OPTIMIZED INDICATORS OF TECHNICAL ANALYSIS ON THE NEW YORK STOCK EXCHANGE

Martin Širůček[1], Karel Šíma[2]

[1] Department of Finance, Faculty for Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic
[2] Faculty for Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

Abstract

ŠIRŮČEK MARTIN, ŠÍMA KAREL. 2016. Optimized Indicators of Technical Analysis on the New York Stock Exchange. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 64(6): 2123–2131.

The article is focused on the use of technical analysis and it's indicators. The main aim is the evaluation of technical analysis for selected index instruments which are traded on NYSE. The secondary objective is the optimization of indicator's parameters of technical analysis and subsequent comparison of profitability of business strategies based on these optimized parameters. The empirical analysis includes the backtesting of optimized indicators and comparison with the default settings of these indicators. The optimization and backtesting were performed on cyclical stocks, represented by stock index S&P 500 Financial from 11/1/2014 to 10/31/2015.

Keywords: technical analysis, indicators, optimization, S&P 500, relative strength, moving average

INTRODUCTION

The implementation of technical analysis has a permanent place amongst investors, particularly since information derived from charts sourced from IT technologies and price analysis of financial assets has been used more frequently. Forecasting the direction of future stock prices is a widely studied topic in many fields including trading, finance, statistics and computer science. As mentioned by Irwin, Park (2007), in finance, statistics and computer science, most traditional models of stock price prediction use statistical models and/or neural network models derived from price data. Computers help not only with the determination of an indicator's value, but also with calculations during various parameter setting of indices and with the identification of the most suitable setting or optimization.

This article is focused on the analysis and specifically on the optimization of indices of technical analysis. The aim of this article is to provide optimization of selected indicators of technical analysis and to compare results achieved for investors, with the default setting of

these indicators. Due to optimization of indices, which was carried out in comparison with the recommended settings, it is possible to answer the question as to whether implementation of optimization is beneficial and whether it is possible to achieve higher revenue through it. Optimization is carried out in order to make a given indicator react better in a new trend at a given volatility. It is based on the assumption that volatility does not change too much, unless there is a sudden shock. If there is a good mood in the markets, then volatility will be at low levels in comparison to a period of distrust and fear in the markets. With optimization, we should reduce the influence of volatility, because at higher volatility, optimization will set parameters of an indicator so that it generates a lower quantity of signals, while at the initial setting an indicator might create a higher quantity of signals, from which more can be false and thus may harm an investor.

Technical analysis is constantly developing and nowadays not only complex econometric models of time series are used but also neural networks, which work as artificial intelligence, learning and automatically adjusting themselves in order

to achieve better results. The submitted article is therefore focused on the analysis of chosen (frequently used) indices of technical analysis in practice, their use by retail investors for the creation of their own business strategy and its optimization from recommended settings with the objective of achieving higher revenue during trading on the stock markets.

Literature survey

Technical analysis, also known as "charting", has been a part of financial practice for many decades, but this discipline has not received the same level of academic scrutiny and acceptance as more traditional approaches such as fundamental analysis. Technical analysis is, according to Veselá (2011), built on the basis of historical repetition of prices, which also repeat with high probability in the future. Unlike fundamental analysis, it answers the question "when will what happen?", which sufficiently defines a sphere of its further use, i.e. "timing" of purchases and sales. Fang, Qin, Jaqcobsen (2014) mention that technical analysis is methodology for forecasting the direction of security prices through the study of past market data.

Technical analysis is widely used among traders and financial professionals, and is very often used by active day traders, market makers and pit traders. According to research provided by Menkhoff (2010), 87 % of 692 fund managers put at least some importance on technical analysis for their investment decisions. In a recent review, Irwin, Park (2007) reported that 56 of 95 modern studies found it produces positive results.

According to Kirckpatrick, Dahlquist (2011), technical analysis monitors prices at freely tradable markets with the intention of creating profit or investment decisions. Technical analysis is based on basic economic theories. According to Víšková (1997), all fundamental, economic, political, psychological and other information is included in prices. Therefore, it is completely useless to study financial statements of companies and to compare a market price of a share with its intrinsic value as it is done by fundamental analysts.

According to Fernández-Blanco *et al.* (2008), real world stock market predictions such as stock prices, unpredictability and stock selection for portfolios are challenging problems. Technical indicators are applied to interpret stock market trending and investment decisions. The main difficulty of indicator use is deciding its appropriate parameter values, such as the number of days of the periods or quantity and kind of indicators. According to Víšková (1997), these indicators can be divided into reverse graphical formations (signalling a trend change), consolidation formations (signalling continuation of an initial trend after its temporary interruptions) and gaps (breakaway gap, common gap, exhaustion gap and measuring gap).

However, the principle and use of technical analysis is not only based on subjective analysis of graphical formations but also on using so-called indicators of technical analysis, which include hundreds of tools helping to identify the power of a new trend or its change, and also its possible buy and sell signals. According to Baetje, Menkhoff (2016) or Reilly (1989), the following belong to the basic groups of indicators: Moving averages and methods based on them, Oscillators, Volume indicators, Sentiment indicators, Indicators of width and relative market performance.

Share quotations, or movements of their prices are very volatile up to the point of being random. One of the techniques to deal with this phenomenon is, according to Pring (2002), the use of moving averages, which attempts to ease fluctuation of price cycles into a smooth trend, thus disfigurement is smoothed to a minimum. A moving average is, according to Murphy (1999), the most universal and widely used among all indicators of technical analysis. Based on Droke (2001),, various types of moving averages are encountered in business practice: a simple moving average (SMA), a triangular moving average (TMA), a weighted moving average (WMA), an exponential moving average (EMA), a variable moving average (VMA) and a time series forecast (TSF).

Moving averages can be calculated for various time spans, a longer time period contains more comparison and thus also more information. By including more data in the calculation, every day becomes less important. Therefore, a large change in value on one day does not have a substantial influence on the long-term time average. In technical analysis there are various popular values for length of observation, for example: 10 days, 40 days or 200 days. The period selected depends on the kind of movement one is concentrating on, such as short, intermediate or long term. In any case, moving average levels are interpreted as support in a rising market or resistance in a falling market.

According to Murphy (1999), what makes this indicator so successful is the fact that it combines something from the principles of oscillators with the approach of crossing of dual moving averages. On the monitor, you can see only two lines, however, three lines are used in calculation. The faster line (called the MACD line) is the difference between two exponential smoothed averages of closing prices (usually the last 12 and 26 days or weeks). The slower line (called the signal line) is usually an exponential smoothed average for 9 periods of the MACD line. Appel (2005) recommends one setting of values for sell signals and a different one for buy signals. A majority of traders, however, use standard values 12, 26 and 9 for all the signals.

MACD is a very strong indicator of timing, but according to Appel (2005), it is possible to identify its complications in trading in a steady trend, in a continuing narrow market channel or in decline. Moving averages and MACD are also, according

to Henderson (2002), an example of late technical indicators as they reflect past price movements.

Another commonly used indicator is Bollinger Bands (BB). A bandwidth changes depending on the volatility of a share and it is possible to influence it by entering a multiple of the standard deviation. Generally, any type of moving average can be used for construction of a BB. Kocer (2016), mentioned that BB is a technical analysis tool which was invented to predict future stock prices. BB is used to predict maximum and minimum future prices based on past prices.

According to Kirckpatrick, Dahlquist (2011), for the construction of BB it is first necessary to calculate a simple moving average. BB uses SMA, because a majority of calculations of standard deviation use SMA. Furthermore, a band with an exact number of standard deviations is drawn.

According to Bollinger (2002), the real power of Bollinger Bands takes effect when they are combined with other indicators, first of all it is recommended to combine it with an RSI indicator or a volume indicator, which is also a suitable choice. The preferred strategy is comparison of a price share within a band, with a share of indicator. Jobman (1994) and also Sahin, Ozbayoglu (2014) stated that RSI is the most commonly used technical indicator due to its simplicity and performance. RSI measures strength of historical price movements by comparison of "positive" and "negative" days. RSI compares the magnitude of stock's recent gains to the magnitude of its recent losses and turns that information into a number that ranges from 0 to 100. Gorgulho, Neves, Horta (2011) mentioned that the RSI line forms a signal between 0 and 100, which specifies determined overbought or oversold conditions when its value is above or below specific levels. There are several ways to calculate this indicator and it depends on whether one wants to calculate a "normal RSI" or gentler RSI formulas. The calculation of the RSI is described in Rodríguez-González et al. (2011) as follows:

For each day, an upward change (U) or downward change (D) is calculated. "Up" days are characterized by the daily close being higher than yesterday's daily close, i.e.:

$$U = close_{today} - close_{yesterday}$$

D = 0.

Conversely, a down day is characterized by the close being lower than the previous day's (note that D is nonetheless a positive number)

U = 0

$$D = close_{yesterday} - close_{today}$$

If today's close is the same as yesterday's, both U and D are zero. An average for U is calculated with an exponential moving average (EMA) using a given N-days smoothing factor, and likewise for D. The ratio of those averages is the relative strength:

$$RS = \frac{EMA[N] of U}{EMA[N] of D}$$

This is converted to a relative strength index between 0 and 100:

$$RSI = 100 - 100 \cdot \frac{1}{1 + RS}.$$

Wilder (1978) established that the most accurate value for value N to calculate the best RSI is 14 because it was half of the lunar cycle. However, depending on the market, the company and other factors, the value 14 is not always the best value to calculate the RSI.

The shorter the period set, the more sensitive the oscillator and the wider the amplitude. RSI works best if fluctuation reaches the top and bottom extremes. Therefore, when an investor trades in very short time intervals and he/she wants to have more significant oscillation, it is possible to shorten the time periods. A period is extended in order to have an oscillator smoother and narrower in amplitude. The amplitude of 9-period RSI is therefore greater than that of the recommended 14-period one. Despite 9 and 14 being the most common settings, analysts have also experimented with other values. As stated by Murphy (1999), some analysts use a shorter interval, such as 5 or 7, in order to increase volatility of the RSI line. Others use 21 or 28 in order to smoothen RSI.

According to Turek (2008), RSI is a moment indicator and despite its main usage is to show overbought and oversold values, these values can stay irrational for a very long time. Simply said, once RSI is used in a strong uptrend, the indicator can be expected to stay in overbought values for a considerable part of the whole increasing movement. RSI should therefore be used as an indicator of a future probable movement and reacted on only after the movement, not vice versa. Once RSI is over 70, it can be thought of as if the market is overbought and that there is a high probability of correction downwards, but it does not mean that this correction will start a new downtrend.

Recommended settings of indicators

For a simple moving average (SMA) a 20-day period length is selected. This fact corresponds with the duration of a selected period, which is recommended in literature (e.g. Kirpatrick, Dahlquist (2011), Drasnar (1995)), but at the same time it corresponds with the setting of another indicator, which is based on a moving average.

Bollinger Bands are based on a 20-day simple moving average and a bandwidth is given as twice the standard deviation. This setting is recommended by the author of the indicator John Bollinger. This setting is also mentioned by Appel (2005).

For the RSI, the setting 14/30/70 was used. Interpretation of this setting is that a 14-day period is used for calculation of RSI, the bottom boundary is set to 30 and the top to 70. This setting is also recommended by the author of the indicator J. W. Wilder. In general, traders use a setting between 9 and 25. For longer term trading, the number might

	SMA	**BB**	**RSI**	**MACD**
default (recommended) settings	20-day	20-day, 2x st. dev.	14/30/70	12/26/9

be increased but fewer trading signals will be generated. Even though Appel (2005), the author of the MACD indicator, recommends two different settings (one for buy and the other one for sell signals), in practice the setting 12/26/9 is often used, because the difference between a 12-day and a 26-day moving average is smoothed by a 9-day moving average. From this perspective, only one recommended setting is selected, corresponding with standard values 12, 26 and 9.

MATERIALS AND METHODS

The time period designated for the optimization of technical analysis indicators is from 1st November 2013 to 31st October 2014 and for the subsequent (back)testing the period from 1st November 2014 to 31st October 2015 was chosen. The selected indexed instrument is Cyclical Index S&P 500 Financials, which includes companies meeting the condition of classification in the financial sector.

Optimization of indicators of technical analysis is carried out so that investment strategy based on a given index maximizes its profitability, thus optimal values of parameters will be those, which when used by a given business strategy, achieve the highest valorisation. Similar methodology for optimization was used by Gencay (1998), and Fernández-Blanco, *et al.* (2008) in their research. The selected indicators for optimization and subsequent (back)testing are:

● Simple Moving Average (SMA)
● Moving Average Convergence/Divergence (MACD)
● Relative Strength Index (RSI)
● Bollinger Bands

These indicators are selected owing to their frequent use, which is because of their relatively easy construction and interpretation. The use of these indicators is recommended by for example: Taylor, Allen (1992), Lui, Mole (1998), Appel (2005), Larsen (2010), Baetje, Menkhoff (2016) and Kocer (2016).

Optimally set parameters of indicators (see Tab. I) are tested within individual business strategies and they are compared with the stated indexed instruments. The input data used were of a daily period in closing prices of indexes (indices?).

For every indicator, boundaries of limits (top and bottom boundaries) are selected, in which individual parameters can be set, selected with respect to recommended values and used in practice.

For SMA, the selected limits are from 1 to 200 days.

For BB, the bottom boundary of the moving average is selected to 1 and the top boundary to 200. At the same time, the boundaries for standard deviation are 1 and 8.

For RSI, a range in which testing occurs is set so that the length of RSI is optimized for the values from 1 to 100, the bottom boundary 10 to 40 (the most used are 8, 9 and 25, Wilder (1978) recommended 14 days) and the top boundary 60 to 90.

In the case of MACD, for a faster SMA the range 1 to 50 is selected and for a slower SMA 10 to 100 and for the trigger 1 to 50 as well (similar settings were used e.g. by Williams (2006)).

RESULTS

For evaluation of performance, the following methods (as in Gencay (1998)) are used: realized profit expressed in percentage, total quantity of trades (one trade contains opening and closing of a position), average profit/loss per one trade, and quantity of profitable trades expressed in percentage.

Other information is also stated, but it is only used to support the evaluation. These are the quantity of profitable and losing trades (expressed in absolute values), average profit in profitable trades, average loss in losing trades, profit in the most profitable trade and loss in the most losing trade.

The selected index, after correction in January 2015, continued in an increasing trend. Despite the growth rate decline, low volatility was maintained. A fall in August 2015 triggered the end of the trend, but from the end of September 2015 it became a growing trend again.

Since the index behaves in the majority of the period as it had been in the previous period, it is probable that the optimized indicators can achieve good results.

The strategy based on the optimized setting generated very low success for trades, and a high average loss per trade, which meant a big total loss for this strategy. From the chart of cumulated profit, it is also obvious that loss from the beginning of the period was, although with few profitable trades, continuously deepened.

The strategy based on the recommended setting had a slightly better outcome, yet it still resulted in loss. Although the strategy exceeded the boundary of 50 % for a successful trade, its deeper loss exceeded the small profits. Despite the last trade being the most profitable, the average profit per trade did not move into positive numbers.

The result of the back tests for Bollinger Bands was reached clearly against the recommended setting. The strategy based on the optimized setting generated signals for 4 trades, which were all

II: *Back test of SMA for S&P 500 Financials*

	Optimized SMA	Recommended SMA
Total profit	−10.64 %	−2.32 %
Total quantity of trades	15	21
Percentage of profitable trades	33.33 %	52.38 %
Quantity of profitable trades	5	11
Quantity of losing trades	10	10
Average profit/loss	−0.73 %	−0.10 %
Average profit in profitable trades	0.67 %	1.06 %
Average loss in losing trades	−1.44 %	−1.37 %
Profit in the most profitable trade	1.81 %	4.33 %
Loss in the most losing trade	−4.62 %	−3.45 %

III: *Back test of Bollinger bands for S&P 500 Financials*

	Optimized BB	Recommended BB
Total profit	15.16 %	−3.55 %
Total quantity of trades	4	2
Percentage of profitable trades	100.00 %	0.00 %
Quantity of profitable trades	4	0
Quantity of losing trades	0	2
Average profit/loss	3.60 %	−1.79 %
Average profit in profitable trades	3.60 %	0.00 %
Average loss in losing trades	0.00 %	−1.79 %
Profit in the most profitable trade	5.47 %	0.00 %
Loss in the most losing trade	0.00 %	−2.19 %

IV: *Back test of RSI for S&P 500 Financials*

	Optimized RSI	Recommended RSI
Total profit	−1.17 %	1.94 %
Total quantity of trades	1	1
Percentage of profitable trades	0.00 %	100.00 %
Quantity of profitable trades	0	1
Quantity of losing trades	1	0
Average profit/loss	−1.17 %	1.94 %
Average profit in profitable trades	0.00 %	1.94 %
Average loss in losing trades	−1.17 %	0.00 %
Profit in the most profitable trade	0.00 %	1.94 %
Loss in the most losing trade	−1.17 %	0.00 %

V: *Back test of MACD for S&P 500 Financials*

	Optimized MACD	Recommended MACD
Total profit	4.74 %	−0.55 %
Total quantity of trades	6	9
Percentage of profitable trades	83.33 %	55.56 %
Quantity of profitable trades	5	5
Quantity of losing trades	1	4
Average profit/loss	0.80 %	−0.03 %
Average profit in profitable trades	1.66 %	1.44 %
Average loss in losing trades	−3.54 %	−1.87 %
Profit in the most profitable trade	3.17 %	4.96 %
Loss in the most losing trade	−3.54 %	−4.60 %

profitable and with high average profit per trade. Success of this strategy is in the fact that the trade was realized only after the August fall. While the other strategy realized 2 losing trades, sale did not happen before the fall, thus the whole decline was reflected in the results of this strategy.

In both cases, the RSI indicator generated signals only for one trade. Unfortunately, the strategy based on the optimized indicators reacted to the fall in December by purchase, after which a sell signal was not recorded, so the trade was completed with loss at the end of the period. The second strategy generated only a buy signal, but only at the end of August, i.e. after the fall, consequently the trade realized by the end of the period was profitable.

The strategy based on the optimized parameters turned out well and was profitable in spite of loss in the last trade. This strategy only had one losing trade out of a total of 6 trades; that and a good profit per trade contributed to a better result. Unfortunately, a bad reaction to the fall caused loss in the last trade, which occurred because the trade was realized later after a slight increase and so for a higher price.

On the other hand, the strategy based on the recommended values of parameters dropped immediately at the beginning of the period and in April, there was a loss higher than 6 %. In spite of more than half success per profitable trade, the average rate of return per trade was –0.03 %. However, this strategy reacted better on the last trade and without the end of the period, a higher return might have been achieved.

VI: *Results of the back test, optimized indicators*

	Opt. SMA	Rec. SMA	Opt. BB	Rec. BB	Opt. RSI	Rec. RSI	Opt. MACD	Rec. MACD
Total profit	–10.64 %	–2.32 %	15.16 %	–3.55 %	–1.17 %	1.94 %	4.74 %	–0.55 %
Total quantity of trades	15	21	4	2	1	1	6	9
Percentage of profitable trades	33.33 %	52.38 %	100 %	0 %	0 %	100 %	83.33 %	55.56 %
Quantity of profitable trades	5	11	4	0	0	1	5	5
Quantity of losing trades	10	10	0	2	1	0	1	4
Average profit/loss	–0.73 %	–0.10 %	3.60 %	–1.79 %	–1.17 %	1.94 %	0.80 %	–0.03 %
Average profit in profitable trades	0.67 %	1.06 %	3.60 %	0.00 %	0.00 %	1.94 %	1.66 %	1.44 %
Average loss in losing trades	–1.44 %	–1.37 %	0.00 %	–1.79 %	–1.17 %	0.00 %	–3.54 %	–1.87 %
Profit in the most profitable trade	1.81 %	4.33 %	5.47 %	0.00 %	0.00 %	1.94 %	3.17 %	4.96 %
Loss in the most losing trade	–4.62 %	–3.45 %	0.00 %	–2.19 %	–1.17 %	0.00 %	–3.54 %	–4.60 %

DISCUSSION AND CONCLUSION

This work proposes a capable new approach to automatically manage a portfolio by using "alternative" settings of selected indicators of technical analysis.

After optimization, the SMA indicator was not able to achieve profit on either of the selected indicators. Looking at individual values of length of a moving average recommended by optimization, it is possible to see that recommended values have a relatively large dispersion. A change in behaviour of the indices is very probably behind the bad results of the optimized SMA indicator. At the same time, if there was loss of power of a trend, then it was negatively reflected on achieving profit. This situation occurred at S&P 500 Financials where an index grew at a slower pace.

Comparing results using the recommended settings, one can see that a lateral trend does not suit the recommended settings. Either there was no change in profit development at this state, or there was loss. The optimized indicator managed to achieve better results in two out of three cases compared to the indicator set according to the recommended settings, probably because of this common property. Rejnuš's (2008) statement was confirmed by the back test; he considers time delay as a weakness of moving averages and formation of signals against actual development of the stock exchange. The empirical analysis confirmed that a large number of trade signals were in the end completed with losing trade. It is possible to say that SMA is more suitable as an additional indicator for trading. It is

possible to determine a direction of trade with recommended settings of various lengths to identify either short-term or long-term trends. The following table shows the difference between unprofitable and profitable deals by using default (recommended) settings and optimization of selected indicators. Not once did BB achieve loss in the total result. However, in one case there was also no profit, because of a trade that was not realized. This happened because very conservative values were set after the optimization. In the other two cases, a relatively small number of trades were realized, which led to a higher percentage of chance that the trade would be profitable. Despite a change in index behaviour, BB achieved non-negative values. There was not even one losing trade out of the four trades, unlike in the case with the recommended setting of this indicator. The optimized strategy was 100 % successful, while the recommended setting achieved zero success per profitable trade.

The setting and use of BB recommended by the author John Bollinger is not borne out by the results of this work. The author recommends the use of the indicator in combination with other indicators. However, after optimization the indicator achieved better results on its own, while not generating false signals. It is clearly evident that this indicator appears to be conservative, which makes it successful and profitable at the same time. For this indicator, optimization and exclusive use are recommended. In Kabasinskas, Macys' (2010) research, using the same parameters of Bollinger Bands, fewer signals were generated in a short-term case and more signals in the long term. That is why specific sets of parameters are needed for a long term and a short-term investment, to obtain maximum profitability in either case.

Following the optimization, the RSI indicator generated the last trade signal (only one), moreover at the time when the cyclical index exhibited a loss by contrast to the recommended setting of this indicator.However, loss could have been caused by closing a position at the end of the period. Turek (2008) states that thanks to a property of the RSI indicator, i.e. values of RSI can stay irrational for a very long time, this indicator generates a very small quantity of trade signals. Therefore, as is proven by this work, it is appropriate to use this indicator with an additional one, in order to confirm the strength of a trend or to warn about a change of trend. Because of this, optimization is not so important and the indicator can be used without it. Fayek et al. (2013) presented other results, in which an optimized RSI indicator provided the highest returns over other techniques in all periods by providing optimization on DJIA during 1982 to 2012.

On the other hand, the MACD indicator was also relatively successful. Optimization of this indicator brought, unlike with the recommended setting, five profitable trades and only one losing (for the recommended setting the ratio was 5:4). Our results correspond with Fernández-Blanco, et al. (2008), where alternative settings of MACD were used by his Evolutionary Algorithm to bring the highest profit on the Dow Jones Industrial Average from 2000 to 2005. In their research, the average profit with optimization of MACD brought the investor an average profit of 50 % with a standard deviation of 14.15 %. In this research, a buy and hold strategy does not provide, on average, a profit greater than 30 %. Standard deviation exceeds 25 %. Consequently, with the data, we can say that a strategy based on MACD parameters optimization bring simillar results. Our results also show that the MACD indicator is an acceptable indicator of trend movements, which was also confirmed by Stanković, Marković, Stojanović (2015).

There were four indicators selected for testing, which are frequently used by the investing public (see Baetje, Menkhoff (2016), Reilly (1989), Murphy (1999), Fernández-Blanco, et al. (2008) or Gencay (1998)). Their frequent use is a consequence of their easy interpretation. The setting of recommended values, used for comparison, was selected according to how they are most often used in practice or what setting was recommended by their authors.

The resulting values of optimization came out differently for every instrument; it is even possible to say that there were extreme differences (a number of profitable vs. losing trades, generating a number of trades). It implies that every indicator behaves differently during use with a given instrument. Therefore, the conclusion is that optimization needs to be carried out continuously, alternatively in combination with another indicator Investors must build their own strategy and it is contingent on them to choose how often they carry out optimization. They must act carefully because optimization is a strong tool only if used correctly. Incorrect execution may lead to staggering loss.

In comparison with the results of optimization of other indicators, MACD and BB deliver the best results in the case of total or average profit or in the ratio of profitable and losing trades. In comparison with other empirical works, our research shows results in the optimization of the four most frequently used indicators. It is difficult to compare our results with other studies, which provided optimization only of one variable and of another market or index. However, optimization of some indicators brings the same results and can be recommended.

A possible direction of an extension of our research is backtesting of optimization on anticyclic or neutral stocks (indices).

REFERENCES:

APPEL, G. 2005. *Technical analysis: Power tools for active investors.* Harlow: Pearson Professional Education.

BAETJE, F., MENKHOFF, L. 2016. Equity premium prediction: Are economic and technical indicators unstable? *International Journal of Forecasting,* (32)4: 1193–1207.

BOLLINGER, J. 2002. *Bollinger on Bollinger bands.* New York: McGraw-Hill. 227.

DRASNAR, G. 1995. *Hazardní hry: Úvod do spekulace s cennými papíry.* 1st ed. Praha: Academia. 108.

DROKE C. 2001. *Moving averages simplified.* Columbia, MD: Marketplace Books.

FANG, J., QIN, Y., JACOBSEN, B. 2014. Technical market indicators: An over view. *Journal of Behavioral and Experimental Finance,* (4): 25–56.

FAYEK, M., B., EL-BOGHDADI, H., M., OMRAN, S., M. 2013. Multi-objective Optimization of Technical Stock Market Indicators using GAs. *International Journal of Computer Applications,* (68)20.

FERNÁNDEZ-BLANCO, P. et al. 2008. Technical Market Indicators Optimization using Evolutionary Algorithms. In: *Paper presented at the Proceedings of the 10th annual conference on Genetic and evolutionary computation (GECCO).* Atlanta, USA.

GENCAY, R. 1998. Optimization of technical trading strategies and the profitability in security markets. *Economics letters,* (59): 249–254.

GORGULHO, A., NEVES R., HORTA, N. 2011. Applying a GA kernel on optimizing technical analysis rules for stock picking and portfolio composition. *Expert System in Applications,* (38)11.

HENDERSON, C. 2002. *Currency strategy: the practitioner's guide to currency investing, hedging and forecasting.* Chichester : Wiley.

IRWIN, S. H., PARK, CH. 2007. What Do We Know About the Profitability of Technical Analysis? *Journal of Economic Surveys,* (21)4: 786–826. Available at: SSRN (http:/ / ssrn. com/ abstract=1006275).

JOBMAN, D. R. 1994. *Handbook of Technical Analysis: A Comprehensive Guide to Analytical Methods, Trading Systems and Technical Indicators.* McGraw-Hill.

KABASINSKAS A., MACYS, U. 2010. Calibration of Bollinger Bands Parameters for Trading Strategy Development in the Baltic Stock Market. *Inzinerine Ekonomika-Engineering Economics,* (21)3: 244–254.

KIRKPATRICK, CH. D., DAHLQUIST, J. R. 2011. *Technical analysis: the complete resource for financial market technicians.* 2nd ed. UpperSaddle River, N.J.: FT Press, xxvi.

KOCER, B. 2016. Bollinger bands approach on boosting ABC algorithm and its variants. *Applied Soft Computing,* (49): 292–312.

KOHOUT, P. 2013. *Investiční strategie pro třetí tisíciletí.* 7. aktualiz. a přeprac. vyd. Praha: Grada.

LARSEN, J., I. 2010. *Predicting stock prices using technical analyses and maschine learning.* [Online]. Norwegian University of Science and Technology.

Available at: diva-portal.org %2Fsmash %2Fget %2Fdiva2 %3A354463 %2FFULLTEXT01. pdf&usg=AFQjCNEMB7ZTPvYbT4XHnWyccK_ cmDLbLg. [Acessed 2016, March 30].

LUI, Y., MOLE, D. 1998. The use of fundamental and technical analyses by foreign exchange dealers: Hong Kong evidence. *Journal of International Money and Finance, Elsevier,* (17)3: 535–545.

MENKHOFF, L. 2010. The use of technical analysis by fund managers: International evidence. *Journal of Banking & Finance,* (34)11: 2573–2586.

MURPHY, J., J. 1999. *Technical analysis of the financial markets: a comprehensive guide to trading methods and applications.* New York: New York Institute of Finance. 542.

PRING, M. J. 2002. *Technical analysis explained: the successful investor's guide to spotting investment trends and turning points.* 4th ed. New York: McGraw-Hill. 641.

REILLY, F., K. 1989. *Investment Analysis and Portfolio Management.* Driden Ed. Chicago, III. USA.

REJNUŠ, O. 2008. *Finanční trhy.* 1st ed. Ostrava: Ekonomie Key Publishing.

RODRÍGUEZ-GONZÁLEZ, A., et al. 2011. *CAST:* Using neural networks to improve trading system based on technical analysis by mean of the RSI financial indicator. *Expert Systems with Applications,* (38)9: 11489–11500.

SAHIN, U., OZBAYOGLU, A. M. 2014. *TN-RSI: Trend-normalized RSI indicator for Stock Trading Systems with Evolutionary Computation.* [Online]. In Complex Adaptive Systems, Publication 4, Conference Organized by Missouri University of Science and Technology 2014,Philadelphia. Available at: http://www.sciencedirect.com/ science/article/pii/S1877050914013350/pdf?md 5=4061f4330ab005f83e48f010de89fab3&pid=1-s2.0-S1877050914013350-main.pdf. [Acessed 2016, October 17].

STANKOVIĆ, J., MARKOVIĆ, I., STOJANOVIĆ, M. 2015. Investment Strategy Optimization Using Technical Analysis and Predictive Modeling in Emerging Markets. *Procedia Economics and Finance,* (19): 51–62.

TAYLOR, M., P., ALLEN, H. 1992. The use of technical analysis in the foreign exchange market. *Journal of International Money and Finance, Elsevier,* (11)3: 304–314.

TUREK, L. 2008. *Jak se stát traderem* [Online]. Available at: http://www.czechwealth.cz/blog/ temata/materialy-zdarma. [Acessed 2015, August 26].

TURNER, T. 2007. *A Beginner's Guide to Day Trading Online.* 2nd edition. Adams Media.

VESELÁ, J. 2011. *Investování na kapitálových trzích.* 2. aktualiz. vyd. Praha: Wolters Kluwer Česká republika.

VÍŠKOVÁ, H. 1997. *Technická analýza akcií.* Praha: HZ.

WILDER, J. 1978. *New concepts in technical trading systems.* Greensboro, N.C.: Trend Research.

WILLIAMS, O., D. 2006. *Emiúpircal Optimization of Bollinger Bands for profitability*. [Online]. British Columbia, Kanada: Simon Fraser University. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2321140. [Acessed 2016, October 19].

Contact information

Ing. Martin Širůček, Ph.D.: martin.sirucek@mendelu.cz
Karel Šíma: sima.karel@gmail.com