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What is the Reaction of Iranian Listed Banks to the Implementation of Liquidity Requirements?

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Abstract

After the financial crisis of 2007-2009, in which liquidity problems led to insolvency and consequently the bankruptcy of many large banks and financial institutions such as Lehman Brothers, Basel Committee on Banking Supervision introduced liquidity requirements for the most part to reduce the possibility of bank insolvency caused by liquidity shocks. This research develops an agent-based model of a banking system to be used to analyze the impact of the liquidity requirements on the solvency position of banks. The model devises a banking system with 12 heterogeneous banks in which banks perform their traditional activities namely taking deposits and making loans. Banks can fulfill their liquidity needs by engaging in interbank lending, selling their securities, and using central bank lending assistance. The model aims to study the behavior of different banks in response to imposing liquidity requirements. This model is calibrated using the data of Iranian listed banks during 2018-2020. Liquidity requirements are measured using liquidity coverage ratio, and the solvency position of a bank is measured using the capital adequacy ratio. The results of the simulations demonstrate that as liquidity requirements increase, the solvency position of some banks improves, some banks deteriorate, and some remain unchanged. Regarding this reaction among other various factors, profitability, inflow, and outflow of liquidity, and finally, the outflow rate parameter play an essential role.

Highlights

- A model to analyze different policy experiments regarding liquidity requirements of the banks which calibrated using Iranian banks data.
- Using an agent-based model to take into account the interaction between banks in the interbank market and banks interactions with the central bank.
- Taking into consideration security market and central bank assistance when a bank faces liquidity problems.

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1. Introduction

The global financial crisis of 2007-2008 demonstrated excessive risk-taking by banks could undermine the vital economic functions they perform, so prudential regulations were designed for the most part to ensure that banks hold adequate capital and liquidity resources to avoid financial crises by imposing capital and liquidity requirements.

Bank's business activities can finance by making use of several different funding sources. Capital is the bank's 'own funds', compared to borrowed funds such as customer's deposits. Capital can be defined as a difference between the value of total assets and liabilities. The capital of bank represents loss absorption capacity of the bank. Capital requirements ensure financial stability by requiring banks to hold large enough buffer of capital, such as shareholder's equity, which may absorb losses that could otherwise threaten a bank's solvency. On the other hand, funding liquidity risk denotes the risk that, under stressed market conditions, the bank would be unable to meet its obligations as they fall due. Liquidity requirements require banks to have sufficiently stable sources of funding and hold an adequate buffer of liquid assets (Farag et al, 2013).

Solvency and liquidity are considered and regulated separately although there is considerable interplay between risks to a bank's solvency and liquidity as Goodhart (2008) mentioned "*Liquidity and solvency are the heavenly twins of banking, frequently indistinguishable. An illiquid bank can rapidly become insolvent, and an insolvent bank illiquid.*"

This paper addresses this pertinent question: what is the effect of imposing liquidity requirements on the solvency position of banks? The aim of this study is to identify the reaction of heterogeneous banks to different values of liquidity requirements. The data for initial values and parameters were collected and calculated from the publications available on the Iranian's Securities & Exchange Organization website[1] (monthly data in the period 2018-2020).

The agent-based modeling (ABM) approach is utilized to model the behavior of banks as individual agents. ABM can provide us with insights into the ways banks interact and the ways shocks can propagate in the financial system. By including a set of individual agents that can interact with one another in the model, ABMs can simplify the modeling of complex systems such as banking systems (Basel Committee on Banking Supervision (BCBS), 2016).

Another approach could be to use econometric and statistical techniques. However, due to reliance on past data, these methods are not able to capture the effects of regime change. As Chan-Lau (2017) mentioned "an econometric model, estimated using data predating the introduction of the Basel III regulatory reforms, may provide poor guidance on the likely impacts of the reforms going forward"

Agent-based models can be used for analyzing risks in financial systems, and serve as computational laboratories for evaluating different scenarios (Bookstaber, 2012).

[1] WWW.CODAL.IR

The organization of the remainder of the paper is as the following. Section 2 reviews the related literature ahead of presenting model dynamics in Section 3. Section 4 describes in detail the parameters and initial value of variables, and Section 5 illustrates the use of the platform to analyze the effects of changes on the liquidity requirements on the solvency position of banks. Finally, section 6 concludes discussing the policy implications of the model.

2. Literature Review

Liquidity requirements lead banks to increasing their stable funding and holding liquid buffers to help protect a bank from risks that may threaten the solvency of the bank (BCBC, 2016). There is a rich updated literature on the interaction between capital requirements, which we consider as a measure of bank's solvency, and liquidity requirements. Some papers analyze the impact of bank' size; they have achieved completely different results though. For instance, Novokmet and Marinovic's (2016) paper shows that the trade-off between the solvency and liquidity level is found in larger banks. They used the data of 32 Croatian banks in the period 2002-2010 to investigate the nexus between solvency and liquidity. The dynamic panel data was implemented to analyze two basic models in which current liquidity ratio and equity-to-asset ratios are set as dependent variables, interchangeably. Capturing the effect of bank size, profitability, and asset quality as well as the macroeconomic environment, some other explanatory variables were employed. According to their findings, there is a two-way positive relationship between bank solvency and liquidity in that bank size plays an essential role in the capital and liquidity management. Based on their findings, they emphasize that policymakers should take into account capital and liquidity interplay, as well as the bank size effect when designing capital and liquidity requirements to minimize the regulatory burden for smaller banks, and increase them for larger banks.

In a similar paper, Schmitz et al. (2019) presented the evidence on the empirical relationship between bank solvency and funding costs by constructing a unique data set consisting of confidential reporting data shared across supervisory agencies from six countries with a total of 54 large banks over 2004–2013. They used a simultaneous equation approach with panel data to estimate the interaction between solvency and funding costs. Their results exhibited that solvency and funding costs were determined simultaneously. A 100-bps increase in regulatory capital ratios would decrease bank funding costs of about 113 bps. A 100-bps rise in funding costs would decrease regulatory capital buffers by 48 bps. Applying their estimation results to the 2014 EU-wide stress test reveals that neglecting the solvency-funding cost nexus leads to the systematic and significant underestimation of the impact of shocks on bank capital ratios.

The results of these two papers accentuate the fact that bank size is an influential factor in the relationship between liquidity risk and bank insolvency; hence, this relationship exists only for large banks. But on the contrary, the paper by Distinguin et al. (2013) show that smaller U.S. banks increase their capital ratios (improve their solvency position) when they face illiquidity as measured by the net stable funding ratio (NSFR). They analyzed the interaction between capital and liquidity requirements. The liquidity position of a bank is measured using an NSFR proxy and a "liquidity creation" proxy which measures the extent to which banks transform liquid liabilities into illiquid assets. However, using an adjusted illiquidity indicator that focuses on core deposits (only for U.S. banks), they suggested some degrees of substitutability between capital and liquidity requirements when some adjustment-to-portfolio occurs in the data.

Also DeYoung et al. (2018) reveal that liquidity behavior of small and large banks in reaction to negative capital shock is similar. They studied the liquidity behavior of commercial banks in response to adverse capital shocks. They used pre-Basel III data, and showed U.S. banks with assets less than $1 Billion treated (unregulated) liquidity and (regulated) capital as substitutes. Following exogenous shocks to their regulatory capital ratios, these banks shifted away from loans, loan commitments, and dividend payouts, actions with which both bank types repaired their capital ratios and enhanced their liquidity positions. They found little similar behavior at larger banks.

Some papers consider systemic significance like that of Aldasoroa and Faia (2016). They proposed that differential (across banks) application of coverage ratios based on a systemic importance ranking reduces the externalities and provides a more stable system. Proposing a network model of optimizing banks featuring contagion on both sides of balance sheets, they used the model to study the effects of phase-in increases of liquidity coverage ratios. In this model, risk-averse banks solve optimal portfolio problems by opting for short term liabilities, liquid and, non-liquid asset investment and, interbank borrowing and lending. Their model is calibrated to the network of large European banks via simulated method of moments. Their findings show that the systemic risk profile of the system is not improved and might even get worse.

Also Hałaj (2018) introduces a model focusing on systemic aspects of liquidity and its links with solvency conditions to investigate the importance of the channels through which the funding shock to financial institutions can spread across the financial system. Interactions among market participants are taken into account using an agent-based modeling approach. The model is calibrated using data from 2014 E.U.

A paper by Carletti et al. (2020) considers the level of capitalization and portfolio liquidity. They built a global game model to analyze the interdependent effects of bank capital and liquidity on the likelihood of solvency- and liquidity-driven crises. They demonstrated that changes at the level of bank capitalization always reduce the likelihood of solvency-driven crises, while changes at the level of liquidity of its portfolio always increase it. The effects on liquidity-driven crises are more mixed and dependent on the initial level of bank capitalization and the liquidity of its portfolio. Improving capitalization is beneficial unless the bank is less capitalized and/or holds an illiquid portfolio. Improving the level of liquidity of the bank portfolio reduces the likelihood of a crisis only if the bank is characterized by an intermediate level of capitalization and portfolio liquidity. They then derive some implications in terms of the design of optimal capital and liquidity regulation. The central insight is that capital and liquidity requirements cannot be set independently of bank capitalization and portfolio liquidity. Moreover, when properly designed, capital and liquidity regulations are perfect substitutes to restoring stability.

And finally, Kara and Ozsoy (2020) investigate the interaction between capital and liquidity requirements and the optimal design of them. Their model is characterized by fire sale externalities, and results indicate that the pre-Basel III regulatory framework, with its reliance on capital requirements alone, was ineffective in addressing systemic instability caused by fire sales.

The above-mentioned papers have addressed various factors such as bank size, profitability, and systemic importance, level of capitalization and portfolio liquidity and optimality. In this paper, we first observe the reaction of different banks to different values of liquidity requirements and then try to find the influential factors in this regard by examining the differences and similarities of banks with the same behavioral patterns.

3. The Model

In this section, we introduce a dynamic agent-based model of a banking system that can be used to analyze the impact of the liquidity requirements on the solvency position of banks. We use the paper by Smaga et al. 2018 and Georg 2013 to devise this model. The model introduces a banking system with 12 heterogeneous banks regarding their size and balance sheet structures and the traditional business models by banks in terms of taking deposits and making loans. Since we would like to analyze the reactions of banks to their liquidity shock, our model focuses on the short term and updates every day. The interbank market arises endogenously when banks access it to meet their liquidity needs. Central bank assistance is accessible to banks failing to find enough funds from the interbank and security market.

3.1 Balance Sheets

The balance sheet of a bank i includes loan to firms and households $Loan_t^i$, cash $Cash_t^i$, security $Secu_t^i$ as assets and deposits $Depo_t^i$, equity Equ_t^i, the loan from interbank INL_t^i and the loan from the central bank CLo_t^i as liabilities every day.

A bank has to maintain a certain fraction of deposit $\beta Depo_t^i$ as required reserves at the central bank, the balance sheet of a bank is given as:

$$Loan_t^i + Cash_t^i + Secu_t^i = (1-\beta)Depo_t^i + Equ_t^i + INL_t^i + CLo_t^i \tag{1}$$

At the beginning of every day, the bank has assets and liabilities from the end of the previous day:

$$Loan_{t-1}^i + Cash_{t-1}^i + Secu_{t-1}^i = (1-\beta)Depo_{t-1}^i + Equ_{t-1}^i + INL_{t-1}^i + CLo_{t-1}^i \tag{2}$$

In day 0, we endow each bank with initial values.

Then, some daily events occur for instance banks obtain interest for the loan R^l and pay interest on deposits R^d. The firms and household pay back some parts of the loans and banks make some new loans to firms and household, so the bank's loans change by $\Delta Loan_t^i$. Afterwards, households can take new deposits or withdraw their deposits, so the bank's deposits change by $\Delta Depo_t^i$. Finally, all central bank loans CLo_{t-1}^i and interbank INL_{t-1}^i plus interests are paid. The interest rate for the central bank loan is R^c and for the interbank loan is R^{in}. Therefore, the cash amount $Cash_t^i$ is given as:

$$Cash_t^i = Cash_{t-1}^i + \Delta Depo_t^i + \left(1 + R^{in}\right) INL_{t-1}^i + R^l - R^d - (1 + R^c) CLo_{t-1}^i - \Delta Loan_t^i \quad (3)$$

Interbank loans can be positive which means the bank has excess liquidity and makes loans to other banks or negative which means the bank has demand for liquidity and gets loans from other banks.

3.2 Calculating Regulatory Ratio

Following the calculation of the cash amount, each bank checks whether it has satisfied liquidity requirements. In our model, we assume two liquidity requirements that banks try to maintain every day. These requirements could trigger banks' behavior in the interbank market, the security market, and interaction with the central bank:

$$Cash_t^i \geq \beta Depo_t^i \quad (4)$$

$$LR: \frac{Cash_t^i + Secu_{t-1}^i}{\delta Depo_t^i} \geq SLR \quad (5)$$

Reserve Requirement (RR) $\beta Depo_t^i$ is an obligatory level of bank reserves set aside for situations that a bank faces liquidity shocks. LR is defined as high-quality liquid assets (cash and security) divided by total net deposit outflows over the next 30 calendar days. δ is the probability of deposit outflows over the next 30 calendar days (deposit outflow rate). SLR is a liquidity requirement imposed by policymakers.

If a bank meets the two liquidity requirements and still has an excess liquidity, it can allocate them to the interbank market. If a bank fails to meet the two liquidity requirements and faces a cash shortfall, it can borrow the amount needed to meet the cash deficit to comply with the two requirements.

3.3 Demand or Supply of Interbank Loan

According to the Central Bank of Iran's reports on the overall performance of the interbank market in Rials, more than 90% of interbank transactions in the Iranian interbank market are overnight loans[2] so for the purpose of simplicity, we can assume that interbank transactions only include unsecured overnight loans.

[2] According to the Central Bank of Islamic Republic of Iran reports on the overall performance of the interbank market in Rials.

$$\underline{INL_t^i} = min\left(Cash_t^i - \beta Depo_t^i\,, Cash_t^i + Secu_{t-1}^i - \delta Depo_t^i * SLR\right) \tag{6}$$

Consequently, the realized interbank loan of a bank can be calculated using Georg (2013) rationing mechanism:

$$INL_t^i = min\begin{Bmatrix} \underline{INL_t^i}\,, -\sum_{j:i} \underline{INL_t^j} \Big| \underline{INL_t^j}.\underline{INL_t^i} < 0; \quad if \quad \underline{INL_t^i} > 0 \\ -\underline{INL_t^i}\,, \sum_{j:i} \underline{INL_t^j} \Big| \underline{INL_t^j}.\underline{INL_t^i} < 0; \quad if \quad \underline{INL_t^i} < 0 \end{Bmatrix} \tag{7}$$

When bank i has liquidity demand (supply), first it will go randomly to the interbank market and asks all banks j that connected to i (denote j: i) if they have liquidity excess (shortfall). If this is the case, the two banks will interchange liquidity via an interbank loan.

3.4 The Securities' demand or supply

If, after the interbank market transactions, the bank still does not meet liquidity requirements, it has to sell securities to cover its cash deficit. On the other hand, after allocating the excess to the interbank market if a bank still has liquidity excess, it can use it to buy securities. Although banks are not the only participants of security market, for the model, we assume that supply and demand of the banks could not influence the price of securities. The value of securities which a bank needs to buy or sell is given as:

$$\underline{Secu_t^i} = \underline{INL_t^i} - INL_t^i \tag{8}$$

$\underline{Secu_t^i}$ could be positive (in case of buying security) or negative (in case of selling securities).

The maximum value of securities which a bank can sell is equal to the value of its securities. It is assumed that each bank could buy enough securities. Security demand for each bank SD_t^i is:

$$SD_t^i = max\left(\underline{Secu_t^i}\,, -(1-\varepsilon)Secu_{t-1}^i\right) \tag{9}$$

ε is the average of daily fluctuations in the price of securities in the market, which can be negative or positive.

After buying (selling) securities, each bank securities' value is:

$$Secu_t^i = (1-\varepsilon)Secu_{t-1}^i + SD_t^i \tag{10}$$

3.5 The demand for Central Bank loan

If after selling securities the bank has a cash deficit, it can use the central bank assistance. Then central bank loan is given as:

$$CLo_t^i = \left|(1+\varepsilon)Secu_{t-1}^i + \underline{Secu_t^i}\right| \tag{11}$$

After all events, the equity of each bank is as follows:

$$Equ_t^i = Equ_{t-1}^i + R^l - R^d + R^{in} INL_{t-1}^i - R^c CLo_{t-1}^i \tag{12}$$

The equity of the bank in each day is equal to the equity of the previous day plus the interest received on loans, and minus the interest paid on deposits, the interbank loans and the central bank loan.

To examine the impact of liquidity requirement on solvency position after 60 working days, we calculate the capital adequacy of banks as following:

$$CAR = \frac{Equ_t^i}{Loan_t^i} \tag{13}$$

4. Model Parameters

We run the simulations with 12 banks and t = 60 update steps. Every simulation was repeated 300 times. The number of banks was chosen according to 12 listed Iranian banks. Frequencies of regulatory data for liquidity and solvency are different. The frequency of the regulatory data for liquidity is usually much higher (up to daily) than that of the solvency (usually quarterly). The analysis focuses on quarterly data of capital adequacy ratio, so the number of update steps was chosen to be 60 working days, i.e. approximately three months.

The interbank rate was chosen to be $r^{in} = 0.19$, according to the annual weighted average interbank rate in Iran at (2018-2020)[3]. The central bank loan interest rate $r^c = 0.34$, which resembles the situation in the Iranian banking system in2018-2020. The required reserve was chosen to be $\beta = 0.1$ which is similar to legal requirements in Iran.

Interest for loan R^l, interest on deposits R^d, loans changes $\Delta Loan_t^i$ and deposit changes $\Delta Depo_t^i$ for each bank are random variables with normal distributions which were calculated according to 12 listed Iranian banks monthly data. For simplicity of calculations, each bank is assigned with a number as a code. Table 1 shows the name of each bank and its code.

Table 1. Bank's Code

Bank Number (code)	Bank Name	Bank Number(code)	Bank Name
1	Sina	7	Melat
2	Day	8	Melal
3	Eghtesadenovin	9	Parsian
4	Tejarat	10	Pasargad
5	Saderat	11	Karafarin
6	Khavarmianeh	12	Postbank

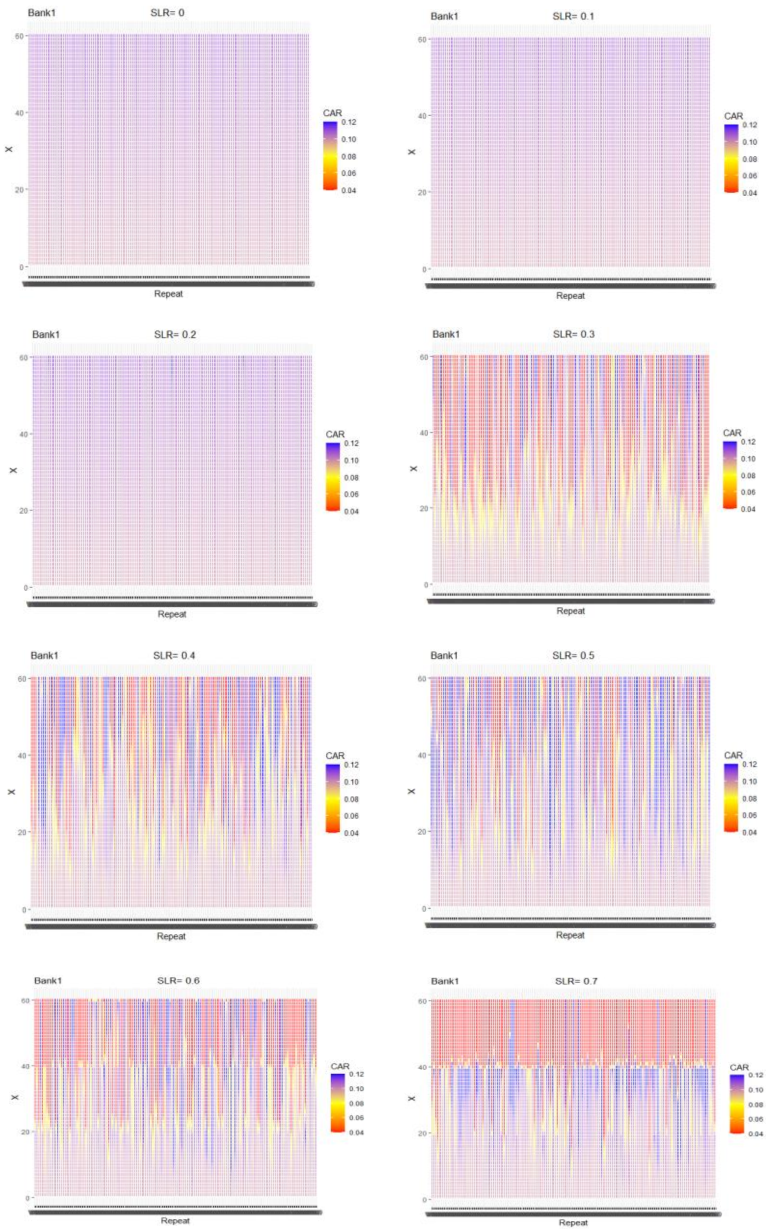
Source: *research computation*

5. Results

The critical question raised in this paper is: what is the effect of changing liquidity requirements on the solvency position of banks? The results show that banks can be divided into four categories based on their response to changes in liquidity requirements (SLR), each of which is described below. Bank 1, Bank 4, Bank 6, Bank 7, Bank 10, Bank 11, and Bank 12 have reacted the same. Figure 1 shows the capital adequacy ratio of Bank1 for different SLR values over 60 days

[3] Central bank of Iran, data on performance of the interbank market in Rials: https://www.cbi.ir/datedlist/8256.aspx

for 300 times simulation runs (figures of other banks of this group are available in Appendix 1).



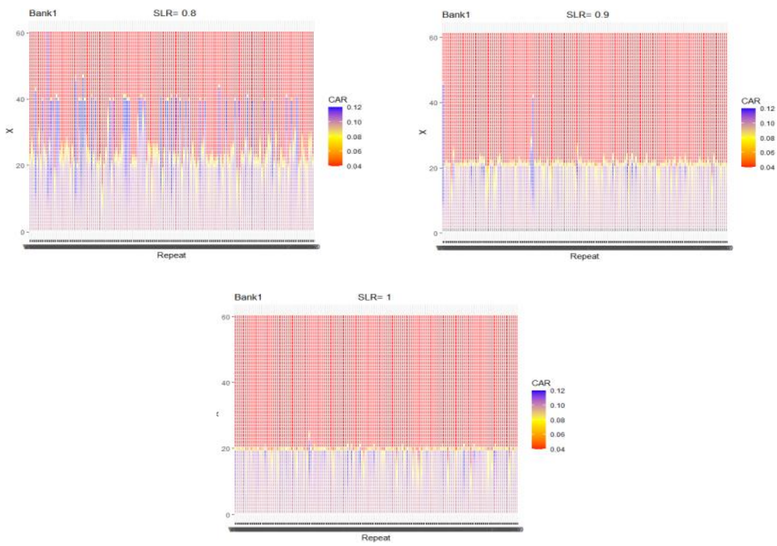


Figure 1. Capital adequacy ratio of Bank1 for different SLR values over 60 days (300 times simulation runs)
Source*: research computation*

In the figure, yellow dots indicate the capital adequacy of 0.08%, i.e. the bank is solvent, while blue dots indicate the improvement of the bank's solvency position. On the other hand, red color represents the deterioration of the bank's capital adequacy and insolvency.

When the liquidity requirement SLR is zero, the bank is solvent over 60 days. Nevertheless, the higher the SLR, the worse the bank's solvency position. Thus, when the SLR is equal to one, at the end of the first month (20 days of the month) due to the liquidity shock caused by meeting the liquidity requirements, the bank is forced to finance costly and eventually its capital deteriorates.

According to Table 1, these banks differ in terms of size as shown by the logarithm of the bank assets. Still, they are similar in terms of parameters related to the inflow and outflow of liquidity as well as profitability. For all of these banks, the mean of liquidity inflow parameters (Deposits and Loan Interest) is higher than the mean of outflow parameters (Loans and Deposit Interest). Therefore, the net liquidity inflow, which is obtained by subtracting the average liquidity inflow parameters and liquidity outflow parameters, is positive for all these banks.

Profitability is the difference between the average interest received on loans and the average interest paid on deposits. With the exception of Bank 11, the profitability of all banks is positive. The profitability of Bank 11 is negative but close to zero.

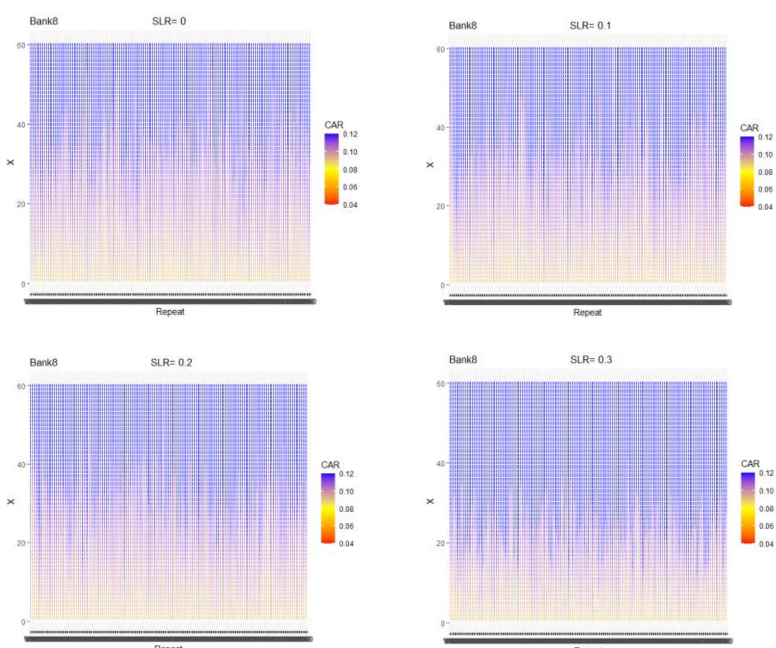
Outflow rate[4] (the probability of deposit outflows over the next 30 calendar days) of all these banks is relatively high, accordingly, they need to hold more liquid assets to meet the requirements, as a result, they see liquidity requirement as a negative liquidity shock; the stricter the liquidity requirements, the worse their solvency position becomes because they have to finance their liquidity needs using costly methods.

Although bank 8 has similar conditions to these banks in terms of positive profitability and net liquidity inflow, it has low outflow rate. For this bank imposing liquidity requirements has no significant impact on its solvency position as seen in Figure 2.

Table 2. Bank Parameters

Bank Name	Size	Profitability	Net Liquidity Inflow	Outflow Rate
Bank1	4.2	1.4	3.5	0.4
Bank4	4.8	6.3	55.9	0.48
Bank6	3.9	2.3	4.2	0.45
Bank7	5.2	25.3	44.6	0.62
Bank10	4.8	10.4	27.5	0.41
Bank11	4.1	-0.4	4.9	0.34
Bank12	3.8	1.05	1.9	0.55
Bank8	4.01	6	4.8	0.18

***Source**: Research Computation*



[4] Outflow rate is anticipated net cash flows, over a 30-day stress period compare to net liquidity inflow that is the realized values.

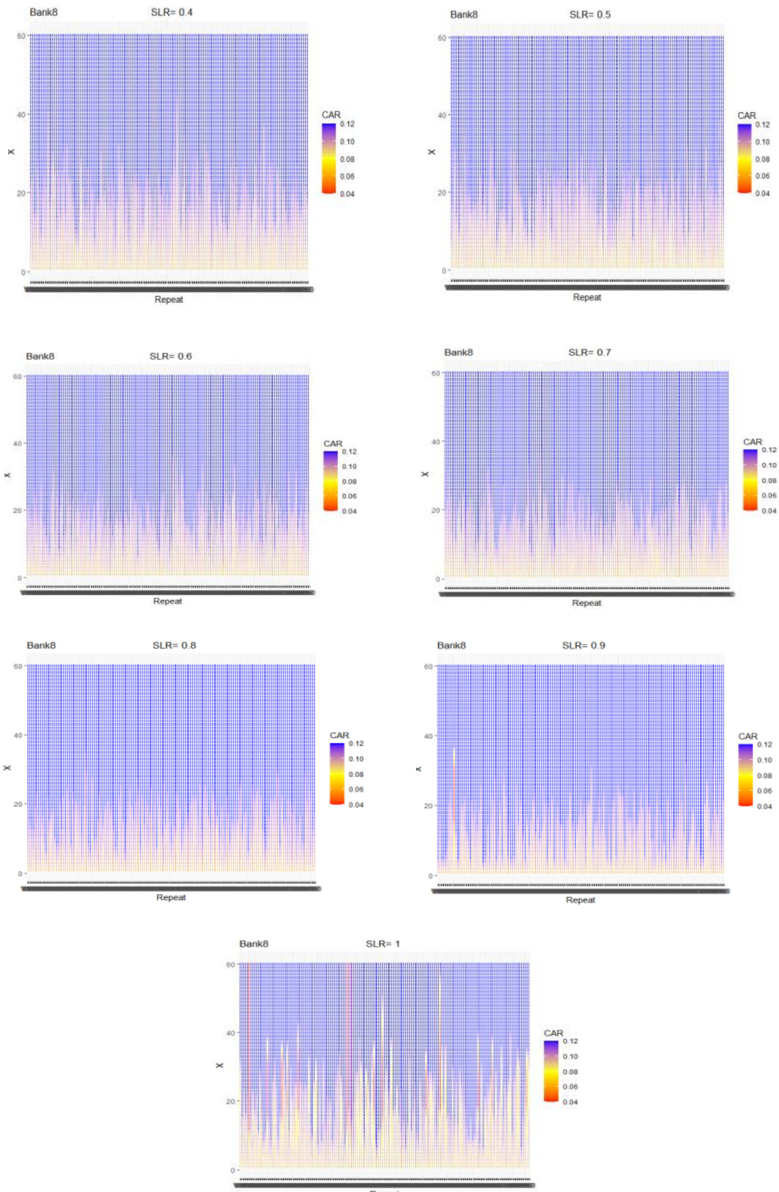


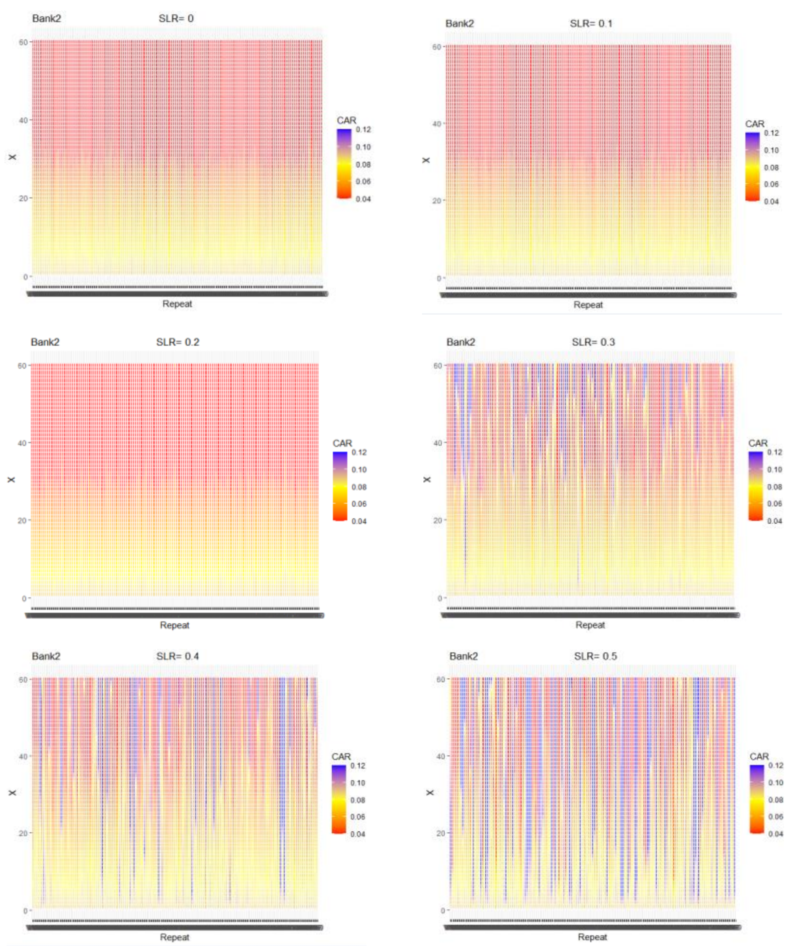
Figure 2. Capital adequacy ratio of Bank8 for different SLR values over 60 days for 300 times simulation runs
Source*: research computation*

The solvency position of Bank 2 is presented in Figure 3. When the SLR is equal to 0, 0.1, and 0.2 over 60 days the bank becomes insolvent (for all 300 hundred simulation runs). But as the SLR rises to 0.3 and more, we can see the probability of insolvency decreases slightly. Thus, we can see some yellow and blue points in the figure. However, for SLR=0.9 the probability of insolvency is lower than other SLR values. According to table 2, this bank has difficulty regarding its profitability and net liquidity inflow but low deposit outflow rate. The impact of liquidity requirements on solvency position of this bank is ambiguous because on the one hand, having low outflow rates lets it hold less liquid asset and it can lend to other banks and receive interest so its capital improves, on the other hand having poor liquidity and profitability worsen its solvency position so the overall effect is unknown.

Table 3. Bank Parameters

Bank Name	Size	Profitability	Net Liquidity Inflow	Outflow Rate
Bank2	4.1	-16.5	-5.2	0.21

***Source**: research computation*



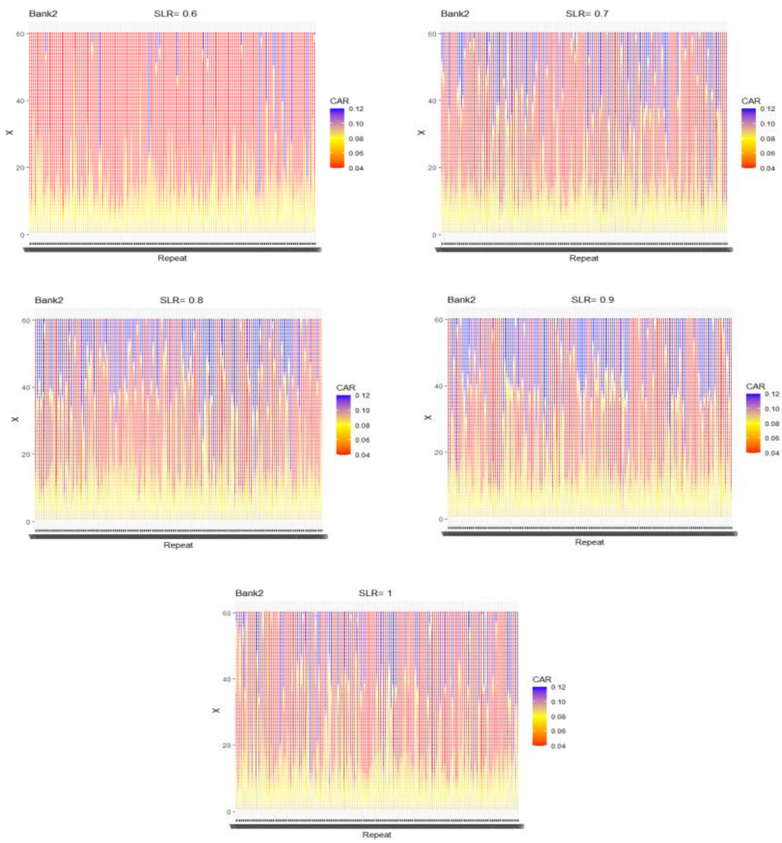


Figure 3. Capital adequacy ratio of Bank2 for different SLR values over 60 days for 300 times simulation runs
Source*: research computation*

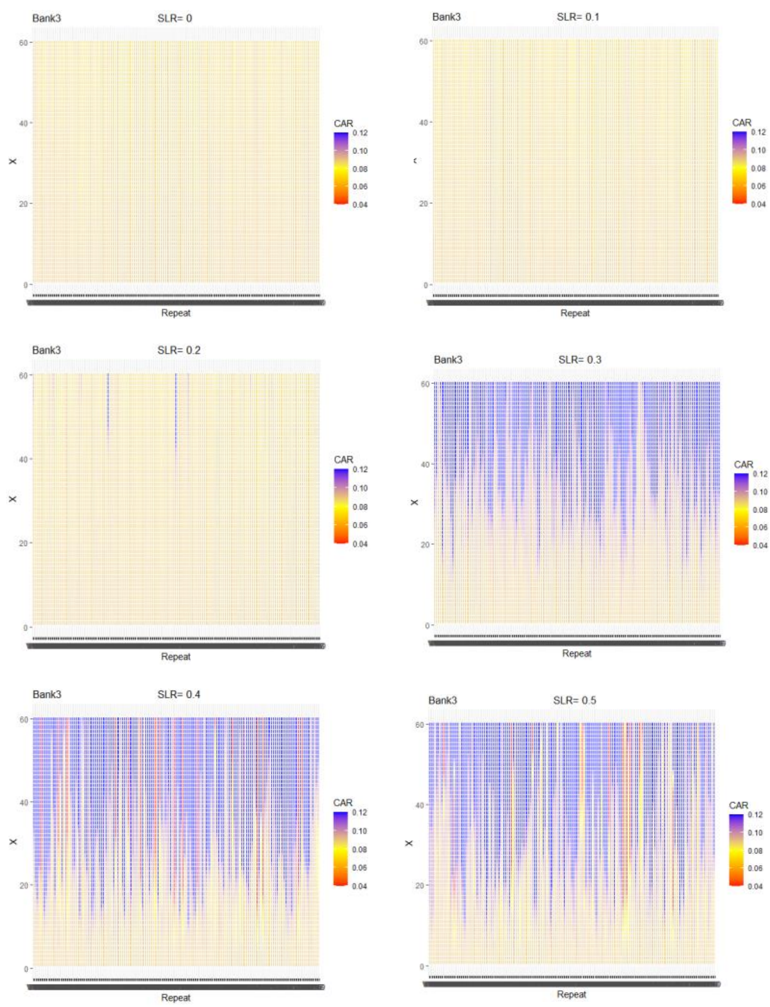
Finally Bank 3, Bank 5 and Bank 9 have shown the same reaction. Figure 4 exhibits the solvency position (capital adequacy ratio) of Bank 3 for different SLR values over 60 days for 300 times simulation runs (figures of other banks of this group are available in Appendix 2). As can be seen in the figure, when the SLR is zero, the bank's capital adequacy ratio increases over the 60-day period. As SLR increases to 0.3 and more, the solvency position improves so you can see the blue points increase. The higher the SLR, the better solvency position of these banks. For SLR values between 0.5 and 0.9, the probability of insolvency is lower than other SLR values.

Table 4. Bank Parameters

Bank Name	Size	Profitability	Net Liquidity Inflow	Outflow Rate
Bank3	4.5	-1.5	24.8	0.29
Bank5	5.0	-11.2	82.9	0.4
Bank9	4.8	-11.9	17.5	0.22

***Source**: research computation*

These banks have low profitability and at the same time have a good liquidity situation. Because they have low deposit outflow rate, they need less liquid asset to meet liquidity requirements so that they can lend to other banks with liquidity problems and receive interest, therefore, their capital situation will eventually improve.



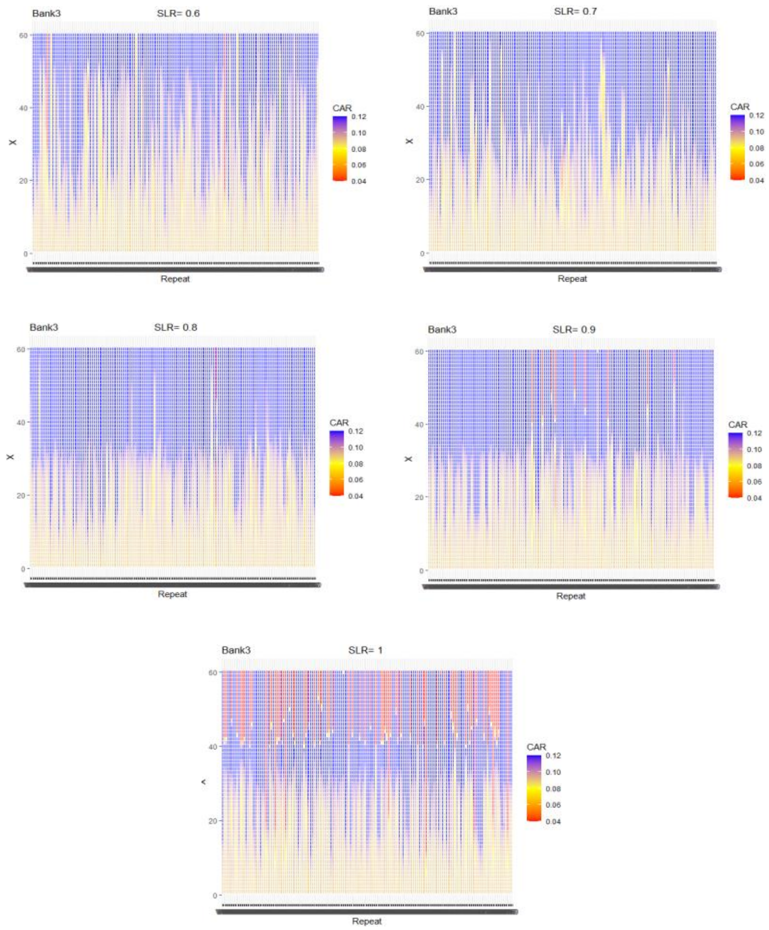


Figure 4. Capital adequacy ratio of Bank3 for different SLR values over 60 days for 300 times simulation runs
***Source**: research computation*

6. Concluding Remarks

Our analysis provides some novel insights into informing subsequent discussions on how to design liquidity and solvency regulations. We devised a banking system model with an interbank market structure dominated by overnight transactions and utilized a sample of Iranian banking system monthly data during 2018-2020 to study the behavior of banks in response to different LCR values. Banks behavior is motivated by the need to fulfill the liquidity requirements. The model's findings suggest that banks show different reactions and based on their response as being divided into four categories:

1) For banks with good liquidity and profitability situation, as liquidity requirements become stricter, the solvency position of these banks deteriorates.

These banks are different in terms of size; however, they are similar in terms of parameters pertinent to the inflow and outflow of liquidity as well as profitability. Hence, outflow rate of these banks which anticipates net cash out flows over a 30-day stress period, is relatively high i.e. they need to hold more liquid assets to meet the requirements, consequently, they see liquidity requirement as a negative liquidity shock; the stricter the liquidity requirements, the worse their solvency position becomes; that is because they have to meet their liquidity needs using costly methods.

2) For banks with good liquidity and profitability situation at the same time, their outflow rate is relatively low, i.e., as liquidity requirements become stricter, its solvency position remains unchanged.

3) For banks with a good liquidity and low outflow rate but poor profitability, as liquidity requirements become stricter, the solvency position of the bank improves. Because it has low deposit outflow rates, it needs less liquid assets to meet liquidity requirements, as a result, it can lend to other banks with liquidity problems and receive interest, eventually its capital will improve.

4) For banks with a poor liquidity and profitability, the impact of liquidity requirements on solvency position is ambiguous. Because on the one hand, having low outflow rates lets it hold less liquid asset and it can lend to other banks receive interest so that its capital improves, and on the other hand, having poor liquidity and profitability makes its solvency position worsen so the overall effect is unknown.

According to our results, bank size does not influence banks response to liquidity requirements which is contrary to the results of Novokmet and Marinovic (2016) and Schmitz et al. (2019). Still, the parameters of liquidity inflows and outflows and bank profitability and the outflow rate play an essential role.

A policy implication of this paper is that as the reactions of banks to liquidity requirements are different imposing the same liquidity requirements on all types of banks could be an inefficient policy. This supports DeYoung et al. (2018), Novokmet and Marinovic (2016) and Aldasoroa and Faia's (2016) results.

We assessed the effect of changes in liquidity requirements on the solvency position of banks. However, both liquidity and solvency can affect solvency position of banks. It would then be of interest to study the design of optimal policy under the situation in which both liquidity and solvency are chosen simultaneously. We leave this to the future research.

7. Acknowledgment

This paper is an outcome of a Ph.D. thesis written by Vahideh Sotoudeh Mollashahi under the supervision of Dr. Mohammad Talebi and advisory role of Dr. Mohammad Ali Rastegar and Dr. Ramin Mojab at the Monetary and Banking Research Institute of Central Bank of Iran.

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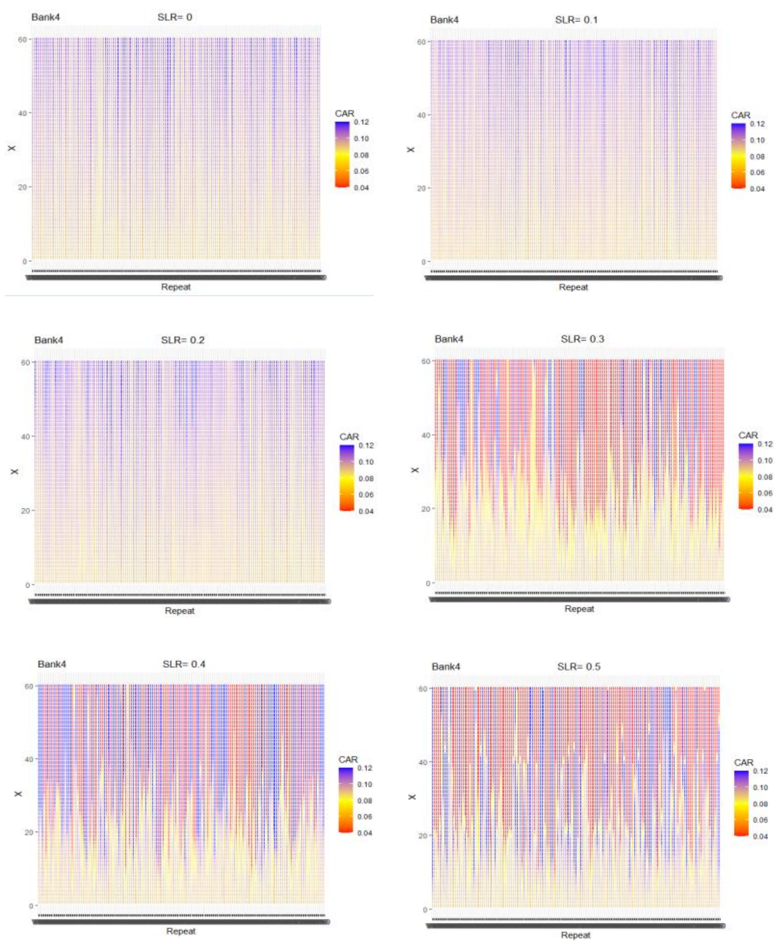
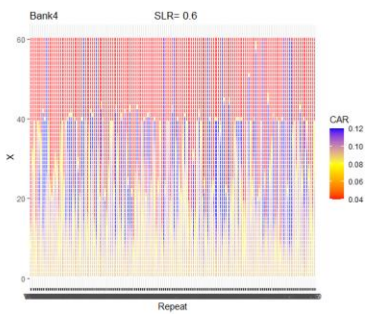
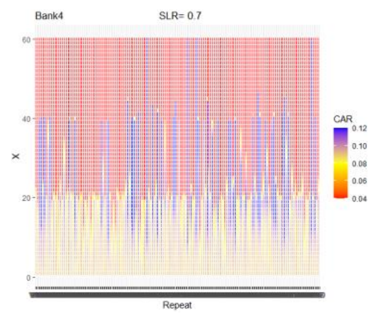
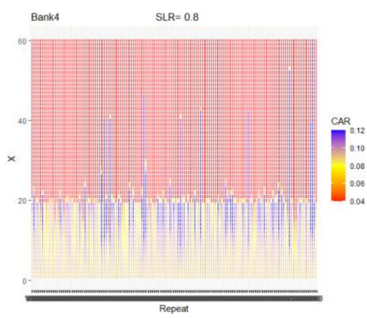
Appendices

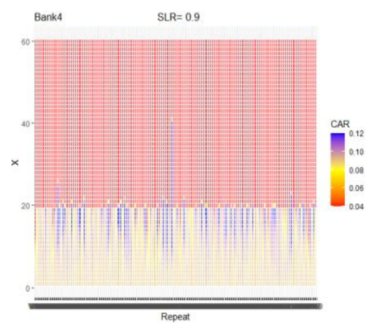
Appendix 1. Capital adequacy ratio of Bank 4, Bank 6, Bank 7, Bank 10, Bank 11, and Bank 12 for different SLR values over 60 days for 300 times simulation runs

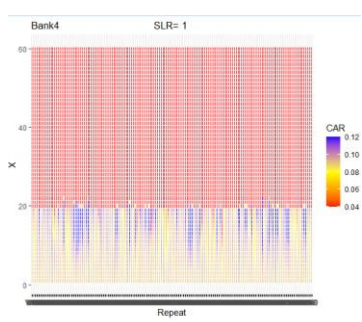


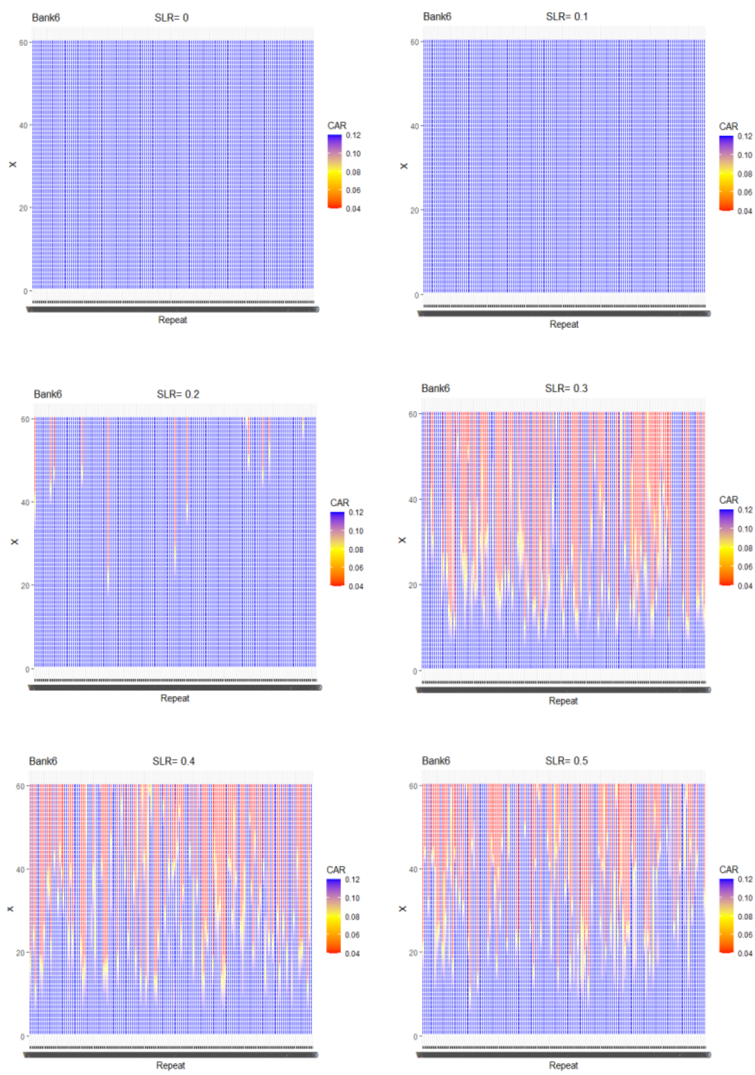

Bank4
SLR= 0.6
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat

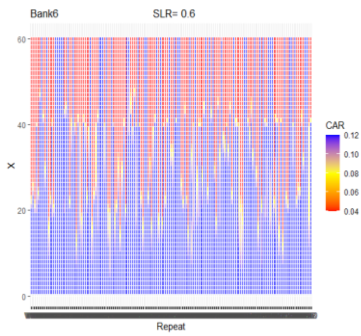

Bank4
SLR= 0.7
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat

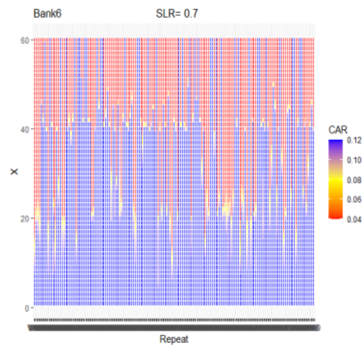

Bank4
SLR= 0.8
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat

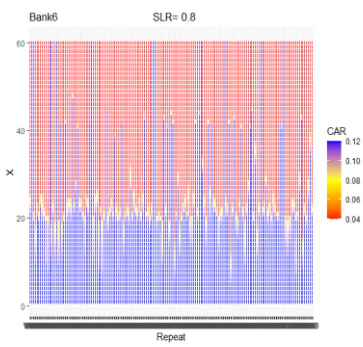

Bank4
SLR= 0.9
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat

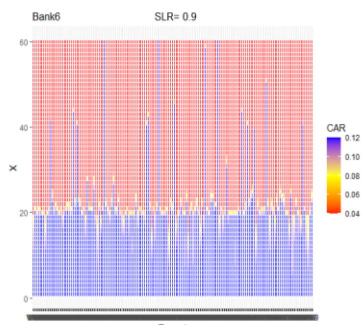

Bank4
SLR= 1
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat

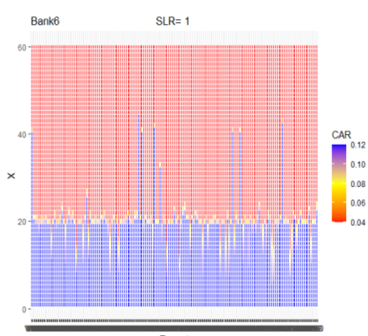

Bank6
SLR= 0
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat
Bank6
SLR= 0.1
Bank6
SLR= 0.2
Bank6
SLR= 0.3
Bank6
SLR= 0.4
Bank6
SLR= 0.5
60
40
20
0

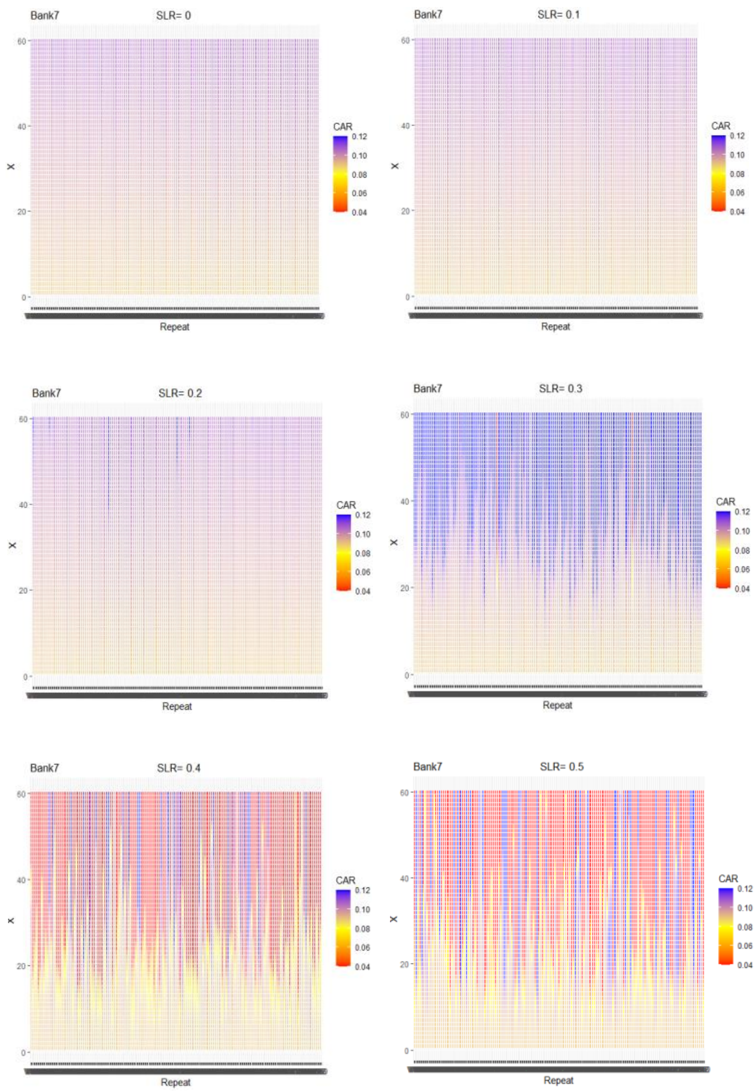

Bank6
SLR= 0.6
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat

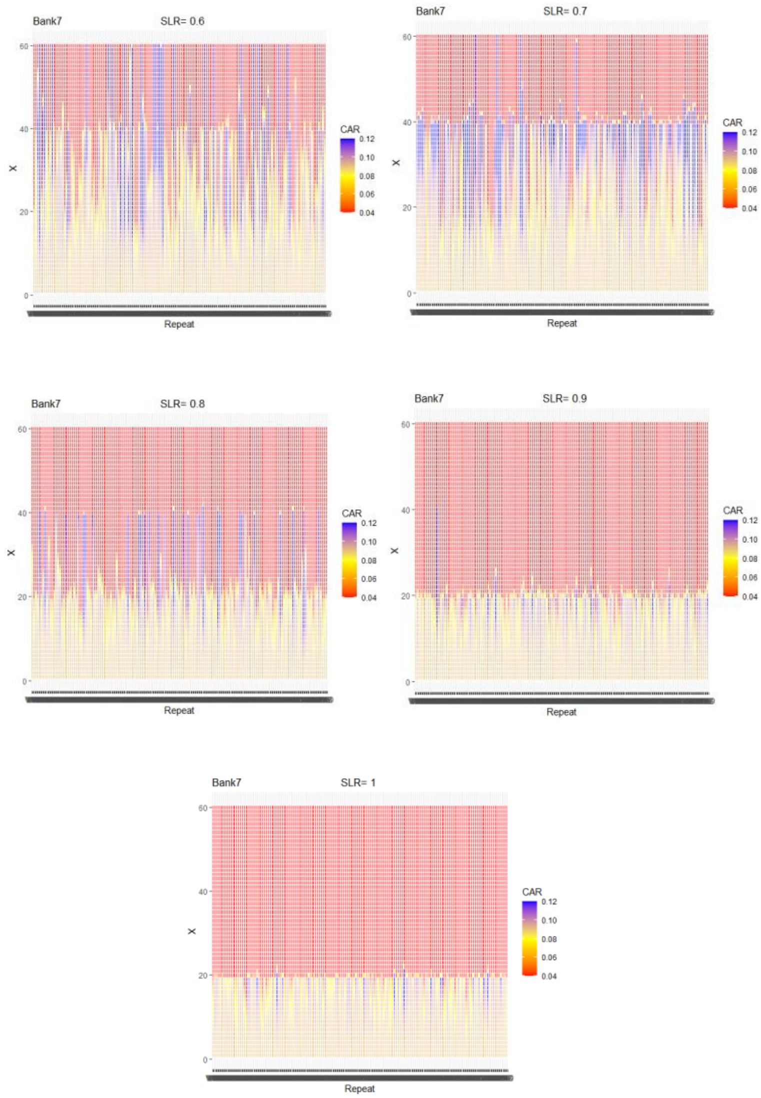

Bank6
SLR= 0.7
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat

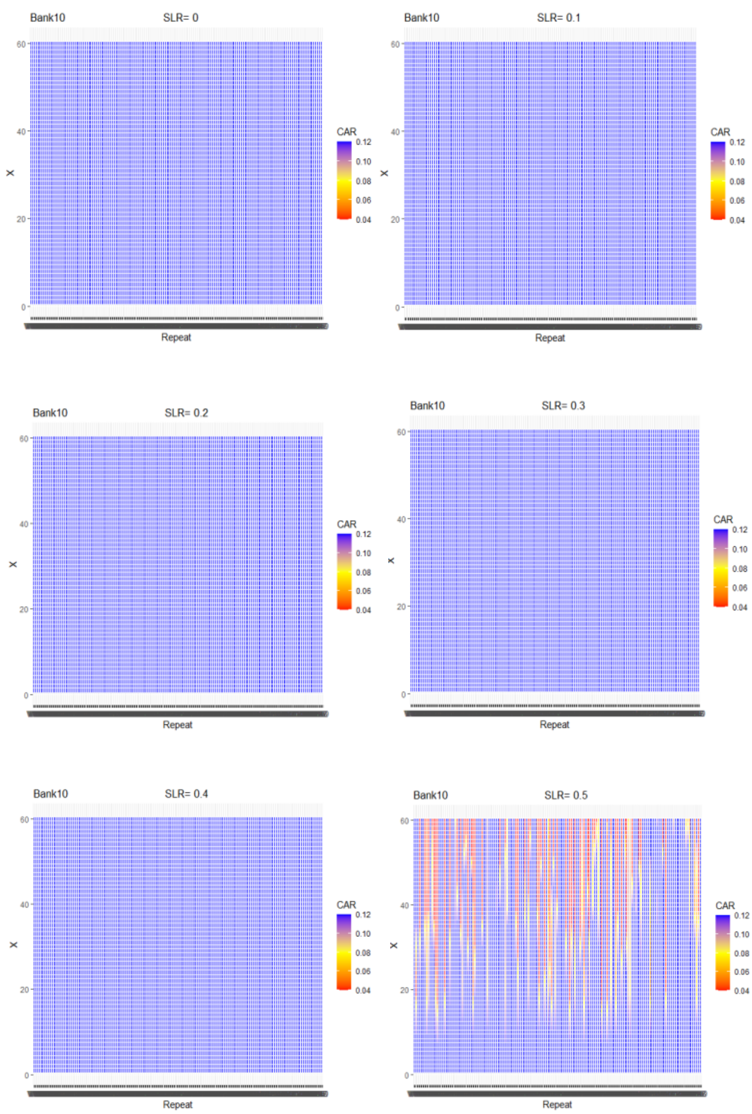

Bank6
SLR= 0.8
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat

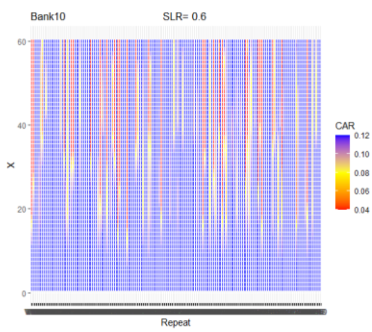

Bank6
SLR= 0.9
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat

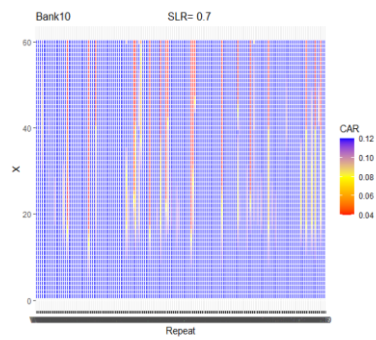

Bank6
SLR= 1
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat

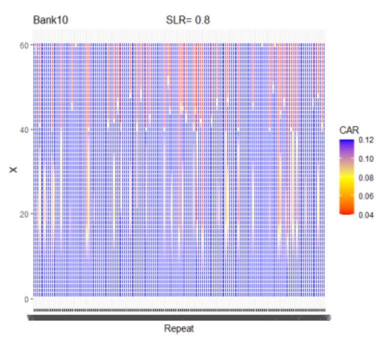

Bank7
SLR= 0
SLR= 0.1
SLR= 0.2
SLR= 0.3
SLR= 0.4
SLR= 0.5
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat
60
40
20
0

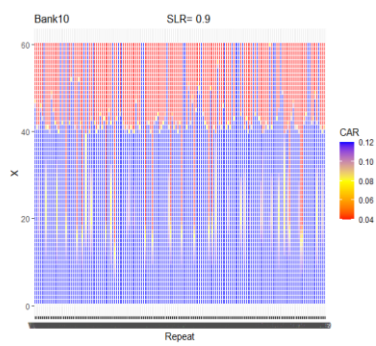

Bank7
SLR= 0.6
Bank7
SLR= 0.7
Bank7
SLR= 0.8
Bank7
SLR= 0.9
Bank7
SLR= 1
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04
0
20
40
60

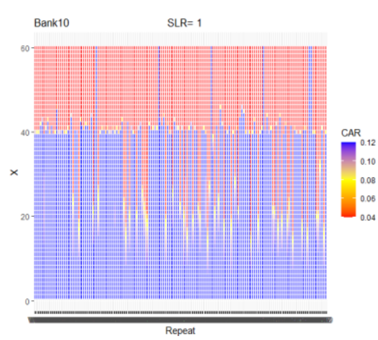

Bank10
SLR= 0
Bank10
SLR= 0.1
Bank10
SLR= 0.2
Bank10
SLR= 0.3
Bank10
SLR= 0.4
Bank10
SLR= 0.5
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat

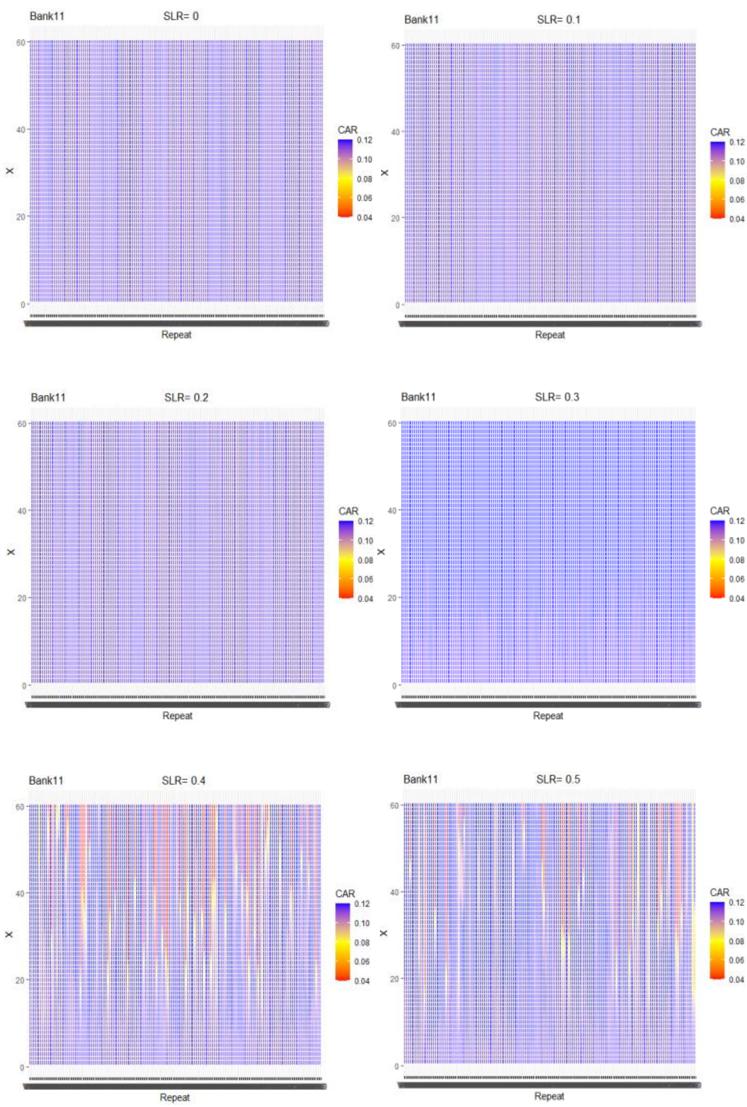

Bank10
SLR= 0.6
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

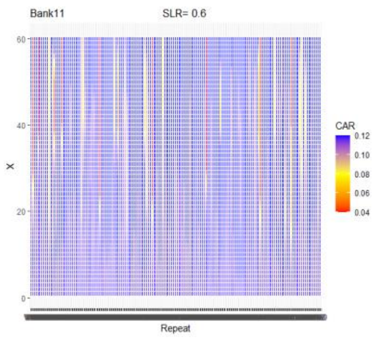

Bank10
SLR= 0.7
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

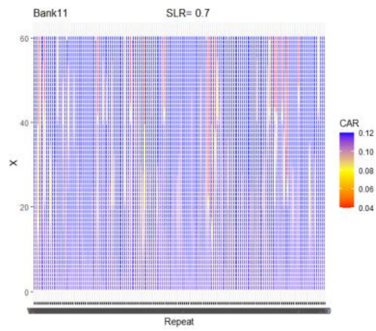

Bank10
SLR= 0.8
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

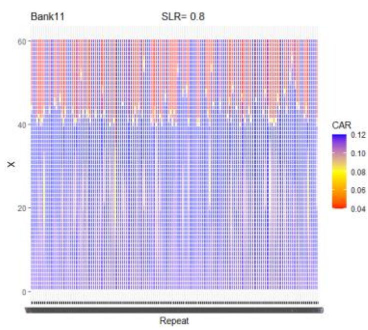

Bank10
SLR= 0.9
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

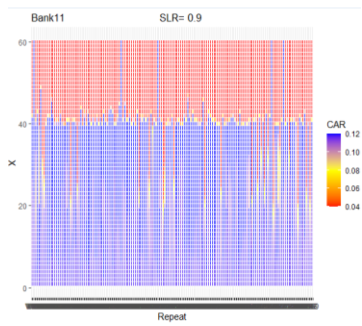

Bank10
SLR= 1
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

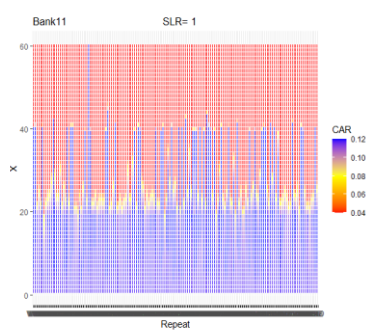

Bank11
SLR= 0
Bank11
SLR= 0.1
Bank11
SLR= 0.2
Bank11
SLR= 0.3
Bank11
SLR= 0.4
Bank11
SLR= 0.5
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat
0
20
40
60

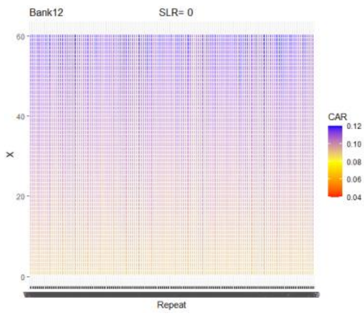

Bank11
SLR= 0.6
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

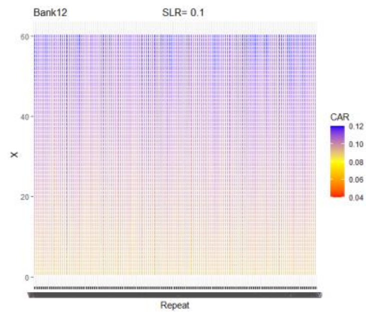

Bank11
SLR= 0.7
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

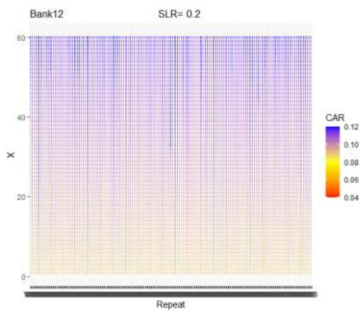

Bank11
SLR= 0.8
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

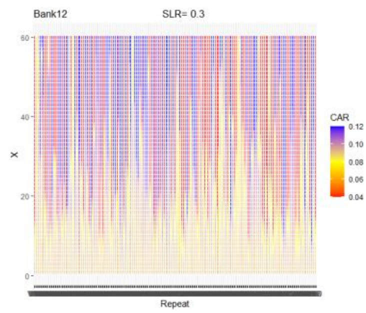

Bank11
SLR= 0.9
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

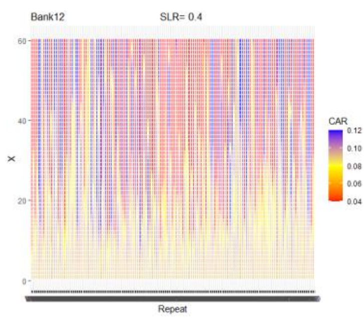

Bank11
SLR= 1
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

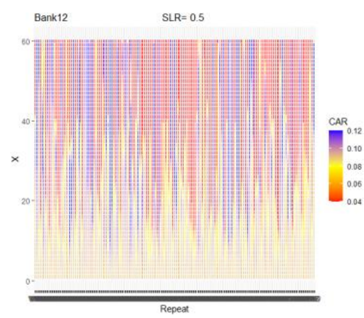

Bank12
SLR= 0
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

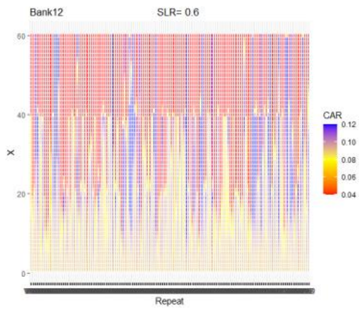

Bank12
SLR= 0.1
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

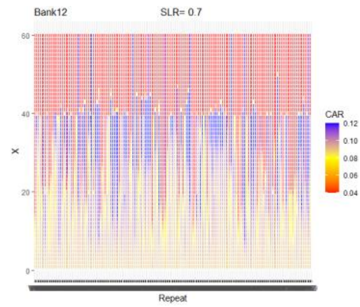

Bank12
SLR= 0.2
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

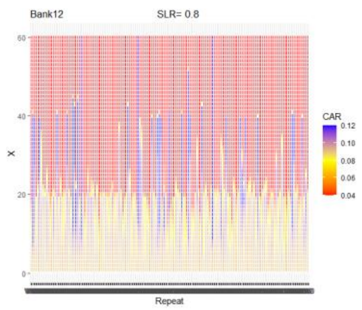

Bank12
SLR= 0.3
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

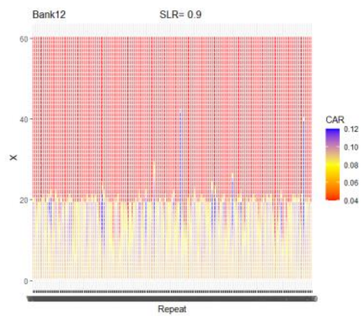

Bank12
SLR= 0.4
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

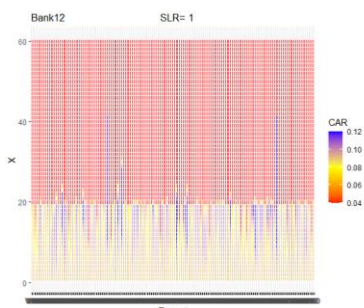

Bank12
SLR= 0.5
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04


Bank12
SLR= 0.6
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

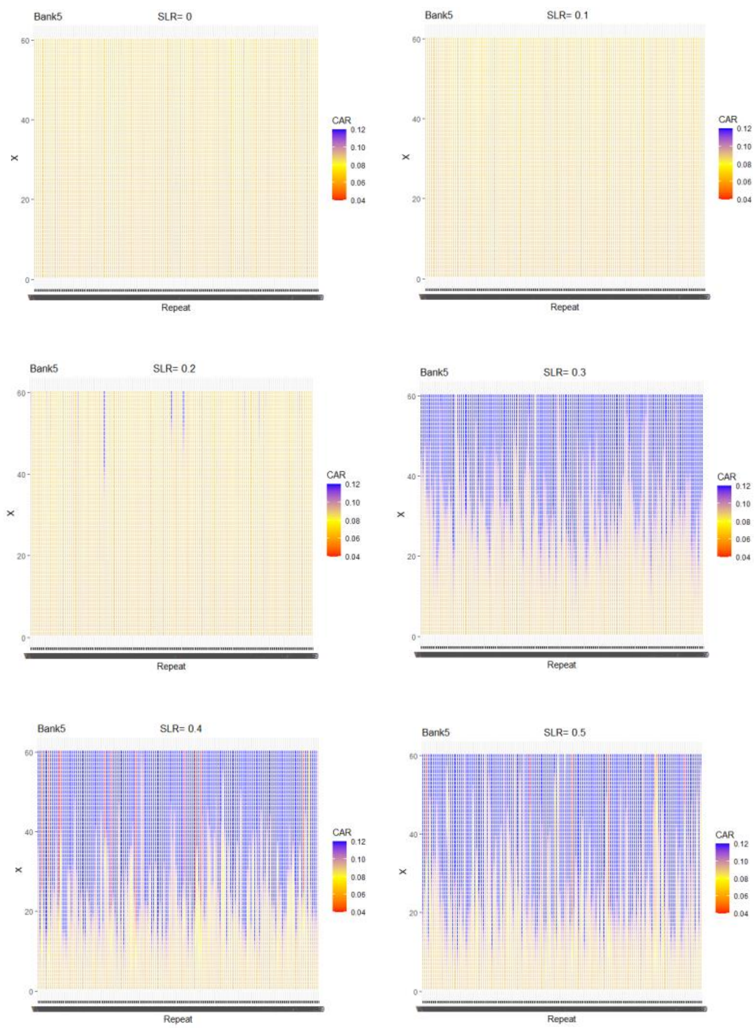

Bank12
SLR= 0.7
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

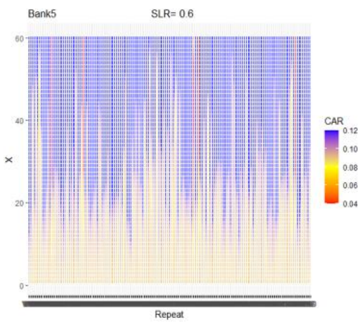

Bank12
SLR= 0.8
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

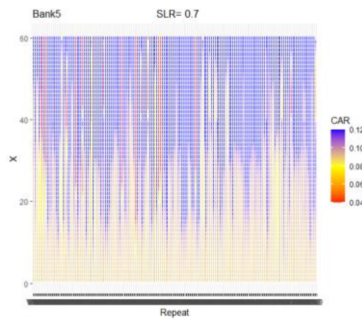

Bank12
SLR= 0.9
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

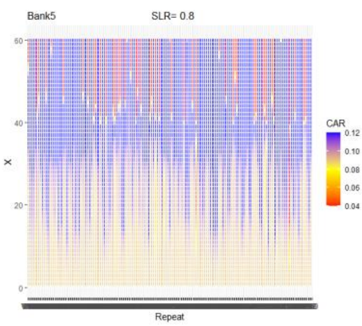

Bank12
SLR= 1
60
40
20
0
X
Repeat
CAR
0.12
0.10
0.08
0.06
0.04

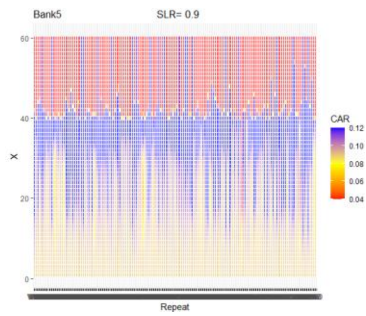
Appendix 2. Capital adequacy ratio of Bank 5and Bank 9 for different SLR values over 60 days for 300 times simulation runs

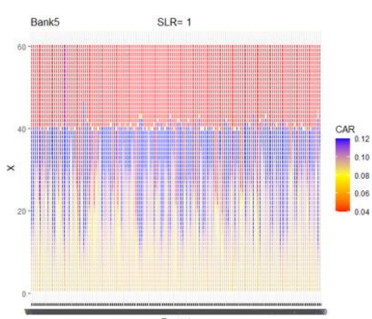


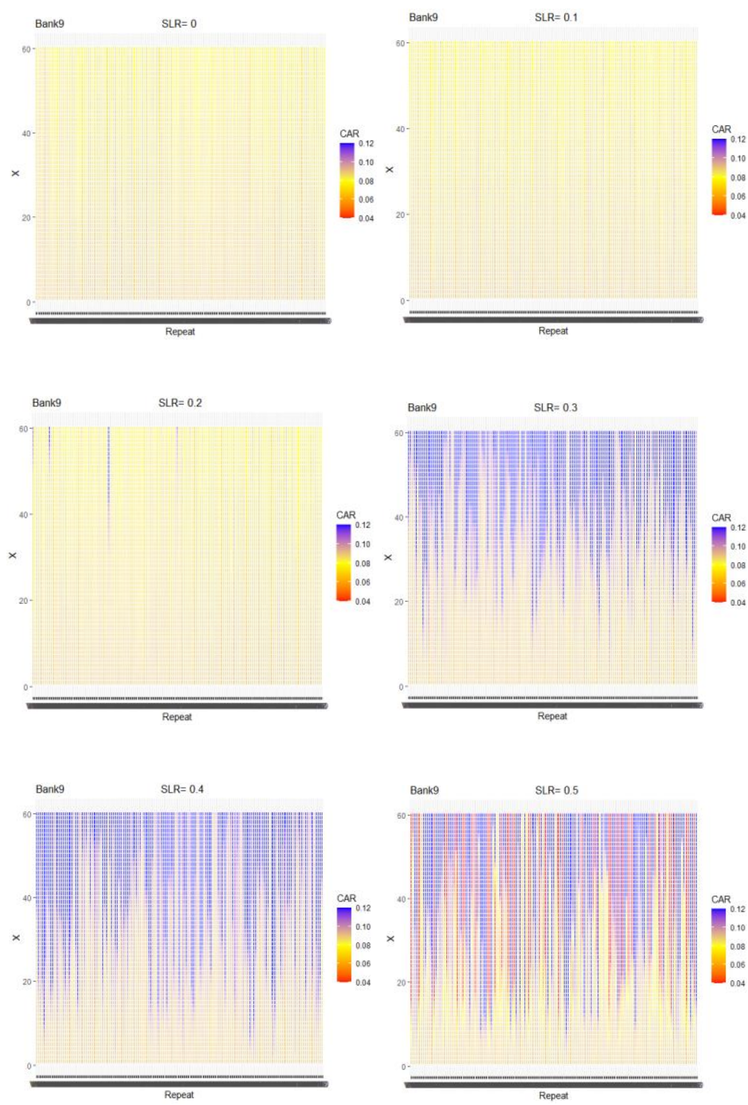

Bank5
SLR= 0.6
CAR
0.12
0.10
0.08
0.06
0.04
60
40
20
0
X
Repeat

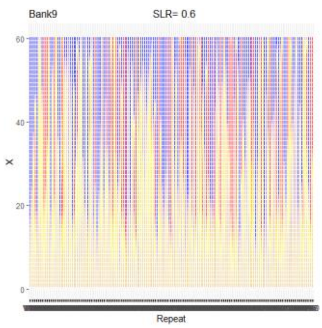

Bank5
SLR= 0.7
CAR
0.12
0.10
0.08
0.06
0.04
60
40
20
0
X
Repeat

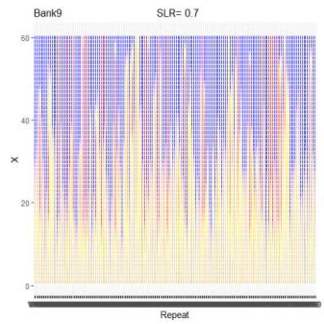

Bank5
SLR= 0.8
CAR
0.12
0.10
0.08
0.06
0.04
60
40
20
0
X
Repeat

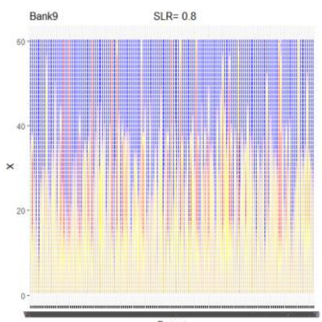

Bank5
SLR= 0.9
CAR
0.12
0.10
0.08
0.06
0.04
60
40
20
0
X
Repeat

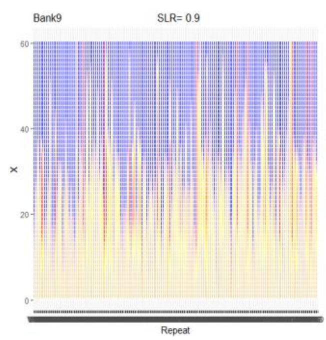

Bank5
SLR= 1
CAR
0.12
0.10
0.08
0.06
0.04
60
40
20
0
X
Repeat

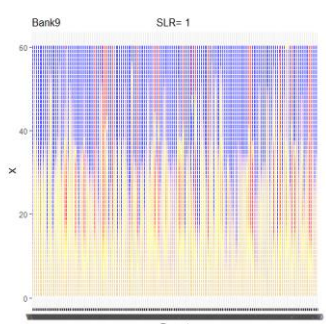

Bank9
SLR= 0
Bank9
SLR= 0.1
Bank9
SLR= 0.2
Bank9
SLR= 0.3
Bank9
SLR= 0.4
Bank9
SLR= 0.5
CAR
0.12
0.10
0.08
0.06
0.04
X
Repeat


Bank9
SLR= 0.6
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat


Bank9
SLR= 0.7
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat


Bank9
SLR= 0.8
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat


Bank9
SLR= 0.9
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat


Bank9
SLR= 1
60
40
20
0
X
CAR
0.12
0.10
0.08
0.06
0.04
Repeat