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ANALYSIS OF THE MOST COMMON CALCULATION METHODS "VALUE AT RISK, VAR"

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ABSTRACT

The Regulation of the National Bank of Ukraine on Risk Management in Ukrainian Banks stipulates that this Regulation obliges banks to use the VaR methodology to assess market risk. The article shows that VaR is the absolute maximum amount of losses of the market investment portfolio due to fluctuations in prices for financial instruments during a certain fixed period of time (VaR horizon) in normal market conditions at a given level of confidence level (confidence level). A study of the Value at Risk methodology as the absolute maximum size of market investment portfolio losses due to price fluctuations in financial instruments during a certain fixed period of time (VaR horizon) in normal market conditions for a given level of confidence level (confidence level). It was found that there are three main methods of VaR: parametric VaR, or delta normal VaR, historical method, or historical simulation, Monte Carlo, or simulation and other methods and models. The parametric VaR method, or the delta-normal VaR method, is based on the assumption of a normal distribution of a random variable. This means that the data are distributed according to the normal distribution law, ie you can calculate the mean and standard deviation. It is proved that these two indicators are the basis of VaR by the parametric method. It is shown that nonparametric VaR methods do not require the hypothesis of normal distribution. Therefore, the form of distribution is determined by empirical data, and percentiles are stored as empirical percentiles of the historical distribution of profitability. The article considers the nonparametric VaR method in comparison with the parametric one on a practical example. It is proved that in the domestic scientific literature there is little research on the practical application of the VaR method in finance and in particular in banking. Therefore, the practical aspects of applying different VaR models to the NBU exchange rate data are demonstrated and conclusions are drawn. It is shown that the practical application of methods is a modern tool for assessing market risks, but with the expansion of the database, the parameters of the models should be refined in combination with the economic method. This requires monitoring and back-testing.

Keywords: market risks, risk assessment, parametric VaR method, non-parametric VaR method, Monte Carlo method, back-testing, normal distribution

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INTRODUCTION

The method of risk assessment, which was once called Value at risk (Var), has a long history of application in the financial sector of Western countries, the problem of the practical application of VaR in Ukraine remains very relevant, especially in the context of declared regulatory intentions. capital adequacy in the banking sector. At present, the banking system of Ukraine does not have the regulator's requirements for the application of the VaR risk assessment methodology, as well as the fact that the practice of using this methodology by banks has not been studied. In particular, the issues of studying the impact of the methodology on the bank's management decisions remain problematic (it is still unknown in which banks, what types, and how often it is used, as well as the consequences of this methodology on banking management). Therefore, it is important to clarify the use of this methodology in order to provide recommendations to the regulator to formulate regulatory requirements for banks on the use of VaR.

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LITERATURE REVIEW

In the classical theory of economic risk by J. Mile and N. Senior, risk is identified with the mathematical expectations of losses that may occur as a result of the chosen solution [1]. That is, the risk arises in the form of damage caused by the implementation of this decision. This approach, however, is rather one-sided, so other definitions of risk have been formulated.

Thus, in the 1930s, economists A. Marshall and A. Pigou developed the foundations of the neoclassical theory of economic risk, according to which the subject of economic activity operates in conditions of uncertainty, and his profit is a random variable [2]. Therefore, the entity in its activities should be guided by two criteria: the size of the expected profit and the magnitude of its possible fluctuations. The Value at Risk (VaR) methodology is a fundamental foundation in risk management in both the European Union and the United States. This methodology is to estimate the probability of possible changes in the market value of the asset.

Analysis of research and publications indicates that Western scientific thought has extensively and deeply researched existing VAR algorithms, identified the conditions for its application, pointed out the existing advantages and disadvantages, and continues to seek its improvement. Among the most well-known researchers and promoters of VAR are F. Jorion, Professor of Finance at the School of Finance [3], Paul Merage at the University of California (USA) and Head of Risk Management at PAAMCO, K. Alexander, Professor of Finance at the University of Sussex (UK) and Managing Editor of Banking Affairs and Finance [4], M. Chaudry is the former Head of Treasury Business in the Global Banking and Markets division of the Royal Bank of Scotland[5]. The list of researchers is certainly not limited to these individuals, but it is their publications and scientific articles, in our opinion, that once gave a significant impetus to disseminate knowledge about VAR and launch a global debate on the development and improvement of both individual methods and general financial risk management.

The leading role in the methodology of banking risk analysis belongs to the materials of the Basel Committee, which provide general recommendations on the methodology of risk analysis in banks. Domestic scientific thought is also trying to keep up with global trends, although it lacks basic research and cooperation with practical business [6]. Analysis of articles and seminar materials on the banking system shows that the topic of the practical application of VaR, although reflected in the professional environment but mostly limited to a general description of the concept without an in-depth analysis of assumptions and prerequisites for VAR, disadvantages and advantages, application statistics, features actions of the methodology in the local market.

Despite the fact that the methodology for risk assessment, which was once called Value at risk (Var), has a long history of application in the financial sector of Western countries, the problem of the practical application of VaR in Ukraine remains very relevant, especially in the context of declared regulatory intentions to introduce best practices in capital adequacy regulation in the banking sector[7]. At present, the banking system of Ukraine does not have the regulator's requirements for the application of the VaR risk assessment methodology, as well as the fact that the practice of using this methodology by banks has not been studied. In particular, the issues of studying the impact of the methodology on the bank's management decisions remain problematic (it is still unknown in which banks, what types, and how often it is used, as well as the consequences of this methodology on banking management) [8]. Therefore, it is important to clarify the use of this methodology to provide recommendations to the regulator to formulate regulatory requirements for banks on the use of VaR. The experience of the banking system of Ukraine shows that the uncontrolled application of the VaR methodology affects its general condition. In the previous article "Some aspects of historical application of Var we showed one of the approaches on a specific example to the method of calculating VaR" and outlines the features of its use.

AIMS

The aim of the article is to demonstrate three main methods for estimating VaR: parametric, historical, and Monte Carlo method (simulation method), as well as to identify their advantages and disadvantages.

The methodological basis of the study is statistical methods of analysis and modeling. To solve the problem posed in the article, general and special research methods were used, namely: statistical analysis (to determine advanced methods for measuring currency risk), system-structural analysis and comparative analysis (to determine the main comparative characteristics of analytical methods) of calculation "Value at stake, Var".

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RESULTS

VaR is the absolute maximum amount of losses of the market investment portfolio due to fluctuations in the price of financial instruments during a certain fixed period (VaR horizon) in normal market conditions at a given level of confidence level (confidence level). The following methods are used to estimate VaR in world banking practice: parametric, which also has several other names (variational-covariance, analytical), historical, and Monte Carlo method (simulation method). The main features of these methods are presented in table 1

Table 1. Analysis of the most common calculation methods "Value at risk, Var". *(Source: Compiled by the authors based on data)*

Method name	Author	The main steps of building a model	Advantages	Disadvantages
Parametric / normal / delta-normal / variational-covariance / analytical. (Parametric VaR)	JPMorgan (1994) Risk Metrics methodology	Selection of the observation window, Calculation of logarithms of yields, Calculation of standard deviations, Construction of a correlation matrix, Construction of the matrix of covariances, Construction of asset vector. Calculation of VaR by methods of matrix algebra (Markovitz portfolio theory approach)	Ease of estimating parameters and aggregating estimates for the asset portfolio	It is not realistic to assume that the return on assets is distributed normally. The possibility of underestimating the risk due to asymmetry and acute apical excess. The possibility of underestimating the risk due to non-stationary distribution parameters.
Historical VaR / historical simulation method (HS VaR)	J.P. Morgan (1994) Risk Metrics methodology	Select the observation window Calculation of historical returns Calculation of historical P&L based on asset data and their historical returns and deductions P&L aggregation into a compatible distribution Calculation of VaR based on the i-th selected distribution percentile (the presence of short positions is taken into account through the position sign)	The model does not depend on the form of distribution, does not require evaluation of parameters, its implementation is quite simple	Critical dependence of the realism of the model estimates on the "depth of the historical window"
Monte Carlo simulation (MC VaR)	J.P. Morgan (1994) Risk Metrics methodology	Calculation of drift and volatility based on historical returns Calculation of the correlation matrix of assets Choice of the form of distribution of a random variable and calculation of a matrix of random variables Generation of multiple scenarios of stochastic values of asset prices taking into account their correlation and calculation of simulated value of positions Calculate VaR as the difference between the current portfolio value and the simulated value per selected lower i quantile (for long positions) / as the difference between the current portfolio value and the simulated value per selected upper i quantile (for short positions), or as the sum of the value differences for long and short positions	Flexible and natural consideration of asymmetry, increased excess, correlation and non-linear relationship between portfolio asset prices possibility of application for portfolios of complex nature	Dependence of realism of estimates on the choice of the simulated distribution form (high model risk)

As can be seen from the table, the parametric VaR method or the delta-normal VaR method is based on the assumption of a normal distribution of a random variable. This means that the data is distributed according to the normal distribution law, that is, you can calculate the average value and standard deviation. These two indicators are the basis of VaR by the parametric method. According to the concepts of risk management, market risk is the risk of losses in financial markets as a result of price movements or changes. Therefore, the subject of market risk research is the mathematical expression of price changes according to the formula:

$$ln \frac{p_t}{p_{t-1}} \quad (1)$$

where p – is the price of the asset.

In accordance with the basics of statistics, each price change is a random variable; a significant number of observations is the basis for the formation of the frequency distribution, allowing statistical analysis and revealing the patterns of this distribution. The parametric method is based on the normal distribution, i.e. the data used must have a normal distribution (Gaussian distribution). If the data does not fit this distribution, then we will not be able to fit it. We use periodic returns for the period 2016, $ln\frac{p_t}{p_{t-1}}$. In order to verify the reliability of the assumption of a normal distribution, we will carry out the following studies. Our null hypothesis is that our sample is normal or conforms to the normal distribution law. If our data do not match this distribution, we cannot approximate them. We will conduct a sample survey using statistical tests. Null hypothesis - our sample is normal or corresponds to the normal distribution law.

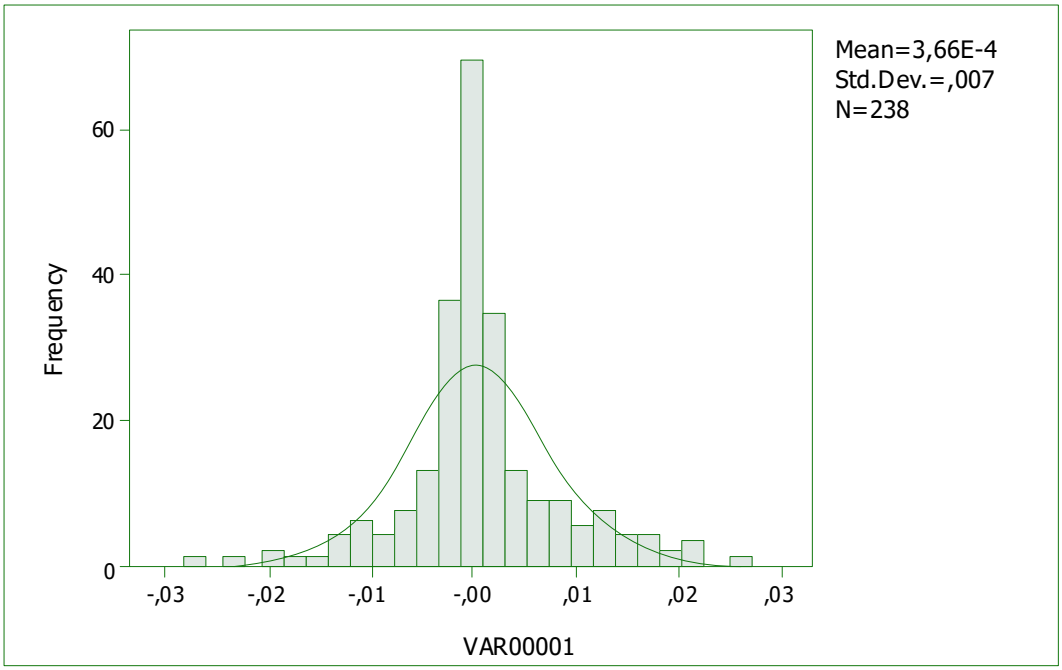

Figure 1. Combination of imperial data histogram and theoretical curve of normal distribution.
(Compiled by the authors based on calculations)

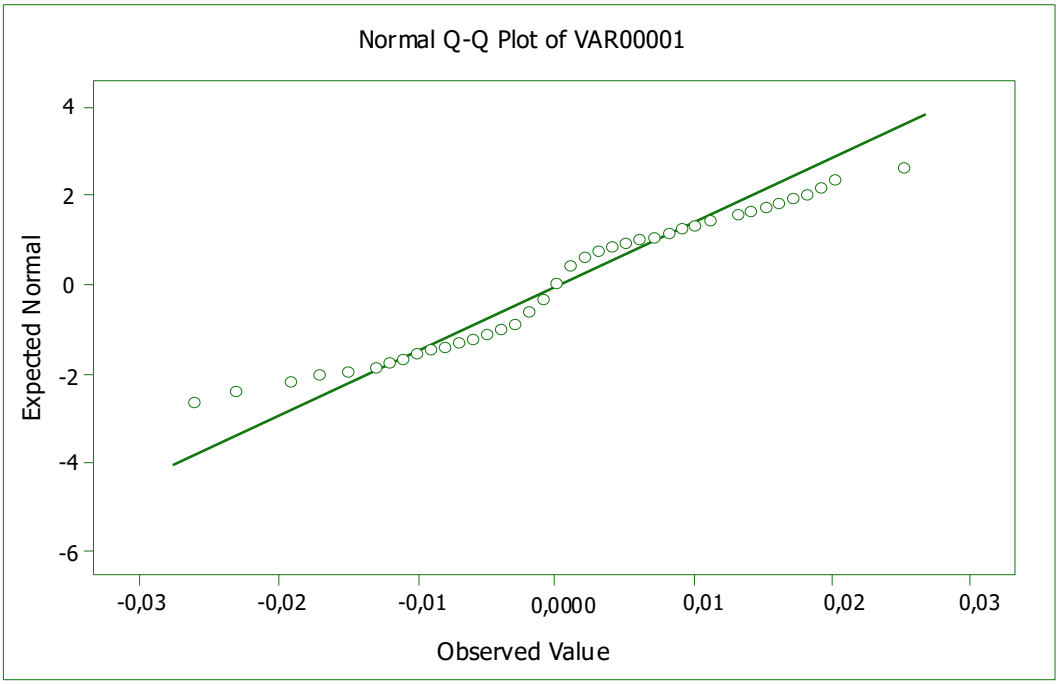

Figure 2. Graphical representation of the distribution (Graph Q-Q, quantile-quantile graph).
(Compiled by the authors based on calculations)

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Table 2. Test data using statistical techniques.

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
VAR00001	177	238	000	918	238	000
a – Lilliefors Significance Correction						

According to calculations, the value of p-value is the probability that there is no difference between the theoretical normal distribution and the empirical distribution. As can be seen from the table, the value of the test, or p-value, is 0.000 (Significant = 0.000). This means that the probability that the difference between the theoretical curve and our data is extremely low and close to zero. The graphical representation of the distribution shows that the distribution is generally symmetric (does not have a pronounced asymmetry), but has a positive "sharp" distribution, which is 2 times greater than the excess that is characteristic of a normal distribution. Empirical data do not exactly coincide with the line of normal distribution but do not deviate much from it. Thus, this distribution may belong to one of the super-Gaussian distributions – it is not completely normal but does not deviate much from it. Therefore, we can use the parametric method, because visual methods showed signs of normal distribution and VaR – the total risk of impairment of the asset, expressed in dollars or in the base currency.

VaR – the maximum loss of the value of an asset or portfolio of assets with a certain confidence probability and a certain time horizon of holding the position.

$$VaR = v \times (\bar{x} - Z \times \sigma) \quad (2)$$

where v is the value of the asset (quantity × price); $\bar{x}$ – is the average value of the asset; Z – quantile of standard normal distribution; σ – standard deviation.

$$Z = \frac{x_i - \bar{x}}{\sigma} \quad (3)$$

This figure shows how much x_i deviates from the mean and is expressed in standard deviations (σ). The standard deviation is a statistical measure of risk and is based on the formula:

$$\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \quad (4)$$

And the greater this value, the greater the degree of risk.

VaR is a measure of risk that shows the maximum amount of money an asset can lose over a period with a given confidence level. Accordingly, VaR also suggests that the loss in portfolio value during this time period will be less than this value with some probability. Confidence probability can be defined as an indicator of how many times out of every 100 times the loss in value of an asset will not exceed this level. Therefore, VaR is designed to answer the following question: "What can be the maximum loss in the value of the portfolio, for example, in 95% of cases during the next day?" The level of trust probability is set in advance and depends on the nature of the company or asset. It is usually 95% or 99%. It should be emphasized that the choice of one or another level of confidence probability does not indicate the investor's attitude to risk, as VaR is only a certain point in the distribution of expected results of portfolio profitability. As already mentioned, VaR assesses market risk, so it allows you to quantify the expected losses in the value of the portfolio in the "normal conditions" of the market.

The properties of the normal standardized distribution are the fact that within the deviation of one standard deviation from the average will be observed 68% of the values of the random variable, and within the deviation of two standard deviations from the mean will be observed 95% of the values of the random variable, etc. As a result, there is a relationship between the degree to which a random variable deviates from its mean and the corresponding cumulative probability of finding that value within that variance. Mathematically, this connection is expressed as a quantile.

Table 3. Cumulative probabilities of normal distribution for the most commonly used VaR quantiles. *(Compiled by the authors based on calculations)*

Probability (X<Z)	1,0%	5%	10,0%
The value of the quantile (Z)	-2,326	-1,645	-1,282

Nonparametric VaR methods do not require the normal distribution hypothesis. Therefore, the form of distribution is determined by empirical data, and percentiles are stored as empirical percentiles of the historical distribution of profitability.

The bootstrapping model refers to non-parametric methods and is the generation of a random sample on limited data. Moreover, each actual observation for 2016 with equal probability can be included in the sample of bootstrap. Since we use data only for the period of 2016 and make calculations, we will test the data for 2017 - the first half of 2018, which is an important period in the formation of the foreign exchange market in the post-crisis period. According to these data, we generated 1000 bootstrap scenarios (random samples) based on the actual sample. In our study, we used exchange rate data for 2016, as this period is characterized by the largest fluctuations in exchange rates over the past 10 years. For each bootstrap scenario, we found 5 percentiles and found an average of 5 percentiles per 1,000 units. This value is a risk assessment.

The Monte Carlo method is a rather poorly formalized method that has no rigid limitations. The analysis uses data generation to simulate data from the general population. After a large number of repetitions, the saved results well mimic the real distribution of the sample.

Table 4. The results of VaR calculations by three methods. *(Compiled by the authors based on calculations)*

	Parametric method	Historical method (bootstrap -method)	Monte Carlo method
Risk assessment	-0,0103905	-0,01009	-0,012291
Number of cases that exceed the risk assessment	3	3	3
Number of back-testing observations 2017 - first half of 2018	341	341	341

As can be seen from the table, the risk assessment by the parametric method is -0.0103905. This means that in 95% of cases out of 100 fluctuations in profitability will be within -0.103905. The risk assessment by the second method is an average of 5 percentiles for each bootstrap scenario and is -0.01009, according to the Monte Carlo method is -0.012291 and is an average of 5 percentiles for each of the 1000 scenarios. The results of back-testing for the period 2017-first half of 2018 showed that in only 3 cases the yield fell below our risk assessment for 342 days of observations of the second method and the Monte Carlo Method also 3 cases, respectively. This is in line with the requirements of the Basel Committee.

DISCUSSION

VaR assessment is a fundamental tool within market risk management. Practitioners and researchers should be familiar with the concept of its calculation and the types of methodologies available. It should also be borne in mind that the effective use of VaR can be achieved not in isolation, but only in combination with VaR with other financial risk management tools.

CONCLUSIONS

The practical application of the methods shows that VaR methods are modern tools for assessing market risks, but with the expansion of the database, the parameters of the models should be refined in combination with the economic method. This requires monitoring and back-testing.

The main task of supervisors in Ukraine is to increase the participation of bank employees in the processes of bank management and increase their awareness of issues related to risk management and control. Therefore, banks must take organizational and control measures for each type of risk. In our opinion, this approach is part of a more general strategy for regulating banks, organizations and internal control systems, which is designed to ensure effective and integrated

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management. A more detailed overall strategy for internal risk assessment serves to calculate capital adequacy, so the effective use of such systems in banking operations for capital supervision is a condition for their recognition and integration.

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Павлюк О. О., Мельник Т. М.

АНАЛІЗ НАЙПОШИРЕНІШИХ МЕТОДІВ РОЗРАХУНКУ «VALUE AT RISK, VAR»

Положенням Національного банку України про управління ризиками в українських банках визначено, що Національний банк України зобов'язує банки використовувати методологію VaR для оцінки ринкового ризику. У статті показано, що VaR – це абсолютна максимальна сума втрат портфеля ринкових інвестицій через коливання цін на фінансові інструменти протягом певного фіксованого періоду (горизонт VaR) у звичайних ринкових умовах при заданому рівні довіри (рівні довіри). Досліджено методологію Value at Risk як абсолютного максимального розміру втрат ринкового інвестиційного портфеля через коливання цін на фінансові інструменти протягом певного фіксованого періоду (горизонт VaR) у звичайних ринкових умовах для заданого рівня довіри (рівень довіри). Було виявлено, що існує три основні методи VaR: параметричний VaR, або дельта-нормальний VaR, історичний метод, або історичне моделювання, Монте-Карло, або моделювання та інші методи й моделі. Параметричний метод VaR, або дельта-нормальний метод VaR, заснований на припущенні нормального розподілу випадкової величини. Це означає, що дані розподіляються за законом нормального розподілу, тобто можна обчислити середнє та стандартне відхилення. Доведено, що ці два показники є основою VaR параметричним методом. Показано, що непараметричні методи VaR не потребують гіпотези нормального розподілу. Отже, форма розподілу визначається емпіричними даними, а процентилі зберігаються як емпіричні процентилі історичного розподілу прибутковості. У статті розглянуто непараметричний метод VaR у порівнянні з параметричним на практичному прикладі. Доведено, що у вітчизняній науковій літературі мало досліджень щодо практичного застосування методу VaR у фінансах і, зокрема, у банківській справі. Тож проілюстровано практичні аспекти застосування різних моделей VaR на даних валютного курсу НБУ та зроблено висновки. Показано, що практичне застосування методів є сучасним інструментом оцінки ринкових ризиків, але з розширенням бази даних параметри моделей необхідно уточнювати в поєднанні з економічним методом. Для цього потрібен моніторинг і бек-тестування.

Ключові слова: ринкові ризики, оцінка ризику, параметричний метод VaR, непараметричний метод VaR, метод Монте-Карло, бек-тестування, нормальний розподіл

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