UDK: 336.76
Paper received: March 21, 2023
Paper accepted: April 28, 2023

Journal of Entrepreneurship and Business Resilience
Year VI • Vol 6, No 1.
pp. 100-111

SCIENTIFIC REVIEW

MEASURING SYSTEMIC BANKING RESILIENCE: A STRESS TESTING APPROACH

VUČINIĆ Dragan,
College of Modern Business, Belgrade, Republic of Serbia
e-mail: prof.dv@mts.rs

ŠEGRT Slobodan,
Faculty of Business Studies and Law,
"Union University - Nikola Tesla", Belgrade, Republic of Serbia,
e-mail: slobodan.segrt@fpsp.edu.rs

ABSTRACT

In accordance with regulatory requirements, banks should perform stress tests on their regulatory basis as well as their economic capital. The variety of stress tests is not crucial and is most often a technique, as an input for determining the form and size of the required bank capital. Another reason for differentiating stress tests is the division into performed and non- performing loans, as their respective capital requirements follow different rules. Special stress tests will be made for defaulted loans, loss provisions. Therefore, the following cases should be considered for stress testing: - Executed loans get a lower grade but achieve executed loans - economic capital assessment includes updating risk parameters;- Performed loans are downgraded and become non-performing loans - commissions must be assessed including net exposures calculated with LGD; and - Deterioration of non-performing loans - commissions must increase based on changing LGD (decrease in LGD).A typical way of categorizing stress tests can be taken from market risks. The most important way of classifying stress tests is through methodology. One can distinguish stress tests with respect to techniques in statistics and model-based methods, and with consideration of conceptual elaboration in sensitivity analysis and scenario analysis.

Keywords: *Stress, credit portfolio, sensitive analysis, resilience, scenarioanalysis, executed loans, risk.*

JEL classification: E51, B41, H81

INTRODUCTION

In accordance with regulatory requirements, banks should perform stress tests on their regulatory basis as well as their economic capital. The diversity of stress tests is not key and the most important way to classify stress tests is through methodology. One can distinguish stress tests with respect to techniques in statistics and model-based methods, and with consideration of conceptual elaboration in sensitivity analysis and scenario analysis.
While the scenario analysis is based on the modeling of economic variances, the sensitivity analysis is statistically determined. The common ground for all these specifications is that they require stress testing to perturb the risk parameters.
They can be basic risk parameters (EAD, LGD, PD). Regulatory capital testing loans. However, they can also be parametric used in the portfolio model such as the correlation of assets or the dependence and systematic of risk drivers is the most common technique, as an input for determining the form and size of the required bank capital.

CLASSIFICATION OF STRESS TESTS

In accordance with regulatory requirements, banks should perform stress tests on their regulatory basis as well as their economic capital. The variety of stress tests is not crucial and is most often a technique, as an input for determining the form and size of the required bank capital.
Another reason for differentiating stress tests is the division into performed and non-performing loans, as their respective capital requirements follow different rules. Special stress tests will be made for defaulted loans, loss provisions. Therefore, the following cases should be considered for stress testing [1]:

- Executed loans get a lower grade but achieve executed loans - economic capital assessment includes updating risk parameters.
- Performed loans are downgraded and become non-performing loans - commissions must be assessed including net exposures calculated with LGD; and
- Deterioration of non-performing loans - commissions must increase based on changing LGD (decrease in LGD).

A TYPICAL WAY OF CATEGORIZING STRESS TESTS CAN BE TAKEN FROM MARKET RISKS

The most important way of classifying stress tests is through methodology. One can distinguish stress tests with respect to techniques in statistics and model-based methods, and with consideration of conceptual elaboration in sensitivity analysis and scenario analysis.
While the scenario analysis is based on the modeling of economic variances, the sensitivity analysis is statistically determined. The common ground for all these specifications is that they require stress testing to perturb the risk parameters [2].
They can be basic risk parameters (EAD, LGD, PD). Regulatory capital testing loans. However, they can also be parametric used in the portfolio model such as asset correlation or dependence and systematic of risk drivers.
A simpler model of performing stress tests is the direct modification of risk parameters and belonging to the class of sensitivity analysis. The goal is to study the impact of the most important parameter changes on portfolio values. For this method, one or more risk parameters are simultaneously increased, and evaluations are made for this new constellation. Increasing parameters should depend on statistical analysis and expert opinion. As all these stress tests are not related to any event or context and they are performed for all loans of the sub-portfolio, without taking into account individual assets, they are considered for flat or uniform stress tests.
The most popular are the flat stress tests for the probability of default, where an increase in the default rate can result from the transition rate between rating levels. One of the advantages is the possibility of their simultaneous execution by different financial institutions and the collection of these results in order to check the financial stability of the system.
Such tests are tailored to check space and buffer capital requirements, but they do not mean any help for portfolio and risk management. The model based on the stress test method includes the observed drivers of risk, and in particular macroeconomic variables to represent changes in risk parameters.
An important method is related to the existence of a model (mostly based on econometric methods) that explains the variations of risk parameters through their changes. A distinction can be made between univariate stress tests, which are defined using the isolated risk factor itself, and multivariate stress tests, where several factors are changed simultaneously. Risk factors can have quite different impacts on risk parameters across a portfolio. Changes in risk factors can be accompanied by higher as well as lower levels of risk parameters.

For example, an increase in the price of an input such as oil or energy may have a negative effect on the probability of default (PD) in automobiles or any other energy-intensive industry but may have a positive effect on the (PD) in the producing and selling country. these inputs. By using univariate stress tests, banks can study specific and particularly important influences on their portfolios. As a consequence, they can be used to determine the weakness of the spot in the portfolio structure. Furthermore, univariate stress tests represent a different type of sensitivity analysis, now under the term risk factors instead of risk parameters [3], [4].

The price is relying on additional statistical analyses, adopting or setting up other models described by the correlation of included (included) risk factors. This is done in a framework known as scenario analysis where hypothetical historical and statistical scenarios are distinguished. This results in the determination of stress values for risk factors that are used to assess the stress values of risk parameters. In connection with the development of the scenario, we can determine the bottom-up approach and top-down approaches. Bottom-up approaches intend to use the results of sensitivity analyzes to determine the sensitivity of risk factor dependencies as a starting point. As a result, we get the answer that the scenario that includes risk factors has a greater impact on risk parameters. For example, for a bank focused on real estate, GDP, employment rate, inflation rate, capacity utilization in countries where they operate will be more important than oil price or exchange rate [11].

Therefore, it is necessary to strive for scenarios that include important risk factors. The top-down approach starts with a chosen scenario such as the terrorist attack in New York on September 11, 2001 and requires an analysis of the impact of this scenario on the portfolio. The task in this situation is to determine those tests that can cause dramatic and significant changes.

Historical scenarios are typical for applying a top-down approach. They refer to extreme constellations of risk factors that have been observed in the past and in most cases can be linked to historical events and crises. They are transferred to the current situation and the portfolio. This can be seen as a disadvantage of this approach since the transfer values will no longer be realistic. Another disadvantage is that it is not possible to determine the probability of the scenario happening. Also, statistically determined scenarios may depend on historical data. They are based on a common statistical distribution of risk factors. In this approach, the scenario can be determined through the quintiles of such distributions. Since it is very difficult to produce a suitable distribution especially a pooled distribution, it is an advantage that it is possible to estimate the probability of a scenario occurring if this is given through the

complementary confidence interval used for the quintiles. The existence of such probabilities of occurrence allows the calculation of expected extreme losses that can be used to estimate economic capital. An important point of this approach is to create a suitable distribution. Finally, there is a hypothetical scenario that focuses on possible rare events that can have an important impact on the portfolio.
An important issue is the representation of the consequences of risk factors. To assess this expert opinion, it is necessary to associate macroeconomic modeling of dependent risk parameters with risk factors. If macroeconomic parameters are not part of the input to determine the risk parameters that are stressed, there are three steps required for macro stress tests.
First, it is necessary to determine the dependence of risk parameters on risk factors in the model. Second, it is necessary to choose values for risk factors that are presented for stress events. Since it is important to determine the causal relationship between risk factors and stress events, it is necessary to carefully implement assessment methods and validation of results in the research.
The disadvantage of a hypothetical scenario should be reduced by determining the probability of its occurrence. On the other hand, this is the main advantage of advanced scenarios (forward looking) which will not necessarily reflect historical events. Furthermore, hypothetical scenarios represent an important addition to VaR-based risk portfolio analysis and are a widely accepted tool for portfolio management.

Inform stress tests

The most well-known stress tests in banks are uniform stress tests specifically for probability of default (PDs). The aim is to use the increase in the probability of default to calculate economic or regulatory capital.
In a simpler case there is a flat (no interest, no interest, stretched) rate increase for all probabilities of non-payment[1] of debtors and/or countries, but generally speaking, the change may depend on the rating, branches, countries, regions, etc. There are several ways of deriving default probability stress:
The first way is to analyze the data on unpaid payments, taking into account the dependence on ratings, branches, countries, regions, etc. This data can come from bank portfolios or from rating agencies. Determination of deviations of the default degree from the probability of non-payment.

[1] Such stress tests are often used by Central Banks to test the stability of the financial system. In studies at the Deutsche Bundesbank in 2016, probabilities of default (PD) increased by 30 to 60 percent. These changes roughly correspond to downgrades of Standard & Poor's ratings by one or two notches.

Another way to determine such variations requires analysis of these spreads (extensions in relation to credit derivatives).
PD stress (probability of default) is derived from PD to which is added the standard deviation or some other relevant characteristic from the distribution of the deviation. It may be argued that it is a good idea to use quintiles (any value of a random variable drawn from a single distribution for a given value or a group of equal frequencies of occurrence of the random variable) in the determination, but the quality and validity of the distributions is an issue with this approach.
The use of migration rates (referring to the bank's own portfolios or those coming from rating agencies) to determine the transition between rating levels. These transitions may depend on the bank, country, etc.
As an intermediate step, stress migration matrices can be generated from rating increases, conditional on economic deterioration.
The following can be derived from each original rating class, one stress rating class by quintile evolution, or any other characteristics of the transition probabilities. Consequently, it is possible to set up a stress test based on the rating class. Now the stress test consists of replacing the original rating classes with stress rating degrees.
Alternatively, it is possible to replace the original PD values (probabilities of default) with those PD values from the stress ratings.
A different approach uses stress migration rates. Depending on their derivation, they can be calibrated to become transition probabilities. Then they can be used in the calculation of expected PD values for each rating class that will play the role of stress-tested PD (probability of default).
We should make a decision about which option we will choose to determine the PD stress based on the data available for statistical processing. Also, expert opinion can be part of the process to create stressed PDs (probability of default). It makes sense to consider the deviations that can be caused by the rating processes due to the dependence on the input parameters. This can lead to additions in the generation of stressed PDs (probability of default). The suitability of stress probabilities of default or stress ratings may depend on the availability of stress tests.
Depending on the portfolio model, the dependence of the PD (probability of default) size on the bank or country in the PD (probability of default) class can be a problem. A criterion in favor of stress rating classes is the inclusion of default avoidance. This stress analysis can lead to the allocation of loans to classes belonging to non-performing portfolios. They can be treated

respectively i.e., instead of capital requirements, a commission may be calculated.
In case the sizes of PDs are stressful, then instead of rating classes, we should first consider the stress of the size of PDs in the portfolio and then stress the transition rates in the uncompleted parts of the portfolio. In this context, Monte Carlo simulation can be used to estimate capital requirements for performing (achieved) and commissions for non-performing (nonperforming) parts of the portfolio.
Transition rates in the non-realized portfolio most often correspond to default rates and can be subjected to stress analysis in the same way and by the same methods as the sizes of PDs (probabilities of default). The same applies to the migration rates between rating grades that we use in some portfolio models.
Flat stress tests on LGD sizes can be based on statistical processing in the case of total loss data. This approach determines a study of deviations in loss rates that is analogous to the one we have in the case of default rates.
Expert opinions can play a bigger role. One example of an interesting stress test can be found in the significant drop in real estate prices in some markets.
A uniform stress analysis of EAD sizes is often not relevant. Exchange rate deviations can be seen as the most important influencing factors on deviations of magnitudes over EAD in relation to expected values. It is recommended to investigate these effects individually.
In uniform analysis, the stress parameters used in the portfolio model are based on the opinion of experts, since it is very difficult to determine and statistically verify the effect of these parameters on the deviations of the expected or predicted default values or losses.
While it is obvious that the determination of suitable parameter values in uniform testing involves only one parameter, it is clear that it becomes very difficult to simultaneously include several parameters in the analysis process.
Experience based on historical observation and expert opinion is crucial in these situations.

SENSITIVITY ANALYSIS OF RISK FACTORS

Risk factor sensitivity analysis is a type of stress testing that is very popular in the risk market where risk factors can be easily identified but can also be seen as a basis for scenario analysis. This follows from the crucial task of adopting appropriate risk factors and introducing valid macroeconomic models in determining risk parameters and risk factors that represent state or business cycles [10]. Of course, there are obvious candidates for risk factors such as interest rates, inflation rates, stock indexes, credit spreads, currency rates, gross

domestic products, oil prices, etc. Others may depend on portfolios in financial institutions and may be recorded by good risk managers. The use of time series in risk factors in the respective markets as well as in the deviation of risk parameters and standard methods of statistical processing such as discriminant analysis leads to an attempt to develop a macroeconomic model and determine the series of factors that are suitable to describe the evolution of risk parameters.
The typical effect of this stress on risk parameters or directly on credit loss characteristics is modeled through the use of linear regression. One of the problems is determining the extent to which risk factors can and must be limited while the model remains viable.
The objective as well as the benefit of sensitivity analysis lies in uncovering the risk factors that have the greatest effect on portfolio risks in terms of VaR or any other factors used in the evaluation of unexpected losses.
Stressing is a process analogous to a uniform stress test by risk parameters. Stress values for each individual risk factor are fixed based on statistical analysis or expert opinion. The consequences for risk parameters are calculated with the help of macroeconomic models and modified values of risk parameters that are ultimately used in the evaluation of capital requirements or conditions. Risk factors that have an effect on several risk parameters and that also play a role in stress testing market risk may be of particular interest or importance [5].
Sensitivity analysis can be used in the verification of uniform stress testing by checking the extent of parameter changes due to sensitivity analysis used in flat stress tests.
Moreover, the sensitivity analysis can be considered as a pre-selective scenario: only those historical or hypothetical scenarios that include risk factors show some significant effects in the sensitivity analysis and are worth further consideration.

SCENARIO ANALYSIS

Historical Scenarios

Specific relevant risk factors can be considered through historical scenarios, statistically determined scenarios and hypothetical scenarios. All three approaches to risk factor analysis
should be viewed as mutually complementary methods.
Historical scenarios are easy to implement since it is only necessary to transfer risk factor values corresponding to historical events under current conditions.

In most cases in absolute or relative form) which is accompanied by the insertion of an event and implies that it applies to the actual evaluation.
The following events are the most popular in historical scenarios:

- Oil crisis 1973/74;
- Stock market crash (Black Monday 1987);
- Global bond market crash 1994, Asia 1998);
- Terrorist attacks (New York 9/11 2001, Madrid 2004) or wars (Gulf War 1990/91, Iraq War 2003, Ukraine War 2002);
- Currency crisis (Asian 1997, European exchange rate crisis 1992, Mexican peso crisis 1994);
- Emerging markets crisis, LTCM footnote error or/and Russian default in 1998. [2]

The implications of historical scenarios and their analysis for risk management [6], can be limited by hindsight approaches and there are good reasons to use them [7].
First of all, there are interesting historical scenarios that have not yet been considered since they happened as incidents, ie. the probability of their occurrence can be evaluated as very small.
Examples of such cases can be found in the coincidence of the LTCM failure and the Russian default in 1994, the year of the global crash in bond prices.
It can be accepted that both events will contribute very little to VaR at the time of their occurrence due to the extremely low probability of the joint occurrence of each of the individual incidents. [3]
It is very important to consider stress testing and scenario analysis based on historical scenarios. On the one hand, the latter can be used to check the validity of uniform stress tests and sensitivity analysis; on the other hand, they can be very helpful in setting up hypothetical scenarios. Therefore, the analysis of historical scenarios offers a unique opportunity to learn about the joint developments in the main changes of various risk factors and the interaction of several types of risks, for example, the effect of credit risk events on liquidity risks [8].

[2] LTCM Long-Term Capital Management Hedge Funds LTCM now has huge but well-diversified risk positions that have impacted in 1998 with the rise in risk in the broad market reinforced by the Russian crisis. This led to large losses in equity value (the value of common shares). Only the united cooperative of several American investment banks under the leadership of the Federal Reserve could have avoided the complete avoidance of the payment of the obligations of the funds and the systemic crisis of the world financial system.

[3] The movement of the yield of Government bonds in America, Europe and Japan is most often seen as uncorrelated, yet their combined movement at most in 1994 can be seen as an extremely unexpected event.

Statistically Determined Scenarios

The analysis of the scenarios that we choose based on the distribution of risk factors plays a special role in the analysis of the scenarios. They are not directly related to other types of scenario analysis. In this approach, the focus is on the distribution of (combined) risk factors.
Distributions generated from historical data may be insufficient. It is much better to use conditional distributions applied in time (moment) stress testing This can be a real problem. Only in the case of reliable distribution factors should this approach be used.
If losses conditioned by quintiles are expected and evaluated for their interpretation, as unexpected losses and treating them as conditions or requirements of economic capital, then the distribution of risk factors should also be adapted to given economic situations.

Hypothetical Scenarios

Hypothetical scenario analysis is the most developed method of stress testing in risk management. It can be combined with the experience of analyzing relevant risk events together with expert opinion in the portfolio as well as economic conditions and statistical capabilities.
The implementation of the hypothetical scenario is analogous to that of the historical scenario. The only difference is in the selection of risk factor values. The selection can be based on/or derived from historical data, but expert opinion can also be used to fix the relevant values. The choice of scenario should maintain the focus of the portfolio when performing the stress test and should also have the most sensitive values of the portfolio as target values.
Common scenarios (along with the risk factors involved) are as follows:

- Significant increase in oil prices (increase in oil prices, reduced annual GDP growth, to describe weakened economic growth, increase in consumer prices, etc.);
- The basic growth of interest rates (indices that describe the instability of the financial market, the increase in spreads, the decrease in annual GDP growth that defines the weakening of economic growth, the instability of currency rates, consumer indices, etc.);
- Decline in global demand (reduced annual GDP growth, stock market indices, consumer indices, etc.) [9]; and
- Emerging market crisis (reduced annual GDP growth that describes the weakening of economic growth, widening of sovereign credit spreads, falling stock prices, etc.).

Hypothetical scenarios have the ability to account for the latest developments, news and perspectives. The scenarios include market parameters such as interest rates, and these are well integrated in combination with stress tests on market or liquidity risks Liquidity.

CONCLUSION

In accordance with regulatory requirements, banks should perform stress tests on their regulatory basis as well as their economic capital. The variety of stress tests is not crucial and is most often a technique, as an input for determining the form and size of the required bank capital.
The most important way of classifying stress tests is through methodology. One can distinguish stress tests with respect to techniques in statistics and model-based methods, and with consideration of conceptual elaboration in sensitivity analysis and scenario analysis.
While the scenario analysis is based on the modeling of economic variances, the sensitivity analysis is statistically determined. The common ground for all these specifications is that they require stress testing to perturb the risk parameters.
They can be basic risk parameters (EAD, LGD, PD). Regulatory capital testing loans. However, they can also be parametric used in the portfolio model such as asset correlation or dependence and systematicity of risk drivers.
A simpler model of performing stress tests is the direct modification of risk parameters and belonging to the class of sensitivity analysis. The goal is to study the impact of the most important parameter changes on portfolio values. For this method, one or more risk parameters are simultaneously increased, and evaluations are made for this new constellation. Increasing parameters should depend on statistical analysis and expert opinion. As all these stress tests are not related to any event or context and they are performed for all loans of the sub-portfolio, without taking into account individual assets, they are considered for flat or uniform stress tests.
The most popular are the flat stress tests for the probability of default, where an increase in the default rate can result from the transition rate between rating levels. One of the advantages is the possibility of their simultaneous execution by different financial institutions and the collection of these results in order to check the financial stability of the system.
Such tests are tailored to check space and buffer capital requirements, but they do not mean any help for portfolio and risk management. The model based on the stress test method includes the observed drivers of risk, and in particular macroeconomic variables to represent changes in risk parameters.

An important method is related to the existence of a model (mostly based on econometric methods) that explains the variations of risk parameters through their changes. A distinction can be made between univariate stress tests, which are defined using the isolated risk factor itself, and multivariate stress tests, where several factors are changed simultaneously.

REFERENCES

[1]. Engeimann B., Rauhmeier R., (2016), The Basel II Risk Parameters Estimation, *Validation and Stress Testing*, Dresdner Bank, Berlin.
[2]. Alastair L., (2013*), Mastering Risk Modeling*, First Edition, London, England.
[3]. Brealey R., (2011), *Principles of Corporate Finance*, McGrew-Hill, New York.
[4]. Gitman L., (2011), *Principles of Managerial Finance*, Harper Collins Publishers, New York.
[5]. Mishkin F., (2020), Banking and Financial Market, Third edition, Collins Publishers.
[6]. Bessis J, (2012), Risk Management in Banking, Amacom, London, Greuning H., (2013), Analyzing and Managing Banking risk, Second Edition, The World Bank.
[7]. Kirillova, O., Yuryevna, E., Sergeevna, E. (2021), Risk management of derivative financial instruments, *International Review*, number 1-2, page 10-16., Faculty of Business Economics and Entrepreneurship, Belgrade,
[8]. Matz L., (2007), Liquidity Risk Measurement and Management, John Wiley Sons,
[9]. Radović-Marković M, Vesić ,T., Dekić, M. (2022), Monetary and financial cash flows as drivers of foreign direct investments at the global level, *International Review*, number 1-2,page 10-16., Faculty of Business Economics and Entrepreneurship, Belgrade.
[10]. Radović Marković, Mirjana & Dukanović, Borislav (2022). *Macroeconomics of Western Balkans in the Context of the Global Work and Business Environment*, Charlotte, US: Information Age Publishing (IAP), Inc., United States.
[11]. Radović-Marković, M. (2018) Resilience of Small and Medium-Sized Enterprises in terms of Globalization: Evidence of Serbia. *Journal of Entrepreneurship and Business Resilience*, 2, pp. 5-15.