Stress Testing Practices in Banks
Background Paper

Objective of the background paper:

This discussion paper aims at laying down the main elements of the banks' stress testing methodologies, as captured by relevant international guidance, for a more informed professional dialogue between the banks and the central bank. The paper also includes the most recent approach of National Bank of Romania for banks' stress testing. A general progressive harmonization of the system-wide stress testing methodologies and institution-specific would be beneficial for ensuring intrinsic consistency. The paper raises a number of questions related to the development and execution of stress tests which could be usefully discussed within a public-private dialogue.

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by the NBR Financial Stability Department and the SPI Secretariat
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Content

The discussion paper draws on the following documents:

"Expert forum on advanced techniques on stress testing: applications for supervisors", International Monetary Fund, May 2006;

"Stress testing at major financial institutions: survey results and practice", Committee on the Global Financial System, Bank for International Settlements, January 2005;

"Financial Stability Report – 2007", National Bank of Romania, April 2007;

"Technical aspects of stress testing under the supervisory review process", Committee of European Banking Supervisors, December 2006.

I – The role and coverage of stress tests in banks

Stress testing represents a risk management tool used to evaluate the potential impact on a bank (or a group of entities) of a specific event and / or movement in a set of financial variables. It is important to note that stress testing has to be regarded as a complementary tool to major risk management instruments such as value-at-risk analysis.

The stress tests permit a forward-looking analysis and a uniform approach to identifying potential risks, generated by exceptional but plausible shocks, to individual institutions, but also to the banking system as a whole[1].

Banks perform stress tests for their internal needs in order to identify reaction of sectors to extreme events; assess the sensitivity of credit factors and approaches to extreme events in order to ensure appropriateness; identify "hidden" correlations within portfolio; support portfolio allocations decisions and strategy beyond normal current conditions; evaluate potential capital requirements under possible future credit environments; and identify benchmarks to create some awareness of the current market situation.

While in general stress testing is a tool that banks can use based on their own judgment and needs, under Pillar II of the Basel II framework, banks are expected to perform "rigorous, forward-looking stress testing that identifies possible events or changes in market conditions that could adversely impact the bank" (Box 1). In addition, banks may run stress tests at the request of the regulators or central banks, as part of system-wise stress testing exercises[2].

Box 1
Basel II guidelines for stress testing

Under Basel II, banks are required to have a routine, robust process for stress testing and scenario analysis to support their measures of capital adequacy, such as establishing events or environmental changes that could lead to adverse development, identifying the impact of such events given current positions, and determining the strategy and processes for managing their portfolios given such events.

According to the Basel II guidelines, the processes for stress testing should cover events as: economic or industry downturns, market events and increased liquidity. Likewise, under Pillar II, banks must be able to prove that the current capital levels are sufficient to resist a "range of severe but plausible events" and that different approaches are utilized in the measurement of the firm's overall capital.

In general, stress tests performed by financial institutions focus primarily on traded market portfolios as they can be marked to market on a regular basis. These portfolios include interest rate, equity, foreign exchange, commodity and credit market instruments. Stress tests on loan

[1] System-wide stress tests can complement stress tests conducted by individual institutions, by acting as a cross-check for their own analyses and by identifying weaknesses in data collection, reporting systems, and risk management processes and practices. The process itself can help to increase expertise in risk assessment by supervisors and the institutions involved, and promote cooperation and a broader understanding of risks by different stakeholders.

[2] System-wide stress tests can be based on a bottom-up approach, where banks themselves carry out individual stress tests for given scenarios and report them to regulators or central banks for aggregation or on a top-down approach, where the analysis is carried out at a centralized level and relies on data available to regulators or central banks.

books are conducted less frequently and, sometimes, by separate business units of the financial institutions.

In addition, stress testing of liquidity risk is employed regularly. On the liabilities side, funding liquidity for individual institutions is tested at various levels by most banks. Scenarios include changes in: client behavior (e.g. the withdrawal of deposits); own credit rating (e.g. a ratings downgrade); funding costs; and collateral requirements (e.g. how much collateral an institution has available and what haircut might be required). These tests may form part of an overall liquidity contingency plan and are generally conducted by the funding division of a financial institution's operations.

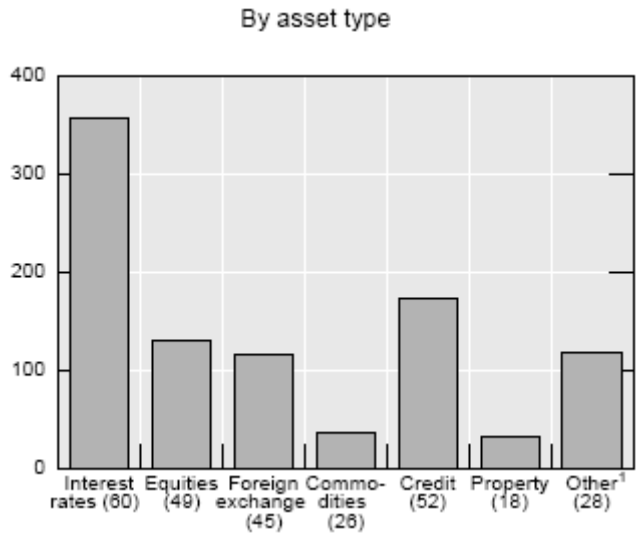
Stress testing of operational risks remains work in progress, owing primarily to data problems, although most institutions have established contingency plans. At present, financial institutions employ operational risk stress tests using internal or shared databases.

II – The banks' international practice in stress testing

A survey undertaken by the Bank of International Settlements (Committee on the Global Financial System) with 64 banks and securities firms from 16 countries on "firm-wide" stress tests that best captured important risks for their firm as at 31 May 2004, outlines the following findings:

1) ***Types of stress tests carried out by financial institutions*** - It should be noted that more than 80% of the stress tests reported in the survey were based on trading portfolios.
Nonetheless, a number of firms also reported stress tests of their loan books, funding liquidity and net interest income. Stress tests based on movements in interest rates remain the dominant type of stress test, while those based on credit, equities and foreign exchange are much smaller (Figure 1);

Figure 1
Classification of Stress Tests



2) ***The demand for stress tests*** - Reflecting the interaction between risk managers and senior management, respondents identified 123 one-off scenarios that had been requested over the preceding 12 months. The split between those requested by management and those requested by regulators was fairly even. Management requests for one-off tests related mainly to real estate, commodity prices and credit spreads. Requests by regulators, some of which were in the form of sensitivity tests, cover issues such as a fall in property prices and generic macroeconomic events.

3) ***Stress tests formulation*** - In terms of historical scenarios, firms continue to focus on a number of major events such as the market turmoil associated with the collapse of LTCM and the Russian debt default in 1998 (particularly popular for interest rate and credit tests). In terms of developing hypothetical stress tests, a large share of these tests is underpinned by scenarios based on changes in economic growth prospects. The majority of cases focus on a rise in interest rates, predicated on a stronger than expected pickup in economic growth in the industrialized countries. In contrast, a number of the emerging market scenarios consider an unexpected slowing in economic growth of the industrialized world, which then translates into widening sovereign credit spreads and a decline in stock prices.

High oil prices feature prominently in a number of stress test scenarios, including some of the economic outlook tests. The way most firms are choosing to look at the scenario of increased oil prices is to fit this into a macroeconomic framework and assess its impact on the broader economy, or, in the case of the loan book, on particular industries. The running of property price scenarios was generally confined to markets that were either experiencing a property price boom, or had been subject to quite wide fluctuations in property prices in the past. More generally, it is noticeable that, even among hypothetical scenarios with a common theme, the economic backdrops underpinning the scenarios are quite different, the parameters of interest vary, and there is a range of periods of interest.

Regarding the sensitivity tests, they focus mainly on movements in interest, while the tests based on equities and foreign exchange are much less evident. In terms of interest rates, parallel shifts predominate, though there are a number of tests involving changes in the shape of the yield curve. Similar to the previous survey, half of all tests including interest rates as a risk factor specify an increase, compared with only 14% specifying a decline.

The remainder of the stress tests is performed in both directions The weighting towards increases may reflect the net long duration position that the respondent financial institutions tend to run. Half of the equity sensitivity tests that firms are running specify a fall in equity prices; only 12% of scenarios incorporated an increase. Tested movements in currencies against the US dollar were more evenly balanced, though they generally favored a decline in the US dollar.

4) ***Stress tests' frequency*** – It has been noticed that historical and sensitivity tests are run more frequently than hypothetical scenarios: 92% of historical tests were run at least once a month; similarly, 74% of sensitivity tests were run over the same period. In contrast, a little more than half the hypothetical tests were run at least once a month, with more than one quarter of these tests run at an annual frequency. The lower frequency may reflect the more complex and situation-specific nature of hypothetical scenarios.

5) ***Treatment of credit risks*** - Interviewed banks feel that developments in this area lagged those in the market risk area by a large margin. Stress testing of credit risks by firms is largely

confined to two main types of testing: stress testing of credit spreads in trading books, such as swap spreads, corporate bond spreads and credit default swap (CDS) spreads; and the independent (and infrequent) stress testing of loan books and other credit exposures.

However, it has to be mentioned that efforts to develop integrated credit stress tests for both trading and loan books are hindered by a number of factors such as: differences in accounting treatment; a lack of trading markets for certain products; and/or the organizational structure of firms, including differences in technology platforms. At the most basic level, some firms lack the system infrastructure to generate an integrated risk profile, or have an insufficient history of aggregated data.

6) ***Integration issues*** - In general, risk managers are striving for a more integrated risk management framework. At a very basic level, the separation of risk management functions has proved problematical for some respondent financial institutions: the stress testing of trading portfolios, loan books, funding liquidity and operational risk is often undertaken in different areas of a firm, making internal consistency across integrated scenarios difficult. However, there is not universal agreement that stress tests should be common across all books, as some scenarios that are appropriate for credit books might not be appropriate for market books, and vice versa.

III – The CEBS basic guidelines for stress testing

The Committee of European Banking Supervisors (CEBS) has issued in 2006 a set of guidelines for stress testing under the supervisory review[3], meant to ensure that stress testing is actually an integral element of the institution's risk management framework. In this regard, CEBS makes the following recommendations to financial institutions:

I. Relevance depending on the size and sophistication of institutions

ST1. The Guidelines on stress testing will be applied to all institutions taking into account their size, sophistication and diversification.

II. Stress testing coverage

ST2. In line with one of the principles listed in the CEBS Guidelines on the Supervisory Review Process, institutions should identify their material risks. In general, institutions should conduct adequate and proportionate stress tests on all the risks they have identified as material.

III. Stress testing calibration

ST3. Based upon the identification of material risks, institutions should derive material risk drivers that should be subject to stress testing.

ST4. Depending on their situation, institutions should consider historical and/or hypothetical scenarios.

[3] http://www.c-ebs.org/documents/GL03stresstesting.pdf .

ST5. Stress testing should be based on exceptional but plausible events.

ST6. Stress testing should in principle be applied at the same level as the internal capital adequacy assessment process (ICAAP).

IV. Frequency and time horizon of stress testing

ST7. The frequency of stress testing should be determined in accordance with the nature of the risks to which the institution is exposed and the types of tests performed.

ST8. Institutions should determine the time horizon of stress testing in accordance with the maturity and liquidity of the positions stressed where applicable.

ST9. Under specific circumstances, supervisors may require institutions to perform ad hoc stress tests at a specific point in time.

V. Data quality and IT systems

ST10. Institutions should use appropriate and representative data when performing stress tests and the IT resources should be commensurate with the complexity of the techniques and the coverage of stress tests performed by institutions.

VI. Role of the management body and senior management; reporting and interpretation of stress testing results.

ST11. The management body has the ultimate responsibility for the overall stress testing framework. Where appropriate the management body can delegate certain aspects of this framework to specific risk committees or senior management, keeping the effective oversight.

ST12. The stress testing process should be an integral part of an institution's risk management framework, with clear reporting lines and communication in an understandable format.

ST13. Where deemed appropriate by the institution, it should take remedial measures or actions considering the level of risk exposure as revealed by stress tests and the objectives and risk tolerances defined by the management body.

ST14. Appropriate documentation should be in place to facilitate the adequate implementation of the whole stress testing framework.

VII. Review and update of stress testing methodology

ST15. Institutions should consider periodically whether stress tests are still adequate. In particular, institutions should ensure that assumptions regarding the risk profile and the external environment are still valid over time.

VIII. Stress testing guidelines by risk categories

VIII.1. Macroeconomic stress tests

ST16. In line with one of the CEBS's High Level Principles listed in the CEBS Guidelines on the Supervisory Review Process (ICAAP 8) institutions should use stress testing as one (among others) tool to assess the risks in a forward looking manner.

VIII.2. Market Risk

VIII.2.a. General principles

ST17. As part of these policies and processes, institutions should conduct stress tests for their positions in financial instruments in the trading book.

VIII.2.b Principles for institutions using an internal model for the calculation of their market risk minimum capital requirements

ST18. For those institutions using internal models for the calculation of regulatory capital requirements for market risks, supervisory requirements for stress testing remain unchanged. Their ongoing fulfillment will be considered under the SREP.

VIII.3. Credit risk stress testing

VIII.3.a. Concentration Risk

ST19. Institutions under the large exposures provisions using the comprehensive method for calculating the effects of financial collateral, or permitted to use their own estimates of LGDs and conversion factors, should identify conditions which would adversely affect the realizable value of their financial collateral.

ST20. According to Article 114 (3) of the CRD, where the results of the stress testing indicate a lower realizable value of collateral, the value of collateral taken into account for the purpose of determining an institution's LE limits should be adjusted accordingly.

VIII.3.b. Stress testing for IRB institutions

VIII.4. Liquidity risk

ST21. Institutions should regularly project cash flows under alternative scenarios of various degrees taking into account both market liquidity (external factors) and funding liquidity (internal factors).

ST22. When assessing the impact of these scenarios on their cash flows, institutions should rely on a set of reasonable assumptions that should be reviewed regularly.

ST23. Institutions should have in place adequate contingency plans in the event of the realization of a liquidity crisis.

ST24. To come up with a complete view of various risk positions, stress testing of other risk types may be usefully considered to design "alternative liquidity scenarios".

ST25. Supervisors may perform their own stress tests based on available data in their assessment of liquidity risk under SREP.

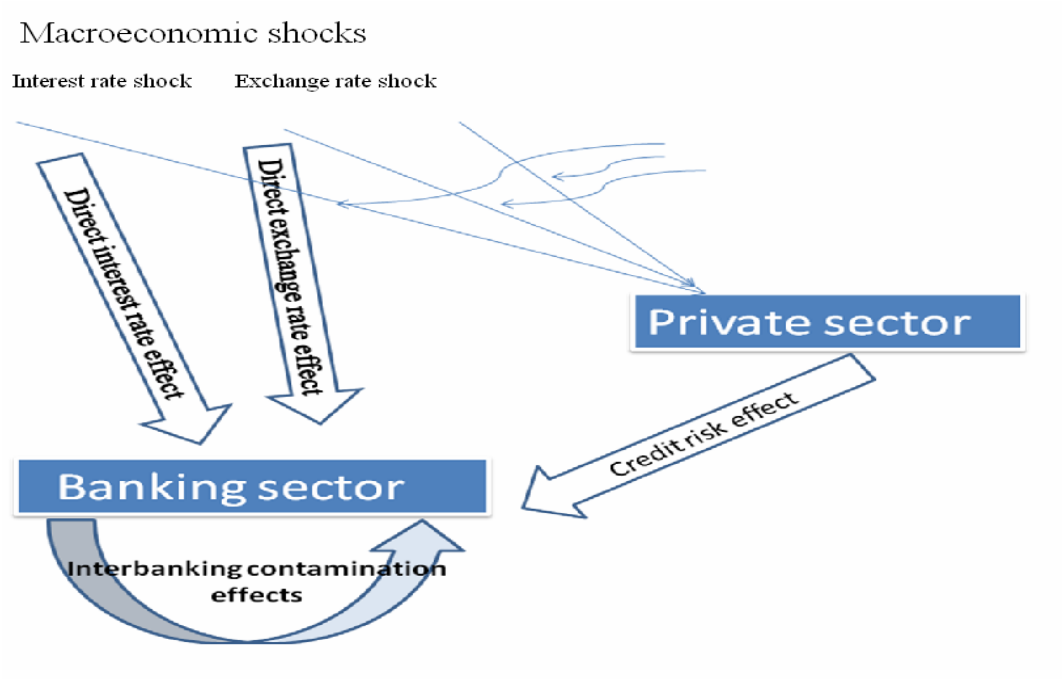
IV - Stress testing Romanian banks – NBR stress testing application methodology for assessing the vulnerabilities of the banking system

The model used by the Financial Stability Department for assessing endemic problems of the Romanian banking system is characteristic of the systemic methodologies category and shows both individual results (including those aggregated for groups of banks), as well as the mechanism of direct contagion at the banking sector level based on inter-banking exposures.

The model allows applying extreme but plausible shocks, external to the banking sector (interest and exchange rate shocks) and evaluates their effect, for the purpose of assessing the stability of the system and identifying potential weak points.

The model is based on data reported by credit institutions, so that the results may be outlined for each individual bank, for groups of banks, as well as for the entirety of the banking system.

Figure 2 – The methodological framework of the stress test model

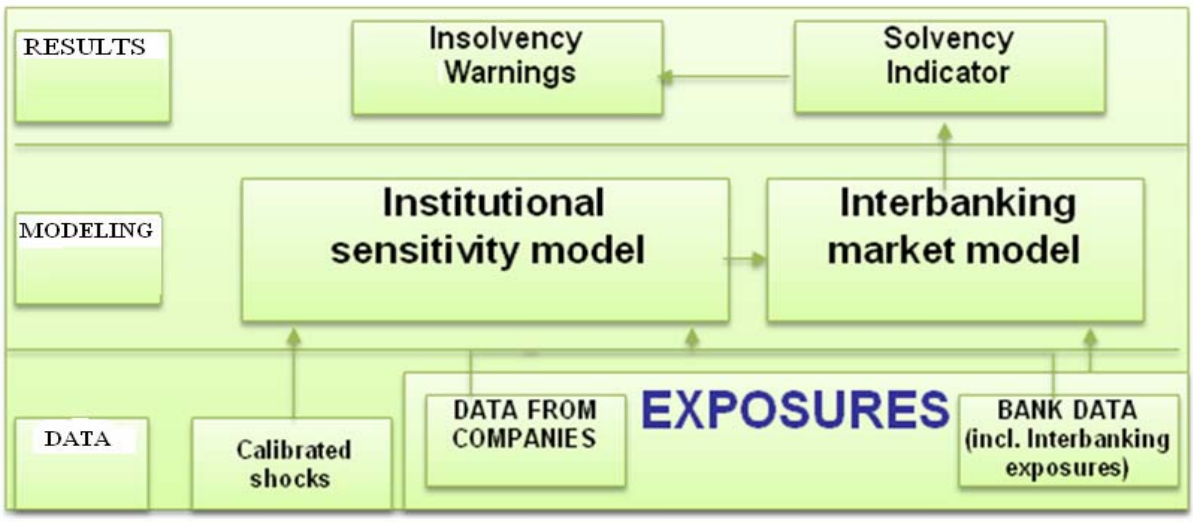


The shocks affect the banking sector both directly and indirectly. Direct shocks are represented by the unmitigated effects of economic shocks over the balance sheet and profit and loss account of banks; the indirect ones are represented by credit risk, generated by the same economic shocks, but which affect non-financial companies.

1. Conceptual model

The stress test model comprises two components: the **sensitivity methodology at an institutional level** and the **inter-banking market model**.

Figure 3 – Conceptual model of the stress testing methodology



The institutional level sensitivity methodology calculates the impact of shocks on each bank, disregarding the effect of inter-banking exposures. The estimated impact comprises both the direct and indirect effects. The scenario sums these effects.

The direct effect comprises the unmitigated effect of the exchange rate risk and of the interest rate risk on the balance sheet and the profit and loss account of credit institutions. The indirect effect is represented by the impact of changes in the exchange rate and in the interest rate through credit risk *(second round effects)* on the financial statements and the performance of credit institutions.

The calculations on which the model for exchange rate risk, interest rate risk and credit risk is based on are presented in the Annex 1.

The inter-banking market model allows for the calculation of the direct contagion effect.

The model uses information on bank solvency after the application of shocks from the institutional level sensitivity methodology. In addition, the net inter-banking exposure matrix is used. In case there are credit institutions which become insolvent, the impact of the losses these incur on other banks through the direct contagion effect is studied.

One of the advantages of this model stems from the possibility of identifying, with a good probability, of the track through which the contagion process occurs among the banking sector entities. In other words, it may be accurately determined which will be the next institution targeted by the systemic shock. This leaves the supervisory authority with more time for adopting the necessary measures for avoiding the bankruptcy of the bank targeted by the occurrence of the systemic process.

The interbank market model is an iterative process which continues until the contagion effect no longer produces bankruptcy for a banking institution.

2. Initial data of the model

The initial data of the model are the **risk factors** values and the considered **exposure** values.

This section describes the methodological options concerning the establishing of the crisis scenario and the data requirements for the considered exposures.

Establishing values for risk factors requires specifying the level of exchange rate and interest rate shocks. The adopted method corresponds with the best practices worldwide. The estimated values are set based on the medium-term macroeconomic forecast model of the Modeling and Macroeconomic Forecast Department of the NBR, on condition that, for two years, the Romanian economy registers zero growth[4]. This way, the exchange and interest rate shocks are considered coherent.

Table nr. 1 – Data requirement for the stress test model

	Exchange rate risk	Interest rate risk	Credit risk	Inter-bank market risk	Solvency indicator
Foreign exchange position	X				
Net sensitive assets separated on maturity patterns		X			
Balance sheet and profit and loss account for economic agents			X		
Foreign currency income and expenses of economic agents			X		
Debts of economic agents to the banking sector			X		
Loans granted on the interbank market by credit institutions				X	
Own funds					X
Risk weighted assets					X

Data on the considered exposures

The **foreign exchange position** represents the direct exposure of banks to the exchange rate risk. The total foreign exchange position, reflected in the prudential reporting of credit institutions (Data source: NBR Supervision Department) is used in the model. We mention that this methodological option (adopted by IMF experts) means that the foreign exchange rates are believed to be perfectly correlated (see annex). We believe that this hypothesis does not significantly affect results.

Net sensitive assets shown on maturity patterns represent the direct exposure of banks to the interest rate risk. In the chosen model (see Annex 1), banks assets and liabilities are classified according to both the type of interest[5] and according to maturities.

Net assets corresponding to client operations are used in the model. In this methodological scenario all client operations are believed to carry variable interest. The data are obtained from the prudential reporting of credit institutions (Data source: NBR Supervision Department).

[4] The definition of the exceptional scenario as well as the procedure for establishing the schocks are similar to those used by Bank of France, following the proposals of the IMF experts for undertaking the own stress testing (De Bandt şi Oung, 2004).
[5] Variable or fixed rate.

Balance sheet and profit and loss account for companies represent the main informational source base the financial performance of legal person debtors (both before and after the application of shocks) is calculated upon. Financial performance is the criterion based on which credit risk is assessed. The data are obtained from the Ministry of Economy and Finance.

Foreign exchange denominated income and expenses represent the key variables of the transmission mechanism of the exchange rate shock over the balance sheet and the profit and loss account of economic agents.

In practice, the values of these variables are necessary for each non-financial company, but we do not hold the necessary data at present. The solution suggested by IMF experts is to take into account a fixed percentage of the operational income, as well as from the operational expenses for all economic agents.

Within the model, The Financial Stability Department used an equivalent ratio with the one between exports and the GDP for the income variable and one equivalent with the ratio between imports and the GDP for liabilities.

This methodological constraint which derives from choosing a fixed percentage may be considerably diminished by obtaining individual data on the value of exports and imports for each individual economic agent from the General Customs Department.

The debts of economic agents represent the value of the gross exposure of banks to their legal person clients. Economic agents' data registered in the Banking Risk Central (BRC) are used in the model. This methodological option (adopted by IMF experts) based on the representativeness of exposures registered in the BRC for the banking system (approximately 85 percent of the value of debits was in the BRC databases in June 2006). We mention that the representativeness of the sample is even higher for medium and long term loans (approximately 90 percent). The data is obtained from the Financial Stability Department, the Banking Risks Central.

Bilateral interbank market exposure represents the main information for estimating the direct contagion effect. The data are collected in a *n x n* matrix (n being the number of banks in the system, including the Central Bank) of inter-bank loans, granted by each bank to other banks in the system. The data is obtained from the credit institutions reports (Data source: the NBR Market Operations Department).

Own funds and risk weighted assets are necessary for the calculation of the solvency indicator. The data is obtained from the prudential reporting of credit institutions (Data source: NBR Supervision Department).

3. The results of the model

The general objective of the stress test model used by the Financial Stability Department is to give a clear picture of the vulnerabilities of the Romanian banking sector. The results show the potential vulnerabilities generated by foreign exchange loans and the gaps between assets

and the liabilities corresponding to client operations, through the introduction of exceptional, but plausible shocks.

In practice, the model quantifies the level of the aggregate impact of the shocks on own funds and the new value of the solvency indicator. In addition, the model provides warnings which point to banks in difficulty (with a solvency indicator under the regulated minimal threshold). In case there are credit institutions which become insolvent[6] , the impact of losses which they might incur other banks in the system as an effect of inter-bank exposures is studied. The severity of the systemic risk is calculated as a ratio of the assets of bankrupt institutions to the total assets of the banking sector.

It should be mentioned that the results of the stress test model cannot be interpreted as having a predictable feature as the initial data are calibrated in the context of very unlikely events. The results describe the state the system would reach if the outstanding considered event were to occur.

Box 1. Results of stress test in assessing the solvency ratio as for 30.06.2006

With a view to assessing, by way of the stress test, the capability of the Romanian banking system to absorb the negative effects of exogenous shocks, the Financial Stability Department built, for 30 June 2006, a scenario envisaging a 19.1 percent depreciation of the domestic currency and a 6.1 percent point decline in interest rate, on the backdrop of a null growth over a two-year period, as an extreme, yet plausible assumption. These values were estimated based on the medium-term forecasting macroeconomic model constructed by the Macroeconomic Modelling and Forecasting Department in the NBR under the said extreme assumption.

As banks still enjoy adequate capitalization and a high level of liquidity, the stress test has revealed that the Romanian banking system is capable of absorbing the negative effects of shocks considered in the scenario. The solvency ratio after the shock, calculated at aggregate level (Table 2), shows a 14.91 percent level, higher than the 12 percent minimum level laid down in the Romanian prudential regulations in force as at 30 June 2006. The impact of the above-mentioned exogenous shocks is differently felt by the groups of banks under scrutiny[7]. Therefore, in the case of privatized banks and domestic banks, which post lower levels of solvency ratio (14.4 percent) as compared to the average calculated at aggregate level, impact of the shocks considered in the scenario is reflected in the decline of this indicator to 11.19 percent and 10.94 percent respectively.

[6] Equivalent to a solvency indicator under 2%.

[7] Banks' classification used by the Financial Stability Department in the stress test analysis takes account of the type of share capital.

Table nr. 2 – Impact of exogenous shocks on banks' solvency ratio

	Total	Banks with state owned capital	Privatized banks	Banks with domestic private capital	Subsidiaries of leading foreign banks	Other banks with foreign capital
Solvency ratio before the shock (%)	17.76	45.41	14.14	14.14	24.69	22.9
Solvency ratio after the shock (%)	14.91	42.12	11.19	10.94	22.51	19.92
Size of total impact (pp)	-2.85	-3.28	-2.95	-3.20	-2.19	-2.99

Source: NBR

As regards the estimated effect of the said shocks on the aggregate level of banks' own funds, it entailed the contraction of these funds by 19 percent. The analysis of own funds by group of banks shows that privatized banks and domestic banks might be most affected. In the case of these banks, the stress test has revealed a decrease in own funds by 23 percent and 25 percent respectively.

As a conclusion, it is worth noting that the capitalization of the Romanian banking system, albeit on a downward path, allows the further deepening of financial intermediation. In the short run, banks are estimated to be capable of absorbing the negative impact of the potential exogenous shocks that will pose no threat to the banking system.

V – Open questions for discussion

The following questions would be useful to be discussed in a public-private dialogue on stress testing:

1. How important is for Romanian banks to start developing internal stress testing models?

2. What are the main issues perceived by Romanian banks in developing and performing stress tests (data availability, methodology development, etc.)? How these problems could be overcame?

3. How are individual banks calibrating their stress testing scenarios? Would central bank guidance be useful in this regard?

4. What are the main types of stress tests used by individual banks (stress testing credit risk, liquidity risk, trading portfolios, net interest income, etc.)? How closely are they integrated with the banks' risk management processes?

5. If stress tests reveal potential risks or weaknesses, how are corrective actions undertaken? Both the experience of individual banks and the central bank would be useful in this regard.

6. Could the individual banks' stress tests be helpful in central bank bottom-up system-wide stress testing? What are the prerequisites for this approach?

ANNEX 1

The banks' stress testing methodology

1.A. The classification of stress tests

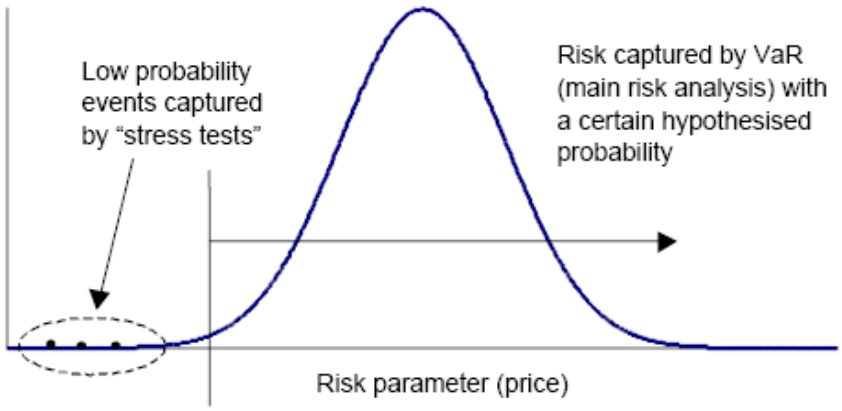
Based on their specific purposes, stress tests can be classified as follows:

a) Stress tests that capture the impact on a portfolio of exceptional but plausible large loss events

Unlike VaR, which reflects price behavior in everyday markets, stress tests simulate portfolio performance during abnormal market periods. Accordingly, they provide information about risks falling outside those typically captured by the VaR framework (Figure 4). These risks are associated with extreme price movements and with forward-looking scenarios that are not reflected in the recent history of the price series that are utilized to compute VaR.

Figure 4

Stress tests capturing exceptional but plausible events



b) Stress tests used to understand the risk profile of a firm

Financial institutions are also using stress tests to better understand their own risk profiles. A stress test of a corporate customer, for example, may reveal exposures which at the individual business unit level are not significant, but which, in aggregate, may have a large negative effect on the overall business. Alternatively, it may highlight offsetting positions in other parts of the business.

In addition, financial institutions are using stress tests - mainly sensitivity tests - to calculate the sensitivity of a firm's portfolio to changes in risk factors, such as an upward shift in a yield curve. Financial institutions also using stress tests to evaluate risks where VaR is of limited use. Examples include markets where the price impact of shocks is non-linear, such as options.

Stress testing is also used to set limits for markets with low historical volatility but which may be subject to large discrete movements, such as for pegged currencies. Risk managers have also found it useful for setting limits and monitoring new products where no historical data are available. Thus stress testing is considerably enhancing firms' overall risk management frameworks.

c) Stress tests used for capital allocation or verification

At some financial institutions, stress testing is used by senior management as a basis for informed decisions about how much risk they are willing to take and identifying where the vulnerabilities in their portfolios actually lie. Such stress tests help to evaluate their tolerance for risks - at both the institution and division level - and understand the combinations of risks that can produce large losses. This is then being linked, both directly and indirectly, to capital allocations.

The small number of firms which are using it as a direct input to the allocation of economic capital are generally adopting two different approaches. The first approach takes the form of constructing scenarios with the input of business units, and ranking them according to their relevance and plausibility. Alternatively, firms can focus on worst case scenarios, owing to concerns about the possibility of scenario manipulation and difficulties with aggregation and the distribution of the diversification benefit.

A much larger number of firms are using stress tests as a diagnostic tool to verify the adequacy of established limits and assigned capital across portfolios and enterprises. Thus while some other methodology, such as VaR, is used in the initial allocation of economic capital, stress testing is employed to ensure that due consideration is given to the impact of a stress-type event.

d) Stress tests used to evaluate the business risk

One of the innovations in stress testing is its application to business plans. In some financial institutions, a stress event is looked at in the context not only of changes in the value of on- and off-balance sheet items of the firm, but also of the effect that it has on revenue sources over subsequent years.

This overlay assists management in deciding whether this type of event is a threat to their underlying business and whether the capital supporting the business is appropriate. In some cases, for example, financial institutions are testing the effect on their profitability of a long period of low interest rates.

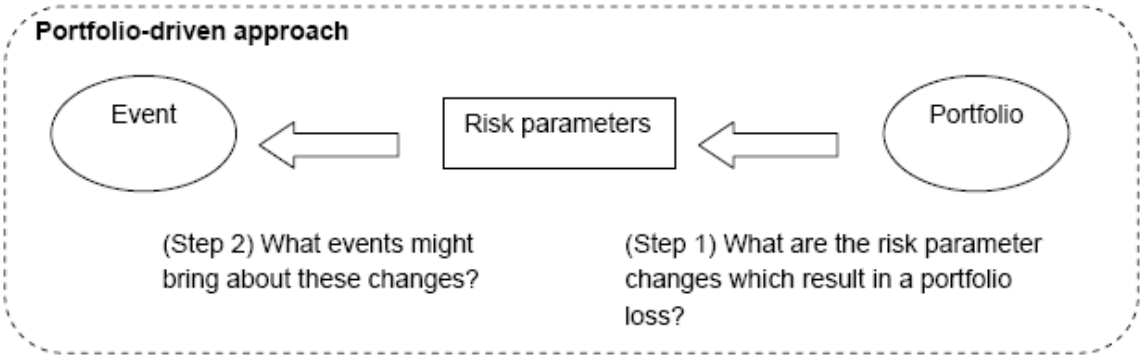
1.B. The formulation of stress tests

Stress tests generally fall into two categories - **scenario tests** and **sensitivity tests**.

A. Scenario stress tests are generally based on either a portfolio-driven approach or an event-driven approach (Figure 5). In a stylized version of the portfolio-driven approach, key risk managers in a financial institution initially discuss and identify the vulnerabilities in the portfolio currently held by the firm. Having determined these vulnerabilities, risk managers work backwards and formulate plausible scenarios under which these vulnerabilities are stressed. For example, for firms that identify interest rate risk as their main vulnerability, stress tests will be formulated around movements in interest rates.

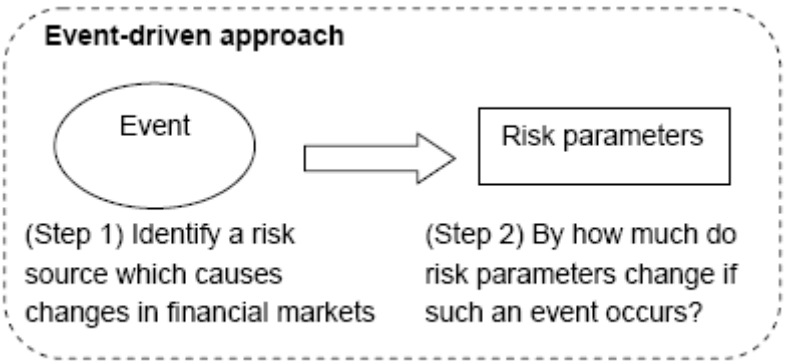
Figure 5 a

Approaches to scenario formulation



In contrast, in **event-driven scenarios,** the scenario is formulated based on plausible events and how these events might affect the relevant risk factors in a financial institution's portfolio (Figure 5 b). These scenarios are often formulated at the request of senior management and are sometimes motivated by recent news (e.g. an increase in oil prices). Correlations across asset classes are normally implicit, although some financial institutions will also examine the implied correlations in order to ensure that the results are not overly conservative.

Figure 5 b



Under either approach, events can be categorized as either **historical** or **hypothetical scenarios**. Historical scenarios rely on a significant market event experienced in the past,

whereas a hypothetical scenario is a significant market event that has not yet happened. The choice of historical or hypothetical scenario depends on a number of factors, including the relevance to the portfolio of historical events, as well as the resources - particularly in terms of time and labor needed for a particular exercise.

Historical scenarios tend to be more fully articulated as they reflect an actual stressed market environment and therefore involve fewer judgments by risk managers. The drawback of the historical scenarios is that they may not reflect the background of interest and the new ways in which financial risk is occurring.

Hypothetical scenarios are potentially more relevant to the risk profile of the firm, but they are labor-intensive and involve considerably more judgment. Accordingly, management- and business-level support for hypothetical scenarios is particularly important. Therefore, some financial institutions invite senior managers, front desks and economists to these discussions in order to secure objectivity and support for the scenario-setting process. Macroeconomic models are sometimes also employed.

In practice, *hybrid scenarios* are quite common, i.e. hypothetical scenarios which are informed by historical market moves, but which are not necessarily linked to a specific crisis. The use of historical episodes assists in the calibration of the size of price changes and other hard-to-set factors, such as the possible effects on market liquidity.

More generally, practitioners repeatedly referred to the trade-off between realism and comprehensibility - the more fully articulated the scenario is, the more complicated and less comprehensible the contents may become - as well as the importance of a qualitative discussion to begin the process.

B. Sensitivity tests are also used by financial institutions regularly.
One of the simpler types can be one whereby risk parameters are moved instantaneously by a unit amount, such as a 10% decline or a 10 basis point rise. These tests can be run relatively quickly and are used by senior managers in a number of institutions to form a first approximation of the impact on the firm of a move in a financial variable. As a result, sensitivity tests are widely used at the trading desk and business line level.

A second group of sensitivity tests examines historical movements in a number of factors. These tests can take several forms. One type is based on worst case movements for each risk factor over a set historical period, e.g. the worst change in the last 10 years for interest rates and equities. This is objective and provides a maximum loss, but the unrealistic combination of risks - the time periods for each risk factor do not have to be coincident - may result in a loss that is overly pessimistic.

ANNEX 2

2.A. EXCHANGE RATE RISK (direct effect)

The exposure of a bank concerning the variation of the price of a foreign currency is determined by the foreign exchange position. The bank's foreign exchange position generates profit or loss depending on the evolution of the exchange rate. Thus,

	Exchange rate increase	**Exchange rate decrease**
Short foreign exchange position	**loss**	profit
Long foreign exchange position	profit	**loss**

The dimension of the loss of a bank incurred by the foreign exchange price is obtained by multiplying the individual adjusted foreign exchange position and the variation of the exchange rate:

$\Omega_i = VIA_i \times \Delta CS_i$	Ω_i - loss/ profit in the *i* foreign currency VIA_i – individual adjusted foreign exchange position ΔCS_i -exchange rate variation

The model uses the total foreign exchange position as exposure, and the exchange rates are believed to be perfectly correlated. The total foreign exchange position is measured as being the highest absolute value between the total of long adjusted foreign exchange positions and the total short adjusted foreign exchange positions, not for each foreign currency separately.

2.B. INTEREST RATE RISK (direct effect)

Interest rate risks originate in the gap between variable interest rate assets and liabilities for each maturity pattern individually. The model calculates the variation in the net income from interest following changes in the interest rate. The impact of an interest rate change is quantified using the re-pricing gap.

2.C. CREDIT RISK (indirect effect)

The rationale of highlighting the indirect effects due to FX and interest rate on the solidity of commercial banks through credit risk is based on the impact of the evolution of these factors on companies, which can be later found in the provisions in the financial statements of banks. It should be noted that the estimation of the indirect effect is done solely on the basis of debts of non-financial companies to the banking sector, due to the difficulty of collecting and processing similar information on natural persons up to this point.

The interest rate and FX fluctuations produce changes in the structure of the balance sheet and the profit and loss accounts of companies, generating changes in their financial performance. Based on the financial solidity of debtors, banks estimate provisions, using the loan classification. Following the depreciation of the national currency (or an increase in the interest rate) there are signs of worsening of the debt service of counterparties and therefore the bank will reach higher levels of provisioning.

An increase in provisions further generates an increase in expenses and therefore lower profits and a decrease in the bank's own funds.

The indirect impact is calculated as a difference between the provisions estimated before and after the introduction of shocks.

Finally, the solvency indicator for each individual bank is calculated through the aggregation of the effects of the three risks:

The calculation formula is:

$$SI_{ST} = \frac{OF + TOTAL\_IMPACT}{NE + TOTAL\_IMPACT}$$

IS_{ST} – solvency indicator after shocks
OF – own funds before applying the model
NE – net exposure before applying the model

In case the solvency indicator is below the regulated threshold the model issues a warning. It also shows the banks which become insolvent at that point.