Market Risk Management in the context of BASEL III

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Abstract

Value-at-Risk models have become the norm in terms of quantifying market risk among academics and practitioners mainly due to the simplicity of the concept. The purpose of this paper is to analyze the market risk management by comparing different methodologies of VaR estimation. We used the parametric method and historical method and two methodologies derived from the historical one: the historical simulation with exponential weights and historical simulation with volatility adjustment. The best results were obtained with the historical simulation with volatility adjustment introduced by Hull and White in 1998. This methodology had among the worst results after testing but resulted in fewer exceptions for the VaR and ES throughout the period even during the crisis in the years 2007-2009.

I. Introduction

The new Basel III accord appeared amid a regulation and oversight that proved insufficient and ineffective in identifying excessive concentration of risk in the pre-crisis period. Losses incurred during the financial crisis, especially in the trading book, despite being compliante to the Basel II accord showed the need for changes in the regulation of market risk to eliminate arbitrage between the banking and trading book. The new agreement aims to obtain benefits from the financial stability of the banking system with a tolerable cost for both credit institutions and the economy.

Value-at-Risk models have become the norm in terms of quantifying market risk among academics and practitioners mainly due to the simplicity of the concept. VaR was implemented by specialists in finance to interpret quickly, using a single number, the information about the risk of a portfolio. Although it is a single number, VaR enables managers to assess risk and allocate capital in a cost effective manner. In addition, VaR is a measure of market risk capital requirements under Basel III. While market risk of a portfolio is reduced to a single value,there are numerous calculation methodologies in this regard. The purpose of this paper is to analyze the market risk management by comparing different methodologies of VaR estimation.

VaR represents the maximum loss of a portfolio within a given time frame and with a certain probability and its benefits are simplicity, applicability and universality as suggested by Jorion (1997). Even if the underlying concept of VaR is simple it is not easy to determine its value. For this purpose the following methods can be used: variance-covariance method or parametric, non-parametric method or historical and Monte Carlo method or semi-parametric. These methodologies are standard and have become the basis to hybrid methodologies in an attempt to refine the models and get more relevant results.

Non-parametric methods for estimating VaR assume that the near future will be similar to the recent past which enables the use of recent data to predict future risk. These methods use the recent empirical distribution of returns without making any assumption that this distribution is similar to a theoretical one. The historical method is among the most common used because of the advantages documented by Dowd (2002) as simplicity of implementation, the lack of assumptions regarding the distribution , the ability to include thick tails, skewness. The biggest disadvantage is its dependence on the database and the delay to reflect unexpected changes in the market. Recent studies like Benito and Abad (2013) and Angelidis et al. (2007) concluded that standard historical method do not result in the most accurate estimates of VaR compared to other methods.

Parametric methods estimate market risk on the assumption that the data follows a theoretical distribution. One of the first methodology of its kind was developed by J.P. Morgan in the 1990s and was called RiskMetrics. The assumption made by this model was that the returns follow a normal distribution but empirical studies have shown that this is not true.

Most financial variables have a negatively skewed distribution, so they are asymmetrical and have thick tails according to Bollerslev (1987) which involves greater losses than the normal distribution would predict. Another feature of the method implemented by J.P. Morgan is the model used to estimate volatility, EWMA. This model manages to capture the phenomenon of volatility clustering, but not asymmetry. Empirical studies ((Abad and Benito, 2013) (Cheng and Hung, 2011)) showed that EWMA models had limited performance in estimating VaR compared to other models. Semi-parametric methods are a combination of non-parametric and parametric.

The questions we aim to answer through research are: What methodology provides the most accurate results for predicting market risk?; Standard models underestimate market risk in times of crisis ?; Expected Shortfall leads to a better quantification of market risk than VaR? To answer these questions we estimated VaR and Expected shortfall (ES) indicators using daily closing value of BET index between 1997 and 2015 by historical and parametric methods. We believe the novelty of this research is due to the extended period of time that included stable and volatile periods for which the indicators were estimated and tested.

The second section of this paper is an analysis of the literature on VaR methodologies and results of empirical studies conducted so far. In the third section we presented the case study database, financial assumptions and econometric research methodology. The descriptive statistics and results can be found in the forth section. The research objective was reached, and the conclusion section presents the results. In future research we intend to improve the testing methodology and apply GARCH models for estimating volatility.

The results may be of interest to investors and portfolio managers who are actively involved in capital markets for the purpose of risk management because it could help them make informed decisions when investing in volatile periods. Also, these results can help managers accomplish better forecasts and react quickly to market changes. The financial crisis has revealed the need to properly forecast risk, not only to determine the capital requirements necessary to financial stability, but also to efficiently allocate capital.

II. Literature review

After applying various testing methods one of the classical theories regarding VaR was developed. This implies that the parametric method which assumes a normal distribution leads to multiple exceptions.

This theory is supported by Sener et al. (2012) which introduced a way of ordering the methodologies for estimating VaR based on performance without considering a benchmark using indices of 11 emerging economies (Brazil, Chile, Colombia, Czech Republic, Hungary, Mexico, Poland, Russia, Turkey South Africa and Argentina) and 7 developed economies (UK, US, France, Spain, Germany, Japan and the Netherlands) during 1995 - 2009. The parametric method achieved the worst results being on the last places in 10 out of 11 emerging and for all of the developed economies.

This methodology overestimated VaR which means an inefficient allocation of capital, and had the biggest exceptions in unexpected situations. The historical method had poor results, but it ranked on a better place than the parametric one in emerging countries. In developed countries, it has achieved the best results, especially in France and UK. RiskMetrics methodology has achieved the best results in emerging markets, particularly in Poland and Hungary, which suggests that this methodology could lead to favorable results in Romania because of the similarities with these countries.

Although leading to a high number of exceptions, parametric methods respond more quickly to market changes. Mentel (2013) conducted a comparison of parametric and non-parametric methods of calculating VaR using 151 historical observations during 2010 - 2012 for 20 companies listed on the Warsaw stock exchange. The historical method has proved less flexible compared with the estimated values of the parametric method because it is less subject to change. Therefore estimates remain approximately constant over a period of time and tend to be much higher than actual losses leading to an overestimation of VaR.

The main opinion in literature after the crisis is that particularly the parametric method, but also the historical method do not produce the best results in volatile periods. Halbleib and Pohlmeier (2012) conclude that the standard methods for estimating VaR based on normal distributions or recent historical data manage to estimate potential losses except in turbulent times.

The study was conducted using 3 indexes with equal weights constructed with 30 randomly selected companies from the Dow Jones US Small , Medium and Large Cap during 2007 - 2009. In the period that preceded the financial crisis, standard methods had adequate results but their performance declined dramatically during the financial crisis. The worst results were obtained when assuming a normal distribution for returns.

Benito and Abad (2013) conducted a comparison of VaR models using daily data indices in Spain, France, Germany, Britain, the US and Japan between 1994 - 2011. In order to determine the best methodology both conditional and unconditional coverage tests were applied. The results showed that the parametric method leads to satisfactory estimates in stable periods, but they are very weak in periods of high volatility. Similar results were obtained for the historical method that produced inaccurate values for all indexes in volatile periods. These results correspond to those obtained by Zikov and Aktan (2009) and Gencay and Selcuk (2004)

Terzic et al. (2013) examine the hypothesis that the historical method and RiskMetrics method underestimates VaR in times of financial stress. The data used was the closing value of indices from Serbia, USA, Czech Republic, Slovakia and Germany in the period 2005 - 2012 which represent 1760 observations. The values obtained were tested by applying both conditional and unconditional tests. Test results from unconditional tests were favorable to the historical method. After performing conditional testing none of the methodologies has achieved satisfactory results. Therefore, neither the historical method nor RiskMetrics method correctly estimated market risk in the period 2005-2012.

III. Methods

The data series used were taken from the database of BSE. The daily closing value of the BET was extracted between 09/19/1997 and 07/04/2015 representing 4414 observations.The present study aims at presenting market risk by calculating daily Value-at-risk (VaR) and Expected shortfall (ES) in percentage and absolute values for BET in the period 15.09.1999 and 04.07.2015 using methods historical and parametric. Estimated percentage was performed to analyze the comparative VaR obtained. Such an analysis would not have been relevant in absolute terms due to the fluctuating level of the index during the period.

BET index value from which we started the VaR estimate was of 532.33 points 14.09.1999. After obtaining the first estimate of rolling-window method was used. The size for the rolling window was set to 501 days, which is moved with a step of 1 day. At each iteration a new estimate was made of the daily value of VaR and ES resulting in 3913 estimates for each method applied.

The methods used to estimate VaR and ES on a daily basis were:

- Historical simulation with equal weights
  The historical simulation method was used for the calculation of VaR and ES. This method involves estimating the probability distribution of changes in the index between the current day and the next day using the changes seen in the past. This method assumes that the past is replicated in the future.
  VaR has been estimated on a time horizon of one day for a confidence level of 99% using 501 daily observations. These observations led to the formation of 500 likely scenarios for the evolution of BET for the next day. Each scenario was assigned a weight equal to 1 / n, where n is the number of scenarios.
- Historical simulation with exponential weights
  With this method, each scenario is assigned a weight. The weight increases exponentially as we move forward in time to give greater importance to the latest data from the past. Sum of the weights equals 1. Boudoukh, Richardson and Whitelaw (1997) proposed such a methodology for calculating VaR because recent data reflects better current market conditions.
  The weight assigned to each scenario is $(\lambda^{(n-1)} (1-\lambda)) / (1-\lambda^{n})$, where n is the number of scenarios, and λequals 0.995 and is the parameter value that shapes weights. The loss for each scenario was computed as with equal weights method. The values obtained were ordered from largest to smallest loss and weight of each scenario cumulated until it exceeded 0.01. The loss that corresponds to this level is VaR with a confidence level of 99%.
- Historical simulation with volatility adjustment
  Historical simulation method can be modified to incorporate volatility according to Hull and White (1998). Volatility was estimated using the model EWMA (Exponentially Weighted Moving Average). Volatility can be calculated at each step according to volatility and return from the previous day: $\sigma_n{}^2 = \lambda\sigma_{n-1}{}^2 + (1-\lambda) R_{n-1}{}^2$. The volatility of the previous day will count 94% and the return will count 6% for λ= 0.94. We estimated daily volatility using EWMA model for λ= 0.94 After the incorporation of the volatility the method of calculation VaR was conducted in the same manner as in the case of of historical simulation with equal weights.
- Parametric model
  The parametric method is an alternative to the historical method for estimating VaR and ES and is known as the variance - covariance method. Average and standard deviation of a portfolio can be calculated from the mean and standard deviation of returns of the instruments in the portfolio and the correlations between them. Assuming that daily returns follow a normal distribution, the change in value of the portfolio over one day will be normal which simplifies calculating Value at Risk. To estimate parametric VaR we calculated the standard deviation of daily returns of the BET index.
  One of the assumptions of this method is that the expected change in a variable over time is considered to be zero. Because the change for a very short period of time is generally low compared to the standard deviation, this assumption is reasonable. A second hypothesis is that the change in the variable, in this case the return of BET, has a normal distribution. Knowing N (-2.326) = 0.01, there is a 1% probability that a normal distribution variable will decrease in value by more than 2,326 standard deviations. Therefore, with a probability of 99% a normally distributed variable will decrease in value by no more than 2,326 standard deviations.

Testing VaR models is performed by backtesting procedure. This procedure is a check to the estimation of VaR and is performed by calculating the number of days that the loss exceeded the VaR with a time horizon of one day and a confidence level of 99%. These days are considered exceptions and if they appear in a number greater or smaller than 1%, the methodology is questionable.

Because it is easier to test VaR than ES, ES can be used for capital requirements, but VaR will be tested. BIS requires that the daily VaR with a probability of 99% to be tested using the previous 250 days. The models were tested in-sample using the previous 250 days as required by BIS.

Three types of statistics were computed to test the VaR models:

- Binomial
- Kupiec
- Christoffersen

IV. Results

After applying iteratively the calculation methodology described above 3313 daily VaR and ES estimates with a confidence interval of 99% in absolute and percentage terms were obtained. Estimates covered the period 15/09 / 1999-07 / 04/2015. The results obtained by the four methods have been backtested and three types of statistics were calculated.

Applying binomial statistics, the best results were obtained by the historical simulation with equal weights where the model was accepted in 91% of cases. A second method that has achieved very good results is the historical simulation with equal weights, followed by the parametric method. The lowest percentage of acceptance of the model was obtained by the historical method with volatility adjustment. This model was validated in only 75% of the time.

Table 1: *Binomial statistics*

Result	HS	HS with weights	HS with volatility	Var Cov
Accepted	89%	91%	75%	80%
Rejected	11%	9%	25%	20%

According to Kupiec statistics the best results were obtained by the historical method with weights which has been accepted in 78% of cases. The worst performer has obtained a validation percentage of 61%.

The parametric method was accepted in 68% of cases, and the historical simulation with volatility adjustment in 63% of cases.Testing ranges historical method with weights first, followed by the parametric, historical with equal weights and historical with adjustment volatility last.

This result is contrary to our expectations which set the parametric method on the last place according to the results obtained in other empirical studies. We also expected that the historical simulation with volatility adjustment to obtain the best results.

Table 2: *Kupiec statistics*

Result	HS	HS with weights	HS with volatility	Var Cov
Accepted	61%	79%	63%	68%
Rejected	9%	8%	19%	15%
Unclear	30%	13%	18%	17%

Testing exceptions independence with the Christoffersen statistic placed the historical simulation first, followed by the parametric, historical simulation with weights, and last the historical simulation with volatility adjustment. It is expected that the historical simulation with volatility adjustment to achieve the worst results due to volatility clustering phenomenon.

Table 3: *Christoffersen statistics*

Result	HS	HS with weights	HS with volatility	Var Cov
Accepted	93%	67%	66%	71%
Rejected	7%	33%	34%	29%

Comparing actual daily loss with VaR and ES for each method we noticed that the fewest exceptions were observed for the historical method with volatility adjustment with 45 exceptions for VaR (1.36%) and 21 for ES (0.63%). These values are close to 1% confidence interval. Similar results were obtained for historical method with 46 exceptions for VaR (1.39%) and 24 for ES (0.72%).

The historical method with weights had a higher number of exceptions, 50 for VaR (1.51%) and 25 for ES (0.75%). The parametric method had almost a double number of exceptions for both indicators which sustains the idea of underestimating loss when this method is used because of the assumption of normality.

VaR was exceeded in 69 cases (2.08%) and ES in 51 cases (1.54%), both exceeding the expected threshold of 1%. Therefore real exceptions obtained by the 4 methods make the testing methodology questionable. Using backtesting results will leand in the selection of a methodology that will underestimate the possible loss due to market risk.

Table 4: *Real exceptions*

Result	HS	HS with weights	HS with volatility	Var Cov
VaR	17	14	5	29
ES	10	10	2	21

To analyze the performance of the models during the financial crisis we compared VaR and ES with the actual losses in that period. The chosen start date was 17/07/2007, the day that the FED has reported the first subprime mortgage market problems and the end date 11/03/2009, the day the BET index started to recover. In this time frame, the least exceptions were obtained by the historical simulation with volatility adjustment. VaR was exceeded in 0.83% of cases and ES in 0.1% cases which is below the 1%.

The parametric method led to the most exceptions for VaR and ES, double compared to the historical methods with equal weights and exponential weights. In conclusion, the historical simulation with volatility adjustment led to a correct estimate during the crisis even though it has not had the best test results. However, exceptions were not independent, which is a weakness of this methodology.

Table 5: *Real exceptions during crisis*

Result	HS	HS with weights	HS with volatility	Var Cov
VaR	46	50	45	69
ES	24	25	21	51

V. Discussion

Value at Risk has become the standard used in the management of market risk because of the simplicity of the concept, computing and ease of applicability. However, the financial crisis revealed weaknesses in the current regulatory framework. Until that time there was no performance assessment of the methodologies for calculating in such situations. The crisis has shown that even if in stable periods these models are validated, they become questionable in times of financial stress.

To determine VaR three types of methods can be applied: parametric, historical method and the Monte-Carlo. These methodologies are standard, but there are methods derived therefrom or hybrid methodologies. In this study, we used the parametric method and historical method and two methodologies derived from the historical: the historical simulation with exponential weights and historical simulation with volatility adjustment.

The parametric method is easy to implement in its classical variant involving a normal distribution of returns. But this assumption is a weakness because it leads to ignoring leptokurtosis and skewness that most financial variables present. If a skewed distribution is assumed the method becomes more difficult to implement. The historical simulation has the advantage of not making assumptions about the distribution of returns and is also easy to implement. As a disadvantage it depends on the database used and does not reflect the rapid market changes.

Recent empirical studies such as Åđener et al. (2012), Halbleib and Pohlmeier (2012) carried out for emerging and developed economies concluded that the parametric method has the worst results when it assumes a normal distribution of returns. RiskMetrics methodology which assumes a normal distribution also, but uses EWMA model to estimate volatility led to the best results for indexes in Poland and Hungary as Åđener et al. (2012) concluded which shows that the results of basic methodologies can be improved by application of models such as EWMA volatility.

In the present study we compared the results of historical method, parametric and two variations for the historical method for BET in 1998 - 2015. Similar to the results of the studies cited above, the parametric method had the weakest performance for the entire period. While not the worst after testing, this method had the most exemptions when VaR and ES were compared with actual losses.

Although the backtesting methodology that uses the binomial and Kupiec statistics is among the most popular in literature and in the industry, it does not correctly predict errors according to Kupiec (1995), Haas (2001) and Campbell (2005). These tests were used in all studies referenced except Åđener et al. (2012) who developed an ordering methodology. As a future direction of research, testing methodologies can be done using a mixed Kupiec test according to Haas (2001). Another future direction of research is the use of GARCH volatility models introduced by Bollerslev (1986).

In the present study, the best results were obtained with the historical simulation with volatility adjustment introduced by Hull and White in 1998. This methodology had among the worst results after testing but resulted in fewer exceptions for the VaR and ES throughout the period even during the crisis in the years 2007-2009.

None of the standard methods, the parametric or historical, lead to an accurate estimate in the period of crisis. The historical simulation with exponential weights performed similar to the historical with equal weights and the parametric had a number of exceptions almost equal to 50% of all exceptions recorded in the whole period only in times of crisis alone. The historical simulation with volatility adjustment estimated correctly the market risk through VaR and ES, both falling below the 1% threshold number of exceptions. This methodology combines the advantages of incorporating skewness and leptokurtosis and volatility update specific to the parametric method.

The ES indicator led to a better quantification of market risk because of the halved number of exceptions for all historical methods and placed them below the threshold of 1%. We believe that its use for capital requirements is a conservative approach, but will limit the likelihood of a financial institution not holding enough capital and endangering its business and other institutions.

These results may be of interest to investors and portfolio managers who are actively involved in capital markets for the purpose of risk management because it could help them make informed decisions when investing in volatile periods. Also, these results can help managers create forecasts closer to reality and react quickly to market changes. The financial crisis has revealed the need to properly forecast risk, not only to determine the capital requirements necessary for financial stability, but also to efficiently allocate capital.

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