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SOUNDNESS OF MARKET RISK MEASUREMENT TECHNIQUES DURING GLOBAL FINANCIAL TURMOIL

Abstract

Value-at-Risk (VaR) is one of the most popular tools used to estimate exposure to market risk and it measures the worst expected loss at a given level of confidence. This paper explains the main characheristics of the VaR concept, as well as, its advantages and limitations. Global financial turmoil changed the whole financial system worldwide and put under the question mark usefulness of market risk techniques. This paper intent to give some frameworks and opinion regarding crucial point impersonate in question: can we blame VaR and other market risk tools for financial turmoil and do they work well during financial crisis? The purpose of paper is presentation of market risk tools to risk management professionals and their possible usefulness in daily operations.

Keywords: *Value-at-Risk (VaR), stress testing, financial crisis, Monte Carlo simulation, Basel Accord*

JEL Classification: G01, G32

ИСПРАВНОСТ ПРИМЕЊЕНИХ ТЕХНИКА МЕРЕЊА ТРЖИШНОГ РИЗИКА У ПЕРИОДУ ФИНАНСИЈСКЕ КРИЗЕ

Апстракт

Валуе-ат-Риск (ВаР) представља једну од најпопуларнијих алатки за процену изложености тржишном ризику и она мери највећи очекивани губитак за дати ниво поузданости (поверења). Овај рад објашњава основне карактеристике ВаР концепта, као и све предности и ограничења овог концепта. Глобална финансијска криза је променила целокупни светски финансијски систем и ставила је под знак питања корисност примењених техника мерења тржишног ризика. У овом раду, аутор даје обрасце и мишљења везана за кључну тачку оличену у следећем питању: да ли се ВаР методу и другим моделима мерења тржишног ризика може приписати кривица за настанак финансијске кризе и да ли уопште ове технике добро функционишу током кризног периода? Циљ овог рада јесте презентовање алатки тржишног ризика професионалцима у области управљања ризицима, који их користе у својим свакодневним операцијама.

Кључне речи: *Валуе-ат-Риск (ВаР), стрес тестирање, финансијска криза, Монте Царло симулација, Базелски стандарди*

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Introduction

Value-at-Risk (VaR), as a standard risk measure, indicates the worst expected loss of a financial portfolio under normal market conditions over certain time horizon at a given confidence level. In other words, as it is stated in *J.P. Morgan, RiskMetrics–Technical Document* "VaR answers the question: how much can I lose with x% probability over a pre-set horizon". In the simplest manner, VaR is a model of the distribution of future profits and losses of a bank's trading portfolio.

VaR was introduced when stock market crashed at the late 1980s, and also has attract global attention when 2007-2009 financial crisis put under the question mark the functionality of whole risk management system. (e.g. Lehman fell, Merrill Lynch was sold, AIG was saved by the U.S. government). The main challenge is to analyze the robustness and accuracy of VaR estimation methods under different market conditions - before and during financial crisis.

VaR has been the subject of criticism in recent years, with note that many of these criticisms relate to important precondition as to how VaR results should be interpreted as well as limitations on their use. For better explanation of VaR we need to back on some details mentioned in VaR definition. First, VaR is an estimate, meaning that value of VaR will depend on the stochastic process, which is assumed to drive the random realization of market data. The structure of random process has to be indentified and specific parameters must be calibrated. This requires historical data and number of other issues such as: the length of the historical sample, weightening of events whether they are more recent or further in the past. All efforts need to be made in order to have the best possible estimate of stochastic process driving market data over specific time period to which VaR estimates apply. Different circumstances in practice require alternative methods for random processes encompassing, so that is a main reason why VaR estimates are not unique. Second, trading positions under review are fixed for the observed period. It creates difficulties when the evaluation period is long enough to make this assumption unrealistic (i.e. to estimate VaR over 10 days for the purpose of regulatory capital calculating under the Basel Accord.). Third, VaR does not give the "whole" picture if it is not used combined with some alternative tools, such as: extreme value theory or simulations guided by historical worst-case market moves.

The basic time period $\boldsymbol{T}$ and the confidence level $\boldsymbol{\alpha}$ are the two major parameters that should be chosen in a way appropriate to the overall objective of risk measurement. The usual holding period is one day or one month, but the institution could holding period adjust to other objective, for example reporting or investment horizons. Holding period depends on market liquidity, so with other data unchanged, the ideal holding period can be described with length of time it takes to ensure liquidation of positions in the market. The choice of confidence level depends on purpose to which risk measures are being put. When the primary goal is to satisfy bank capital requirements, the confidence level is usually very small (e.g. 1% of worst outcomes).

At the same time, for an internal risk management model used by a company to control the risk exposure, the confidence level is around 5%. In the context of VaR, suppose that a portfolio manager has a daily VaR equal to $1 million at 1%. This means that there is only one chance in 100 that a daily loss bigger than $1 million occurs under normal market conditions or the bank's trading portfolio should not lose more than $1 million the next day.

VaR measures can have many applications, for example: to evaluate the performance of risk takers and for regulatory requirements. Namely, in 1996 the Basel Committee on Banking Supervision imposes to financial institutions to meet capital requirements based

on VaR estimates, emphasizing the importance of providing accurate estimates. If the underlying risk is not properly estimated, a sub-optimal capital allocation will affect the profitability of financial institutions and thorough their stability. The number of VaR estimations growing rapidly, so we can divide VaR models into several different manners. Although Monte Carlo simulation and stress testing are commonly used methods for VaR estimations, one often used classification is related to 3 broad categories:

1) parametric Var models – such as RiskMetrics
2) non-parametric models – i.e. historical simulations
3) semi-parametric models – e.g. Extreme Value Theory.

Parametric models has an advantage that they allow complete characterization of distribution of returns and through avoiding the normality assumption it has a greater opportunity for performance improvement. On the other hand, the major disadvantage is tendency for VaR underestimating. The most common used non-parametric model is historical simulation, which simplifies the calculation of VaR, because it does not make explicit assumption about distribution of portfolio returns. But this is not completely true due to existence of implicit assumption that derives a lot of problems, such as logical consistency of the model. In order to overcome the wrong premises of parametric and non-parametric models, there were introduced semi-parametric models, such as Extreme Value Theory.

In this paper, it will be presented only the simpliest model – analytical VaR model. It assumes that holding period returns are normally distributed so if n-day returns R normally distributed with mean μ and standard deviation σ:

$$R \sim N(\mu, \sigma^2) \tag{1}$$

When the portfolio is worth S, our n-day VaR at confidence level 100 (1- α) is:

$$VaR = -x_\alpha S \tag{2}$$

Xα – is the lower α percentile of normal distribution N (μ, σ^2).

Taking into account requirement of high degree of confidence, α is small value, usually between 0 and 0,1. As it can be seen, estimating VaR at a given probability using normal distribution is very easy.

Example of analytic VaR calculation

Suppose a portfolio worth $1 million and we are interested in normal daily VaR at 95% confidence level while mean is 0,005 and standard deviation 0,02.

$VaR_{1,0.05}$ = - (0,005 – 1,64485[2] × 0,02) × $1 million = $ 27.897

The important conclusion is correlation between confidence level and VaR in the sense that the higher confidence level is, the greater is VaR. For 99% confidence level and other equals data, the daily VaR is:

[2] NORMSINV function in Excel for 95% confidence level.

$VaR_{1,0.01}$ = - (0,005 – 2.32634[3] × 0,02) × $1 million = $ 41.527

If we are going to change basic assumption regarding one day holding period into for example 10 days, the corresponding VaRs would be:

$VaR_{10,0.05} = \sqrt{10}\ VaR_{1,0.05} \approx 3{,}16228 \times \$\ 27.897 = \$\ 88.218$; and
$VaR_{10,0.01} = \sqrt{10}\ VaR_{1,0.01} \approx 3{,}16228 \times \$\ 41.527 = \$\ 131.320$

Although VaR is simple and intuitive technique, it has also some shortfalls which must be emphasized. Maybe the most important disadvantage is that almost all parametric VaR models are based on assumption of normal distribution of market data changes, which is in practice very rare situation. Beginning with wrong assumption regards normal distribution; we are close to wrong estimates of VaR so VaR will be underestimated at relatively high confidence level and overestimated at relatively low confidence level.

Also, market value sensitivies are not stable as market conditions change and as a consequence even modest instability of the value sensitivies can result in major distortions in VaR estimate. Analytic VaR is inappropriate when there are discontinuous payoffs in the portfolio*. In order to exceed shortcomings of analytic Var, a lot of simulation methods were designed, but there will not be the subject of this paper.

Financial turmoil and VaR

Global financial crisis put under the question mark usefulness and validity of some market risk measurement techniques, in first line VaR method. In that sense, some economists (namely, *Nassim Nicholas Taleb*) strongly argued and criticized the main thesis of VaR methodology. He emphasized the influence of VaR methodology and subscribed the largest responsibility for financial crisis escalation to VaR. Although, only one short review on historical events could help us for unambiguous evaluation regarding financial crisis. Namely, financial crisis did not originate on large dependency upon risk measurement techniques and optimization models, already reasons for their existence are much more different, such as: over-indebtedness of physical and legal entities, outrageous greed for large profits, problematical operations and frauds. VaR measure is a mandatory technique in process of risk meauserement and banks are obliged to apply VaR, but managers were reluctant toward VaR. Managers argue with attitude that top management ignore or did not respect enough their opinion, because of mostly profit-orientation, non risk-orientation. Clearly, they emphasized that source of the problem was not on risk management side, rather in the area of corporate management.

Problem, originated from VaR concept essentially, is related to impossibility of applying VaR as a tool for total encompassing of leverage and liquidity risk. Hence, careful risk managers treat VaR only as one of the many techniques on which they rely on in a process of risk-taken evaluation. In the criticisms of VaR technique, Taleb highlighted assumption on normal distribition and emphasized the importance of Monte Carlo simulation. He also stressed that Monte Carlo simulation is a helpful tool for the most important conclusions from future simulations (which is superior than past) and could help us in resolving problems, independently of people appeal to forgot many useful lessons from past.

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[3] NORMSINV function in Excel for 99% confidence level.

Beside theoretical approach, we can be faced with one logical fact: if market movements are oposite from our expectations, then neither VaR concept nor some other methods will not help us to avoid financial crisis. Only reasonable question in that case would be: how much we will be dependent upon VaR concept in crisis?

Philippe Jorion, famous economist and one of the supporters of VaR method, has qualified VaR as „wobbly compass in a dense forest. It can point you in the right direction, but it never gives you a proper coordinates where exactly you need to go“. That opinion regarding VaR is maybe the closer definition of VaR, which simbolically show us the level of their usefulness.

Consequently, VaR needs complement tools for risk measuring, in order to make reliable conclusions. As a result of research, parametar VaR model does not give satisfactory results because of large number of limit excessess, if we compare daily VaR prices with daily gains and losses in portfolio. Taleb stressed significantly this argument, while Monte Carlo simulation, although burdened with a lot of shortfalls, performed better results in a period of high volatility.

Statisticaly observed, at 95% confidence level, it can be expected limit excess on every 20 trading dates, whilst applying parameter model we have 4 limit excesses in 21st day, which is comlpetely unacceptable result. Furthermore, at 99% confidence level, one limit excess shows on every 100 days, while applying parameter model, limit breach exists on every 20 day. Abovementioned data clearly shows that parameter VaR model is not adequeate and economist can not believe in it too much, mainly due to embedded assumption of normal distribution. Empiric evidence goes in favor of VaR applying for encompassing and aproximation of risky assets, such as: equities, swaps, futures etc. Even in conditions, without high volatility, parameter VaR undervalues risk when asset with non-linear or asimetric distribution is involved in portfolio (for example, options).

Monte Carlo simulation, combined with conditional VaR model[4], gave much better and comprehensive picture of porfolio risk, especially comparing with parameter VaR. Certainly, it does not mean that Monte Carlo simulation is the perfect solution. On the contrary, the choice of Monte Carlo simulation has a lot of weaknesses:

- complexity of calculation increasing as number of risk factors rise;
- random simulations are not always a proper projection of future;
- Monte Carlo simulation is created on the large number of embedded covariance matrices. If those matrices are not applicable in future or if they are not success in crisis situations, the whole simulation is wrong.
- volatility parameter is constant during the simulation period. In case of computation 1-day VaR, it could not have massive consequences, but it has important consequences if the horizon is longer, for example 10 days.

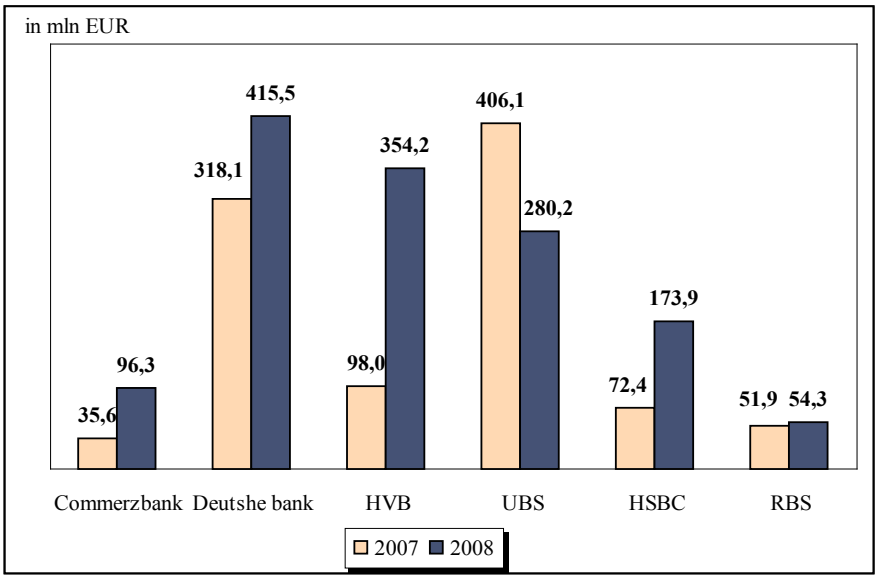
In order to overcome mentioned shortfalls, risk managers implement historical scenario to define performances of current portfolio during extremely negative market events. Guiding idea is derived from a famous cliche: the history repeats itself. Each new event has some specific characteristics, while some events are very unpredictable, so experience from the past can help and prevent, due to high level of similarity between unexpected market events. Risk managers take steps in order to hedge their portfolio and must take care of predictable negative events extent and possible manner of events controling. Hence, they will focus on stress scenarios conducting on certain number of

[4] That is usually case for certain types of barrier options. Barrier options are type of exotic derivatives, in practice very similar to ordinary option with the difference that they become active when the price of underlying asset reaches pre-determined level (barrier level).

risk factors and will try to make some conclusions, which could be helpful when they deal with unpredictible market events.

Final result would be possible gain or loss under hypothetic stress situations. VaR methodology implementation, must be kept with dosage of qualitative scepticism, transparency and strict qualification to compliance measure (liquidity limits, exposures limits etc.), which make possible for risk managers to efficiently control, report and limit risk-taken, if situation required limitations. VaR model weaknesses, particularly expressed in a period of global crisis, ilustratively are presented with Figure 1:

Figure 1: Comparing 10-day VaR model for trading book activities, at 99% confidence level, in millions EUR in 2007. and 2008.



Source: Commerzbank AG Frankfurt

Clearly, VaR measure in observed period, was significantly larger in 2008 than in previous 2007 year for each bank (except UBS), proving once again the fact that VaR has a lower power in predicting the possible losses under extraordinary circumstances. Observed banks had faced with greater potential losses in 2008, as well as global financial crises expanding. During financial crisis, VaR model did not show a high level of efficency for prediction of potential losses and also had embedded assumption of liquidation of all position overnight, which meant direct influence on market liquidity. Many economists consider modern financial crisis as the largest from the period of Great Depression, in 30th years of previous century, but only the future period can give the correct answer regarding of modern financial crisis extent.

Surely, this crisis is very serious with consequences to whole planet. Models for risk measurements were wrong, even in their basic assumptions, annuling famous Keynes test that is „better to be aproximetaly correct, rather than completely incorrect“[5]. In that sense, risk models were imprecised and wrong, in other words incorrect, so 2008 year can be qualified as failure year for stress testing.

[5] this quote was attributed to Keynes after his death, whilst origin of this quote is related to Carveth Read and sounds as follows: “It is better to be vaguely right than exactly wrong”.

Stress test as a complementary tool

It is very difficult to define the exact origin of stress testing, but in 2001 IMF released details of methodology for stress testing and experiences, which has been considered as the main contribution in the second technological revolution in risk management. New age started with simultaneous low risk and high return. Sub-prime mortgages market had a significant role in whole process, because people changed expectations regarding financial system efficency, especially when system seems showed great results during period of high returns. When mortgage prices felt down as well as serious decrease of share market prices in banking industry (loss even more than 60% of value) initiated entire surge of negative events, the main question was related to efficient risk management. Namely, the most of financial insitutions need to revise their procedures in the risk management area, due to real danger of enormous losses during financial turmoil.

Even before financial crisis began, Bank of England and Financial Services Authority (FSA) organized seminars about stress testing practice, with main intention to define different types of stress tests, which companies usualy could used. At the same time, FSA made several very interesting and potentially useful suggestions for improvement of stress testing practice in financial institutions. Those suggestions could be categorized into following 5 categories:

1) stress scenarios definition – which means deriving multi-factor risk scenario by government bodies due to solving the problem of myopia in treatment of unexpected market events. The optimum could be achieved if those scenarios also include liquidity and solvency scenarios.

2) regular evaluation of stress scenarios – the aim is to provide comparable results between institutions, comparation between models and implementation of results based on stress testing for decision making.

3) review of stress testing effects – as a starting point for risk evaluation inherent to the system. Stress testing conducted by banks and decisions made by management initiate the second phase of stress tests, to whom are companies faced. Companies could adequately evaluate consequences of its actions as well as actions of competitors and in that way could create the framework for network effects monitoring.

4) transfer of stress testing results into the liquidity planning and the firm capital - results had to influence on management if they are treated as useful. Bank management periodically had to react on stress testing results and those results are inputs for decision making regarding liquidity and the firm equity.

5) transparency in relation with regulators and financial markets – banks regularly report to official regulatory bodies regarding equity and liquidity. Transparency significantly improves to exerting of higher level market discipline and more efficient functioning of whole market.

Although it seems that mentioned program is robust, it is very important because it exceeds all weaknesses with which are we faced in the process of using stress test techniques in period of financial crisis.

Basel II achieved very well results in area of recovery losses in a periods before, ongoing and after financial crisis. It could be concluded that countries which have not accepted Basel II yet, must do that in a shorter period. Beside this, one additional reccommendation for Basel II modification in daily capital requirements area is related to shortening average day's number from currently 60 working days on for example 20 days. On described manner, capital requirements daily adjustment will be faster in compliance with VaR changes.

Considering period from 2008 to 2009 and financial crisis, volatility was 4 times increased and it was maintained on the extremely high level. Financial turmoil had changed risk measuring model for optimization of daily capital requirements. Various risk models were optimal in a period before and during crisis. Mixed use of different models for VaR evaluation is the basic and major strategy taken in crisis situations. Agressive strategy for risk management gives the lowest average capital requirements and has the largest frequency of daily capital requirements due evaluation periods, but also has frequent limit excesses (that could bring negative publicity in the public and temporary trading prohibition). On the other side, conservative strategy of risk management is followed with a less number of limit breaches and higher average of daily capital requirements. It is consider that optimized strategy is those that combine alternative risk models for VaR evaluation and minimizing daily capital requirements.

In the background of financial crisis, implementation of Basel II Accord in many countries, as well as in Serbia, was slowed down due to lack of financial resources. Basel Committee suggested, at the beginnig of 2009, series changes which have to improve regulatory rules in crisis period. In first pillar, the most important change is related to resecuritization of assets for efficient risk management. As a part of second pillar, guidelines for concentration risk are predicted, while changes in the third pillar are related to increasing of transparency in risk management and market discipline. Major focus for banks in following period (i.e. period after global financial crisis) should be upgrading of risk management process, development of new instruments for client selection and increasing level of control and monitoring of loan portfolio.

Introducing Basel III, as the answer on some unresolved problems founded in a crisis period, has the main objective in strengthening the resilence of banks during crisis, emphasizing the importance of efficient risk management in banks and higher transparency in banking industry. The key changes are related to capital requirements in terms of larger amount and quality of capital which consists of Tier 1 and Tier 2 capital. Tier 1 capital include share capital and retained earnings, with minimum of share capital at 4.5% of risk weighted assets, whils total Tier 1 capital could not exceed 6% of risky assets. Also, through Basel III are introduced: capital conservation buffer, countercyclical capital buffer, leverage ratio and 2 separate minimum standards for liquidity, namely: liquidity coverage ratio – for short term liquidity and net stable funding ratio – for long term liquidity. Implementation of mentioned indicators represents a great challenge for banking sector, with a lot of demands in order to meet requirements and make banking industry efficient.

European Banking Authority (EBA), released in July 2011, the results of analyis in banking sector which undoubtfully showed that negative shocks caused a lot of problems for banks, in other words there is a need for prompt and significant regulatory reaction in order to achieve and later maintain financial stability. In that study, 8 European banks did not pass stress testing, because they did not succeed to reached desired level of capital adequacy set at 5%. Detailed analysis indicated that those banks have 2.5 billions euros lack in case of pessimistic scenario arrival. Capital adequacy between 5% and 6% was recorded in other 16 banks, whilst another 20 European banks will be in "trouble" if increasing capital was not allowed them after testing already began. An introduced figure tells us how much banking industry need more discipline and transparency in operating especially in a periods which follow financial crisis.

During May 2012, Basel Committee on Banking Supervision takes into consideration and proposes the possibility of scrapping VaR as the basis for modeling market risk capital requirements and their replacement with expected shortfall. One of the main arguments was found in encouraging false confidence in bank boards and

investors prior to the financial crisis. As a alternative method is observed expected shortfall, which measures the expected values of losses above a given confidence level and has an advantage in measuring of tail risk. It has been noted that expected shortfall requires greater computation power than VaR, but is more problematic to backtesting. Theoretical superiority of experted shortfall in comparison with VaR does not mean that it will make better results in practice.

Financial entities are obliged to measure risk applying portfolio theory, i.e. VaR as a product of portfolio theory, according to official legal act. In that sense, planning for the moment of crisis is more important than VaR technique implementation, so imperatively need to complement VaR with other methodologies: with stress testing, in first instance. New methodologies are the most appropriate answer on crisis in financial sector, while they also require development of new products and education of potential new members on the market, which are interested in implementation of new products. If we implement dynamic measures of risk defining, the whole market could be made less affected by financial crisis.

Conclusion

Value at Risk (VaR) has an important role in process of measuring bank's exposures to market risk. Although, it has some shortcomings, it also has a lot of advantages which are going in favor of VaR as an irreplaceable tool. In this paper, it must be pointed that VaR and other quantitative methods are necessary in risk management, but they are not sufficient for risk controlling. It is widely agreed that stress tests can address some of the shortcomings in VaR estimates, but stress tests have their own problems. Some of the problems with building good stress tests can be dealt with given sufficient resources. Financial turmoil caused a lot of distortions on financial markets worldwide and in the financial system generally. Subscribing the guilty for escalating financial crisis to VaR and other market risk techiques is too biased approach. VaR can not be blamed for efficiency during financial turmoil, because the concept of VaR was not designed to operate under extreme conditions, on the contrary it was created to help in measuring of market risk exposure under normal circumstances. So, it is wrong to put under the question mark the validity of VaR during crisis, although some poor results in that period.

During financial turmoil, some firms identified shortcomings in VaR assumptions about the scale of shocks or degree of market volatility they may face; how their holdings of instruments may behave in comparison with more established debt products when shocks strike markets; or how the accuracy of their VaR measure is affected by the accuracy of price estimates for less liquid or illiquid securities. Nonetheless, some companies emphasized that the dependence on historical data makes it unlikely that a VaR-based measure could ever capture severe market shocks that exceed recent or historical experience, highlighting the importance of supplementing VaR with other views on risk. Only acceptable approach would be focused on acceptation of all VaR limitations and using its advantages complementary with other market risk techniques in order to achieve objectives and get the most reliable results. Obtained results are major input for top management's decision making in banks confirming that VaR methodology (independently from latest information about scrapping VaR and replacing with expected shortfall) has the important historical role in risk management evolution.

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