Original Scinetific Paper

An mpirical evaluation of value-at-risk: the case of the belgrade stock exchange index - BELEX15*

UDK 005.334:336.76 (497.11)

Goran B. Anđelić, Educons University , Faculty of Business in Services, Sremska Kamenica
Vladimir Đ. Đaković, University of Novi Sad , Faculty of Technical Sciences, Novi Sad
Mirjana M. Sujić, University of Novi Sad , Faculty of Technical Sciences, Novi Sad

Summary: The subject of the research is to test and analyse VaR (Value-at-Risk) methods of market risk management on the financial market of the Republic of Serbia. Thus, concrete research is conducted in the period 2005 – 2011, with the goal of VaR methods performance assessment on the Serbian financial market. The tested VaR methods are Historical simulation (HS) and Delta normal VaR with 95% and 99% confidence level for 50, 100, 200 and 250 days. BELEX15 stock index of the Belgrade Stock Exchange, which comprises of 15 most liquid securities of the Serbian financial market, is used as a benchmark indicator of the conditions on the Serbian financial market. The goals which are intended for achieving in the research are focused to Historical simulation (HS) and Delta normal VaR performance assessment on, according to many criteria, "specific"-transitory financial market of the Republic of Serbia. The basic goal of the research is to come to concrete, practically tested, knowledge about the possibility and performance of VaR methods application on the financial market of the Republic of Serbia in function of investment decisions optimising. Research results point to the necessity of VaR methods application in market risk management on the financial market of the Republic of Serbia.

Key words: Value-at-Risk, historical simulation, delta normal VaR, risk management, market risk

Rezime: Predmet istraživanja u radu je testiranje i analiziranje VaR (Value-at-Risk) metoda upravljanja tržišnim rizikom na finansijskom tržištu Republike Srbije. U tu svrhu u radu je sprovedeno konkretno istraživanje koje obuhvata period od 2005. do 2011. godine, sa ciljem procene uspešnosti VaR metoda na srpskom finansijskom tržištu. Testirani VaR metodi su istorijska simulacija (HS) i delta normal VaR sa nivoom pouzdanosti od 95% i 99% za 50, 100, 200 i 250 dana. Kao reperni pokazatelj stanja i prilika na srpskom finansijskom tržištu korišćen je BELEX15 indeks Beogradske berze, koji u sebi obuhvata 15 najlikvidnijih hartija od vrednosti srpskog finansijskog tržišta. Ciljevi koji se teže ostvariti istraživanjem su usmereni u pravcu procene uspešnosti primene istorijske simulacije (HS) i delta normal VaR-a na, po mnogim kriterijumima, „specifičnom"-tranzitornom finansijskom tržištu Republike Srbije. Osnovni cilj istraživanja jeste dolaženje do konkretnih, u praksi testiranih, saznanja o mogućnostima i uspešnosti primene VaR metoda na finansijskom tržištu Republike Srbije u funkciji optimizacije odluka o investiranju. Rezultati istraživanja ukazuju na neophodnost primene VaR metoda upravljanja tržišnim rizikom na finansijskom tržištu Republike Srbije.

Ključne reči: Value-at-Risk, istorijska simulacija, delta normal VaR, upravljanje rizicima, tržišni rizik

** This papar forms part of the results of research on project 34014 financed by Ministry of Education and Science of the Republic of Serbia*

1. INTRODUCTION

As a result of volatile market conditions, there are many risks during investment processes on the financial markets. Some of these risks are attributed to the market, to the interest rates, to liquidity and to operational challenges. There are different definitions of risk, and as such it can be defined as the possibility of occurrence of adverse results and consequences [8]. There is no single definition of risk because there are different types of risks, but there are some common elements in all definitions, such as exposure, uncertainty and losses. Risk is the probability of the occurrence of a negative case and the intensity of these cases effects. Any investment process carries certain risks. In case a good result of the investment process is expected, it is necessary to predict the possible risks and the ways that will reduce the consequences of those risks. It is necessary to mention the most important elements of risks, which are the followings:

- probability (likelihood, chance),
- consequences (influence),
- variability,
- management skills.

As the focus of this work is on the investment processes on the financial market, market risk is the most significant of all risks. Market risk is the result of changes in market prices of securities [3]. To put it simply, market risk is the risk of changes in market value of the portfolio [23]. The question is how market risk arises, and the best explanation is that it occurs in the processes of trade, or during the investment processes in the instruments of assets and liabilities due to changes in interest rates, exchange rates or market prices of securities. Market risk is usually reflected in the change of the portfolio's market value.

In order to successfully manage the risks, there must be a possibility for their quantification. Over the years, different ways of data collection and market risk quantifications were proposed. However, one of the most intuitive and sensible methods of managing market risks is the Value-at-Risk (VaR) method. VaR method is one of the most advanced modern methods that allow quantification of market risks in the investment processes. The VaR measures the maximum possible potential losses of investment activities in a given period due to changes in prices of portfolio elements, based on past data [24]. There are three ways of quantifying market risks. One of them is evaluating investment positions based on the market value of each element of the portfolio; the second approach is based on measuring the flexibility of the portfolio's value with changes in interest rates; and the third, and certainly the most complete approach is the VaR method [15]. The need for the quantification of market risks of the most important financial institutions was stated in the early seventies of the 20th century due to increased financial instability. In the recent years, there have been numerous examples of poor management of market risks in the developed countries. VaR is a method created at the beginning of the nineties of the 20th century in the broker-dealer business. The main goal was to systematize the measurement of market risk. VaR method allowed better monitoring and management of market risks. In early 1993, the Global Derivatives Study Group reported the investor community about the benefits of the VaR methodology in managing market risk. In addition, the history of the VaR method can also be attributed to three major events: (1) The Basel Agreement of 1995, (2) the creation of the JP Morgan`s RiskMetrics web page, and (3) the request of the U.S. Securities and Exchange Commission for companies to publish their VaR value in the annual reports [24].

Another very important feature of the VaR method is the possibility of its application at risk management in emerging markets, i.e. transitory economies. There is a fundamental difference between developed markets and emerging markets, and therefore the market risk must be assessed in different ways on these two types of markets. Research also indicated that the VaR method can be applied equally well to the developed markets and emerging markets with respect to certain specific features. The main difference between developed markets and emerging markets is that developed markets are more liquid and efficient while a lack of liquidity, low trading volume and the lack of availability of historical data over a longer period of time are noted on emerging markets. Emerging markets are also characterized by the reform of capital markets, the common occurrence of internal and external financial shocks, high level of country risk, credit rating changes, exchange rate volatility, high level of trading based on insider information, and the like. Financial theory suggests that higher volatility, which is typical of the yields on emerging markets, corresponds to higher expected returns in these markets [21]. Shallow markets, the relatively low number of securities that are actively traded with, the appearance of heteroscedasticity and autocorrelation between the sets of the security yields, lack of market transparency, high transaction costs, problems in the full implementation of international accounting standards and weak corporate governance are the common characteristics of emerging capital markets [19].

Having in mind the above mentioned, a special challenge is to test the possibility of using the VaR method at the market risk management on the financial market of the Republic of Serbia. Consequently, the subject of the paper is to test the performance of historical simulation (HS) and delta normal VaR on the financial market of the Republic of Serbia in the period from 2005 to 2011. The aim of the research is to analyse the application performance of the VaR methods of risk management, that is the success of application of the methods given in predicting market risks on the "specific"-transitory financial market of the Republic of Serbia. This paper analyses the theoretical foundations and empirically evaluates the results of the application of historical simulation (HS) – as a representative of a non-parametric approach, – and the delta normal VaR – as a representative of a parametric approach – in the quantification of market risks of the BELEX15, the stock index of the Belgrade Stock Exchange. The results of the research will be useful to both the professional-business community, and the academic community, with the aim of gaining pragmatically tested knowledge about the possibilities of using the VaR method on the financial market of the Republic of Serbia.

The paper is structured into six chapters. In the introduction, a summary of the primary determinants is given of the investigated problem, the case and the aims are discussed. The second chapter reviews the VaR methods tested in the study with assessment of their strengths and weaknesses. Then follows a detailed description of the research methodology, with a preliminary analysis of the data used in the study, followed by the results. Concluding remarks, as well as noted limitations and directions for future research are presented in the sixth chapter.

2. THEORETICAL BACKGROUND

The term Value-at-Risk (VaR) is not found in widespread use before 1990, but the origin of this method reaches back quite far in the past, because in the core of this model is Markowitz`s portfolio theory and other theories and models. Although the given theories and models have very different origins, there is a similarity between them, and the goals were substantially the same for all researchers, which was the creation of efficient portfolios. The main purpose of the VaR method is to focus on market risks and their quantification and prediction. The incentives for the use of VaR methods came from the needs of financial institutions involved in investment activities to quantify and predict market risks the best possible way. By using VaR methods, financial institutions can perform calculations of maximum possible losses in a given time horizon, usually for 1 or 10 days, for a given confidence level [5]. Value at Risk (VaR) is the maximum loss that may occur at the given level of tolerance. The tolerance level is the probability of losses exceeding the mathematically projected limits [11].

The first regulatory measures indicating the VaR appeared in 1980, when the U.S. Securities and Exchange Commission (SEC) laid claim to financial companies with a market capital exceeding $ 2.5 billion to publicise data on the value of their VaR with a confidence level of 95% for a period of 30 days. However, in order to retain enough capital to cover possible losses, it became clear that it was necessary to express the value of VaR with a confidence level higher than 95%. At the same time trading on financial markets had been increasing, while commercial banks had become more volatile, which created the need for more frequent and more sophisticated risk controls. In the early nineties of the 20th century, many financial institutions have developed their own methods of risk assessment with wide variations in order to quantify the risk. One of the largest U.S. banks (JP Morgan) in the beginning of 1994, published on its Internet site correlation coefficients among the most important financial instruments, i.e. the RiskMetrics model was used for almost a decade to manage risk.

With the Basel agreement in 1995, the capital reserves of banks were determined. Basically, this agreement extended the previous Basel Agreement of 1988 by the fact that a special emphasis is placed on the quantification of market risks and that banks were allowed to set their capital reserves for market risks on the basis of their internal models. The Basel Agreement of 1988 was enforced among the members of the group G-10 (Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Sweden, UK and U.S.) [22].

The assessment of market risks in the investment processes is best quantified by the VaR [12]. There are several methods for calculating the VaR, as follows:

- Delta normal VaR (RiskMetrics);
- Historic simulation;
- Monte Carlo simulation; etc.

Calculating the VaR is possible in the following ways [24]:

VaR = the position's market value * price sensibility * potential change of interest rates (1)

or

VaR = the position's market value * price variability (2)

As seen, the basic elements for the calculation the VaR are the market value, standard deviation and the market value of the instruments. Bearing in mind that the market value of the instrument is very easy to evaluate, it is seen that the individual risk factors (price changes) have a normal distribution. As the values below the normal distribution curve can be statistically determined, the price changes can also be predicted.

The main disadvantage of this method is that it assumes a normal distribution of data, and that the model calculation is developed for the overall VaR on the grounds of this assumption. However, in finance it is very difficult to find a normal distribution, because market movements often deviate from it. Most VaR methods are based on the normal distribution, but many empirical studies have shown that the distribution of returns is not normal [4], and consequently VaR overestimates or underestimates the actual market risk in a number of cases. This would mean that the assumption of normal distribution of returns results in a lower yield values of the calculated VaR than the actual.

There is one another significant disadvantage of this method for calculating the VaR, and it is reflected in the fact that even if one assumes a normal distribution, the VaR could still be calculated incorrectly if there is an error in the estimate of variance and covariance. To some extent, these estimated values, obtained from the empirical data may be inaccurate. In other words, the variance and covariance matrices, which are the input in the calculation, are merely a sum of estimates. When the errors in the estimates are added up, a great mistake may appear that will greatly affect the calculation of the VaR. A lot of researchers have worked in the field, trying to improve the techniques for a more reliable estimation of the variance and covariance, which are the inputs of the VaR calculation. Some studies show that the best results are achieved by refining sampling methods, allowing thus a better estimation of the variance and covariance, while other studies suggest that it is the existing data that need a better assessment. For example, conventional VaR estimates are based on the assumption that the standard deviation does not change over time, while by research it was concluded that better estimates are obtained by models that explicitly permit the assumption that the standard deviation is variable [6]. Two variants are proposed, the ARCH and the GARCH methods that provide better estimates of the variance, and as a result a better estimation of the VaR. The GARCH method allows dynamic feedback between the components [1]. Another problematic assumption is that there is usually no change in the portfolio during the observed period, which is usually in the course of a single day [16]. This assumption can be taken as accurate, that is realistic, for smaller institutions; but it is questionable for larger institutions with active portfolios.

The most common methods for assessing the VaR are the historical simulation (HS VaR), the parametric VaR (Delta normal VaR) and the Monte Carlo simulation. These three methods of calculating the VaR do differ, but they also have certain common characteristics. Each of the methods use risk factors, as well as the historical distribution of price changes on the market. Generally, none of the methods of calculating the VaR is superior to the other under all conditions and all markets [9]. Namely, methods that allow accurate estimation of VaR in developed markets, not necessarily have global application possibilities [2]. The common problem is in the choice of the time horizon from which the historical data are taken as a basis to predict future distributions of returns [13].

Each of these approaches have their advantages and disadvantages. Some authors have focused on the historical VaR, due to three main advantages this model has over the parametric approach for the quantification of the VaR. The Historical VaR: 1. does not start from the assumption of normal distribution; 2. is easy to calculate because there is no need for the variance-covariance matrix, and 3. can easily carry the characteristics of the empirical distribution that cause serious problems for the parametric approach [26]. The main characteristic of the historic simulation is that in assessing the VaR of a portfolio it does not starts from an assumption of the analytical form of distribution, nor from the degree and direction of the correlation between portfolio components. This makes the method extremely convenient for inefficient markets, where it is noted that the matrix of correlations between securities are unstable and subject to rapid change [20]. Further research led to the conclusion that the method and VaR models such as the EVT (Extreme Value Theory) and HHS (Hybrid Historical Simulation) can reach the best results of risk quantification, according to the results obtained from the Croatian and Turkish markets during the economic crisis [28].

The above stated confirms the actuality of the researched area, and the orientation of the authors to test the historical simulation (HS), and delta normal VaR in the quantification of market risks in the investment processes on the financial market of the Republic of Serbia, in order to reach realistic and scientifically verified results of applying the given methods of the VaR calculations.

3. RESEARCH METHODOLOGY

In this section, an overview of research methodology is given with an emphasis on performance analysis of the historical simulation (HS) and the delta normal VaR on the financial market of the Republic of Serbia. Performance testing was carried out, i.e. the degree of efficiency was determined of the HS and the Delta normal VaR with a confidence level of 95% and 99%. The research determines the prediction of the market risk, i.e. the maximum possible losses in the investment processes. The study sample consists of the daily returns of the BELEX15 index of the Belgrade Stock Exchange during the period between 10.04.2005 – 20.05.2011. The survey was conducted in the given period due to the historical data available for BELEX15 stock market index.

The initial period for the calculation of the VaR is comprised of the data from 2005 and 2006, while the testing element for the efficiency of the historical simulation (HS) and the delta normal VaR with a confidence level of 95% and 99% is from the period between 2007 and 2011. On the basis of the calculated values of HS and the delta normal VaR for 50, 100, 200 and 250 days, the success of their predictions were followed for the market risk of the following day. The prediction of the market risk, based on the VaR, is successful if the resulting loss in value is less than the VaR for the previous period, and consequently, the prediction of the market risk is unsuccessful in case the realized loss exceeds the VaR values of the previous period. The procedure was performed for the HS and the delta normal VaR with 95% and 99% confidence levels. At the beginning of the analysis, the distribution of the sample was tested by the Kolmogorov-Smirnov test, with an aim to determine whether the sample has a normal distribution. The image of the sample distribution was obtained on the basis of the central dispersion parameters. Also, the Kolmogorov-Smirnov test was used to test the distribution of the sample divided by the observed years [18]. This analysis covered the periods (years) based on data from January to December for each year respectively. Consequently, the differences in the value distribution of the BELEX15 stock market index have been analysed for 2006, 2007, 2008, 2009 and 2010.

The correlation between the variables of the index values in one year compared to the index value in the second year were tested by factor analysis. First, the correlation matrix was calculated; and on the basis of this data the correlations between certain variables were determined, and then the characteristic roots were calculated, according to which the variables were grouped (based on similarities) into two factors. Thus, the obtained results of the factor analysis indicate which years are mutually correlated, and the results also point to the characteristics that the daily values of the BELEX15 stock market index possess. Based on the results of the correlation matrix, information is gained about the correlation between the movement of the index value over the years; and accordingly, it can be concluded which years are similar to each other according to the stock index value changes. The results also provide information about the changes that have emerged in the market, suggesting the causes and describing the consequences of these changes.

Given the advantages and disadvantages of historical simulation (HS) and delta normal VaR, the authors have tested the application of both methods in the prediction of market risk, and determined which method is more appropriate for monitoring the maximum possible losses in investment activities. Accordingly, the study includes an analysis of the number of days with successful predictions, in relation to the number of days with unsuccessful predictions for the market risk of the HS and the delta normal VaR – with a confidence level of 95% and 99%, and for 50, 100, 200 and 250 days. Namely, performance predictions were analysed for the market risk of the BELEX15 on a daily basis, depending on the length of the interval for which the VaR calculation was performed. The analysed period was divided into six segments. The first segment represents the period for which the VaR values were calculated, and that is the basis for its calculation (from 10.04.2005 to 31.12.2006); while in the second, third, fourth and fifth segments the efficiency of the HS and Delta-normal VaR were tested for 50, 100, 200 and 250 days. The second segment represents BELEX15 yield data for 2007, the third for 2008, the fourth for 2009, the fifth for 2010, and the sixth for 2011. Given the lack of data of the values for the BELEX15 stock market index from a historical point of view (which is one of the characteristics for emerging and transitory financial markets), a shorter number of days was used to test the efficiency of the VaR methods [27]. When there is a sufficient number of historical data, the research can be done for a longer number of days [7]. The division of the research segments is determined by observing the yields of the BELEX15 stock market index by years, where one year represents one cycle. The testing of the application’s efficiency, - i.e. the calculations of the HS and the delta normal VaR, - is done on the returns of the stock market indices, which is enabled by the possibility of monitoring changes of the same movements, that is when data can be reduced to unified values [7], [10], [14] and [28].

Calculations of the historical (HS) VaR can be represented mathematically as follows [17]. With an a% certainty we will not lose more than V dinars in the next N day. V is a function of two variables:

- N – the time period in days,
- a – confidence level.

Let ΔP be the change of the portfolio’s value in the following N days. The VaR in that case corresponds to the loss (100 - a) of the ΔP distribution. Then:

$$P(\Delta P < VaR) = 1 - a \qquad (3)$$

VaR is a (100 - a) percentile of the value distribution, and is usually calculated on a daily basis, the confidence level being 95% or 99%.

Delta Normal VaR represents the maximum loss observed over some time period in relation to the chosen confidence level (usually 95% or 99%).

$$VaR_{\alpha}^{\%} = Z_{\alpha}\sigma \tag{4}$$

where:

Zα – value of theoretical distribution,

σ – standard deviation during the observed time period.

Zα depends on the confidence level of the VaR calculations. In case the confidence level is 95% (VaR95%), Z95% is then -1.645, while for a 99% confidence level (VaR95%) Z95% is -2.33.

For the calculation of the VaR different time intervals (days) are used. The most commonly used intervals represent a small number of days such as 50 or 100 days, while other intervals can be up to 500 or 1000 days. It is not possible to calculate the VaR for such long intervals, as there are no historical data available for such a large number of days for the BELEX15 stock market index. For this reason, for the longer intervals 200 and 250 days are used.

To test the method of VaR (back-testing) the Kupiec test was used with a confidence level of 95% and 99%, and based on it, the efficiency of the HS and delta normal method of calculating VaR is accepted or rejected. The number of days, when it is expected to obtain unsuccessful predictions, it can be calculated as follows: 1 - confidence level. For a sample of a 100 observations and at the confidence level of 99%, one unsuccessful prediction can be expected (100% - 99% x 100 = 1), thus 1 allowed (targeted) number of unsuccessful predictions is expected (exceeding the VaR). The calculation is the same for the confidence level of 95%. Larger or smaller numbers of unsuccessful predictions than the expected indicate the inadequacy of applying the chosen method for calculating the VaR. The Kupiec test uses the binomial distribution to calculate the probability that a certain number of unsuccessful predictions would occur for a given confidence level and sample size. Mathematically, the Kupiec test can be represented as follows [25]:

$$P(x|n,p)=\binom{n}{x}p^{x}(1-p)^{n-x} \tag{5}$$

where:

x – the variable representing the number of VaR exceeds,

N – sample size,

p – the chosen confidence level.

If the sample size and p as a 1-confidence level are used as an input, the binomial function gives the probability of the occurrence of a given number exceeding the VaR. Using the cumulative binomial distribution, the interval can be calculated to which the values exceeding the VaR belong, in order to accept the tested method of calculating the VaR. The interval is obtained when calculating the value of N for which the cumulative binomial distribution gives the probability that the interval of 2.5%<P<97.5% (the confidence level of 95%). The method of the VaR is accepted if the given value N is located within a given interval. Otherwise, the method is rejected. The rejection of the method implies that, for the chosen confidence level that is being used, the values calculated using the VaR methods are not consistent with the probability. This is an indication that the performance of selected the VaR method is not satisfactory and that the method should therefore be rejected.

4. PRELIMINARY DATA ANALYSIS

Given the historical data available, the survey sample includes daily values of the BELEX15 stock market index, in the period from 10.04.2005 to 20.05.2011 (1414 days). The existence of short time series of individual stock returns or long periods of inactivity on the market (lack of trading and the like) represent a significant limitation for statistical data analysis. Accordingly, it is practical to analyse the stock market indices of transitory financial markets of Serbia, especially the BELEX15 stock market index. Namely, the BELEX15 is the leading index at the Belgrade Stock Exchange, and it represents the price movements of the 15 most liquid Serbian stocks and can be viewed as a portfolio of selected stocks. The data was taken from the official Internet site of the Belgrade Stock Exchange.

The data used in the study cover the period from 10.04.2005 to 20.05.2011, as follows: 64 days in 2005, 247 days in 2006, 250 days in 2007, 253 days in 2008, 253 days in 2009, 250 days in 2010 and 91 days in 2011. Changes in returns of the BELEX15 are shown in Fig. 1.

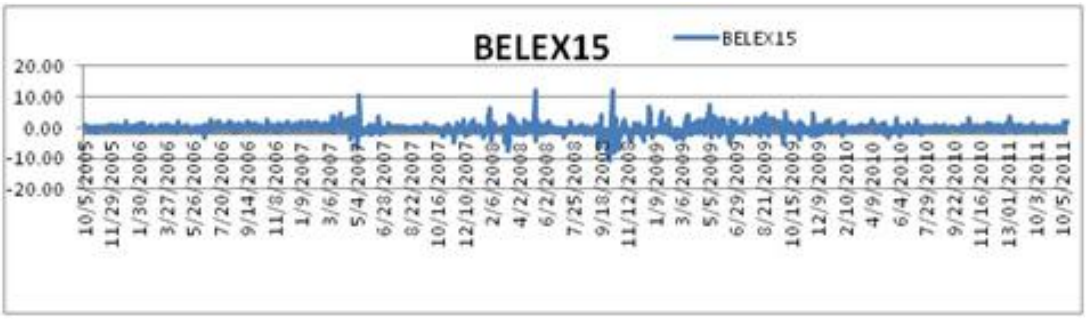

Figure 15. - Return changes at the BELEX15 in the period between 10.04.2005 and 20.05.2011

The testing of the normal distributions of the BELEX 15 was carried out by the Kolmogorov-Smirnov test. Table 1. shows the results of the test of the normal distribution.

Table 1. - The central and dispersion parameters, and the skewness and kurtosis values of the BELEX15 stock market index by years

Year	Mean value	Std. Deviation	Error	Min.	Max.	c. var	confidence level		sk	ku	p
2006	1241.70	189.06	12.01	1013.3	1675.2	15.23	1218.05	1265.36	0.73	-0.79	0.000
2007	2621.09	378.78	24.05	1704.4	3304.6	14.45	2573.70	2668.47	-0.58	-0.71	0.000
2008	1461.42	530.12	33.66	474.6	2346.2	36.27	1395.11	1527.74	-0.44	-0.92	0.002
2009	598.03	138.61	8.80	354.4	862.8	23.18	580.69	615.36	0.14	-0.95	0.007
2010	659.48	39.74	2.52	600.9	765.5	6.03	654.51	664.46	0.82	-0.20	0.000

sk – skewness, ku – kurtosis in the intervals from -0.04 to 0.04 are not discussed

Source: Author's calculations

Higher values of the coefficient of variation (c. var) indicate heterogeneous index values for the years: 2008 (36.27) and 2009 (23.18). Also, the coefficient of variation (c. var) indicate that the sample is more homogeneous in 2006 (15.23), 2007 (14.45) and 2010 (6.03). Higher levels of skewness (sk) indicate that the distribution is negatively asymmetric, meaning that the curve of the distribution results tends to lean toward higher values, meaning that there are more larger values than the normal distribution. For 2006 (0.73), 2009 (0.14) and 2010 (0.82), lower values of skewness (sk) indicate that the distribution is positively asymmetric, which means that the curve of the distribution results tends to lean toward smaller values, i.e. that there are more smaller values than the normal distribution. For 2007 (-0.58) and 2008 (-0.44), negative values of kurtosis (ku) indicate that the curve flattened, also as in 2006 (-0.79), 2007 (-0.71), 2008 (-0.92), 2009 (-0.95) and 2010 (-0.20). The distribution of values deviates from the normal distribution (p) in 2006 (0.000), 2007 (0.000), 2008 (0.002), 2009 (0.007) and 2010 (0.000).

Based on the results of the Kolmogorov-Smirnov test it can be concluded that the values of the BELEX15 stock market index differ from the normal distribution. Looking at the mean values of the index by the years, a trend of change in the index values is visible. Namely, in 2006, the mean value was 1241.70, only to double in 2007, after which a drop in the values is seen in 2008 to 1461.42 (representing a large drop in one single year). This trend is maintained in 2009 (598.03), and finally there was a slight increase in 2010 (659.48). This movement in the values of the BELEX15 stock market index shows the changes that happened in the market during this period. Based on the results, it can be observed that the market volatility was high in 2007, when a large increase in values was recorded, as well as in 2008 and 2009, when there was a large decline in the value of the index. Based on the standard deviation, it can be concluded that the market volatility was the highest in 2008 (530.12), which is caused by a sudden drop in the index value, and then volatility was high also in 2007, as seen by the value of the standard deviation of 378.78, which is caused by the growth of the index values in 2007. In 2009 and 2010, there was a lower volatility (with no significant oscillations) according to the values of the

BELEX15 stock market index, which is the result of the reduction in trading volume, and the reduced investment activity on the market.

By the Kolmogorov-Smirnov test the differences in the distributions of index values were analysed, and it was found that all the years show significant differences among each other, which is indicated by the value of p (Table 2.).

Table 2. - Kolmogorov-Smirnov test differences of value movements of the BELEX15 stock market index by the observed year

Year I	Year II	F(I)	F(II)	F(I)-F(II)	maxD	lambda	p
2006	2007	F(I)	F(II)	F(I)-F(II)	0.073	33.3221	0.000
2006	2008	F(I)	F(II)	F(I)-F(II)	0.216	87.9794	0.000
2006	2009	F(I)	F(II)	F(I)-F(II)	0.045	14.2243	0.000
2006	2010	F(I)	F(II)	F(I)-F(II)	0.083	27.1985	0.000
2007	2008	F(I)	F(II)	F(I)-F(II)	0.153	74.0098	0.000
2007	2009	F(I)	F(II)	F(I)-F(II)	0.098	33.9386	0.000
2007	2010	F(I)	F(II)	F(I)-F(II)	0.055	19.7037	0.000
2008	2009	F(I)	F(II)	F(I)-F(II)	0.243	78.9776	0.000
2008	2010	F(I)	F(II)	F(I)-F(II)	0.135	45.3202	0.000
2009	2010	F(I)	F(II)	F(I)-F(II)	0.112	31.2736	0.000

Source: Author's calculations

The correlation matrix is the initial step of factor analysis, because based on the correlation matrix information is obtained on the correlation between pairs of traits. Consequently, it is known how the characteristics are associated to each other, and by factor analysis the characteristics are summed into one factor. In our research, we have five groups – the stock market index in one year makes one group. The goal of factor analysis is to determine whether there are similarities in the movement trends of the stock exchange indices between years. Thus we can conclude which years are inter-related and which years are contrary to the link. On the basis of factor analysis, it is obtained into how many factors the observed variables (years) can be divided, and the relationship between the variables within each factor can also be determined. There are various analysis according to which correlation between variables can be established, and one of the most commonly used is the Pearson correlation. In our study, the intention was to establish, in addition to the correlation between variables, the number of factors based on which we get the dimension of space (two-factor structure).

Structure analysis was performed by using principal components factor analysis, on the basis of five traits that represent the years: 2006, 2007, 2008, 2009 and 2010. The objective of the structure analysis is to observe whether there is a correlation between the values of the indices by the observed years. The value of the returns is calculated on the basis of the index values, thus if the value of the index is changing, the value of the yield also changes. Accordingly, the results that are valid for the index value, are valid for the return values, as well.

The analysis reveals that the highest correlation (0.731) is seen between 2009 and 2006, and the maximum negative value is -0.946 for 2008 and 2006 (Table 3.). Factor analysis does not test the significance, but only groups variables by correlation. When the level of integration is less than 0.4 it is considered that the correlation is not significant, when the correlation is from 0.4 to 0.6 there is a moderate correlation, and when the value is over 0.6 then there is high correlation. It should be noted that the level of correlation coefficients range from -1 to 1. If the coefficient is -1, the correlation is inversely proportional, when it is 0 then there is no correlation, and when it is 1, then there is maximum correlation. Table 3. shows that each year is in maximum correlation with itself, with a value of 1.

Table 3. - Correlation matrix of the analysis of similarities in the returns for the BELEX 15 index by the observed years

Year	2006	2007	2008	2009	2010
2006	1				
2007	-0.085	1			
2008	-0.946	-0.109	1		
2009	0.731	0.071	-0.706	1	
2010	-0.382	-0.141	0.402	-0.727	1

Source: Author's calculations

The percentage of the characteristic roots ranges from 0.639% to 59.597%. The newly obtained structure consists of two separate factors containing 80.904% of the information of the entire test series. By separating two factors in the factor analysis, 80.904% of the information of the entire sample was covered (Table 4.).

Table 4. - The characteristic root and the percentage in the structure

n	Root	Percentage (%)	Sum
1	2.980	59.597	59.597
2	1.065	21.307	80.904
3	0.756	15.110	96.014
4	0.167	3.347	99.361
5	0.032	0.639	100.000

Source: Author's calculations

Also, the structure of the two separate factors was analysed (by the method of principal components) in relation to 2006, 2007, 2008, 2009 and 2010 (Table 5.). In Table 5, the columns mean the following: qlt - communality, wrig - weight variables, inr - inertia; krd - coordinates; cor – contribution of the factor to the characteristics; ctr – contribution of the characteristic to the factor.

Table 5. - Time periods (years) divided into two separate factors according to similarities

					1 -factor			2 -factor		
	Year	qlt	wrig	inr	krd	cor	ctr	krd	cor	ctr
1	2006	0.9	0.001	0.2	-0.903	0.815	0.274	0.291	0.085	0.079
2	2007	0.879	0.001	0.2	-0.094	0.009	0.003	-0.933	0.870	0.817
3	2008	0.833	0.001	0.2	0.906	0.821	0.276	-0.106	0.011	0.011
4	2009	0.846	0.001	0.2	-0.918	0.842	0.283	-0.059	0.003	0.003
5	2010	0.588	0.001	0.2	0.702	0.492	0.165	0.310	0.096	0.09
			0.005	1			1			

Source: Author's calculations

Larger values of communality are seen in 2006 (0.9), 2007 (0.879), 2009 (0.846) and 2008 (0.833). Moderate communality values indicate that the structure of the two separate factors include moderate information for 2010 (0.588). The results indicate that the two extracted factors to a greater extent represent 2006, 2007, 2009 and 2008, while to a lesser extent, represents the state in 2010. The previous results can be interpreted as consequences of the global economic crisis - low trading volume and lower volatility of the market in the given period.

The structure of the first separated-extracted factor is made of four analysed periods: 2009 with the contribution of factor (cor) 0.842, 2008 (0.821), 2006 (0.815) and 2010 (0.492). The relationship of the period of 2009 agrees with the period of 2006. The correlation of 2009 was inversely proportional to the periods of 2008 and 2010. The structure of the second separated factor is the period of 2007 with the contribution of the factor (cor) 0.870.

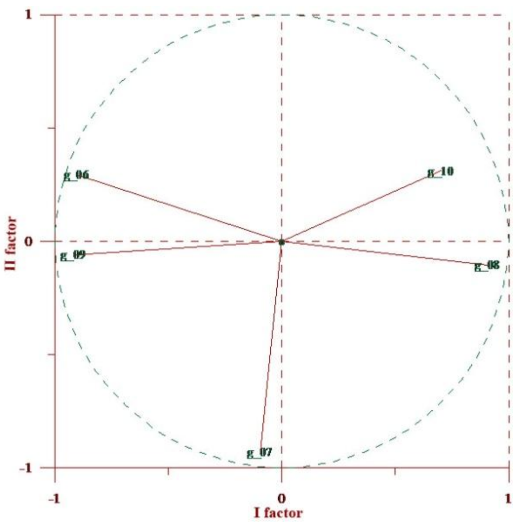

Figure 2. - The image of time periods (years) in space of the two factors – divided by similarities

Based on the previous results it can be observed that of all the analysed periods, the value movements of the BELEX15 stock market index are the most similar in 2006 and 2009, while the other two periods that are most similar to each other are 2010 and 2008. It is important to emphasize that the observed periods of 2006 and 2009 are opposite to periods of 2010 and 2008. This means that the growth of the index values in 2006 and 2009, are followed by periods of decline in the values in 2010 and 2008, or vice versa (Fig. 2). The above stated suggests that the processes, which occurred during the observed years, were not compatible.

The fact that there is an agreement in the movements of the index values in the period of 2006 and 2009, means that similar changes have occurred in the BELEX15 stock market index values in both years, but that does not necessarily mean that they were the same (there is a similarity, but they are not completely the same). That can be seen from the chart, because the angle that closes lines g_10 (2010) and g_08 (2008) indicates that differences do exist in relation to these two periods. The fact is, that the periods are grouped into three groups, namely: the first group consists of 2006 and 2009; the second group consists of 2010 and 2008; and the third group of 2007. The results can be seen in Fig. 2. 2007 (g_07) is a completely separate entity, which means that the changes in the index value had no similarities with any of the other two groups.

The results above indicate the movements of the BELEX15 stock market index in the period between 2006 and 2010, i.e. in which years were the changes similar. In order to be able to adequately interpret the obtained results, it is necessary to bear in mind the impact of the overall economic trends during the years examined on the value of the BELEX15 stock market index. It is known that during the period before the negative impact of the global economic crisis, there was a period of expansion (2006 and 2007), which was characterized by a continuous inflow of capital, employment growth, an increased participation of institutional investors on the market, and so on; that is a generally positive growth of all economic indicators. The positive market trends were particularly present in 2007, which resulted in the obtained values for this year – 2007 becoming a completely separate entity in relation to other periods observed. In contrast, the decline in value of the BELEX15 stock market index, as a result of the crisis, is especially marked in 2008 and 2010. Further studies of the causes and consequences of changes in the BELEX15 stock market index values are beyond the scope of this study.

It is important to mention that – based on the Kolmogorov-Smirnov test, – there are significant differences in the values of the BELEX15 stock market index, while the factor analysis showed that beside the differences, there were also some similarities. In this respect, the three groups were formed – that two periods belong to the same group does not mean that they are the same, but that they are similar in some respects.

5. RESEARCH RESULTS

In this section, the results of the efficiency of the historical simulation (HS) and the delta normal VaR are presented and discussed, at a confidence levels of 95% and 99% (in respect to the observed number of days - 50, 100, 200 and 250 days) when predicting the maximum possible losses from investment activities for the BELEX15 stock market index. The success and acceptance, or accordingly, the rejection or failure of the VaR methods is determined by the Kupiec test. The successful method is the one with the smaller number of days deviating from the Kupiec test. Namely, based on the analysis of the HS and the delta normal VaR, the number of days was determined in which the prediction was unsuccessful. The number of days per year, where the prediction was not successful, was compared to the Kupiec test, which gave a limit in respect to the comparison (acceptance / rejection of the model).

In the HS-VaR at 99%, the obtained results indicate that the efficiency of the VaR 99% compared to the Kupiec was small at the VaR which was calculated on the lower number of days, as seen for the HS50, because in none of the given years the method has shown success. Greater success in predicting market risk, that is in the prediction of the maximum possible losses from investment activities, was for HS200 and HS250. The results indicate that in 2009, 2010 and 2011 the method of assessing the market risk has been successful (Table 6.).

Table 6. - Results for HS VaR 99% in respect to Kupiec 99%

HS VaR 99%	HS50	No. of days	Probability value	HS100	No. of days	Probability value	HS200	No. of days	Probability value	HS250	No. of days	Probability value
2007	Reject	-20	0.002	Reject	-19	0.004	Reject	-21	0.001	Reject	-22	0.001
2008	Reject	-6	0.072	Reject	-6	0.072	Reject	-4	0.031	Reject	-4	0.031
2009	Reject	-2	0.008	Accept	1	0.000	Accept	1	0.000	Accept	3	0.000
2010	Reject	-1	0.003	Accept	0	0.001	Accept	2	0.000	Accept	3	0.000
2011	Reject	-1	0.103	Reject	-1	0.103	Accept	1	0.009	Accept	1	0.009
Unsuccessful	5			3			2			2		

Source: Author’s calculations

Based on the results, it can be seen that the number of days deviating from the Kupiec ranges from -22 to -20 in 2007, and from -4 to -6 in 2008. In 2009, 2010 and 2011, at the HS50 a deviation was noted from -2 to -1, while for the HS200 and HS250 a positive deviation is seen, and it ranges from +1 to +3 days (Table 6.).

In the delta normal VaR 99%, an equally efficient application was obtained for all days, i.e. at 50, 100, 200 and 250 days. Namely, greater success was achieved with the D50 and D100, while the success of the D200 and D250 is the same as in the HS VaR. The number of days deviating from the Kupiec is negative in

2007 and 2008, ranging from -2 to -13 days. In 2009, 2010 and 2011, positive deviations are seen ranging from 0 to +3 days (Table 7.).

Table 7. - Results for delta normal VaR 99% in respect to the Kupiec 99%

Delta VaR 99%	D50	No. of days	Probability value	D100	No. of days	Probability value	D200	No. of days	Probability value	D250	No. of days	Probability value
2007	Reject	-7	0.095	Reject	-6	0.075	Reject	-2	0.008	Reject	-3	0.018
2008	Reject	-10	0.112	Reject	-12	0.086	Reject	-12	0.086	Reject	-13	0.067
2009	Accept	2	0.000	Accept	2	0.000	Accept	2	0.000	Accept	3	0.000
2010	Accept	1	0.000	Accept	0	0.001	Accept	3	0.000	Accept	3	0.000
2011	Accept	1	0.009	Accept	1	0.009	Accept	1	0.009	Accept	1	0.009
Unsuccessful	2			2			2			2		

Source: Author's calculations

It should be noted that the number of failures in predicting the market risk was the highest at the HS-VaR, while a much smaller number of failures is seen at the delta normal VaR. The success of predicting the market risk – with both methods, - is better in 2009, 2010 and 2011; while in 2007 and 2008 the deviations from the threshold were higher from the Kupiec.

Based on the results for the HS VaR 95%, it can be observed that greater efficiency was seen in 2009, 2010 and 2011, especially in the VaR which is calculated for a higher number of days (Table 8.).

Table 8. - Results for HS VaR 95% in respect to the Kupiec 95%

HS VaR 95%	HS50	No. of days	Probability value	HS100	No. of days	Probability value	HS200	No. of days	Probability value	HS250	No. of days	Probability value
2007	Reject	-10	0.000	Reject	-9	0.000	Reject	-11	0.000	Reject	-12	0.000
2008	Reject	-6	0.000	Reject	-6	0.000	Reject	-7	0.000	Reject	-9	0.000
2009	Reject	-3	0.000	Accept	5	0.003	Accept	8	0.069	Accept	9	0.137
2010	Reject	-4	0.000	Reject	-1	0.000	Accept	9	0.135	Accept	10	0.215
2011	Accept	0	0.002	Accept	1	0.012	Accept	2	0.051	Accept	3	0.169
Unsuccessful	4			3			2			2		

Source: Author's calculations

The deviations from the Kupiec were higher in 2007 and 2008, while there are minor deviations in 2009 and 2010 for the HS50, and in 2010 for the HS100. Greater success was recorded in 2009 and 2010 for the HS200 and HS250, while somewhat lower in 2011. For HS50 the results differ for a number of days, which is the result of the effects of extreme values in the calculation of the VaR. In 2008, there is a large number of extreme values, both positive and negative. For HS200 and HS250, the values that are much larger or smaller than the usual changes of index values, due to the large number of days used for the calculation, do not have a greater effect; while for the HS50 the influence of extreme values is more pronounced. From Table 8, it can be seen that negative deviation from the Kupiec was recorded in 2007 and 2008, where the number of days range from -6 to -12 days. The number of days for the HS50 in 2009 and 2010 is negative; namely, -3 and -4 days; and for the HS100 in 2010 the situation is similar, though the number of deviations is -1. HS200 and HS250 in

2009, 2010 and 2011 were successful (number of days of positive deviations ranged from 2 days to 10 days).

The results of delta normal VaR 95% in respect to the Kupiec 95% indicate that the greatest success was measured for the D200 and D250 in all of the observed years. For the D50 and D100 in 2007 and 2008 there have been more unsuccessfully predicted days as compared to the Kupiec. Very high performance was recorded in 2009 and 2010, while slightly lower in 2011. It may be noted that there is a negative number of days in 2007 and 2008 for the D50 and D100 (-4), while in all other cases, there is a positive number of days ranging from 0 to 10 days (Table 9.).

Table 9. - Results for delta normal VaR 95% in respect to the Kupiec 95%

Delta VaR 95%	D50	No. of days	Probability value	D100	No. of days	Probability value	D200	No. of days	Probability value	D250	No. of days	Probability value
2007	Reject	-4	0.000	Reject	-4	0.000	Accept	5	0.003	Accept	2	0.000
2008	Reject	-4	0.000	Reject	-4	0.000	Accept	5	0.000	Accept	2	0.000
2009	Accept	7	0.029	Accept	10	0.217	Accept	10	0.217	Accept	10	0.217
2010	Accept	0	0.000	Accept	4	0.001	Accept	9	0.135	Accept	10	0.215
2011	Accept	2	0.050	Accept	3	0.167	Accept	3	0.167	Accept	3	0.167
Unsuccessful	2			2			0			0		

Source: Author's calculations

Higher success of the HS and delta normal VaR is recorded at 200 and 250 days, and the reason for that is the frequent and extreme changes (volatility) in values of the BELEX15 stock market index during several consecutive days. For this reason, the calculation of VaR on most days reduces the extreme values, while for 50 or 100 days, the same cannot be fully absorbed.

The results are consistent with the comparative studies which have included analysis of the application of the VaR methods on the transitory markets of Slovenia, Croatia, Serbia and Hungary, i.e. the following stock market indices: SBI20, CROBEX, BELEXline and BUX [2]. In fact, research has shown that it is necessary to use several methods for calculating the VaR in assessing the market risk, and that the provided methods give better results on developed financial markets, which are characterized by low volatility and a rare occurrence of extreme values.

6. CONCLUSION

The results indicate to a limited ability to predict the maximum potential losses from investment activities using the historical simulation (HS) and the delta normal VaR on the financial market of the Republic of Serbia in the period between 2005 to 2011. For the period between 2006 and 2007, it can be concluded that that was a period of growth (increasing trends), which is evident by the average values of the BELEX15 stock market index. In 2008, there was a sharp decrease in the index value, which continued in 2009, only to recover slightly in 2010. In addition to the tested stock market index values, it is necessary to pay attention to the standard deviation, because it shows the deviations of the index values when compared to the mean. Based on these parameters and the performance results of the applications of the HS and the delta normal VaR, it can be concluded that in the observed period between 2005 and 2011, large changes in index values have occurred. These changes on an annual basis in 2006 were lower, while in 2007 and 2008 were much greater, not only in the index value, but also in the deviations from the average values, as indicated by the standard deviation. This should be taken into consideration, because after testing the HS and the delta normal VaR, very little success has been seen, i.e. there were no successful predictions of the market risks in 2007 and 2008. The delta normal VaR 95% proved to be successful for D200 and D250. It is a fact, that the into the delta normal VaR calculations the daily return values enter and based on that values the threshold is set at 95% or 99%, which is the starting point for greater effectiveness in relation to the HS VaR. The reason for this can be found in the manner of calculation, for the delta normal VaR calculation is based on the number of days (50, 100, 200 and 250), where the extreme return values shift the distribution curve to the left, and have such an effect that the projected limits become very strict (extreme yield changes with a negative sign affect the delta normal VaR by moving it to the left). This is not the case with the HS VaR, because during the calculation a part of 1% or 5% is taken out (depending on whether the VaR 95% or the VaR 99% is calculated) of the minimum return values that are ordered from the least to the highest, respectively. In this way, deviations, or the intervals between them, have no influence on the calculated projection (projected value for the next day).

Given the fact that on the financial market of the Republic of Serbia often appear extremely large changes in daily returns, it is important to include all changes that occur. Also, it is necessary to pay attention to the number of days in the calculation, which had an important role in the prediction of the maximum possible losses from investment activities. The results indicate that the prediction performance was always higher for the 200 and 250 days, which means that the higher number of the days contributed to a better and more successful prediction. The reason for this should be sought in the fact that the return values do change, and that there are periods in which the changes are slight, while there are periods in which these changes are large, and in such a way that in one single day the maximum growth may be recorded for that month, and already in the next day or the day after, there may be a great fall, which results in a fall in the observed index period in general. Extreme values occur repeatedly during the year, which means that when the calculations are done for a larger number of days these negative (extreme) changes and their effects are reduced. The problem in this case may be the fact that in calculating with a higher number of days, due to great fluctuations, the threshold is moved to the left towards negative values, and when a period occurs without extreme changes in the index values, the threshold that had been previously obtained by the delta normal VaR becomes wide and may significantly exceed the returns value. This creates a need for greater allocation of resources from the necessary, in order to provide grounds for the function of predicting maximum possible losses from investment activities (as a result of overestimation of market risk in the given case).

Based on the results of the research, it can be concluded that in 2007 there was a trend of growth on the observed market, while in 2008 there was a sharp decline in values of the stocks that are marked on the BELEX15. The declining trend lasted until 2011, when it was halted. These changes greatly affect the prediction of the maximum possible losses and prevent or hinder the prediction in investment processes. Consequently, it is necessary to apply both the HS and delta normal VaR, in the function of adequate prediction of market risks, and in order to avoid overestimation / underestimation of market risks.

On the basis of factor analysis, it can be concluded that the years 2006 and 2009 were similar considering the changes of the index values, and also the years 2008 and 2010 are similar, with a note that these latter two years are opposite in comparison to 2006 and 2009. This means that the value changes of the BELEX15 stock market index that have occurred in these years agree on the one hand, while disagree on the other (as in the cases of 2006 and 2009 when compared to 2008 and 2010). It should be noted that 2007 is unique under all parameters, and as such it does not agree with any of the analysed periods, and as such it stands in the space as special when compared to other periods. The reason for this is the fact that in that year the highest growth in index values was recorded, and was followed by the biggest drop in index values, which makes the year 2007 different from other periods tested. In order to recognize the causes and consequences of changes in the values of the BELEX15 stock market index in the studied period, it is necessary to further analyse the movements of the values in each year separately, as well as the economic trends, that partially cause the index value changes.

The limitation of the study, historically speaking, is asymmetrical; and is due to the low number of trading days on the Belgrade Stock Exchange, the low level of market liquidity, a large number of days when there was no trading at all, the occurrence of extreme values, the volatility of the market, the choice of the time horizon, risks in the peripheral parts of the distribution, and the like. These limitations significantly affect the efficiency of the tested VaR methods, i.e. the adequate prediction of market risks in the investment process.

Directions for future research include continued monitoring of the performances of both the HS and the delta normal VaR in the investments processes, and especially so on the transitory markets. In addition, it is necessary to take into account the specificities of the same, and in particular the possible occurrence of extreme values, with repeated studies for longer time intervals in the VaR calculations in the future, when the circumstances allow it.

REFERENCES:

1. Adcock C., N. Areal, B. Oliveira, Value-at-Risk forecasting ability of filtered historical simulation for non-Normal GARCH returns, European Financial Management Association, Braga, 2011, 1-34.

2. Andjelić, G., V. Djaković, S. Radišić, Application of VaR in emerging markets: A case of selected Central and Eastern European Countries, African Journal of Business Management, 4(17), 2010, 3666-3680.

3. Bessis, J., Risk management in banking, 2nd edition (New York: John Wiley & Sons, 2002).

4. Duffie, D., J. Pan, An overview of Value-at-Risk, Journal of Derivates, 4(3), 1997, 7-49.

5. Đorić, D., E. Nikolić-Đorić, Return distribution and value at risk estimation for BELEX15, Yugoslav Journal of Operations Research, 21(1), 2011, 103-118.

6. Engle, R.F., S. Manganelli, CAViaR: Conditional autoregressive Value at Risk by regression quantile, Journal of Business and Economic Statistics, 22(4), 2004, 367-381.

7. Gencay, R., F. Selcuk, Extreme Value Theory and Value-at-Risk: Relative Performance in Emerging Markets, International Journal of Forecasting, 20(2), 2004, 287-303.

8. Heffernan, S., Modern banking in theory and practice (Chichester (etc): John Wiley and Sons, 1996).

9. Hendricks, D., Evaluation of value-at-risk models using historical data, Economic Policy Review, Federal Reserve Bank of New York, 2(1), 1996, 39-69.

10. Huang, Y.C., B.J. Lin, Value-at-Risk Analysis for Taiwan Stock Index Futures: Fat Tails and Conditional Asymmetries in Return Innovations, Review of Quantitative Finance and Accounting, 22(2), 2004, 79-95.

11. Jazić, V., Primena VaR metodologije, Bankarstvo, 36(11-12), 2007, 44-57.

12. Jorion, P., How Informative Are Value-at-Risk Disclosures?, The Accounting Review, 77(4), 2002, 911-931.

13. Kritzman, M., D. Rich, The Mismeasurement of Risk, Financial Analysts Journal, 58(3), 2002, 91-99.

14. Koopmana, S.J., B. Jungbackera, E. Hol, Forecasting daily variability of the S&P 100 stock index using historical, realised and implied volatility measurements, Journal of Empirical Finance, 12(3), 2005, 445-475.

15. Leon, M., Managing and measuring market risk, Trusts and Estates, 138(11), 1999, 28-30.

16. Nuxoll, D.A., Internal risk-management models as a basis for capital requirements, FDIC Banking Review, 12(1), 1999, 18-29.

17. Ottenwaelter, M., Value-at-Risk for commodity portfolios, INP Grenoble – ENSIMAG, 2008, 1-43.

18. Panchenko. D., Statistics for applications – L14 Kolomogorov-Smirnov test, MITOPENCOURSEWARE, Massachusetts institute of technology, lecture notes, 2006, 1-8.

19. Radivojević, N., J. Lazić, J.M. Cvijanović, Ograničenja primene savremene portfolio teorije na tržištima u nastajanju - primer srpskog tržišta kapitala, Industrija, 37(4), 2009, 1-13.

20. Radivojević, N., J. Lazić, J.M. Cvijanović, Aplikativnost istorijske simulacije vrednosti pri riziku na tržištu kapitala Srbije, Industrija, 38(3), 2010, 19-29.
21. Salomons, R., H. Grootveld, The equity risk premium: emerging vs. developed markets, Emerging Markets Review, 4(2), 2003, 121-144.
22. Saunders, A., Credit risk measurement (New approaches to Value at Risk and other paradigms) (John Wiley & Sons, New York, 1999).
23. Sinkley, J.F.Jr., Commercial bank financial management in the financial-services industry (Prentice Hall, New Jersey, 1998).
24. Šverko, I., Rizična vrijednost (value at risk) kao metoda upravljanja rizicima, Ekonomski pregled, 53(7-8), 2002, 640-657.
25. Veiga, B., F. Chan, M. McAleer, Evaluating the impact of market reforms on Value-at-Risk forecasts of Chinese A and B shares, Pacific-Basin Finance Journal, 16(4), 2008, 453-475.
26. Žiković, S., Implications of measuring VaR using Historical simulation; an example of Zagreb Stock Exchange index – Crobex, in Roufagalas J. (Ed.), Resource Allocation and Institutions: Explorations in Economics, Finance and Law, (Greece: Athens, Athens Institute for Education and Research, 2006) 367-389.
27. Žiković, S., Measuring market risk in EU new member states, Dubrovnik Economic Conference, Dubrovnik, Croatia, 2007, 1-39.
28. Žiković, S., B. Aktan, Global financial crisis and VaR performance in emerging markets: A case of EU candidate states – Turkey and Croatia, Proceedings of Rijeka, Faculty of Economics – Journal of Economics and Business, 27(1), 2009, 149-170.

Corresponding Autor: Vladimir Đaković, v_djakovic@uns.ac.rs

To cite article, use the following format: Anđelić, G., V. Đaković, M. Sujić: An Empirical Evaluation of Value-At-Risk: The Case of the Belgrade Stock Exchange Index - BELEX15, Industrija, Vol. 40, No. 1, pp 41-60