SCIENTIFIC REPORT

Comparative Analysis of VaR Models Aplicability in the Evaluation of Exchange Rate Risk in the B&H Banking Sector

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ABSTARCT *– In this paper the author tests a variety of market VaR models for evaluation of exposure to exchange rate risk, in order to illuminate the advantages and disadvantages of their implementation in the B&H banking sector. As known, B&H monetary policy operates on the basis of currency board arrangement.*

The selection of a particular VaR model is determined with the fact that income generated from taking the risk should always exceed the cost of keeping capital reserves needed to cover taken risks. In the concrete bank three VaR models are applied and comparation of the results is done.

KEY WORDS: *exchange rate risk, evaluation, bootstrapping, RiskMetrics™, Monte Carlo simulation for VaR*

Introduction

Generally speaking, VaR model involves a combination of financial theory, mathematics and logic to "motivate" VaR measure as an algorithm by which portfolio's VaR is calculated. Market VaR models in practice are usually classified as:

- historical model (historical simulation for VaR),
- *RiskMetrics™* model and
- *Monte Carlo* simulation for VaR.

Although it would be more representative to test historical model through the example of the evaluation of market risk related to price movements of securities that banks hold in their assets, considering the fact that banks in B&H mostly have no portfolio of securities (i.e. trading book), there is an objective determination to implement the historical model in evaluation of market risk resulting from fluctuations in exchange rates of specific B&H Bank's long position (the Bank).

The historical model

The practical procedure of calculating VaR according to historical model passes through 5 successive phases. These are:[1]

- conversion, or calculation of BAM equivalents;
- calculate the deviation, or delta position (δ);
- calculation of individual and total daily risks;

[1] See: (Šverko, 2001).

- the ranking of overall daily risks;
- determining the confidence level and finding VaR.

This process will hereinafter be implemented in order to evaluate the risk of long foreign currency positions of the Bank on 28th of December, 2007, pursuant to the known long foreign currency positions on 25th of December, 2007, and the movements of corresponding foreign exchange rates in the last 253 (working) days.[2] In other words, on 25th of December, 2007, the Bank had long positions in currencies and in the amounts shown in Table 1.

Table 1. Review of long foreign exchange positions

Currency	The nominal amount of positions
Swiss franc - CHF	621,000
British pound - GBP	75,000
Croatian kuna - HRK	254,000
Danish krone - DKK	145,000
Swedish krona - SEK	146,000

First stage: Calculation of BAM equivalents on the basis of foreign exchange rates to BAM on 25th of December, 2007, is presented in Table 2.

Table 2. Calculation of BAM equivalents of long foreign exchange positions on 25th of December, 2007

Currency	The nominal amount of positions	The course of foreign currencies to BAM	Original BAM equivalent
CHF	621,000.00	1.265254	785,722.73
GBP	75,000.00	2.780933	208,569.98
HRK	254,000.00	0.258537	65,668.40
DKK	145,000.00	0.262859	38,114.56
SEK	146,000.00	0.216473	31,605.06
		Sum	1,129,680.72

Accordingly, 621,000 CHF worthed on 25th of December 785,722.73 BAM, £ 75,000 on the same day worthed 208,569.98 BAM, etc. Total of BAM equivalent of long foreign currency position of the Bank was 1,129,680.72 BAM on 25th December.

Phase Two: In order to calculate the δ position or variations in BAM, the trends of exchange rates of observed foreign currencies to BAM in the last 100-500 working days, for example, 253 days,[3] should be taken into account, and then assume for 28th of December:

- for CHF appreciation of 0.002881%;
- for GBP appreciation of 0.000285%;
- for DKK appreciation of 0.000233% and

[2] Please note: As each Monday applies exchange rate list from the last Saturday, Mondays are excluded from consideration.

[3] www.cbbh.gov.ba

- for SEK appreciation of 0.001674%.

These are actually the average daily changes of appropriate exchange rates in the last 253 (working) days. δ position is obtained as the difference between the expected (assumed) and the original BAM equivalents. Calculation of the δ position on 25th of December, 2007, is given in Table 3.

Table 3. The calculation of δ position

Currency	BAM exchange rate to foreign currency	Expected exchange rate of BAM to foreign currency (%)	BAM corrected exchange rate to foreign currency	Expected equivalent of BAM	The difference between the expected and the original BAM equivalent (δ)
CHF	0,790355	-0,002881	0,790332	785.745,37	22,64
GBP	0,359592	-0,000115	0,359591	208.570,22	0,24
HRK	3,867925	-0,004231	3,867761	65.671,06	2,78
DKK	3,804321	-0,000233	3,804312	38.114,64	0,09
SEK	4,619514	-0,001674	4,619436	31.605,59	0,53

Phase Three: It is the most complex considering calculation. First, it requires that number of observed (working) days is precised. In the specific example the sample of 253 last days was taken, i.e. the period between 25th of December, 2007, and 1st of January, 2007, speaking backwards, in which the daily movements of the relevant foreign currency exchange rates by BAM, are observed. Basic calculation part of the third phase refers to the determination of actual and expected daily changes of exchange rates and the multiplication of the relative relation of these changes with δ, which are calculated in the second phase.

Based on the BAM exchange rates to the appropriate foreign currencies for the last 253 days, actual daily changes of these rates were determined, which divided with the expected changes, and then multiplied with the corresponding δ, give daily risks of individual long foreign currency positions of the Bank. By adding them together, the total of daily exchange rate risks of the specific Bank's position for the last 252 days, are obtained.

If, therefore, on 25th of December, BAM exchange rate compared to CHF appreciated to 0.097135%, compared to GBP appreciated to 0.285192%, compared to HRK appreciated to 0.144080%, compared to DKK appreciated to 0.040326% and also appreciated against SEK for the 0.082689% and if position of δ CHF is 22.64 BAM, GBP of position 0,24 BAM, the position of HRK 2.78 BAM, 0.09 BAM DKK positions and, finally, the position of SEK 0.53 BAM, daily exchange rate risk of these positions is -763.30 BAM, -592.82 BAM, -94.67 BAM, -15.57 BAM and -26.18 BAM, respectively. The sum of the daily risks of all long positions provides overall risk of the exchange rate of the Bank's position, which was -1,492.53 BAM on 25th of December.

Phase Four: In the observed sample, the ranking of overall daily risks according to the largest potential losses, or from the largest losses to the largest gain, needs to be done. This phase of the process of calculating VaR is presented in Table 4.

Table 4. Risk ranking

Order	Date	Total risk
1	12/23	-4,125.83
2	6/30	-4,013.93
3	4/16	-3,992.06
4	**7/21**	**-3.919,71**
5	5/1	-3,808.39
6	6/23	-3,458.74
7	6/29	-3,288.95
8	1/7	-3,009.03
9	12/3	-2,926.96
10	7/15	-2,857.15
11	12/2	-2,845.24
12	1/20	-2,776.29
13	2/3	-2,769.18
14	**8/4**	**-2,744.62**
15	12/22	-2,710.78
.	.	.
.	.	.
.	.	.
252	6/12	5,381.57

The fifth phase: After ranking has been made, and then the desired confidence level is specified, VaR of long foreign exchange positions for the next working day, i.e. 28th of December, 2007, can be determined. If the confidence level is 95%, then this is the amount of 14-th biggest risk because this is a sample of 252 days (for example, in a sample of 100 or 200 days, the amount of 6-th or 11-th largest risk would be taken etc.). Therefore, the data from the past have shown that long foreign currency positions of the Bank on 28th of December, 2007, in 95% of cases will not lose more than 2,744.62 BAM.

If, however, that analysis is tried to be applied with 99% of confidence, then the VaR is equal to the amount of the fourth greatest risk (for example, in a sample of 100 or 200 days, the amount of the second or the third largest risk would be taken etc.). Furthermore, one may conclude that, according to data from the past, long currency Bank's positions on 28th of December in 99% of cases will not lose more than 3,919.71 BAM.[4]

According to that, the amounts of 2,744.62 BAM and 3,919.71 BAM represent $VaR_{95\%}$ and $VaR_{99\%}$ of portfolio of long foreign exchange Bank's positions on 28th of December. That is the amount of reserves (capital), that the Bank needs to form to be able, in 95% or 99% of cases, to cover the total loss next day, arised from exchange rate movements, according to its long foreign currency positions.

[4] Some banks in B&H base their VaR calculations on the 99% level of confidence that the bank portfolio in foreign currencies can suffer changes during the portfolio holding period of 10 days due to changes in exchange rates and based on daily changes in the last 250 days of trading. Also, VaR are presented separately for the USD, CHF, GBP, SEC, etc.

Finally, by ex post analysis, the evaluation of the efficiency of the historical model impementation in evaluation of the risk of long foreign currency Bank's positions, was made. Calculation of BAM equivalents for nominal amounts on 25th of December, 2007,[5] on the basis of foreign exchange rates to BAM on 28th of December, 2007, is presented in Table 5.

Table 5. Calculating of BAM equivalents at 28th of December, 2007

Currency	The nominal amount of positions	The course of foreign currencies to BAM	Original BAM equivalent
CHF	621,000.00	1.263130	784,403.73
GBP	75,000.00	2.779747	208,481.03
HRK	254,000.00	0.258181	65,577.97
DKK	145,000.00	0.262842	38,112,09
SEK	146,000.00	0.216612	31,625.35
		Ukupno	1,128,200.17

According to that, on 28th of December, the Bank did not realize a loss larger than the VaR (which is equal to 2,744.62 BAM at 95% of confidence level and 3,919.71 BAM at 99% of confidence level), which has confirmed the usefulness of this approach in evaluating the risk of exchange rate or, wider, market risk. The actual loss of the Bank was 1,480.55 BAM (1,128,200.17 BAM - 1,129,680.72 BAM).

In conclusion, another important explanation could be added: The reason for such a small daily VaR compared to the total BAM equivalent of long foreign currency Bank's positions results from the currency board arrangement under which monetary policy of B&H operates (mainly from the fixed BAM exchange rate against EUR, 1 BAM = 0.51 EUR), followed by a very weak fluctuations of exchange rates in which the Bank has long positions (CHF, GBP, HRK, DKK and SEK) against EUR, and thus the BAM. We should accent the fact that the Bank at observing day had a short position in USD, which, as is well known, are subject to much wider range of changes in relation to the EUR than the previous currencies, by which the Bank is actually protected from the excessive foreign exchange exposure. Moreover, the Bank may be concluded as the one that is exposed to very low level of risk of exchange rate, or, wider, the market risk.[6]

RiskMetrics™

RiskMetrics™ model has two characteristics. First, *RiskMetrics™* assumes that changes in market factors (i.e. exchange rates) are distributed normally. Second, it is the only VaR model which during the calculation of VaR takes into account the effects of portfolio diversification,

[5] A propos, the mere assumption about constant structure of the portfolio has its stronghold in the Basel II because the Basel Committee, in addition to 99% confidence level, it is recommended portfolio holding period of 10 days.

[6] However, including in international business and financial markets, banks in B&H in the future, no doubt, have to be more exposed to market risks.

by introducing a correlation matrix or variance-covariance matrix, which is directly related to Modern Portfolio Theory (MPT).

By introducing of variance-covariance matrix, the correlation or interdependence between the individual parts ("particles") of portfolio are taken into account (not only the risk of individual positions), which are in this example, with the Bank's portfolio of long foreign currency positions, N(N-1)/2 = 5(5-1)/2 = 10 (See Table 6). It is known that the lower risk of portfolio can be achieved through low correlation and/or by investing in a large number of instruments of portfolio.

Table 6. Correlation matrix of exchange rates (period 1/1-12/25/2007)

	CHF/BAM	GBP/BAM	HRK/BAM	DKK/BAM	SEK/BAM
CHF/BAM	1.000000	0.005536	0.607637	0.921060	0.392015
GBP/BAM	0.005536	1.000000	0.573704	-0.142484	-0.687682
HRK/BAM	0.607637	0.573704	1.000000	0.528907	-0.244216
DKK/BAM	0.921060	-0.142484	0.528907	1.000000	0.541801
SEK/BAM	0.392015	-0.687682	-0.244216	0.541801	1.000000

When calculating the VaR according to *RiskMetrics*™ model we should start from the basic definition by which VaR is the product of volatility (standard deviation) and the loss of multiple volatility, where you can use algebraic and/or matrix notation. However, before that, in addition to correlation, it is also necessary to calculate the standard deviation of individual exchange rates (Table 7).

Table 7. The standard deviation of exchange rate (period 1/1-12/25/2007)

	CHF/BAM	GBP/BAM	HRK/BAM	DKK/BAM	SEK/BAM
σ	0.014910	0.053199	0.003786	0.000235	0.001943

In algebraic form the volatility of Bank's portfolio of long foreign currency positions[7] (σ_{port}) will have to be equal:

$$\sqrt{\begin{aligned}&\omega_{CHF}^2\sigma_{CHF/KM}^2+\omega_{GBP}^2\sigma_{GBP/KM}^2+\omega_{HRK}^2\sigma_{HRK/KM}^2+\omega_{DKK}^2\sigma_{DKK/KM}^2+\omega_{SEK}^2\sigma_{SEK/KM}^2+\\&+2\omega_{CHF}\omega_{GBP}\rho_{CHF/KM,GBP/KM}\sigma_{CHF/KM}\sigma_{GBP/KM}+2\omega_{CHF}\omega_{HRK}\rho_{CHF/KM,HRK/KM}\sigma_{CHF/KM}\sigma_{HRK/KM}+\\&+2\omega_{CHF}\omega_{DKK}\rho_{CHF/KM,DKK/KM}\sigma_{CHF/KM}\sigma_{DKK/KM}+2\omega_{CHF}\omega_{SEK}\rho_{CHF/KM,SEK/KM}\sigma_{CHF/KM}\sigma_{SEK/KM}+\\&+2\omega_{GBP}\omega_{HRK}\rho_{GBP/KM,HRK/KM}\sigma_{GBP/KM}\sigma_{HRK/KM}+2\omega_{GBP}\omega_{DKK}\rho_{GBP/KM,DKK/KM}\sigma_{GBP/KM}\sigma_{DKK/KM}+\\&+2\omega_{GBP}\omega_{SEK}\rho_{GBP/KM,SEK/KM}\sigma_{GBP/KM}\sigma_{SEK/KM}+2\omega_{HRK}\omega_{DKK}\rho_{HRK/KM,DKK/KM}\sigma_{HRK/KM}\sigma_{DKK/KM}+\\&+2\omega_{HRK}\omega_{SEK}\rho_{HRK/KM,SEK/KM}\sigma_{HRK/KM}\sigma_{SEK/KM}+2\omega_{DKK}\omega_{SEK}\rho_{DKK/KM,SEK/KM}\sigma_{DKK/KM}\sigma_{SEK/KM}\end{aligned}}$$

[7] The market values of the positions (ω_{CHF}, ω_{GBP}, ω_{HRK}, ω_{DKK}, ω_{SEK}) are actually what is in the historical simulation model for VaR nominated as "original BAM equivalent" of individual positions on the date 12/25/2007.

When we include the appropriate values, we get that

$\sigma_{port} = \sqrt{267{,}087{,}566.42} = 16{,}342.81.$

Therefore, the VaR estimated using *RiskMetrics*^{TM} model for the next day (28th of December), with the 95% of confidence level is

VaR = 1.65 × 16,342.81 = **26,965.64** BAM,

or with confidence level of 99%

VaR = 2.33 × 16,342.81 = **38,078.75** BAM.

This practically means that, based on past data, the conclusion can be drawn, that the portfolio of the Bank's foreign exchange long positions in 95% or 99% cases of the next day will not lose more than 26,965.64 BAM or 38,078.75 BAM. The question is how the correlation coefficients, and thus the effects of diversification, influenced the VaR of the total portfolio compared to the VaR, which would be obtained simply by adding together the VaR of individual positions?

VaR of particular position, at 99% of confidence level, is:

VaR_{CHF} = 785,722.73 × 2.33 × 0.014910 = 27,296.24;

VaR_{GBP} = 208,569.98 × 2.33 × 0.053199 = 25,853.01;

VaR_{HRK} = 65,668.40 × 2.33 × 0.003786 = 579.29;

VaR_{DKK} = 38,114.56 × 2.33 × 0.000235 = 20.87 i

VaR_{SEK} = 31,605.06 × 2.33 × 0.001943 = 143.08,

and their sum is 53,892.49 BAM. In other words, because of the introduction of correlation coefficient (-0.687682 ≤ ρ_{ij} ≤ 0.921060, $i \neq j$) VaR of the total portfolio is less for 15.813,74 BAM than what would be gained by adding the VaR of portfolio of individual positions.

In matrix form, for example, 99% of confidence level, will have the following expression:

$$\text{VaR} = 2.33 \times \left[\begin{pmatrix} V_1 & V_2 & V_3 & V_4 & V_5 \end{pmatrix} \times \begin{pmatrix} 1 & \rho_{1,2} & \rho_{1,3} & \rho_{1,4} & \rho_{1,5} \\ \rho_{2,1} & 1 & \rho_{2,3} & \rho_{2,4} & \rho_{2,5} \\ \rho_{3,1} & \rho_{3,2} & 1 & \rho_{3,4} & \rho_{3,5} \\ \rho_{4,1} & \rho_{4,2} & \rho_{4,3} & 1 & \rho_{4,5} \\ \rho_{5,1} & \rho_{5,2} & \rho_{5,3} & \rho_{5,4} & 1 \end{pmatrix} \times \begin{pmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{pmatrix} \right]^{\frac{1}{2}},$$

Where are:

$V_1 = \omega_{CHF}\sigma_{CHF/BAMe}$ = 11,715.13;

$V_2 = \omega_{GBP}\sigma_{GBP/BAM}$ = 11,095.71;

$V_3 = \omega_{HRK}\sigma_{HRK/BAM}$ = 248.62;

$V_4 = \omega_{DKK}\sigma_{DKK/BAM}$ = 8.96;

$V_5 = \omega_{SEK}\sigma_{SEK/BAM}$ = 61.41.

By including of the appropriate values in the upper matrix, the amount of 38,078.75 BAM, which is $VaR_{99\%}$, is obtained.

Monte Carlo simulation for VaR

In *Monte Carlo* simulation for VaR also went from a sample of 253 days (from 12/25 to 1/1/2007, speaking backwards) and the corresponding value in foreign exchange rates in the Bank's portfolio (CHF, GBP, HRK, DKK and SEK) to BAM, in those days. Historical courses for some foreign currency to BAM are divided into 30 intervals, or classes, going from the smallest to the largest, and after determining the frequency of their occurrence in each interval, the probability distribution had been formed. After that, using *Microsoft Office Excel 2007*, by 253 random numbers for each course were generated. This number was taken for comparison possibility with the historical model. Then the intervals were determined for random numbers and the corresponding class of middle courses, for assignment of the same, previously generated random numbers (Table 8).

Table 8. The initial table (distributions of probability for individual courses, intervals for random numbers and the corresponding classes of middle courses)

	Intervals for exchange rates		Frequencies	Probabilities	Intervals for random numbers		Class middle courses
CHF/BAM	1,234897	1,236952	2	0,007905	0,000000	0,007905	1,235924
	1,236952	1,239007	5	0,019763	0,007905	0,027668	1,237979
	1,239007	1,241061	5	0,019763	0,027668	0,047431	1,240034
	1,241061	1,243116	8	0,031621	0,047431	0,079051	1,242089
	1,243116	1,245171	1	0,003953	0,079051	0,083004	1,244143
	1,245171	1,247226	12	0,047431	0,083004	0,130435	1,246198
	1,247226	1,249280	12	0,047431	0,130435	0,177866	1,248253
	1,249280	1,251335	4	0,015810	0,177866	0,193676	1,250308
	1,251335	1,253390	5	0,019763	0,193676	0,213439	1,252363
	1,253390	1,255445	10	0,039526	0,213439	0,252964	1,254417
	1,255445	1,257499	3	0,011858	0,252964	0,264822	1,256472
	1,257499	1,259554	9	0,035573	0,264822	0,300395	1,258527
	1,259554	1,261609	12	0,047431	0,300395	0,347826	1,260582
	1,261609	1,263664	12	0,047431	0,347826	0,395257	1,262636
	1,263664	1,265719	8	0,031621	0,395257	0,426877	1,264691
	1,265719	1,267773	7	0,027668	0,426877	0,454545	1,266746
	1,267773	1,269828	14	0,055336	0,454545	0,509881	1,268801
	1,269828	1,271883	23	0,090909	0,509881	0,600791	1,270855
	1,271883	1,273938	12	0,047431	0,600791	0,648221	1,272910
	1,273938	1,275992	17	0,067194	0,648221	0,715415	1,274965
	1,275992	1,278047	13	0,051383	0,715415	0,766798	1,277020
	1,278047	1,280102	6	0,023715	0,766798	0,790514	1,279074
	1,280102	1,282157	11	0,043478	0,790514	0,833992	1,281129
	1,282157	1,284211	7	0,027668	0,833992	0,861660	1,283184
	1,284211	1,286266	5	0,019763	0,861660	0,881423	1,285239
	1,286266	1,288321	12	0,047431	0,881423	0,928854	1,287294
	1,288321	1,290376	5	0,019763	0,928854	0,948617	1,289348
	1,290376	1,292430	8	0,031621	0,948617	0,980237	1,291403
	1,292430	1,294485	3	0,011858	0,980237	0,992095	1,293458
	1,294485	1,296540	2	0,007905	0,992095	1,000000	1,295513
GBP/BAM	2,775014	2,781956	2	0,007905	0,000000	0,007905	2,778485
	2,781956	2,788898	5	0,019763	0,007905	0,027668	2,785427

	2,788898	2,795839	7	0,027668	0,027668	0,055336	2,792368
	2,795839	2,802781	5	0,019763	0,055336	0,075099	2,799310
	2,802781	2,809723	7	0,027668	0,075099	0,102767	2,806252
	2,809723	2,816665	8	0,031621	0,102767	0,134387	2,813194
	2,816665	2,823606	2	0,007905	0,134387	0,142292	2,820135
	2,823606	2,830548	15	0,059289	0,142292	0,201581	2,827077
	2,830548	2,837490	14	0,055336	0,201581	0,256917	2,834019
	2,837490	2,844432	9	0,035573	0,256917	0,292490	2,840961
	2,844432	2,851373	5	0,019763	0,292490	0,312253	2,847903
	2,851373	2,858315	5	0,019763	0,312253	0,332016	2,854844
	2,858315	2,865257	10	0,039526	0,332016	0,371542	2,861786
	2,865257	2,872199	7	0,027668	0,371542	0,399209	2,868728
	2,872199	2,879141	7	0,027668	0,399209	0,426877	2,875670
	2,879141	2,886082	9	0,035573	0,426877	0,462451	2,882611
	2,886082	2,893024	4	0,015810	0,462451	0,478261	2,889553
	2,893024	2,899966	9	0,035573	0,478261	0,513834	2,896495
	2,899966	2,906908	10	0,039526	0,513834	0,553360	2,903437
	2,906908	2,913849	13	0,051383	0,553360	0,604743	2,910378
	2,913849	2,920791	14	0,055336	0,604743	0,660079	2,917320
	2,920791	2,927733	17	0,067194	0,660079	0,727273	2,924262
	2,927733	2,934675	16	0,063241	0,727273	0,790514	2,931204
	2,934675	2,941616	15	0,059289	0,790514	0,849802	2,938146
	2,941616	2,948558	14	0,055336	0,849802	0,905138	2,945087
	2,948558	2,955500	6	0,023715	0,905138	0,928854	2,952029
	2,955500	2,962442	6	0,023715	0,928854	0,952569	2,958971
	2,962442	2,969383	7	0,027668	0,952569	0,980237	2,965913
	2,969383	2,976325	2	0,007905	0,980237	0,988142	2,972854
	2,976325	2,983267	3	0,011858	0,988142	1,000000	2,979796
HRK/BAM	0,253422	0,253861	10	0,039526	0,000000	0,039526	0,253641
	0,253861	0,254299	2	0,007905	0,039526	0,047431	0,254080
	0,254299	0,254738	4	0,015810	0,047431	0,063241	0,254518
	0,254738	0,255176	5	0,019763	0,063241	0,083004	0,254957
	0,255176	0,255615	9	0,035573	0,083004	0,118577	0,255395
	0,255615	0,256053	8	0,031621	0,118577	0,150198	0,255834
	0,256053	0,256492	2	0,007905	0,150198	0,158103	0,256272
	0,256492	0,256930	0	0,000000	0,158103	0,158103	0,256711
	0,256930	0,257369	3	0,011858	0,158103	0,169960	0,257149
	0,257369	0,257807	4	0,015810	0,169960	0,185771	0,257588
	0,257807	0,258246	10	0,039526	0,185771	0,225296	0,258026
	0,258246	0,258684	18	0,071146	0,225296	0,296443	0,258465
	0,258684	0,259123	10	0,039526	0,296443	0,335968	0,258903
	0,259123	0,259561	6	0,023715	0,335968	0,359684	0,259342
	0,259561	0,260000	9	0,035573	0,359684	0,395257	0,259780
	0,260000	0,260438	7	0,027668	0,395257	0,422925	0,260219
	0,260438	0,260877	15	0,059289	0,422925	0,482213	0,260657
	0,260877	0,261315	12	0,047431	0,482213	0,529644	0,261096
	0,261315	0,261754	6	0,023715	0,529644	0,553360	0,261535
	0,261754	0,262192	1	0,003953	0,553360	0,557312	0,261973
	0,262192	0,262631	8	0,031621	0,557312	0,588933	0,262412
	0,262631	0,263069	2	0,007905	0,588933	0,596838	0,262850
	0,263069	0,263508	4	0,015810	0,596838	0,612648	0,263289
	0,263508	0,263946	6	0,023715	0,612648	0,636364	0,263727
	0,263946	0,264385	9	0,035573	0,636364	0,671937	0,264166
	0,264385	0,264823	19	0,075099	0,671937	0,747036	0,264604
	0,264823	0,265262	23	0,090909	0,747036	0,837945	0,265043

	0,265262	0,265700	25	0,098814	0,837945	0,936759	0,265481
	0,265700	0,266139	10	0,039526	0,936759	0,976285	0,265920
	0,266139	0,266577	6	0,023715	0,976285	1,000000	0,266358
DKK/BAM	0,262443	0,262471	11	0,043478	0,000000	0,043478	0,262457
	0,262471	0,262499	16	0,063241	0,043478	0,106719	0,262485
	0,262499	0,262527	2	0,007905	0,106719	0,114625	0,262513
	0,262527	0,262555	3	0,011858	0,114625	0,126482	0,262541
	0,262555	0,262583	8	0,031621	0,126482	0,158103	0,262569
	0,262583	0,262610	8	0,031621	0,158103	0,189723	0,262596
	0,262610	0,262638	9	0,035573	0,189723	0,225296	0,262624
	0,262638	0,262666	7	0,027668	0,225296	0,252964	0,262652
	0,262666	0,262694	4	0,015810	0,252964	0,268775	0,262680
	0,262694	0,262722	4	0,015810	0,268775	0,284585	0,262708
	0,262722	0,262750	5	0,019763	0,284585	0,304348	0,262736
	0,262750	0,262778	0	0,000000	0,304348	0,304348	0,262764
	0,262778	0,262806	3	0,011858	0,304348	0,316206	0,262792
	0,262806	0,262834	7	0,027668	0,316206	0,343874	0,262820
	0,262834	0,262862	14	0,055336	0,343874	0,399209	0,262848
	0,262862	0,262889	11	0,043478	0,399209	0,442688	0,262875
	0,262889	0,262917	6	0,023715	0,442688	0,466403	0,262903
	0,262917	0,262945	11	0,043478	0,466403	0,509881	0,262931
	0,262945	0,262973	16	0,063241	0,509881	0,573123	0,262959
	0,262973	0,263001	12	0,047431	0,573123	0,620553	0,262987
	0,263001	0,263029	16	0,063241	0,620553	0,683794	0,263015
	0,263029	0,263057	12	0,047431	0,683794	0,731225	0,263043
	0,263057	0,263085	16	0,063241	0,731225	0,794466	0,263071
	0,263085	0,263113	6	0,023715	0,794466	0,818182	0,263099
	0,263113	0,263141	11	0,043478	0,818182	0,861660	0,263127
	0,263141	0,263168	11	0,043478	0,861660	0,905138	0,263154
	0,263168	0,263196	9	0,035573	0,905138	0,940711	0,263182
	0,263196	0,263224	8	0,031621	0,940711	0,972332	0,263210
	0,263224	0,263252	2	0,007905	0,972332	0,980237	0,263238
	0,263252	0,263280	5	0,019763	0,980237	1,000000	0,263266
SEK/BAM	0,210735	0,211036	2	0,007905	0,000000	0,007905	0,210886
	0,211036	0,211338	6	0,023715	0,007905	0,031621	0,211187
	0,211338	0,211639	4	0,015810	0,031621	0,047431	0,211488
	0,211639	0,211940	8	0,031621	0,047431	0,079051	0,211790
	0,211940	0,212242	10	0,039526	0,079051	0,118577	0,212091
	0,212242	0,212543	11	0,043478	0,118577	0,162055	0,212393
	0,212543	0,212845	21	0,083004	0,162055	0,245059	0,212694
	0,212845	0,213146	17	0,067194	0,245059	0,312253	0,212995
	0,213146	0,213447	21	0,083004	0,312253	0,395257	0,213297
	0,213447	0,213749	11	0,043478	0,395257	0,438735	0,213598
	0,213749	0,214050	19	0,075099	0,438735	0,513834	0,213899
	0,214050	0,214351	16	0,063241	0,513834	0,577075	0,214201
	0,214351	0,214653	14	0,055336	0,577075	0,632411	0,214502
	0,214653	0,214954	16	0,063241	0,632411	0,695652	0,214803
	0,214954	0,215256	12	0,047431	0,695652	0,743083	0,215105
	0,215256	0,215557	8	0,031621	0,743083	0,774704	0,215406
	0,215557	0,215858	5	0,019763	0,774704	0,794466	0,215708
	0,215858	0,216160	11	0,043478	0,794466	0,837945	0,216009
	0,216160	0,216461	7	0,027668	0,837945	0,865613	0,216310
	0,216461	0,216762	7	0,027668	0,865613	0,893281	0,216612
	0,216762	0,217064	1	0,003953	0,893281	0,897233	0,216913
	0,217064	0,217365	1	0,003953	0,897233	0,901186	0,217214

	0,217365	0,217666	2	0,007905	0,901186	0,909091	0,217516
	0,217666	0,217968	1	0,003953	0,909091	0,913043	0,217817
	0,217968	0,218269	11	0,043478	0,913043	0,956522	0,218118
	0,218269	0,218571	3	0,011858	0,956522	0,968379	0,218420
	0,218571	0,218872	2	0,007905	0,968379	0,976285	0,218721
	0,218872	0,219173	2	0,007905	0,976285	0,984190	0,219023
	0,219173	0,219475	2	0,007905	0,984190	0,992095	0,219324
	0,219475	0,219776	2	0,007905	0,992095	1,000000	0,219625

Random numbers were then given the appropriate class's middle courses and so the simulated future courses of certain foreign currencies to BAM are determined. Multiplying them with their nominal amounts of the positions, simulated BAM equivalent of portfolio is calculated. From the obtained values, the current value of the portfolio is taken and, as results, simulated or hypothetical gains and/or losses of portfolio in 253 scenarios, are obtained.

Simulated total profits and/or losses of the portfolio are ranked from the largest loss to the largest profit and after that VaR is determined (see Table 9).

Table 9. Ranking of the total of simulated profit/loss

Order	Total of simulated profit/loss
1	-13,971.75
2	-10,919.03
3	-10,766.48
4	**-9,126.25**
5	-8,464.59
6	-8,464.51
7	-7,742.29
8	-7,272.61
9	-7,222.57
10	-7,215.78
11	-6,182.50
12	-6,070.88
13	-5,915.04
14	**-5,881.06**
15	-5,737.31
.	.
.	.
.	.
253	31,674.11

Since it is about the sample of 253 days, VaR portfolio of the Bank for the next day, i.e. 28th of December, estimated by *Monte Carlo* simulation procedure, with confidence level of 95%, is 5,881.06 BAM, or, with confidence level of 99%, it is equal to 9,126.25 BAM.

Comparation and valorization of the models

As it can be noted and summarized, VaR estimates are different in all market VaR models (Table 10). By *RiskMetrics™* model the largest VaR amount is obtained and by historical model, the smallest is obtained. The differences, of course, derive from different assumptions on which these models are based.

Historical model assumes that the past quite accurately reflects what will happen in the future. In this particular example, with a sample of 252 daily changes of exchange rate, where their oscillations are in accordance with the assumption of "normal market movements," as well as the exchange rate on the forecast day (12/28), historical model is fully acceptable and useful model. However, the historical model, like other VaR models, is unable to predict extreme loss. For example, if we, on the date of 22nd of December, do the VaR forecast for 12/23, when the biggest loss is made in the observed sample (249 of daily changes in exchange rates were taken into account) in the amount of 4,147.93 BAM (BAM 1,132,447.89 - 1,136,595.82 BAM), ceteris paribus, we will get that $VaR_{95\%}$ is 2,756.90 BAM or $VaR_{99\%}$ is 3,949.38 BAM. This is one of the biggest weaknesses of the historical model.

Table 10. The evaluation of the VaR for 28th of December, 2007, obtained by different models

Model	**Historical model**	***RiskMetrics™***	***Monte Carlo* simulation for VaR**
$VaR_{99\%}$	3,919.71 BAM	38,078.76 BAM	9,126.25 BAM

Note: The actual daily loss was 1,480.55 BAM.

In *Monte Carlo* simulation for VaR, although in this case it is based on data from the historical volatility of the basic risk factors (i.e. exchange rates), and a statistical distribution derived from them, rather than the assumption of their theoretical distribution, the mentioned weakness of the historical model is overcomed. Using generator of the pseudo-random numbers the 252 (random) scenario movements are simulated for each exchange rate so that the VaR estimated by this model is much larger than the historical VaR. Commitment of the Bank for one or another model depends on whether the Bank prefers higher "safety margin" in order to avoid impending insolvency, at the expense of profitability, or vice versa.

Finally, the question is why VaR estimated by *RiskMetrics™* model overestimated the amount of actual loss so much. The answer should be sought in limits of normal distribution and coefficients of correlation from which *RiskMetrics™* starts.

First, since it takes into account only the first two moments (μ and σ), but not more moments around the middle (a measure of asymmetry and flattening), the normal distribution represents well only the central part of the area under the curve of distribution, but not its end (boundary) parts. Because of that, the normal distribution, and therefore *RiskMetrics™*, can often underestimate/ overestimate the risk that the portfolio is exposed to at the uttermost parts of the distribution (cases where high confidence level is required). Second, the problem of the normal distribution is represented by a fact that gains/losses on the portfolio can take any value ($-\infty, +\infty$), which means that, theoretically, a bank (or any other financial institution) may lose more than they invested. This is not possible in reality

for a portfolio consisting of stocks and bonds because of the limited liability of holders of financial instruments, it is only possible in a portfolio containing financial derivative instruments, such as short positions in options, swaps or futures. Since the normal distribution is not limited to the maximum possible loss, VaR calculated by *RiskMetrics™* model can highly overestimate potential losses. Third, coefficients of correlation in crisis situations, but sometimes in situations that are not crisis as is the case with countries in transition, change significantly, i.e. converge to 1, which makes VaR forecasts using *RiskMetrics™* incorrect.[8]

Conclusion

The basic principle of optimizing a risk-return profile of the bank implies that the income on the risk exceeds the cost of capital for its coverage, and it should be considered while choosing an appropriate VaR model. Under normal market conditions, the historical model is a very useful model for evaluating market risk and calculating the appropriate level of economic capital adjusted for risk (i.e. risk capital). However, if the risk manager believes that the prediction based on historical data is not sufficiently realistic, one can apply *Monte Carlo* simulation, which has a task to statistically generate random scenarios which can be used to determine VaR. *RiskMetrics™* model, due to the underdevelopment of the B&H financial market, is obviously not an approach that could adequately evaluate market risk and required capital, since it highly overestimates the risk and makes holding (keeping) of required economic capital too expensive.

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[8] For more details, see: (Žiković, 2005).