

VALUE AT RISK FOR CAPITAL
RESERVE REQUIREMENT
REGULATION IN UKRAINIAN
BANKS

by

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Abstract

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REQUIREMENT REGULATION IN
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Value at Risk (VaR) has been widely promoted by the Bank for International Settlement as well as central banks of the developed countries as a way of monitoring and managing market risk and as a basis for setting regulatory minimum capital reserves. The thesis studies the market risk estimation methodology VaR and its implementation in the big size Ukrainian bank for determining the capital reserve requirement. Three VaR methods, namely Variance/Covariance method, Historical simulation and Monte Carlo simulation, are applied for the considered bank. The Variance/Covariance matrix of risk factors is estimated using GARCH models. The empirical results show that all three VaR methods are adequate to use in the bank, but Variance/Covariance method overestimates VaR, Historical simulation and Monte Carlo simulation underestimate VaR. Nevertheless, Historical simulation is chosen as the best method for the considered time period of data. The market risk is defined as 18169 UAH and market risk capital reserves are defined as 59594 UAH. The results of the thesis are implemented in the big size Ukrainian bank; therefore, VaRs are monitoring and capital reserves are defined daily there.

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GLOSSARY

Equity risk. The capital loss due to changes of financial elements prices (usually stocks).

Exchange risk. The capital loss due to unfavorable changes of exchange rates.

Generalized Autoregressive Conditional Heteroskedasticity (GARCH).

The class of models that models persistent movements in volatility as a distributed lag of past squared shocks or innovations and past volatility.

Interest risk. The capital loss due to unfavorable changes of interest rates of interest-bearing financial instruments (for example, bonds).

Market risk. Capital risk that appears on account of unfavourable price fluctuations of stocks, goods and exchange rates that are in the market portfolio.

VaR (Value at Risk). The predicted worst-case loss at a specific confidence level (e.g., 95%) over a certain period of time (e.g., 1 day).

Chapter 1

INTRODUCTION

The main idea of my thesis is to estimate market risk in the Ukrainian bank and give recommendations about the value of capital that must be reserved for a certain period of time to avoid the possibility of bankruptcy or default. The thesis considers market risk (equity and exchange) and its influence on capital reserve requirement. At first, I estimate the behavior of the following elements of financial market: stock prices and exchange rates and model their volatilities and covariances, form the portfolios of the mentioned financial elements for the big size Ukrainian bank; secondary, develop a model for the financial elements revaluation, simulate the changes of the portfolio market value, estimate the Value at Risk (VaR) of the bank's market portfolio and give recommendations about the amount of capital reserve for the considered period of time.

In 2007 National Bank of Ukraine will require using the Basel Committee on Banking Supervision II regulations in all Ukrainian banks that means to meet capital requirements based on Value at Risk estimates. There are a lot of different banks in Ukraine and it is very urgent for them to distribute the capital rationally, banks' boards want to have minimum capital reserve and minimize the probability of bankruptcy at the same time.

Although, many Ukrainian banks have already begun to use VaR methodology for their risks estimation, not all of them use the whole set of VaR models and methods, they usually use only Variance-Covariance Method and Historical Simulation. Venchak (2005) applied Historical Simulations and Delta-Normal Method (Variance-Covariance Method) for the estimation of exchange risk in 'Kredyt-Bank (Ukraine)'. In distinction to Venchak's research, my thesis considers all the market risks, uses different data and more VaR methods, and

also estimates the behavior of the elements of financial market and their variances and covariances using GARCH models.

Therefore, I am the first to consider and compare a set of VaR models and methods that are already used worldwide for the market risk estimation for a big size Ukrainian bank and give recommendations about capital reserve requirement regulation, namely the value of capital that must be reserved for a certain period in the bank in order to minimize the probability of the bankruptcy or default on account of changes in the market stock prices or exchange rates. In one year every bank in Ukraine will be interested in the topic of my thesis, because they should use their interior VaR models in the market risk management.

The model GARCH is used for the estimation of stock prices and exchange rates behaviors, namely their variances and covariances. The appropriate portfolios of currencies and stocks are formed according to the structure of the chosen bank portfolios. The VaR of the bank's portfolio is estimated by Monte Carlo simulation, Historical simulation and Variance/Covariance method. Additionally, the best model of VaR estimation is chosen by back testing. The market risk in the bank is defined as the obtained most adequate Value at Risk. Consequently, the capital reserve requirement regulation can be hold in the following way. The market risk signifies the value at risk, which is the loss of capital due to the future changes in the stock prices or exchange rates at the market. Therefore, the value of money three or four times more the obtained VaR must be reserved in the bank for a certain period, the value of multiplicative factor depends on how much a bank underestimates VaR. In addition, the amount of required capital reserves can be decreased by the market risk reduction that can be achieved by changing the structure of the bank's portfolio.

Daily stock prices and daily exchange rates for the period from January, 2004 till December, 2005 are analyzed in the thesis. The structure of the bank's market

portfolio is obtained from one of the big-size Ukrainian banks (it is in the first ten of all Ukrainian banks according to the ratings of the assets value).

The rest of the thesis is organized as follows: Chapter 2 reviews the literature about VaR, namely the history of VaR methodology, the description and theoretical background of VaR methods and their implementation in different foreign financial markets. Chapter 3 presents the methodology used to perform empirical estimation. In this part the general algorithm of the empirical research is developed and three VaR methods are described. Chapter 4 describes the data used for empirical work. Chapter 5 presents the results of empirical estimation. Chapter 6 concludes and describes possible implications.

Chapter 2

LITERATURE REVIEW

Value at Risk is a standard methodology for market risk estimation in the USA and West Europe. Russian banks and investment companies only now begin to use VaR in the risk management, but it is not popularly in Ukraine. Therefore, there are numerous international studies about Risk Management, Value at Risk, Basel Committee on Banking Supervision II regulations, VaR methods, some Russian literature and only some Ukrainian articles about VaR in general.

Volkov (2005) has explained the reasons of VaR popularity as a tool of risk management and controlling in the different companies. The reasons are the following: 1) US investment company J.P. Morgan founded RiskMetrics and gave its dataset everyone for free in 1994, this system is the first to compute VaR; 2) investment climate in the end of the 90's when a lot of companies lost huge amount of money; 3) Basel Committee on Banking Supervision that makes the regulations in the banking sector decided to use VaR estimation in 1995. According to Jorion (2001) the term Value at Risk was firstly widely published in the report of the Group of Thirty meeting in July 1993, this Group had a discussion of best risk-management practices.

VaR methodology is usually used in risk measurement which attempts to answer the following questions (Marrison, 2002):

- how much can the company or a bank loose with certain probability;
- can a bank absorb a significant loss without becoming a bankrupt;
- is the return high enough for a bank to take a certain risk;
- how can a bank reduces the risk without significantly reducing the return.

NBU's methodic instructions (2004) have defined the market risk in the following way: "Market risk is the explicit or potential return or capital risk that appears on account of unfavorable value fluctuations of stocks, goods and exchange rates of the financial instruments that are in the market portfolio". Thus, the market risk in Ukraine consists of the interest risk, exchange risk and equity risk. Exchange risk shows the capital loss due to unfavorable changes of exchange rates, equity risk shows the capital loss due to changes of financial elements prices (usually stocks) and interest risk shows the capital loss due to unfavorable changes of interest rates of interest-bearing financial instruments (for example, bonds).

Marrison (2002) has mentioned that 'VaR is a measure of market risk that tries objectively to combine the sensitivity of the portfolio to market changes and the probability of a given market change'. The main reasons for analyzing the capital consumed by market risks are the following:

- complying with industry regulations;
- calculating economic capital to control the bank's default probability;
- measuring Risk-Adjusted Profitability.

Allen, et al. (2004) mentioned that regulatory total capital in the bank is equal to the sum of credit risk capital requirement, market risk capital requirement and operational risk capital requirement. The market risk capital requirement depends on the bank's choice of the internal model approach. Therefore, the bank can choose its own model of VaR estimation and calculate the market risk capital requirement based in this VaR.

Duffie and Pan (1997) have defined value at risk as the loss in market value over a certain time horizon that is exceeded with probability $1-p$, where p is a confidence level; in addition, NBU's methodic instructions (2004) have defined value at risk as a method of quantitative risk estimation that represents the

economic capital at risk that can be lost; Jorion (2001) has defined VaR more formally as the quantile of the projected distribution of gains and losses over the target horizon.

According to Committee of Chief Risk Officers Valuation (2002), the three main methods of VaR calculations are the following: Parametric analysis, Historical simulation, Monte Carlo simulation. Jorion (2001) has divided VaR approaches into two groups: local-valuation and full-valuation methods. The Delta-Normal method can be considered as a local-valuation approach that means the portfolio is valued once and local derivatives are used for the modeling of possible movements. Historical simulation and Monte Carlo simulation can be considered as full-valuation methods that mean the portfolio is fully revalued over a range of scenarios.

The following comparison and description of the mentioned methods has been done by RiskMetrics Group (1999), Committee of Chief Risk Officers Valuation (2002), and J. P. Morgan/Reuters (1996). Parametric methodology (Variance-Covariance, Delta, Delta-plus, Delta-Normal, Delta-Gamma) uses specific parameters (volatility, correlation, delta, and gamma) in VaR estimation equation. This methodology is fast and simple and it does not require extensive historical data, but it needs the assumption of Normal distribution of returns of financial instrument that is considered. Monte Carlo simulation generates random scenarios and revalues portfolio positions for VaR estimation. This methodology can be used for all financial instruments, it gives a full distribution of portfolio values, works with any distribution and it does not need extensive historical data. However, it needs a huge number of computations, therefore, Monte Carlo simulation is time consuming, and the results of Monte Carlo method can never be reproduced. Historical simulation takes actual historical rates and revalues portfolio positions for each change in the market for VaR estimation. This methodology gives a full distribution of portfolio values, works with any distribution, does not need extensive historical data and it is faster than Monte Carlo simulation, but it needs a huge number of computations, high

confidence levels (usually 99%), is time consuming and requires huge daily rate history.

Engel and Gizycki (1999) made a wide research of Variance-Covariance matrix estimation, which is needed for Variance/Covariance method of VaR computation. They concluded that GARCH models estimate variances and covariances of exchange rates very good and they showed two approaches of GARCH adaptation to VaR methodology.

Confidence level and time horizon must be determined before VaR computing (J. P. Morgan/Reuters, 1996). Confidence level is usually 95%, although Historical simulation methodology requires 99% level. Banks and hedge funds usually use a 1-day time-horizon, because their trading positions can change dynamically from one day to the next. Investment companies often use a 1-month time-horizon, because their portfolios might not be changed over the whole month.

Duffie and Pan (1997) have estimated the risk of changes in the spreads of publicly traded corporate and sovereign bonds and found that Monte Carlo simulation and variance-reduction method are the best approximation for short and long versions of the reference option portfolio; Monte Carlo simulation and delta-approximation are the best for 1-day and 2-week horizons; Monte Carlo simulation and delta-gamma approximation are the best for the range of confidence intervals approximation.

As mentioned by Lambadiaris, et al. (2003), although VaR has a number of limitations, it is the standard method to measure the market risk of financial assets portfolio that is recommended by the Basel Committee on Banking Supervision II. Some modification of the VaR methodology is shown by Kaplanski and Levy (2003, 2004), who analyzed optimal portfolio policies of expected utility maximizing agents under VaR Capital Requirement regulation in comparison to the optimal policy under exogenously-imposed VaR Limit and Limited-Expected-Loss regulations. They have found that the larger the

required level of eligible capital, the greater the incentive for the agent to reduce the portfolio VaR at the expense of the worst states insurance, that is one of the requirements of Basel Committee on Banking Supervision.

Wide research of the VaR methodologies for Indian Banking system is made by Nath and Samanta (2004), they applied Variance-Covariance method, Historical Simulation and Extreme Value Theory for the VaR calculations and got the following results: Variance-Covariance method underestimated VaR numbers, Historical Simulation provided quite reasonable VaR estimates and Extreme Value Theory overestimated VaR. Manganelli and Engle (2001) have considered the existing VaR models and made their comparison. They defined that financial return distribution had heavier tails and a higher peak (greater kurtosis) than normal distribution and squared returns have significant autocorrelation, which allows using models of volatilities, that are changing in long-run and stable in short run. They have introduced the Conditional Autoregressive Value at Risk and have shown that it is had the best estimates for heavy-tailed financial instruments. Manganelli and Engle (2001) have also introduced a regression-based method that is the alternative to Extreme Value theory and had better estimates even at 1% and 5% confidence levels.

Glasserman, et al. (2000) has investigated the modification of Monte Carlo Method for VaR. They have found that the calculation of VaR for large portfolios presented a trade-off between speed and accuracy and Monte Carlo method was often too slow. Therefore, they combined two approaches: the speed of the delta-gamma approximation and the accuracy of Monte Carlo simulation. The drawback of Glasserman, et al approach is the assumption that changes in market risk factors over the VaR horizon are normally distributed.

A variety of Russian economists have already compared different VaR methods for the Russian market of financial derivatives (for example, Lobanov and Poroh, 2001 and Cherkashenko and Vecherin, 2002). Lobanov and Poroh (2001) concluded that Historical Method is better than Variance-Covariance

Method to forecast stock prices at Russian market at 1-day horizon, that means Russian stock prices have not Normal distribution; therefore, the Variance-Covariance Method is not appropriate according to the requirements of the Basel Committee on Banking Supervision. It is very interesting to test the Variance–Covariance method on Ukrainian market and compare results with Russia. Cherkashenko and Vecherin (2002) defined the algorithm of the VaR methodology in the following way: 1) choose the risk factors that show the level of portfolio uncertainty; 2) define the link between the portfolio return and risk factors; 3) define the model of risk factors; 4) model the future portfolio returns and find the distribution.

Risk is a multi-dimensional event and no single algorithm can estimate Value at risk by considering all possible market changes (Kao-Tai Tsai, 2004). Therefore, there is no best VaR method according to different conditions such as dataset quality, time consuming, simplicity, confidence intervals and returns of financial instruments distributions. In addition, each bank or company should determine the most appropriate methodology for its own business. Kao-Tai Tsai (2004) mentioned that risk management is more than just a regulatory reporting exercise, it also can regulate the capital reserves requirement and in such way increases the profitability of a bank.

According to Marrison (2002) the following summary of VaR Techniques can be done.

Table 1. Summary of VaR Techniques

	Parametric VaR	Monte Carlo Simulation	Historical Simulation
Speed of computation	●	○	◐
Ability to capture nonlinearity	○	●	●
Ability to capture nonnormality	○	◐	●
Independence from historical data	◑	◑	○

Consequently, in the case of the absence of Ukrainian literature and empirical estimations of VaR methodologies, it is very useful and interesting to test all three VaR techniques for market risk estimation in the Ukrainian bank.

Chapter 3

METHODOLOGY

Jorion (2001) has defined the following steps in VaR constructing:

1. Mark-to-market the current portfolio;
2. Measure the variability of the risk factors;
3. Set the time horizon;
4. Set the confidence level;
5. Report the worst loss by processing all the preceding information.

The market portfolio of the considered bank consists of foreign currencies and stocks, there are no bonds and no interest risk correspondently; therefore, my research estimates the market risk, which consists only of exchange and stock price risks. The general algorithm of the thesis empirical study is the following.

1. Model stock prices and exchange rates volatilities and covariances using GARCH
2. Form the portfolios of currencies and stocks
3. Set the time horizon and the confidence level
4. Use Monte Carlo simulation, Historical simulation and Variance/Covariance method for computing market VaR
5. Choose the most adequate VaR from three above methods by Binomial test

6. Define market risk as the most adequate VaR from step 5

7. Set capital reserve requirement regulation: $R = \lambda \cdot VaR_M$, $3 \leq \lambda \leq 4$ (1)

The value of money three or four times more the obtained VaR must be reserved in the bank for a certain period according to the recommendations of Basel Committee on Banking Supervision II.

Further, all these steps are considered in details and algorithms of VaR techniques (Variance/Covariance method, Monte Carlo simulation and Historical simulation) are cited.

Time series of exchange rates and stock prices are usually non-stationary, their volatilities are changing in time and, therefore, GARCH model is used for the estimation of heteroscedastic series volatilities and covariances. All the time series are transformed in the log-form of first differences in order to avoid nonstationarity and receive returns of the financial elements. Exchange rates and stock prices are the risk factors in our model and their volatilities and variances can be obtained from the following model. If the time series are described by the process GARCH (1,1), then the variance of returns is defined by (2):

$$h_t = \omega + \alpha r_{t-1}^2 + \beta h_{t-1} \quad (2),$$

where: h_t – the conditional variance of the risk factor at time t ;

r_{t-1}^2 – innovations or unexpected returns (residuals).

Non-negativity constraints need to be imposed on the variance parameters to ensure that the conditional variance estimates are always positive and stationarity requires to have $\alpha + \beta < 1$.

All the considered returns should be estimated by autoregression models and then tested for ARCH (GARCH) effects. After GARCH estimation, the forecasting of conditional variances is made for each risk factor using a formulation (3).

$$\sigma_{i,t+1}^2 = \bar{\omega}_i + \alpha_i r_{i,t}^2 + \beta_i \sigma_{i,t}^2 = \frac{\bar{\omega}_i}{1 - \beta_i} + \alpha_i \sum_{j=0}^T \beta_i^j r_{i,t-j}^2 \quad (3),$$

where: $\sigma_{i,t+1}$ – the conditional standard deviation of risk factor i at time t+1;

T – number of days used in the estimation.

In this case the unconditional variance for each risk factor is the mean of conditional variances. The correlations between risk factors are assumed to be constant, therefore, the conditional covariances are calculated by the formula (4) and then the unconditional covariances are defined as the mean of conditional covariances for each pair of risk factors.

$$\sigma_{ij,t+1} = \rho_{ij} \sigma_{i,t+1} \sigma_{j,t+1} \quad (4),$$

where: ρ_{ij} - correlation between risk factor i and risk factor j that is calculated based on the historical data of returns.

Furthermore, the portfolios of currencies and stocks can be formed according to the structure of portfolio from the Chapter 4, it means that the open positions in currencies and stocks are determined for the following VaR analysis.

In addition, the time horizon and the confidence level must be set; 99% is usually set for Historical Simulation and 95% for Monte Carlo Simulation and Variance/Covariance method according to the recommendations of Basel Committee on Banking Supervision II. The time horizon means the period of time, when the open positions of financial elements do not change, therefore, it is also the time that is needed to buy or sell this financial element at the market. Time horizon is set at 1 day, because the market of currencies is very liquid in Ukraine and their positions are changed every day. The market portfolio of the bank also includes stocks and stock market is not liquid in Ukraine. Nevertheless, the time horizon is set at 1 day, because exchange rates and stock prices are analyzed together.

3.1 Variance/Covariance method

Variance/Covariance method is also known as Parametric, Linear, Greek-Normal, Delta-Gamma Normal. At first VaR is calculated for each risk factor by formula (5):

$$VaR_i = V_i \cdot (z_\alpha \cdot \sigma_i \sqrt{t} - \mu_i t), \quad (5)$$

where: V_i – value of the financial element (currency position or stock position),

σ_i – unconditional standard deviation of risk factor,

μ_i – mean of risk factor,

z_α - the quantile of Normal distribution at α confidence level,

t - the time horizon (the number of days).

Then the total VaR for the bank can be calculated by formula (6).

$$VaR_T = \sqrt{VaR^T \cdot VAR/COV \cdot VaR}, \quad (6)$$

where: VAR/COV – Variance-Covariance matrix of risk factors;

VaR – the vector of VaRs of all risk factors.

3.2 Monte Carlo Simulation

Main steps of Monte Carlo for VaR are (Glasserman et al, 2000):

1. Generate N scenarios by sampling changes in risk factors $\Delta S^{(1)}, \dots, \Delta S^{(N)}$ over horizon t ;
2. Revalue portfolio at end of horizon t in scenarios $S + \Delta S^{(1)}, \dots, S + \Delta S^{(N)}$; determine losses $L^{(1)}, \dots, L^{(N)}$ by subtracting revaluation in each scenario from current portfolio value;

3. Calculate fraction of scenarios in which losses exceed x : $\frac{\sum_{i=1}^N I(L^{(i)} > x)}{N}$, (7)

where $I(L^{(i)} > x) = 1$ if $L^{(i)} > x$ and 0 otherwise;

4. VaR is estimated by the repeating the step 3 for multiple values of x and then quantile finding at predetermined confidence level;

where: S – vector of risk factors;

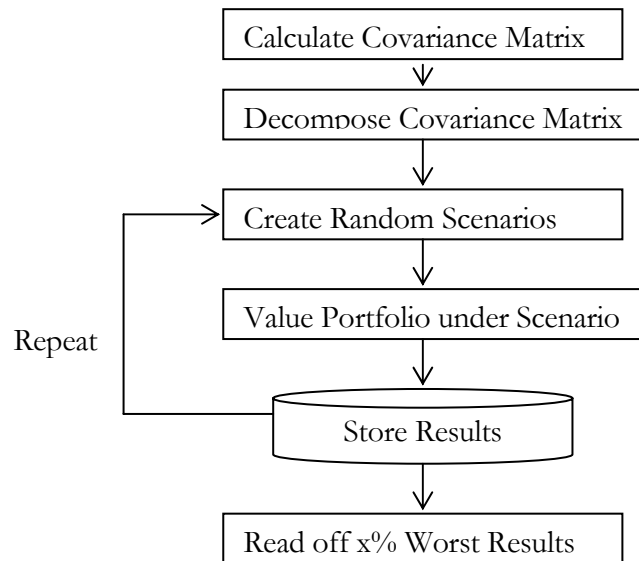
t – time horizon;

ΔS – change in risk factors over time horizon;

L – loss in portfolio value resulting from change ΔS over time horizon
(L is the difference between the current value of the portfolio and the portfolio value at the end of the VaR horizon).

Marrison (2002) has obtained the following schema for Monte Carlo algorithm:

Figure 1. Monte Carlo algorithm



Difficult step here is to decompose covariance matrix in such a way as to create random scenario with the same correlation as the historical market data. The stocks and exchange rates usually have distribution like Normal, but with fat tails and high peak (high kurtosis). The following approach is used for generating of random variables with fat tails (Da Costa Lewis, 2003).

1. Set a probability threshold parameter φ , set counter 1 and choose a value for N.
2. Generate a uniform $(-1,1)$ random variable, u_1 .
3. If $u_1 > \varphi$, let $Y=1$. Otherwise, let $Y=0$.
4. Generate $X \sim N(-1,1)$.
5. If $Y=1$, then let $z=\alpha X$. Otherwise, let $z=\beta X$.
6. If counter = N, then end. Otherwise, add 1 to counter and return to (2).

We receive the random variable z with the variance:

$$\text{var}(z) = \varphi\alpha^2 + (1 - \varphi)\beta^2 = 1 \quad (8)$$

$$\text{with } \beta = \sqrt{\frac{1 - \varphi\alpha^2}{1 - \varphi}} \quad (9) \text{ and kurtosis } k(z) = 3(\varphi\alpha^4 + (1 - \varphi)\beta^4) \quad (10)$$

To achieve a given level of kurtosis, suitable values of φ and α should be chosen. To get kurtosis 4 (as Normal distribution has), $\alpha=0.3$ and $\varphi=0.3$ must be set.

Furthermore, Monte Carlo simulates the price for the next day (as the time horizon is set at 1 day) for all considered financial elements and the portfolio marked-to-market using full valuation, $V_k = V(S_{i,k})$; each of these realizations is used to make a distribution of returns, from which VaR can be measured as the worst $(1-\alpha)*N$ portfolio return, where α is the level of confidence and N is number of random scenarios.

3.3 Historical Simulation

The main feature of this approach is the assumption that price elasticity of returns today is the same as price elasticity of returns yesterday: $\varepsilon_{t+1} = \varepsilon_t$ (11).

Historical Simulation simulates the values of portfolio according to the today's open positions of risk factors for each day under consideration. Then all the portfolio values are rearranged in the ascending order.

The VaR is the worst $(1 - \alpha)T$ portfolio return, where α – confidence level, T – number of observations.

3.4 Back testing

The obtained VaR estimations should correspond to the actual profit/loss distribution on account of market risk. The obtained number of exceptions (the day when the predicted VaR is less than actual loss of portfolio for that day) should be almost equal to the expected number of exceptions.

To verify the adequacy of the obtained VaRs, the Binomial test statistic (12) is used.

$$\hat{T} = \frac{p - p_0}{\sqrt{\frac{p_0(1-p_0)}{N}}} \approx N(0,1) \quad (12),$$

where: p – actual observed proportion of exceptions above VaR given by X/N (X – number of exceptions, N – the number of observations);

p_0 – expected proportion of exceptions (for confidence level 95% $p_0=5\%$).

Therefore, the hypothesis $H_0: p_0=p$ against $H_1: p_0 \neq p$ should be tested. If the absolute value of above statistic is less than critical value of Normal distribution, then H_0 is not rejected and VaR is working adequately. Otherwise, the model should be reconstructed (the volatilities of financial elements should be recalculated (Variance/Covariance method) or the number of observations should be changed (Historical simulation) or the distribution of financial elements should be reconstructed (Monte Carlo simulation)).

Chapter 4

DATA DESCRIPTION

Time series that are examined in the thesis are the following:

- daily stock prices from PFTS;
- daily interbank exchange rates.

Time period: January, 2004 - December, 2005

Sources:

- Reuters 3000 System
- www.finances.kiev.ua
- www.finance.com.ua
- www.bank.gov.ua
- www.aub.com.ua
- www.sokrat.com.ua

The structure of one big size Ukrainian bank market portfolio is obtained from the bank directly.

The bank's market portfolio consists of:

- open positions of currencies;
- open positions of stocks.

There are a lot of foreign currencies and stocks in the bank portfolio, but only the relatively highest open positions are considered, because other positions do not have significant influence on the market risk of the whole bank. The highest open position in currency is UAH, but it is the base currency in Ukraine, therefore, it is excluded from the bank portfolio in the further analysis and all exchange rates are determined in terms of UAH.

Table 2 presents the most significant open positions of foreign currencies and stocks and their percent in the total currency or stock portfolio.

Table 2. Currencies and stocks open positions

Currency/Stock	Open position	% in total currency/stock portfolio
EUR	55,802,386.79	25.3%
USD	162,324,187.22	73.6%
UNAF	6,064,691.41	18.24%
DNEN	14,934,386.79	44.91%
DOEN	11,149,283.54	33.52%
KIEN	808,745.42	2.43%

UNAF is stock of company Ukrnafta, DNEN is stock of Dniproenergo, DOEN is stock of Donbasenergo, KIEN is stock of Kyivenergo.

Table 3 contains the descriptive statistics for the financial elements that are in the market portfolio of the bank and the positions of these elements are significantly high, therefore only these six elements are analyzed.

Table 3. Descriptive statistics of the initial data

Name of financial element	Mean	Standard deviation	Min	Max	# of obs.
UAH/USD	5.21151	0.1462489	4.93	5.5	520
UAH/EUR	6.486577	0.3524157	5.863	7.237	520
Stock DNEN	232.1905	108.3627	60	450	520
Stock DOEN	18.89036	4.888033	7.5	31	520
Stock KIEN	6.34609	1.624028	4	8.69	520
Stock UNAF	119.9123	54.99978	33.25	250	520

Figures 2-7 present the dynamics of considered financial time series during 2004 and 2005 years.

Figure 2. The dynamics of exchange rate UAH/USD

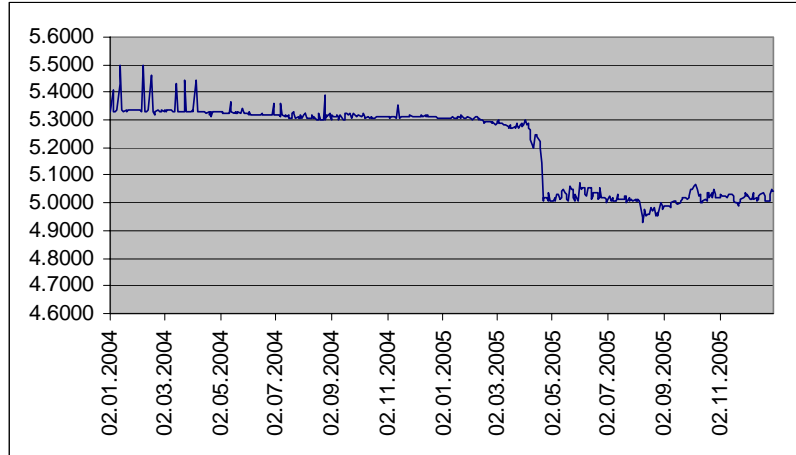


Figure 3. The dynamics of exchange rate UAH/EUR

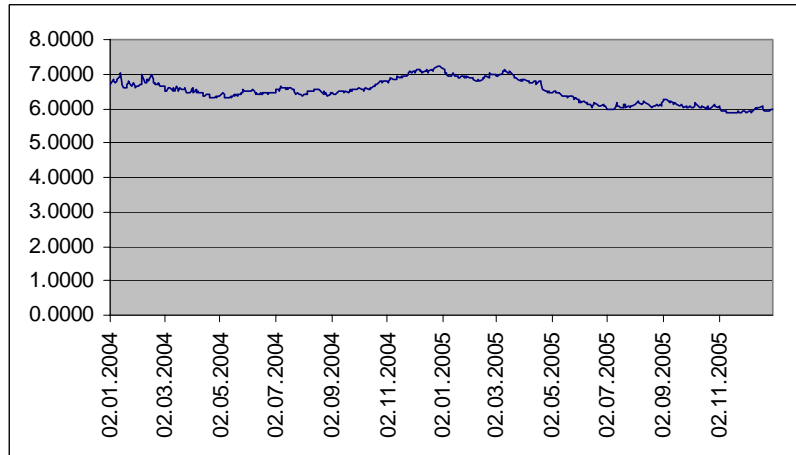


Figure 4. The dynamics of stock DNEN price

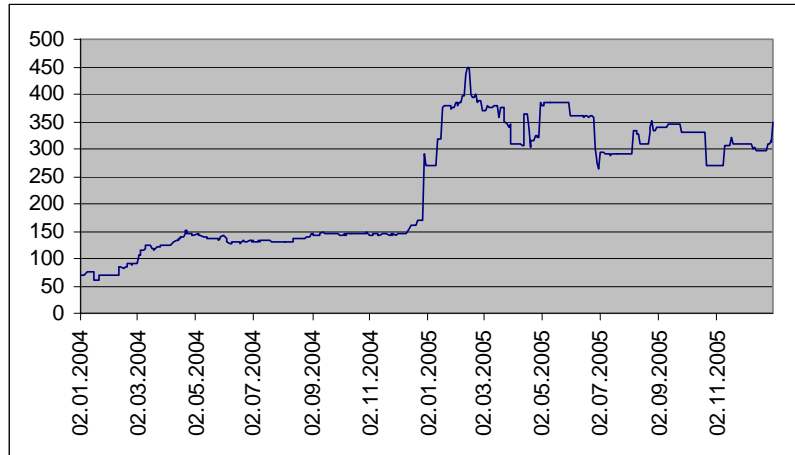


Figure 5. The dynamics of stock DOEN price

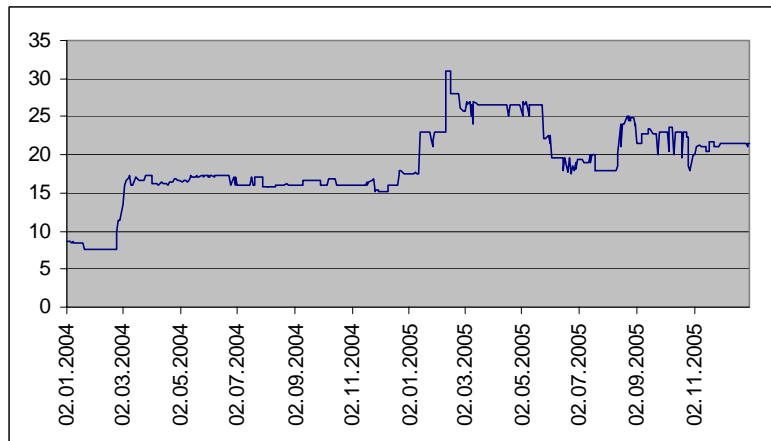


Figure 6. The dynamics of stock KIEN price

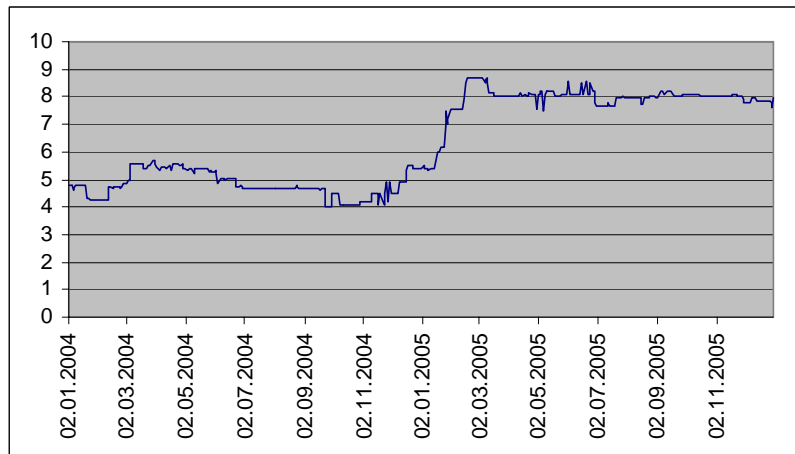
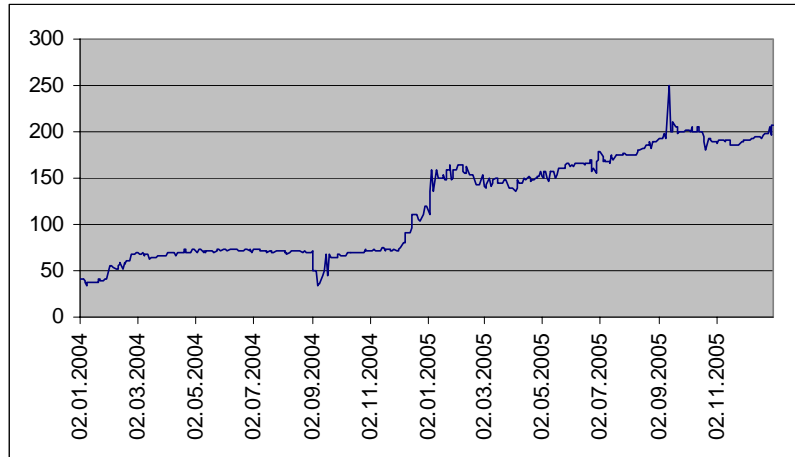


Figure 7. The dynamics of stock UNAF price



The visual analysis of the Figures 2-7 shows that all time series have trends, therefore, time series might be nonstationary, formal tests are cited in the next Chapter and further returns of time series are considered. Table 4 presents the descriptive statistics of the returns of financial elements.

Table 4. Descriptive statistics of the returns

Name of return	Mean	Standard deviation	Min	Max	# of obs.
UAH/USD	-0.0001063	0.0047359	-0.031284	0.031397	519
UAH/EUR	-0.0002238	0.0075976	-0.039918	0.044393	519
DNEN	0.0030955	0.040339	-0.223144	0.540335	519
DOEN	0.0017655	0.0428653	-0.190397	0.298493	519
KIEN	0.0009698	0.0255396	-0.154151	0.154151	519
UNAF	0.0031434	0.0526027	-0.407968	0.39803	519

EMPIRICAL RESULTS

5.1 Variance estimation using GARCH

The time series of exchange rates UAH/USD and UAH/EUR and stocks DNEN, DOEN, KIEN, UNAF are considered as risk factors in the model. For further modeling time series must be stationary, but according to the Dickey-Fuller test for unit root (Appendix A) all the series of financial elements are not stationary. Additionally, according to the theory returns should be analyzed by VaR. Therefore, returns of all six time series are calculated as relative changes of exchange rates or stock prices by the formula (13).

$$r_t \approx \ln\left(\frac{P_t}{P_{t-1}}\right), \quad (13)$$

where P_t – the exchange rate or stock price in the day t .

Obtained time series of returns are stationary according to the Dickey-Fuller test (Appendix A). Figures 8-13 show the dynamics of obtained returns.

Figure 8. The dynamics of exchange rate UAH/USD returns

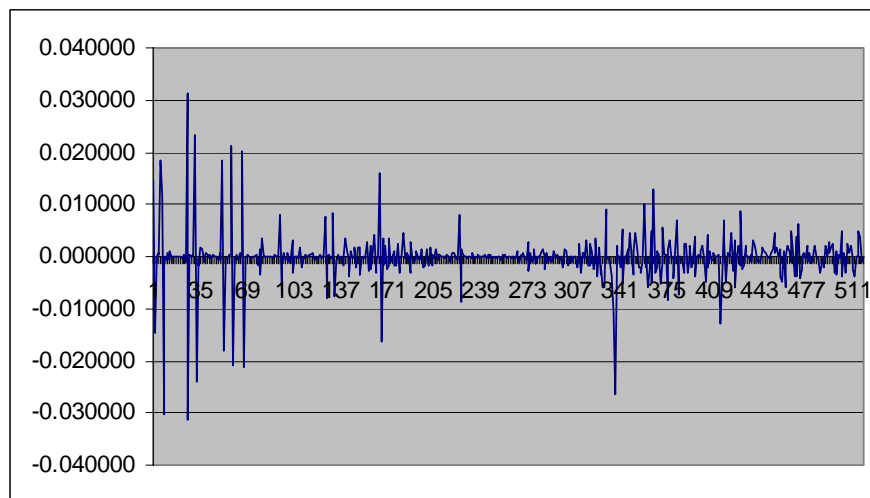


Figure 9. The dynamics of exchange rate UAH/EUR returns

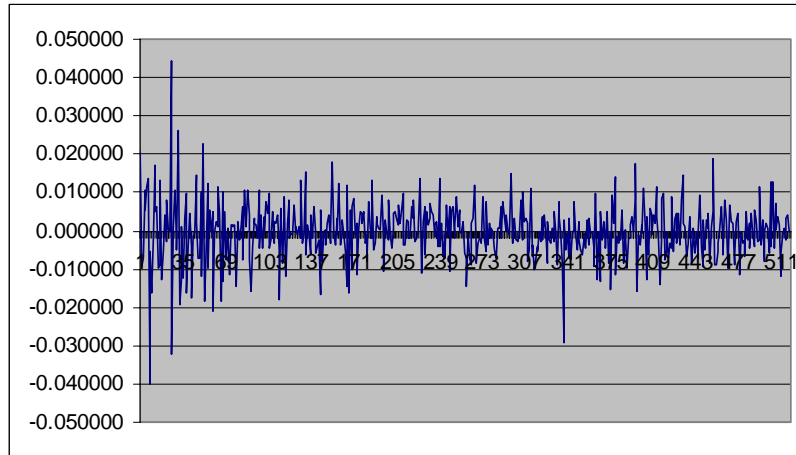


Figure 10. The dynamics of stock DNEN returns

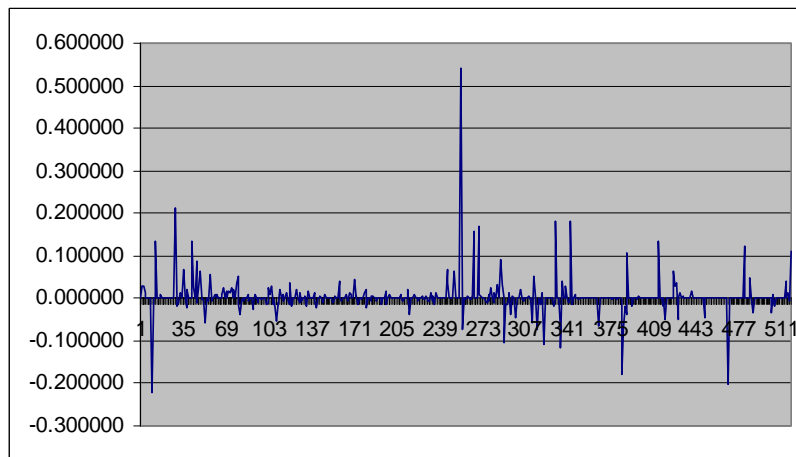


Figure 11. The dynamics of stock DOEN returns

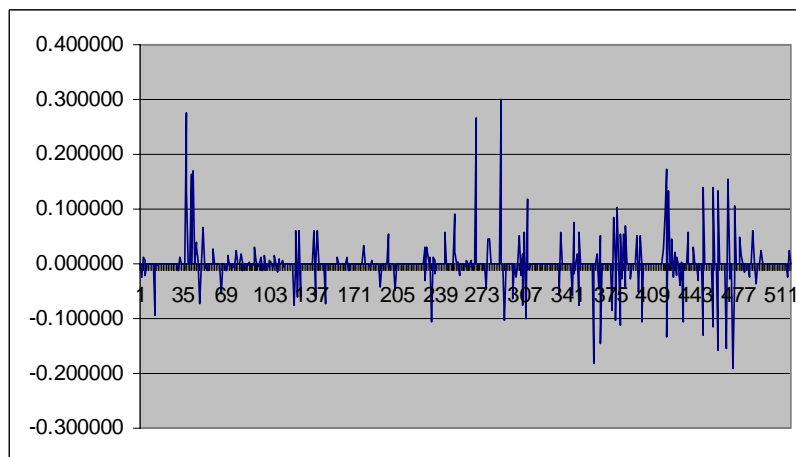


Figure 12. The dynamics of stock KIEN returns

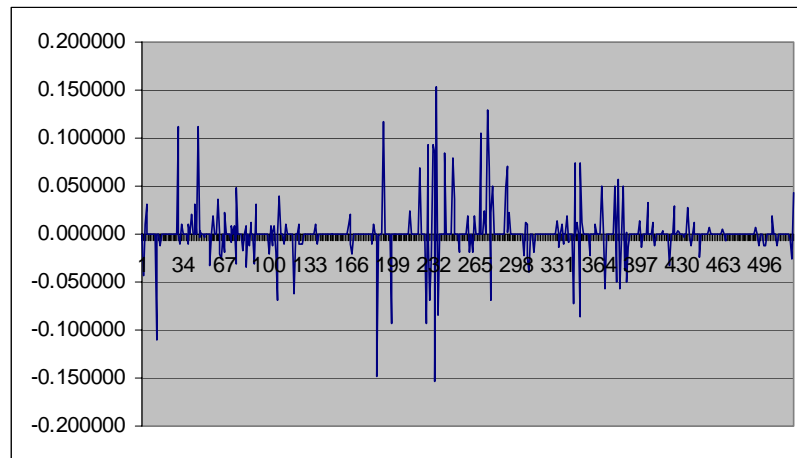
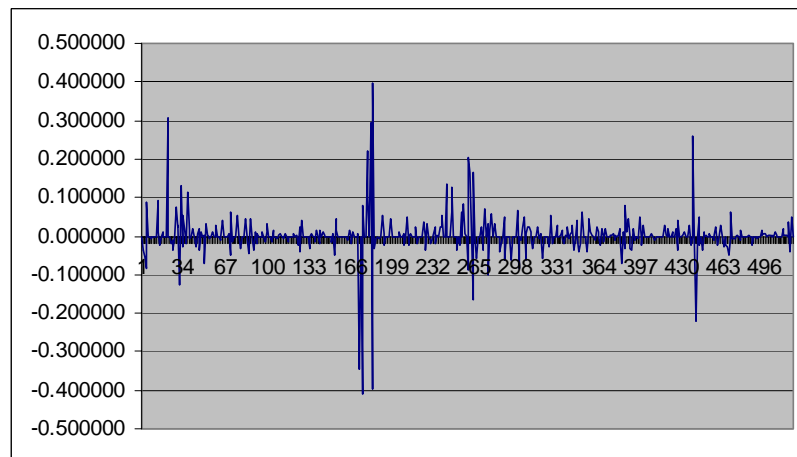


Figure 13. The dynamics of stock UNAF returns



It can be seen from the Figures 8-13 that all the series have variable variance in time that means GARCH model might describe the considered processes good. Each series were tested for autocorrelation and partial autocorrelation and then the appropriate models AR were chosen (Appendix B). Durbina test for autocorrelation was developed for all 6 models and it showed that the chosen models do not contain autocorrelation (Appendix B); all regression coefficients are significant at 5% confidence level, only constant coefficient in the model for stock UNAF is significant at 10% level of confidence. Therefore, next autoregression models describe considered time series of financial elements:

$$\begin{aligned} \text{UAH_USD} = & -0.4447667512*\text{UAH_USD}(-1) - 0.2666576062*\text{UAH_USD}(-2) - \\ & 0.195085492*\text{UAH_USD}(-3) - 0.1567461061*\text{UAH_USD}(-4) - \\ & 0.1519699789*\text{UAH_USD}(-5) \end{aligned} \quad (14)$$

$$\text{UAH_EUR} = -0.2014916354*\text{UAH_EUR}(-1) \quad (15)$$

$$\text{DNEN} = 0.1150878165*\text{DNEN}(-10) + 0.1729513099*\text{DNEN}(-14) \quad (16)$$

$$\text{DOEN} = -0.1789108276*\text{DOEN}(-1) \quad (17)$$

$$\text{KIEN} = -0.2072163832*\text{KIEN}(-1) - 0.1020945616*\text{KIEN}(-2) \quad (18)$$

$$\text{UNAF} = -0.2547894295*\text{UNAF}(-1) \quad (19)$$

Further analysis showed that there are ARCH effects in all models and, finally, the model GARCH(1,1) was obtained for all time series (Appendix C). More complicated GARCH models were also appropriate for some financial elements, but as the goal of GARCH application is only to obtain the estimation of variance in this research, other models are not considered (the difference in the unconditional variances is not significant among different GARCH specifications). Therefore, the variances are estimated using the following formula:

$$\sigma_{T+1}^2 = \omega + \alpha r_T^2 + \beta \sigma_T^2 \quad (20)$$

The results of variances estimations using GARCH(1,1) are shown in the Table 5.

Table 5. Estimations of variance equations parameters using GARCH(1,1)

Time series	ω	α	β
UAH/USD	1.00E-05 0.0000	0.526975 0.0000	0.073853 0.0834
UAH/EUR	6.08E-07 0.0015	0.000787 0.0863	0.984391 0.0000
DNEN	0.000264 0.0030	0.001735 0.0231	0.059898 0.0000
DOEN	0.000563 0.0000	0.123155 0.0000	0.560506 0.0000
KIEN	8.02E-05 0.0000	0.110846 0.0000	0.756382 0.0000
UNAF	0.000527 0.0000	0.216512 0.0000	0.522047 0.0000

The coefficients of variance equation are all nonnegative and the sum of α and β are less than one for all six time series that ensure the conditional variances are positive and stationary. All the coefficients are statistically significant at 10% level of significance (p-values are shown in the Table 5 in the right bottom corner of each cell).

The forecasting of conditional variance is made for each financial element after the GARCH(1,1) estimation and unconditional variances are found as the mean of conditional variances. The covariances between considered financial elements are computed as a product of correlation (correlation is assumed to be constant over concerned period) and corresponding standard deviations, which are the square roots of obtained unconditional variances. The results are represented as Variance/Covariance matrix in the Table 6.

Table 6. Variance/Covariance matrix

	UAH/USD	UAH/EUR	DNEN	DOEN	KIEN	UNAF
UAH/USD	0.00001970	0.00001820	0.00000076	-0.00000526	-0.00000025	-0.00001052
UAH/EUR	0.00001820	0.00004810	0.00000302	-0.00001183	-0.00000183	-0.00002056
DNEN	0.00000076	0.00000302	0.00144100	-0.00000634	0.00002500	0.00007097
DOEN	-0.00000526	-0.00001183	-0.00000634	0.00177000	-0.00006567	0.00010756
KIEN	-0.00000025	-0.00000183	0.00002500	-0.00006567	0.00060000	0.00002855
UNAF	-0.00001052	-0.00002056	0.00007097	0.00010756	0.00002855	0.00202500

5.2 Market risk estimation

For VaR computing the confidence level and time horizon should be chosen at first. The confidence level is set at 95% for Historical Simulation, Monte Carlo Simulation and Variance/Covariance method. Usually Historical Simulation uses 99% confidence level, but it is appropriate only for time series that do not have

sudden changes. In our case, there was big drop of UAH/USD in the end of April 2005, because of revaluation of Ukrainian hryvnya by National Bank of Ukraine. Therefore, lower confidence level is needed to avoid the interpretation of this big drop of exchange rate as usual risk, it is only extreme event that must not be analyzed daily. The market portfolio of the bank includes foreign currencies and stocks, the currency market is very liquid and stock market is not very liquid in Ukraine. Nevertheless, the time horizon is set at 1 day, because the bank's open positions in foreign currencies are changed every day.

Table 7 shows the calculated VaR for each risk factor by Variance/Covariance method and the general VaR for the bank.

Table 7. Variance/Covariance method

Risk factor	Standard deviation	Position	VaR	General VaR
UAH/USD	0.004438	162 324 187	1 202 315	51 576
UAH/EUR	0.006935	55 802 387	649 069	
DNEN	0.037961	14 934 387	886 266	
DOEN	0.042071	11 149 284	751 860	
KIEN	0.024495	808 745	31 800	
UNAF	0.045000	6 064 691	429 835	

As there are correlations between all risk factors, the general calculated VaR is smaller than majority of individual VaRs. The conclusion about diversified market portfolio can be made: it is better to have diversified market correlated portfolio to reduce market risk.

Table 8 and Table 9 represent the calculated VaR by Monte Carlo and Historical simulations.

Table 8. Monte Carlo simulation

Risk factor	Standard deviation	Mean	Position	# of scenarios	General VaR
UAH/USD	0.004438	-0.000106	162 324 187	1000	17 171
UAH/EUR	0.006935	-0.000224	55 802 387		
DNEN	0.037961	0.003096	14 934 387		
DOEN	0.042071	0.001765	11 149 284		
KIEN	0.024495	0.000970	808 745		
UNAF	0.045000	0.003143	6 064 691		

Table 9. Historical simulation

Risk factor	Last return	Elasticity of position	General VaR
UAH/USD	0.000000	1 623 242	18 169
UAH/EUR	-0.000169	558 024	
DNEN	0.112069	149 344	
DOEN	0.000000	111 493	
KIEN	0.043765	8 087	
UNAF	0.000000	60 647	

The largest VaR is obtained by Variance/Covariance method, and the smallest one is obtained by Monte Carlo simulation, but the best estimation is chosen by the binomial test. The history of open currencies positions and actual profit/loss of the bank due to market risk for 2 months (November, December, 2005) are used for back testing of VaRs. For each day the general VaR for the bank is calculated by three methods and the obtained values are compared with actual loss of the bank on account of market risk. Table 10 shows the results of Binomial test.

Table 10. Binomial test

Method	Value of Binomial test statistic
Variance/Covariance	-1.52
Monte Carlo	1.25
Historical	0.55

The critical value for 95% level of confidence is 1.96, all the methods have the absolute value of statistic less than critical value, which means the hypothesis H_0 is not rejected. Therefore, the real proportions of exceptions do not significant differ from the expected proportions of exceptions (5% in our case) and all three methods give adequate estimation of VaR.

Additionally, Variance/Covariance method overestimates VaR (Binomial test statistic is negative), Historical simulation and Monte Carlo simulation underestimate VaR (Binomial test statistic is positive).

5.3 Capital reserve requirement

Basle Accord makes it mandatory for banks to use VaR as a basis for determining the amount of capital adequate for covering market risk. According to the recommendations of Bank for International Settlement, the minimum capital requirement should be the constant from 3 to 4 multiplying by the

previous day's VaR. The value of the constant depends on the back testing of the model. For considered data the best VaR method is Historical Simulation, because the Binomial test statistic of this method has the smallest absolute value, therefore, VaR is equal to 18169 UAH.

The best case will be, if the real proportion of exceptions is exactly the expected proportion of exceptions and the Binomial test statistic is equal to 0. Additionally, the smallest possible value of capital reserve should be defined and it is equal to the 3 multiplying by VaR. The worst case will be, if the absolute value of Binomial test statistic is equal to the critical value, 1.96 for 5% level of significance. Additionally, the largest possible value of capital reserve should be defined and it is equal to the 4 multiplying by VaR.

VaR calculated by Historical Simulation is chosen as the best model and its Binomial test statistic is equal to 0.55, it is 28% of critical value 1.96. Therefore, the constant of capital reserve requirement should be corrected by this addition 28% of the back testing. The constant is calculated according to the equation (21):

$$\lambda = 3 + \frac{0.55}{1.96} = 3 + 0.28 = 3.28 \quad (21)$$

Consequently, the capital reserve requirement is defined by formula (22) for the next day, namely 1st January of 2006.

$$R = \lambda \cdot VaR = 3.28 \cdot 18169 = 59594 \quad (22)$$

Bank must have capital reserves of 59594 UAH next day to cover market risk.

Chapter 6

CONCLUSIONS

According to Basel Committee on Banking Supervision II regulatory total capital in a bank should be equal to the sum of credit risk capital requirement, market risk capital requirement and operational risk capital requirement. This thesis presents the method of market risk capital requirement determination. Capital reserve requirement is defined on the VaR basis, which is the predicted worst-case loss at a specific confidence level over a certain period of time.

Conducted research allows mentioning the actuality of the theoretical and empirical results. Theoretically the actuality is confirmed by the new methodology VaR implementation in the Ukrainian banks for market risk measurement. Insufficiency of Ukrainian researchers' studies of VaR and complicity of international practice implantation determine the necessity of permanent improvement of market risk estimation methodology. Now Ukrainian banks might have high losses on account of wrong models implementation.

Empirically the actuality is confirmed by the real VaR calculation in the Ukrainian bank and accordance of market risk capital reserve requirement on the daily basis. The obtained VaR model was approved in the big size Ukrainian bank in April 2006 and recommended market risk capital reserve requirements are used there now. VaR and capital reserves are computed daily, back testing of VaR model is conducted in the end of each month.

The obtained results suggest that risk management department must exist in each bank and the results of their work should be permitted only for the bank's board, NBU and auditors. Market risk managers influence on the bank's financial reports by the setting the capital reserve requirement.

The following conclusions can be made for the considered time period in the thesis empirical analysis. According to the back testing, Historical simulation must be used in the bank for VaR computing in January 2006. The market risk is equal to 18169 UAH for the 1st of January 2006 given the bank's market portfolio, which consists of the two most significant foreign currencies open positions and of the four most significant stocks open positions. The bank must have capital reserves of 59594 UAH to cover market risk, this amount of capital minimizes the probability of the bank's default or bankruptcy on account of market fluctuations of exchange rates or stock prices.

To eliminate the possible criteria of supervised banks to underestimate VaR so as to reduce the capital requirements, Bank for International Settlement has prescribed certain minimum standard of VaR estimates and also certain tests, such as back testing of VaR models. If VaR model of a bank fails in back testing, a penalty is imposed resulting to higher capital charge. Thus, providing accurate estimates of VaR is of crucial importance for all stakeholders. A bank would like to pick up a model that would generate as low VaR as possible but pass through the back testing.

In calculating the VaR, each bank is allowed to use whatever method it thinks will best pass the back testing. However, the model selected must be used consistently, and it must be the primary model for reporting and managing risks within the bank. Therefore, the similar research as in the thesis should be done in all Ukrainian banks in the nearest future.

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APPENDICES

Appendix A

. dfuller u_u

```

Dickey-Fuller test for unit root                      Number of obs   =      519
-----
              Test          ----- Interpolated Dickey-Fuller -----
              Statistic     1% Critical   5% Critical   10% Critical
                              Value         Value         Value
-----
Z(t)              -1.880         -3.430         -2.860         -2.570
-----
MacKinnon approximate p-value for Z(t) = 0.3415

```

. dfuller u_e

```

Dickey-Fuller test for unit root                      Number of obs   =      519
-----
              Test          ----- Interpolated Dickey-Fuller -----
              Statistic     1% Critical   5% Critical   10% Critical
                              Value         Value         Value
-----
Z(t)              -1.346         -3.430         -2.860         -2.570
-----
MacKinnon approximate p-value for Z(t) = 0.6077

```

. dfuller dn

```

Dickey-Fuller test for unit root                      Number of obs   =      519
-----
              Test          ----- Interpolated Dickey-Fuller -----
              Statistic     1% Critical   5% Critical   10% Critical
                              Value         Value         Value
-----
Z(t)              -1.338         -3.430         -2.860         -2.570
-----
MacKinnon approximate p-value for Z(t) = 0.6116

```

. dfuller do

```

Dickey-Fuller test for unit root                      Number of obs   =      519
-----
              Test          ----- Interpolated Dickey-Fuller -----
              Statistic     1% Critical   5% Critical   10% Critical
                              Value         Value         Value
-----
Z(t)              -2.565         -3.430         -2.860         -2.570
-----
MacKinnon approximate p-value for Z(t) = 0.1003

```

. dfuller ki

```

Dickey-Fuller test for unit root                      Number of obs   =      519
-----
              Test          ----- Interpolated Dickey-Fuller -----
              Statistic     1% Critical   5% Critical   10% Critical
                              Value         Value         Value
-----

```


. dfuller kien

Dickey-Fuller test for unit root Number of obs = 518

Test Statistic	----- Interpolated Dickey-Fuller -----		
	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-27.452	-3.430	-2.860

MacKinnon approximate p-value for Z(t) = 0.0000

. dfuller unaf

Dickey-Fuller test for unit root Number of obs = 518

Test Statistic	----- Interpolated Dickey-Fuller -----		
	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-29.618	-3.430	-2.860

MacKinnon approximate p-value for Z(t) = 0.0000

Appendix B

. reg uah_usd l1.uah_usd l2.uah_usd l3.uah_usd l4.uah_usd l5.uah_usd, noconsta
> nt

Source	SS	df	MS	Number of obs =	514
Model	.00202935	5	.00040587	F(5, 509) =	22.55
Residual	.009161181	509	.000017998	Prob > F	= 0.0000
Total	.011190531	514	.000021771	R-squared	= 0.1813
				Adj R-squared	= 0.1733
				Root MSE	= .00424

uah_usd	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
uah_usd					
L1	-.4447668	.043801	-10.15	0.000	-.5308197 - .3587138
L2	-.2666576	.0475377	-5.61	0.000	-.3600518 - .1732634
L3	-.1950855	.0482794	-4.04	0.000	-.289937 - .100234
L4	-.1567461	.0474194	-3.31	0.001	-.249908 - .0635842
L5	-.15197	.0433014	-3.51	0.000	-.2370414 - .0668986

. durbina

Durbin's alternative test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	2.297	1	0.1297

H0: no serial correlation

. reg uah_eur l1.uah_eur, noconstant

Source	SS	df	MS	Number of obs =	518
Model	.001214993	1	.001214993	F(1, 517) =	22.21
				Prob > F	= 0.0000

Residual		.028285262	517	.00005471	R-squared	=	0.0412

Total		.029500255	518	.00005695	Adj R-squared	=	0.0393

					Root MSE	=	.0074

uah_eur		Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	

uah_eur							
L1		-.2014916	.0427568	-4.71	0.000	-.28549	-.1174933

. durbina

Durbin's alternative test for autocorrelation

lags(p)		chi2	df	Prob > chi2

1		0.166	1	0.6838

H0: no serial correlation

. reg dnen l10.dnen l14.dnen, noconstant

Source		SS	df	MS	Number of obs =	505

Model		.035351497	2	.017675748	F(2, 503) =	11.96
Residual		.743457109	503	.001478046	Prob > F	= 0.0000

Total		.778808606	505	.001542195	R-squared	= 0.0454

					Adj R-squared	= 0.0416
					Root MSE	= .03845

dnen		Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	

dnen							
L10		.1150878	.0421595	2.73	0.007	.0322574	.1979182
L14		.1729513	.0421229	4.11	0.000	.0901929	.2557097

. durbina

Durbin's alternative test for autocorrelation

lags(p)		chi2	df	Prob > chi2

1		0.212	1	0.6449

H0: no serial correlation

. reg doen l1.doen, noconstant

Source		SS	df	MS	Number of obs =	518

Model		.030517794	1	.030517794	F(1, 517) =	17.10
Residual		.922892602	517	.001785092	Prob > F	= 0.0000

Total		.953410396	518	.001840561	R-squared	= 0.0320

					Adj R-squared	= 0.0301
					Root MSE	= .04225

doen		Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	

doen							
L1		-.1789108	.0432703	-4.13	0.000	-.2639182	-.0939035

. durbina

Durbin's alternative test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	0.116	1	0.7331

H0: no serial correlation

. reg kien l1.kien l2.kien, noconstant

Source	SS	df	MS	Number of obs =	517
Model	.015313547	2	.007656773	F(2, 515) =	12.28
Residual	.321238483	515	.000623764	Prob > F	= 0.0000
				R-squared	= 0.0455
				Adj R-squared	= 0.0418
Total	.33655203	517	.000650971	Root MSE	= .02498

kien	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
kien					
L1	-.2072164	.0438152	-4.73	0.000	-.2932949 -.1211378
L2	-.1020946	.0438592	-2.33	0.020	-.1882595 -.0159296

. durbina

Durbin's alternative test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	0.343	1	0.5581

H0: no serial correlation

. reg unaf l1.unaf

Source	SS	df	MS	Number of obs =	518
Model	.096361905	1	.096361905	F(1, 516) =	37.19
Residual	1.33695438	516	.002590997	Prob > F	= 0.0000
				R-squared	= 0.0672
				Adj R-squared	= 0.0654
Total	1.43331628	517	.002772372	Root MSE	= .0509

unaf	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
unaf					
L1	-.2592876	.042517	-6.10	0.000	-.3428152 -.1757599
_cons	.0039661	.0022405	1.77	0.077	-.0004356 .0083677

. durbina

Durbin's alternative test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	1.046	1	0.3063

H0: no serial correlation

Appendix C

Convergence achieved after 105 iterations

Variance backcast: ON

$$\text{GARCH} = C(6) + C(7)*\text{RESID}(-1)^2 + C(8)*\text{GARCH}(-1)$$

	Coefficient	Std. Error	z-Statistic	Prob.
UAH_USD(-1)	-0.432953	0.071215	-6.079545	0.0000
UAH_USD(-2)	-0.281857	0.056384	-4.998834	0.0000
UAH_USD(-3)	-0.230532	0.055228	-4.174178	0.0000
UAH_USD(-4)	-0.145998	0.028908	-5.050378	0.0000
UAH_USD(-5)	-0.229208	0.018169	-12.61538	0.0000

Variance Equation

C	1.00E-05	5.29E-07	18.99048	0.0000
RESID(-1)^2	0.526975	0.077149	6.830584	0.0000
GARCH(-1)	0.073853	0.042664	1.731034	0.0834

R-squared	0.172574	Mean dependent var	-0.000109
Adjusted R-squared	0.161128	S.D. dependent var	0.004669
S.E. of regression	0.004277	Akaike info criterion	-8.437983
Sum squared resid	0.009254	Schwarz criterion	-8.371956
Log likelihood	2176.562	Durbin-Watson stat	1.957284

Convergence achieved after 17 iterations

Variance backcast: ON

$$\text{GARCH} = C(2) + C(3)*\text{RESID}(-1)^2 + C(4)*\text{GARCH}(-1)$$

	Coefficient	Std. Error	z-Statistic	Prob.
UAH_EUR(-1)	-0.167903	0.041669	-4.029426	0.0001

Variance Equation

C	6.08E-07	1.91E-07	3.183079	0.0015
RESID(-1)^2	0.000787	0.004565	0.172366	0.0863
GARCH(-1)	0.984391	0.008051	122.2765	0.0000

R-squared	0.038864	Mean dependent var	-0.000264
Adjusted R-squared	0.033254	S.D. dependent var	0.007549
S.E. of regression	0.007423	Akaike info criterion	-7.094903
Sum squared resid	0.028319	Schwarz criterion	-7.062084
Log likelihood	1841.580	Durbin-Watson stat	2.072132

Convergence achieved after 40 iterations

Variance backcast: ON

$$\text{GARCH} = C(3) + C(4)*\text{RESID}(-1)^2 + C(5)*\text{GARCH}(-1)$$

	Coefficient	Std. Error	z-Statistic	Prob.
DNEN(-10)	0.113190	0.024091	4.698450	0.0000
DNEN(-14)	0.170709	0.028815	5.924271	0.0000

Variance Equation

C	0.000264	8.91E-05	2.966021	0.0030
RESID(-1)^2	0.002076	0.001735	1.196802	0.0231
GARCH(-1)	0.823707	0.059898	13.75180	0.0000

R-squared	0.038904	Mean dependent var	0.003224
Adjusted R-squared	0.031215	S.D. dependent var	0.039177
S.E. of regression	0.038561	Akaike info criterion	-3.670245
Sum squared resid	0.743464	Schwarz criterion	-3.628418
Log likelihood	931.7369	Durbin-Watson stat	1.942749

Convergence achieved after 59 iterations

Variance backcast: ON

$$\text{GARCH} = C(2) + C(3)*\text{RESID}(-1)^2 + C(4)*\text{GARCH}(-1)$$

	Coefficient	Std. Error	z-Statistic	Prob.
DOEN(-1)	-0.269364	0.062868	-4.284606	0.0000

Variance Equation

C	0.000563	7.70E-05	7.307824	0.0000
RESID(-1)^2	0.123155	0.027651	4.453885	0.0000
GARCH(-1)	0.560506	0.058082	9.650327	0.0000

R-squared	0.022165	Mean dependent var	0.001769
Adjusted R-squared	0.016458	S.D. dependent var	0.042907
S.E. of regression	0.042552	Akaike info criterion	-3.584372
Sum squared resid	0.930693	Schwarz criterion	-3.551553
Log likelihood	932.3522	Durbin-Watson stat	1.814952

Convergence achieved after 59 iterations

Variance backcast: ON

$$\text{GARCH} = C(3) + C(4)*\text{RESID}(-1)^2 + C(5)*\text{GARCH}(-1)$$

	Coefficient	Std. Error	z-Statistic	Prob.
KIEN(-1)	-0.120925	0.057433	-2.105510	0.0352
KIEN(-2)	-0.090252	0.066689	-1.353335	0.0759
Variance Equation				
C	8.02E-05	1.18E-05	6.799557	0.0000
RESID(-1)^2	0.110846	0.022465	4.934125	0.0000
GARCH(-1)	0.756382	0.033619	22.49881	0.0000
R-squared	0.036646	Mean dependent var		0.001056
Adjusted R-squared	0.029119	S.D. dependent var		0.025517
S.E. of regression	0.025143	Akaike info criterion		-4.733091
Sum squared resid	0.323664	Schwarz criterion		-4.692007
Log likelihood	1228.504	Durbin-Watson stat		2.160582

Convergence achieved after 138 iterations

Variance backcast: ON

$$\text{GARCH} = C(3) + C(4)*\text{RESID}(-1)^2 + C(5)*\text{GARCH}(-1)$$

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.002979	0.001529	1.948607	0.0513
UNAF(-1)	-0.287135	0.070399	-4.078670	0.0000
Variance Equation				
C	0.000527	6.77E-05	7.780079	0.0000
RESID(-1)^2	0.216512	0.041398	5.230040	0.0000
GARCH(-1)	0.522047	0.058401	8.939066	0.0000
R-squared	0.066037	Mean dependent var		0.003149
Adjusted R-squared	0.058755	S.D. dependent var		0.052653
S.E. of regression	0.051083	Akaike info criterion		-3.595102
Sum squared resid	1.338664	Schwarz criterion		-3.554079
Log likelihood	936.1315	Durbin-Watson stat		1.916701