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Parametric and Nonparametric VaR Daily Returns Estimation⁴

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Abstract: *Taking into account current trends and opportunities in the transitional markets, the subject of the research is to analyze and quantify the different Value at Risk (VaR) calculation models in the light of investment risk assessment performance in the domestic market. The research objective is to gain a series of qualitative and quantitative information about the possibilities of effective application of different VaR models in investment decision-making in order to minimize risks of investment activities. The research focuses on the domestic financial market and covers the period 2006-2012. The research methodology involves the use of MANOVA analysis, discriminant analysis, and Roy's test, and is adapted to the specific characteristics of the transitional market of the Republic of Serbia. The research results confirm the prominent place, role and importance of different VaR models in the light of the investment risk quantification in the domestic market, with reference to the specificities between particular VaR models. In this sense, the results will be useful both for academic and professional communities, in the context of the successful application of different VaR models in decision-making about investment activities.*

Keywords: *Value at Risk, VaR model, Extreme Value Theory, Delta normal VaR, Historical Simulation, Risk, Investment.*

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Parametarska i neparametarska VaR procena dnevnih prinosa

Apstrakt: Uvažavajući aktuelne trendove i tržišne prilike na tranzitornim tržištima, predmet istraživanja u radu jeste analiziranje i kvantifikacija različitih modela merenja Value at Risk-a (VaR) u svetlu uspešnosti procene rizika od aktivnosti investiranja na domicilnom tržištu. Cilj koji se želi ostvariti istraživanjem jeste dolaženje do niza kvalitativnih i kvantitativnih informacija o mogućnostima uspešnosti primene različitih modela VaR-a u donošenju odluka o investiranju, a u funkciji minimiziranja rizika od aktivnosti investiranja. Istraživanje je fokusirano na domicilno finansijsko tržište i obuhvata period od 2006-2012 godine. Metodologija istraživanja podrazumeva primenu analize MANOVA, diskriminativne analize i Roy-evog testa, a prilagođena je specifičnostima tranzitornog tržišta Republike Srbije. Rezultati istraživanja potvrđuju istaknuto mesto, ulogu i značaj različitih modela VaR-a u svetlu kvantifikacije rizika od aktivnosti investiranja na domicilnom tržištu, uz ukazivanje na specifičnosti razlika između pojedinih modela VaR-a. U tom smislu, dobijeni rezultati će biti korisni kako akademskoj zajednici, tako i stručnoj javnosti u kontekstu uspešne primene različitih modela VaR-a prilikom donošenja odluka o aktivnostima investiranja.

Ključne reči: Value at Risk, VaR model, Teorija ekstremnih vrednosti, Delta normal VaR, Istorijska simulacija, rizik, investiranje.

1. Introduction

The current market conditions, globalized trends, the crisis that has turned into a recession and high market volatility are some of the key conditions that have contributed to the change in logical financial thinking and decision-making. Methods and techniques used to predict the expected effects of investment activities successfully have necessarily been changed and adapted to the altered market conditions and opportunities. Since the investment activity return function has got a different shape and behavior (the symmetrical sine function has grown into an asymmetric one - Pareto distribution), the methods and techniques used to predict and quantify the effects of investment activities have been changed and adapted to the current market conditions.

Transitional markets, being highly volatile, low liquid and shallow markets, have reacted particularly fiercely to the changed market conditions. The consequences are the altered expectations of investment activities and the tendency to optimize the effects of these activities, with constant risk minimization. Investors in these markets are particularly sensitive to the risks

of investment activities, so the methods and techniques focused to investment risk quantification have a special place, role and importance in such markets. Serbian financial market and investors are the true example of the above mentioned thesis, in the sense that they are more careful than ever in their investment decisions, constantly focused to anticipate and quantify their expectations of investment activities.

In this sense, the subject of the research is to analyze the effectiveness of parametric and nonparametric VaR daily returns estimation in the domestic financial market, in order to obtain qualitative and quantitative information about the application possibilities of different VaR models in practice and the differentiation between them. The research objective is to obtain the scientifically-verified knowledge about the application possibilities of parametric and nonparametric VaR calculation models in the context of optimal decision-making in the investment processes. The scientific contribution of this research is particularly reflected in the above mentioned, since so far very few studies have been conducted with such a subject. The practical contribution of this research is very important, because it leads to concrete knowledge about the application effectiveness of the different parametric and nonparametric VaR models in the practice of transitional markets, which significantly increases the efficiency of investment decision-making in these markets.

Testing and analyzing different VaR calculation models in the actual practice of Serbian financial market not only provide the quality information on the effectiveness of their implementation, but the analysis of mutual differences of these models in specific market circumstances. Thus, the following hypotheses are tested in the study:

H₁: There is no statistically significant difference in the application performances of parametric and nonparametric VaR daily returns estimation, with the confidence level of 95% for 50 and 200 days, in the period 2007-2012.

H₂: There is no clearly defined boundary between different VaR models, compared with risk quantification effectiveness, with the confidence level of 95% for 50 and 200 days, in the period 2007-2012.

H₃: There is no statistically significant difference in the application performance of the parametric and nonparametric VaR daily returns estimation, with the confidence level of 95% for 50 and 200 days, per years.

The research results are derived from the author's doctoral thesis (Djakovic, 2013). The research purpose is to analyze the application performance of the tested parametric and nonparametric VaR calculation models, in the context of optimal investment decision-making. The research importance and originality are reflected in the fact that there exist relatively few studies in this

area focused on transitional markets, taking into account the specificities of a given market environment, i.e. volatile business conditions, characterized by frequent crises. Consequently, the research results provide important qualitative and quantitative contribution to the subject area.

The paper is structured as follows: the research subject, objective and hypotheses are defined in the introduction. The next part of the paper presents the relevant domestic and international literature in the research area. The third section reviews the methodology used in the study, with emphasis on the research sample. The results and discussion are presented in the next part, followed by the conclusions and references used in the paper.

2. Literature review

Taking into account the dynamic environmental conditions, it is evident that the frequency of extreme market movements significantly influences the course and effects of investment activities. Because of the outbreak of the global economic crisis, as well as redefined market relations and business conditions, the performances of different risk management models are the focus of many researchers. In this regard, the effectiveness estimation of different Value at Risk (VaR) calculation models is particularly important, being a widespread risk measure. A particular challenge in the research performance of these models is their testing in underdeveloped and low propulsive transitional markets, such as the Serbian market. In fact, owing to the extremely volatile market conditions, the special attention should be given to an adequate consideration and quantification of risk, and the performance of the investment process. Accordingly, the research of different parametric and nonparametric VaR calculation models and, consequently, the adequacy of their application in volatile environmental conditions are particularly important (Andjelic, Djakovic & Sujic, 2012).

To analyze the nonparametric VaR calculation model in the market of the Republic of Serbia, it is necessary to use an extremely high confidence levels for an adequate prediction of market risk (Radivojevic, Lazic & Cvijanovic, 2010). Consequently, daily returns estimates are not adequate with extremely low levels of confidence. It is necessary to determine the characteristics of the environment and the tested model assumptions, regarding its successful implementation possibility. This research is significant because it represents the guidelines for the successful implementation of the tested nonparametric VaR calculation model, i.e. historical simulation, with special emphasis on the possibility of a reliable risk measurement in the market of the Republic of Serbia.

Vujnovic-Gligoric & Jakupovic (2010) have been focused on the ability to adequately evaluate the investment market risk. The authors have also analyzed the maximum possible loss of the investment portfolio because of the volatile price movements of its elements, i.e. financial instruments. The corresponding VaR methodologies (analytical and historical methods and Monte Carlo Simulation) have been applied. Taking into account the performance of the tested VaR methodology, the authors conclude that the Monte Carlo Simulation is more suitable because it allows flexibility, i.e. adaptability to volatile environmental conditions.

Barone-Adesi & Giannopoulos (2001) have also analyzed the nonparametric VaR calculation models. The authors have applied the following two approaches to the three selected hypothetical portfolios: variance-covariance and historical simulation. The special attention has been given to the statistical problems of VaR calculations considering the risk prediction effectiveness in investment, and the volatility impact on the adequacy of VaR estimates with a longer time horizon. Filtered Historical Simulation (FHS) has been proposed, because the research results have indicated the superiority of the same over the traditional Historical Simulation (HS). The research is significant because it highlights the need for further development of the tested models in order to remove the identified application limitations in the VaR context.

Morales, Rebelatto & Sartoris (2013) have analyzed parametric VaR calculation models with special emphasis on Extreme Value Theory (EVT). The research is focused on the extreme returns and the methodology involves Empirical Distribution Function (EDF), together with the possible application in Enterprise Risk Management (ERM). The selected model does not include "ad-hoc" assumptions, which implies its broad usability and advantage in the application of Extreme Value Theory (EVT), with the particularly adequate consideration of return distribution tails of investment activities. The authors conclude that the developed model can be applied to a wider area (ERM and the like), and that it is possible to analyze the company risk exposure during the investment implementation.

Lamantia, Ortobelli & Rachev (2006), Angelidis, Benos & Degiannakis (2007), Gurtler & Rauh (2009), Samia, Dalenda & Saoussen (2009), Sheng, Benshan & Zhongping (2012) and Ghatak (2013) emphasize the validity of the different VaR model applications as a reliable risk assessment in the investment processes, with the need of their continuous improvement and adequate risk management in those processes.

Given the previous theoretical and empirical research, the study actuality is particularly evident because it gives a systematic, comparative review of application performances, of both parametric and nonparametric VaR calculation models on a daily basis, which provides the actual empirical data

on their performances in volatile market conditions, in the context of the successful investment risk assessment in the specific, transitional market of the Republic of Serbia.

3. Materials and Methods

The study research sample includes daily values of BELEX15 stock index, as a representative of the state and conditions in transitional market of the Republic of Serbia, in the period from January 1, 2006 to December 31, 2012.

The corresponding methodology is to test the research hypotheses. Specifically, MANOVA analysis is used to test the hypothesis H_1 , discriminant analysis to test the hypothesis H_2 and Roy's test to test the hypothesis H_3 . The alternative hypotheses A_1 , A_2 and A_3 represent the opposite hypotheses to the hypotheses H_1 , H_2 and H_3 .

The parametric models of the VaR daily returns estimation are the Extreme Value Theory (EVT) and the Delta normal VaR (D VaR), while the Historical Simulation (HS VaR) is a nonparametric model. The performances of parametric and nonparametric VaR daily returns estimation are tested with a confidence level of 95% for 50 and 200 days (rolling windows).

The analysis and quantification of different VaR calculation models in relation to the investment risk assessment performance is done on a daily basis in accordance with the given confidence level and rolling windows. The number of days with the unsuccessful risk prediction of the tested VaR calculation models in the domestic market is analyzed at the end of each annual period. The initial values of VaR are calculated based on the daily returns values in 2006.

The VaR risk measurement can be mathematically represented in the following way (Ottenwaelter, 2008). If the ΔP is the change of the portfolio value in the next N days and the VaR corresponds to the loss of $(100-\alpha)$ percentile of the ΔP distribution, it follows:

$$P(\Delta P < VaR) = 1 - \alpha \quad (1)$$

VaR represents $(100-\alpha)$ percentile of the distribution value and is generally calculated on a daily basis, with different confidence levels. The calculation of the Delta normal VaR (D VaR) is performed as follows:

$$VaR(p^*) = Z_{1-p^*} \sigma_P \quad (2)$$

where

Z_{1-p} – value of the theoretical distribution,

σ_p – standard deviation (Kondapaneni, 2005)

The asymptotic properties of random values are examined by Extreme Value Theory (EVT), in the forms:

$$M_n = \max\{X_1, X_2, \dots, X_n\}$$

$$m_n = \min\{X_1, X_2, \dots, X_n\}$$

when $n \rightarrow \infty$, whereat X_1, X_2, \dots, X_n are random values with given probability distributions.

If for the random value M_n is valid:

$$P\left\{\frac{M_n - b_n}{a_n} \leq x\right\} \rightarrow G(x), n \rightarrow \infty \quad (3)$$

where $G(x)$ is a non degenerate distribution function, and $a_n > 0$ and b_n ($n \in \mathbb{N}$) are real numbers. In that case, it is said that $G(x)$ determines the marginal distribution of linearly normalized maxima M_n , while a_n and b_n are stipulating constants (Jockovic, 2009).

4. Results and discussion

In this part of the study, the research results of the application of parametric and nonparametric VaR daily returns estimation for BELEX15 stock index, with a confidence level of 95% for 50 and 200 days, will be presented.

Table 1. Significance testing between different VaR models in comparison to the effectiveness of risk quantification for BELEX15 (95%, 50 days) in the period 2007-2012

Analysis	n	F	p
MANOVA	6	1.762	0.052
Discriminant	6	1.771	0.050

Legend: n – years (features), F – the values of Fisher distribution, p – significance level

Source: the author's calculations (Djakovic, 2013)

According to the results shown in Table 1 of MANOVA analysis ($p=0.052$) and discriminant analysis ($p=0.050$), the hypotheses H_1 and H_2 are rejected, whereas the alternative hypotheses A_1 and A_2 are accepted. According to these results, there is a difference between VaR calculation models for BELEX15 (95%, 50 days).

Table 2. Significance testing between different VaR models in comparison to the effectiveness of risk quantification for BELEX15 (95%, 200 days) in the period 2007-2012

Analysis	n	F	p
MANOVA	6	3.604	0.000
Discriminant	6	3.609	0.000

Source: the author's calculations (Djakovic, 2013)

According to the results shown in Table 2 of MANOVA analysis ($p=0.000$) and discriminant analysis ($p=0.000$), the hypotheses H_1 and H_2 are rejected, whereas the alternative hypotheses A_1 and A_2 are accepted. According to these results, there is a difference between VaR calculation models for BELEX15 (95%, 200 days).

Table 3. The difference significance of different VaR models in comparison to the effectiveness of risk quantification for BELEX15 (95%, 50 days) per years

Year	χ	R	F	p	d. coeff
2007	0.029	0.029	0.313	0.731	0.013
2008	0.020	0.020	0.156	0.856	0.010
2009	0.025	0.025	0.240	0.787	0.003
2010	0.036	0.036	0.479	0.620	0.012
2011	0.009	0.009	0.028	0.973	0.004
2012	0.010	0.010	0.036	0.965	0.001

Legend: χ – Pearson's contingency coefficient, R – multiple correlation coefficient, F – Fischer value distribution, p – significance level, d. coeff – discrimination coefficient

Source: the author's calculations (Djakovic, 2013)

The hypothesis H_3 is accepted on the basis of the obtained results (Table 3, Roy's test: $p>0.1$). For BELEX15 (95%, 50 days), per years, there is no significant difference in the context of different VaR calculation models: 2007 (0.731), 2008 (0.856), 2009 (0.787), 2010 (0.620), 2011 (0.973) and 2012 (0.965). The discrimination coefficient indicates that the difference is the largest in 2007 (0.013), 2010 (0.012), 2008 (0.010), 2011 (0.004), 2009 (0.003) and 2012 (0.001). The years 2007 (0.731), 2008 (0.856), 2009 (0.787), 2010 (0.620), 2011 (0.973) and 2012 (0.965) are the latent features for which there are no differences between the different VaR calculation models.

Table 4. The difference significance of different VaR models in comparison to the effectiveness of risk quantification for BELEX15 (95%, 200 days) per years

Year	χ	R	F	p	d. coeff
2007	0.138	0.140	7.508	0.001	0.023
2008	0.018	0.018	0.128	0.880	0.015
2009	0.048	0.048	0.884	0.414	0.006
2010	0.073	0.073	2.021	0.134	0.009
2011	0.100	0.100	3.845	0.022	0.007
2012	0.036	0.036	0.501	0.606	0.000

Source: the author's calculations (Djakovic, 2013)

Roy's test ($p < 0.1$) indicates that the alternative hypothesis A_3 is accepted, while there is a significant difference in comparison to the VaR calculation models, according to the risk measurement in 2007 (0.001) and 2011 (0.022) for BELEX15 (95%; 200 days). Additionally, the results from Table 4 of Roy's test ($p > 0.1$) indicate that the hypothesis H_3 is accepted, which indicates the lack of significant difference between the VaR calculation models in risk quantification in 2008 (0.880), 2009 (0.414), 2010 (0.134) and 2012 (0.606) for BELEX15 (95%, 200 days). The discrimination coefficient indicates that the greatest contribution to discrimination and the largest differences are in the years 2007 (0.023), 2008 (0.015), 2010 (0.009), 2011 (0.007) and 2009 (0.006) between the different VaR calculation models for BELEX15 (95%, 200 days). The years 2008 (0.880), 2009 (0.414) and 2010 (0.134) are the latent features for which there are no differences between the VaR calculation models.

Considering the research results (Tables 3 and 4), the hypothesis H_3 is confirmed with a confidence level of 95% for 50 days per years, while it is not confirmed with a confidence level of 95% for 200 days per years (2007 and 2011). Therefore, the H_3 hypothesis is partially confirmed for a particular part of the research sample.

Based on the previously obtained research results, it can be concluded that none of the tested parametric and nonparametric models of VaR daily returns estimation of investment activities has advantage, especially if the overall study period with the volatile market conditions of the observed transitional market is evaluated. All the above mentioned is in accordance with the comparative study by Angelidis, Benos, & Degiannakis (2007). Additionally, Radivojevic, Lazic & Cvijanovic (2010) suggest that it is necessary to test the

validity of the VaR models adequately, especially considering the chosen levels of confidence. Further, Vujnovic-Gligoric & Jakupovic (2010) conclude that in the periods of extreme market volatility it is necessary to apply sophisticated mathematical models for the performance maximization in the investment processes. In his empirical research, Ghatak (2013) confirms the importance of adequate model analysis of VaR estimation in the context of the risks that are intended to be covered. Also, Mentel (2013) presented VaR as the risk reduction instrument, while defining its scale and concluded that some models often overestimate VaR, but that the level of significance increases the efficiency of the tested models.

5. Conclusions

The research results unambiguously indicate the importance of the subject of the research through the prism of validation and optimization of investment activity effects in the contemporary business conditions. In practice, the research tests the place, role and importance of parametric and nonparametric VaR daily returns estimation on the example of transitional market of the Republic of Serbia. With the research focus on the Serbian transitional market, the authors intentionally emphasized the importance of business decision-making analysis and optimization, in the sphere of investment activities in transitional markets that are highly volatile, low efficient and low propulsive market forms.

The scientific contribution of the study is reflected in the quality and significance of the results about the possibilities of effective application of parametric and nonparametric VaR daily returns estimation, in the context of the investment risk management in transitional markets, which significantly expands the cognitive base of the research area. The practical contribution of the research is in expanded possibilities of effective application of parametric and nonparametric VaR daily returns estimation in daily decision-making in the investment processes.

Several hypotheses are tested in the research. The hypothesis H_1 , which assumes that there is no statistically significant difference in the application performances of parametric and nonparametric VaR daily returns estimation with the confidence level of 95% for 50 and 200 days in the period 2007-2012, is rejected, i.e. there is no significant difference in VaR daily returns estimation of investment activities.

The hypothesis H_2 , claiming that there is no clearly defined boundary between different VaR models in comparison to the risk quantification performance, with the confidence level of 95% for 50 and 200 days in the period from 2007-2012, is also rejected, as well as the hypothesis H_3 , which only indicates the

significance of the application performance differences for the analyzed VaR daily returns estimation.

These facts point to the importance of difference testing between different models of VaR daily returns estimation and their different "behaviors" in certain market circumstances, which only additionally supports the thesis of the necessity of holistic, comprehensive and systematic approach to analysis, anticipation and validation of investment expectations. The special quality of research results stems from the fact that the study has been focused to the transitional market of the Republic of Serbia, since the analysis of the comparative literature in this research area shows that relatively few studies have been performed with this topic, with the focus on transitional markets.

In conducting this research, on the one side the authors have dealt with the problems and challenges that arise from the specific characteristics of transitional markets, and on the other, from the need to adjust the tested VaR models to the specificities of these markets. It is the greatest challenge of this research to adjust the used VaR models to specific Serbian market and thereby enable its successful implementation and get results that are grounded in science and practice.

Further research will be directed to expand the research focus on other transitional markets and increase the flexibility of the tested VaR models in practice to respond to the challenges of the environment with even higher level of success, in light of return maximization of investment activities. In this sense, the focus of future research will be expanded and applied methodology significantly modified to a higher level of flexibility and adaptability, taking into account the dynamics of changes in both micro and macro levels and the expressed globalized trends.

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