STRESS TEST ON MARKET RISK: SENSITIVITY OF BANKS' BALANCE SHEET STRUCTURE TO INTEREST RATE SHOCKS

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I. INTRODUCTION

Stress tests, applied to the banking system, have been a tool widely used by several private and governmental institutions at the international level, especially after the global financial crisis. This tool assesses the resilience of banks to numerous macro-financial shocks in different dimensions.

In 1996, the Basel Committee on Banking Supervision (BCBS) recommended banks and investment firms to conduct stress tests to determine their ability to respond to market events. Initially, stress tests were only part of the internal self-assessment. But after the global financial crisis, some advanced economies, such as the United States, the European Union, and the United Kingdom, started stress testing for major banks. Although the Federal Reserve highlighted the use of stress tests before, these were only implemented formally in 2012 following the requirements of the Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank Act). On the other hand, the Committee of European Banking Supervisors (CEBS) conducts annual stress tests since 2009, while the Financial Policy Committee (FPC) of the Bank of England published their first stress test results in 2014.

The Central Bank of Chile has carried out stress tests since 2004 and has reported its aggregate results semiannually in its *Financial Stability Report*. The methodology of the exercises has been improved and extended according to the evolution of market structures and exposures, in a constant assessment of banking risks. The works of Jara et al. (2007), Alfaro et al. (2008, 2009), Alfaro and Sagner (2011), and Becerra et al. (2017) describe the progress of the methodology used by the Central Bank of Chile.

According to the international experience, credit and market risks have traditionally been the main sources of losses for banks. The credit risk is the potential loss due to the default on a debt. The market risk is primarily divided into interest rate risk and exchange risk. Interest rate risk is also separated into valuation and repricing risk. The valuation risk is defined as the loss of value of the trading book due to changes in interest rates, while the repricing risk is related to the additional cost of rollover of the long and short positions of the banking book. On the other hand, the exchange rate risk is the loss caused

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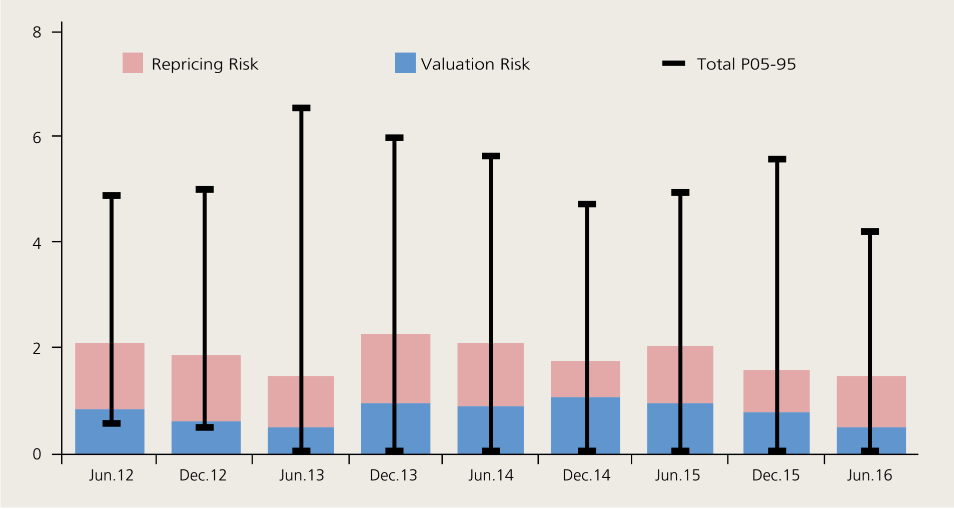
by changes in the exchange rate. However, there exist other types of risk such as operational and reputational risks and liquidity risk.[1]

In the case of Chile, based on the exercises conducted by the Central Bank of Chile, the exposure to credit risk could imply losses of around 20% of the overall banking system's capital. On the other hand, the interest rate risk is on average close to 2% of the capital (figure 1), while the exchange rate risk is almost zero because there is a small but long foreign currency position. However, despite the low magnitude of the interest rate risk as compared to credit risk, it has been volatile over time. Furthermore, some banks have reached figures above 6% of bank capital. In particular, the impact of the interest rate risk on the banking book (repricing risk) could reach 4% of the capital for some banks, while valuation losses on the trading book (valuation risk) could reach 5% (without including the treasury banks).

In this context, it is important to understand the changes of interest rate risks over time and between banks. This study aims to calculate the sensitivity of the level of interest rate risk of the banking and trading book to: (i) the structure of the banks (exposure); (ii) the initial interest rate curve (base); and (iii) the stress scenarios (shocks). Thus, when comparing the results of the exercises we can answer the following questions: What drives the differences of the results (exposure, basis or shocks)? What type of shock has the biggest impact on the structure of banks (e.g. short or long rates)?

Figure 1

Interest rate risk (average losses as a percentage of capital)



Source: Authors, based on data from the SBIF.

1 *The operational risk is the potential loss arising from problems from internal controls, systems, people and external events. The reputational risk arises from negative perception on the part of customers, counterparties, shareholders, investors or regulators that can adversely affect a bank. The (funding) liquidity risk arises when the necessary liquidity to fund illiquid asset positions over a time horizon cannot be obtained in the expected terms and with immediacy.*

We found that the structure of the trading and banking book determine the level of the valuation and repricing risk, respectively. Given that initial exposure, the sensitivity of valuation risk is greater for the longer interest rate shock than for the short term, while the latter has greater effect on the repricing risk.

Additionally, shocks to interest rates do not necessarily affect in the same magnitude the assets and liabilities in the banking book. For example, an increase in bank funding costs (e.g. deposits, bonds), do not necessarily pass-through completely to their debtors. This asymmetry impact increases the magnitude of the repricing risk. Thus, this document also answers the question of what is the sensitivity of the repricing risk to the degree of asymmetry of shocks.

For instance, using a pass-through of 90% could double the result of the repricing risk that assumes a complete shock transmission.

The document is organized as follows. Section II describes the approach to calculate and stress the yield and forward curves. Section III describes the methodology of the valuation risk and addresses the sensitivity to shocks and to the trading book structure. Section IV focuses on the repricing risk and also evaluates the effect of an asymmetric shock transmission to assets and liabilities on potential bank losses. Section V concludes.

II. STRESSING THE YIELD CURVES

The estimation of the yield curve used in the Chilean stress tests follows the dynamic version of Nelson and Siegel (1987) proposed by Campbell et al. (1997), Diebold and Li (2006), and Alfaro and Sagner (2011). Hence, the rate of return or yield $y_{n,t}$ of a CERO coupon bond for a maturity n at time t corresponds to:

$$y_{n,t} = \lambda_{1,t} + \frac{\lambda_{2,t}}{n}\left(\frac{1-\phi^n}{1-\phi}\right) + \frac{\lambda_{3,t}}{n}\left[\left(\frac{1-\phi^n}{1-\phi}\right) - n\phi^{n-1}\right] \tag{1}$$

If we calibrate and fix the parameter $0 < \phi < 1$, the equation (1) becomes linear. Additionally, if the parameters $\lambda_{1,t}$, $\lambda_{2,t}$, and $\lambda_{3,t}$ are considered constant for a relatively short period of time, say a month, the parameters λ_1, λ_2, and λ_3 can be estimated by using daily data by OLS. Thus, under the specified assumptions, we can remove the temporal dynamics of the parameters. For a given period we have that:

$$y_n = \lambda_1 + \lambda_2 \frac{1}{n}\left(\frac{1-\phi^n}{1-\phi}\right) + \lambda_3 \frac{1}{n}\left[\left(\frac{1-\phi^n}{1-\phi}\right) - n\phi^{n-1}\right] \tag{2}$$

We can also show that:

$$\lim_{n\to 0} y_n = \lambda_1 + \lambda_2\left(\frac{-ln\phi}{1-\phi}\right) + \lambda_3\left(\frac{-ln\phi}{1-\phi} - \phi^{-1}\right) \tag{3}$$

$$\lim_{n\to\infty} y_n = \lambda_1 \tag{4}$$

In addition, if we use monthly rates, we have that the rate for the first month is:

$$y_1 = \lambda_1 + \lambda_2 \tag{5}$$

Then, the instantaneous rate is determined by equation (3). However, for a ϕ close to 1, the instantaneous rate approaches y_1. Therefore, using equation (5), we can define the short-term rate as $y_0 \approx y_1 = \lambda_1 + \lambda_2$. Using equation (4), the long-term rate converges to the parameter λ_1. For practical purposes, a long enough maturity T is assumed such that $y_T \approx y_\infty = \lambda_1$.

Thus, the yield curve consists of three factors: (i) the level or long-term rate λ_1; (ii) the inverse of the slope λ_2; and (iii) the curvature λ_3.

To carry out the stress tests, we consider a shock to the short rate (s_1) and a shock to the long rate (s_T). These shocks are related to changes in the parameters λ_1 and λ_2 as follows:

$$\Delta\lambda_1 = s_T \tag{6}$$

$$\Delta\lambda_2 = -\left(s_T - s_1\right) \tag{7}$$

Therefore, substituting (6) and (7) into (2), the stressed yield curve y_n^* is calculated as:

$$y_n^* = \left(y_T + s_T\right) + \left(y_1 + s_1 - y_T - s_T\right)\frac{1}{n}\left(\frac{1-\phi^n}{1-\phi}\right) + \lambda_3\frac{1}{n}\left[\left(\frac{1-\phi^n}{1-\phi}\right) - n\phi^{n-1}\right] \tag{8}$$

Or:

$$y_n^* = y_n + s_T + \left(s_1 - s_T\right)\frac{1}{n}\left(\frac{1-\phi^n}{1-\phi}\right) \tag{9}$$

The sensitivities of the yield curve (y_n^*) to the initial short-term rate (y_1), long-term rate (y_T), short-term shock (s_1), and long-term shocks (s_T) are, respectively:

$$\frac{\partial y_n^*}{\partial y_1} = \frac{\partial y_n^*}{\partial s_1} = \frac{1}{n}\left(\frac{1-\phi^n}{1-\phi}\right) \tag{10}$$

$$\frac{\partial y_n^*}{\partial y_T} = \frac{\partial y_n^*}{\partial s_T} = 1 - \frac{1}{n}\left(\frac{1-\phi^n}{1-\phi}\right) \tag{11}$$

From the equations (10) and (11) we obtain two important insights. First, the effects of changes in the initial short- and long-term rate are equivalent to the effect of their corresponding shocks. Second, the effect at each maturity is constant and depends only on the parameter ϕ.

The corresponding initial and stressed forward rates are obtained by the expectation hypothesis:

$$f_n = \frac{\left(1+y_n\right)^n}{\left(1+y_{n-1}\right)^{n-1}} - 1 \tag{12}$$

Thus, this curve is used to determine the future interest rates at which the assets and liabilities will be negotiated as time passes.

1. Stress scenario

The yield curves are calculated for local (CLP and UF) and foreign currencies (USD). Local yields are based on daily data of prime rate for the short term (1, 3, and 6 months) and bonds from the Central Bank of Chile for the long-term (1, 2, 5, 10, 20, and 30 years). In the case of USD yield curves, we use the daily treasury yield rates from the U.S. Department of the Treasury. Since the external rates are applied to local banks, we add a risk premium of 100 basis points (bp) at each maturity.

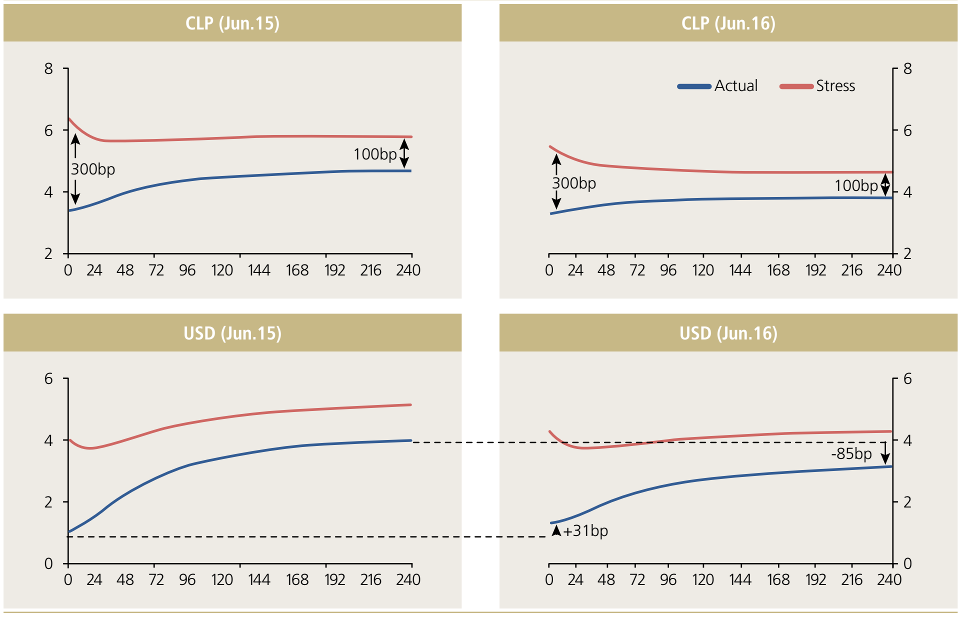
In order to maintain comparability of the stress tests' results across time, we apply a fixed shock of 300bp to the short-term rate and 100bp to the long-term one. That is, we apply a reversion of the curve (higher short-term yields than longer-term ones) and convergence to a higher interest rate (figure 2). It is also worth noticing that the stressed shape of the curve depends on the initial yield curve. Consequently, changes in the interest rate risk are influenced by changes in the yield curves across periods. For example, the yield curve in USD flattened from June 2015 to June 2016 reducing its slope (difference between long- and short-term yield) by about 116bp.

It is possible, at least operationally, to maintain the initial yield curve fixed in time in order to analyze the impact due only to the banks' exposures.[2] Nonetheless, is not plausible that banks do not adjust their positions according to all the available information at that time. Moreover, the procedure has to justify the use of an arbitrary initial yield curve (e.g. the average curve in a given period). Therefore, the methodology uses the actual yield curve and bank position to which we apply an unexpected shock.

2 *Notice that variations in the initial yield curve in time can be incorporated as additional shocks.*

Figure 2

Yield curves used on stress tests (percentage)



Source: Authors, based on data from the SBIF.

The following sections evaluate the sensitivity of the valuation and repricing risk to the shocks described here.

III. VALUATION RISK

For the stress tests, it is considered that in the event of a significant unanticipated shock in the yield curve, banks recognize the loss and sell their portfolios or close their positions in derivatives. The loss is caused by the increase in the discount factors, which reduce the assets' value, generating margin calls and valuation losses, which are disclosed in the balance sheets.

Typically, banks maintain a (net) long position. However, in case of observing a (net) short position, it is assumed that the holders also sell their assets and, in such case, the banks will rescue (buy) their liabilities. Although this would generate benefits to the bank, it could limit its funding or decrease its liquidity in the case of repurchasing its commitments.

On the other hand, the issuer's credit risk (counterparty risk) is assumed to be null. In that sense, we consider only the effect of changes in interest rates by maintaining the credit risk premium constant and equal to zero.[3]

3 Due to the non-linearity in the valuation of instruments, although they are considered risk premiums invariants, its level has an effect on the price. Therefore, in order to simplify the analysis, zero premiums are considered.

1. Valuation model

For our purposes we use the mark-to-model price P of the trading book instruments, which is given by:

$$P = \sum_{n=1}^{T} \frac{C_n}{\left(1+y_n\right)^n} \tag{13}$$

Where c_n is the payoff (income – outcome) at maturity . Therefore, using (13) and the stressed yield curve defined in (9), the change in the value of the trading book, equivalent to the valuation risk R^V, is equal to:

$$R^V = \sum_{n=1}^{T} \left[\frac{1}{\left(1+y_n\right)^n} - \frac{1}{\left(1+y_n+s_T+\left(s_1-s_T\right)\frac{1}{n}\left(\frac{1-\phi^n}{1-\phi}\right)\right)^n} \right] c_n \tag{14}$$

In order to characterize the trading book structure, we can simplify c_n as a linear equation:

$$c_n = c_1 + \frac{n-1}{T-1}\left(c_T - c_1\right) \tag{15}$$

Therefore, we are able to use OLS to obtain the average initial payoff (β_0) and the trend (β_1) by:

$$c_n = \beta_0 + \beta_1 n + \varepsilon_n \tag{16}$$

where ε_n is an error term.

The expression in (16) allows us to distinguish the approximate effects of monetary exposure (*level* or constant) to the average time mismatch represented by the *trend*. In particular, the level is given in monetary units and the trend is expressed as the pecuniary exposure per unit of time expressed in years. In what follows, we will use the decomposition of *level* and *trend* to approximate the total exposure and average time mismatch, respectively.

2. Trading book structure

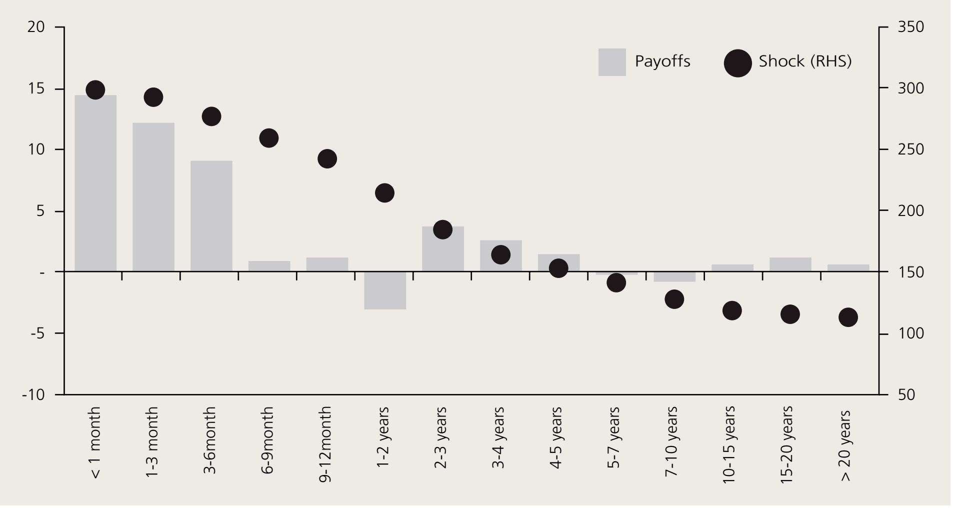
The trading book is composed by financial instruments (fixed income) and derivatives. These instruments may in principle be tradable at any time; however, some of them are delivered as collateral or used for hedging purposes.

Almost 45% of the payoffs of the trading book are due in less than a month and basically the system has a long position on each maturity (figure 3).

Figure 3

Temporal structure of the trading book (Jun.16)

(percentage of capital; basis points)



Source: Authors, based on data from the SBIF.

In that sense, coherent with the stress exercise purposes, an increase in the yield curve lowers the value of the trading book, especially the short-term shocks at which it is concentrated.

3. Empirical results

Exposures and heterogeneity

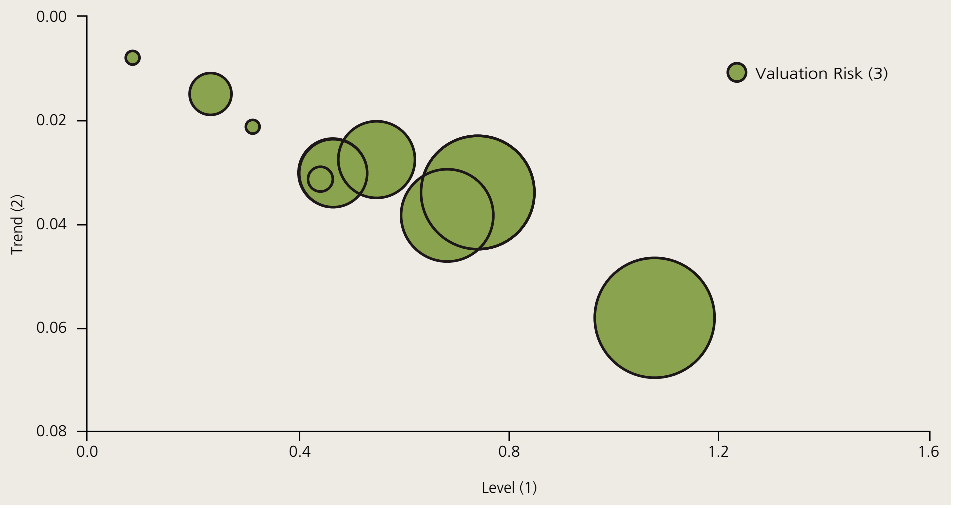
The valuation risk is influenced by the structure of the trading book of both the mismatch level and the (monetary) relevance of the payoffs in the short term. We revise this effect by using the expression in (16) and looking at the heterogeneity of the trading books among banks (figure 4).

We can observe that the initial exposure (*level*) is positive. This is due to the positive payoffs at shorter maturities of the trading book (figure 3). Also, the maturity mismatch (*trend*) is negative because payoffs decrease on average over time. In that sense, higher exposures are related to higher negative mismatches in order to converge to zero payoffs in the long run. Notice that this structure is different from a positive short-maturity payoff compensated by future negative payoffs. In such a case, we would observe higher maturity mismatches for the same level of exposure. Thereafter we can appreciate that, as the total exposure increases, so does the valuation risk. Likewise, the greater the maturity mismatch, the greater the magnitude of the risk.

Figure 4

Valuation risk by banks characteristics (Jun.16)

(percentage of capital in basis points)



Source: Authors, based on data from the SBIF.

(1) The level value corresponds to the β_0 of the equation (16) of a particular bank.

(2) The trend value corresponds to the β_1 of the equation (16) of a particular bank.

(3) The size of the circle represents the relative risk level of the bank (wrt its own capital).

The above conclusions persists if we consider the differences between banks as changes of the structure across time. Therefore, even if the yield curves and shocks remain equal, variations in the valuation risk could be explained by changes in the size of the trading book and its duration, approximated by the level and the trend, respectively.

Sensitivity to shocks

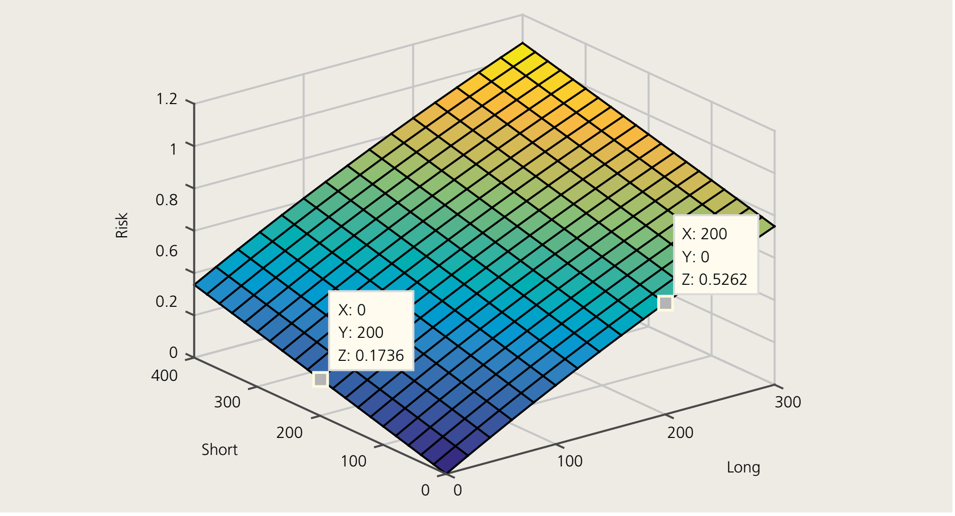
In order to isolate the effect of changes in the magnitudes of the shocks, we take the yield curve and the trading book of June 2016 (figures 2 and 3). Then, we consider a combination of short- and long-term shocks (which includes the typically applied set of 300 and 100bp in the reported stress tests).

By varying the scenarios of the interest rates' shocks, we can identify that the sensitivity of valuation risk is greater for the longer-interest rate component. In particular, the effect of a shock of 1bp on the long-term interest rate is 0.26bp on the valuation risk, higher than the 0.08bp of the short-term shock (figure 5). Although the trading book is concentrated in short maturities,[4] the discount factor is more sensitive to shocks in longer maturities.

4 We also have to consider that banks maintain financial instruments with short maturities, mainly to manage their liquidity, and also to fulfill their liquidity requirements.

Figure 5

Sensitivity of the valuation risk to shocks (percentage of capital)



Source: Authors, based on data from the SBIF.

However, the valuation risk as a percentage of bank capital is still low (less than 1%) as compared to other sources of risk (e.g. credit). Additionally, given the above assumptions, in figure 5 we observe that the joint sensitivity of risk with respect to the short- and long-term component of the interest rate shocks is practically linear.

IV. REPRICING RISK

Typically, the duration of the banks' assets is longer that their liabilities. Therefore, in the short run banks have to renew their liabilities (including deposits) more frequently than their loans or assets. In that context, an increase in the interest rates raises the interest expenses more than the interest incomes, generating losses.

The stress test methodology used by the Central Bank of Chile considers that the institutions rollover their net positions at every point in time, for all maturities, for the same horizon, at the current interest rate.[5] Nevertheless, the exercise evaluates the results only up to the end of the first year. Although this assumption can be easily relaxed, it obeys to the fact that the one-year period is sufficient for the banks to manage their banking book mismatches.

5 *Notice that this process does not keep the maturity structure of the banking book constant.*

1. Repricing model

The estimated income/expenses e_n of the net capital payoff c_n with maturity n at the end of a year, using monthly interest rates, are obtained by:

$$e_n = \sum_{i=1}^{int(12/n)} \left[c_n \left(1 + f_{n \cdot i}\right) \cdot \min\left(n, 12 - n \cdot i\right) \right] \quad / \quad 0 < n \leq 12 \tag{17}$$

In order to simplify the expression in (17), we use the weight $\omega_{n,i}$, which can be interpreted as the average period that the capital payoff c_n is affected by the interest rate $f_{n.i}$.

$$\omega_{n,1} \equiv \min\left(n, 12 - n \cdot i\right) \tag{18}$$

In the special case of invariant interest rates $f_1 = f_2 = \cdots = f_T$ considered as benchmark, the income/expenses correspond to:

$$\overline{e}_n = c_n \left(1 + f_1\right)\left(12 - n\right) \tag{19}$$

Therefore, using (17), (18), and (19), the repricing risk is defined as the additional expenses over the benchmark:

$$R^R = \sum_{n>0}^{T} \left(\overline{e}_n - e_n^*\right) = \sum_{n>0}^{T} \sum_{i=1}^{int(12/n)} \omega_{n,i} \left(f_1 - f_{n \cdot i}^*\right) c_n \tag{20}$$

where e_n^* is the estimated income/expenses under the stressed forward $f_{n \cdot}^*$.

As in the case of valuation risk, here we use the equation (16) to characterize the banking book structure.

2. Asymmetry

In the standard exercise, presented in the Bank's *Financial Stability Reports*, we use the net capital payoff c_n, assuming that there is no difference between assets and liabilities and they can be netted. However, in a more realistic setting, if the transmission of interest rates is asymmetrical for assets and liabilities, the full netting is unlikely. In that sense, we distinguish the long (A_n) and short (L_n) positions as:

$$c_n = A_n - L_n \tag{21}$$

Additionally, we define an asymmetric factor $0 \leq \rho \leq 1$. We consider that, in a stressed period, the banks, in order to meet their loans demand, cannot increase their interest rate spread immediately. Thus, we assume that the variation of the assets' forward rate, due to the short- and long-term shocks, is a proportion ρ of the change in the liabilities rate. Thus, the asymmetric repricing risk R_ρ^R is obtained by:

$$R_{\rho}^{R} = \sum_{n>0}^{T} \sum_{i=1}^{int\left(12/n\right)} \omega_{n,i} \left(f_1 - f_{n\cdot i}^{*}\right)\left(\rho A_n - L_n\right) \tag{22}$$

In the especial case when the banks are able to pass all the increase of the liabilities interest rates (*complete pass-through*) to their assets (ρ = 1), then $R_{\rho}^{R} = R^{R}$. On the contrary, if the assets' interest rates remain constant, then the repricing risk reflects only the higher cost of funding.

3. Banking book structure

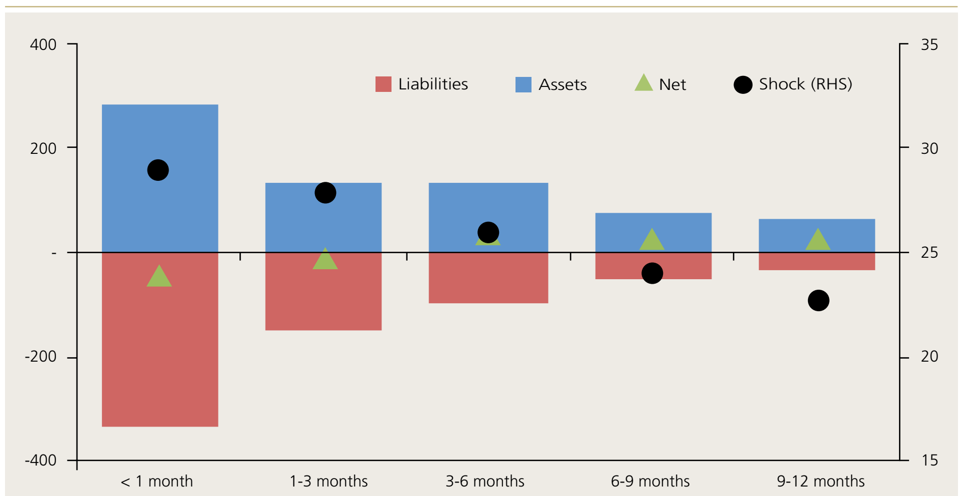
As we already specified, we assume that the time horizon for the repricing risk is one year. The main components of the banking book in that period are the demand deposits, which account for approximately 17% of the total assets. On the other hand, since they can be withdrawn at any time, their maturity is practically zero. However, they virtually do not pay interests. The Chilean stress test methodology, coherent with the current regulation framework, considers that in the case of a sharp increase of the (short) interest rate, approximately 25% of the demand deposits migrate to time deposits of a maturity less than one month.

Due to the banks' business nature, the expenses exceed the incomes in the first three months, and then the banks show a net long position (figure 6).

Figure 6

Temporal structure of the banking book (Jun.16)

(percentage of capital; basis points)



Source: Authors, based on data from the SBIF.

For a greater mismatch —especially in the short-term— the greater is the effect of a shock in the short-term interest rate. Given that we limit the exercise to the first year of refinancing, the result of a long-term interest rate shock is relatively small.

In the Chilean banking system data we typically observe not only a short position in the first couple of months, but also a greater magnitude of the incomes and expenses. Thus, the banking book structure is more sensitive to the asymmetric factor, because it depends on the generation of income in the short run.[6]

4. Empirical results

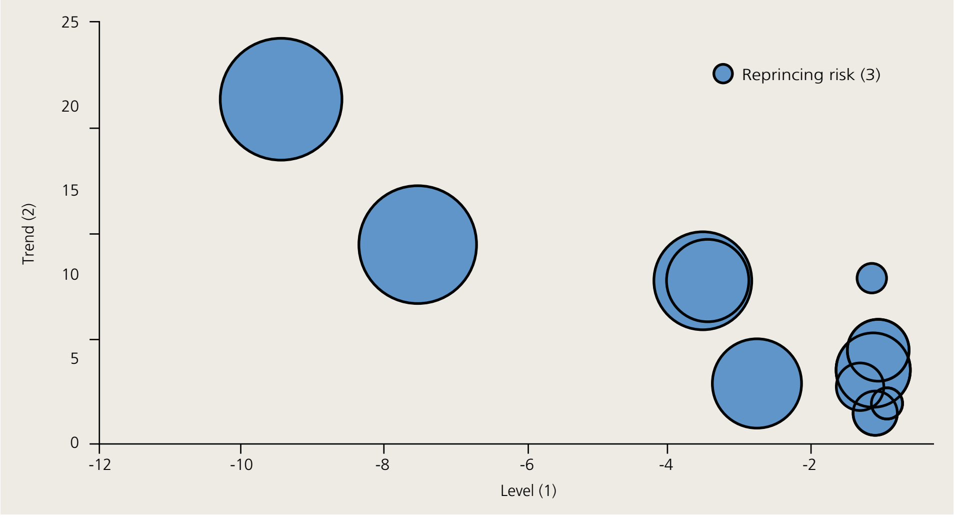
Exposures and heterogeneity

Similar to the analysis in section III.3, we compare the repricing risk of the banks in June 2016 and their banking book structure (figure 7). The banking book is characterized by the equation (16) using payoffs with maturities no longer than a year. It can be observed that the initial exposure is negative, consistent with a high level of deposits with short maturities. Also, the maturity mismatch is positive and leads to positive income in about six months.[7] This is also coherent with long-term loans and short-term funding.

Figure 7

Repricing risk by banks characteristics (Jun.16)

(percentage of capital in basis points)



Source: Authors, based on data from the SBIF.

(1) The level value corresponds to the β_0 of the equation (16) of a particular bank.

(2) The trend value corresponds to the β_1 of the equation (16) of a particular bank.

(3) The size of the circle represents the relative risk level of the bank (wrt its own capital).

6 *Suppose that the short net position in the first months is equal to the expenses, that means zero income. In such a case, proportionally decreasing the income does not affect the results. Intuitively, the inverse case will increase the sensitivity to the asymmetry factor.*

7 *On average, the trend is twice the constant. Therefore, it reaches a level of zero in 0.5 years.*

On the other hand, the magnitude of the repricing risk is heterogeneous among entities, and it is in the range of 0.4 to 3.5% of the banks' own capital. Figure 7 also shows that greater exposures and maturity mismatches drive to higher repricing risks (i.e. bigger circles). In particular, the effect of the exposure is more statistically significant to determine the level of risk than the maturity mismatch.[8]

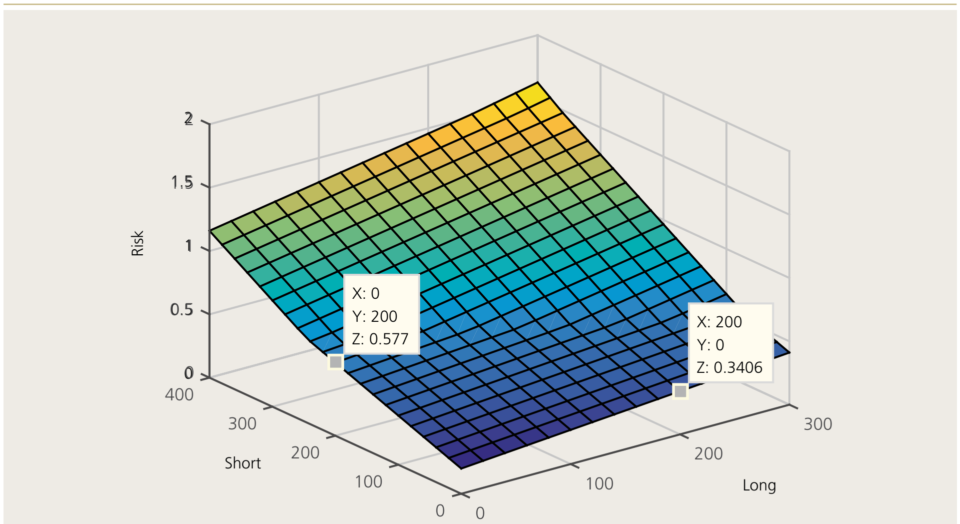
Sensitivity to shocks

By varying the scenarios of the interest-rate shocks, we are able to identify that the sensitivity of the repricing risk is greater for the shorter-interest rate component. In particular, the repricing risk of an increase of 1bp in the short-term interest rate is greater that a rise in the long-term one, 0.29 vs 0.17bp respectively (figure 8). These results illustrate bank activity sensitivities, where funding has a shorter duration that the assets (i.e. loans).

Additionally, given the above assumptions, in figure 8, we observe that the joint sensitivity of risk with respect to the short- and long-term components of the interest-rate shocks has a non-linearity. In particular, the impact of shocks increases more than proportionally for short-term interest rate shocks greater than 200bp.

Figure 8

Sensitivity of the repricing risk to shocks
(percentage of capital)



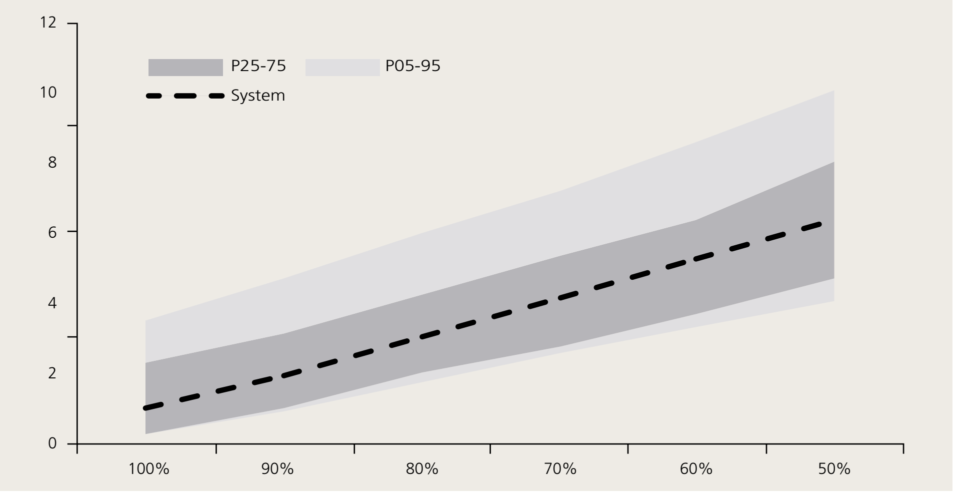
Source: Authors, based on data from the SBIF.

8 *See, the appendix for details.*

Figure 9

Distribution of repricing risk by asymmetry factor (Jun.16)

(losses as a percentage of capital)



Source: Authors, based on data from the SBIF.

Asymmetry

In this sub-section we analyze the sensitivity of the repricing risk to the pass-through coefficient. We can observe that if we fix the structure of the banking book and the yield curve at June 2016, an asymmetry factor of 90% almost doubles the repricing risk for the system (figure 9). Although the figure does not explicitly display it, there is a slight non-linearity of this effect around 90%.[9] Below this magnitude, a decrease of 10pp in the pass-through coefficient goes from an impact of 0.96pp (of capital) to 1.11pp. Additionally, we can see that the effect on repricing risk of the pass-through coefficient is more disperse across bank entities for lower values of the same.

V. CONCLUSIONS

In this note we have shown a number of regularities related to the exposures of the trading and banking books, yield (and forward) curve shocks and their impact on interest-rate risks. We have concentrated our analysis in valuation and repricing risks. In doing this task, we have investigated several questions, such as: What drives the differences of the results (exposure, basis or shocks)?

9 *Preliminary estimates indicate that the actual pass-through of interest rates to liabilities and assets is around 90%.*

What type of shocks has the biggest impact on the structure of banks (e.g. short or long rates)? What is the sensitivity of the repricing risk to the degree of asymmetry of shocks?

We can observe that, as the total exposure (level) or maturity mismatch increases, so does the valuation risk. Likewise, the repricing risk increases as exposure and maturity mismatch increases. In particular, the effect of exposure has a stronger relation with the level of risk. By varying the scenarios of the interest rates' shocks, we are able to identify that the sensitivity of valuation risk is greater for the longer interest rate component. This is opposed to the repricing risk where there is greater sensitivity to the short-term component.

Also, we observe that the joint sensitivity of the valuation risk with respect to the short- and long-term component of the interest-rate shocks is practically linear. Nonetheless, there is a slight non-linearity of repricing risk to the short-term interest-rate component of the shock.

Finally, we confirmed that an incomplete pass-through of interest rates from liabilities to assets would have a significant impact on repricing risk. In particular, with a pass-through of 90% the repricing risk can be doubled, as compared to the complete shock transmission across assets' and liabilities' interest rates.

All of the above findings call for a more comprehensive market risk stress test scenario definition, and assessment of the implied sensitivities. Hence, we will start incorporating this type of analysis in the following releases of stress testing results.

REFERENCES

Alfaro, R. and A. Sagner (2011). “Stress Test for Banking Sector: A Technical Note.” Working Paper No. 610, Central Bank of Chile.

Alfaro, R., D. Calvo and D. Oda (2008). “Riesgo de Crédito de la Banca.” Working Paper No. 503, Central Bank of Chile.

Alfaro, R., D. Calvo and D. Oda (2009). “Riesgo de Crédito de la Banca de Consumo.” *Economía Chilena* 12(3): 59–77.

Becerra J.S., R. Cifuentes and J.F. Martínez (2017). “Pruebas de Tensión Bancaria del Banco Central de Chile: Actualización.” Mimeo, Central Bank of Chile.

Campbell, J., A. Lo and A. MacKinlay (1997). *The Econometrics of Financial Markets*. Princeton, NJ: Princeton University Press.

Diebold, F. and C. Li (2006). “Forecasting the Term Structure of Government Bond Yields.” *Journal of Econometrics* 130: 337–64.

Jara, A., L. Luna and D. Oda (2007). “Pruebas de Tensión de la Banca en Chile.” *Informe de Estabilidad Financiera*, segundo semestre, Banco Central de Chile.

Nelson, C. and A. Siegel (1987) “Parsimonious Modeling of Yield Curve”. *Journal of Business* 60(4): 473–89.

APPENDIX

Tables A1 and A2 show the results of an OLS regression of risk R_i of the bank i on the initial exposure $\beta_{0,i}$ and maturity mismatch $\beta_{1,i}$ from the equation (16).

$$R_i = \gamma_0 + \gamma_1\beta_{0,i} + \gamma_2\beta_{1,i} + \varepsilon_i$$

As the number of observations is relatively low, the outcomes are presented for reference only.

For valuation risk (table A1), both exposure and maturity mismatch are significant in explaining the level of risk. Notice that the signs are as intuitively expected, since exposure takes positives values, while the maturity mismatch takes negative ones. In addition, because of the high correlation (-0.97) between both factors, the joint regression has the opposite sign for the maturity mismatch, although it is significant.

Table A1

Valuation risk (OLS)

	(1)		(2)		(3)	
Initial exposure	3.040	***			7.310	***
	(0.463)				(1.152)	
Maturity mismatch			-56.108	***	90.828	***
			(14.372)		(23.827)	
Constant	-0.587	*	-0.672		-0.116	
	(0.270)		(0.463)		(0.200)	
Observations	9		9		9	
R-squared	0.86		0.69		0.96	

Source: Authors, based on data from the SBIF.
Standard error in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

In the case of repricing risk (table A2), exposure and maturity mismatch are significant individually. Nonetheless, the exposure is more relevant to explain the risk level (i.e. higher R-squared and significant in the joint regression). It should be noted that the correlation between exposure and maturity mismatch is also high (-0.89).

Table A2

Repricing risk (OLS)

	(1)		(2)		(3)	
Initial exposure	-0.356	***			-0.449	***
	(0.044)				(0.096)	
Maturity mismatch			0.142	***	-0.051	
			(0.037)		(0.046)	
Constant	0.409	**	0.422		0.493	**
	(0.174)		(0.331)		(0.189)	
Observations	12		12		12	
R-squared	0.87		0.59		0.88	

Source: Authors, based on data from the SBIF.
Standard error in parenthesis. *** p<0.01, ** p<0.05, * p<0.1