INNOVATIVE METHODS TO MEASURE THE MARKET RISK OF THE FOREX MARKET

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Abstract: The impact of market risk on the performance of economic agents is significant. The focus of this study is on the various models and techniques to quantify the market risk of the FOREX market. The results from the empirical testing of Monte Carlo simulation models, VaR, CVaR, MVaR, VaR historical simulation, and Delta Normal VaR indicate the presence of market risk in the Foreign exchange market. Of these models, the simulation model is the best measure of market risk. Historical simulation and Delta Normal VaR, on the other hand, help diversify risk by building investment portfolios.

Keywords: market risk, FOREX, simulation model, VaR models.
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1. Risk, types of risk on the „FOREX" market

Risk is a state of uncertainty and an attribute of any investment. Because of the ambiguity of its manifestation and its influence on the positions of individual and institutional investors, we need to measure, model, manage, forecast and minimize it. This will result in rational, precise, accurate, objective and adequate investors' decisions.

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By its nature, risk is the chance that the actual return on an investment may be different from the expected return. The economic science has developed models, concepts, theories and strategies to minimize and eliminate the impact of risk. Some of them are based on the basic statistical values belonging to the set of descriptive statistics, such as: rank, standard deviation, dispersion, and coefficient of variation. As time goes by, as a result of the turbulent development of financial markets and the ability to trade around the clock (except on holidays and weekends) in the foreign exchange market, the basic statistical risk metrics are not so powerful to adequately account for the real-time fluctuations in the exchange rate dynamics of a given currency asset. This calls for the use of more complicated risk assessment models. The academic community has worked hard on the challenging and difficult task to create a set of risk-measuring and adaptable models that will meet the requirements of the modern foreign exchange market and will assist individual and institutional investors in their trading.

The research object of the paper is the market risk of the FOREX market.

The research subject is the market risk measurement models of the FOREX market and their theoretical roots and interpretation.

The purpose of the paper is the systematic application of the market risk assessment models of the FOREX market - Monte Carlo simulation, VaR, CVaR, MVaR, VaR historical simulation and Delta Normal VaR. Based on the applied models to make a detailed and comprehensive analysis of the results obtained and to define which of the models most accurately measures the market risk, using annual data for the period (1.06.2014 - 30.10.2018) per daily base for the respective currency pairs CHF / USD, EUR / USD, JPY / USD, CNY / USD and AUD / USD. In addition to the parameters set, the author aims to calculate the maximum loss that a particular investor may incur, directing his/her available capital to a particular currency pair for a predefined time horizon and confidence interval.

Based on the above research object, subject and purpose, the main **tasks** to perform are:

• Theoretical interpretation and definition of market risk and the models for its measurement.

• Practical implementation of a simulation model, a quantitative model and CVaR, MVaR, VaR historical simulation, Delta Normal VaR.

• Measuring the exchange rate fluctuations of the basic currency pairs CHF / USD, EUR / USD, JPY / USD, CNY / USD and AUD / USD and applying a mechanism to reduce the impact of market risk.

• Empirical testing of Monte Carlo simulation models, VaR, CVaR, MVaR, VaR historical simulation, Delta Normal VaR to measure the

combined impact of market risk on the foreign exchange market and, on the other hand, on the investment behaviour of the investment community.

The basic types of risks directly related with and having an impact on the financial markets are:

- Market risk. It is the main object of research, determination, evaluation, minimization in the present paper. Market risk is the change in the price of an asset (be it financial or real), here - of a currency pair, in a direction which is unfavourable for the investor. In most of the risk management studies, market risk has the most significant impact on the financial situation of individual and institutional investors. This requires the development of a complex, econometric and practical methodology to help forecast its size and make appropriate decisions to counteract its impact. Modern science knows a number of models to help assess market risk. The main models are Monte Carlo Simulation, VaR, CVaR, MVaR, VaR Historical Simulation, Delta Normal VaR. In the research work we will apply these models to actual foreign exchange market data for the period (01.06.2014 - 30.10.2018) on the currency pairs CHF / USD, EUR / USD, JPY / USD, CNY / USD and AUD / USD. These are the most traded currency pairs in terms of transaction rates on a daily basis on international markets, according to a study by the International Bank for Reconstruction and Development, based in Basel, Switzerland. The idea underlying our research is by applying the predefined models to actual data on the current situation of the forex market to assess, using a given scale, which model best reflects reality and which one measures the market risk most precisely.
- Liquidity risk. It is of ambiguous nature. In terms of assets, it is the lack of possibility to convert an asset into money (cash) without problems. If the focus is on a business, the liquidity risk occurs when the firm is unable to cover the debt obligations, which have a maturity of less than one calendar year, that is, its current debt obligations when they arise. Here, this type of risk is not analysed and described in detail because liquidity risk does not fall in the area of assessment and research in this paper.
- Interest-rate risk. Interest-rate risk directly affects investors who have directed their available capital assets to the bond market and to bank savings products. The existence of interest rate risk is associated with a change in the interest rates on debt instruments. The interest-rate risk of government bonds is more limited since the issuer, i.e. the state is secured by its huge money resource and is a guarantor that the interest payments will be regularly effected on the maturity of the bond. Bank savings products, mainly time and savings deposits, pose a significant degree of risk to their holder in adverse changes in interest rates due to changes in the market situation. This

may result from the inefficient credit policy of the bank management, and thus harm the interests of bank depositors.

- Exchange-rate risk. It can arise from several possible situations resulting from the actions of the market participants. Foreign-exchange risk is part of any currency transaction executed on the FOREX market. Some traders ignore its impact and rely only on graphical models and technical indicators in making investment decisions, rather than use a more reliable source of information on the impact of risk like the quantitative methods and models developed by researchers. Tempted by the size of the leverage and the ability to trade with modest capital, they quickly lose their money.

Exchange-rate risk is closely related to international trade in the process of the purchase and sale of goods by entities from different geographic regions around the world. The main question is the currency in which the sale of a good will be effected. The interests of one of the two parties may be affected by adverse events - in the event of a change in foreign exchange rates.

- Political risk. Political risks arise in countries of fragile central governance. This inevitably leads to civil wars, protests, unrest, and recently - terrorist attacks. The result of these events is catastrophic for the population of the country. This gives birth to phenomena and processes that disrupt the normal function of the foreign exchange markets.
- Inflation risk. It is directly related to the monetary policy pursued by the central bank. Inflation risk is a rapid increase in the prices of basic goods and services comprising the consumer basket of a given economic group, which has an adverse effect on the economic agents (the state, firms and households). At the macro (national) level, the cash in circulation depreciates and its amount (supply) increases. To neutralize and counteract the impact of the inflationary process, the national central bank implements an adequate monetary policy in order to maintain the stability of the national currency, protect household income and create normal conditions for the functioning of the national economy. This can only be achieved with discipline and the opportunity to pursue a rational monetary policy. If the country is in a currency board arrangement, things are more complicated due to the limited role of the central bank in the implementation of monetary policy. For the business sector and households, inflationary risk directly concerns the stability of their earnings and capital. The saying, often quoted in corporate finance courses that ‘a dollar today is worth more than a dollar tomorrow’, requires both groups of economic agents to invest their cash and equivalents in assets to store their value.

The classification of the main types of risks (which does not claim to be exhaustive) is required because of the closeness of the related concepts.

Market risk is directly related to the above-mentioned risks. In the field of modern risk management, many researchers describe in their work that market risk includes exchange-rate, liquidity, political, inflation and interest-rate risks. As a result of the analysis, it is necessary to briefly present the relevant risk processes. It cannot and should not easily ignore the impact of the rest types of risks. Every investor and analyst in constructing their concept of measuring, assessing, modelling and analyzing risk aspects should not neglect the impact of the rest risks.

The methodology used to forecast the risk aspects of an investment activity must include, both the market risk and the closely related to it (inflation, exchange-rate, interest-rate, liquidity and political) risks.

2. Innovative methodology to assess the market risk of the FOREX market

2.1. MONTE CARLO simulation

The Monte Carlo simulation is a wide-ranging model used and applied in a number of scientific areas: physics, mathematics, the military industry, economics and finance. The simulation model was created in the US during the Second World War for purely military purposes - the design and the construction of a nuclear bomb.

The Monte Carlo simulation method was developed by three physicians – Nicholas Metropolis, Stanislaw Ulam and John von Neumann. In the modern world of rapid development of scientific and technical progress and academic thought the Monte Carlo simulation method is applied in credit risk assessment, forecasting the future price of a financial instrument, determining the maximum loss that an investor may incur in an investment, assessment of derivative instruments, and selection and construction of investment portfolios.

In the next section of this paper, the Monte Carlo simulation model will be used and applied to measure and assess the market risk of the foreign-exchange market with the most traded currency pairs. In its essence, the model is a forecast of the future development of the price or the rate of an asset by using random variables with predefined probability distribution. This in practice creates a vast array of options for studying phenomena and processes in different spheres of financial science. It is widely used by a number of large banking institutions to assess market risk. Using the model, they assess and measure market risk or the maximum loss measured in cash equivalents of what has been invested in different types of investment assets

(stocks, bonds, derivatives and currencies in our case). The simulation model includes several stages-steps:

- Collection, processing, systemization and selection of a database - the subject of research. Here, it is worth mentioning that the database is the price dynamics of the respective simulated asset, in this case the exchange rates of the currency pairs CHF / USD, EUR / USD, JPY / USD, CNY / USD and AUD / USD for the period (01.06.2016 - 30.10.2018), on a daily basis.
- After the required information has been collected, we need to calculate the return on each period and then for the entire database. The one period return is calculated as follows:

(2.1.1) $R = LN(\frac{P_t}{P_{t-1}})$,

where:

R is the one period return;

LN – natural logarithm;

P_t – the current price of an asset in period t;

Pt-1 – the closing price of an asset for a past period.

This is the most precise method for calculating the return on exchange rate yields.

The next step in the second stage is to determine the return for the entire period analysed in this paper. The basic way to determine the return is to calculate the arithmetic mean. It is the sum of daily returns divided by their number. The arithmetic mean is calculated according to the formula:

(2.1.2) $R = \frac{\sum R}{N}$,

where:

R is the arithmetic average return for the entire analysed period;

N – the number of observations;

$\sum R$ – the sum of all returns calculated for the respective period.

Next, we need to calculate the risk of the data sample. This is done by using the standard deviation. From statistics basics we know, that the standard deviation is the square of the difference between each return for a given period and the average return over the whole analyzed period divided by the number of counts less one. The formula for calculating the standard deviation is as follows:

(2.1.3) $\sigma = \sum \frac{(R-Rs)\text{^}2}{N-1}$,

where:

σ is the standard deviation;

R – the returns for each period;

Rs – the arithmetic mean return for the entire analysed period;

N-1 – the number of counts less one.

At this stage of the simulation model, we need to determine the distribution of the return. According to Plamen Patev (Patev, 2002, 2008) the returns of the shares of the companies follow a normal distribution. For the exchange rates in the next paragraph of this paper, we can easily identify the existence of a lognormal distribution in the returns. The distribution is determined using the built-in MS EXCEL functions NORMINV and RAND. The first function NORMINV defines the inverse of the normal distribution. With its help, we obtain the simulated mean using the mean return and the standard deviation, calculated in the previous stage. The RAND function presents various random combinations and variations of numeric values with a range of 0 to 1. Each time we press this function, it automatically generates random and different values in the range between (0 and 1).

Essential in using and applying the Monte Carlo model is to make the crucial decision on the number of simulations. According to Alexander Ganchev (Ganchev, 2006), the number of simulations should be 10,000 and this will create a more detailed picture of the possible future values of random quantities and their distributions. Another author working in the field of bank risk management - Georgi Georgiev (Georgiev, 2012) is of the same opinion regarding the number of simulations applied.

In some studies, the authors use a significantly smaller size of simulated variables - 100 and 1000 counts. This is typical of capital budgeting, e.g. in the works of Stoyan Prodanov (Prodanov, 1999) and of Rafailov (Rafailov, 2008) in the assessment of investment projects involving a lot of variables and components. In this study, the number of simulations performed will be 10,000 due to the large number of data analyzed.

The last - the final stage of the practical and empirical application of the Monte Carlo simulation model, is the calculation of market risk. This is done using MS EXCEL built-in functions, in particular - the PERCENTILE function. This function is used to determine market risk as a centile. To apply this function we need a number of simulations performed and a certain confidence interval. The next paragraph will clearly show and define that the increase in the confidence interval also increases the amount of potential market risk.

The main advantages of the Monte Carlo simulation according to Georgi Georgiev (Georgiev, 2012) are:

- Accuracy – gives the full picture of risk;
- Flexibility - allows risk managers to use different theoretical distributions;
- Ability to integrate into various risk modules.

In his textbook on financial derivatives, Stefan Simeonov (Simeonov, 2005) outlines the following main advantages of the Monte Carlo simulation

method in the evaluation of options and other types of derivative financial instruments:

- The simulation is applicable in the case of several variables, while most other derivative valuation models are not applicable in such cases.
- It is expressed in numbers and efficiently, regardless of the number of variables. The timing of the simulation increases almost linearly with the increase in the number of variables.
- There is an advantage of this method in terms of the standard error of the findings as well.

Like any other model, the Monte Carlo simulation also has its drawbacks and negative features. These are best described by Nadya Velinova, the Director of the Litigation and Market Analysis Directorate of the Financial Supervision Commission in the article Risk Rating of a Derivative Portfolio (Velinova, 2008):

- This method very often underestimates and do not account for the big probability changes in the market;
- It is not so easy to determine the sensitivity of the portfolio or the sources of risk as it is presented;
- The implementation of the model takes time.

To the above critical notes on the simulation model, we can add the great number of simulations that not every computer system can calculate. Applying the model requires risk managers to have solid training, skills and knowledge in the areas of statistics, econometrics and information technology. And last but not least, time for performing all computational procedures from the collection of market information (database) to its processing.

2.2. VaR

VaR is the maximum loss that a bank, hedge fund, pension fund, investment company, portfolio company, investment firm and individual investor may incur when investing in shares, bonds, gold, silver, consumer goods (coffee, cocoa sugar , flour, etc.), fuels and, in this case, currencies over a given period at a given confidence interval. VaR is widely used to determine the market risk of the above items mainly for a short period of time. Its main application is to forecast market risk for a future period of time in most cases within a few days. Its calculation comprises several steps:

- Collection of data for implementation of the model. Here again, we use the same data used for the Monte Carlo simulation. The daily data for the exchange rates of the main currency pairs CHF / USD. EUR / USD, GBP / USD, JPY / USD, CNY / USD and AUD / USD for the period (01.06.2016 - 30.10.2018).

- The next stage requires the determination of the weighted arithmetic mean and the standard deviation. The calculation procedure, in short, is identical to the one used in the Monte Carlo simulation.
- An important component of calculating market risk using VaR is to determine the distribution of returns. This is done with the help of the asymmetry and extraction coefficients. They can easily be calculated either with the MS EXCEL SKEW and KURT functions or with the built-in MS EXCEL DESCRIPTIVE STATISTIC function. In this paper, we have used the descriptive statistics function. To provide for a more precise and detailed definetion of the distribution of the data, we have also used the Jarque-Bera coefficient to determine the distribution of the returns on the assets under investigation using asymmetry and skewness.
- The formulas used to determine VaR are as follows:

Relative VaR (%) = $-z*\sigma*\sqrt{t}$,
where:

z – is the predefined by the risk manager confidence interval;
σ – standard deviation;
$\sqrt{t}$ – square root of the predefined time horizon.

Relative VaR (on currency basis) = $-z*\sigma*\sqrt{t}*w$,
where:

z – is the predefined by the risk manager confidence interval;
σ – standard deviation;
$\sqrt{t}$ – square root of the predefined time horizon.
w – the value of the invested capital in a given currency.

Absolute VaR (%) = $\mu*t-z*\sigma*\sqrt{t}$,
where:

μ – is the average return for the analysed period;
z – is the predefined by the risk manager confidence interval;
σ – standard deviation;
$\sqrt{t}$ – square root of the predefined time horizon.

Absolute VaR (%) = $\mu*t-z*\sigma*\sqrt{t}*w$,
where:

μ – is the average return for the analysed period;
z – is the predefined by the risk manager confidence interval;
σ – standard deviation;
$\sqrt{t}$ – square root of the predefined time horizon.
w – the value of the invested capital in a given currency.

The main advantages of VaR for market risk assessment according to Patev & Kanaryan (Patev & Kanaryan, 2008) are the small number of required data and the relatively simple calculation procedure. This, in turn, allows less experienced people to implement the VaR concept and thus to determine and calculate the market risk that may come with a particular business venture.

3. Results from the implementation of the market risk assessment models on the Forex market

3.1. The MONTE CARLO simulation

The results from the implemented simulation model for the needs of this research paper are presented in the tables below:

Table 3.1.1
Results from the Monte Carlo simulation based on the currency pair CHF–USD

Probability	Z-Value	VaR MC
99%	-2,326348	-1,72%
95%	-1,644854	-1,20%
90%	-1,281552	-0,94%

Table 3.1.2
Results from the Monte Carlo simulation based on the currency pair EUR–USD

Probability	Z-Value	VaR MC
99%	-2,326348	-0,68%
95%	-1,644854	-0,48%
90%	-1,281552	-0,38%

Table 3.1.3
Results from the Monte Carlo simulation based on the currency pair JPY–USD

Probability	Z-Value	VaR MC
99%	-2,326348	-1,51%
95%	-1,644854	-1,06%
90%	-1,281552	-0,84%

Table 3.1.4

Results from the Monte Carlo simulation based on the currency pair CNY–USD

Probability	Z-Value	VaR MC
99%	-2,326348	-1,35%
95%	-1,644854	-0,95%
90%	-1,281552	-0,74%

Table 3.1.5

Results from the Monte Carlo simulation based on the currency pair AUD–USD

Probability	Z-Value	VaR MC
99%	-2,326348	-1,46%
95%	-1,644854	-1,02%
90%	-1,281552	-0,80%

From the simulation model used, it can be seen that the size of the potential loss (market risk) increases with the growth in the confidence interval. The highest risk incurs the investment in the pair *CHF–USD* (-1.72%) while the most risk-free investment is in the EUR-USD pair, with the risk below 1% (-0, 68%). For the rest currency pairs, market risk ranges from -1.35% to -1.51%.

3.2. The VaR concept.

Here, it is important to specify that the relevant VaR is set for a 10-day period with several confidence intervals (90%, 95% and 99%), calculated as a percentage. The absolute VaR for a longer period is calculated, as a percentage, over 60 days with several confidence intervals (90%, 95% and 99%).

Table 3.2.1

Results from the implementation of the VaR concept based on the currency pair CHF–USD

Z-Value	Days	VaR in (%)
-2,326348	10	-16,82%
-1,644854	10	-11,89%
-1,281552	10	-9,26%

Z-Value	Days	VaR in (%)
-2,326348	60	-13,60%
-1,644854	60	-9,78%
-1,281552	60	-7,75%

Table 3.2.2

***Results from the implementation of the VaR concept based on the currency pair* EUR–USD**

Z-Value	Days	VaR in (%)
-2,326348	10	-6,26%
-1,644854	10	-4,43%
-1,281552	10	-3,45%

Z-Value	Days	VaR in (%)
-2,326348	60	-7,55%
-1,644854	60	-6,13%
-1,281552	60	-5,37%

Table 3.2.3

Results from the implementation of the VaR concept based on the currency pair JPY–USD

Z-Value	Days	VaR в (%)
-2,326348	10	-15,09%
-1,644854	10	-10,67%
-1,281552	10	-8,32%

Z-Value	Days	VaR в (%)
-2,326348	60	-12,14%
-1,644854	60	-8,72%
-1,281552	60	-6,89%

Table 3.2.4

Results from the implementation of the VaR concept based on the currency pair CNY–USD

Z-Value	Days	VaR в (%)
-2,326348	10	-13,47%
-1,644854	10	-9,52%
-1,281552	10	-7,42%

Z-Value	Days	VaR в (%)
-2,326348	60	-10,48%
-1,644854	60	-7,42%
-1,281552	60	-5,80%

Table 3.2.5

Results from the implementation of the VaR concept based on the currency pair AUD–USD

Z-Value	Days	VaR в (%)
-2,326348	10	-14,14%
-1,644854	10	-10,00%
-1,281552	10	-7,79%

Z-Value	Days	VaR в (%)
-2,326348	60	-12,30%
-1,644854	60	-9,09%
-1,281552	60	-7,38%

3.3. The CVaR model.

Table 3.3.1

Results from the implementation of the CVaR concept based on the currency pair CHF–USD

Probability	CVaR в (%)
99%	-1,71%
95%	-1,20%
-90%	-0,96%

Table 3.3.2

Results from the implementation of the CVaR concept based on the currency pair EUR–USD

Probability	CVaR в (%)
99%	-1,81%
95%	-1,22%
90%	-0,99%

Table 3.3.3

Results from the implementation of the CVaR concept based on the currency pair JPY–USD

Probability	CVaR в (%)
99%	-2,04%
95%	-1,37%
90%	-1,24%

Table 3.3.4

Results from the implementation of the CVaR concept based on the currency pair CNY–USD

Probability	CVaR в (%)
99%	-1,71%
95%	-1,20%
90%	-0,96%

Table 3.3.5

Results from the implementation of the CVaR concept based on the currency pair AUD–USD

Probability.	CVaR в (%)
-1,61%	-1,85%
-1,07%	-1,41%
-0,79%	-1,16%

3.4. The MVaR model.

Table 3.4.1

Results from the implementation of the MVaR concept based on the currency pair CHF–USD

Probability	Z-Value	Zcf	MVaR в (%)
99%	-2,326348	-8,0845	-5,85%
95%	-1,644854	9,4803	6,84%
90%	-1,281552	11,5555	8,34%

Table 3.4.2

Results from the implementation of the MVaR concept based on the currency pair EUR–USD

Probability	Z-Value	Zcf	MVaR в (%)
99%	-2,326348	-2,7589	-0,79%
95%	-1,644854	-1,5635	-0,47%
90%	-1,281552	-1,1049	-0,34%

Table 3.4.3

Results from the implementation of the MVaR concept based on the currency pair JPY–USD

Probability	Z-Value	Zcf	MVaR в (%)
99%	-2,326348	-2,9388	-1,81%
95%	-1,644854	-1,5734	-0,53%
90%	-1,281552	-1,0738	-0,07%

Table 3.4.4

Results from the implementation of the MVaR concept based on the currency pair CNY–USD

Probability	Z-Value	Zcf	MVaR в (%)
99%	-2,326348	-3,9230	-2,27%
95%	-1,644854	-1,6905	-0,98%
90%	-1,281552	-0,9611	-0,56%

Table 3.4.5

Results from the implementation of the MVaR concept based on the currency pair AUD–USD

Probability	Z-Value	Zcf	MVaR в (%)
99%	-2,326348	-2,6409	-1,63%
95%	-1,644854	-1,6710	-1,04%
90%	-1,281552	-1,2352	-0,77%

3.5. The VaR Delta Normal model

Table 3.5.1

Input data for construction of an investment portfolio based on three currency pairs (CHF/USD, CHY/USD, AUD/USD)

Portfolio	100
Counts	1173
Z-Value	-2,32635
Days	10

Table 3.5.2

Results from the construction of an investment portfolio based on three currency pairs (CHF/USD, CHY/USD, AUD/USD)

10-day VaR	CHF/USD	CHY/USD	AUD/USD	Total
Weight	0,333333333	0,333333	0,333333	1
Individual stock VaR	1,772462253	1,419144	1,490098	4,681704
Portfolio VaR				2,544783
VaRBeta	1,39567218	0,40241	1,201918	
VaRBeta*Weight	0,46522406	0,134137	0,400639	1
Component VaR	1,183894063	0,341348	1,01954	2,544783
Portfolio Effect	0,58856819	1,077796	0,470558	2,136922

3.6. VaR historical simulation

Table 3.6.1

Results from the empirical testing of VaR historical simulation for three currency pairs (CHF/USD, CHY/USD, AUD/USD).

CHF/USD	CHY/USD	AUD/USD	Portfolio
-1,84773	-0,68670768	-2,069931154	-3,09309842

Table 3.6.2

Results from the construction of an investment portfolio based on three currency pairs (CHF/USD, CHY/USD, AUD/USD)

10-day VaR	CHF/USD	CHY/USD	AUD/USD	Total
Weight	0,33333	0,333333	0,3333333	1
Individual stock VaR	1,84773	0,686708	2,0699312	4,6044
Portfolio VaR				3,0931
Beta	1,67208	0,14936	1,1785649	
Beta*Weight	0,55736	0,049787	0,392855	1
Component VaR	1,72396	0,153995	1,2151391	3,0931
Portfolio Effect	0,12377	0,532713	0,8547921	1,5113

The implemented scenarios illustrate in tables the impact of the market risk on investment in currency pairs. The VaR concept can be called a "guiding light" for investors. Forecasting market risk for a future period indicates the potential future loss and signals the immediate need of development of a plan and strategy to counteract. Following the Risk Model test, managers of large banking institutions and corporations can take measures directly related to their available capital.To avoid losing their cash (capital), they need to assess, model and analyze market risk in a timely manner for any future investment, which will provide security for their financial resources.

From the empirically rich "bunch" of models and concepts for market risk management and modelling, each of which, at a different confidence interval the time horizon, shows investors in which currency pair it is most appropriate and reasonable to invest their capital. Of the five currency pairs, it is most risky to invest in CHF / USD and JPY / USD currency pairs. The whole range of VaR models - CVaR, MVaR, HS VaR - empirically proves that the most risky investments are in the above-mentioned currency pairs. For more reliable and accurate analyses and forecasts, different confidence intervals and time horizons have been used in this research paper. To achieve

optimal results, we developed and constructed investment portfolios (kind of currency baskets) to achieve risk diversification. With the Delta Normal model, the total size of market risk is dramatically reduced compared to the individual risk characteristics of the individual currency pairs. In numbers, the sum of individual risk components amounted to 4,681,704 and, with portfolio construction, the portfolio's risk was 2,544,783. The figures irrefutably show that investors need to construct portfolios, so, that, even if they do not succeed in neutralising the market risk, at least to limit and minimize their exposure to it. Each of the applied models has its strengths and weaknesses. Their development, empirical testing and implementation in everyday investment practice definitely prove that the tendency in recent years has been to create models with better qualities and advantages than the foregoing ones. Like all other models, the most recent ones also have flaws that motivate the academic community to create new and more reliable models in order to generate results that are more accurate.

4. Findings and conclusions

The research has empirically supported the following results related to the assessment and the calculation of market risk:

- All methods used to analyze and assess the market risk of the foreign exchange market have given very good results.
- Their empirical testing fully confirmed and proved that the Monte Carlo simulation and the concept VaR, CVaR, MVaR, VaR historical simulation, Delta Normal VaR are very suitable instruments to assess market risk.
- The complexity and the ability to use a range of scenarios and variations give the Monte Carlo simulation advantage over the VaR concept. This, in turn, shows a significant number of possible future variants of the expected risk variables.
- On the other hand, the VaR concept provides for an instrument that can be used by a wider range of users to assess market risk because of it is easier to calculate and does not require specific knowledge in the areas of statistics, econometrics and computer technology.
- The great number of variables and the number of simulations requires the use and disposal of high-quality computer software. The VaR concept does not require complex computer systems to be implemented.
- The possibility to apply the VaR concept for different time intervals allow for flexibility and speed in the assessment of the market risk, which in turn gives a quick future period risk forecast. This enables companies'

managers to take measures, which provide for smooth and prosperous operation. This way they will know the maximum loss that an investment can make.

- An essential advantage in constructing the Monte Carlo simulation and in its implementation is that the return on the analysed assets may not follow a normal distribution. This requirement gives a number of managers the freedom to assess the risk without taking into account the existence of changes in the distribution of return over the period under review.
- It is difficult to give an explicit answer to the question of which of the two market risk indicators is more accurate, precise and correct. Both methods have considerable individual advantages, as well as many flaws. To create a full picture of the market risk, both models for its assessment should find their place in the risk managers' analysis. This will ensure a more favourable environment for the company to operate smoothly and normally.
- The CVaR model offsets a number of imperfections of the traditional VaR models. Its primary positive side is that the aggregate risk of an investment portfolio is lower than or, respectively, equal to the sum of the personal risk measures or the well-known in specialised literature notion of sub-additivity. The average loss represented by the model is extremely useful to the investment community. Taking into account the positive and negative values of the standard (normal) probability distribution gives the model merits when it comes to market risk quantification.
- MVaR is a model for market risk measurement and assessment. Although it is used to assess the hedge funds risk positions (Ganchev, 2012), its methodology can also be used to empirically determine market risk. Its main constituent elements are asymmetry and skewness, with the help of which, following a given method, its confidence interval is determined. The empirical testing presented here has undoubtedly demonstrated its practical usefulness and integrity in measuring the risk characteristics of various assets - in our case currency pairs.
- Delta Normal VaR assists in the construction and use of investment portfolios to help diversify the overall market risk of several currency pairs – here of a three-currency pair model. The creation of a currency basket allows the minimization of market risk compared to the individual risk values of individual assets. This is done using the different correlation coefficients of the assets in the portfolio. The relation of the individual currency pairs allows the formation of a currency basket with better risk characteristics. This is an important contribution of this concept. The ranging of the individual currency pairs facilitates the determination and the assessment of the market risk.
- From the empirical analysis of the main models for market risk assessment in the foreign exchange market, we can arrive at the conclusion

that each risk model has its advantages and disadvantages. To achieve more favourable results when forecasting the future value of market risk, investors must use all models of market risk assessment, both in parallel and in combination, to make well-grounded and well-reasoned investment decisions. This will provide for the security of their personal capital resources.

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