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TESTIRANJE APLIKATIVNOSTI PARAMETARSKE I NEPARAMETARSKE METODE VREDNOSTI PRI RIZIKU NA TRŽIŠTU KAPITALA SRBIJE

Rezime

U radu je izvršena komparacija parametarske i neparametarske metode vrednosti pri riziku, s ciljem dobijanja odgovora na pitanje koja je metoda adekvatnija za srpsko tržište kapitala, imajući u vidu da brojna empirijska istraživanja ukazuju da pretpostavka o normalnoj raspodeli na kojoj počiva parametarska metoda, odnosno da pretpostavke o identičnoj i nezavisnoj raspodeli, na kojoj počiva neparametarska metoda, nisu realne za srpsko tržište kapitala. Aplikativnost obe metode je testirana empirijskim istraživanjem na primeru opšteg berzanskog indeksa Belexline u periodu od 01.03. do 31.03.2009. godine. Aplikativnost je testirana tako što su dnevne procene VaR-a dobijene primenom parametarske odnosno neparametarske metode komparirane sa stvarnim kretanjem prinosa opšteg berzanskog indeksa *BELEXline*. Za procenu VaR-a primenom neparametarske metode u radu je razvijen model HS-255.

Ključne reči: Vrednost pri riziku, tržište kapitala Srbije, volatilnost, normalna raspodela, parametarska metoda, neparametarska metoda, pretpostavka identične i nezavisne raspodele.

TESTING THE APPLICABILITY OF PARAMETRIC AND NONPARAMETRIC METHODS OF VALUE-AT-RISK AT THE SERBIAN CAPITAL MARKET

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Summary

This paper presents a comparison of parametric and nonparametric methods of value at risk, with the aim of obtaining answers to the question of which method is more appropriate for the Serbian capital market, given that many empirical studies suggest that the assumption of normal distribution underlying the parametric methods, ie that the assumption of identical and independent distribution, which relies nonparametric method are not realistic in the Serbian capital market. Applicability of both methods was tested by empirical research on the example of the index Belexline from 01. 03. to 31. 03. 2009. year. Applicability has been tested by the daily VaR estimates obtained by parametric and nonparametric methods we compared with the actual yield changes in general stock index BELEXline. Model HS-255 has been developed for the assessment VaR.

Keywords: Value at Risk, capital market of Serbia, the volatility, the normal distribution, parametric method, non-parametric method, IDD

Sredinom devedesetih godina XX veka, vrednost pri riziku (Value at Risk - VaR) postaje široko prihvaćen koncept za merenje i upravljanje tržišnim rizicima. Revolucija koncepta vrednost pri riziku započinje 1993. godine, kada je Grupa 30 (*Group of Thirty*) odobrila VaR kao "najbolju praksu" za postupnje sa finansijskim derivatima. Iako sam pojam vrednost pri riziku nije bio u širokoj upotrebi pre sredine devedesetih godina, njegovo poreklo leži dalje u prošlosti. Tačnije koreni koncepta VaR nalaze se u Markovitzovoj portfolio teoriji. Metodologija na kojoj počiva VaR predstavlja rezultat integrisanja savremene portfolio teorije, koja se fokusira na vrednovanje i senzitivnost finansijskih instrumenata i statističke analize, koja proučava ponašanje faktora rizika.

Porast volatilnosti na finansijskim tržištima i česte krize kojima su bile izložene finansijske institucije krajem osamdesetih i tokom devedesetih godina, a posebno nemogućnost njihovog predviđanja i veličina gubitaka koje su generisale, snažno su uticali na široko prihvatanje VaR koncepta. Danas VaR koncept predstavlja najrasprostranjeniji i najpoznatiji koncept za merenje i upravljanje tržišnim rizicima. U okviru koncepta razvijene su brojne metode, među kojima se svojom popularnošću posebno izdvajaju dve: parametarska metoda i neparametarska metoda VaR-a (istorijska simulacija). Aplikativnost obe metode determinisana je stepenom kompatibilnosti između pretpostavki na kojima su izgrađene i karakteristika realnog okruženja. Parametarska metoda je izgrađena na pretpostavci normalne raspodele, dok je neparametarska metoda izgrađena na pretpostavci da svaki istorijski prinos (opažaj) sa istim intenzitetom utiče na vrednost portfolija, što je ekvivalentno pretpostavci o identičnoj i nezavisnoj raspodeli.

Pojava nesinhronog trgovanja, autokorelacija između serija prinosa hartija od vrednosti i grupisanje varijabilnosti u periode visoke i niske varijabilnosti na tržištu kapitala Srbije stvaraju nestabilno okruženje što u kontekstu procene vrednosti pri riziku dovodi u pitanje validnost pretpostavki na kojima su metode izgrađene. Naime, grupisanje varijabilnosti tokom vremena dovodi do leptokurtične raspodele, što

je u suprotnosti sa pretpostavkama o normalnoj i identičnoj raspodeli. Sa druge strane, pojava autokorelacije između serija prinosa hartija od vrednosti je u suprotnosti sa pretpostavkom o nezavisnoj raspodeli. Otuda je cilj ovog rada da ispita koja je metoda adekvatnija za procenu vrednosti pri riziku imajući u vidu specifične tržišne uslove koji vladaju na tržištu kapitala Srbije. Nakon kratkog predstavljanja obe metode, razmatranja u radu će započeti analizom stepena kompatibilnosti osnovnih karakteristika srpskog tržišta kapitala sa pretpostavkama metoda, kako bi se identifikovali specifični tržišni uslovi koji limitiraju aplikativnost metoda vrednosti pri riziku. Zatim će biti izvršeno testiranje aplikativnosti parametarske i neparametarske metode vrednosti pri riziku na primeru opšteg berzanskog indeksa *BELEXline*.

Parametarska metoda versus neparametarska metoda vrednosti pri riziku

Vrednost pri riziku predstavlja maksimalni potencijalni gubitak koji može nastati u određenom vremenskom periodu za datu verovatnoću. To znači da je u pitanju mera gubitka koji može nastati usled "normalnog" kretanja tržišta i koji može biti prekoračen samo u malom i precizno definisanom procentu. Teškoće u dobijanju pouzdanih procena VaR-a potiče iz činjenice da obe metode uključuju određene simplifikacije, odnosno da počivaju na određenim pretpostavkama kojima su se nastojali pojednostaviti tržišni uslovi.

Parametarska metoda vrednosti pri riziku polazi od pretpostavke da je vrednost portfolio linearna funkcija faktora rizika, odnosno da su prinosi portfolija normalno distribuirani (Radivojević, Lazić, Cvijanović, 2009). Drugim rečima, to znači da se pretpostavlja da su promene u vrednosti portfolija normalno distribuirane. Pretpostavka normalnosti (iako ima limitiranu verodostojnost) ima veliku prednost jer mnogo pojednostavljuje procenu VaR-a (Jorion, 2003). Pod ovim pretpostavkama procena VaR-a portfolija je sadržilac standardne devijacije portfolija, a standardna devijacija portfolija je linearna funkcija individualnih varijansi i kovarijansi. Otuda se procena VaR-

In mid 1990s, Value-at-risk - VaR became a widely accepted concept for market risks measurement and management. The revolution of value-at-risk concept started back in 1993 when the Group of Thirty approved VaR as “the best practice” for financial derivatives treatment. Although it was not until the mid 1990s that the value-at-risk concept itself started to be widely used, its origins go further back in the past. More precisely, the roots of VaR concept are in Markowitz's portfolio theory. Methodology that VaR is based on is a result of integrating modern portfolio theory, focused on valuation and sensitivity of financial instruments, and statistical analysis, examining risk factors behaviour.

Increasing volatility in the financial markets and frequent crises that financial institutions were exposed to in late 1980s and during 1990s, and especially the inability of their prediction along with the size of losses that they generated, strongly influenced the wide acceptance of VaR concept. Today VaR concept represents the most widely used and most famous concept for market risks assessment and management. Numerous methods have been developed within this concept, the most popular of which are the following two: parametric VaR method and non-parametric VaR method (historic simulation). Applicability of both these methods is determined by the level of compatibility between their underlying assumptions and the real environment characteristics. Parametric method is based on the normal distribution assumption, whereas non-parametric method is based on the assumption that each historic return (observation) impacts the portfolio value with the same intensity, which is equivalent to the assumption of identical and independent distribution.

Non-synchronous trading, autocorrelation among series of securities returns and grouping of variability into periods of high and low variability create unstable environment on the Serbian capital market, which, in the context of value-at-risk assessment, challenges the validity of assumptions that these methods are based on. Namely, grouping of variability in time leads to leptokurtic distribution, which is in opposition to the assumptions of normal and identical distribution. On the other hand,

autocorrelation among series of securities returns opposes the assumption on independent distribution. Therefore, the objective of this paper is to examine which of the two methods is more adequate for value-at-risk assessment, bearing in mind the specific market conditions present in the Serbian capital market. After a brief presentation of both methods, the paper goes on to analyze the level of compatibility of the main characteristics of the Serbian capital market with the methods' assumptions, in order to indentify specific market conditions that limit the applicability of value-at-risk methods. Further, the paper tests the applicability of parametric and non-parametric value-at-risk methods using the general stock exchange index *BELEXline* as an example.

Parametric versus nonparametric value-at-risk method

Value-at-risk represents the maximum potential loss that might occur in a certain time period for a given probability. This means that it is a measure of loss that might occur due to the “normal” market trends and that might be exceeded only in a small and precisely defined percentage of cases. Difficulties in obtaining reliable VaR assessments arise from the fact that both methods include certain simplifications, i.e. that they are based on certain assumptions that are intended to simplify market conditions.

Parametric value-at-risk method starts from the assumption that portfolio value is a linear function of risk factors, i.e. that portfolio returns are normally distributed (Radivojević, Lazić, Cvijanović, 2009). In other words, this means that it is assumed that the changes in portfolio value are normally distributed. The assumption of normality (though of limited credibility) has a great advantage since it largely simplifies the VaR assessment (Jorion, 2003). Under these assumptions the assessment of portfolio VaR is a denominator of the portfolio standard deviation, and portfolio standard deviation is a linear function of individual variances and covariances. Thus, the VaR assessment is reduced to a simple use of a variance-covariance matrix and information on the size of individual positions, in order to determine the portfolio standard deviation, which is then multiplied by

a svodi na jednostavnu upotrebu matrice varijansa-kovarijansa i informacija o veličinama individualnih pozicija, kako bi se determinisala standardna devijacija portfolija, koja se zatim množi sa nivoom poverenja (α) i skalarom koji odražava vrednost portfolija. Otuda je metoda poznata pod nazivom varijansa-kovarijansa metoda.¹

Prethodno rečeno matematički može se napisati:

$$VaR = -\alpha \sqrt{w' \Sigma w}$$

pri čemu je w vektor apsolutnih pondera portfolija, w' transponovan w , Σ matrica varijansi kovarijansi i α nivo poverenja. Ocena varijanse i kovarijanse najčešće se vrši na osnovu vremenske serije dnevnih stopa prinosa uz uslov (Alexander, 1997) da je sredina jednaka nuli i varijansa jedanka σ_t .

Prednost parametarske metode procene VaR-a se ogleda u tome što omogućava lako preračunavanje VaR-a za različite nivoe poverenja i različite holding periode. Ovo omogućava komparaciju procena VaR-a sa različitim finansijskih tržišta i između različitih finansijskih institucija. Međutim, osnovni nedostatak ove metode je nemogućnost njene primene za portfolije kod kojih su prinosi nelinearna funkcija faktora rizika. Ovo je slučaj kod finansijskih derivata ili kada su faktori rizika, odnosno prinosi ne-normalno distribuirani. U tom slučaju koriste se druge metode kojima se vrši aproksimacija prvog i drugog reda.

Za razliku od parametarske metode, kod neparametarske metode vrednosti pri riziku se ne postavlja pretpostavka o analitičkoj formi raspodele niti o stepenu i smeru korelacije između faktora rizika koji determinišu vrednost portfolija (Radivojević, 2009). Umesto toga pretpostavlja se da je raspodela prinosa konstantna tokom perioda uzorkovanja. Naime, neparametarska metoda vrednosti pri riziku počiva na uverenju da se istorija ponavlja, te da se na osnovu podataka o tržišnim rizicima iz ranijih perioda može predvideti kretanje rizika

u narednim periodima. Otuda, procena VaR-a portfolija se vrši na osnovu istorijskih podataka o prinosima odnosno vrednosti portfolija, na taj način što se iz istorijskih podataka izračunavaju procentualne promene za svaki faktor rizika. Zatim se te procentualne promene množe sa sadašnjom vrednošću portfolija i na taj način se utvđuje "pretpostavljena" tržišna vrednost portfolija. Otuda i naziv ovog metoda istorijska simulacija jer se stvarne istorijske vrednosti (stope prinosa) koriste za utvrđivanje hipotetičke vrednosti portfolija.

VaR izračunat primenom neparametarske metode može se izraziti na sledeći način (Žiković, 2007):

$$HS - VaR_{T=1}^C \equiv r_w((T+1)C)$$

pri čemu je $r_w((T+1)C)$ preuzet iz uređenog skupa prinosa $\{r_w(1), r_w(2), \dots, r_w(T)\}$

Budući da većina hartija od vrednosti ima raspodelu prinosa sa debelim repovima neparametarska metoda nudi bolje rešenje jer uvažava činjenicu da se ekstremni prinosi dešavaju češće nego što se predviđa normalnom raspodelom. Nepostojanje pretpostavke o analitičkoj formi raspodele ovu metodu procene VaR-a čini izuzetno prikladnom u uslovima kada se smer i stepen korelacije između faktora rizika i prinosa hartija od vrednosti menjaju brzo u kratkim vremenskim intervalima.

Osnovni nedostatak neparametarske metode jeste da se svakom opažaju dodeljuje isti ponder. Drugim rečima, to znači da se pretpostavlja da prinosi (opažaji) iz bliže i dalje prošlosti imaju isti uticaj na vrednost portfolija. Ova pretpostavka je ekvivalentna pretpostavci da su faktori rizika, odnosno simulirani prinosi identično i nezavisno distribuirani (Pritsker, 2001). Problem aplikativnosti neparametarske metode javlja se kada postoji trend grupisanja volatilnosti u klastere. Ovo je posebno izraženo na tržištima u razvoju. Naime, na tržištima u razvoju uobičajena je pojava heteroskedastičnosti i postojanje značajne autokorelacije između prinosa.

¹ O metodi varijansa - kovarijansa detaljno videti u: Jorion, P., Financial Risk Manager, John Wiley and Sons, Inc., Hoboken, New Jersey, 2003.

the confidence level (α) and the scalar reflecting portfolio value. Therefore, this method is known as variance-covariance method.¹

In mathematical terms, the above can be expressed as:

$$VaR = -\alpha \sqrt{w' \Sigma w}$$

where w is a vector of absolute portfolio weights, w' is transposed w , Σ is the variance and covariance matrix, and α is the confidence level. Variance and covariance assessment is most frequently conducted based on a time series of daily rates of return, under the condition (Alexander, 1997) that the mean equals zero and the variance equals σ_r .

The advantage of parametric VaR assessment method lies in the fact that it enables easy recalculation of VaR for various confident levels and various holding periods. This, in turn, enables the comparison of VaR assessments from different financial markets and among different financial institutions. However, the main drawback of this method is the inability of its application to the portfolios whose returns are a non-linear function of risk factors. This is the case with financial derivatives or when risk factors, i.e. returns are not normally distributed. In such cases other methods are used to conduct first and second order approximation.

As opposed to parametric method, in case of non-parametric value-at-risk method there is no assumption on analytical form of distribution or level and direction of correlation among risk factors determining the portfolio value (Radivojević, 2009). Instead, it is assumed that the distribution of returns is constant during the sampling period. Namely, non-parametric value-at-risk method relies on the belief that the history repeats itself, and that, based on the market risks data from the previous periods, one can predict the risk trends in the forthcoming periods. Therefore, portfolio VaR assessment is conducted based on historic data on returns, i.e. portfolio values, by calculating

percentage changes for each risk factor. Then these percentage changes get multiplied by the present portfolio value, thus determining the "assumed" market value of the portfolio. This is why this method is called historic simulation, because actual historic values (rates of return) are used for determining hypothetical portfolio values.

VaR calculated by means of the non-parametric method can be expressed in the following way (Živković, 2007):

$$HS - VaR_{T=1}^C \equiv r_w((T+1)C)$$

where $r_w((T+1)C)$ is taken from the ordered set of returns $\{r_w(1), r_w(2), \dots, r_w(T)\}$.

Given that most securities have a fat-tail distribution of returns, non-parametric method offers the best solution because it takes into account the fact that extreme returns occur more frequently than normal distribution predicts. The absence of assumption of analytical form of distribution makes this VaR assessment method highly suitable for the conditions when the direction and level of correlation between risk factors and securities returns change swiftly in short time intervals.

The main drawback of the non-parametric method is that each observation is awarded the same weight. In other words, this means that it is assumed that returns (observations) from the recent and distant past bear the same influence on the portfolio value. This assumption is equivalent to the assumption that risk factors, i.e. simulated returns are identically and independently distributed (Pritsker, 2001). The problem of applicability of non-parametric method occurs when there is a trend of grouping volatility into clusters. This is particularly prominent in the developing markets. Namely, in the developing markets the phenomenon of heteroskedasticity is typical, along with the existence of significant correlation among returns.

¹ For more details on variance-covariance method, see: Jorion, P., *Financial Risk Manager*, John Wiley and Sons, Inc., Hoboken, New Jersey, 2003

Analiza kompatibilnosti pretpostavki metoda var i karakteristika tržišta kapitala u Srbiji

Već je istaknuto da aplikativnost parametarske i neparametarske metode vrednosti pri riziku zavisi od stepena kompatibilnosti pretpostavki na kojima su metode izrađene sa karakteristikama realnog okruženja. Tačnije aplikativnost parametarske metode vrednosti pri riziku zavisi od toga da li je ispunjena pretpostavka o normalnoj raspodeli faktora rizika odnosno serije stopa prinosa. Sa druge strane aplikativnost neparametarske metode zavisi od toga da li su ispunjene pretpostavke o identičnoj i nezavisnoj raspodeli serije stopa prinosa.

Kako bi se utvrdilo u kojoj su meri karakteristike srpskog tržišta kapitala kompatibilne sa pretpostavkama metoda vrednosti pri riziku neophodna je analiza specifičnosti srpskog tržišta kapitala kontekstu VaR analize. Ovakva analiza podrazumeva analizu osnovnih karakteristika raspodele serije dnevnih stopa prinosa tržišnog portfolija, budući da tržišni portfolio najbolje reprezentuje karakteristike i stepen razvijenosti jednog tržišta. Međutim, pošto je nemoguće formirati takav portfolio u radu je analiziran opšti tržišni indeks *BELEXline*, budući da predstavlja najbolju aproksimaciju tržišnog portfolija na tržištu kapitala Srbije.

Analiza osnovnih karakteristika tržišnog indeksa *BELEXline* prikazana je u tabeli 1, pri čemu je kao period uzorka uzet period od 03.01. do 31.12.2008. godine.

Analiza osnovnih karakteristika raspodele dnevnih stopa prinosa *BELEXline*-a otkriva da raspodela odstupa od pretpostavke normalnosti. Prvi pokazatelj odstupanja jeste prosečan prinos *BELEXline*-a. Naime, u posmatranom periodu prosečan prinos iznosi -0,41% i značajno odstupa od nule, što je u suprotnosti sa pretpostavkom normalnosti.

Takođe, analiza viših momenata raspodele ukazuje na značajno odstupanje od normalne raspodele. Pri normalnoj raspodeli stopa prinosa koeficijent asimetrije iznosi nula i označava jednaku verovatnoću ostvarenja pozitivnih i negativnih stopa prinosa. Koeficijent asimetrije raspodele dnevnih stopa prinosa *BELEXline*-a iznosi 1,0399, tako da značajno odstupa od iznosa predviđenim normalnom raspodelom. Ovakav rezultat upućuje na zaključak da postoji veća verovatnoća ostvarivanja pozitivnih stopa prinosa. U slučaju normalne raspodele stopa prinosa koeficijent spljoštenosti iznosi 3 i ukazuje na koncentraciju skupa elemenata oko sredine. Koeficijent spljoštenosti u slučaju raspodele dnevnih stopa prinosa *BELEXline* iznosi 13,6150. Ovaj rezultat upućuje na zaključak da je raspodela dnevnih stopa prinosa *BELEXline* izdužena u odnosu na normalnu, tj. da ima zaobljene repove, što znači da postoji veća verovatnoća nastanka ekstremnih događaja nego što se predviđa pretpostavkom normalnosti i to pozitivnih.

Vizualna analiza raspodele dnevnih stopa prinosa *BELEXline* potvrđuje prethodno iznete zaključke.

Tabela 1. Osnovne karakteristike raspodele tržišnog indeksa *BELEXline*

	Prosečna stopa prinosa (\bar{r})	Varijansa (σ^2)	Standardna devijacija (σ)	Koeficijent asimetrije (β_1)	Koeficijent spljoštenosti (β_2)
<i>BELEXline</i>	-0,41%	0,03%	1,64%	1,0399	13,6105

Analysis of compatibility of VaR methods assumptions and Serbian capital market characteristics

It has already been underlined that applicability of parametric and non-parametric value-at-risk method depends on the level of compatibility between the methods' underlying assumptions and the real environment characteristics. More precisely, applicability of the parametric value-at-risk method depends on whether the assumption of normal distribution of risk factors, i.e. series of rates of return, is met. On the other hand, applicability of the non-parametric method depends on whether the assumptions of identical and independent distribution of a series of rates of return are met.

In order to determine the extent to which the characteristics of the Serbian capital market are compatible with the assumptions of value-at-risk methods, it is necessary to conduct the analysis of the specificities of the Serbian capital market within the context of VaR analysis. Such analysis implies the analysis of the main characteristics of distribution of a series of daily rates of return of a market portfolio, given that market portfolios best represent the characteristics and the level of development of any market. However, since it is impossible to form such a portfolio, in this paper we analyzed the general market index *BELEXline*, given that it represents the best approximation of a market portfolio at the Serbian capital market.

The analysis of the main characteristics of *BELEXline* market index is presented in Table 1, with the sampling period from 03.01.2008 to 31.02.2008.

The analysis of the main characteristics of distribution of *BELEXline* daily rates of return reveals that distribution deviates from the assumption of normality. The first indicator of deviation is the average *BELEXline* return. Namely, in the observed period, the average return amounts to -0.41%, thus significantly deviating from zero, which opposes the assumption of normality.

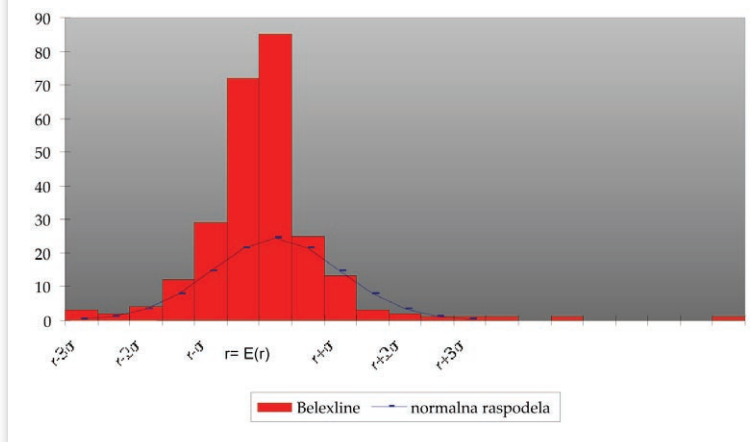
Also, the analysis of higher points of distribution indicates considerable deviation from normal distribution. In case of normal distribution of rates of return, skewness coefficient amounts to zero and indicates equal probability of achieving positive and negative rates of return. Skewness coefficient of the distribution of *BELEXline* daily rates of return amounts to 1.0399, thus significantly deviating from the amount predicted by means of normal distribution. Such a result points to the conclusion that there is higher probability of achieving positive rates of return. In case of normal distribution of rates of return, kurtosis coefficient amounts to 3 and indicates the concentration of a set of elements around the middle. Kurtosis coefficient of the distribution of *BELEXline* daily rates of return amounts to 13.6150. Such a result points to the conclusion that the distribution of *BELEXline* daily rates of return is skewed in comparison to normal distribution, i.e. that it has fat tails, which means that there is a higher probability of extreme, positive events occurrence than predicted under the assumption of normality.

Visual analysis of distribution of *BELEXline* daily rates of return confirms the above conclusions.

Table 1. Main characteristics of *BELEXline* market index distribution

	Average rate of return (\bar{r})	Variance (σ^2)	Standard deviation (σ)	Skewness coefficient (β_1)	Kurtosis coefficient (β_2)
<i>BELEXline</i>	-0, 41%	0, 03%	1, 64%	1, 0399	13, 6105

Slika 1. Raspodela dnevnih stopa prinosa *BELEXline* u periodu od 03.01. do 31.12.2008. godine

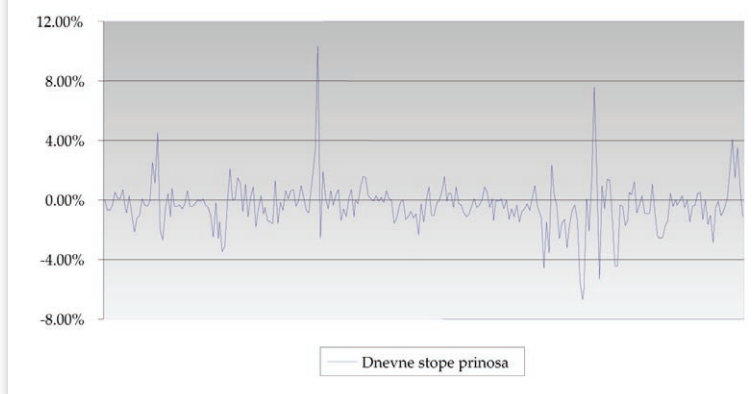


Sa slike 1. se jasno uočava da je raspodela dnevnih stopa prinosa *BELEXline* značajno izdužena u odnosu na normalnu raspodelu i da ima blagi nagib i izduženi rep raspodele na desnoj strani, odnosno oštrij nagib i kraći rep na levoj.

Tržišni rizik *BELEXline*-a, meren varijansom, odnosno standardnom devijacijom, u posmatranom periodu iznosi 0,03%, odnosno 1,64%.

Analiza kretanja dnevnih stopa prinosa *BELEXline*-a u posmatranom periodu, prikazana na slici 2. ukazuje na nekompatibilnost karakteristikama srpskog tržišta kapitala sa pretpostavkom o identičnoj raspodeli. Sa slike se jasno uočava grupisanje volatilnosti u periodu visoke i niske varijabilnosti.

Slika 2. Kretanje dnevnih stopa prinosa *BELEXline*-a u periodu od 01.01. do 31.12. 2008. godine



Postojanje perioda visoke i niske volatilnosti na tržištu kapitala Srbije u posmatranom periodu indicira postojanje autokorelacije u seriji stopa prinosa *BELEXline* jer grupisanje

volatilnosti podrazumeva da su velike promene u vrednosti *BELEXline* praćene periodima velikih promena, a male periodima malih promena. To sugeriše da su promene u vrednosti *BELEXline*-a u narednim periodima povezane sa promenama u tekućim vrednostima. Drugi naziv za ovu pojavu jeste serijalnost.

Potvrda ove indikacije data kroz kvantifikaciju autokorelacionog koeficijenta prvog reda, koji iznosi $\rho = 0,3285$.

Dobijeni koeficijent autokorelacije ukazuju da su pozitivne promene u vrednostima *BELEXline* praćene pozitivnim promenama iz ranijih perioda, a negativne negativnim promenama. Ovakav rezultat ukazuje da ni pretpostavka o nezavisnoj raspodeli nije validna za srpsko tržište kapitala.

Empirijska analiza

Prethodna analiza otkriva da pretpostavke na kojima je izgrađena parametarska, odnosno neparametarska metoda vrednosti pri riziku nisu realne za srpsko tržište kapitala. Otuda se postavlja pitanje da li je moguća pouzdana procena VaR-a na tržištu kapitala Srbije, te koja je metoda adekvatnija imajući u vidu nekompatibilnost pretpostavki sa karakteristikama tržišta.

Kako bi se odgovorilo na ova pitanja u radu je izvršeno testiranje validnosti metoda na taj način što su dnevne procene VaR-a opšteg tržišnog indeksa *BELEXline* dobijene primenom parametarske, odnosno neparametarske metode u periodu od 03.01. do 31.03.2009. komparirane sa stvarnim kretanjem prinosa indeksa u istom periodu. Kao kriterijum validnosti u radu

je korišćen kriterijum za validnost da broj dozvoljenih prekoračenja bude jednak $T(1-\alpha)$, pri čemu je T - dužina vremenskog horizonta, a $(1-\alpha)$ - nivo poverenja. Procena VaR-a izvršena

Figure 1. Distribution of BELEXline daily rates of return in the period from 03.01.2008 to 31.12.2008

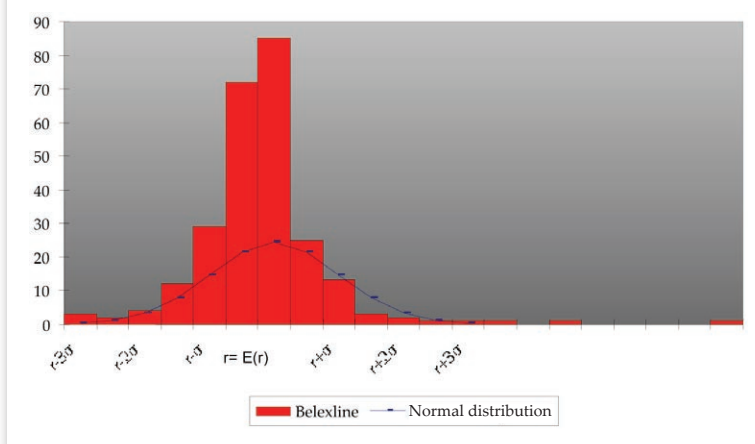
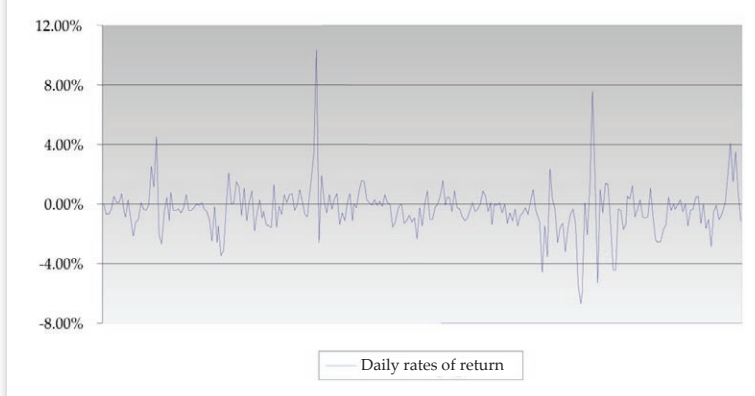


Figure 1 clearly indicates that the distribution of *BELEXline* daily rates of return is considerably skewed in comparison to normal distribution, that it has a slight skew and fat tail of distribution at the right side, and a bigger skew and a thinner tail at the left side.

BELEXline market risk, measured by means of variance and standard deviation, in the observed period amounts to 0.03% and 1.64% respectively.

The analysis of movements of *BELEXline* daily rates of return in the observed period, as shown in Figure 2, indicates the incompatibility with the characteristics of the Serbian capital market under the assumption of identical distribution. The figure clearly shows the grouping of volatility in the period of high and low variability.

Figure 2. Movements of BELEXline daily rates of return in the period from 01.01.2008 to 31.12.2008



The existence of a period of high and low volatility at the Serbian capital market in the observed period indicates the existence

of autocorrelation in the series of *BELEXline* rates or return, since the grouping of volatilities implies that the big changes in *BELEXline* value are followed by periods of big changes, and small changes by periods of small changes. This further suggests that the changes in *BELEXline* values in the forthcoming periods are related to the changes in current values. Another name for this phenomenon is seriality.

What confirms this indication is the quantification of the first order autocorrelation coefficient, which amounts to $\sigma = 0.3285$. The obtained autocorrelation coefficient indicates that the positive changes in *BELEXline* values are followed by positive changes from the past periods, and the negative changes are followed by negative ones. Such a result shows that the assumption of independent distribution is not valid for the Serbian capital market either.

Empirical analysis

The previous analysis reveals that the underlying assumptions of the parametric and non-parametric value-at-risk methods are not realistic for the Serbian capital market. Hence the question arises as to whether it is

possible to have a reliable VaR assessment at the capital market of Serbia, and which method is more adequate, bearing in mind the incompatibility of assumptions with the market's characteristics.

In order to answer these questions, in this paper we tested the validity of methods by comparing the daily VaR assessments of the general *BELEXline* market index, obtained by means of parametric and non-parametric methods, in

the period from 03.01.2009 to 31.03.2009, with the real trends of the index's returns in the same period. As a criterion of validity, in this paper we

je za nivo poverenja od 90 i 99%, na uzorku od 255 radnih dana koji prethode danu za koji se vrši procena VaR-a. Za potrebe procene VaR-a primenom neparametarske metode u radu razvijen model HS-255. Istorijski simulirani prinosi koji su korišćeni u modelu HS-255 su generisani na taj način što je fiksirano relativno učešće akcija u indeksu na dan 03.01.2008. godine. Na taj način je izbegnuto svakodnevno

prilagođavanje vrednosti indeksa, u smislu da se od vrednosti indeksa oduzimaju dobiti i nadoknađuju gubici, kako bi se ponderi zadržali nepromenjenim.

Rezultati testiranja parametarske metode vrednosti pri riziku dati su u tabeli 2. Rezultati testiranja neparametarske metode vrednosti pri riziku dati su u tabeli 3.

Tabela 2. Rezultati testiranja validnosti parametarske metode vrednosti pri riziku

Datum	Stvarno kretanje prinosa BELEXline (u baznim poenima)	Procena VaR-a za nivo poverenja (u baznim poenima)	
		90%	99%
31.12.2008	1198	90%	99%
5.1.2009	-14	24.33	46.08
6.1.2009	-2	22.61	42.82
9.1.2009	-13	22.57	42.75
12.1.2009	-15	22.32	42.28
13.1.2009	-23	22.03	41.74
14.1.2009	0	21.59	40.91
15.1.2009	-2	22.98	43.53
16.1.2009	-3	22.94	43.45
19.1.2009	-9	22.86	43.30
20.1.2009	-7	22.68	42.96
21.1.2009	-2	22.53	42.68
22.1.2009	12	22.49	42.60
23.1.2009	31	22.73	43.07
26.1.2009	-2	23.46	44.45
27.1.2009	1	23.42	44.37
28.1.2009	-16	23.48	44.48
29.1.2009	-8	23.13	43.81
30.1.2009	-1	23.01	43.59
2.2.2009	-4	22.95	43.47
3.2.2009	-10	22.86	43.31
4.2.2009	-10	22.53	42.67
5.2.2009	12	22.29	42.23
6.2.2009	-13	22.18	42.01
9.2.2009	20	21.88	41.45
10.2.2009	-5	22.27	42.19
11.2.2009	6	22.17	42.00
12.2.2009	-12	22.30	42.24
13.2.2009	-20	22.02	41.72
17.2.2009	-17	21.65	41.01

Datum	Stvarno kretanje prinosa BELEXline (u baznim poenima)	Procena VaR-a za nivo poverenja (u baznim poenima)	
		90%	99%
18.2.2009	-19	21.31	40.37
19.2.2009	-12	20.96	39.71
20.2.2009	-12	20.73	39.27
23.2.2009	-24	20.98	39.75
24.2.2009	-18	20.47	38.79
25.2.2009	-3	20.12	38.12
26.2.2009	-15	19.92	37.73
27.2.2009	-20	19.52	36.98
2.3.2009	-1	19.15	36.28
3.3.2009	-9	19.04	36.07
4.3.2009	-14	18.86	35.72
5.3.2009	-17	18.59	35.22
6.3.2009	-7	18.23	34.53
9.3.2009	-18	18.05	34.20
10.3.2009	-16	17.73	33.59
11.3.2009	-19	17.40	32.96
12.3.2009	-3	17.05	32.30
13.3.2009	10	16.99	32.18
16.3.2009	-3	17.20	32.58
17.3.2009	12	17.11	32.42
18.3.2009	15	17.40	32.95
19.3.2009	20	17.76	33.64
20.3.2009	-15	18.26	34.58
23.3.2009	-5	17.97	34.05
24.3.2009	6	17.86	33.83
25.3.2009	-10	17.98	34.07
26.3.2009	0	17.77	33.66
27.3.2009	-17	17.73	33.58
30.3.2009	-12	17.40	32.95
31.3.2009	-2	17.16	32.51

used the following: number of allowed excesses should equal $T(1-\alpha)$, where T is the length of the time horizon, and $(1-\alpha)$ the confidence level. VaR assessment was conducted at the 90% and 99% confidence level, at the sample of 255 working days preceding the day for which VaR assessment is being conducted. For the sake of VaR assessment by means of non-parametric method, in this paper we developed HS-255 model. Historically simulated returns used

in HS-255 are generated by fixing the relative number of shares in the index as of 03.01.2008. Thus we avoided the daily adjustment of index value, in terms of deducting profits and compensating for losses in order to keep the weights unchanged.

The results of testing the parametric value-at-risk method are shown in Table 2. The results of testing the non-parametric value-at-risk method are shown in Table 3.

Table 2. Test results of parametric VaR method validity

Date	Actual movements of BELEXline (in basic points)	VaR estimate for a confidence level (in basic points)	
		90%	99%
31.12.2008	1198		
5.1.2009	-14	24.33	46.08
6.1.2009	-2	22.61	42.82
9.1.2009	-13	22.57	42.75
12.1.2009	-15	22.32	42.28
13.1.2009	-23	22.03	41.74
14.1.2009	0	21.59	40.91
15.1.2009	-2	22.98	43.53
16.1.2009	-3	22.94	43.45
19.1.2009	-9	22.86	43.30
20.1.2009	-7	22.68	42.96
21.1.2009	-2	22.53	42.68
22.1.2009	12	22.49	42.60
23.1.2009	31	22.73	43.07
26.1.2009	-2	23.46	44.45
27.1.2009	1	23.42	44.37
28.1.2009	-16	23.48	44.48
29.1.2009	-8	23.13	43.81
30.1.2009	-1	23.01	43.59
2.2.2009	-4	22.95	43.47
3.2.2009	-10	22.86	43.31
4.2.2009	-10	22.53	42.67
5.2.2009	12	22.29	42.23
6.2.2009	-13	22.18	42.01
9.2.2009	20	21.88	41.45
10.2.2009	-5	22.27	42.19
11.2.2009	6	22.17	42.00
12.2.2009	-12	22.30	42.24
13.2.2009	-20	22.02	41.72
17.2.2009	-17	21.65	41.01

Date	Actual movements of BELEXline (in basic points)	VaR estimate for a confidence level (in basic points)	
		90%	99%
18.2.2009	-19	21.31	40.37
19.2.2009	-12	20.96	39.71
20.2.2009	-12	20.73	39.27
23.2.2009	-24	20.98	39.75
24.2.2009	-18	20.47	38.79
25.2.2009	-3	20.12	38.12
26.2.2009	-15	19.92	37.73
27.2.2009	-20	19.52	36.98
2.3.2009	-1	19.15	36.28
3.3.2009	-9	19.04	36.07
4.3.2009	-14	18.86	35.72
5.3.2009	-17	18.59	35.22
6.3.2009	-7	18.23	34.53
9.3.2009	-18	18.05	34.20
10.3.2009	-16	17.73	33.59
11.3.2009	-19	17.40	32.96
12.3.2009	-3	17.05	32.30
13.3.2009	10	16.99	32.18
16.3.2009	-3	17.20	32.58
17.3.2009	12	17.11	32.42
18.3.2009	15	17.40	32.95
19.3.2009	20	17.76	33.64
20.3.2009	-15	18.26	34.58
23.3.2009	-5	17.97	34.05
24.3.2009	6	17.86	33.83
25.3.2009	-10	17.98	34.07
26.3.2009	0	17.77	33.66
27.3.2009	-17	17.73	33.58
30.3.2009	-12	17.40	32.95
31.3.2009	-2	17.16	32.51

Tabela 3. Rezultati testiranja validnosti neparametarske metode vrednosti pri riziku

Datum	Dnevne procene VaR-a primenom neparametarske metode		Stvarno kretanje prinosa
	99%	90%	
5.1.2009	-5.49%	-1.77%	-1.15%
6.1.2009	-5.49%	-1.77%	-0.21%
9.1.2009	-5.49%	-1.77%	-1.03%
12.1.2009	-5.49%	-1.77%	-1.34%
13.1.2009	-5.49%	-1.77%	-0.76%
14.1.2009	-5.49%	-1.77%	0.04%
15.1.2009	-5.49%	-1.77%	-0.18%
16.1.2009	-5.49%	-1.77%	-0.31%
19.1.2009	-5.49%	-1.77%	-0.80%
20.1.2009	-5.49%	-1.77%	-0.59%
21.1.2009	-5.49%	-1.77%	-0.21%
22.1.2009	-5.49%	-1.77%	-1.10%
23.1.2009	-5.49%	-1.77%	2.77%
26.1.2009	-5.49%	-1.74%	-0.18%
27.1.2009	-5.49%	-1.74%	0.08%
28.1.2009	-5.49%	-1.74%	-1.35%
29.1.2009	-5.49%	-1.74%	-0.73%
30.1.2009	-5.49%	-1.74%	-0.07%
2.2.2009	-5.49%	-1.74%	-0.36%
3.2.2009	-5.49%	-1.74%	-0.95%
4.2.2009	-5.49%	-1.74%	-0.86%
5.2.2009	-5.49%	-1.74%	1.14%
6.2.2009	-5.49%	-1.74%	-1.23%
9.2.2009	-5.49%	-1.68%	1.82%
10.2.2009	-5.49%	-1.62%	-0.46%
11.2.2009	-5.49%	-1.62%	0.55%
12.2.2009	-5.49%	-1.62%	-1.09%
13.2.2009	-5.49%	-1.62%	-1.74%
17.2.2009	-5.49%	-1.68%	-1.59%

Datum	Dnevne procene VaR-a primenom neparametarske metode		Stvarno kretanje prinosa
	99%	90%	
18.2.2009	-5.49%	-1.68%	-1.76%
19.2.2009	-5.49%	-1.74%	-1.20%
20.2.2009	-5.49%	-1.74%	-1.15%
23.2.2009	-5.49%	-1.74%	-2.31%
24.2.2009	-5.49%	-1.74%	-1.82%
25.2.2009	-5.49%	-1.74%	-0.25%
26.2.2009	-5.49%	-1.74%	-1.52%
27.2.2009	-5.49%	-1.74%	-1.95%
2.3.2009	-5.49%	-1.74%	-0.25%
3.3.2009	-5.49%	-1.74%	-0.90%
4.3.2009	-5.49%	-1.74%	-1.47%
5.3.2009	-5.49%	-1.74%	-1.84%
6.3.2009	-5.49%	-1.74%	-0.76%
9.3.2009	-5.49%	-1.74%	-2.08%
10.3.2009	-5.49%	-1.76%	-1.75%
11.3.2009	-5.49%	-1.76%	-2.18%
12.3.2009	-5.49%	-1.76%	-0.34%
13.3.2009	-5.49%	-1.76%	1.11%
16.3.2009	-5.49%	-1.76%	-0.27%
17.3.2009	-5.49%	-1.76%	1.35%
18.3.2009	-5.49%	-1.76%	1.79%
19.3.2009	-5.49%	-1.76%	2.20%
20.3.2009	-5.49%	-1.76%	-1.69%
23.3.2009	-5.49%	-1.76%	-0.53%
24.3.2009	-5.49%	-1.76%	0.69%
25.3.2009	-5.49%	-1.76%	-1.12%
26.3.2009	-5.49%	-1.76%	-0.04%
27.3.2009	-5.49%	-1.76%	-1.91%
30.3.2009	-5.49%	-1.76%	-1.35%
31.3.2009	-5.49%	-1.76%	-0.30%

Stvarni gubitak u posmatranom periodu nijednom nije premašio iznos VaR-a utvrđen primenom parametarske metode za nivo poverenja od 99%, dok je samo pet puta premašio iznos VaR-a utvrđen za novo poverenja od 90%. To znači da se metoda varijanse-kovarijanse može pouzdano koristiti za procenu VaR-a na tržištu kapitala Srbije za ekstremne nivoe poverenja jer broj dozvoljenih prekoračenja iznosi 1 za eksterno visok nivo poverenja, odnosno 7 za eksterno nizak nivo poverenja.

Rezultati testiranja neparametarske metode ukazuju da se metoda može pouzdano koristiti na tržištu kapitala za ekstremno visok nivo

poverenja jer stvarni gubitak u posmatranom periodu nijednom nije premašio utvrđeni nivo VaR-a. Međutim, stvarni gubitak je čak devet puta premašio iznos VaR-a utvrđen za nivo poverenja od 90%. S obzirom da je broj dozvoljenih prekoračenja za nivo poverenja 7, može se zaključiti da se metodom istorijske simulacije ne može pouzdano vršiti procena VaR-a za ekstremno nizak nivo poverenja.

Zaključak

U radu je izvršeno testiranje aplikativnosti parametarske i neparametarske metode vrednosti pri riziku na tržištu kapitala

Table 3. Test results of non-parametric VaR method validity

Date	Daily VaR assessments by means of non-parametric method		Actual movements of returns
	99%	90%	
5.1.2009	-5.49%	-1.77%	-1.15%
6.1.2009	-5.49%	-1.77%	-0.21%
9.1.2009	-5.49%	-1.77%	-1.03%
12.1.2009	-5.49%	-1.77%	-1.34%
13.1.2009	-5.49%	-1.77%	-0.76%
14.1.2009	-5.49%	-1.77%	0.04%
15.1.2009	-5.49%	-1.77%	-0.18%
16.1.2009	-5.49%	-1.77%	-0.31%
19.1.2009	-5.49%	-1.77%	-0.80%
20.1.2009	-5.49%	-1.77%	-0.59%
21.1.2009	-5.49%	-1.77%	-0.21%
22.1.2009	-5.49%	-1.77%	-1.10%
23.1.2009	-5.49%	-1.77%	2.77%
26.1.2009	-5.49%	-1.74%	-0.18%
27.1.2009	-5.49%	-1.74%	0.08%
28.1.2009	-5.49%	-1.74%	-1.35%
29.1.2009	-5.49%	-1.74%	-0.73%
30.1.2009	-5.49%	-1.74%	-0.07%
2.2.2009	-5.49%	-1.74%	-0.36%
3.2.2009	-5.49%	-1.74%	-0.95%
4.2.2009	-5.49%	-1.74%	-0.86%
5.2.2009	-5.49%	-1.74%	1.14%
6.2.2009	-5.49%	-1.74%	-1.23%
9.2.2009	-5.49%	-1.68%	1.82%
10.2.2009	-5.49%	-1.62%	-0.46%
11.2.2009	-5.49%	-1.62%	0.55%
12.2.2009	-5.49%	-1.62%	-1.09%
13.2.2009	-5.49%	-1.62%	-1.74%
17.2.2009	-5.49%	-1.68%	-1.59%

Date	Daily VaR assessments by means of non-parametric method		Actual movements of returns
	99%	90%	
18.2.2009	-5.49%	-1.68%	-1.76%
19.2.2009	-5.49%	-1.74%	-1.20%
20.2.2009	-5.49%	-1.74%	-1.15%
23.2.2009	-5.49%	-1.74%	-2.31%
24.2.2009	-5.49%	-1.74%	-1.82%
25.2.2009	-5.49%	-1.74%	-0.25%
26.2.2009	-5.49%	-1.74%	-1.52%
27.2.2009	-5.49%	-1.74%	-1.95%
2.3.2009	-5.49%	-1.74%	-0.25%
3.3.2009	-5.49%	-1.74%	-0.90%
4.3.2009	-5.49%	-1.74%	-1.47%
5.3.2009	-5.49%	-1.74%	-1.84%
6.3.2009	-5.49%	-1.74%	-0.76%
9.3.2009	-5.49%	-1.74%	-2.08%
10.3.2009	-5.49%	-1.76%	-1.75%
11.3.2009	-5.49%	-1.76%	-2.18%
12.3.2009	-5.49%	-1.76%	-0.34%
13.3.2009	-5.49%	-1.76%	1.11%
16.3.2009	-5.49%	-1.76%	-0.27%
17.3.2009	-5.49%	-1.76%	1.35%
18.3.2009	-5.49%	-1.76%	1.79%
19.3.2009	-5.49%	-1.76%	2.20%
20.3.2009	-5.49%	-1.76%	-1.69%
23.3.2009	-5.49%	-1.76%	-0.53%
24.3.2009	-5.49%	-1.76%	0.69%
25.3.2009	-5.49%	-1.76%	-1.12%
26.3.2009	-5.49%	-1.76%	-0.04%
27.3.2009	-5.49%	-1.76%	-1.91%
30.3.2009	-5.49%	-1.76%	-1.35%
31.3.2009	-5.49%	-1.76%	-0.30%

In the observed period the actual loss not once exceeded the VaR amount determined by means of parametric method at the 99% confidence level, whereas it exceeded the VaR amount determined at the 90% confidence level only five times. This implies that variance-covariance method is reliable to be used for VaR assessment in the Serbian capital market at the extreme confidence levels, since the number of allowed excesses at extremely high confidence levels is one, and at extremely low confidence levels seven.

The results of testing the non-parametric method indicate that this method is reliable to be used at the Serbian capital market at the

extremely high confidence level since the actual loss in the observed period not once exceeded the determined VaR level. However, the actual loss exceeded the VaR amount determined at the 90% confidence level nine times. Given that, at that confidence level, the allowed number of excesses is 7, it may be concluded that historical simulation method cannot be used for a reliable VaR assessment at the extremely low confidence level.

Conclusion

The paper tested the applicability of parametric and non-parametric value-at-risk

Srbije, kako bi se uvidelo koja metoda pruža pouzdanije procene VaR-a, imajući u vidu činjenicu da karakteristike tržišta kapitala nisu kompatibilne sa pretpostavkama na kojima su izgrađene metode vrednosti pri riziku. Testiranje je izvršeno u periodu od 03.01. do 31.03. 2009 na taj način što su stvarni prinosi i gubici *BELEXline*-a komparirani sa procenama VaR-a dobijenih primenom parametarske, odnosno neparametarske metode. Procene VaR-a vršene su za nivo poverenja od 90 i 99%. Zbog kratkog vremenskog perioda kao kriterijum za testiranje aplikativnosti metoda koristi se uslov da broj dozvoljenih prekoračenja bude jednak $T(1-\alpha)$, pri čemu je T - dužina vremenskog horizonta, a $(1-\alpha)$ - nivo poverenja.

Rezultati testiranja pokazuju da se

parametarska metoda vrednosti pri riziku može pouzdano koristiti za procenu VaR-a na tržištu kapitala Srbije, budući da stvarni gubitak *BELEXline*-a u posmatranom periodu nije nijednom premašio iznos VaR-a utvrđen za ekstremno visok nivo poverenja, dok je samo pet puta premašio iznos VaR-a utvrđen za ekstremno nizak nivo poverenja. Sa druge strane, rezultati istraživanja pokazuju da se neparametarska metoda vrednosti pri riziku može pouzdano koristiti samo za ekstremno visok nivo poverenja jer stvarni gubitak u posmatranom periodu nije nijednom premašio iznos VaR-a utvrđen za nivo poverenja od 99%, dok je čak devet puta premašio iznos VaR-a utvrđen za ekstremno nizak nivo poverenja.

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method at the Serbian capital market in order to determine which method provides more reliable VaR assessments, bearing in mind the fact that capital market characteristics are incompatible with the underlying assumptions of value-at-risk methods. The testing was conducted in the period from 03.01.2009 to 31.3.2009, by comparing the actual *BELEXline* returns and losses with VaR assessments obtained by means of parametric and non-parametric methods. VaR assessments were done at 90% and 99% confidence levels. Due to the short time period, the criterion for testing the methods' applicability is the condition that the number of allowed excesses equals $T(1-\alpha)$, where T is the length of the time horizon, and $(1-\alpha)$ the confidence level.

The test results indicate that the parametric value-at-risk method is reliable to be used for VaR assessment at the Serbian capital market, given that the actual *BELEXline* loss in the observed period not once exceeded the VaR amount determined at the extremely high confidence level, whereas it only five times exceeded the VaR amount determined at the extremely low confidence level. On the other hand, the results of the research indicate that the non-parametric value-at-risk method is only reliable at the extremely high confidence level, because the actual loss in the observed period not once exceeded the VaR amount determined at the 99% confidence level, whereas it exceeded the VaR amount determined at the extremely low confidence level nine times.