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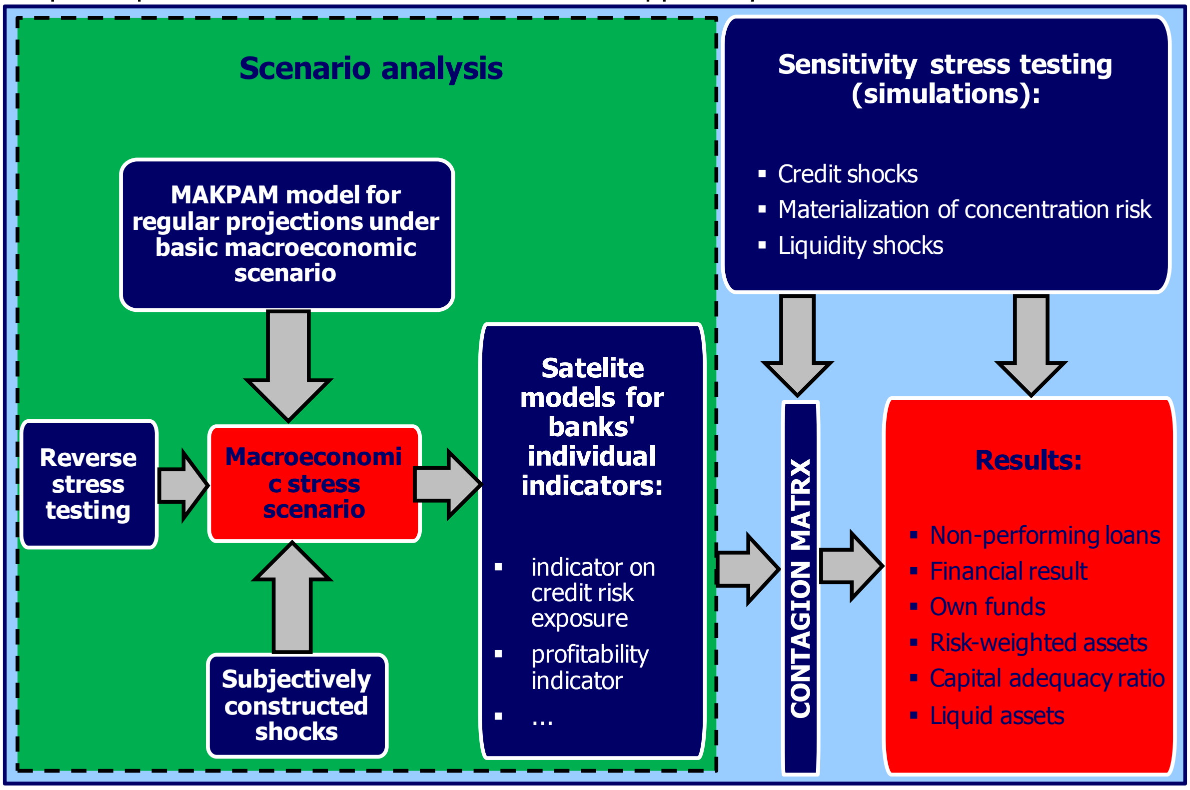
Annex 1 Stress testing of the banking system of the Republic of Macedonia using scenario analysis of and contagion matrix

For testing the resilience of the Macedonian banking system to various extreme but plausible shocks, the National Bank of the Republic of Macedonia conducts sensitivity tests (every three months)[1], and once a year it conducts so-called scenario analysis for the banking system, which assumes unfavorable trends in the macroeconomic environment. Moreover, the scenario analysis also includes development of so-called contagion matrix designed to examine any spillover of problems from one bank to another, and from the banking system to the insurance companies and fully funded pension funds.

Figure 1
Simplified presentation of stress test framework applied by the National Bank[2]



Source: Developed by the National Bank staff.

Below, there is a brief description of each stage of the scenario analysis, and the end of this annex presents the results of the latest scenario analysis developed for the domestic financial system.

Construction of stress scenarios

For the purpose of scenario analysis, the National Bank has produced at least two scenarios at various levels of extremeness. Stress scenarios usually describe extreme but

[1] For more details on individual sensitivity tests and their outcomes see the reports on risks in the banking system of the Republic of Macedonia, prepared on a regular quarterly basis. The reports are available at http://www.nbrm.mk/?ItemID=D38D33E964D84D45B2E6EFBCB996848B and http://www.nbrm.mk/?ItemID=6421C6EE3906F448B7E7A8E978BA933A. Specific details regarding the manner of preparation of individual sensitivity tests can be found below.

[2] The National Bank of the Republic of Macedonia prepared a document that defines and describes in detail the methodology related to the applied stress-test framework: Methodology for stress tests conducted by the Financial Stability Department at the National Bank of the Republic of Macedonia.

plausible shocks/movements in the internal and/or external, primarily macroeconomic, environment of the financial system. The period covered in the stress scenarios extends for at least two years, but can be assumed and sudden, one-off adverse movements in the macroeconomic environment, when the stress scenario virtually has no time dimension. The type and intensity of extreme shocks assumed in the scenarios can be an expert judgement or empirically simulated (using appropriate econometric models). However, they are often a construction of two possibilities when there is an expert assumption of unfavorable trends in a number of macroeconomic variables (usually from external macroeconomic environment), and proper quantitative models help model/design the movement of other macroeconomic variables depending on the determined empirical interdependence (among those that are expertly "designed" and those that are empirically modeled).

The stress scenario can be exclusively historical, when mirroring the dynamics of movements of macroeconomic variables observed during crises in the past, but also including hypothetical scenarios. It is recommended that the latter be specially prepared for the Macedonian economy, as an extreme pessimistic version of the baseline macroeconomic scenario, which underlies the regular forecasts of the National Bank. However, we can also use an extreme stress scenario made by a relevant institution regarding global economic trends or developments in some economies that established close economic and other relations with Macedonia. For example, in recent years, the European Central Bank, together with other relevant EU institutions has developed unfavorable scenarios for the global economy, including the EU economies, for conducting stress tests on EU banks. Assumed extreme shocks/events in the global economy and/or the EU economies have adequate adverse effect on the Macedonian economy, i.e. on the variables of the domestic macroeconomic environment, whose movement has been modeled using appropriate quantitative models.

Econometric models used in formulating stress scenarios are part of the set of instruments used by the National Bank for making regular macroeconomic forecasts for the developments in the Macedonian economy. It should be borne in mind that the power to forecast of these econometric models when are used to model exceptionally extreme movements in external and/or internal macroeconomic environment of the country can be reduced. It should be considered that they are primarily designed and intended for forecasts at the so-called baseline macroeconomic scenario whose likelihood of materialization is very high and which assumes more or less regular, normal, customary, but not extreme movements in the economy.

Modeling relations between macroeconomic environment and standards/ indicators for the banks' risk

To investigate the behavior of the Macedonian banking system in extreme but plausible macroeconomic scenarios, satellite quantitative models[3] (in the form of econometric equations) that describe the interdependence among selected performance indicators of banks (as dependent variables) and certain macroeconomic variables, primarily from domestic macroeconomic environment (as independent or explanatory variables) have been developed. More precisely, econometric equations usually have the following general form:

[3] These are mutually independent econometric models developed for quantitative description of certain segments (blocks) of the banking system.

$$Y_{it} = \alpha Y_{it-1} + \beta Z_{it} + \delta V_{it} + \omega S_{it} + C + \varepsilon_{it} \quad (1)$$

where,

Y: selected indicator for banks' operations and risks exposure[4];
Z: vector of macroeconomic and other variables (factors) from the external environment of the banks (on which the bank's management cannot influence)[5];
V: vector of variables (factors) related to the features of the banking system as a whole (on which the bank's management can only have limited influence)[6];
S: vector of internal variables (factors specific to each bank, which the bank's management can and should control)[7];
C: constant;
$\alpha, \beta, \delta, \omega$: coefficients before each vector of independent (explanatory) variables;
$\boldsymbol{\varepsilon}$: error term;
i: designation for a bank, i=1, 2, 3, ..., N;
t: indication for a time period (quarter or year), t= 1, 2, 3, ..., T.

While it is advisable to include all presented vectors of independent variables, for the purposes of stress testing, simplified econometric equations may be used. Thus, the side of independent (explanatory) variables may cover only the vector of macroeconomic variables, which is the minimum requirement for describing the interdependence between the internal environment of the banks and their macroeconomic (external) environment.

Modeling of relations between macroeconomic environment and risk standards of banks uses panel data composed of, at least, currently active banks, except for one bank[8], for time series that began in the first quarter of 2003 (i.e. since 2003). The main source of data on the banks' operations include various financial and regulatory reports that banks are required to submit to the National Bank on a regular or extraordinary basis. Most data obtained from banks are processed and organized in applications within the National Bank, which are made specifically for that purpose (Credit Register - KRIS and KRISTINA, KN BIFO, EriKlient etc.). Data pertaining to the external (macroeconomic) environment originate from the organizational units of the National Bank or are obtained from external institutions based on the regular cooperation, at request or on their websites. Variables used in the construction of each satellite quantitative model have been subject to stationarity test[9] (absence of so-called unit root test), the correlation among various independent variables etc.

Concerning the econometric method used for determining the empirical interdependence between banks' risk standards and macroeconomic environment, the literature in this area favors the dynamic estimator. This is achieved by including the so-called lagged dependent variable in the econometric equation (member Y_ (it-1) of the econometric equation (1),

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[4] Example: an indicator of the non-performing to total loans ratio (standard/indicator of banks' exposure to credit risk), rate of return on average assets (indicator of banks' earnings), share of liquid assets in short-term liabilities (standard/indicator of banks' exposure to liquidity risk) and the like.
[5] Example: growth of gross domestic product (GDP), inflation rate, level of interest rates in the economy, rate of (un)employment, change in the real effective exchange rate, share of budget deficit in GDP etc.
[6] Example: indicators of levels of competition and concentration in the banking system and its ownership structure and the like.
[7] Example: rate of capitalization of the bank, share of liquid assets in total assets, indicator of the share of operating costs in total operating income, etc.
[8] Panel data does not include the Macedonian Bank for Development Promotion AD Skopje, given the specific nature of its business model.
[9] Stationarity implies that the change in the mean, variance and autocorrelation is not statistically significant over time. Commonly used unit root tests include Augmented Dickey Fuller test, Phillips Perron test, and Levin-Lin-Chu unit root panel test.

shown above). More specifically, the National Bank uses the so-called generalized method of moments - GMM developed by Arellano-Bover, 1995 and Blundell-Bond, 1998), in the form of so-called system one-step GMM[10,11]. The system GMM bridges the problem of autocorrelation and heteroscedasticity of residuals, and by applying the so-called instrumental variables (of a second or higher order) that reduces any negative effect arising from the correlation of lagged dependent variable with error term and further increases accuracy and efficiency when calculating the parameters. As recommended in the literature, the specification of econometric equations and robustness of the results (in addition to the requirements for statistical significance of the coefficients preceding the independent variables) are tested using appropriate diagnostic tests: first-order serial correlation - AR (1) and second-order serial correlation - AR (2) tests, Wald test, Hansen test), difference-in-Hansen test, or optionally, Sargan and difference-in-Sargan tests. Also, we implement so-called in-sample and out-of-sample validations. Initial results have been evaluated using alternative econometric method. We also used the so-called Vector Autoreggresive Method - VAR, and confirmed the results obtained with the system GMM.

A practical example is given below of the appearance of two econometric equations (which were also used for scenario analysis conducted in early 2016), designed to model relationships among selected variables of the macroeconomic environment on the one hand, and indicators of credit risk exposure, i.e. banks' profitability, on the other:[12]:

$$LNPL_{it} = 0{,}86 * LNPL_{it-1} - 0{,}03 * GDP\_R_{it} - 0{,}14 * EMP\_R_{it} + 0{,}05 * REINT_{it} + \varepsilon_{it} \qquad (2)$$

$$ROAA_{it} = 0{,}50 * ROAA_{it-1} + 0{,}22 * GDP\_R_{it} - 0{,}06 * INF_{it} - 0{,}42 * LEND\_R_{it} + \varepsilon_{it} \qquad (3)$$

where,

$LNPL$: logit form of the ratio of non-performing loans to total loans of non-financial entities, i.e. ln(NPL/(1-NPL)), where NPL indicates the share of non-performing loans in total loans[13];
$ROAA$: rate of return on average assets;
GDP_R: annual growth rate of real GDP;
EMP_R: annual growth rate of employment rate;
INF: inflation rate;
$REINT$: real lending interest rate (on a system level);
$LEND\_R$: nominal lending interest rate (on a system level)
ε_{it}: error term;
i: designation for a bank, i= 1, 2, ..., 14;
t: designation for a year, t= 1, 2, …, 12 (time period covered by econometric equations).

The risk of any incorrectly specified model and wrong results therefrom is potentially the greatest weakness of this phase of the scenario analysis.

[10] In 2006, the author Roodman sets out the fundaments of the system GMM using STATA software.
[11] This is only a version (form) of the GMM, which is usually preferred in the literature.
[12] Currently, the ratio of non-performing to total loans is used as an indicator of banks' exposure to credit risk, and the rate of return on average assets is modeled as an indicator of the banks' profitability. In the future, there is a possibility to choose completely different parameters (for example, default rate as an indicator of credit risk exposure) and/or the list of indicators will be expanded with additional indicators, for the same risks, or for some others not covered so far.
[13] This transformation of the indicator for the share of non-performing loans to total loans limits its movement in the range from 0% to 100%, which corresponds to practice. This transformation is also recommended in the literature since it gives the nonlinear features of the econometric model, which are particularly relevant for the purposes of conducting the stress test (nonlinearity implies that relatively small changes in a certain variable cause large changes in another variable which usually happens in times of crisis).

Transmission of shocks from the macroeconomic environment to the capital adequacy ratio

Outputs derived from econometric models used in the formulation of stress scenarios (that describe the movements of macroeconomic variables amid assumed extreme but plausible shocks) act as input variables in the econometric equations developed for modeling the relationships between the macroeconomic environment and the banks' risk standards. Thus, a relatively simple mathematical calculation gives the indications for the banks' performance and risk exposure, in conditions of assumed extreme, but plausible shocks in the macroeconomic (external) environment. Moreover, for the purpose of stress testing (as recommended in the literature[14]) we use so-called long-run coefficients[15], which takes into account the cumulative effect of the assumed changes in the macroeconomic variables on the banks' risk standards (the equations above show the so-called short-run coefficients). Also, when modeling the relationships between banks' credit risk exposure indicator (non-performing to total loans) and variables of the macroeconomic environment, we usually "penalize" banks with higher level of concentration of loan portfolio (mostly measured as share of the ten largest credit exposures to certain non-financial entities in the total credit exposure of the bank). Namely, these banks are assumed to have proportionally higher deterioration of credit exposure than banks with a lower concentration of credit portfolios. The method of determining penalties is subject to expert (subjective) judgment and, inter alia, depends on the sensitivity of the banks' capital adequacy ratio to the assumed deterioration in the creditworthiness of its largest debtors - non-financial entities (this sensitivity can be checked through sensitivity tests discussed below). For example, the indicator for the share of nonperforming loans in total loans, calculated on the basis of the assumed shocks in the macroeconomic environment, using the econometric equation (2) presented above may be further "penalized" only for banks whose share of the ten largest credit exposures in total credit exposure is higher than the median value of this share for the sector. These banks are "penalized" through proportional increase in their indicator for the non-performing to total loans ratio (following shocks in the macroeconomic environment) for a fixed percentage, calculated as follows:

$$\frac{(CONC_r - CONC_{median})}{(CONC_{max} - CONC_{median})} * CAP$$

(4)

where,

$CONC_r$: share of the ten largest credit exposures in total credit exposure to non-financial entities (only for banks that are above the median);
$CONC_{median}$: median value of the shares of the ten largest credit exposures in total credit exposure to nonfinancial entities calculated for all banks in the system;
$CONC_{max}$: maximum share of the ten largest credit exposures in total credit exposure to non-financial entities registered in individual banks;
CAP: subjectively given constant related to the maximum percentage of "penalizing", i.e. maximum percentage of increase of the indicator for the share of nonperforming loans in total loans, which will be applied to the bank with the highest concentration of credit exposure;
r: designation of a bank whose share of the ten largest credit exposures in total credit exposure to non-financial entities is higher than the calculated median value for all banks in the system, r = 1, 2, ..., 7 (half of the total number of banks).

[14] See, for example, Henry and Kok, 2013.
[15] Long-run coefficient for different macroeconomic variables is calculated when the coefficient before the macroeconomic variable of econometric equations previously presented (so-called short-run coefficient) is divided by the difference of 1 (one) and the coefficient before the lagged dependent variable (logit - form of the ratio for the share of nonperforming loans in the total loans, with a time lag of one period - quarter). Such estimated long-run coefficients are significantly higher than the short-run ones, and their use in implementing stress tests raises the level of extremity of assumed shocks.

The econometric equations (2) and (4) determine the amount of additional non-performing loans to non-financial entities as a result of the assumed deterioration of the macroeconomic environment, and the amount of losses (in the form of impairment losses[16]) arising from the materialization of credit risk:

$$IMP\_new_{it} = [(NPLr\_after_{it} * CREDIT\_after_{it}) - NPL\_before_{it}] * IMP\%_{it}$$
(5)

where,

IMP_new_{it}: new impairment as a result of the materialization of credit risk (treatment of accounting recognized and/or unrecognized impairment);
$NPLr\_after_{it}$: indicator for the share of non-performing to total loans following shocks in the macroeconomic environment (resulting from the econometric equation (2)), including the effect of any "penalization" for the high level of concentration of loan portfolio;
$CREDIT\_after_{it}$: stock of credit following shocks in the macroeconomic environment (data obtained from the model for formulating stress scenarios);
NPL_before_{it}: stock of credits before the stress testing;
$IMP\%_{it}$: subjectively[17] given percentage of impairment for new non-performing loans obtained following shocks;
i: designation for a bank, i= 1, 2, ..., 14;
t: designation for a year, t= 1, 2 (the stress test usually covers a time period of two years).

Amid assumed shocks in the macroeconomic environment, the additional amount of impairment that results from the materialization of credit risk is not the only reason for losses and reduced banks' income. Hence, using the econometric equation (3), we should determine the additional amount of losses over those resulting from the reduced quality of credit portfolios, i.e. the total financial result of banks after the assumed shocks in the macroeconomic environment:

$$FIN.RES\_after_{it} = ROAA\_after_{it} * ASSETS\_after_{it}$$
(6)

where,

$FIN.RES\_after_{it}$: financial results after assumed shock in the macroeconomic environment;
$ROAA\_after_{it}$: rate of return on average total assets following shocks in the macroeconomic environment (obtained using the econometric equation (3));
$ASSETS\_after_{it}$: total assets following shocks in the macroeconomic environment (data obtained using models for formulating stress scenarios, i.e. using forecasts of credit growth/decline amid unfavorable developments in the macroeconomic environment);
i: designation for a bank, i= 1, 2, ..., 14;
t: designation for a year, t= 1, 2 (the stress test usually covers a time period of two years).

The deductible item in own funds of banks that after the assumed shocks in the macroeconomic environment operate at a loss, includes absolutely higher amount than the amount calculated using equation (5) and the one calculated using equation (6). On the other hand, the deductible item in own funds of banks that after the assumed shocks

[16] The new amount of impairment is treated as accounting unrecognized impairment (this is subject to expert judgment, i.e. it can be selected and vice versa), which means that, as deduction, it directly reduces banks' own funds, but not the risk weighted assets. However, on the next date of the stress test period, this impairment is considered accounting recognized and it proportionately reduces the financial result (earnings) and risk-weighted assets. In that case, according to the regulatory rules, if the bank's financial result is negative (which among other things is due to the higher recognized impairment), as deduction, they reduce bank's own funds.
[17] Depending on the chosen level of extremity, this parameter ranges from the percentage of impairment the bank usually applies to non-performing loans in its portfolio, up to a maximum of 100%.

generate profit, includes (accounting unrecognized) impairment calculated using equation (5). Banks that generate profit in the current year are assumed to reinvest part of it in their own funds in the next year (the amount of reinvested profit is subject to expert judgment[18]). On the other hand, in the period covered with the stress-testing, it is assumed that the banks will not be able to recapitalize, in any form. Hence, the stock of banks' own funds after the assumed shocks in the macroeconomic environment is obtained as follows:

$$OF\_after_{it} = OF\_before_{it} + FIN.RES\_after_{jt} + IMP\_new_{kt} + RETAINED\_E_{ot} \quad (7)$$

where,

OF_after_{it}: stock of their own funds following shocks in the macroeconomic environment;
OF_before_{it}: stock of their own assets before the stress test;
$FIN.RES\_after_{jt}$: negative financial result after assumed shocks in the macroeconomic environment only for banks *(j)* whose absolute value of the recognized loss is higher than the absolute value of the new (accounting unrecognized) impairment as a result of materialization of credit risk (recognized with a negative sign);
IMP_new_{kt}: new (accounting unrecognized) impairment as a result of materialization of credit risk only for banks (k) that generate profit (following shocks in the macroeconomic environment) or operate at a loss, which in absolute value is less than the new impairment (recognized with a negative sign);
$RETAINED\_E_{ot}$: retained earnings from previous year, only for banks (o) that reported profit in the previous year (subjectively determined as percentage of the profit reported in the previous year);
i: designation for a bank, i= 1, 2, ..., 14;
t: designation for a year, t= 1, 2 (the stress test usually covers a time period of two years).
j: designation of a bank whose absolute value of the recognized loss is higher than the absolute value of the new (accounting unrecognized) impairment as a result of the materialization of credit risk, j= 1, 2, ...
k: designation for a bank that generates profit (following shocks in the macroeconomic environment) or operate at a loss, but in absolute value it is less than the new impairment as a result of the materialization of credit risk, k= 1, 2, …;
o: designation for a bank that reported profit in the previous year, o= 1, 2, ...

An important feature of the stress test for the banking system is the built-in dynamic character, i.e. the assumption for growth of banks' activities in the analyzed period, at a percentage rate corresponding (adequate) to the changes in the macroeconomic environment in each adverse scenario. The forecast of the credit growth/decline (obtained by using models used in the formulation of stress scenarios) amid unfavorable developments in the external environment is used as a proxy for the growth/decline that total activities of the banking system should register amid assumed extreme events. Hence, the risk-weighted assets after the assumed shocks in the macroeconomic environment is obtained as follows:

$$RWA\_after_{it} = RWA\_before_{it} + (EXPOSURE\_after_{it} - EXPOSURE\_before_{it}) * RW\%_{it} + IMP\_new_{it} \quad (8)$$

where,

RWA_after_{it}: risk weighted assets, after assumed shocks in the macroeconomic environment;
RWA_before_{it}: risk weighted assets, before the stress testing;
$EXPOSURE\_after_{it}$: carrying amount of banks' exposure following shocks in the macroeconomic environment (data obtained using models for formulating stress scenarios, i.e. based on forecast for credit growth/decline amid unfavorable developments in the macroeconomic environment);
$EXPOSURE\_before_{it}$: carrying amount of banks' exposure before the stress testing;

[18] Depending on the features and assumptions of the formulated stress scenarios and chosen level of extremeness, this parameter can get different values. It is commonly placed at a level similar to what the bank usually applies when generating profit.

$RW\%_{it}$: subjectively determined average risk weight of the new banks' exposure[19];
IMP_new_{it}: new impairment caused by materialization of credit risk (depending on the treatment of impairment, accounting recognized impairment is included in the calculation of risk weighted assets in the current period while accounting unrecognized impairment is included in the calculation of this item in the coming period);
i: designation for a bank, i= 1, 2, ..., 14;
t: indication for a year, t= 1, 2 (the stress-test usually covers a time period of two years).

Finally, capital adequacy ratio after the assumed shocks in the macroeconomic environment is calculated as:

$$CAR\_after_{it} = \frac{OF\_after_{it}}{RWA\_after_{it}} \quad (9)$$

where,

CAR_after_{it}: capital adequacy ratio following shocks in the macroeconomic environment (in percentage);
OF_after_{it}: own funds following shocks in the macroeconomic environment;
RWA_after_{it}: risk weighted assets after assumed shocks in the macroeconomic environment;
i: designation for a bank, i= 1, 2, ..., 14;
t: indication for a year, t= 1, 2 (the stress-test usually covers a time period of two years).

The results obtained in this phase of the scenario analysis are not final, but represent input variables for the next phase, where with the help of the so-called contagion matrix, we determine any adverse effect that might occur in the operation of financial institutions (and the financial system as a whole) as a result of full or partial default and/or early withdrawal or non-rollover of mutual claims/obligations. The main weakness of this phase of the scenario analysis is the fact that some of the input parameters that can affect the results from the stress test are given as expert (subjective) judgement. Although it is made sure that their assumed level corresponds (is adequate) to the unfavorable developments/events that are forecast in each stress scenario, their reliability cannot be completely verified in stressful situations. Moreover, the results from the stress tests are largely induced by assumptions for growth of the banks' activities in each adverse scenario, which in turn are based on forecasts for credit growth/decline derived from models for formulating stress scenarios. However, lending, although one of the most important, is not the only activity carried out by domestic banks.

Contagion Matrix

The main purpose of the contagion matrix is to examine and determine any spillover of problems from one bank to another, due to an assumed total or partial default and/or early withdrawal or non-rollover of interbank claims/liabilities, as a logical continuation of assumed shocks in the macroeconomic environment. In addition, the contagion matrix is used to determine any negative effect of the assumed "turmoil" in individual banks on the non-banking financial institutions and any rebound of the problems in these institutions on domestic banks. Contagion channels within the banking system and beyond, to individual non-bank financial institutions, pass mainly through (balance sheet) claims/liabilities that institutions have among each other, although they are not alone (however, these contagion channels are the most relevant, given the level of development and complexity of the Macedonia financial system).

[19] Risk weight is a ratio between credit risk weighted assets and the carrying amount of banks' exposure. For the purpose of stress testing, this parameter is normally set at a level similar to what was calculated for the total exposure of banks before applying the stress test (i.e. the risk weight for the new exposure is assumed to be similar to an already existing exposure).

In the literature that refers to this area, there are a variety of more or less complex and sophisticated quantitative (econometric) models that simulate transfer of contagion among individual financial institutions. Typically, the level of complexity and sophistication of the model chosen depends on the size and complexity of financial institutions subject to stress test. Hence, starting from the proportionality principle, the contagion matrix used by the National Bank for the stress test is based on an excel document that in a relatively simple way simulate the negative effects of any default and/or early withdrawal or non-rollover of claims of each financial institution on another. The contagion matrix covers at least all banks that are operational during the scenario analysis, and besides them, it may also include non-banking financial institutions (primarily mandatory pension funds, insurance companies, etc.). Data used as input variables in the contagion matrix is obtained directly from banks (through the Credit Registry), as well as from the responsible regulatory and supervisory authorities on each type of non-banking financial institution (non-public data). These data primarily relate to the amount of claims of each individual financial institution on another but also to the indicators for the volume and quality of liquidity and capital positions of these institutions and the like (for example, solvency margin for insurance companies, value of the accounting unit in pension and investment funds, etc.). The contagion matrix simulates the amount of so-called net-claims calculated as a positive difference of mutual claims between every two financial institutions.

The contagion matrix can simulate early withdrawal or non-rollover of (part of) net-claims among financial institutions (materialization of liquidity risk), or can assume (the rate of) default of net-claims between financial institutions (materialization of credit risk). Alternatively, we can also assume a combination of liquidity and credit risk shocks as a result of materialization of contagion risk among financial institutions. The choice of the type and intensity of the shock is the subject of expert judgment (depending on the chosen level of extremeness and conservativeness of the stress test), but usually the magnitude of the assumed shock depends on the capitalization level of each financial institution obtained from previous phases of the scenario analysis. Thus, for example, for claims on banks whose capital adequacy significantly dropped after the assumed shocks in the macroeconomic environment, it is logical to assume higher rates of early withdrawal or non-rollover (assuming materialization of liquidity risk) i.e. higher default rates of these claims by other banks and non-bank financial institutions (assuming materialization of credit risk). The table shown below gives an arbitrary example of selected percent of early withdrawal or non-rollover of claims on the banks in the sector, as well as selected rates of impairment of the residual of these claims, depending on the capital adequacy ratio of the banks after the assumed shocks in the macroeconomic environment (CAR_after_{it}):

Table 1
Rates of early withdrawal of claims to banks and rates of impairment of residual claims, depending on the capital adequacy ratio

CAR_after_{it}	% of premature withdrawal / non-renewal of claims	Impairment of remaining claims (%)
over 12%	5%	0%
10.01% - 12.00%	10%	20%
8.01% - 10.00%	25%	45%
2.01% - 8.00%	50%	70%
below 2.01%	80%	100%

Example: If the capital adequacy of a particular bank, following shocks in the macroeconomic environment is 7%, it is assumed that other banks and financial institutions withdraw or non-rollover 50% of the claims on this bank, and correct the residual part of the claims in their balance sheets by 70%.

Similarly, we can give (assume) rates of early withdrawal and/or rates of impairment of claims to non-bank financial institutions as well, depending on the capitalization of these institutions (before or after shocks in the macroeconomic environment), depending on whether these institutions were involved in previous stages of scenario analysis, or not.

Early withdrawal or non-rollover of claims among financial institutions reduces liquid assets in institutions that are net debtors to others, which could eventually fully deplete their cash:

$$LIQUIDITY\_after_{pt} = LIQUIDITY\_before_{pt} - NET\_INTER\_CLAIMS_{pt} * WITHDRAWAL\%_{pt}$$
(10)

where,

$LIQUIDITY\_after_{pt}$: liquid assets after the assumed withdrawal of a certain percentage of claims among financial institutions;
$LIQUIDITY\_before_{pt}$: liquid assets before the stress testing;
$NET\_INTER\_CLAIMS_{pt}$: net claims among financial institutions;
$WITHDRAWAL\%_{pt}$: subjectively determined rate of assumed early withdrawal/rollover of net claims among financial institutions;
p: designation for financial institutions included in the contagion matrix, p= 1, 2, 3, ...
t: designation for a year, t= 1, 2 (the stress-test usually covers a period of two years).

However, analyzed aggregately, total liquid assets of the financial sector remain unchanged i.e. are only redeployed within the financial system from financial institutions that are net debtors to those who have net claims on other institutions.

Assumed impairment (of part) of the claims among financial institutions creates additional impairment as a result of the materialization of contagion risk among financial institutions. If the additional impairment in financial institutions creates total negative financial result (or even greater increase in the already recognized loss), it reduces the capital positions of these institutions. The deterioration in the capitalization of financial institutions can trigger a new cycle of additional early withdrawal and/or further impairment of claims/liabilities among institutions. The design of contagion matrix allows multiple re-assessment of the negative effects of the materialization of contagion risk until their complete exhaustion, according to the specified parameters (given in table 1, for example).

Equations (7), (8) and (9) of the previous stage of the scenario analysis (stage of transmission of shocks from macroeconomic environment to capital adequacy ratio) undergo appropriate changes in order to take into account the effect of the additional impairment as a result of the materialization of contagion risk. Thus, the eventual amount of banks' own funds after the cumulative effect of assumed shock in the macroeconomic environment and the materialization of contagion risk is as follows:

$$OF\_final_{it} = OF\_before_{it} + FIN.RES\_final_{qt} + IMP\_new_{st} + RETAINED\_E_{ot}$$
(11)

OF_final_{it}: own funds after assumed shocks in the macroeconomic environment and the materialization of contagion risk;
OF_before_{it}: own funds before the stress testing;
$FIN.RES\_final_{qt}$: negative financial result after assumed shocks in the macroeconomic environment and the materialization of contagion risk only for banks (q) whose absolute value of the recognized loss is higher than the absolute value of the new (accounting unrecognized) impairment as a result of the materialization of credit risk and the contagion risk;

IMP_new_{st}: new (accounting unrecognized) impairment as a result of the materialization of credit risk and contagion risk, only for banks (s) that generate profit (following shocks in the macroeconomic environment and the materialization of contagion risk) or operate at a loss, but it is in absolute value less than the new impairment;
$RETAINED\_E_{ot}$: retained profit from previous year, only for banks (o) that recognized profit in the previous year (subjectively determined as a certain percentage of the profit shown in the previous year);
i: designation for a bank, i= 1, 2, ..., 14;
t: designation for a year, t= 1, 2 (the stress-test usually covers a time period of two years).
q: designation for a bank whose absolute value of the recognized loss is higher than the absolute value of the new (accounting unrecognized) impairment as a result of the materialization of credit risk and contagion risk, q= 1, 2, ...;
s: designation for a bank that generates profit (following shocks in the macroeconomic environment and the materialization of contagion risk) or operate at a loss, but it is in absolute value less than the new impairment as a result of the materialization of credit risk and contagion risk, s= 1, 2, …;
o: designation for a bank that showed profit in the previous year, o= 1, 2, ...

Furthermore, the final amount of risk weighted assets following shocks in the macroeconomic environment and the materialization of contagion risk is as follows:

$$RWA\_final_{it} = RWA\_before_{it} + (EXPOSURE\_after_{it} - EXPOSURE\_before_{it}) * RW\%_{it} + IMP\_new_{it} + IMP\_contagion_{it} * RW\_Banks\%_{it}$$
(12)

where,

RWA_final_{it}: risk weighted assets, after assumed shocks in the macroeconomic environment and the materialization of contagion risk;
RWA_before_{it}: risk weighted assets, before the stress testing;
$EXPOSURE\_after_{it}$: carrying amount of banks' exposure to shocks in the macroeconomic environment (data obtained based on models for formulating stress scenarios, i.e. based on projected credit growth/decline amid unfavorable developments in the macroeconomic environment);
$EXPOSURE\_before_{it}$: carrying amount of banks' exposure before the stress testing;
$RW\%_{it}$: subjectively determined average risk weight of the new banks' exposure[20];
IMP_new_{it} : new impairment as a result of the materialization of credit risk (depending on the treatment of impairment, accounting recognized impairment is included in the calculation of risk-weighted assets in the current period, while accounting unrecognized impairment is included in the calculation of this rate in the coming period);
$IMP\_contagion_{it}$: new impairment as a result of the materialization of contagion risk (depending on the treatment of impairment, the accounting recognized impairment is included in the calculation of risk-weighted assets in the current period while the accounting unrecognized impairment is included in the calculation of this item in the coming period);
$RW\_Banks\%_{it}$: subjectively determined average risk weight for banks' claims on other banks, for which certain impairment is assumed as a result of the materialization of the contagion risk[21]
i: designation for a bank, i= 1, 2, ..., 14;
t: designation for a year, t= 1, 2 (the stress-test usually covers a time period of two years).

Accordingly, the eventual amount of the capital adequacy ratio is calculated from the following ratio:

$$CAR\_final_{it} = \frac{OF\_final_{it}}{RWA\_final_{it}}$$
(13)

[20] Risk weight is a ratio between credit risk weighted assets and the carrying amount of the bank's exposure. For the purpose of stress testing, this parameter is normally set at a level similar to that calculated for the banks' total exposure before the stress test (i.e. the average risk weight for the new exposure is assumed to be similar to the existing exposure).
[21] This risk weight is a ratio between credit risk weighted claims on banks and the carrying amount of claims on banks. When determining the parameters for the purposes of stress testing, we take into account the risk weight for claims on banks calculated before the stress testing, as well as the assumed migration of part of the regular, performing claims on banks to non-performing.

where,

CAR_final_{it}: capital adequacy ratio, following shocks in the macroeconomic environment and the materialization of contagion risk (in percentage);
OF_final_{it}: own funds, following shocks in the macroeconomic environment and the materialization of contagion risk;
RWA_final_{it}: risk weighted assets, after assumed shocks in the macroeconomic environment and the materialization of contagion risk;
i: designation for a bank, i= 1, 2, ..., 14;
t: designation for a year, t= 1, 2 (the stress-test usually covers a time period of two years).

Sensitivity tests as part of the scenario analysis

The National Bank applies the sensitivity test to complement the scenario analysis, which also works as a standalone tool usually used every three months. Sensitivity tests, as part of the scenario analysis are used to examine the sensitivity of certain aspects of banks' operations (exposure to certain types of risks), which are not covered in previous phases of the scenario analysis. In this part of the scenario analysis, the emphasis is placed on sensitivity tests that assume any liquidity outflow outside the banking system (in addition to the assumed liquidity shocks, simulated with the contagion matrix) due to withdrawal of certain percentage of household deposits, deposits of largest depositors, liabilities to nonresidents etc. The choice of the type and intensity of these liquidity shocks is again subject to expert judgment, but the decisions also take into account the capital adequacy ratio and the rate of return on average assets obtained upon the assumed shocks in the macroeconomic environment and the materialization of contagion risk for each bank, the assumptions and features of each stress scenario, the concentration of the deposit base of individual banks, the percentage of deposit coverage with the insurance scheme of the Deposit Insurance Fund and the like.

As mentioned in the annex, simulations for materialization of concentration risk in the loan portfolio are yet another type of sensitivity test, which is used as part of the scenario analysis as a tool for "penalizing" banks with high concentration of credit exposure, when determining the indicator for the non-performing to total loans in the assumed shocks in the macroeconomic environment. More details about specific types of liquidity shocks and the mechanism of implementing individual sensitivity tests are discussed below.

Tests of sensitivity to materialization of credit risk, applied as a standalone tool

When applying the test of sensitivity to the materialization of credit risk, shocks are simulated as one-time shocks and directly on the measurements of credit risk present in the banks/banking system, without identifying the reasons that led to the sudden and extraordinary shift in risk standards. The purpose of testing is to determine how the extreme, but plausible change in each credit risk standard affect the financial result, the level of own funds and capital adequacy ratio of banks. The credit risk standard which is directly subjected to assumed shocks refers to the amount of credit exposure classified in higher risk (non-performing part of C, D and E) or the credit exposure classified in lower risk categories (A, B, and regular, performing part of C). More precisely, the shock is simulated as an extreme but plausible increase in credit exposure classified in higher risk categories, at the expense of the reduction of the exposure classified in a lower risk categories or, vice versa (extreme reduction of exposure classified in lower risk categories, i.e. its migration to higher risk categories) most commonly assuming an unchanged total credit exposure. Alternatively, for simpler simulation of shock, it can be constructed as a complete or partial default of the credit exposure of banks/banking system, less the already made impairment.

Tests of sensitivity to materialization of credit risk can be combined with an assumed extreme shift in interest rates (applied to banks' assets and liabilities) and/or exchange rate (value of denar against another foreign currency, usually euro). Any depreciation of the denar against the euro and/or substantial increase in interest rates on approved loans have adverse effects on the creditworthiness of banks' clients and lead to materialization of credit risk. Hence, interest rates and exchange rate play the role of factors of indirect credit risk[22], which are subject to extreme shocks (interest rate and/or currency shock), combined with a simultaneous deterioration in the quality of banks' loan portfolio (credit shock).

Assumed migration of credit exposure from higher risk categories to lower risk categories "deteriorates" the structure of credit exposure (in terms of the classification by risk category) and creates additional impairment for banks. Typically, it is assumed that the percentage of impairment for each risk category is the same before and after the assumed shocks, although depending on the chosen level of extremeness of sensitivity tests, we could assign higher rates of impairment for each risk category. The new impairment is treated as accounting unrecognized impairment, which means that as deduction, it directly reduces banks' own funds, but not the risk weighted assets. Besides, the new non-performing loans in banks' portfolios reduce the performing, interest-bearing loans and, consequently, interest income that banks earn from loans approved. The reduction of financial result (earnings) (due to lower interest income) may be such to increase "current loss" as a deductible from banks' own funds and, consequently, reduce capital adequacy ratio[23].

Interest rate shock is usually constructed as an extreme increase (rarely, cut) in interest rates applied to certain items of interest sensitive assets and liabilities of banks. The goal is to determine the change in the earnings (net interest income) of banks/banking system as a result of assumed extreme shifts in the levels of interest rates, which may eventually cause changes in the "current loss" as a deductible of banks' own funds (depending on the direction and extent of change in the financial result). Moreover, the interest sensitive items with adjustable interest rates assume change in interest rates on all assets and liabilities regardless of the estimated frequency of reassessment set by the banks. Interest sensitive items with variable interest rate assume to have observed the frequency of reassessment set by banks and we calculate the change in the financial result arising from those positions with variable interest rates where the frequency of reassessment is set to 1 year. Interest sensitive positions with fixed interest rate assume that after the prescribed period to maturity banks roll them over (in the same amount), but at new interest rates (i.e. we calculate the change in earnings arising from those positions with fixed interest rates where the period to maturity is up to 1 year). Given the fact that the interest rate shock is usually simulated in combination with simultaneous credit shock, when determining the change in net interest income of banks (due to extreme interest rate shift) we take into account the reduction of banks' regular, interest-bearing loans, because of the assumed deterioration of the quality of loan portfolio.

[22] Direct exposure of the banking system to movements in market financial variables so far is small, given the low probability of materialization of currency risk amid monetary strategy of maintaining a fixed exchange rate of the denar against the euro and the still small direct exposure to interest rate risk in the banking book. However, indirect exposure to these risks, i.e. potential exposure to credit risk arising from the loans with currency component and loans with adjustable interest rates in the banks' portfolios is high.

[23] In this case, the increase in current loss as a deductible item from own funds would be registered in banks operating at a loss before the stress testing, but also in banks, which prior to the stress testing generate profit, but after the fall of net interest income show loss.

The currency shock involves extreme change (usually a depreciation) in the value of denar against other foreign currencies (mostly euro), which has a corresponding impact on the Denar equivalent of individual items of assets and liabilities with currency component of the banks, i.e. on the net income from exchange rate differentials. Change in net income from exchange rate differentials is the difference between open the currency position[24] of banks (for each currency), calculated after and before the currency shock. Moreover, depending on the direction and extent of changes in net income from exchange rate differentials and the subsequent change in earnings, it may result in a change in "current loss" as a deductible item from banks' own funds, as well as in the capital adequacy ratio. Also, the assumed extreme change in the exchange rate of the denar against the euro has a corresponding impact on the capital requirement for currency risk (under the regulations), as well as on the currency risk weighted assets.

Hence, banks' earnings, after testing the sensitivity to the materialization of credit risk (including interest and currency shocks) is obtained as follows:

$$FIN.RES\_sensitivity_i = FIN.RES\_before_i + \Delta NET.INT_i + \Delta NET.FX.INCOME_i + IMP\_sensitivity_i$$
(14)

where,

$FIN.RES\_sensitivity_i$: financial result after testing the sensitivity to the materialization of credit, currency and interest rate shock;
$FIN.RES\_before_i$: financial result before sensitivity tests;
$\Delta NET.INT_i$: change in net interest income as a result of the: reduction of interest-bearing loans (i.e. due to increasing non-performing loans) and increase/cut in interest rates on interest-bearing assets and liabilities (interest rate shock);
$\Delta NET.FX.INCOME_i$: change in net income from exchange rate differentials as a result of the assumed currency shock;
$IMP\_sensitivity_i$: new (accounting unrecognized) impairment as a result of the materialization of credit risk;
i: designation for a bank, i= 1, 2, ..., 15.

Own funds and risk weighted assets of banks are obtained as follows:

$$OF\_sensitivity_i = OF\_sensitivity_i + IMP\_sensitivity_i + LOSS\_sensitivity_c + \Delta LOSS\_sensitivity_x$$
(15)
$$RWA\_sensitivity_i = RWA\_before_i + \Delta RWA\_currency_i$$
(16)

where,

$OF\_sensitivity_i$: own funds after testing the sensitivity to the materialization of credit, currency and interest rate shock;
$IMP\_sensitivity_i$: new (accounting unrecognized) impairment as a result of the materialization of credit risk;
$LOSS\_sensitivity_c$: banks' loss (*c*), which prior to the stress testing generated profit, and after the sensitivity test operate at a loss (the accounting unrecognized impairment as a result of the credit shock is not considered);
$\Delta LOSS\_sensitivity_x$: change in banks' loss (*x*), which after the sensitivity test operate at a larger loss than shown before the stress testing (the accounting unrecognized impairment due to credit shock is not considered);
$RWA\_sensitivity_i$: risk weighted assets after currency shock;
RWA_before_i: risks weighted assets before stress testing;
$\Delta RWA\_currency_i$: change in currency risk weighted assets as a result of the currency shock;
i: designation for a bank, i= 1, 2, ..., 15;

[24] Not taking into account off-balance sheet items (potential assets and contingent liabilities) with currency component. Specifically, it is a gap between banks' assets and liabilities with currency component.

c: designation for a bank, which prior to the sensitivity test generates profit, and after the stress testing, operates at a loss, c= 1, 2, ...;
x: designation for a bank, which after the sensitivity test operates at a larger loss than before the stress testing, x= 1, 2, ...;

Finally, the capital adequacy ratio, after the sensitivity test, is calculated as:

$$CAR\_sensitivity_i = \frac{OF\_sensitivity_i}{RWA\_sensitivity_i}$$
(17)

where,

$CAR\_sensitivity_i$: capital adequacy ratio, after sensitivity testing (in %);
$OF\_sensitivity_i$: own funds, after sensitivity testing;
$RWA\_sensitivity_i$: risk weighted assets, after sensitivity testing;
i: designation for a bank, i= 1, 2, ..., 15.

Tests of sensitivity to the materialization of credit risk are conducted to the total loan portfolio of banks/banking system or its segments i.e. within:
- credit exposure to nonfinancial entities/credit exposure to financial institutions and the government;
- credit exposure to non-financial companies, by industry;
- credit exposure to households, by credit product;
- credit exposure to categories of clients, including:
  - credit exposure (individually or aggregately) to the ten largest borrowers (including connected entities) of each bank (for testing the banks' sensitivity to the materialization of concentration risk in credit portfolios),
  - credit exposure to non-residents originating from the selected country, to domestic legal entities that make net exports to the selected country (it mostly covers the 100 largest net exporters) and to domestic legal entities that have liabilities and/or claims based on credit operations to the selected country (for examining some of the channels of potential spillover of unfavorable developments in a country, in the domestic banking system).

When conducting tests of sensitivity to the materialization of credit risk (individually or in combination with currency and interest rate shock) within the total credit exposure or within the credit exposure to nonfinancial entities, we usually assume the following extreme but plausible changes:
- Increase in exposure to risk categories C-non-performing, D and E by 10%/30%/50%/80% at the expense of the reduced exposure to risk category A[25];
- Increase in exposure to risk categories C-non-performing, D and E by 30%/50%/80% at the expense of the reduced exposure to risk category A, and rise in interest rates from 1 to 5 percentage points;
- Increase in exposure to risk categories C-non-performing, D and E by 50%/80% at the expense of the reduced exposure to risk category A, and depreciation of the denar against the euro;
- Increase in exposure to risk categories C-non-performing, D and E by 50%/80% at the expense of the reduced exposure to risk category A, depreciation in the denar against the euro by 20%/30% and increase in interest rates from 1 to 5 percentage points;

[25] If the assumed absolute increase in non-performing loan exposure is greater than the total exposure classified in A, then the exposure to A reduces to zero, and the rest of the estimated absolute increase in non-performing loan exposure is deducted from the exposure to B risk category.

- Appreciation of the denar against the euro by 20%;
- Increase in exposure to risk categories C-non-performing, D and E by 100% at the expense of the reduced exposure to risk categories A and B, with 50% of the increase being at the expense of the reduced exposure to risk category A, and the remaining 50% is at the expense of the reduced exposure to risk category B;
- Increase in exposure to risk categories C-non-performing, D and E by 150% at the expense of the reduced exposure to risk categories A and B, with 50% of the increase being at the expense of the reduced exposure to risk category A, and the remaining 50% is at the expense of the reduced exposure to risk category B and the depreciation of the denar against the euro by 30%;
- Migration of 10%/20%/30% of credit exposure from risk categories A, B and C-performing to risk categories C-non-performing, D and E where the migrated exposure is distributed evenly (33.3%);
- Migration of 10%/20%/30% of credit exposure from risk categories A, B and C-performing to risk categories C-non-performing, D and E where the migrated exposure is distributed evenly (33.3%) and depreciation of the denar against the euro of 30%;
- Required growth of C-non-performing, D and E (in%) at the expense of reduced exposure to risk category A on capital adequacy to be brought down to 8% for each bank;
- Required migration of credit exposure from risk categories A, B and C-performing to risk categories C-non-performing, D and E for the capital adequacy to be brought down to 8% for each bank.

For testing the sensitivity of banks/banking system to deterioration of the creditworthiness of clients from various industries and/or natural persons indebted based on various credit products, the following hypothetical sensitivity tests are conducted:

- Migration of 10% of the credit exposure to non-financial companies (by activity), to households (by credit product), and to both sectors together, from each risk category to the two next higher risk categories (where migrated credit exposure is distributed equally, with the exception of exposure that migrates from risk category D, that entirely migrates to risk category E);
- Migration of 30% of the credit exposure to non-financial companies (by activity), to households (by credit product), and to both sectors together, from each risk category to the two next higher risk categories (where migrated credit exposure is distributed equally, with the exception of exposure that migrates from risk category D, that entirely migrates to risk category E);

Often applied simulations of materialization of concentration risk in the loan portfolio are as follows:

- Migration of the five largest exposures to non-financial entities from the current risk category to risk category "C-non-performing/D;
- Migration of the ten largest exposures to non-financial entities from the current risk category to risk category "C-non-performing/D;
- Migration of the largest credit exposure to non-financial entities from the current risk category to risk category "C-non-performing/D;

Some of the potential transmission channels of adverse, crisis events from a country is tested using the following sensitivity tests:

- Full (100%) or partial default of 30%/50% of credit exposure (net impairment) to non-residents originating from the country affected by the crisis, to domestic net exporters to the selected country (it mostly covers the 100 largest net exporters) and to domestic legal persons that have liabilities and/or claims based on credit operations to the specific country[26].

Tests of sensitivity to liquidity shocks - simulations of liquidity risk, applied as a standalone tool

Banks as financial institutions that perform maturity transformation of their liabilities and assets are inevitably exposed to liquidity risk. Source for materialization of the liquidity risk can be any event of either internal and idiosyncratic nature of the bank (e.g. drastic withdrawal of deposits by the largest depositors due to the worsened perceptions of clients, i.e. the risk profile of a particular bank), or any event of external and/or systematic nature (e.g. general loss of depositors' confidence in the banking system). The materialization of liquidity risk in any bank of the system can easily cause systemic effects, i.e. spill over to other banks at considerably increased speed rate compared to the materialization of credit risk. Hence, liquidity risk has special significance for the banking system, in the sense that it could swiftly disturb the financial stability. Therefore, when stress testing a bank, it is necessary to incorporate certain assumptions about hypothetical events that could cause liquidity shocks, which, in turn, would cause outflows of liquid assets outside banks and/or banking system. For this purpose, it is necessary to identify key risk factors and based on that, to design hypothetical risk events, which by their nature are extreme, but plausible. This could provide an approximate idea of the level of liquidity necessary for banks to be operationally able to weather such shocks alone without support of external sources i.e. any form of public or private intervention. This would indirectly show their tolerance of liquidity risk, amid possible materialization of individual or combined shocks caused by various hypothetical events.

Liquidity risk in banks can be manifested in two basic forms: 1) default risk and/or funding liquidity risk and 2) market liquidity risk. The risk arising from funding sources is the risk that the bank will not be able to meet any expected and unexpected, current and/or future cash outflows, or to renew its funding sources, without causing negative effects either on its general financial situation or in the everyday work processes. The risk of market fluctuations is the risk that the bank will not be able to liquidate or offset positions in certain financial instruments at prevailing market prices (and thereby, to generate cash inflows), either because of inadequate market liquidity or due to shocks in market movements[27].These two dimensions of liquidity risk are connected and interacting, considering the relation between securing funding sources from banks and the general condition of the financial markets.

In the simulation of the resilience of the banking system to liquidity shocks, based on the proper application of the principles of stress-testing, the emphasis has been placed on assumed risk events relating to the first dimension of liquidity risk - the risk of default and renewal of funding sources. Given the profile of operations carried out by domestic banks, the size and structure of their assets, the type and concentration of their funding sources, and their internal organizational structures, but taking into account the movements and liquidity of market segments for important financial assets subject to bank's investments, the second dimension of liquidity risk is outside the scope of assumed risk events, but

[26] In this case, simulations of credit shock are most often combined with the usual simulations of liquidity shocks in domestic banks whose parent entities originate from a country with unfavorable developments. This is to examine the negative effects of any materialization of reputational risk as a result of liquidity problems with parent entities of domestic banks. Tests of sensitivity to the materialization of liquidity risk will be discussed hereafter in this annex.

[27] Source: Bank for International Settlements, Principles for Sound Liquidity Risk Management and Supervision, Basel, September 2008, ISBN web: 92-9197-767-5.

could be included in the future, for example, by introducing haircuts for certain categories of liquid financial instruments of banks. Therefore, simulations are based on balance sheet-based liquidity stress test. The design of these simulations requires understanding of banks' business and, consequently, the structure of their assets and sources of funding, especially their features that would affect the possibility to be converted into cash inflows.

The resilience of the Macedonian banks and/or banking system to liquidity shocks is presented through loss, i.e. outflow of liquid assets and a corresponding decrease in total assets, with liquid assets being presented at three levels:

I) Liquid assets according to the definition used for the preparation of quarterly reports for the banking system. Liquid assets of the banking system include: 1) cash and claims on the National Bank, which includes cash, cash accounts of banks with the National Bank, deposit facilities with the National Bank and CB bills; 2) funds on correspondent accounts and short-term deposits with foreign banks and 3) carrying value of investments in securities issued by the Republic of Macedonia, both short-term (treasury bills) and long-term (government bonds) securities and in eurobonds (if banks can invest in this instrument), as well as investments in securities issued by non-resident foreign countries. If there are denar funds with FX clause, in terms of liquidity, they are regarded as denar liquidity because the cash flow that results from such assets is in denars. If it is deemed necessary and if banks create relatively greater portfolio of foreign securities, the liquid assets may also include other mark-to-market foreign securities and are part of the trading book. There can also be a classification by securities issued by non-resident foreign countries, by level of credit rating[28]. Liquid assets of each bank, besides the asset categories listed above include funds on correspondent accounts and short-term deposits with other domestic banks.

II) Liquid assets listed in item I), less investments in government bonds issued by the Republic of Macedonia. This reduction in liquid assets would correspond to the assumption of materialization of credit risk arising from long-term claims on the government. If deemed necessary, the liquid assets listed in item I) can also be reduced by the short-term government securities, i.e. to avoid term differentiation of this category of financial instruments.

III) Liquid assets listed under item I), plus banks' investments in foreign government bonds, banks' investments in long-term deposits in foreign banks, roughly calculated part of the foreign exchange reserve requirement that would have been reversed as a result of the assumed withdrawal of deposits by households, as well as loans to non-financial entities with contractual residual maturity up to 30 days. If deemed necessary, the liquid assets listed under item I) and other securities may increase, but if banks classified them as trading assets and in accordance with such accounting classification, they are measured at fair value.

Shocks representing stress test on liquidity risk of the Macedonian banks and/or banking system relate to, but are not exhausted by, the following assumed events:

1) Loss of confidence in the banks and/or banking system by the households as determined by the assumed withdrawal of 20% of the household deposits. This assumption corresponds to the shock of the so-called sources of funding from retail segment, and verified by the historical experience of some banks during the crisis in 1999 and the size of the then withdrawal of household deposits. If deemed necessary,

[28] This distinction is consistent with the requirements of the Basel Committee on Banking Supervision concerning the treatment of government securities and other financial instruments in the calculation of liquidity standards.

we could increase the assumed rate of withdrawal of household deposits, include some withdrawal of deposits of companies that are not large depositors or in some banks, differentiate (increase) the proportion of the assumed withdrawal depending on the share of deposits not covered by the insurance of the Deposit Insurance Fund[29] and the like.

2) Loss of confidence of large depositors in the banks and/or banking system determined by assumed withdrawal of deposits of 20 largest depositors. This assumption corresponds to the shock in the so-called sources of funding from the wholesale segment. If deemed necessary, we may extend the scope of the withdrawn funding sources with other categories, primarily deposits of other financial institutions (pension funds and insurance companies).
3) Full conversion of certain banks' off-balance sheet exposure categories in the balance sheet claims, which implies an outflow of liquid assets from banks and/or banking system. Off-balance sheet items of banks and/or banking system subject to this assumption include uncovered L/Cs, irrevocable credit lines and unused credit cards and overdrafts. If deemed necessary, we may extend the scope of off-balance sheet liabilities of banks or apply a different conversion rate rather than the full one.
4) Full withdrawal of banks' sources of funding from their parent entities. This assumption corresponds to the deteriorating financial position of the parent entities of domestic banks and their problems to find liquidity. The assumption of an outflow does not refer to the sources of funding based on subordinated instruments and hybrid capital instruments, since the regulations for calculating capital adequacy prescribe that they are not available for early payment[30]. If deemed necessary, we can also assume outflow of such capital instruments.
5) Worsened perceptions of foreign creditors for the domestic banks and/or banking system due to the assumed withdrawal of 50% of the sources of funding from non-residents, excluding liabilities to non-resident parent entities. This assumption corresponds to the shock in the so-called external funding. If deemed necessary, we may increase the assumed rate of withdrawal of banks' liabilities to non-residents.

Data used for simulation of liquidity shocks are obtained by banks, due to their obligation for accounting or regulatory reporting, but can also be obtained based on special data request, as is the case with the size and maturity of the sources of funding from their parent entities. Data are part of the internal applications of the National Bank (KNBIFO and ERIKLIENT), which have been either directly entered by the banks or obtained from internal surveys and reporting forms to the Financial Stability and Banking Regulation Department.

The results from these liquidity shocks to the Macedonian banks and/or banking system may be provided cumulatively or individually, by shock, which could identify the significance and contribution of each shock to the total outflow. The results refer to, but are not exhausted by, the following measures:

1) Percentage of reduction in liquid funds. When this percentage is above 100, it is considered that the bank does not have sufficient liquidity to overcome shock. The basic result of the test of sensitivity to liquidity shocks refers to liquidity following shocks, derived as follows:

$$LIQUID.ASSETS\_after_i = LIQUID.ASSETS\_before_i - WITHDRAWAL_i \quad (18)$$

[29] The criteria for covering deposits with the Fund's insurance are set out in the relevant Law of Deposit Insurance Fund.
[30] As specified in items 16 and 17 of the Decision on the methodology for determining capital adequacy, available at http://www.nbrm.mk/?ItemID=9EC394F58759E443A82E25AE22BBC7CF

where,

$LIQUID.ASSETS\_after_i$: liquidity after supposed liquidity shocks;
$LIQUID.ASSETS\_before_i$: liquidity before testing the sensitivity to liquidity shocks;
$WITHDRAWAL_i$: total liquidity outflow, depending on the assumed liquidity shocks;
i: designation for a bank, i= 1, 2, ..., 15;

1) Indicator for the share of liquid assets in total assets. For calculating this indicator, the total assets of banks and/or banking system adequately reduce the potential liquidity outflow.
2) Indicator of coverage of short-term liabilities with liquid assets. For the purpose of calculating this indicator, short-term liabilities of banks and/or banking system accordingly reduce by the part of the potential liquidity outflow that correspond to the outflow of short-term liabilities.

Limiting factor for the use of the sensitivity tests is the fact that data used in testing are often subject to so-called structural breaks because of the methodological and/or regulatory changes in the manner/form of their determination/calculation/reporting by banks. This is especially true in the construction of historical series for the results obtained from testing.

Results from the scenario analysis for 2016 and 2017

At the beginning of 2016, the stress testing of the banking system using scenario analysis required development of **two adverse scenarios**. Both stress scenarios cover a period of two years (2016 and 2017).

The first macroeconomic stress scenario is hypothetical and extension to the alternative macroeconomic scenario that was prepared (and presented to the public) by the National Bank within the April cycle of macroeconomic projections[31]. The hypothetical stress scenario, same as the alternative macroeconomic scenario, assumes a prolonged period of political instability in the country, coupled by adverse assumptions regarding the external environment of the Macedonian economy. More specifically, it assumes significant increase in oil prices by the end of 2016 (up to 100 US dollars per barrel), which will continue in 2017. It is assumed that the increasing price of this energy comes primarily from the significant cuts, i.e. optimization of oil supply and production in the world, rather than from the dramatically increased global economic activity. Hence, at the end of 2016, foreign inflation in the countries that are major trade partners of the Republic of Macedonia will be higher by 50% compared with the assumptions of the baseline and alternative macroeconomic scenario (from the regular macroeconomic forecasts), and in 2017, foreign inflation would double compared to that assumed by regular macroeconomic forecasts. Also, the hypothetical stress scenario assumes unfavorable movements in foreign demand for Macedonian products, primarily because of the domestic political developments, which are assumed to have had negative effect on the decisions of the foreign partners of the domestic companies in terms of cancellation /delay of planned/ initiated business deals/ ventures/projects. Thus, it assumes zero change in foreign demand for domestic products in 2016 and 2017, despite

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[31] Within the April cycle of macroeconomic forecasts, the National Bank of the Republic of Macedonia developed baseline and alternative macroeconomic scenarios regarding the future developments in the Macedonian economy. The main difference between the two scenarios relates to the assumption for the duration of the political instability in the country. Namely, the baseline macroeconomic scenario assumes soon stabilization of the political context, while the alternative macroeconomic scenario assumes continuation of political instability by the end of 2016. For more details about both scenarios visit: http://www.nbrm.mk/WBStorage/Files/WebBuilder_Prezentacijaproekcii_Bezoska_ambasadori.pdf.

the assumed growth in this demand in the baseline macroeconomic scenario, 1.5% and 1.9% in 2016 and 2017, respectively. Thus, in case of materialization of the scenario described above, the growth of the Macedonian economy would be slower than projected in the baseline macroeconomic scenario, prepared by the NBRM, by 2.0 percentage points in 2016, i.e. by 1.2 percentage points in 2017. Thus, in case of materialization of the scenario described above, the growth of the Macedonian economy would be slower than projected in the baseline macroeconomic scenario, prepared by the NBRM, by 2.0 percentage points in 2016, i.e. by 1.2 percentage points in 2017. The nominal lending interest rate will be higher by 1.2 to 1.4 percentage points, while the rate of inflation in 2016 will be by 0.5 percentage points lower than projected in the baseline macroeconomic scenario but higher by 0.8 percentage points in 2017. In the hypothetical stress scenario, the employment rate would be lower in comparison to the forecast, by 0.1 percentage point in 2016, and by 0.9 percentage points in 2017[32].

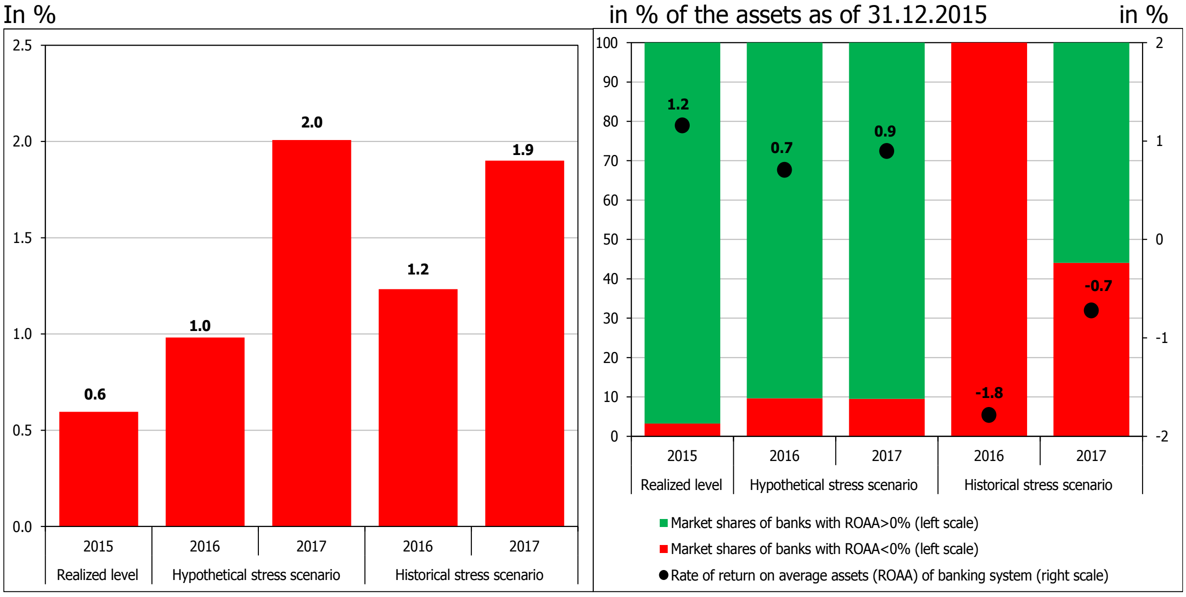
Chart 1
Comparison between forecasted movements of the main macroeconomic variables in the baseline macroeconomic scenario, the historical and hypothetical stress scenario
in %

Source: National Bank calculations.

[32] If the comparison is made to the regular macroeconomic forecasts using the alternative macroeconomic scenario, then, with the exception of the inflation rate, the differences with the hypothetical stress scenario (which is based on the alternative macroeconomic scenario) are smaller. Annual real growth rate of GDP in the hypothetical stress scenario is lower, compared to that observed in the alternative macroeconomic scenario, by 0.1 percentage points in 2016, i.e. by 1.2 percentage points in 2017. The gap in nominal lending interest rate between the two scenarios is +0.8 percentage points for 2016, i.e. +1,0 percentage points for 2017, and in the inflation rate, this gap is wider, +1.3 percentage points for 2016 and +2.9 percentage points for 2017. The employment rates, in both scenarios (hypothetical stress scenario and alternative macroeconomic scenario), are almost identical to each other, both for 2016 and for 2017.

The second adverse macroeconomic scenario is the so-called historical scenario, which in the following two-year period (2016 and 2017) assumes mirroring of the movements in the analyzed macroeconomic variables from a selected past period. Namely, within this scenario, there was a mirroring to the next two-year period, of the dynamics of changes in the macroeconomic variables from 2001 and 2002, when the adverse effects of the security and political instability in the country on the domestic economy were more pronounced. The historical scenario is characterized by higher level of extremeness compared to the hypothetical stress scenario and assumes slightly less favorable movements in some macroeconomic variables, primarily, in the annual GDP growth rate (for more details see the charts above).

Chart 2
Share of the annual growth in non-performing loans to non-financial entities in the total performing loans at the end of the previous year (left) and return on average assets and market shares of banks, by financial result (right)

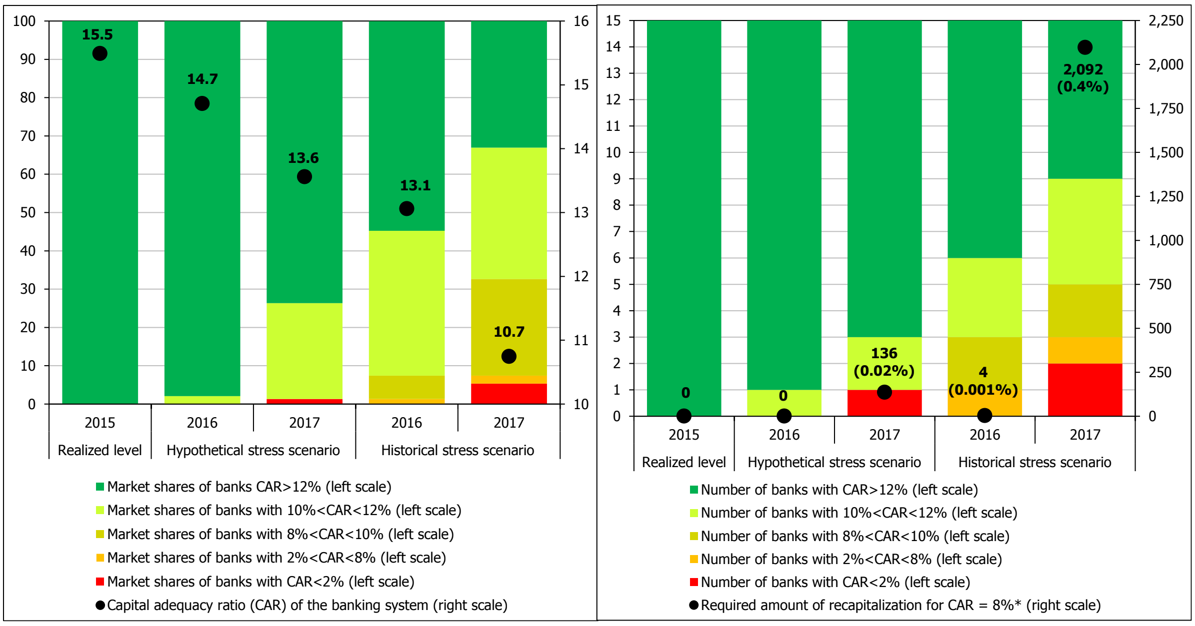


Source: National Bank calculations.

The results of the stress testing conducted as a scenario analysis indicate generally satisfactory resilience of the total banking system to unfavorable movements in the macroeconomic environment. However, the bank-by-bank analysis suggests vulnerability of some banks to the assumed adverse macroeconomic scenarios and hypothetical need for recapitalization and liquidity support amid possible materialization of these scenarios. The scenario analysis shows that in some years, non-performing loans to non-financial entities increased at a rate, which is by almost four times higher, compared to the growth in 2015, and in some years, the banking system reported a loss of 1.8% of average assets (which has not been seen in the past sixteen years or more). The decline in liquid assets of the banking system would eventually be 15.3% or about Denar 20 billion (total, over two years), and own funds was reduced by almost 30% (or about Denar 14 billion), in the same period. Despite these unfavorable trends, the capital adequacy ratio of the banking system reduces below 10.7%. Analyzed by individual bank, in the most extreme case, ten banks (with a total market share of 44% in the assets of the banking system) reported a loss, and three of them (with a total market share of 7.4%) reported a capital adequacy ratio below 8%, with one of these banks (with market share of 1.3%) would also report lack of liquid assets. The necessary recapitalization of banks required for the capital adequacy ratio to go back to 8%, in the extreme case, is Denar 2 billion (about 0.4% of GDP in 2015), which also covers the aforementioned liquidity shortage that occurs in one of the banks.

Chart 3
Capital adequacy ratio and market shares of banks, according to level of capital adequacy ratio (left) and required amount of recapitalization and structure of number of banks according to level of capital adequacy ratio (right)

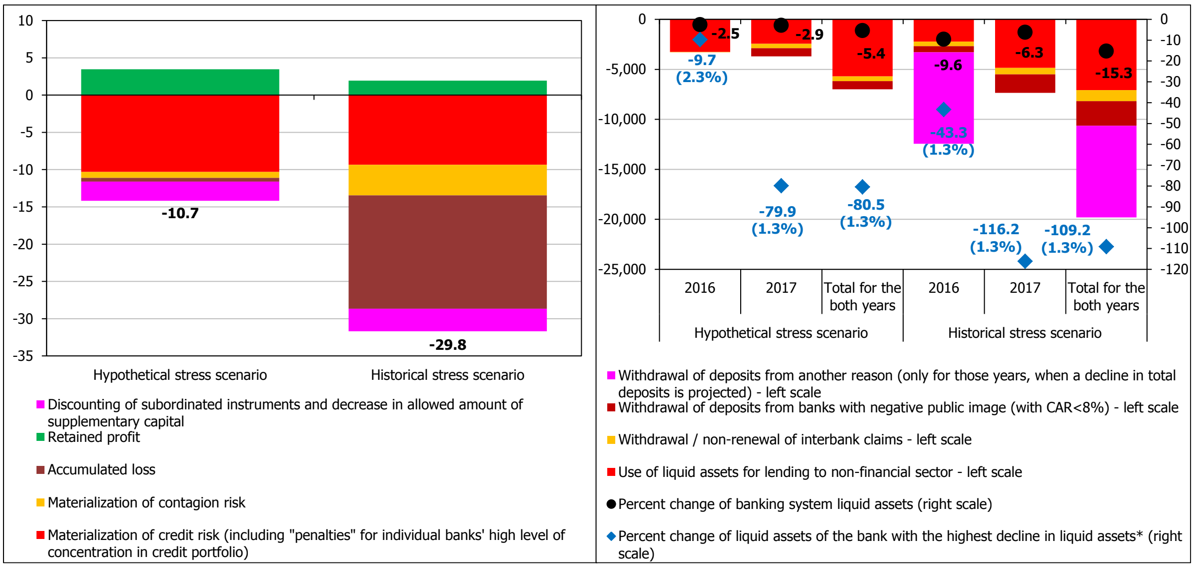
in % of assets as of 31.12.2015 in % number of banks in millions of Denars



*The share of required amount of recapitalization in GDP (GDP amount refers to 2015) is given in brackets.

Chart 4
Structure of total percentage decline of own funds (left) and percentage decline of liquid assets and structure of liquid assets decline (right)

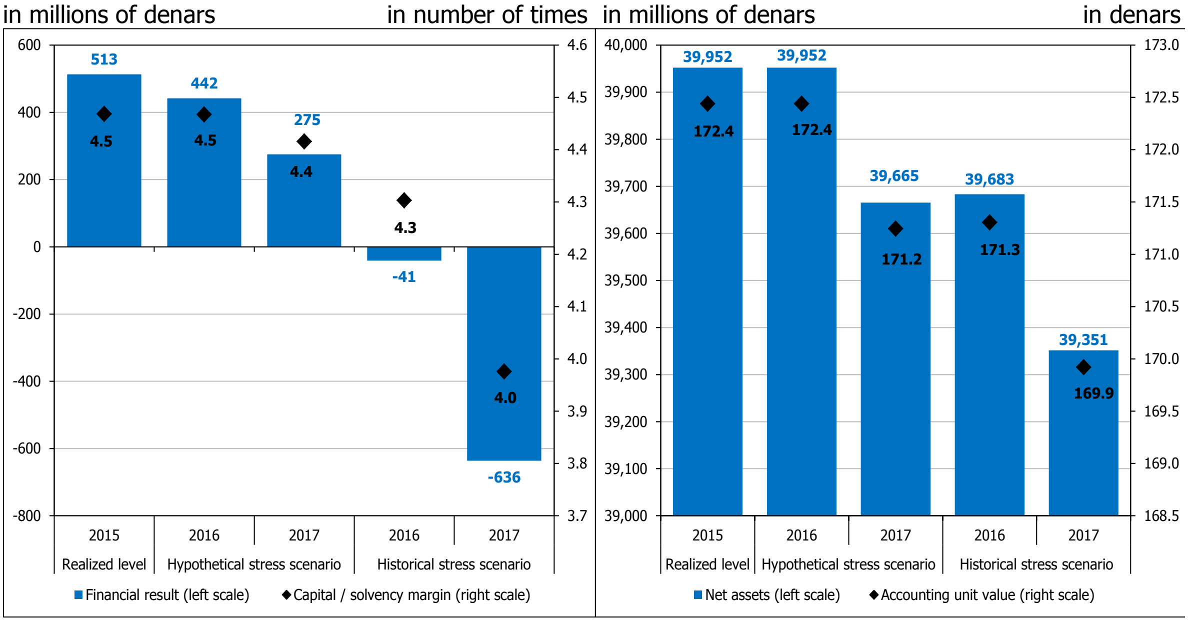
In % in millions of Denars in %



*The market share of the bank with highest decline in liquid assets is given in brackets.
Source: National Bank calculations.

Insurance companies and mandatory pension funds are relatively resilient to the potential problems in the banking system and their assumed spillover to these two largest non-banking segments of the financial system. Namely, in the extreme case, almost all insurance companies (with the exception of two) would have reported an operating loss, but no insurance company would be in non-compliance with the legal obligation to maintain regulatory capital at least at the level of the calculated solvency margin. At the same time, net assets of mandatory pension funds would lose only 1.5% of its value due to unfavorable developments in the banking system.

Chart 5
Financial result and ratio of capital / solvency margin in the insurance sector (left) and amount of net assets and value of accounting unit in mandatory pension funds (right)



Source: NBRM's calculations, based on data from AIS and MAPAS.