Optimal Portfolio of Chosen Stocks of the Prague Stock Exchange

Radim Gottwald
Mendel University in Brno

Abstract

The aim of the article is to assemble an optimal portfolio of chosen stocks of the Prague Stock Exchange. The Markowitz portfolio model is used. At first, Pearson correlation coefficients and covariance are calculated for the stocks ČEZ, KOMERČNÍ BANKA, TELEFÓNICA, UNIPETROL, NWR and PX Index in order to find the dependence measure from 2003–2012. These values are presented in a correlation matrix and covariance matrix. Yield, risk and yield to risk ratios are calculated for stocks and PX Index. The dependence between yield and risk of stocks as well as yield and risk of portfolios are found. Stocks have different weights in a portfolio. A set of possible portfolios and a set of efficient portfolios are assembled for various combinations of five-component stock portfolios. Based on that, an optimal portfolio is assembled. This article brings a method that can be used by investors and other subjects of the financial market while deciding to what stocks to invest in.

Keywords: management stock portfolio, market portfolio, Stock Exchange index, Stock Exchange

Introduction

Many investors invest on financial markets in various securities including stocks. Stocks belong to rather risky securities. Making investment decisions, investors try to find the risk related to investments in stocks. Kohout (1998) states that risk of stock price change is determined by standard deviation that takes account of stock price trend in time over a period. Investors find both risk and yield related to investing in stocks. According to Rejnuš (2008), the total yield is the sum of current and capital yield. Rejnuš (2001) presents that capital yield depends on achieved investment management results. To estimate yield, static methods and dynamic methods are usually used. While static methods do not take account of time factor, dynamic ones do.

In creating a portfolio, all investors are similarly motivated to combine stocks held in order to realize maximum yield with minimum risk. In the case of only partial positive correlation of stocks in a portfolio, possible diversification leads to a reduction of risk. The size of reduction depends on statistical

dependence between number of stocks and flow of income from investments. The higher statistical dependence is and the lower number of investments, the lower is the profit as a result of diversification. Various sets of portfolios have been described and analysed. A set of possible portfolios includes all possible combinations of portfolios.

Markowitz (1952) describes the set of efficient portfolios as such a set of portfolios with returns that are maximized for a given level of risk based on the mean-variance portfolio construction. Sharpe (1964) considers the market portfolio to be a portfolio consisting of a weighted sum of every asset in the market. On an efficient market where all information is immediately reflected in stock price change, investing in a market portfolio is optimal for many investors. León (2008) focuses on Markowitz's efficient portfolio optimization. He describes assumptions of this mean-variance framework like a static correlation matrix and normality of returns. The inconvenience of using an estimated correlation matrix typical of tranquil and the choice of the risk metric limits this framework. Almgren and Chriss (2004) extend Markowitz's notion of an efficient portfolio, specifically they introduce a preference relation on the set of possible portfolios. They also define an efficient portfolio as one which is most preferable among those with a given level of risk. Knowing expected returns, final optimal portfolios are theoretically superior all other possible portfolios and return Markowitz optimal portfolios.

The optimal portfolio is usually assembled based on choice of set of efficient portfolios. Investors prefer an optimal portfolio for its most favourable ratio of yield and risk. Cipra (2005) explains the attitude of investors to risk by means of indifferent curves. Investors consider these connecting lines from their perspective as identically acceptable. In the case of an optimal portfolio, indifferent curve of investor is the tangent of a set of efficient portfolios. The final choice of set of efficient portfolios depends, according to Levy and Sarnat (1999), on preferences of investors. This choice enables investors to achieve the highest indifferent curve, because the higher the indifferent curve, the higher utility investors will achieve. Brada (1996) presents that three basic assumptions should be ensured from the investor's view while assembling an optimal portfolio: to achieve maximum yield, maximum liquidity and minimum risk related to portfolio. The market portfolio is the only optimal portfolio to what all investors can invest in. In the case of an efficient market, all investors have the same opportunities as to what securities to invest in. Moreover, all investments are fairly valued within the market equilibrium. Bai, Liu and Wong (2010) focus on Markowitz's mean-variance portfolio optimization. They develop bootstrap estimators for the optimal return and its asset allocation. The PX Index as an official index of the Prague Stock Exchange is a price-weighted index. Kohout (2000) presents that investing in stock market indexes in the long-term horizon brings to investors an optimal combination of yield and risk.

Some authors focuse on the way of creating an optimal portfolio and an efficient portfolio which contains stocks of the Prague Stock Exchange. Portfolios created in different ways are compared. Husárová (2012) examines daily prices of 14 stocks from 2009–2012 and she creates portfolios in several ways.

In detail, according to minimum risk, maximum yield-to-risk ratio and maximum Sharpe ratio. Weekly prices of 5 stocks from 2005–2010 are analysed by Zajíček (2011). He creates portfolios according to minimum risk, minimum risk together with a necessary level of yield and Cutoff rate model. Roušavý (2010) measures daily prices of 14 stocks of the Prague Stock Exchange, similarly like previous authors. He uses the period 2009–2010 and creates offensive, defensive and mixed portfolios. The creation of the optimal portfolio and efficient portfolio are at the centre of attention of Kislingerová (2011) and Fotr and Hnilica (2009), who show how the yield-to-risk could be used to create such portfolios.

The aim of the article is to assemble an optimal portfolio of chosen stocks of the Prague Stock Exchange between 2003–2012. To assemble the portfolio, modern portfolio theory is applied, specifically the Markowitz portfolio model. Applying this model, a set of possible portfolios, a set of efficient portfolios in the Markowitz sense and Markowitz optimal portfolio are assembled. The reason, why the author focuses on this topical interesting problematic, why he writes the article and uses the chosen method is that stock portfolios are assembled by means of the presented method of mostly foreign stock markets.

Materials and Methods

At first, five stocks of the Prague Stock Exchange are chosen. Data needed for empirical analysis are founded through Patria Online, a.s. (2013) and Prague Stock Exchange (2013). In detail, historical stock prices and PX Index values in quarterly periodicity are founded.

The statistical dependence between stocks is found by means of several formulae presented by Brada (1996). Pearson correlation coefficients are calculated as follows:

$$\rho_{ij} = \frac{\sum_{t=1}^{N}(i_t - E(i))(j_t - E(j))}{\sqrt{\sum_{t=1}^{N}(i_t - E(i))^2 \cdot \sum_{t=1}^{N}(j_t - E(j))^2}}$$

where ρ_{ij} is the Pearson correlation coefficient of i-th and j-th stock, N is number of trading days, i_t is yield change of i-th stock in time t, j_t is yield change of j-th stock in time t, $E(i)$ is mean yield of i-th stock and $E(j)$ is mean yield of j-th stock. The Pearson correlation coefficient relates to linear function, which describes the relation between stock prices. Covariance could be considered to be a linear gauge of dependence. In detail, covariance measures how much two stock prices change together. When the covariance is normalized, the correlation coefficient is obtained. Markowitz (1952) uses this coefficient also to create a diversified portfolio.

Covariances are calculated as follows:

$$C_{ij} = \beta_i \cdot \beta_j \cdot \sigma^2$$

where C_{ij} is the covariance of i-th and j-th stock, β_i is the beta coefficient of i-th stock, β_j is the beta coefficient of j-th stock and σ^2 is the second power of standard deviation, which is defined subsequently.

Risk, specifically the mentioned standard deviation of stock price is calculated as follows:

$$\sigma = \sqrt{\sum_{t=1}^{N} \frac{(R_t - E(R))^2}{N-1}}$$

where σ is the standard deviation, N is number of trading days, R_t is stock price and $E(R)$ is average stock price during the period. Musílek (2011) describes this risk as the probability that return on an investment will be different from the expected return.

Yield, risk and yield to risk ratio of stocks are calculated. Yield, specifically relative capital yield is calculated as follows:

$$Y_{itk} = \frac{P_{it} - P_{it-k}}{P_{it-k}}$$

where Y_{itk} is stock price growth of i-th stock during interval $\langle t-k, t \rangle$, P_{it} is stock price of i-th stock in time t and P_{it-k} is stock price of i-th stock in time $t-k$.

Yield, risk and yield to risk ratio of portfolios are also calculated. Yield of n-component stock portfolios, specifically relative capital yield is calculated as follows:

$$R_p = \sum_{i=1}^{n} w_i \cdot R_i$$

where R_p is yield of n-component stock portfolio, n is number of stocks in portfolio, w_i is weight of i-th stock in portfolio and R_i is yield of i-th stock.

Risk of two-component stock portfolios, specifically standard deviation of portfolios is calculated as follows:

$$\sigma = \sqrt{(w_1^2 \cdot \sigma_{11} + 2 \cdot w_1 \cdot w_2 \cdot \sigma_{12} + w_2^2 \cdot \sigma_{22})}$$

where σ is the standard deviation of n-component stock portfolio, n is number of stocks in portfolio, w_i is weight of i-th stock in portfolio, w_j is weight of j-stock in portfolio and σ_{ij} is covariance of i-th and j-th stock.

Using presented formulas, a set of possible portfolios, a set of efficient portfolios and an optimal portfolio is assembled.

A set of efficient portfolios in the Markowitz sense is expressed as follows:

$$E_M = E_r \cap E_S$$

where E_M is set of efficient portfolios in the Markowitz sense, E_r is set of portfolios with minimum risk (set of efficient portfolios in the Sharpe sense) and E_S is set of portfolios with maximum yield.

Portfolio diversification is measured by the Herfindahl Index as follows:

$$HI = 1 - \sum_{i=1}^{n} w_i^2$$

where HI is the Herfindahl Index, n is number of stocks in portfolio and w_i is weight of i-th stock in portfolio.

Results

First, five stocks of the Prague Stock Exchange are chosen. Trading volumes in CZK from 2003–2012 ordered from the highest are found. Tab. 1 reports the first 10 trading volumes ordered from the highest.

Table 1: Top 10 Trading Volumes on the Prague Stock Exchange during 2003–2012

Stock	**Trading volume (CZK)**
ČEZ	1 962 555 878 883.99
Komerční banka	904 975 334 830.32
Telefónica	653 995 085 234.33
Erste bank	500 779 637 052.34
Unipetrol	201 690 774 821.18
NWR	154 574 174 287.86
CETV	127 756 125 512.69
Philip Morris	105 450 515 551.82
Pegas Nonwovens	31 602 370 464.86
VIG	8 371 222 216.03

Source: Own calculations using Patria Online, a.s. (2013)

ERSTE BANK is not chosen, because possible inclusion of two stocks from the same industry (here KOMERČNÍ BANKA and ERSTE BANK) to the portfolio implies distortion of results. Chosen stocks should be independent of each other. So that following five stocks are chosen: ČEZ, KOMERČNÍ BANKA, TELEFÓNICA, UNIPETROL and NWR.

Then, statistical dependence between stocks is found. The correlation matrix of stocks is reported in Tab. 2.

Table 2: Correlation Matrix of Stocks

Stock	**ČEZ**	**Komerční banka**	**Telefónica**	**Unipetrol**	**NWR**	**PX**
ČEZ	1.00	0.71	0.80	0.87	0.83	0.79
Komerční banka	0.71	1.00	0.57	0.72	0.37	0.69
Telefónica	0.80	70.57	1.00	0.88	0.57	0.93
Unipetrol	0.87	0.72	0.88	1.00	0.75	0.92
NWR	0.83	0.37	0.57	0.75	1.00	0.90
PX	0.79	0.69	0.93	0.92	0.90	1.00

Source: Own calculations using Patria Online, a.s. (2013)

The higher the correlation coefficient between two stocks, the stronger is dependence between these stocks. In the case of a correlation coefficient close to 1.00, yields of two stocks change similarly. It means that when the first is increasing, the growth of the second is almost the same. On the contrary, when the first is decreasing, the decrease of the second is almost the same. When correlation coefficient equals to 1.00 there is a linear dependence with positive direction.

Correlation coefficients 1.00 are in Tab. 2 only at main diagonal of this symmetric matrix. This fact has influence on value of correlation coefficients. The PX Index is mostly influenced by TELEFÓNICA. The lower is dependence between stocks and the higher is number of stocks, the higher is possible profit followed from diversification.

To calculate risk the of portfolios, the covariance matrix is found. This covariance matrix, that is similarly as correlation matric symmetric, is reported in Tab. 3.

Table 3: Covariance Matrix of Stocks

Stock	**ČEZ**	**Komerční banka**	**Telefónica**	**Unipetrol**	**NWR**	**PX**
ČEZ	118 308	162 796	22 258	22 076	13 243	98 764
Komerční banka	162 796	444 138	30 381	35 502	22 038	167 505
Telefónica	22 258	30 381	6 508	5 193	1 896	27 124
Unipetrol	22 076	35 502	5 193	5 406	2 375	24 556
NWR	13 243	22 038	1 896	2 375	10 869	16 244
PX	98 764	167 505	27 124	24 556	16 244	130 953

Source: Own calculations using Patria Online, a.s. (2013)

Dispersions of parameters are at the main diagonal of Tab. 3. Elton, Gruber, Brown and Goetzmann (2006) describe covariance as a statistical indicator derived from dispersion measuring to what extent two parameters move similarly. High covariances are measured by combinations of KOMERČNÍ BANKA with other stocks or with a PX Index. Dispersion of KOMERČNÍ BANKA is distinctly higher than dispersions of other stocks and PX Indexs.

Then, yield, risk and yield to risk ratio of stocks are founded. They are reported in Tab. 4.

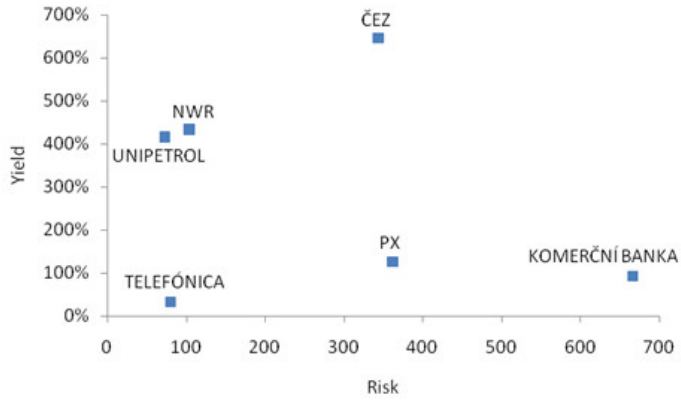
Table 4: Yield, Risk and Yield to Risk of Stocks

Indicator	**ČEZ**	**Komerční banka**	**Telefónica**	**Unipetrol**	**NWR**	**PX**
Yield	646 %	92 %	32 %	415 %	434 %	125 %
Risk	344	666	81	74	104	362
Yield to Risk	1.88 %	0.14 %	0.40 %	5.61 %	4.17 %	0.35 %

Source: Own calculations using Patria Online, a.s. (2013)

It is clear that all yields are positive. The trend of whole market represented by the PX Index in the chosen period is in terms of direction similar to the trend of stock prices of all five stocks. Maximum yield is found by ČEZ, while maximum risk by KOMERČNÍ BANKA. The dependence between yield and risk of stocks is illustrated in Graph 1.

Graph 1: The Dependence between Yield and Risk of Stocks

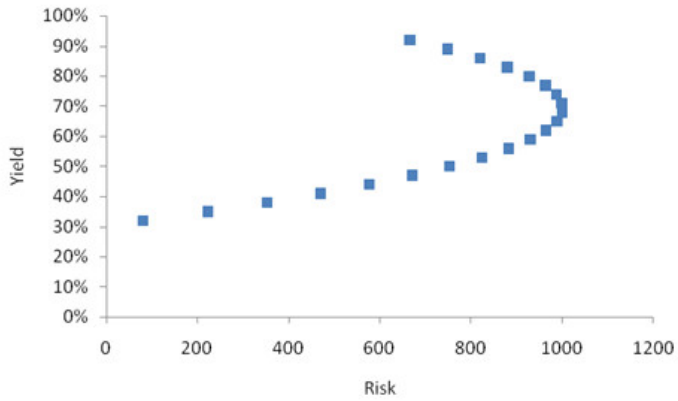


Source: Own calculations using Patria Online, a.s. (2013)

It is clear that investment to KOMERČNÍ BANKA brings lower yield and a higher risk than investment to UNIPETROL, NWR and ČEZ. These three stocks are dominant assets in relation to KOMERČNÍ BANKA. Investment to them brings also higher yield and a lower risk than investment to the PX Index. Possible investment to the other two stocks, specifically KOMERČNÍ BANKA and TELEFÓNICA will be diversified according to weights of stocks.

Then yield and risk of two-component stock portfolios are calculated. Weights of individual stocks in portfolios are either 5 % or multiples of it. Progression 5 %, 10 % etc. affords sufficient and clearly arranged ways how to present individual differences in portfolios. 21 portfolios are assembled by combinations of different weights of stocks in the portfolios. The dependence between yield and risk of portfolios is illustrated in Graph 2.

Graph 2: The Dependence between Yield and Risk of Portfolios



Source: Own calculations using Patria Online, a.s. (2013)

Also the set of possible portfolios is illustrated in Graph 2. It is clear that both yield and risk related to different portfolios are also different. Thus, possible weight changes of stocks in portfolios lead to changes of yield and risk of portfolios.

The set of efficient portfolios is a subset of the set of possible portfolios. Yield to risk ratios of efficient portfolios must be higher than yield to risk ratio of PX Index. Based on values of PX Index presented in Tab. 4, the yield to risk ratio equals to 0.35 %. Tab. 5 contains indicators related to set of possible portfolios sorted in ascending order for KOMERČNÍ BANKA weight in portfolio.

Table 5: Indicators Related to Set of Possible Portfolios

Komerční banka weight in portfolio	**Telefónica weight in portfolio**	**Portfolio yield**	**Portfolio risk**	**Yield to risk ratio**	**Herfindahl Index**
0 %	100 %	32.08 %	80.67	0.40 %	0.00 %
5 %	95 %	35.07 %	222.47	0.16 %	9.50 %
10 %	90 %	38.06 %	352.42	0.11 %	18.00 %
15 %	85 %	41.05 %	470.53	0.09 %	25.50 %
20 %	80 %	44.04 %	576.80	0.08 %	32.00 %
25 %	75 %	47.03 %	671.23	0.07 %	37.50 %
30 %	70 %	50.02 %	753.81	0.07 %	42.00 %
35 %	65 %	53.01 %	824.55	0.06 %	45.50 %
40 %	60 %	56.00 %	883.44	0.06 %	48.00 %
45 %	55 %	58.98 %	930.50	0.06 %	49.50 %
50 %	50 %	61.97 %	965.71	0.06 %	50.00 %
55 %	45 %	64.96 %	989.07	0.07 %	49.50 %
60 %	40 %	67.95 %	1000.60	0.07 %	48.00 %
65 %	35 %	70.94 %	1000.28	0.07 %	45.50 %

70 %	30 %	73.93 %	988.12	0.07 %	42.00 %
75 %	25 %	76.92 %	964.11	0.08 %	37.50 %
80 %	20 %	79.91 %	928.26	0.09 %	32.00 %
85 %	15 %	82.90 %	880.57	0.09 %	25.50 %
90 %	10 %	85.89 %	821.04	0.10 %	18.00 %
95 %	5 %	88.88 %	749.66	0.12 %	9.50 %
100 %	0 %	91.87 %	666.44	0.14 %	0.00 %

Source: Own calculations using Patria Online, a.s. (2013)

It is clear that the set of efficient portfolios contains only the first portfolio in Tab. 5. Only in this case is the yield to risk ratio higher than 0.35 %. Similarly to Graph 2, increasing the yield to 32.08 % higher, the risk of portfolios of the set of possible portfolios increases from 80.67 to 1000.60 and later decreases to 666.44. Portfolio diversification is expressed by the Herfindahl Index. Increase of this Index is connected with decrease of the yield to risk ratio and vice versa.

The optimal portfolio is the efficient portfolio with the highest yield to risk ratio. Investments to UNIPETROL, NWR and ČEZ could be considered to be efficient, because their yield is higher and their risk is lower than corresponding values of the PX Index. Moreover, their yield to risk ratio is higher than 0.35 %. Based on Tab. 5, investment only to TELEFÓNICA leads also to yield to risk higher than 0.35 %. Optimal portfolio consists of UNIPETROL (weight 47 %), NWR (35 %), ČEZ (16 %) and TELEFÓNICA (2 %). Weights of these stock in an optimal portfolio are derived of corresponding yield to risk ratios presented in Tab. 4.

Discussion

In the context of similarly focused empirical studies, the composition of set of possible portfolios, set of efficient portfolios and optimal portfolio depends on many factors chosen within assembling. Such factors are the choice of security (stocks are in this article), market portfolio (stock market indexes or risk-free assets), stock market, historical period and number of portfolios assembled of different weights and other factors. Given the obligation of portfolio managers in some countries to hold at most 20 % of one stock in a portfolio also the potential limit of one stock weight in portfolio has certain influence on composition. Financial analysts could assemble optimal portfolios for investors differently averse to risk, especially for conservative, neutral and aggressive investors.

Low liquidity in the Prague Stock Exchange may lead to such values of correlation coefficients, covariances, yields and risks of stocks, which are not too comparable with the values obtained by analysis of high liquidity stock markets. In general, low liquidity may lead to certain distortion of calculated values. Thus, deduced findings need not correspond with results of the most of empirical studies, which are focused on modern portfolio theory.

In the opinion of the author, further research in this field can go in several directions. Based on presented factors, a method could be modified. Expected values in the future could be calculated instead of historical values from the

past. There are several ways how to estimate expected values. Quantitative analysis examines the development of ratio indicators and the horizontal or vertical analysis. Expected values could be estimated based on historical values. Econometric approach proceeds from knowledge of factors having an impact on expected values. These tools of financial analysis are used within the company analysis, which belongs, together with macroeconomic analysis and industry analysis, among parts of the fundamental analysis. Long-term fundamental analysis assumes, in contrast to short-term technical analysis, the existence of overvalued or undervalued stocks. Tools of the technical analysis like candlestick charts, Elliot waves, Bollinger bands and others could be used to for stock timing. Thus, investors can find when they should buy or sell stocks. Fundamental and technical analysis could be considered to be specific cases of investment analysis. In general, the aim of the investment analysis is to examine and assess important market trends, earnings ratios and other indicators to determine a suitable investment strategy.

Conclusion

The article was focused on the assembling of an optimal portfolio of chosen stocks of the Prague Stock Exchange. To find dependence among stocks ČEZ, KOMERČNÍ BANKA, TELEFÓNICA, UNIPETROL, NWR and PX Index between 2003–2012, correlation and covariance matrixs were presented. Yield, risk and yield to risk ratios were measured, too. The dependence between yield and risk of stocks and the dependence between yield and risk of portfolios were illustrated. Using different weights of stocks in the portfolio, a set of possible portfolios and set of efficient portfolios as its subset were assembled. Weight of stock in the portfolio, portfolio yield and portfolio risk were presented for all stocks from a set of possible portfolios. Portfolio diversification was expressed by the Herfindahl Index. Based on results, the author found that investments to UNIPETROL, NWR and ČEZ could be considered to be efficient.

Highlighting to the contribution of this article, investors and other subjects of the financial market could use the presented method when they look for an optimal investment opportunity. This way will make their choice easier. Using the analysis of the dependence between yield and risk of various portfolios these subjects could find such an investment portfolio which is for them more attractive to investing than a market portfolio.

This article has been created within the research project IGA 28/2013 of Mendel University in Brno “Stock markets sensitivity to information in period after the financial crisis”.

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Optimální portfolio z vybraných akcií obchodovaných na pražské Burze cenných papírů

Cílem článku je sestavení optimálního portfolia z vybraných akcií pražské Burzy cenných papírů. Je použit Markowitzův model portfolia. V rámci časového období 2003–2012 jsou nejdříve za účelem zjištění míry vzájemné závislosti vypočteny pro akcie ČEZ, KOMERČNÍ BANKA, TELEFÓNICA, UNIPETROL, NWR a burzovní index PX Pearsonovy korelační koeficienty a kovariance. Tyto hodnoty jsou znázorněny v korelační a kovarianční matici. Pro akcie a index PX jsou vypočteny výnosnosti a rizikovosti. Je zjištěna závislost mezi výnosností a rizikovostí akcií i mezi výnosností a rizikovostí portfolií. Akcie mají v portfoliu různou váhu. Pro různé kombinace akciových portfolií je sestavena množina přípustných portfolií a množina efektivních portfolií. Na základě toho je sestaveno optimální portfolio. Přínosem článku je prezentace způsobu, který mohou investoři a další subjekty na finančním trhu použít při rozhodování o tom, do jakých akcií budou investovat.

Klíčová slova: akciové portfolio, tržní portfolio, burzovní index, burza cenných papírů

Contact address:
Ing. Mgr. Radim Gottwald, Department of Finance, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, *e-mail: radim.gottwald@mendelu.cz*

GOTTWALD, R. Optimal Portfolio of Chosen Stocks of the Prague Stock Exchange. *Littera Scripta*. 2014, **7**(1), 12–24. ISSN 1805-9112.