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Variance – Covariance Risk Value Model for Currency Market

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Developing international market increases the number of international payments. At the same time the number of currency exchange transactions also increases. Every year the amount of exchange operations grows together with the profits of market participants. The majority of these market participants faces currency exchange rate fluctuations, because there is a lack of currency rate forecasting model helping to operate on the market profitably for a longer period. This influences the need for various currency rate risk management models development.

Investing in international currency market, it is very important to know what types of risk can be met and what level of risk is related with one or another currency position opening. That is why for selection of investment decisions it is very important to estimate and manage risk. For risk valuation different mathematical – statistical methods are used, however, most of them estimate risk separated from the trade model and with known trade results. It is not an occasion that models become more popular. This allows to valuate risk in advance, moderate it and calculate possible foreign currency positions.

Paper analyzes possibilities of risk management using value at risk (VaR) methods, theoretical presumptions of VaR method applications are also discussed. The authors of this paper present complex variance – covariance VaR model, which allows to moderate rate risk of a given currency. Proposed model is tested using regressive testing with real currency market data, aiming to estimate the reliability level of the proposed model. Calculation data allows to make conclusions that model is reliable and ready for practical use.

Keywords: *currency rate risk, currency rate risk management, risk value, risk valuation models, value at risk.*

Introduction

Researchers propose different ways for solving currency rate forecasting problem, which is actual for the majority of international market participants. One of the most popular proposed tools is technical analysis, that was started to be applied at the end of the 19th century and is successfully applied till these days. The main shortcomings of technical analysis are named as their uncertainty and ambiguity. Majority of technical analysis researchers and practices (Eng, 1988; Niemira, Zukowski, 1994; Frost, Prechter, 1998; and others) aimed to describe mathematically technical analysis methods and in this way to develop almost automated trade systems (strategies) delivering one-way currency trade solutions or signals. However, there is no absolutely acceptable and applied model for all currency market situations in the world, as at the same time the market could possibly lose its profitability because of this model existence. Technical analysis researchers improve this methodology all the time to include state of the art tendencies of the market.

It is also very important to evaluate acceptable risk level when investment models are analyzed. For risk valuation different mathematical – statistical models are used too. But most models estimate risk separately from trade models and usually with already known trade results. That is why some models become more popular and allow to valuate risk, moderate it calculating highest possible open foreign currency positions. In this case, only integration of risk management and trade parts leads to profitable investing in currency markets.

Risk management analysis is widely discussed by Lithuania's researchers such as Vaškelaitis (2003), Titarenko (2000), Grigaravičius (2003), Mackevičius (2005) and others. Recently risk management, especially market risk management, was analyzed by Dzikevičius (doctoral thesis "Trading portfolio risk management in banking", 2005). Many foreign authors analyzed this topic (Altman, Brady, Resti and Sirini, 2005; Bessis, 1998; Heffernan, 2005; and others).

However, the majority of authors analyze risk on the general basis or take only separate elements of risk. Usually risk management aspects are analyzed separately from investment decision selection problems. That is why there is a lack for complex model moderating acceptable investment risk level and giving buy – sell signals.

The aim of the paper – to construct a variance – covariance currency rate risk management model.

Research object – currency rate risk management methods.

Research methods. Currency rate risk analysis with the help of a variance – covariance risk value (VaR) management model.

Value at risk (VaR) methods

Risk management is one of the most important every company's managerial tasks especially in commercial banks sectors. In recent years risk management questions in the global and Lithuania's context were defined as priority issues of management (Kazlauskienė, Christauskas, 2007). Effective risk valuation for commercial bank increases its value on the market and confidence between potential investors (Strumickas, Valančienė, 2006). Over the last years the majority of commercial banks operating in Lithuania adjusted their risk management procedures according to VaR methodology (Nedzveckas, Aniūnas, 2007). This influences the need for summarizing the main VaR methods' descriptions and their classification. Risk value concept can be explained as the highest possible loss of separate position or trade portfolio, influenced by market parameters change over selected or holding period with acceptable confidence level.

Value at risk methods are most advanced modern methods which allow to measure foreign currency rate risk. These methods encompass sensitivity and volatility measuring tools together with negative uncertainty influence measurement possibilities.

Value at risk methods were started to be applied in financial institutions and big companies. In 1994 concept of value at risk was applied in J. P. Morgan created CreditMetrics methodology, later in RiskMetrics, or in "Bankers Trust" - RAROC models. This concept was widely spread and such companies as "Xerox", "Enron", "General Motors" and other created their own methodologies (Berkowitz, 2002)

Mathematically this methodology was defined by Duffie and Pan (1997) (Equation 1): value at risk – possible highest loss of separate position or portfolio over period t, which will be exceeded with probability (l –p). This methodology is comparatively new but widely accepted in the world.

$$\text{VaR} = \alpha\sigma_p\sqrt{\Delta t} \qquad (1)$$

In equation:

Δt - holding period for financial asset;

α - confidence interval constant (value of Laplace function) for normal distribution value is taken from tables (for instance, when confidence level is 99 percent, $\alpha = 2.33$);

σ_p - standard deviation of portfolio profitability.

Value at risk methodology allows to apply common risk valuation metrics for financial assets using risk management software. Results obtained using this methodology are clearly understandable, however, it might be difficult to calculate them. The methodology can be applied valuating risk for separate instrument position or portfolio. Value at risk is the most advanced contemporary method, used in various financial institutions.

Basel Committee of Banking Supervision, USA Federal Reserve System and USA Stock Committee in 1995, European Union Capital Requirements Directive in 1996 proposed to use value at risk method as one for market risk management. This method is also accepted by the Bank of Lithuania.

Value at risk (VaR) concept is based on statistical methods and used to define the possible losses for trade position or portfolio, influenced by market rate and price fluctuations, using defined confidence interval (usually from 95 to 99 percent), for a defined period (Bessis, 1998).

VaR calculation process is organized in five stages:

1. Identification of current position for the institution.
2. Identification of risk factors related with the valuation of these positions.
3. Identification and assignment of scenario possibilities for these risk factors.
4. Definition of all positions pricing function as a value function for risk factors.
5. Marking of positions in all scenarios using pricing function and obtaining results distribution.

Very important step in calculating value at risk is a correct evaluation of position size. It is more complicated to do with debt instruments in comparison to stock valuation. Calculating VaR all positions have to be evaluated at the current value. Stock and currency positions are such at the same moment. Every instrument has its market price, depending on time to maturity, becoming shorter every day. Practically, it is not possible to calculate every market instrument earnings fluctuation, because it is almost impossible to find reasonable historical data for it. Solving this problem can be addressed to changing the instrument with analogous instrument with similar risk parameters but longer data history.

VaR methods require historical data for comparatively long time period in order to estimate fluctuations of financial instrument. At the same time value at risk method has its advantages and disadvantages.

Advantages of VaR methods according Heffernan (2005), Kudinska (2003), and others:

1. Easy to understand.
2. Easy to apply calculating different complexity levels and portfolios, also can be applied for risk concentration valuation according traders, markets instruments.
3. Valuates differently even very complex movements of related instruments, at the same time estimating risk decrease because of diversification.
4. Can be applied for limits determination because links loss value with probability.
5. Results are easily compared, allowing to measure activity effectiveness of traders.

Disadvantages of VaR methods according Charles and Miller (2001), Heffernan (2005), and others:

1. Calculation methodology can be very complex and difficult to understand in comparison to results obtained.
2. Extensive data blocks are necessary for calculations;

3. Methods are based on presumption that profitability is distributed according normal distribution function, however it is not correct in all cases.
4. Methods are based on presumption that future can be reflected by historical data for forecasting, but this is not always the truth.
5. Value at risk limits do not help if unexpected price fluctuations are happening, it means that methods are used under "normal" conditions.
6. Methodology ignores operational and liquidity risks. Every less liquid position can be brought to separate liquidity levels depending on liquidity cost level (for instance, 0-5 percent, 5-10 percent, etc. from current market value).
7. Methodology does not help to select instruments for portfolio formation, but only shows possible loss.

Classification of VaR methods

Though existing VaR methods uses different methodologies, all of them have the same core structure, which is defined by 3 features: 1) portfolio should be identified on the market; 2) it is necessary to estimate distribution of portfolio profitability; 3) calculation of VaR for portfolio (Manganelli & Engle , 2002).

The main differences between VaR methods are related with the second point, how they are solving possible portfolio value fluctuation measurement problems. Existing models can be classified in 4 groups (Manganelli and Engle, 2002):

- parametrical (RiskMetrics and GARCH);
- non-parametrical (historical simulation and hybrid model);
- semi-parametrical (extreme value theory);
- other (CAViaR, quasi-maximum similarity GARCH).

The results obtained using these methods calculations can be very different. Beder (1995) applied different VaR methods for three hypothetical portfolios. Analysis revealed difference in the results for the same portfolio in 14 times. It shows that in order to understand what methodology to select, it is necessary to analyze models' presumptions and quantitative characteristics. Only after this first step the right method for defined targets will be chosen (http://www.riskglossary.com/link/var_measure.htm).

One of the most commonly used VaR valuation methodologies is historical simulation. This method simplifies risk value calculation procedure because it does not require any distribution presumptions about portfolio profitability. Historical simulation is based on "moving window" methodology. Observation window is selected in the first stage, usually it encompasses from 6 months to 2 years. Then, profit of the portfolio is ranked in increasing manner and necessary quintile is presented according contiguous observation results. Calculating of next day VaR the window is moved by one observation and the procedure is repeated.

VaR model is a powerful tool for market risk valuation, but at the same time it is also a great challenge. All liquid assets have unspecified market values, what can be described by probability distribution functions. All risk sources come into these functions. Because VaR can be applied for all liquid assets and theoretically encompassing all risk sources, it is a wide risk measurement tool (Berkowitz and O'Brien, 2002).

In order to evaluate market risk of portfolio using VaR, market value fluctuation probability distribution has to be defined. This task becomes more complex if the portfolio consists of different assets categories and risk sources at the same time.

Many studies are made for data transformation procedures, but 4 main forms can be abstracted (Kancerevyčius, 2004):

- *linear* transformations;
- *square* transformations;
- *Monte Carlo* transformations;
- *historical* transformations.

Linear transformations are simple and real-time. They can be applied when portfolio function is linear polynomial. Square transformations are slightly sophisticated but also real–time. They are applied only when portfolio function is square polynomial. Monte Carlo and historical transformations are widely used but consume a lot of time for calculations. These two functions differ only with obtained results. Monte Carlo transformations use pseudo random number generator and historical transformations use information from market historical data (http://www.gloriamundi.org).

VaR methodology classification and the main requirements for the application in The Bank of Lithuania

In Lithuania qualitative and quantitative requirements for VaR models are formulated only by The Bank of Lithuania. That is why VaR methods are applied in credit institutions, usually in commercial banks. Commercial banks have to pursue strict requirements of the Bank of Lithuania in order to be accepted by their VaR methodology. Approved VaR method in the bank of Lithuania can be used by the commercial bank for delivered ratios calculations and to estimate capital requirements. But it should be noticed that for internal VaR calculations banks are using different methodologies, which are not corresponding to the Bank of Lithuania requirements and approved models. However complying capital sufficiency requirements and using VaR method commercial bank can estimate more precisely capital need for market risk covering. Using VaR method foreign currency rate, market interest rate, equity securities', stock price fluctuations risk can be estimated. VaR method helps to diversify risk and sustain effective risk management process in bank. The Bank of Lithuania (2002) in described methodology presents classification of VaR methods:

- *variance - covariance method;*
- *historical simulation method;*
- *Monte Carlo simulation method.*

Commercial bank can choose what method will be applied for its financial tools risk evaluation.

Variance – covariance method (sometimes called parametrical, analytical, matrix or enclosed form VaR). Valuating foreign currency rate risk with this method, systematized historical data about currency rate changes are used together with their correlation coefficients. But also using this model statistical, information reliability and political factors influence should be estimated.

The problem may arise because of huge amount of information. For instance, making an assumption that currency rates change according normal distribution function, calculating distribution of values for 6 currencies portfolio results, 27 parameters are needed (6 mathematical means, 6 dispersion values and 15 covariance results). Usually company's currency portfolio is less diversified and in this cases the need of data amount decreases. Using only historical data, important information from current situation on the market can be lost, but inclusion of new information requires changes in coefficients, or to change valuation schemes to calculate these coefficients. Thus, the method is more adopted for relatively constant and predictive currency rate risk valuation.

Historical simulation method is the method using data about changes of risk factors in the past over period analyzed. Historical simulation helps to estimate currency rate changes what might happen over a simulation period. This method has several advantages in comparison to variance – covariance method. Firstly, there is no need for presumptions about variables distribution, because calculated risk value with the defined confidence level is the loss of certain portfolio over period. Secondly, there is no need to calculate every position's dispersion and covariance. Thirdly, there is no need for random corrections when simulation details are defined.

The main disadvantage of this method is that measuring foreign currency rate risk current information is not used and information about market environment changes is not included.

Monte Carlo simulation method is the method which is applied for simulation of various market risk changes scenarios. Every scenario crates possible financial asset risk value over a selected period in the future. Risk value using this method is calculated from many simulated currency rate trajectories. In the general case currency trajectories are simulated using dynamic programming model, entering big amount of random information leaps (random information also requires some predictions to be made). If price change model is correct, it is possible to calculate very precisely risk value. The advantage of this model is that it uses the newest possible data about currency rate changes from the market. Thus, if dynamical model is not correct, calculated value will be also incorrect. The number of selected scenarios may reach up to 5-10 thousands.

Methods applied by the Bank of Lithuania can be compared (Table 1).

When calculating capital sufficiency normative a commercial bank can apply VaR method if it corresponds to qualitative standards formulated by the Bank of Lithuania (the results of VaR method are included into every day risk management process. There are also defined VaR method observations and control procedures, ensuring general bank risk management policy following, etc.).

Table 1

Comparison of the main VaR methods

Criterions	Variance – covariance method	Historical simulation method	Monte Carlo simulation method
Simplicity	Simple	Average simple	Complex
Applicability	Easy to apply	Easy to apply	Complex
Calculation rate	Instant	Average	Slow
Distribution presumption	Normal distribution	No	Normal distribution
Number of factors	Limited	Non - limited	Limited

Source: constructed by the authors.

Quantitative VaR methodology standards

According to the requirements of the Bank of Lithuania approved by Board of the Bank in 2002, commercial bank calculating capital sufficiency normative can use VaR method if it satisfies these quantitative standards:

1. Market risk is estimated every day using VaR method.
2. VaR method uses these assumptions:
   - 99 percents confidence level;
   - 10 working days holding period;
   - no less than 250 working days historical data (a shorter period can be justified only for higher price fluctuation observations);
   - data is reviewed every day;
   - correlation between market risk categories and out of market risk categories can be applied if bank demonstrates that correlation measurement system is fully implemented;
   - method encompasses significant risk appearing for option or similar contracts.

Bank VaR method quality is valued using back testing methodology. Using this methodology each working day net result – income (loss) is compared with calculated VaR method result. If actual result ($R_{act.}$) exceeds calculated with VaR result ($VaR_{calc.}$), it means that VaR method is not precise enough. Every time when actual result exceeds calculated with VaR results deviation is recorded:

$$\text{Deviation} = R_{act.} - VaR_{calc.} > 0 \qquad (2)$$

Formal registration of deviations should start no later than the first day after VaR method application beginning. Large number of deviations shows that VaR method is not precise enough and has to be improved.

Construction of variance – covariance risk value model

Application of VaR methodology for currency risk management allows to moderate currency positions up to acceptable level. Based on indicators and investment strategies back testing results, complex investment model for investing in global markets is constructed.

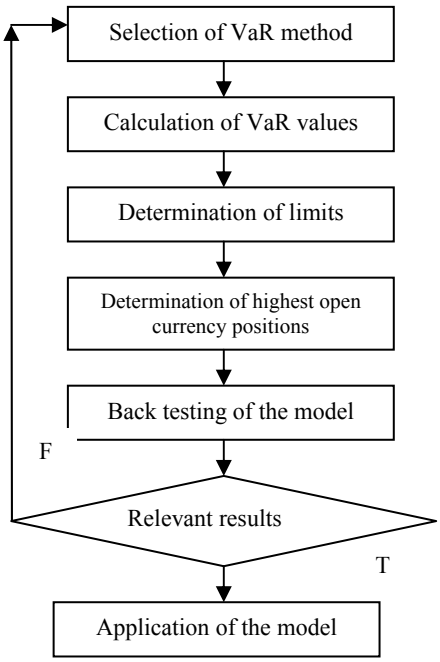

Figure 1. Logical sequence of the model

This enables to select investment decisions based on profitability and confidence level calculations. Also, model allows to generate revenue from investments in currency markets with acceptable risk level. Model integrates several investment strategies, indicators and risk management methods what leads to the testing results exceeding standard models' results. Constructed model's core scheme is presented in the Figure 1. The main stages of the model construction are described in the following parts of the paper.

Risk valuation using the constructed model

For risk valuation and management authors propose to use adopted variance – covariance model, in which risk value of financial assets is calculated using collected data about previous period market risk factors (historical data). Risk is valued for each currency position separately. Risk value calculation in this case can be performed by refined variance – covariance methodology formula:

$$R_i = P_i \cdot \sigma_i \cdot K \cdot \sqrt{T} \qquad (3)$$

In the formula:

P_i - value of *i* currency;

σ_i - standard deviation for currency rate, calculated using formula:

$$\sigma_i = \sqrt{\frac{n\sum Y_i^2(t) - \left(\sum Y_i(t)\right)^2}{n(n-1)}}. \qquad (4)$$

$Y_i(t)$ - artificial numbers of currency rate;,

n – size of data set;

$$Y_i(t) = \begin{cases} \ln\left(\dfrac{X_i(t)}{X_i(t-1)}\right) \\ \ln\left(\dfrac{1}{X_i(t-1)}\right), \quad if\ X_i(t) = 0 \\ \ln\left(X_i(t)\right), \quad if\ X_i(t-1) = 0 \end{cases} \qquad (5)$$

K – constant (quintile), where:

K=2.326 with confidence level equal to 99 percent;

K=1.645 with confidence level equal to 95 percent;

T – time horizon. This dimension can be chosen, standard value in the model is 24 hours.

Calculation of the highest acceptable losses with the proposed model

For foreign currency trade in the market between banks and open currency position holding the highest possible annual loss level is determined. Other losses are calculated using these annual numbers. Half of the year losses are equal for half of the annual loss. Starting monthly loss is equal to half of the year loss amount. Later monthly loss is calculated as follows:

$$L_{month} = \begin{cases} \dfrac{L_{half}}{2}, & if\left(\dfrac{pmR}{2} + pmL\right) \geq L_{half} \\ \dfrac{pmR}{2} + pmL, & if\left(\dfrac{pmR}{2} + pmL\right) < L_{half} \end{cases}. \qquad (6)$$

$L_{month.}$ – monthly loss level;

$L_{half.}$ – half - year loss level;

pmL – previous month loss level;

pmR – previous month result.

Starting loss for one week is equal to the half of monthly loss. Later loss for one week is calculated as follows:

$$L_{week} = \begin{cases} \dfrac{L_{month}}{2}, & if\left(\dfrac{psR}{2} + psL\right) \geq L_{month} \\ \dfrac{psR}{2} + psL, & if\left(\dfrac{psR}{2} + psL\right) < L_{month} \end{cases}. \qquad (7)$$

$L_{month.}$ – monthly loss level;

L_{week} – one week loss level;

pwL – previous week loss level;

pwR – previous week result;

Starting loss for one day is equal to the half of one week loss. Later loss for one day is calculated as follows:

$$L_d = \begin{cases} \frac{L_{week}}{2}, & if \left(\frac{pdR}{2} + pdL \right) \geq L_{week} \\ \frac{pdR}{2} + pdL, & if \left(\frac{pdR}{2} + pdL \right) < L_{week} \end{cases} . \quad (8)$$

L_{week} – one week loss level;
L_d – one day loss level;
pdL – previous day loss level;
pdR – previous day result;

Calculation of open currency position limit with the proposed model

After the highest acceptable one day loss level is calculated, next step is related with open foreign currency position calculation. When acceptable loss level and VaR values for currency pairs are known, the highest allowable currency position can be estimated. Calculated one day loss, depending on investor needs, can be treated in different aspects. Usually financial institutions use these approaches (Bessis, 1998):

- Normally active currency trade in financial institutions lasts for 8 hours per day, only low level positions are left over night. In this case calculated one day loss is divided into two parts – loss level for working day (for instance, can form 90 percent of one day loss) and night (for instance, can form 10 percent of one day loss). The sum of working day's and night's losses has to form one day loss level. Based on calculated one day loss level and 8 hours length forecasting horizon, one day open currency position limit can be calculated. Based on calculated night loss level and 16 hours horizon, one night open currency position limit can be calculated.
- Other financial institutions perform active trade 24 hours per day (technically it is solved by all-time dealer duty or providing dealers to track market and make operations from home). On the other hand, institutions operating using the first approach, dealers are leaving "stop-order" for a night (orders to buy or sell currency if determined currency rate level will be reached), that is why deals can be made during the night. According to this approach, working day loss level is not estimated, then VaR value for 24 hours horizon is calculated.

Corresponding the loss level, highest open position for each currency is calculated. If VaR value for currency is lower than acceptable loss level, value of portfolio can be increased or vice versa. The highest open currency position is calculated using the formula:

$$MAXP_i = \frac{(L - VAR_{LTL})}{VaR_i \times K_i} \cdot P_i . \quad (9)$$

$MAXP_i$- the highest allowable i^{th} currency open position;
VAR_i- i^{th} currency VaR value;
P_i- open position for i^{th} currency;
L- acceptable loss level;
VAR_{LTL}- accumulated VaR value in LTL for all currencies;
K_i- i^{th} currency rate.

When the highest allowable open currency positions are calculated the construction of risk management model is finished. Next step, related with model's reliability, will be back testing with historical currency market data. Only if positive testing results are obtained, it can be stated that the model is reliable and applicable.

Reliability testing for the constructed model

The constructed model is tested using real market data. Usually for variance – covariance VaR models, back-testing methodology is used. In this case VaR model is tested with historical data and if the number of deviations fall into confidence interval, VaR model's feasibility is acceptable and it can be used.

Proposed VaR model was tested with 8 main currencies, which are used in the majority of speculative trades. List of the main currencies is presented in Table 2. Euro for testing was selected because it is used as the base currency and Litas (LTL) rate is connected with Euro by fixed rate. that is why, performing trade operations in Lithuania, calculation results should be transformed to Euro or national currency LTL. It should be noticed that back testing results obtained using Euro were the same as using LTL.

Table 2

Currencies used for back testing

Currency	Currency code
USA, Dollars	USD
Great Britain, Pounds	GBP
Japan, Yen	JPY
Switzerland, Francs	CHF
Canada, Dollars	CAD
Australia, Dollars	AUD
Norway, Krone	NOK
Sweden, Kronor	SEK

When currencies are selected, the main parameters for VaR model testing should be selected too. The set of parameters is presented in Table 3. Confidence interval is selected equal to 95%, because it is commonly used in commercial banks of Lithuania for internal currency rate risk valuation despite that the Bank of Lithuania in its methodology recommends to use no less than 99% confidence level. 24 hours – one day time horizon is selected. The constructed VaR model will show currency rate fluctuation per day and for the highest rate fluctuation the highest possible loss will be determined. One day time horizon is selected because of acceptable one day loss level selection (methodology described early in the paper) and the allowable open currency position calculation for dealers. Separation into working day and night would bring additional over information for testing and burden calculation.

Size of data set shows how much data will be used

for certain VaR value calculation. In this analysis 1 000 historical data items were used for each VaR value calculation. It makes calculations complicated, but allows to obtain more accurate and at the same time not too high VaR values. Large size of data set sleeks currency rate variation curves, but on the other hand forces VaR model to remember critical points where noticeable changes in rates are tracked. It is also accepted that using size of data set equal to 1000, VaR models accuracy is sufficient (Berkowitz, 2006).

Hourly data was used in calculations and time horizon was applied in the same units (hours). Testing period from the beginning of 2006 till the end of September 2007 was selected.

Table 3

Main parameters of tested VaR model

Parameter	Value
Confidence level	95%
Time horizon	24 val.
Size of data set (number of historical data used for VaR calculation)	1 000
Data periodicity	1 hour
Testing period	01.01.2006 – 31.09.2007

Large number of deviations reveals that VaR model is not accurate enough and should be improved. Back testing results of the main currency pairs with Euro and deviations are presented in Table 4.

Table 4

Number of deviations for VaR model back testing

Data	USD	GBP	JPY	CHF	CAD	AUD	NOK	SEK	Total
2006.01	11		2	1	7	7	1		**29**
2006.02	17	20	25	20	19		10	17	**128**
2006.03		2	4				1		**7**
2006.04	12	1	6	20	13	13	8		**73**
2006.05	9	3	10	9	6	17	2	1	**57**
2006.06	3	2			7	5	6	7	**30**
2006.07	3	7		3	2	1			**16**
2006.08	3	12	7	0	14	16	13	9	**74**
2006.09	0	15	30	28	5	11	24	5	**118**
2006.10	12	0	1	0	1	1	4	1	**20**
2006.11	10	0	2	3	9	6	7	1	**38**
2006.12	3	2	10	1	9	1	0	1	**27**
2007.01	0	14	14	0	2	2	13	1	**46**
2007.02	1	19	2	1	10	0	0	14	**47**
2007.03	7	7	11	3	12	11	0	0	**51**
2007.04	0	5	1	0	0	0	4	3	**13**
2007.05	6	20	6	21	29	20	2	5	**109**
2007.06	6	0	4	0	0	0	13	15	**38**
2007.07	18	5	10	7	3	12	7	0	**62**
2007.08	9	0	13	10	0	25	1	1	**59**
2007.09	2	4	0	0	0	4	0	0	**10**
Total	**132**	**138**	**158**	**127**	**148**	**152**	**116**	**81**	**1052**

Number of deviations differs for different months, however, it can be noticed that there are some trends:

- For some currencies calculated VaR values were more close than for the other (over testing period number of deviations in currency pairs was fluctuating from 148 cases in EUR/CAD pair to 81 case in EUR/SEK pair). This reveals that some currencies can be determined as more fluctuating in relation to Euro (at the same time LTL in this case). On the other hand, it should be noticed that large deviations were not observed, what shows the similarities of VaR models results for all analyzed pairs.
- For some periods an increased number of deviations is observed (over a testing period a number of deviations in different months noticeably diverge from 7 cases in March 2006 to 128 cases in February 2006). This fluctuation of results is related with general market volatility.

Still homogenous conclusions about deviation number can be made only by calculating deviation percentage. Deviation percentage is calculated as ratio between deviation and all cases analyzed over period. Calculation results are presented in Table 5.

Table 5

VaR model back testing deviations' percentage

Data	USD	GBP	JPY	CHF	CAD	AUD	NOK	SEK
2006.01	1.48%		0.27%	0.13%	0.94%	0.94%	0.13%	
2006.02	2.71%	**3.18%**	**3.98%**	**3.18%**	**3.03%**		1.59%	2.71%
2006.03		0.27%	0.54%				0.14%	
2006.04	1.67%	0.14%	0.83%	2.78%	1.81%	1.81%	1.11%	
2006.05	1.22%	0.41%	1.36%	1.22%	0.82%	2.31%	0.27%	0.14%
2006.06	0.42%	0.28%			0.98%	0.70%	0.84%	0.98%
2006.07	0.40%	0.94%		0.40%	0.27%	0.13%		
2006.08	0.42%	1.67%	0.97%	0.00%	1.94%	2.22%	1.81%	1.25%
2006.09	0.00%	2.12%	**4.25%**	**3.97%**	0.71%	1.56%	**3.40%**	0.71%
2006.10	1.65%		0.14%		0.14%	0.14%	0.55%	0.14%
2006.11	1.40%		0.28%	0.42%	1.26%	0.84%	0.98%	0.14%
2006.12	0.40%	0.27%	1.34%	0.13%	1.21%	0.13%		0.13%
2007.01	0.00%	1.88%	1.88%		0.27%	0.27%	1.75%	0.13%
2007.02	0.15%	2.83%	0.30%	0.15%	1.49%			2.09%
2007.03	0.94%	0.94%	1.48%	0.40%	1.62%	1.48%		
2007.04	0.00%	0.69%	0.14%				0.56%	0.42%
2007.05	0.82%	2.74%	0.82%	2.87%	**3.97%**	2.74%	0.27%	0.68%
2007.06	0.88%		0.59%				1.91%	2.21%
2007.07	2.54%	0.71%	1.41%	0.99%	0.42%	1.69%	0.99%	
2007.08	1.23%		1.78%	1.37%		**3.42%**	0.14%	0.14%
2007.09	0.31%	0.62%				0.62%		

Results of the Table 5 can be treated as reliable. Why? VaR models calculations were made with 95% confidence level and deviation percentage in any should not have to exceed 5%. Data in Table 5 demonstrates that neither currency pair over-passed this margin during the period analyzed. However, application practice of VaR models require higher quality. The

attitude is that deviation percentage should not exceed 3% (Coleman, 1994). In Table 5, theses cases are marked (bold). If this margin is over-passed, it is recommended to perform deviations analysis and to assure models reliability. It should be noticed that in EUR/USD pair deviation percentage was not over-passed in any case.

After case analysis when deviation percentage exceeded 3% margin, some trends in fluctuations were noticed:

- "Real" deviations for rapid changes in currency rates on the market VaR models results for anticipated change were too small;
- "Occasional" deviations for longer periods of different seasonal occasions currency rates are fixed, however, various fundamental events influencing currency rates happen. In such cases currency rate after seasonal occasions is opened with "gap" and variance is registered;
- "Poor data" deviations - FOREX data, especially that are free of charge, are not absolutely reliable, sometimes different technical mistakes can be found there and it generates variances.

Taking into account that part of deviations are false or partially false, it can be stated that back testing results are reliable. Summarizing deviations' analysis Table 6 presents data, depicting average deviation percentage in analyzed pairs that was about 1% (and it is a good result). Higher deviation during analyzed period were observed only in EUR/JPY, EUR/CAD and EUR/AUD currency pairs.

Table 6

VaR model back testing results

	USD	GBP	JPY	CHF	CAD	AUD	NOK	SEK
VaR deviations	132	138	158	127	148	152	116	81
Cases analyzed	12072	12072	12072	12072	12072	12072	12072	12072
Deviation percentage	1.09%	1.14%	1.31%	1.05%	1.23%	1.26%	0.96%	0.67%

Summarizing model testing results, it can be stated that the model approved itself and obtained results are reliable, and this model is recommended for application.

Conclusions

1. Value at risk (VaR) methods are one of the most advanced tools for risk valuation, enabling to moderate acceptable risk. There are variety of risk valuation methods, however, they are classified according to different factors. One of the classification methods, approved by the Bank of Lithuania, groups risk valuation into tree categories: variance - covariance method, historical simulation method and Monte Carlo simulation method.
2. This paper suggests to apply variance – covariance risk value model and presents risk value together with loss level calculation methodology. Measuring foreign currency rate risk with the proposed model, historical data was used about currency rate changes and their correlation coefficients. However, using only historical data, important current market data may be not included, but, if it is included, coefficients have to be changed or evaluation scheme modified to calculate these coefficients. The model proposed approved its reliability measuring risk of the main currency pairs.
3. Proposed variance – covariance risk value model was tested using back testing methodology with real market data for the period 01.2006 – 09.2007. Results of the testing revealed that critical margin of 5 percent deviation was not over-passed by any tested currency for any period. EUR/USD currency pair have not over-passed even 3 percent margin. These results approve VaR model possibilities in managing currency rate risk.

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Variacinis-kovariacinis rizikos vertės modelis valiutų rinkoje

Santrauka

Investuojant tarptautinėje valiutų rinkoje, labai svarbu žinoti, su kokiomis rizikomis susiduriama ir kokio dydžio rizika yra susijusi su viena ar kita pozicija. Todėl, priimant investicinius sprendimus, būtina vertinti su jais susijusią riziką, mokėti ją apskaičiuoti ir valdyti. Siekiant sėkmingai dirbti pasaulinėje valiutų rinkoje, tenka nuolat kurti naujus valiutų kursų kitimo rizikos valdymo metodus. Garsiausi šią problemą nagrinėję užsienio autoriai yra Altman, Brady, Resti and Sironi (2005), Bessis (1998), Heffernan (2005) ir daugelis kitų.

Gana plačiai rizikos valdymo klausimai nagrinėjami ir Lietuvoje: Vaškelaičio (2003), Titarenko (2000), Grigaravičiaus (2003), Mackevičiaus (2005) ir kitų darbuose. Pastaraisiais metais rizikos valdymo (ypač rinkos rizikos valymo) srityje daug darbų paskelbė A. Dzikevičius (2005 m. apginta disertacija „Prekybinio portfelio rizikos valdymas banke“). Tačiau daugelis tiek lietuvių, tiek užsienio autorių nagrinėja rizikos valdymą bendru mastu arba tik tam tikrus rizikos valdymo aspektus. Dažniausiai rizikos valdymo aspektų nagrinėjimas nesusietas su investavimo sprendimų priėmimo problematika, todėl galima teigti, kad kompleksinio modelio, leidžiančio įvertinti prisiimamą investicinių sprendimų riziką ir pateikti pirkimo ir pardavimo signalus, kol kas nėra paskelbta.

Darbe pasiūlytas rizikos vertės modelis valiutų rizikai valdyti leidžia apriboti valiutų pozicijas tiek kad jos taptų priimtinos. Remiantis indikatorių ir investavimo strategijų testavimo rezultatais, sudarytas kompleksinis investavimo pasaulinėse rinkose modelis, leidžiantis pelningiau ir patikimiau investuoti pasaulinėse valiutų rinkose ir pasirinkti optimalų pozicijos dydį.

Straipsnyje nagrinėjamos valiutos kurso rizikos valdymo rizikos vertės (*ang. Value at Risk – VaR*) metodais galimybės, aptariamos teorinės VaR metodų prielaidos ir jų taikymo galimybės praktikoje. Straipsnyje pasiūlytas kompleksinis variacinis-kovariacinis VaR modelis, kuris leidžia apriboti prisiimamą valiutos kurso riziką. Pasiūlytas modelis testuojamas (atgalinio testavimo metodu), taikant realius valiutų rinkos duomenis, kad įsitikintume modelio patikimumu. Gauti rezultatai leidžia teigti, kad modelis pakankamai patikimas ir taikytinas praktikoje.

Šio straipsnio tikslas – sudaryti valiutų kursų rizikos valdymo modelį, kuriuo pasirėmus būtų galima:

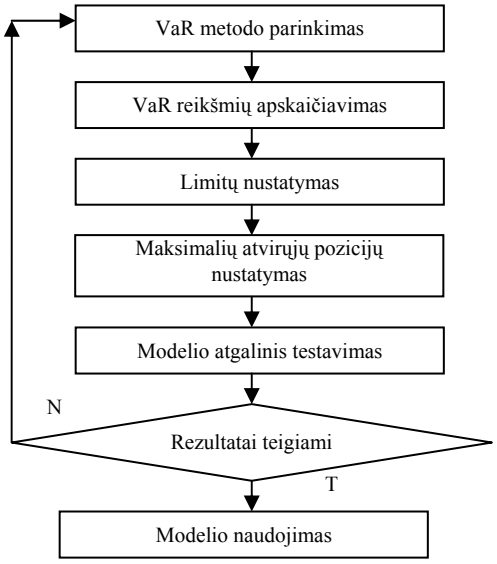
1) įvertinti galimų valiutų kursų svyravimų rizikos lygį;

2) apskaičiuojant maksimaliai galimas atviras užsienio valiutų pozicijas, apriboti galimos rizikos lygį.

Straipsnyje valiutų kursų rizika vertinama variaciniu-kovariaciniu rizikos vertės VaR metodu.

Rizikai vertinti ir valdyti siūloma taikyti variacinį-kovariacinį metodą. Rizika vertinama kiekvienai valiutai atskirai. Prekybai valiutomis tarpbankinėje rinkoje ir atvirųjų pozicijų laikymui nustatomas maksimalus nuostolių dydis metams. Pusmečio nuostolių dydis yra lygus pusei metų nuostolių dydžiui. Pradinis mėnesio nuostolių dydis yra lygus pusei pusmečio nuostolių dydžio, pradinis savaitės nuostolių dydis yra lygus pusei mėnesio nuostolių dydžio, o pradinis dienos nuostolių dydis yra lygus pusei savaitės nuostolių dydžio. Apskaičiavus maksimalias leistinas atviras valiutų pozicijas, rizikos valdymo modelio sudarymas baigtas.

Siūlomo modelio principinė schema pateikta paveiksle:



VaR modelio sudarymo loginė schema

VaR modelis buvo testuojamas su 8 pagrindinėmis valiutomis, kuriomis sudaroma didžioji dauguma spekuliacinių sandorių. Parinkus valiutas, toliau testuojant reikia parinkti VaR modelio pagrindinius parametrus. Jie pateikiami lentelėje. Pasikliautinas intervalas parinktas 95 %, nes šis dydis dažniausiai taikomas Lietuvos komerciniuose bankuose vidiniam valiutų kurso rizikos įvertinimui, nepaisant to, kad Lietuvos bankas savo metodiniuose nurodymuose (aprašytuose anksčiau) reikalauja taikyti ne mažesnį nei 99 % pasikliovimo lygmenį. Skaičiavimuose naudojami valandiniai duomenys, nes duomenų periodiškumas turi sutapti su laiko horizonto matavimo vienetais (duomenys valandiniai ir laiko horizontas matuojamas valandomis). Testavimo periodas parinktas toks: 2006-01-01–2007-09-31.

Testuojamo VaR modelio pagrindiniai parametrai

Parametro pavadinimas	**Parametro reikšmė**
Pasikliovimo lygmuo	95 %
Laiko horizontas	24 val.
Imties tūris (istorinių duomenų kiekis naudojamas VaR reikšmei apskaičiuoti)	1 000
Duomenų periodiškumas	1 val.
Testavimo periodas	2006-01-01–2007-09-31

Vienareikšmiškai pasakyti, ar didelis, ar mažas neatitikimų skaičius yra konkrečioje poroje, galima tik apskaičiavus neatitikimų procentą. Neatitikimų procentas skaičiuojamas kaip neatitikimų ir visų nagrinėtų atvejų per laikotarpį santykis. Gauti rezultatai vertintini kaip patikimi. Tai reiškia, kad neatitikimų procentas nė vienu iš atvejų neturėjo viršyti 5 %. Tyrimas parodė, kad EUR/USD poroje neatitikimų procentas nė karto neviršijo 3 % ribos.

Atlikus atvejų, kai neatitikimų procentas viršijo 3 % ribą, analizę, buvo pastebėti kelių tipų neatitikimai:

- „Tikrieji“ neatitikimai – staigiai pasikeitus rinkos kursui, apskaičiuotas VaR modelio tikėtinas pokytis buvo per mažas.
- „Šventiniai“ neatitikimai – esant ilgesniam švenčių periodui, valiutų kursai nesikeičia, tačiau įvairūs fundamentalūs įvykiai, darantys įtaką valiutų kursui, vyksta nuolat. Tokiu atveju valiutos kursas po švenčių pradeda funkcionuoti su „tarpu“ ir užfiksuojamas neatitikimas.
- „Prastų duomenų“ neatitikimai – FOREX rinkos duomenys, ypač nemokami, nėra idealiai teisingi, todėl kartais juose įsivelia įvairių klaidelių, kurios vėliau analizuojant sukelia neatitikimus.

Įvertinus, kad dalis neatitikimų iš dalies ar visiškai neteisingi, galime sakyti, kad gauti atgalinio testavimo rezultatai yra patikimi. Apibendrinant neatitikimų analizę paaiškėjo, kad per nagrinėjamą laikotarpį vidutinis neatitikimų procentas daugumoje porų (išskyrus EUR/SEK) buvo mažesnis nei 1 %. Tai yra tikrai geras rezultatas. Didesni nukrypimai per nagrinėjamą laikotarpį pastebėti tik EUR/JPY, EUR/CAD ir EUR/AUD valiutų porose. Apibendrinant modelio testavimo rezultatus galima teigti, kad modelis pasiteisino ir gauti patikimi jo testavimo rezultatai leidžia modelį taikyti.

Raktažodžiai: *valiutos kurso rizika, valiutos kurso rizikos valdymas, rizikos vertė, rizikos vertės modeliai, VaR.*

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