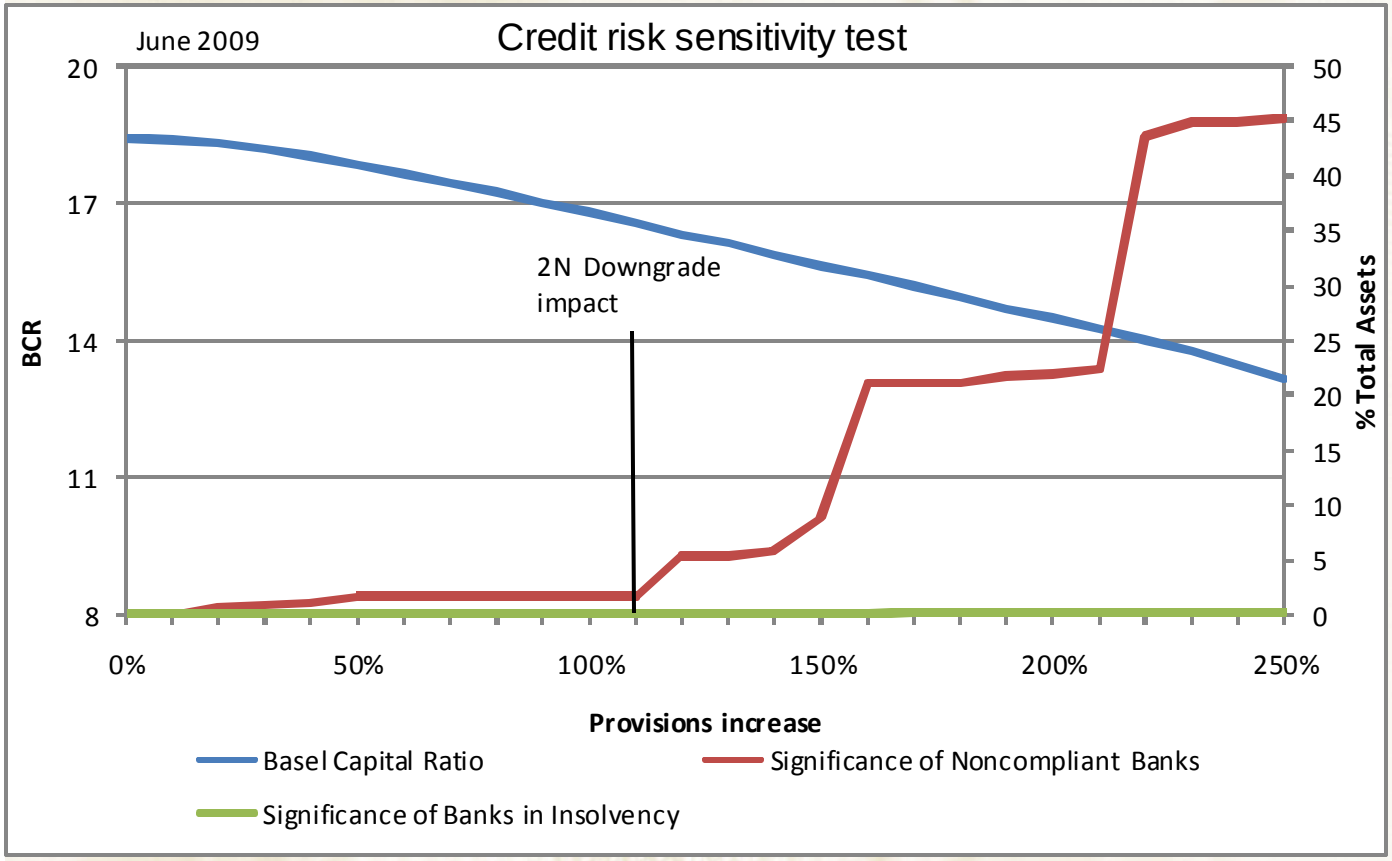

Approaches to scenario formulation
Portfolio-driven approach
Event
Risk parameters
Portfolio
(Step 2) What events might bring about these changes?
(Step 1) What are the risk parameter changes which result in a portfolio loss?
Event-driven approach
Event
Risk parameters
(Step 1) Identify a risk source which causes changes in financial markets
(Step 2) By how much do risk parameters change if such an event occurs?

# Scenarios

- **Concrete extreme historical scenario** (e.g., the East Asian crisis of 1997): it measures what would be the impact of repeating such a scenario (or an adaptation of such scenario) in the present situation of the banking system.

- **Hypothetical scenario** is based on an existing macroeconomic model (e.g., a model used by the central bank for macroeconomic forecasts and policy analysis).

# Sensitivity tests




- Sensitivity tests: shock individual parameters or inputs without relating those shocks to an underlying event or real-world outcomes.
- The risk factors are simulated through gradual increments.

# Credit risk

- There are three basic groups of approaches to modeling credit risk:
  - **First,** there are mechanical approaches (ad-hoc approaches).
  - **Second**, there are approaches based on loan performance data (e.g., PD, LGD, NPLs, and provisions) and regressions (e.g., single equation, panel data, and VAR/VECM models).
  - **Third**, there are approaches based on micro-level data related to the default risk of the household/ corporate sector data.

# Credit Risk

- Mechanical approaches: banks' balance sheets are shocked directly, i.e., shocks are directly applied to nonperforming loans (NPLs) or provisions.
- A link to the macroeconomy is not modeled explicitly.
- Typical tests assess what would happen if banks raise their provisioning to reflect loan quality deterioration.

# Credit Risk

- Two-notch downgrade

| Classification | Stressed Classification |
|---|---|
| AA | B |
| A | C |
| B | D |
| C | E |
| D | F |
| E | G |
| F | H |
| G | H |
| H | H |

Increase in credit risk (Jun/2009) %

| Controlling stake | Basel capital ratio | | Relevance (Total Assets) | |
|---|---|---|---|---|
| | Original | Stressed | Noncompliant banks | Insolvents |
| Foreign | 22.4 | 20.6 | 1.4 | - |
| Domestic private | 17.5 | 15.6 | 2.9 | - |
| Government owned | 16.5 | 12.8 | 0.9 | - |
| Total | 18.5 | 16.1 | 5.3 | - |

# Credit risk

- **ST based on data on loan performance**: the assumption is that loan quality is sensitive to the economic cycle.
- A typical stress test in this category models NPLs or loan-loss provisions as a function of various macroeconomic variables.
- Example: DNB uses the LLP ratio to measure credit quality at the individual bank level, with dynamic panel data estimation.

$$\lambda(Defaultrate)_t = \alpha + \beta_1 GDP_t + \beta_2 (RL_t - RS_t) + \nu_t$$

$$\lambda\left(\frac{LLP}{CRED}\right)_{i,t} = fixedeffects_i + \beta_1 GDP_t + \beta_2 RL_t + \beta_3 \lambda(Defaultrate)_t + \eta_t$$

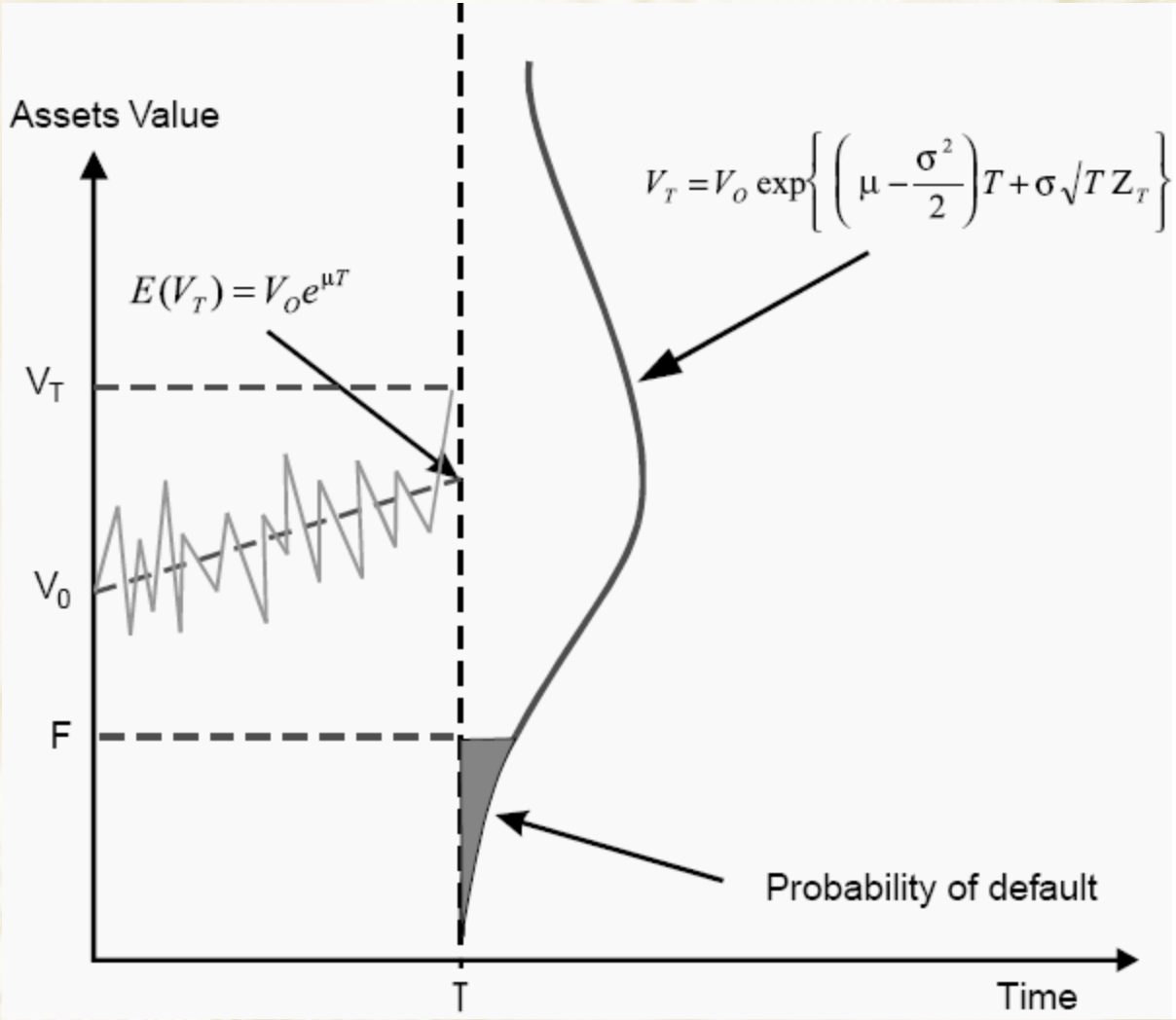
# Credit risk

- **ST based on micro-level data:** credit risk is measured using individual borrower data from credit register and using a model based on *Moody's KMV EDF or CSFB's CreditRisk+*, for example.

- *Moody's KMV EDF* is based on the asset value model originally proposed by Merton. In this model the default process relates to the capital structure of the firm.

- Default occurs when the value of the firms assets falls below some critical level.

# Credit risk


Assets Value
$E(V_T) = V_O e^{\mu T}$
$V_T = V_O \exp\left\{\left(\mu - \frac{\sigma^2}{2}\right)T + \sigma\sqrt{T}\,Z_T\right\}$
$V_T$
$V_0$
F
Probability of default
T
Time

# Credit risk

- *CreditRisk*+ applies an actuarial science framework to the derivation of the loss distribution of a loan portfolio.

- No assumption is made about the causes of default: an obligor A is either in default with probability P, or it is not in default with probability (1 – P).

- The probability distribution for the number of defaults, during a given period of time (say 1 year) is well represented by a Poisson distribution.

# Credit risk

- The Poisson distribution is fully specified by only one parameter $\mu$.

$$P(n\_defaults) = \frac{\mu^n e^{-\mu}}{n!} \qquad for\ n = 0, 1, 2 \ldots$$

where $\mu$ average number of defaults per year.

- For example, if we assume $\mu = 3$ then the probability of no default in the next year is

$$P(0\_defaults) = \frac{3^0 e^{-3}}{0!} = 0.05 = 5\%$$

# Credit risk

- One of the main strengths of the *CreditRisk+* model is the ability to calculate loss distributions with relatively low numerical effort compared to the other models.

- This model is used by the ECB to carry out its credit risk stress test.

- A VAR links the EDF for each industry to macro-economic variables:

$$EDF = \alpha + \beta_1 \Delta GDP_t + \beta_2 \Delta CPI_t + \beta_3 \Delta EQ_t + \beta_4 \Delta EP_t + \beta_5 \Delta IR_t$$

# Credit risk

- The impact is not equal to each bank and the worst scenario is an increase in long-term interest rates.

**Chart 4.13 Unconditional expected default frequencies for selected sectors in the euro area**

(July 2007 – Mar. 2009; percentage probability)

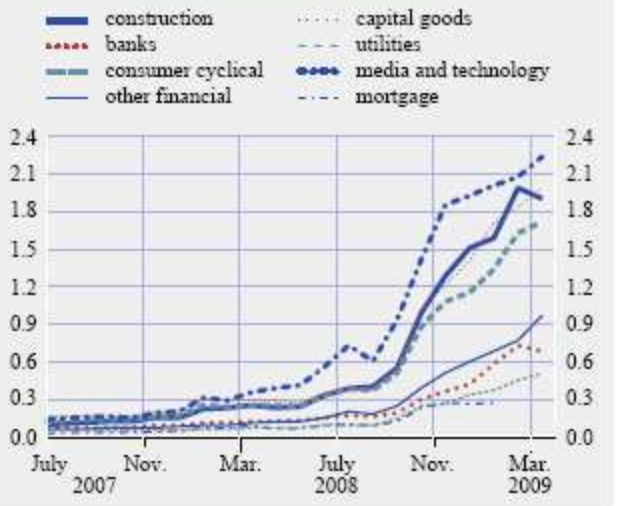
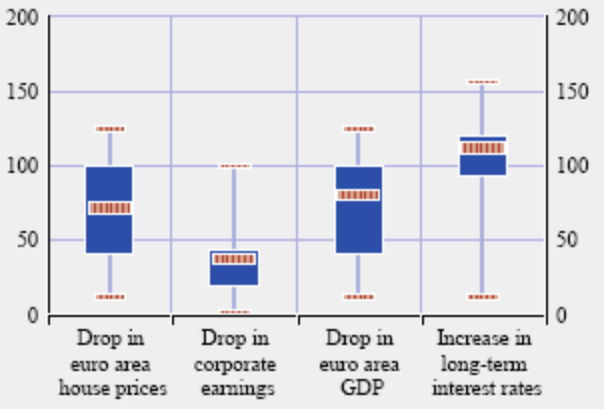



**Chart 4.14 Changes in credit VaRs relative to the baseline scenario across euro area large and complex banking groups under different scenarios**

(percentage of Tier 1 capital; maximum, minimum, interquartile distribution and median)



# Market risk

- Market risk has tended to show smaller effects in STs, partly due to the shorter horizon but also presumably reflecting the fact that it is often an area better managed by banks.
- The analysis of market risks has used a range of different approaches for interest rate risk and exchange rate risk (i.e. VaR, duration, maturity gaps, net open positions.)
- It might include asset price shocks (shocks to real estate prices), and shocks to commodity prices (in countries with significant exposures to commodities).

# Interest rate risk

- Direct interest rate risk is the risk incurred by a financial institution when the interest rate sensitivities of its assets and liabilities are mismatched.

- Financial institution is also exposed to indirect interest rate risk, resulting from the impact of interest rate changes on borrowers' creditworthiness and ability to repay.

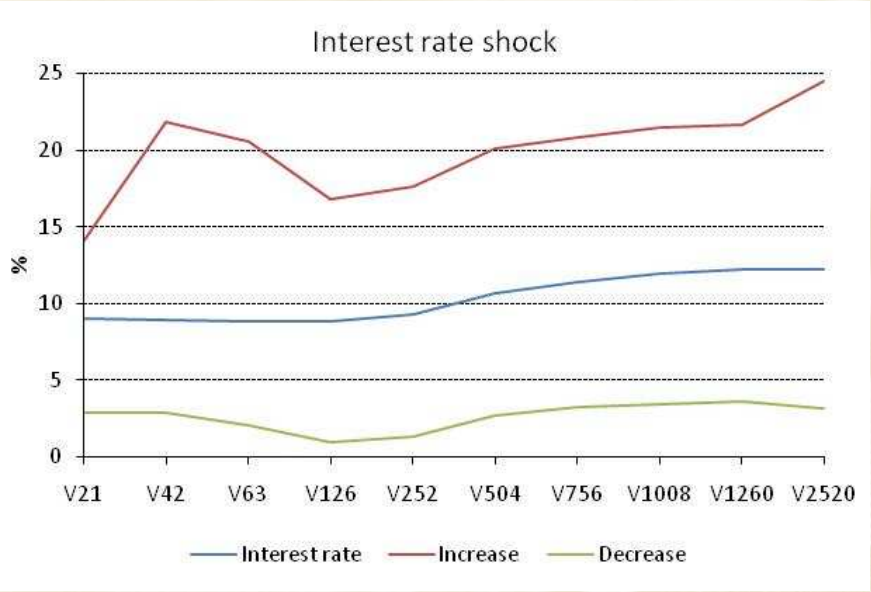
- The indirect interest rate risk is a part of credit risk.

# Interest rate risk

- **Direct Interest Rate Risk** calculates the changes in interest income and interest expenses resulting from the "gap" between the flow of interest on the holdings of assets and liabilities in each bucket.

| Interest Rate Scenarios Used | Examples of Shock Sizes |
|---|---|
| •Ad hoc or hypothetical interest rate increase<br>•Parallel shift in yield curve<br>•Flattening/steepening of yield curve<br>•Historical interest rate increase | •3 std deviations of 3-month changes<br>•50%-100% increase<br>•three-fold increase in nominal rate<br>•100 basis point shock to interest rates<br>•100 basis point shock to dollar interest rates and 300 basis point shock to local currency interest rates |

# Interest rate risk




Increase/decrease of interest rates (Jun/2009)

%

| Itemization | Basel capital ratio | | Relevance (Total Assets) | |
|---|---|---|---|---|
| | Original | Stressed | Noncompliant banks | Insolvents |
| Increase | | | | |
| Foreign | 22.4 | 16.0 | 18 | 0.1 |
| Domestic private | 17.5 | 14.3 | 4.0 | - |
| Government owned | 16.5 | 12.3 | 13.4 | - |
| Total | 18.5 | 14.3 | 19.1 | 0.1 |
| Decrease | | | | |
| Foreign | 22.4 | 15.0 | 0.9 | - |
| Domestic private | 17.5 | 14.1 | 3.8 | - |
| Government owned | 16.5 | 17.8 | 18 | - |
| Total | 18.5 | 15.2 | 6.5 | - |

# Foreign exchange risk

- The foreign exchange risk is the risk that exchange rate changes affect the local currency value of financial institutions' assets, liabilities, and off-balance sheet items.
- The foreign exchange risk is composed of three types:
  - the direct solvency risk;
  - the indirect solvency risk;
  - and the foreign exchange liquidity risk.

# Foreign exchange risk

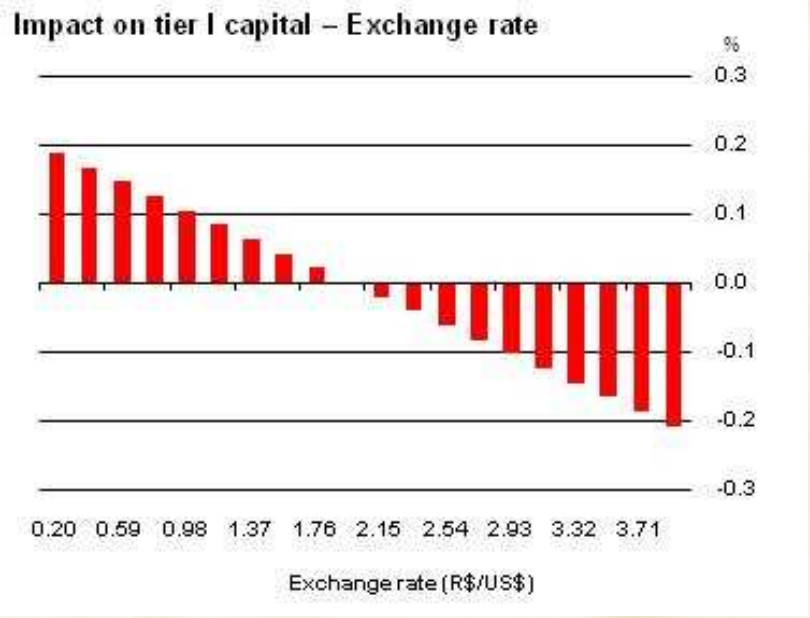
- **Direct Foreign Exchange Risk** testing is based on the net open position in foreign exchange.
- Exchange rate shock translates directly into a increase or decline in capital and impacts on the ratio of capital to risk-weighted assets.
- Only a very limited number of banks have short positions, therefore the direct depreciation effects are very small.

# Foreign exchange risk

| Exchange Rate Scenarios Used | Examples of Shock Sizes |
|---|---|
| •Ad hoc or hypothetical devaluation<br>•Historical large exchange rate changes | •20%-50% depreciation<br>•20% depreciation/appreciation<br>•40% depreciation/appreciation of Euro/Dollar exchange rate |

R$/US$ 1.95 → R$/US$ 2.77

R$/US$ 1.95 → R$/US$ 1.75



# Contagion risk

- Stress testing contagion risk is an important complement to stress tests of individual institutions faced with common shocks.

- These tests often focus on **"Pure" Interbank contagion**, i.e., they assess whether the (random) failure of a bank causes a substantial deterioration in the capital adequacy in other banks.

- **"Macro" Interbank contagion** models the case when bank failures are triggered by macroeconomic developments.

# Contagion risk

- **“Pure” Interbank Contagion** shows what would happen with the capital of the “Bank 1” if the “Bank 2” failed and defaulted on all its interbank borrowing.

- The stress test is run in several iterations.

- It is assumed that if a bank’s capital stays positive after an iteration, the banks does not fail and remains able to repay all its interbank obligations.

# Contagion risk

- In the contagion risk stress testing carried out by BCB, if a Bank's CAR is less than 5% after an iteration, the bank fails and does not repay its obligations.

- The calculation can be made more realistic by estimating a more complex mapping between the capital adequacy ratio and the bank's probability of failure.

- The "pure" interbank contagion test could be interpreted as a measure of systemic importance of individual banks.

# Contagion risk

R$ millions

| Bank | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | … | **45** | 32 | -4 | 10 | -13 | -9 | 12 |
| 2 | **-45** | … | 30 | 70 | 55 | 60 | 16 | 20 |
| 3 | -32 | -30 | … | -26 | -40 | -10 | -14 | 31 |
| 4 | 4 | -70 | 26 | … | -5 | 2 | 7 | 32 |
| 5 | -10 | -55 | 40 | 5 | … | 2 | 3 | 26 |
| 6 | 13 | -60 | 10 | -2 | -2 | … | -3 | 29 |
| 7 | 9 | -16 | 14 | -7 | -3 | 3 | … | 20 |
| 8 | -12 | -20 | -31 | -32 | -26 | -29 | -20 | … |

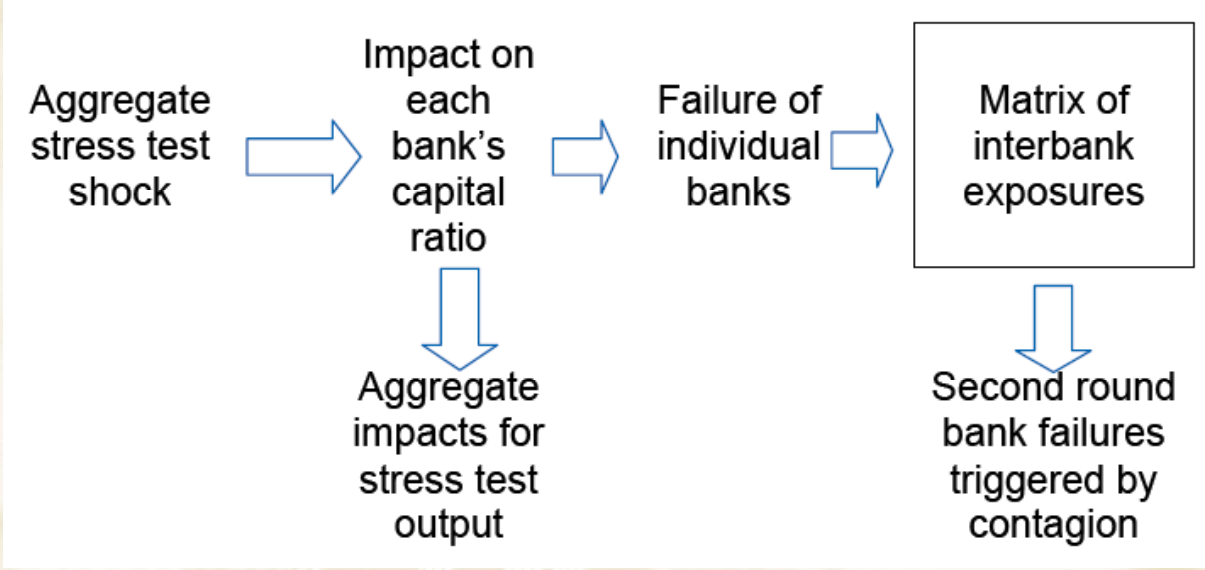
# Contagion risk

- “Macro” Interbank Contagion models the case when bank failures are triggered by macroeconomic developments (scenario that is already modeled).

- It analyzes situations when all banks are weakened at the same time by a common external (typically macroeconomic) shock, which affects each bank differently depending on its exposures to the various risk factors, and makes some of the banks fail.

# Contagion risk

## "Macro" Interbank Contagion



# Liquidity risk

- Liquidity is the ability of a bank to fund increases in assets and meet obligations as they come due, without incurring unacceptable losses.

- Testing for liquidity risks is less common in FSRs than testing for risks to solvency, reflecting mostly the fact that modeling liquidity risks is more complex.

- The financial crises emphasised the importance of liquidity to the functioning of financial markets and the banking sector.

# Liquidity risk

- Stress tests have assumed shocks to deposits and wholesale funding or include a cross-border scenario in which foreign investors stop funding the domestic banks.
- A few FSRs have also stressed market liquidity by assuming haircuts on quasi-liquid assets.
- The shocks have been calibrated based on historical data or assumed to be ad hoc.
- The results have been reported in terms of changes to a liquidity ratio measure. Some FSRs reported the days until the banks become illiquid.

# Liquidity risk

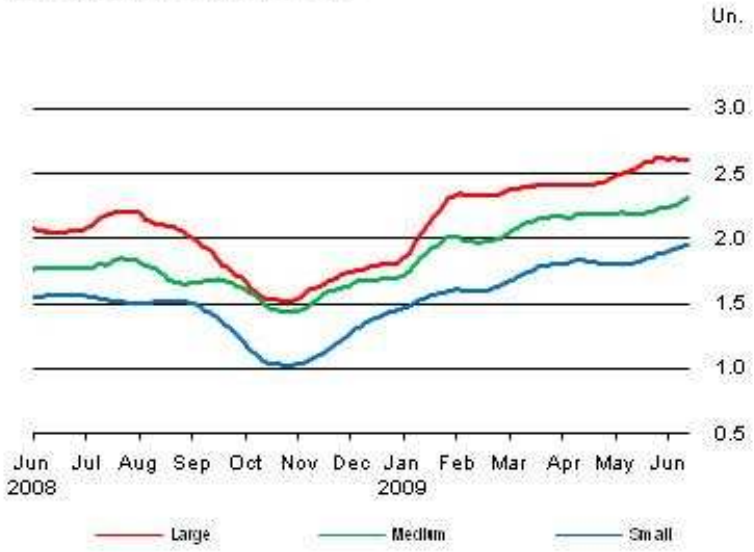
- BCB uses a Liquidity Ratio (LR = Available Liquidity / Estimated Liquidity Needs) for measuring and monitoring liquidity risk in stressed situations.
  - Available liquidity (AL) represents the amount that a bank could raise in a short period of time.
  - AL is a function of net positions on interbank deposits, repo, government bonds, foreign currency and other liquid assets.
  - Estimated liquidity needs (ELN) represents the amount a bank would need to meet the potential liquidity demands in stressed situations given its nature and open positions.
  - ELN is a function of concentration and deposits' volatility, liabilities and stressed net open positions (market risk) .

# Liquidity risk

**AL *vs* ELN**


Source: Bacen calculations

**Liquidity ratio by bank size**




Source: Bacen Calculations

# Conclusion

*"…no single model is ever likely to capture fully the diverse channels through which shocks may affect the financial system.*

*Stress testing models will, therefore, remain a complement to, rather than a substitute for broader macroprudential analysis of potential threats to financial stability."*

*IMF WP/08/206*

*Muchas Gracias!*

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