Estimate of Capital Requirements According to Market Risk

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Introduction

Entities and regulators alike are becoming more interested in measuring and the market risk (MR) associated with the trading book[1], given the growing share of investments comprising the financial system's assets. The Office of the Superintendencia Bancaria (Banking Superintendency)[2] in Colombia took an initial step in this direction in January 2002 when it set capital requirements based on MR. Nevertheless, this Law has come under fire lately, particularly concerning the suitability of the method used to measure and hedge exposure properly.

In this respect, the objective of the present article is to present the results of MR estimates based on alternative methods for comparing and evaluating the usefulness of current requirements. The calculations presented herein refer to the standard model proposed by the Basel Committee and to the value-at-risk (VaR) models included in both the historic simulation method and the variance and covariance-based technique (EWMA approach) proposed by RiskMetrics.

I. Methods For Calculating Value-At-Risk

The concept of value-at-risk plays a fundamental role in all the methods presented in this article, as well as in current regulation. This measure of risk is an attempt

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[1] The trading book is the portfolio of positions maintained by the bank to derive benefits from their short-term purchase and sale.

[2] Now part of the Superintendencia Financiera.

to summarize, in a single number, the total exposure of an entity's portfolio to changes in market variables. Specifically, VaR is an estimate of loss that will not be exceeded, given a particular time horizon and confidence level. The main differences between the approaches outlined herein are rooted in the positions used, the market variables regarded as having an effect on portfolio value, the way shocks to these variables are calculated, and whether or not the correlations between the various risk factors are considered or omitted.

A. Data and Assumptions

For the following exercises, following the recommendations of the Basel Committee on Banking Supervision, the market risk associated with interest rate and stock holdings only take into account the trading book. On the other hand, those associated with the exchange rate include the total net position held in balance.

For the calculations in this paper, the trading book is comprised of the sum of negotiable investments, investments available for sale[3] and the repurchase rights on said investments. As to the stock positions, the aforementioned groups are taken into account only in the case of stock-market assets. Equity securities and those not listed on the stock market are not included.

Due to a lack of detailed information on the investment portfolio in securities issued by the private sector or by public entities other than the national government, the calculations presented herein only include positions in fixed-rate treasury bonds in pesos (TES) and TES UVR[4] . The same applies to interest rate options and derivatives (SWAPS and FRA). Hence, calculations do not include the capital charges applied to these positions in the trading book. The percentage of trading-book TES as a share of total TES in the financial system's portfolio is used to scale the actual capital requirement, since the information that is available does not allow for a breakdown between securities in the trading book and those in the banking book (investments to maturity).

Details on the features (residual maturity, coupon rate, etc.) of the securities comprising the financial system's portfolio were obtained from the Deposito Central de Valores (DCV). The spot curves used for their valuation are from the Bolsa de Valores de Colombia (BVC). Finally, net positions in dollars and stock come from the market-risk format currently submitted to the Banking Superintendency. In all the aforementioned cases, the positions refer to credit entities (commercial banks, commercial finance corporations and investment banks).

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[3] These positions are included because they are valued at market prices.

[4] These positions account for 66% of the total trading book.

The series used to calculate the shocks cover the period from April 19, 2003 to November 4, 2005, with a daily interval (working days only), and contemplate at least two extreme scenarios of major importance: April 2004 and March 2005[5] . The actual portfolio at November 4, 2005 is taken into account as well[6] .

B. The Method Currently Used by the Superintendencia Bancaria de Colombia

As suggested in A Proposal for Modifying the SBC Method to Gauge Market Risk[7] , the current method calculates this measurement on the expected maximum variation of the risk factor multiplied by its duration and by the net present value of the exposed amount.

$$VaR_i = \Delta Factor_i \ Dur_i \ PVMexposed_i$$

Where, VaR is the value-at-risk of the position exposed to factor i (individual VaR). Fifteen risk factors are used and the portfolio includes both the trading book and the banking book (even with respect to the factors related to interest rates and stock-market risk, in contrast to the Basel proposal).

Maximum variations are calculated for a period of 10 days and one year, depending on the classification of positions between negotiable investments (10 days), investments available for sale (one year) and to maturity (one year).

The VaR calculation is the sum of matrices of the individual VaR positions, taking into account the correlation matrix of the form:

$$VaR = \sqrt{V' \cdot \Sigma \cdot V}$$

Here, V is the vector of individual VaR positions and Σ is the positive semi-defined correlation matrix of the risk factors. The capital requirements are shown in Table 1, based on the credit institutions' portfolio as of October 31 2005.

5 In April 2004, the interest rates on TES maturing in January 2012, April 2012 and February 2009 rose by around 250 basis points, followed by another increase of approximately 100 bp in March 2005.

6 The foreign-currency and stock positions are those reported on October 31, 2005.

7 Superintendencia Bancaria (2005).

TABLE 1

CAPITAL REQUIREMENTS FOR MARKET RISK
CURRENT CBS METHOD
(BILLIONS OF PESOS) OCTOBER 2005

VaR by Risk Factor		Total VaR (*)	
DTF	-555	Capital Requirement	870.2
Repo	-0.3		
Interbank	0		
Real interest rate	46.6		
Libor	5.7		
Interest rate on consumer credit	289.4		
Money Market	-0.5		
TES	704.5		
RUV	339.1		
TCRM	7.2		
Euro	0.7		
Yen	-0.1		
IGBC	322.3		
FCO	14.1		
Dow Jones	-		

(*) Does not equal the sum of the individual factors, as these do not take correlations into account.
Source: Superintendencia Bancaria value-at-risk form.

C. The Standard Basel Method

The Committee on Banking Supervision included MR in the calculation of capital requirements to financial institutions with the 1996 amendment to the Capital Accord initially signed in 1988[8]. The suggested approach includes a standard model for the banking authority, as well as the possibility of institutions developing their own internal models, which would require prior approval from the banking authority.

The standard method proposes a module approach that includes four different types of MR which affect bank balance sheets: interest risk, stock market risk, exchange rate risk and commodities risk. The capital requirements calculated for the first three modules are listed in Table 2 and include only the portion pertaining to general risk[9].

TABLE 2

CAPITAL REQUIREMENTS FOR MARKET RISK
THE BASEL METHOD
(BILLIONS OF PESOS) MAXIMUM SHOCK (100%)

04-Nov-05	Capital Requirement
Interest rate module	1,298
Exchange rate module	23
Stock market module	196
Total	1,516

Source: Calculations by the authors.

8 Amendment to the Capital Accord to Incorporate Market Risk (1996). Several later modifications include Principles for the Management of Interest Rate Risk (1997) and Amendment to the Capital Accord to Incorporate Market Risk, Updated to April 1998 (1998), among others.

9 The portion on specific risks was not included due to a lack of information on the securities issued by agents other than the national government. For the effects of the portfolio considered in this exercise, the specific risks are applicable only to the stock market module, as explained later. For the TES positions, the weight factor suggested by Basel is 0%.

1. Interest Rate Module

To calculate the MR associated with changes in the interest rate, the standard methodology suggests that positions in securities be assigned to the 13 time bands illustrated in Table 3, depending on their residual maturity. Contrary to the Basel Committee's suggestion, in this exercise, as stipulated in Chile's regulations, the principal and the coupons are assigned independently, and the registered amounts pertain to the face value of each[10].

Once the net exposure has been determined for each band, it is multiplied by a weight factor that reflects the change in the current net value of a peso payable at the mid-point in the band, given occurrence of the maximum expected shock.

The weight factor of the band with mid-point t (in number of years) is defined as:

$$weight_t = \frac{1}{2}\left[\left(\frac{1}{(1+r_t)^t} - \frac{1}{(1+r_t+\Delta r)^t}\right) + \left(\frac{1}{(1+r_t-\Delta r)^t} - \frac{1}{(1+r_t)^t}\right)\right]$$

Here, the first term represents the change in the current value of a one-peso flow midway through the band, given an increase of Δr in the spot rate for this maturity (r_t). The second represents the change in current value, given a decline of the same magnitude.

As proposed in Chile's regulation[11], the calculated shocks pertain to monthly variations (21 working days) in the spot rate for the average of the band. The maximum shock was found for each of the bands to calculate the respective requirements. The decision to use the largest of the shocks was based on the

[10] For this same reason, the zero coupon curve was used to calculate the weights and not the yield curve, as suggested by the Basel Committee.

[11] Central Bank of Chile (2002).

TABLE 3

TIME BANDS IN THE BASEL STANDARD METHOD

Months				Years								
0 - 1	1 - 3	3 - 6	6 - 9	1 - 2	2 - 3	3 - 4	4 - 5	5 - 7	7 - 10	10 - 15	15 - 20	20<

Source: BIS (1998).

constraints imposed by the sample's coverage, which considers a period of low volatility and decline in interest rates. In particular, not including the August 2002 stress scenario[12] may mean the shocks used and, therefore, the capital requirements are underestimated. This exercise gives us the respective capital requirement associated with fixed-rate TES and TES UVR.

However, because the portfolio information made available by the DCV does not allow for a breakdown between securities in the trading book and those in the banking book, capital requirements are scaled by the percentage of the former (fixed-rate TES) as a share of the total [13](Table 4).

1. *Exchange Rate Module*

Information from the MR form filed to the Superintendencia Bancaria was used to obtain the net positions in each of the currencies analyzed. The capital requirement was then calculated by multiplying the weight factor (8%) by the greatest exposure between the sum of net asset positions and the sum of net liability positions. The resulting charge is approximately $23 billion (Table 5).

2. *Stock Market Module*

The information from the MR form filed with the Superintendencia Bancaria was used to obtain the net position exposed to stock market risk. However, investments classified as non-stock market shares and investments were not included, nor were equity securities. These positions were multiplied by the relevant weight factor (8%) to calculate the capital requirement. The result was $195.6 billion. This requirement includes only the charges for general risk, since specific risk is not employed in other countries where this method is used (e.g. Chile). If applied, this requirement would represent an additional 8% of regulatory capital (Table 6).

TABLE 4

CAPITAL REQUIREMENTS FOR MARKET RISK
BASEL STANDARD METHOD
INTEREST RISK MODULE
MAXIMUM SHOCK (100%)

04-Nov-05	Capital Requirement
Fixed-rate TES	1,050
TES UVR	247
Interest rate module	1,298

Source: Calculations by the authors.

TABLE 5

CAPITAL REQUIREMENT FOR MARKET RISK
EXCHANGE MODULE
BASEL STANDARD METHOD
(BILLIONS OF PESOS) OCTOBER 31, 2005

	Net Position Value
U.S. dollar	296.3
Japanese yen	(1.2)
Pound sterling	(23.9)
Venezuelan bolivar	0.2
Canadian dollar	1.2
Swiss franc	(0.0)
Euro	13.5
Swedish kroner	0.1
Danish kroner	0.3
Largest net position	286.4
Weight factor (percentage)	8.0
Capital requirement	22.9

Source: Value-at-risk form used by the Banking Superintendency. Calculations by the authors.

12 The rates on TES maturing in January 2012, April 2012 and February 2009 increased by about 500 bp between the minimum and maximum rates registered in the July-August 2002 period.

13 This information is from the MR forms filed monthly with the Superintendencia Bancaria. For October 2005, they pertain to 89% and 82% for fixed-rate TES and UVR's, respectively.

D. VaR According to Riskmetrics

For the internal models, the Basel Committee suggests a similar method to the one proposed by RiskMetrics[14]. This methodology is based on the idea that financial institutions' portfolio can be separated (mapped) through a set of simpler instruments that are exposed to a single risk factor. In the case of interest-rate-exposed positions, each of the flows associated with the security is treated independently. For example, a fixed-rate bond with one-year residual maturity and semiannual coupons is separated into three securities: one for each coupon and one for the principal. Each of these flows is assigned a position in one or more of the vertexes suggested by RiskMetrics[15] (Table 7).

Unless the residual maturity concurs exactly with one of the vertexes, assigning a cash flow implies dividing it between the two closest vertexes. For example, a TES with a residual maturity of 10 months is distributed between two positions: one with nine months residual maturity and another with twelve months residual maturity (Figure 1).

The value of a portfolio that is comprised solely of fixed-rate instruments and broken down as described earlier would be a linear function of 14 risk factors (i.e. daily percentage changes in the current value of one peso at each vertex[16]). Because the following exercise has two independent mappings, one for the fixed-rate TES positions and another for the TES UVR, there are 28 risk factors for TES positions. In addition, the implicit risk in stock and foreign-currency positions is considered by contemplating two other risk factors: the Colombian Stock Exchange General Index (IGBC) and the representative market exchange rate (TRM). In other words, 30 risk factors are used to calculate the MR of credit institutions' portfolio.

TABLE 6

CAPITAL REQUIREMENTS FOR MARKET RISK
STOCK MARKET
RISK MODULE
(BILLIONS OF PESOS) OCTOBER 31, 2005

	Net Position Value
Negotiable investments	344.4
Investments available for sale	2,100.7
Weight factor	8.0
Capital requirement (%)	195.6

Source: Value-at-risk form used by the Superintendencia Bancaria. Calculations by the authors.

TABLE 7

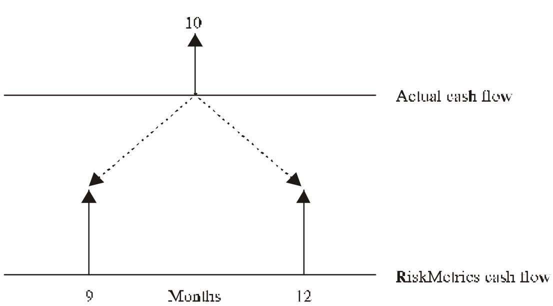
VERTEXES USED IN THE EXERCISE

Months					Years									
0	1	3	6	9	1	2	3	4	5	6	7	8	9	10

Source: RiskMetrics technical document.

FIGURE 1

RISKMETRICS CASH FLOW MAPPING



Source: RiskMetrics technical document.

14 J. P. Morgan (1996). RiskMetrics Technical Document.

15 The vertexes for the exercise in question are different from those suggested by RiskMetrics. For example, the longest vertex is 10 years, as opposed to the maximum 30 years with the J.P. Morgan method. This selection is justified by the fact that there are no securities with a residual maturity of more than 15 years and the reduced size of the spot-rate sample for maturities beyond 10 years.

16 The spot rate for each vertex can be used to estimate a series of prices to find the percentage variations.

Since the assumption is that returns will be distributed normally and the expected change in prices is zero, the VaR of the position exposed to factor *i* (VaR_i) is calculated as the outcome between the expected maximum shock ($2.33 * s$, for a 99% confidence level) and the exposure to that factor:

$$VaR_i = 2.33 \cdot s_i \cdot Position_i$$

The model used to estimate s_i is an EWMA[17], where the assumption is that the variances follow a data generating process described by:

$$s^2_{i,n} = l\, s^2_{i,n-1} + (1 - l)\, u^2_{i,n-1}$$

Here, $s_{i,n}$ is the volatility estimated for factor i on day n, $u_{i,n-1}$ is the most recent percentage change in the price, and l is a constant between zero and one[18] (exponential run-down factor). The initial value of this recursive formula, $s_{i,0}$, is the simple average of the actual percentage changes observed in prices.

A subsequent step results in an estimate of the matrix of correlations between the returns on diverse factors (Σ). This is done to consider the effects of the hedging result from diversification possibilities provided by assets with different characteristics. In this case, an EWMA model also was used to calculate the respective covariances[19].

Consequently, for the total portfolio, the daily 99% VaR *is calculated as:*

$$VaR_{portfolio} = \sqrt{VaR_F \cdot \Sigma \cdot VaR_F'}$$

Where, VaR_F is the vector containing the VaR_i. Following the suggestion of the Basel Committee, capital requirements are calculated as:

$$RK = 3 \cdot VaR_{portfolio} \cdot \sqrt{10}.$$

The results of the exercise done for the credit institutions' trading book portfolio at November 4, 2005 can be found in Table 8.

Table 8

Capital Requirements for RiskMetrics Market Risk (Billions of Pesos) Nov. 4, 2005

1-day 99% VaR	144
10-day 99% VaR	456
Capital requirement	1,368

Source: Calculations by the authors.

17 See Hull, J. (2000) for a more detailed explanation.

18 Higher values of mean the estimated volatility responds little to new information provided by recent daily shocks.

19 The covariances are calculated using $Cov(i, j)_n = l\, Cov(i, j)_{n-1} + (1 - l)\, u_{i,n-1}\, u_{j,n-1}$. The correlation matrix can be estimated using these along with the variances.

E. VaR by Historic Simulation

Historic simulation is another way to measure VaR. It uses data on the past to predict what could occur in the future[20]. Like the other alternatives for estimating VaR, the first step is to select the time horizon for the calculations, the confidence level, the risk factors that might affect the portfolio, and the quantity of data available on these variables. The number of scenarios that can be generated will depend on the length of the series obtained.

If, for example, there are 501 daily figures (from day 0 to 500) for each variable, 500 different scenarios (from 1 to 500) can be calculated for what can occur between today and tomorrow. Scenario 1 is where the percentage changes for all the variables (on the last day) are equal to those observed on day 1 of our historical series. In the second scenario, all the changes are equal to those on day 2, and so on until day 500. Formally speaking, what we have is the following: v is defined as the value of a market variable on day *i*, and supposing it is on day *m* (which represents the last day for which information is available, for example, day 500). The i scenario assumes that the value of the market variable tomorrow (day 501) will be:

$$v_m(v_i / v_{i-1})$$

Thus, 500 possible changes in percentage are obtained for each of the variables on day 500, which constitutes the possible scenarios for day 501. With each of these scenarios, the resulting portfolio value at the new prices is calculated and compared with the portfolio value today, so as to arrive at the expected valuation loss (gain). By this way a distribution of daily changes in portfolio value is generated. These changes in value are arranged in order, from the largest to the smallest loss, to select the first percentile, which constitutes the VaR of one day at 99%. This VaR is then scaled by $\sqrt{N}$ to obtain the VaR at N days and multiplied by a factor of 3 to determine the capital requirements.

In our specific case, we have 618 observations (617 possible price scenarios), 30 risk factors and a VaR at 10 days with a 99% confidence level. The results are presented in Table 9. They show the maximum calculated loss and the capital requirements obtained from percentile 1, after considering the fixed-rate TES and UVR positions, as well as those in foreign currency and stocks.

TABLE 9

CAPITAL REQUIREMENTS ACCORDING TO MARKET RISK
HISTORICAL SIMULATION
(BILLIONS OF PESOS)
NOV. 4, 2005

Maximum loss	387
1-day VaR	146
10-day VaR	463
Capital Requirement	1,388

Source: Calculations by the authors.

[20] See Hull, J. (2000) for a more detailed explanation.

II. Verifying Goodness of Fit

A. Back Testing: the RiskMetrics Model

Regardless of the method used to estimate the VaR, an important goodness of fit test for the model is what we call back testing. It implies verifying how well the VaR estimates might have performed in the past. Let us suppose a daily VaR at 99% confidence is calculated. Back testing would imply seeing how many times the loss for one day exceeded the VaR calculated for that day. If this occurs on approximately 1% of the days, we can reasonably assume the method is adequate.

For this exercise, it is indispensable to isolate the effect of the actual price. For this purpose, a proxy of the final quantities are obtained by dividing the value of the positions by that price. The value of this portfolio is calculated with the observed prices at each point in time, and also a vector that contains, in each position, the valuation loss (gain) between two consecutive days, can be constructed.

To do the back testing exercise, the values of the parameters that minimize the mean quadratic error (k = 107, l = 0.94, tolerance = 0.0001) in the conditional variance estimate based on the EWMA method are set. A moving window with 107 observations is defined, based on the value of parameter k, and the RiskMetrics methodology is applied for each window. Once all the information is supplied for each simulation, a projection of the variance-covariance and correlation matrix is obtained. It is used to calculate the value of the shocks and, therefore, the positions at risk, in order to obtain the daily value of the VaR in each simulation. This constitutes the capital requirement for each of the 510 replications.

The capital requirements are compared to the changes in portfolio value due to price variations. Formally speaking, the occurrences of:

$$(P_{t-1} - P_t)\,(Quantities) \geq VaR_{daily}\ 99\%$$

must be recorded to determine the percentage of coverage against portfolio valuation losses, based on this method. As illustrated in Table 10, the requirements obtained with the RiskMetrics technique for VaR calculation cover nearly 98% of the occurrences.

Table 10

RiskMetrics Back Testing Model
(Billions of Pesos)

Simulation No.	Change in Portfolio Value	1-day VaR
128	187	180
130	368	183
142	481	199
143	275	208
359	246	184
434	172	145
490	138	115
491	261	117
492	156	122
494	211	127
501	165	121
Events not covered (%)		2.2

Source: Calculations by the authors.

TABLE 11

HISTORICAL SIMULATION BACK TESTING MODEL (BILLIONS OF PESOS)

Simulation No.	Change in Portfolio Value	1-day VaR
130	373	205
142	489	194
143	278	188
359	248	210
Events not covered (%)		0.8

Source: Calculations by the authors.

B. Back Testing: Historical Simulation

An analog exercise was conducted on the historical simulation procedure. As with back testing of the RiskMetrics model, a moving window of 107observations was used. The valuation loss distribution was calculated for each of these windows, as explained in Part I, Section C herein, to select percentile 1 and to calculate the capital requirements associated with the mentioned loss[21]-

The exercise was repeated 510 times and we calculated the percentage of occurrences in which the necessary capital requirement was exceeded by the change that might have occurred in the portfolio if the quantities where the same of the actual portfolio. As illustrated in Table 11, the requirements obtained with the historical simulation method for VaR calculation cover slightly more than 99% of the occurrences.

III. CONCLUSIONS

Despite the preliminary nature of the exercises presented in this article, the results underscore the importance of continuing to develop methods for efficiently measuring and managing the risks to which credit institutions' portfolios are exposed. In this respect, the combined agenda being pursued by the Superintendency of Financial Institutions and Banco de la República is a step in the right direction, by offering alternatives for adapting the rules to scenarios where market risk is becoming more and more relevant.

[21] Basically, the exercise is identical to the one done earlier, but assumes there are only 107 pieces of historical data available each day.

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