

Annex 2 Methodologies

2.1 Scheduled Commercial Banks

Banking stability map and indicator

The banking stability map and indicator present an overall assessment of changes in underlying conditions and risk factors that have a bearing on the stability of the banking sector during a period. The five composite indices used in the banking stability map and indicator represent the five dimensions of soundness, asset-quality, profitability, liquidity and efficiency. Each composite index is a relative measure during the sample period used for its construction, where a higher value means higher risk in that dimension.

The ratios used for constructing each composite index are given in Table 1. Each ratio is first normalised for the sample period using the following formula:

$$\frac{X_t - \min(X_t)}{\max(X_t) - \min(X_t)}$$

where X_t is the value of the ratio at time t . Thereafter, composite index of each dimension is calculated as a weighted average of the normalised ratios used for that dimension where the weights are based on the scores assigned for assessment for the CAMELS rating (exception: equal weights used for efficiency dimension). Thus, each composite index takes values between zero and one. Finally, the banking stability indicator is constructed as a simple average of these five composite indices.

Table 1: Ratios used for constructing the banking stability map and indicator

Dimension	Ratios			
Soundness	CRAR #	Tier-I Capital to Tier-II Capital #	Leverage Ratio as Total Assets to Capital and Reserves	
Asset-Quality	Net NPAs to Total Advances	Gross NPAs to Total Advances	Sub-Standard Advances to Gross NPAs #	Restructured Standard Advances to Standard Advances
Profitability	Return on Assets #	Net Interest Margin #	Growth in Profit Before Tax #	
Liquidity	Liquid Assets to Total Assets #	Customer Deposits to Total Assets #	Non-Bank Advances to Customer-Deposits	Deposits maturing within 1-year to Total Deposits
Efficiency	Cost to Income	Business (Credit + Deposits) to Staff Expenses #		Staff Expenses to Total Expenses

Note: # Negatively related to risk.

Macro stress testing

Macro stress test for credit risk ascertains the resilience of banks against macroeconomic shocks. It assesses the impact of macroeconomic shocks on GNPA ratio of banks (at system level and at major bank-group level) and finally on their capital adequacy (bank-by-bank and system level for a sample of 46 banks).

Impact of GNPA ratio

Here, the slippage ratio (SR)¹ is modelled as a function of macroeconomic variables, using various econometric models that relate the select banking system aggregates to macroeconomic variables. The system-level and bank group-level slippage ratios are modelled using (i) multivariate regression; (ii) VAR and (iii) quantile regression. The banking system aggregates include current and lagged values of slippage ratio, while macroeconomic variables include gross domestic product (GDP), weighted average lending rate (WALR), CPI (combined) inflation, exports-to-GDP ratio, annualized current account balance-to-GDP ratio and annualized combined gross fiscal deficit-to-GDP ratio.

While multivariate regression allows evaluating the impact of select macroeconomic variables on the banking system's GNPA, the VAR model takes into account the feedback effect also. In these methods, the conditional mean of slippage ratio is estimated wherein it is assumed that the impact of macro-variables on credit quality will remain the same, irrespective of the level of the credit quality, which may not always be true. In order to relax this assumption, quantile regression was adopted, wherein conditional quantile is estimated instead of the conditional mean to deal with tail risks and to account for the non-linear impact of macroeconomic shocks.

The following econometric models are used to estimate the impact of macroeconomic shocks on the slippage ratio:

System level models

The system level GNPA's are projected using three different but complementary econometric models: multivariate regression, VAR and quantile regression. The final projection is derived by averaging the projections based on these three models.

- *Multivariate regression*

The following multivariate regression model is used for projecting the slippage ratio of SCBs as a whole:

$$SR_t = \alpha_1 + \beta_1 SR_{t-1} - \beta_2 \Delta NGDP_{t-2} + \beta_3 RWALR_{t-2} - \beta_4 \left(\frac{CAB}{GDP}\right)_{t-3} + \beta_5 \left(\frac{GFD}{GDP}\right)_{t-1} + \beta_6 \text{Dummy}$$

where, $\alpha_1, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ and $\beta_6 > 0$

- *VAR model*

In notational form, mean-adjusted VAR of order p can be written as:

$$y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + u_t; t=0,1,2,3,\dots$$

where, $y_t = (y_{1t}, \dots, y_{Kt})'$ is a $(K \times 1)$ vector of variables at time t, the A_i ($i=1,2,\dots,p$) are fixed $(K \times K)$ coefficient matrices and $u_t = (u_{1t}, \dots, u_{Kt})'$ is a K-dimensional white noise or innovation process.

The VAR model is estimated using slippage ratio, real WALR, nominal GDP growth, annualized current account balance-to-GDP ratio and annualized combined gross fiscal deficit-to-GDP ratio. The appropriate

¹ Slippages are fresh accretion to NPAs during a period. Slippage Ratio = Fresh NPAs/Standard Advances at the beginning of the period.

order of VAR selected based on minimum information criteria as well as other diagnostics is two. The impact of various macroeconomic shocks is determined using the impulse response function of the selected VAR.

- *Quantile regression*

The following quantile regression model is used to estimate the conditional quantile of slippage ratio at 0.8:

$$SR_t = \alpha_1 + \beta_1 SR_{t-1} - \beta_2 \Delta NGDP_{t-2} + \beta_3 RWALR_{t-2} - \beta_4 \left(\frac{CAB}{GDP}\right)_{t-3} + \beta_5 \left(\frac{GFD}{GDP}\right)_{t-1} + \beta_6 \text{Dummy}$$

Bank group level models

The bank group-wise slippage ratios are projected using three different but complementary econometric models: multivariate regression, VAR and quantile regression. The final projection is derived by averaging the projections based on these three models.

- *Multivariate regression*

The following multivariate regressions are used to model the slippage ratio of various bank groups:

Public Sector Banks (PSBs):

$$SR_t = \alpha_1 + \beta_1 SR_{t-1} + \beta_2 RWALR_{t-2} - \beta_3 \Delta NGDP_{t-2} + \beta_4 \left(\frac{GFD}{GDP}\right)_{t-3} - \beta_5 \left(\frac{CAB}{GDP}\right)_{t-3} + \beta_6 \text{Dummy}$$

Private Sector Banks (PVBs):

$$SR_t = \alpha_1 + \beta_1 SR_{t-1} + \beta_2 RWALR_{t-3} - \beta_3 \Delta NGDP_{t-1} - \beta_4 \left(\frac{EXP}{GDP}\right)_{t-1} + \beta_5 \text{Dummy}$$

Foreign Banks (FBs):

$$SR_t = \alpha_1 + \beta_1 SR_{t-1} + \beta_2 \Delta^2 CPI_{t-4} + \beta_3 \Delta \left(\frac{GFD}{GDP}\right)_{t-3} - \beta_4 \Delta \left(\frac{EXP}{GDP}\right)_{t-1} + \beta_5 \text{Dummy}$$

- *VAR model*

In order to model the slippage ratio of various bank groups, different VAR models are estimated based on the following macro variables:

PSBs: NGDP, RWALR, CAB- to -GDP ratio and GFD- to- GDP ratio of order 1.

PVBs: NGDP, RWALR and exports- to- GDP ratio of order 1.

FBs: GDP, CPI, exports- to- GDP ratio and GFD-to-GDP ratio of order 1.

- *Quantile regression*

The following quantile regression models are used to model the conditional quantile of slippage ratios at 0.8 for various bank groups:

Public Sector Banks (PSBs):

$$SR_t = \alpha_1 + \beta_1 SR_{t-1} + \beta_2 RWALR_{t-2} - \beta_3 \Delta NGDP_{t-1} + \beta_4 \left(\frac{GFD}{GDP}\right)_{t-3} - \beta_5 \left(\frac{CAB}{GDP}\right)_{t-3} + \beta_6 \text{Dummy}$$

Private Sector Banks (PVBs):

$$SR_t = \alpha_1 + \beta_1 SR_{t-1} + \beta_2 RWALR_{t-4} - \beta_3 \Delta NGDP_{t-1} - \beta_4 \left(\frac{EXP}{GDP}\right)_{t-1} - \beta_5 \left(\frac{CAB}{GDP}\right)_{t-3} + \beta_6 \text{Dummy}$$

Foreign Banks (FBs):

$$SR_t = \alpha_1 + \beta_1 SR_{t-1} + \beta_2 \Delta^2 CPI_{t-1} + \beta_3 \Delta \left(\frac{GFD}{GDP} \right)_{t-3} - \beta_4 \Delta \left(\frac{EXP}{GDP} \right)_{t-1} + \beta_5 \text{Dummy}$$

Estimation of GNPA's from slippages

Once, slippage ratio is projected using the above-mentioned models, GNPA is projected using the identity given below:

$$GNPA_{t+1} = GNPA_t + Slippage_{(t,t+1)} - Recovery_{(t,t+1)} - Write-off_{(t,t+1)} - Upgradation_{(t,t+1)}$$

Derivation of GNPA's from slippage ratios, which are projected using the above mentioned credit risk econometric models, are based on the following assumptions: credit growth of 6.9 per cent, 7.5 per cent, 7.7 per cent and 7.8 per cent respectively; recovery rates of 3.6 per cent, 2.6 per cent, 2.0 per cent and 3.0 per cent, respectively; write-off rates of 5.7 per cent, 7.3 per cent, 5.3 per cent and 5.1 per cent respectively; upgradation rates of 1.0 per cent, 1.2 per cent, 2.3 per cent and 2.3 per cent respectively during quarters ending December 2021, March 2022, June 2022 and September 2022.

Impact on capital adequacy

The impact of macro shocks on capital adequacy of banks is captured through the following steps;

- The impact on future capital accumulation is captured through projection of profit under the assumed macro scenarios, assuming that only 25 per cent of profit after tax (PAT) (which is minimum regulatory requirements) goes into capital of banks.
- The requirement of additional capital in future are projected by estimating risk-weighted assets (RWAs) using internal rating based (IRB) formula.

Formulae used are:

$$CRAR_{t+1} = \frac{Capital_t + 0.25 * PAT_{t+1}}{RWAs(credit\ risk)_{t+1} + RWAs(others)_{t+1}}$$

$$Common\ Equity\ Tier\ 1\ Capital\ Ratio_{t+1} = \frac{CET1_t + 0.25 * PAT_{t+1}}{RWAs(credit\ risk)_{t+1} + RWAs(others)_{t+1}}$$

where, PAT is projected using satellite models, elucidated in the subsequent section. RWAs (others), which is total RWAs minus RWAs of credit risk, is projected based on average growth rate observed in the past one year. RWAs (credit risk) is estimated using the IRB formula given below:

IRB Formula: Bank-wise RWA for credit risk is estimated using the following IRB formula:

$$RWAs(credit\ risk) = 12.5 \times \left(\sum_{i=1}^n EAD_i \times K_i \right)$$

where, EAD_i is exposure at default of the bank in the sector i (i=1,2,...n).

K_i is minimum capital requirement for the sector i which is calculated using the following formula:

$$= \left[LGD_i \times N \left[(1 - R_i)^{-0.5} \times G(PD_i) + \left(\frac{R_i}{1 - R_i} \right)^{0.5} \times G(0.999) \right] - PD_i \times LGD_i \right] \\ \times (1 - 1.5 \times b(PD_i))^{-1} \times (1 + (M_i - 2.5) \times b(PD_i))$$

where, LGD_i is loss given default of the sector i , PD_i is probability of default of the sector i , $N(..)$ is cumulative distribution function of standard normal distribution, $G(..)$ is inverse of cumulative distribution function of standard normal distribution, M_i is average maturity of loans of the sector (which is taken 2.5 for all the sector in this case), $b(PD_i)$ is smoothed maturity adjustment and R_i is correlation of the sector i with the general state of the economy. Calculation of both, $b(PD)$ and R depend upon PD .

This IRB formula requires three major inputs, namely, sectoral PD , EAD and LGD . Here, sectoral PD s are proxied by annual slippage of the respective sectors using banking data. PD for a particular sector is taken as same (*i.e.* systemic shocks) for each of the 46 selected banks, whereas, EAD for a bank for a particular sector is total outstanding loan (net of NPAs) of the bank in that particular sector. Further, assumption on LGD was taken as follows; under the baseline scenario, $LGD = 60$ per cent (broadly as per the RBI guidelines on 'Capital Adequacy - The IRB Approach to Calculate Capital Requirement for Credit Risk'), which increases to 65 per cent under medium macroeconomic risk scenario and 70 per cent under severe macroeconomic risk.

Selected sectors: The following 17 sectors/sub-sectors (and others) are selected for the stress test.

Table 2: List of selected sectors/sub-sectors

Sr. No.	Sector/Sub-sector	Sr. No.	Sector/Sub-sector
1	Engineering	10	Basic Metal and Metal Products
2	Auto	11	Mining
3	Cement	12	Paper
4	Chemicals	13	Petroleum
5	Construction	14	Agriculture
6	Textiles	15	Retail-Housing
7	Food Processing	16	Retail-Others
8	Gems and Jewellery	17	Services
9	Infrastructure	18	Others

The stochastic relationship of sectoral annual slippage ratio (*i.e.* sectoral PD s) with macro variables is estimated using multivariate regression for each sector. Using these estimated regressions, sectoral PD s of each sector are projected for four quarters ahead under assumed baseline as well as two adverse scenarios, namely, medium stress and severe stress. The sectoral regression models are presented in the next section.

The bank-wise profit after tax (PAT) is projected using the following steps:

- Components of PAT (*i.e.* Net Interest Income(NII), Other Operating Income(OOI), Operating Expenses(OE) and Provisions & Write off) of each bank-group is projected under baseline and adverse scenarios, using the method explained in the subsequent section.
- Share of components of PAT of each bank (except income tax) in their respective bank-group is calculated.
- Each component of PAT (except income tax) of each bank is projected from the projected value of the component of PAT of respective bank-group and applying that bank's share in the particular component of PAT .

- Finally, bank-wise PAT was projected by appropriately adding or subtracting their components estimated in the previous step and using income tax rate at 35 per cent.

Using these formulae, assumptions and inputs, impact of assumed macro scenarios on the capital adequacy of each bank is estimated and future change in capital adequacy under baseline from the latest observed data and change in the capital adequacy of banks from baseline to adverse macro shocks are calculated. Finally, these changes are appropriately applied on the latest observed capital adequacy (under Standardised Approach) of the bank.

Projection of Sectoral PDs

1. Engineering

$$\Delta PD_t = \alpha + \beta_1 \Delta PD_{t-1} + \beta_2 \Delta WALR_{t-2} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-2} - \beta_4 \Delta GVA(Industry)_{t-3} + \beta_5 Dummy$$

2. Auto

$$PD_t = \alpha + \beta_1 PD_{t-1} - \beta_2 \Delta GDP_{t-1} + \beta_3 WALR_{t-1} - \beta_4 \left(\frac{EXP}{GDP}\right)_{t-2} + \beta_5 \Delta CPI_{t-2} + \beta_6 Dummy$$

3. Cement

$$PD_t = \alpha + \beta_1 PD_{t-1} - \beta_2 \Delta GDP_{t-2} + \beta_3 \Delta WALR_{t-1} - \beta_4 \left(\frac{EXP}{GDP}\right)_{t-2} + \beta_5 Dummy$$

4. Chemicals and Chemical Products

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-1} - \beta_3 \Delta GDP_{t-1} + \beta_4 Dummy_t$$

5. Construction

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-1} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-1} - \beta_4 \Delta GDP_{t-1} + \beta_5 Dummy_t$$

6. Textiles

$$PD_t = \alpha + \beta_1 PD_{t-1} - \beta_2 \Delta GDP_{t-1} + \beta_3 \Delta WALR_{t-1} - \beta_4 \left(\frac{EXP}{GDP}\right)_{t-2} + \beta_5 \Delta CPI_{t-3} + \beta_6 Dummy$$

7. Food Processing

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-3} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-1} - \beta_4 \Delta GDP_{t-2} + \beta_5 Dummy_t$$

8. Gems and Jewellery

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-1} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-3} - \beta_4 \Delta GDP_{t-2} + \beta_5 Dummy_t$$

9. Infrastructure

$$PD_t = \alpha + \beta_1 PD_{t-1} - \beta_2 \Delta GDP_{t-2} + \beta_3 WALR_{t-1} + \beta_4 \Delta CPI_{t-1} + \beta_5 Dummy_t$$

10. Basic Metal and Metal Products

$$PD_t = \alpha + \beta_1 PD_{t-1} - \beta_2 \Delta GDP_{t-3} + \beta_3 WALR_{t-1} - \beta_4 \left(\frac{EXP}{GDP}\right)_{t-1} + \beta_5 Dummy_t$$

11. Mining and Quarrying

$$PD_t = \alpha + \beta_1 PD_{t-1} - \beta_2 \Delta GDP_{t-2} + \beta_3 \Delta CPI_{t-1} - \beta_4 \left(\frac{EXP}{GDP}\right)_{t-2} + \beta_5 Dummy_t$$

12. Paper and Paper Products

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-4} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-2} - \beta_4 \Delta GDP_{t-1} + \beta_5 Dummy_t$$

13. *Petroleum and Petroleum Products*

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-2} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-2} - \beta_4 \Delta GDP_{t-2} + \beta_5 Dummy_t$$

14. *Agriculture*

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-1} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-2} - \beta_4 \Delta GDP_{t-1} + \beta_5 Dummy_t$$

15. *Services*

$$\Delta PD_t = \alpha + \beta_1 \Delta PD_{t-1} + \beta_2 \Delta WALR_{t-1} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-2} - \beta_4 \Delta GDP_{t-2} + \beta_5 \Delta CPI_{t-1}$$

16. *Retail Housing*

$$\Delta PD_t = \alpha + \beta_1 \Delta PD_{t-1} + \beta_2 \Delta WALR_{t-2} - \beta_3 \Delta GDP_{t-1}$$

17. *Other Retail*

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-2} - \beta_3 \left(\frac{EXP}{GDP}\right)_{t-1} + \beta_4 Dummy_t$$

18. *Others*

$$PD_t = \alpha + \beta_1 PD_{t-1} + \beta_2 \Delta WALR_{t-2} - \beta_3 \Delta GDP_{t-1} + \beta_4 Dummy_t$$

Projection of bank-group wise PAT

The various components of PAT of major bank-groups (namely, PSBs, PVBs and FBs), such as, NII, OOI, OE and Provisions & Writeoff are projected using different time series econometric models (as given below). Finally, PAT is estimated using the following identity:

$$PAT = NII + OOI - OE - Provisions \& \text{writeoff} - Income \text{ Tax}$$

where, *NII* is net interest income, *OOI* is other operating income and *OE* is operating expenses.

Net Interest Income (NII): NII is the difference between interest income and interest expense and is projected using the following regression model:

$$LNII_t = -\alpha_1 + \beta_1 LNII_{t-1} + \beta_2 LNGDP_SA_{t-1} + \beta_3 Adv_Gr_{t-1} + \beta_4 Spread_t$$

LNII is log of NII. *LNGDP_SA* is seasonally adjusted log of nominal GDP. *Adv_Gr* is the y-o-y growth rate of loans and advances. *Spread* is the difference between average interest rate earned by interest earning assets and average interest paid on interest bearing liabilities.

Other Operating Income (OOI): Log of OOI (*LOOI*) of SCBs is projected using the following regression model:

$$LOOI_t = -\alpha_1 + \beta_1 LOOI_{t-1} + \beta_2 LNGDP_SA_t$$

Operating Expense (OE): OE of SCBs is projected using an Autoregressive Moving Average (ARMA) model.

Provisions (including write-off): The required provisioning is projected using the following regression:

$$P_Adv_t = \alpha_1 + \beta_1 P_Adv_{t-1} - \beta_2 \Delta GDP_{t-2} + \beta_3 GNPA_{t-1} - \beta_4 Dummy$$

P_Adv is provisions to total advances ratio. *ΔGDP* is the y-o-y growth rate of real GDP. *GNPA* is gross non-performing assets to total advances ratio.

Income Tax: The applicable income tax is taken as 35 per cent of profit before tax, which is based on the past trend of ratio of income tax to profit before tax.

Single factor sensitivity analysis – Stress testing

As a part of quarterly surveillance, stress tests are conducted covering credit risk, interest rate risk, liquidity risk *etc.* and the resilience of commercial banks in response to these shocks is studied. The analysis is done on individual SCBs as well as on the system level.

Credit risk (includes concentration risk)

To ascertain the resilience of banks, the credit portfolio was given a shock by increasing GNPA ratio for the entire portfolio. For testing the credit concentration risk, default of the top individual borrower(s) and the largest group borrower(s) was assumed. The analysis was carried out both at the aggregate level as well as at the individual bank level. The assumed increase in GNPA was distributed across sub-standard, doubtful and loss categories in the same proportion as prevailing in the existing stock of NPAs. However, for credit concentration risk (exposure based) the additional GNPA under the assumed shocks were considered to fall into sub-standard category only and for credit concentration risk (based on stressed advances), stressed advances were considered to fall into loss category. The provisioning requirements were taken as 25 per cent, 75 per cent and 100 per cent for sub-standard, doubtful and loss advances respectively. These norms were applied on additional GNPA calculated under a stress scenario. As a result of the assumed increase in GNPA, loss of income on the additional GNPA for one quarter was also included in total losses, in addition to the incremental provisioning requirements. The estimated provisioning requirements so derived were deducted from banks' capital and stressed capital adequacy ratios were computed.

Sectoral Risk

To ascertain the Sectoral credit risk of individual banks, the credit portfolios of particular sector was given a shock by increasing GNPA ratio for the sector. The analysis was carried out both at the aggregate level as well as at the individual bank level. Sector specific shocks based on standard deviation(SD) of GNPA ratios of a sector are used to study the impact on individual banks. The additional GNPA under the assumed shocks were considered to fall into sub-standard category only. As a result of the assumed increase in GNPA, loss of income on the additional GNPA for one quarter was also included in total losses, in addition to the incremental provisioning requirements. The estimated provisioning requirements so derived were deducted from banks' capital and stressed capital adequacy ratios were computed.

Interest rate risk

Under assumed shocks of the shifting of the INR yield curve, there could be losses on account of the fall in value of the portfolio or decline in income. These estimated losses were reduced from the banks' capital to arrive at stressed CRAR.

For interest rate risk in the trading portfolio (HFT + AFS), a duration analysis approach was considered for computing the valuation impact (portfolio losses). The portfolio losses on these investments were calculated for each time bucket based on the applied shocks. The resultant losses/gains were used to derive the impacted CRAR.

Equity price risk

Under the equity price risk, impact of a shock of a fall in the equity price index, by certain percentage points, on profit and bank capital were examined. The fall in value of the portfolio or income losses due to change in equity prices are accounted for the total loss of the banks because of the assumed shock. The estimated total losses so derived were reduced from the banks' capital.

Liquidity risk

The aim of the liquidity stress tests is to assess the ability of a bank to withstand unexpected liquidity drain without taking recourse to any outside liquidity support. Various scenarios depict different proportions (depending on the type of deposits) of unexpected deposit withdrawals on account of sudden loss of depositors' confidence along with a demand for unutilised portion of sanctioned/committed/guaranteed credit lines (taking into account the undrawn working capital sanctioned limit, undrawn committed lines of credit and letters of credit and guarantees). The stress tests were carried out to assess banks' ability to fulfil the additional and sudden demand for credit with the help of their liquid assets alone.

Assumptions used in the liquidity stress tests are given below:

- It is assumed that banks will meet stressed withdrawal of deposits or additional demand for credit through sale of liquid assets only.
- The sale of investments is done with a haircut of 10 per cent on their market value.
- The stress test is done under a 'static' mode.

Bottom-up Stress testing: Select banks

Bottom-up sensitivity analysis was performed by 18 select scheduled commercial banks. A set of common scenarios and shock sizes were provided to the select banks. The tests were conducted using March 2021 data. Banks used their own methodologies for calculating losses in each case.

Bottom-up stress testing: Derivatives portfolios of select banks

The stress testing exercise focused on the derivatives portfolios of a representative sample set of top 20 banks in terms of notional value of the derivatives portfolios. Each bank in the sample was asked to assess the impact of stress conditions on their respective derivatives portfolios.

In case of domestic banks, the derivatives portfolio of both domestic and overseas operations was included. In case of foreign banks, only the domestic (Indian) position was considered for the exercise. For derivatives trade where hedge effectiveness was established it was exempted from the stress tests, while all other trades were included.

The stress scenarios incorporated four sensitivity tests consisting of the spot USD/INR rate and domestic interest rates as parameters.

Table 3: Shocks for stress testing of derivatives portfolio

Domestic interest rates		
Shock 1	Overnight	+2.5 percentage points
	Up to 1yr	+1.5 percentage points
	Above 1yr	+1.0 percentage points
Domestic interest rates		
Shock 2	Overnight	-2.5 percentage points
	Up to 1yr	-1.5 percentage points
	Above 1yr	-1.0 percentage points
Exchange rates		
Shock 3	USD/INR	+20 per cent
Exchange rates		
Shock 4	USD/INR	-20 per cent

2.2 Primary (urban) Co-operative Banks

Stress testing of UCBs was conducted with reference to the reported position as on March 31, 2021. The banks were subjected to baseline, medium and severe stress scenarios in the areas of credit risk, market risk and liquidity risk as follows:

a. Credit Default Risk

- Under Credit Default Risk, the model aims to assess the impact of stressed credit portfolio of a bank on its CRAR.
- Arithmetic mean of annual growth rate was calculated based on reported data of NPAs between 2009 and 2020 of the UCB sector as a whole.
- The annual growth rate was calculated separately for each NPA class (sub-standard, D1, D2, D3 and loss assets). This annual growth rate formed the baseline stress scenario, which was further stressed by applying shocks of 1.5 Standard Deviation (SD) and 2.5 SD to generate medium and severe stress scenarios for each category separately.
- Based on the above methodology, the annual NPA growth rate matrix arrived at under the three stress scenarios was as below. These were further adjusted bank wise based on their NPA divergence level.

(per cent)

	Increase in Substandard Assets	Increase in D1 assets	Increase in D2 assets	Increase in D3 assets	Increase in Loss assets
Baseline Stress	22.06	18.08	16.53	13.88	4.81
Medium Stress	61.93	47.00	41.24	51.32	16.51
Severe Stress	88.52	66.27	57.71	76.27	24.31

b. Credit Concentration Risk

- It was assumed that under the three stress scenarios the top 1, 2 and 3 single borrower exposures respectively move from 'Standard Advances' category to 'Loss Advances' category leading to 100 per cent provisioning and its consequent impact on CRAR.

c. Interest Rate Risk in Trading Book

- The duration analysis approach was adopted for analyzing upward movement of interest rates on AFS and HFT portfolio of UCBs.
- Due to absence of data with respect to Modified Duration (MD) for UCBs, the model used the Weighted Average MD of small finance banks (SFBs) given the structural similarities between SFBs and UCBs, with an increase of 50 basis points as a conservative approach.
- Upward movement of interest rates by 50 bps, 150 bps and 250 bps were assumed under the three stress scenarios and provisioning impact on CRAR was assessed.

d. Interest Rate Risk in Banking Book

- The Banking Book of UCBs was subjected to interest rate shocks of 50 bps, 150 bps and 250 bps under three stress scenarios and impact on Net Interest Income was arrived at.

Liquidity Risk

The stress test was conducted based on cumulative cash flows in the 1-28 days' time bucket. The cash inflows and outflows were stressed under baseline, medium, and severe scenarios as below:

(per cent)

Stress Scenario	Decrease in Inflows	Increase in Outflows
Baseline	5	25
Medium	5	50
Severe	5	100

The banks with negative cumulative mismatch (cash inflow less cash outflow) exceeding 20 per cent of the outflows were considered to be under stress on the basis of the circular RBI/2008-09/174 UBD. PCB. Cir. No12/12.05.001/2008-09 dated September 17, 2008, which stipulates that the mismatches (negative gap between cash inflows and outflows) during 1-14 days and 15-28-days' time bands in the normal course should not exceed 20 per cent of the cash outflows in each time band.

2.3 NBFC Stress Testing – Single factor sensitivity analysis**Credit Risk**

A shock was applied to the credit portfolio of NBFCs at individual level and system level by increasing the GNPA ratio by 1 SD and 2 SD under medium and high-risk scenarios. Credit exposure and risk weighted assets (RWA) were assumed to grow at 75 per cent of compound annual growth rate compounded annual growth rate (CAGR) over the past three years. Additional NPAs due to shocks in credit risk were added to sub-standard advances and existing GNPA's were distributed based on ageing impact as per the extant regulations on provisioning requirements. Provisioning requirements were applied at 10 per cent for substandard advances, at the existing proportion as on March 2021 for doubtful advances and at 100 per

cent for loss advances as per the regulatory requirements. Additional provision requirements and income loss due to increase in GNPA were deducted from the earnings before provisions and taxes (EBPT) for 2020-21 to calculate new profit before tax (PBT). Tax rate of 22 per cent was applied to calculate profit after tax (PAT) and the entire PAT was accrued to existing capital with no dividend payment assumption. Based on the new capital and RWA, new capital to risk weighted assets ratio (CRAR) was arrived at for individual NBFCs and entire sector for the assumed scenarios.

Liquidity Risk

Stressed cash flows and mismatch in liquidity position were calculated by assigning predefined stress percentage to the overall cash inflows and outflows in different time buckets over the next one year. Projected outflows and inflows as on March 2021 over the next one year were considered for calculating the liquidity mismatch under baseline scenario. The shocks applied were 5 per cent and 10 per cent decrease in inflows and 10 per cent and 15 per cent increase in outflows for time buckets over the next one year for the medium and high risk scenarios respectively. Cumulative liquidity mismatch due to such shocks were calculated as per cent of cumulative outflows and NBFCs presenting negative cumulative mismatch were identified.

2.4 Interconnectedness – Network analysis

Matrix algebra is at the core of the network analysis, which uses the bilateral exposures between entities in the financial sector. Each institution's lendings to and borrowings from all other institutions in the system are plotted in a square matrix and are then mapped in a network graph. The network model uses various statistical measures to gauge the level of interconnectedness in the system. Some of the important measures are given below:

Connectivity Ratio: This statistic measures the extent of links between the nodes relative to all possible links in a complete graph. For a directed graph, denoting total number of out degrees to equal $K = \sum_{i=1}^N k_i$ and N as the total number of nodes, connectivity ratio is given as $\frac{K}{N(N-1)}$.

Cluster coefficient: Clustering in networks measures how interconnected each node is. Specifically, there should be an increased probability that two of a node's neighbours (banks' counterparties in case of a financial network) are neighbours to each other also. A high clustering coefficient for the network corresponds with high local interconnectedness prevailing in the system. For each bank with k_i neighbours the total number of all possible directed links between them is given by $k_i(k_i-1)$. Let E_i denote the actual number of links between agent i 's k_i neighbours, viz. those of i 's k_i neighbours who are also neighbours. The clustering coefficient C_i for bank i is given by the identity:

$$C_i = \frac{E_i}{k_i(k_i - 1)}$$

The clustering coefficient (C) of the network as a whole is the average of all C_i 's:

$$C = \frac{\sum_{i=1}^N C_i}{N}$$

Tiered network structures: Typically, financial networks tend to exhibit a tiered structure. A tiered structure is one where different institutions have different degrees or levels of connectivity with others in the network. In the present analysis, the most connected banks are in the innermost core. Banks are then placed in the mid-core, outer core and the periphery (the respective concentric circles around the centre in the diagrams), based on their level of relative connectivity. The range of connectivity of the banks is defined as a ratio of each bank's in-degree and out-degree divided by that of the most connected bank. Banks that are ranked in the top 10 percentile of this ratio constitute the inner core. This is followed by a mid-core of banks ranked between 90 and 70 percentile and a 3rd tier of banks ranked between the 40 and 70 percentile. Banks with a connectivity ratio of less than 40 per cent are categorised as the periphery.

Colour code of the network chart: The blue balls and the red balls represent net lender and net borrower banks respectively in the network chart. The colour coding of the links in the tiered network diagram represents the borrowing from different tiers in the network (for example, the green links represent borrowings from the banks in the inner core).

Solvency contagion analysis

The contagion analysis is in nature of stress test where the gross loss to the banking system owing to a domino effect of one or more banks failing is ascertained. We follow the round by round or sequential algorithm for simulating contagion that is now well known from Furfine (2003). Starting with a trigger bank i that fails at time 0, we denote the set of banks that go into distress at each round or iteration by D_q , $q = 1, 2, \dots$. For this analysis, a bank is considered to be in distress when its Tier-I CRAR goes below 7 per cent. The net receivables have been considered as loss for the receiving bank.

Liquidity contagion analysis

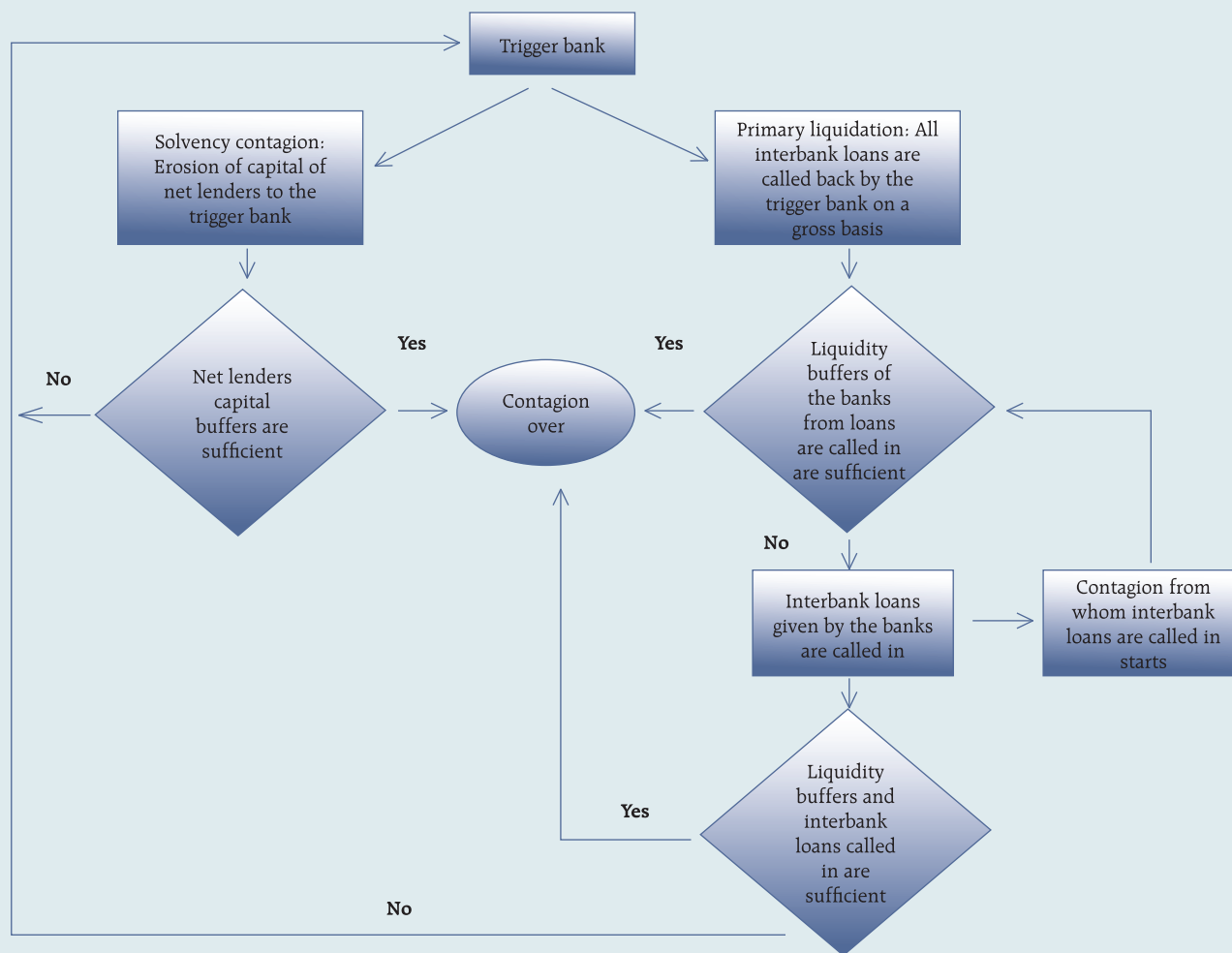
While the solvency contagion analysis assesses potential loss to the system owing to failure of a net borrower, liquidity contagion estimates potential loss to the system due to the failure of a net lender. The analysis is conducted on gross exposures between banks. The exposures include fund based and derivatives ones. The basic assumption for the analysis is that a bank will initially dip into its liquidity reserves or buffers to tide over a liquidity stress caused by the failure of a large net lender. The items considered under liquidity reserves are: (a) excess CRR balance; (b) excess SLR balance; and (c) 18 per cent of NDTL. If a bank is able to meet the stress with liquidity buffers alone, then there is no further contagion.

However, if the liquidity buffers alone are not sufficient, then a bank will call in all loans that are 'callable', resulting in a contagion. For the analysis only short-term assets like money lent in the call market and other very short-term loans are taken as callable. Following this, a bank may survive or may be liquidated. In this case there might be instances where a bank may survive by calling in loans, but in turn might propagate a further contagion causing other banks to come under duress. The second assumption used is that when a bank is liquidated, the funds lent by the bank are called in on a gross basis (referred to as primary liquidation), whereas when a bank calls in a short-term loan without being liquidated, the loan is called in on a net basis (on the assumption that the counterparty is likely to first reduce its short-term lending against the same counterparty. This is referred to as secondary liquidation).

Joint solvency-liquidity contagion analysis

A bank typically has both positive net lending positions against some banks while against some other banks it might have a negative net lending position. In the event of failure of such a bank, both solvency and liquidity contagion will happen concurrently. This mechanism is explained by the following flowchart:

Flowchart of Joint Liquidity-Solvency contagion due to a bank coming under distress



The trigger bank is assumed to have failed for some endogenous reason, *i.e.*, it becomes insolvent and thus impacts all its creditor banks. At the same time it starts to liquidate its assets to meet as much of its obligations as possible. This process of liquidation generates a liquidity contagion as the trigger bank starts to call back its loans.

Since equity and long-term loans may not crystallize in form of liquidity outflows for the counterparties of failed entities, they are not considered as callable in case of primary liquidation. Also, as the RBI guideline dated March 30, 2021 permits the bilateral netting of the MTM values in case of derivatives at counterparty level, exposures pertaining to derivative markets are considered to be callable on net basis in case of primary liquidation.

The lender/creditor banks that are well capitalised will survive the shock and will generate no further contagion. On the other hand, those lender banks whose capital falls below the threshold will trigger a fresh contagion. Similarly, the borrowers whose liquidity buffers are sufficient will be able to tide over the stress without causing further contagion. But some banks may be able to address the liquidity stress only by calling in short term assets. This process of calling in short term assets will again propagate a contagion.

The contagion from both the solvency and liquidity side will stop/stabilise when the loss/shocks are fully absorbed by the system with no further failures.