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Digital Methods of Technical Analysis for Diagnosis of Crisis Phenomena in the Financial Market

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Abstract. Periodically occurring crisis phenomena in financial markets make urgent the issues related to prompt diagnostics and forecasting of crisis phenomena development to minimize financial risks. Modern technical analysis, based on the extensive use of digital methods, is one of the main approaches to the prompt processing of stock exchange real-time information. However, the current instability of the economy requires the improvement of existing technical methods. This study aims to develop the tools for technical analysis of financial assets to improve investment strategies in crisis periods. In this direction, using the methods of mathematical statistics, indicators of volatility and depth of economic crisis were developed to optimize portfolio investment management strategies. The offered technical analysis tools have been tested by the example of the financial crises in 2008-2009, 2014-2015, 2019-2020 concerning the Russian stock market. The authors presented the investment strategy results based on the developed approach. The results obtained demonstrate the positive economic efficiency of the suggested recommendations. The application of the developed algorithm based on technical analysis allows for monitoring the financial market situation. It reveals critical points of crisis phenomena (for example, periods of maximum volatility, the 'bottom' of the crisis, etc.). The algorithm is used for analysis of information transmitted by a trading platform.

Keywords: Financial Crisis; Stock Exchange; Stock Prices; Technical Analysis of Financial Market; Trading Algorithm

1. Introduction

Periodically occurring crisis phenomena in the financial market significantly complicate the problem of forecasting its dynamics. The need to use digital methods and tools for making economic decisions under conditions of uncertainty and risk has been repeatedly emphasized in contemporary works by numerous authors (for instance, in the papers by (Lyukevich et al., 2020; Polyanin et al., 2020; Berawi, 2021; Petrov et al., 2021).

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The existing digital methods of diagnosing and forecasting the financial market are mainly based on machine learning principles. Such techniques imply automated analysis to recognize existing patterns in a significant amount of online data. A trading robot can simultaneously monitor stock exchange prices of dozens and even hundreds of financial assets, instantly perform complex calculations, make decisions and immediately make transactions. The use of modern digital technologies allows us to significantly reduce the time needed to complete such transactions to milliseconds. A trading robot can perform up to several hundred transactions with financial assets per second. Nevertheless, despite the significant scientific developments in this area, only a few algorithms show positive results when tested in a natural trading environment. The use of modern technical analysis, neural networks, and cluster analysis allows trading robots to detect subtle non-linear interdependencies and patterns in the financial market. As a result, algorithmic trading is turning into a highly accurate digital analytical tool which helps to generate investor return at a speed and frequency that are impossible for human capabilities.

At the present stage, it is possible to distinguish several critical directions in developing the automated technical analysis of financial markets. One of the directions is related to the construction of combined technical indicators and models for forecasting the dynamics of stock markets Todorova (Teixeira & Oliveira, 2010). The main idea behind this approach is to combine the most efficient indicators and models to achieve a financial result that would exceed the market average.

In particular, Teixeira and Oliveira (2010) have proposed a new automated stock exchange trading method. The technique combined technical analysis tools and an intelligent forecasting system based solely on the history of daily stock prices and closing volumes. It was shown in their work that application of this method allowed them to get significantly higher profits in comparison with the passive ‘buy and hold’ investment strategy for most of the analyzed companies. The distinctive feature of this strategy is an insignificant number of trading operations, which allows for to minimize the risk of influencing the market price dynamics. It is widely known that high-frequency trading robots, by making mass transactions, can affect the market dynamics of the financial market, increasing its volatility.

Combining science’s advances and technology in stock exchange trading, Feng et al. (2004) have proposed trading strategies based on the application of artificial intelligence and technical analysis. The authors considered two automated stock exchange trading systems using the Penn-Lehman Automated Trading (PLAT) simulator (like in the paper by (Kearns & Ortiz, 2013) which is a market simulator with real-time data. The first system involved the development of an investment strategy based on the stock market's volatility, without forecasting its price movement's direction. The second system was based on technical analysis and consisted of forming an oppositely directed strategy known in the economic literature (Chan et al., 2003). The study results have shown that the joint application of these systems in an automated mode demonstrates high economic efficiency (Feng et al., 2004).

Of particular note is the work by (Lo et al., 2000), in which the authors have proposed an automated approach to recognizing stable recurring combinations of the data on prices, trading volume, or indicators used in technical analysis with the use of non-parametric regression. Comparing the unconditional empirical distribution of daily stock returns with the conditional distribution due to specific technical indicators, it was found that over a 31-year sample period several technical indicators provided additional information and were of practical value (Lo et al., 2000).

One more direction of the development of the automated technical analysis of financial markets at the present stage is an optimization of the existing and development of new models of technical analysis to forecast the dynamics of stock markets (Inumula et al., 2019; Fayek, 2013; Kutluk, 2013). One more direction of the development of the automated technical analysis of financial markets at the present stage is the optimization of the existing and development of new models of technical analysis to forecast the dynamics of stock markets (Inumula et al., 2019; Fayek, 2013; Kutluk, 2013). In particular, Fayek et al. (2013) proposed a technique for optimizing the parameters of technical indicators using a genetic algorithm concerning objective functions for the Sharpe ratio and annual return. The algorithm was based on the use of indicators such as double exponential moving average crossover (DEMAC), relative strength index (RSI), moving average convergence-divergence (MACD). Testing the methodology demonstrated better results compared to passive and random investment strategies on the historical data of the US stock index for 30 years.

Another direction in further development of technical analysis is adapting its tools concerning volatile stock markets, including the emerging and crisis ones (Altarawneh, 2022; de Souza et al., 2018; Lubnau & Todorova, 2014; Chong et al., 2010). The paper's authors (de Souza et al., 2018) developed an automated trading system that simulated trades in this portfolio using the methods of technical analysis and fundamental indicators. The results of the study have shown that the developed trading system based on the use of technical analysis can exceed the profitability of the passive 'buy and hold' investment strategy for certain financial assets traded on the stock markets of the developing BRICS countries (Brazil, Russia, India, China, South Africa.) However, the profit received was significantly higher than the amount invested. This study has confirmed the assumption that the 'age' of a stock market is directly related to its efficiency Chong et al. (2010). An idea has been substantiated that markets become more efficient over time, that is, their price efficiency, considered in the Efficient Market Hypothesis (EMH), increases (Fama, 2014).

Despite the large number of scientific publications dedicated to the formation and empirical testing of the work of the technical analysis indicators, the issue of the applicability of data in conditions of financial crises remains debatable. This study aims to develop technical analysis models for diagnosing crisis phenomena in the financial market using digital methods. The method may be valid over the long term if active investment strategies based on revealed regularities demonstrate promising results. The approach involves building crisis technical indicators and testing an investment strategy based on their application. The developed algorithm can be used for the automated processing of exchange data for online monitoring of crisis phenomena and constructing trading robots. The results of this study will contribute to obtaining opportunities for leveling the negative impact of crisis phenomena on the financial market.

2. Methods

The developed tools of technical analysis are based on the relative variations of the following indicators, calculated every minute (if necessary, the frequency of calculations can be different) using a natural logarithm: opening price (I_1), closing price (I_2), maximum price (I_3), a minimum price (I_4), trading volume (I_5) and their combinations, in particular, the difference between the maximum and minimum prices. Calculation of the mentioned indicators applied to the model is made according to the following formula:

$$I_i = Ln\left(\frac{I_{t+1}}{I_t}\right) \quad (1)$$

where I_{i+1} is the indicator value at the subsequent time point (t+1), I_t is the indicator value at the current time point t.

To diagnose the crisis phenomena, the Crisis Volatility Indicator (CVI) was introduced. It is the ratio of every minute scope of variation in the prices of financial assets to the standard deviation of the relative change in the prices of financial assets. The indicator considers considering the degree of price changes within the interval specified in the technical system. It is determined according to the following formula:

$$CVI = \frac{\overline{Rv_n}}{\sigma} \tag{2}$$

where $\overline{Rv_n}$ is the scope of variation in the prices of financial assets for a given interval n; σ is the standard deviation of the relative change in the prices of financial assets.
Further, the dynamics of the CVI in crisis years were evaluated. It was found that this indicator demonstrated a significant amplitude of fluctuations in the periods of fluctuating price trends. The dominant presence of the indicator within the range of conditional value limits [–10; +10] characterizes the onset of a crisis state.

Using the methods of mathematical statistics, the Financial Crisis Depth Indicator (FCDI) was developed, allowing to identify of the process of reaching the 'bottom' of financial crises. The construction of the technical crisis indicator model was based on determining the sensitivity of closing prices to regressors. The beta coefficient (β) was considered a measure of sensitivity. The formula representation of the obtained model is as follows:

$$FCDI = (0.285 \times LN\left(\frac{I_{1\,(t+1)}}{I_{1\,(t)}}\right) + 0.812 \times LN\left(\frac{I_{3\,(t+1)}}{I_{3\,(t)}}\right) + +0.004 \times LN\left(\frac{I_{5\,(t+1)}}{I_{5\,(t)}}\right) - 0.004 \times LN(\frac{I_{3\,(t+1)}-I_{4\,(t+1)}}{I_{3\,(t)}-I_{4\,(t)}}) \tag{3}$$

The Financial Crisis Depth Indicator characterizes the scale of a financial crisis. The increment of its fluctuations and regular renewal of the extreme points indicates that the 'bottom' of a financial crisis is approaching and has been reached. Based on the results of the indicator testing, it was found that the area above the level (+3%) characterizes the overbought zone, at this point, a signal to sell assets is fixed. When the indicator reaches a value below (–3%), it is recognized as the oversold zone and means a signal to buy financial assets.

The data recording and calculations of technical indicators were carried out using a specially designed computer program that can be integrated into a trading robot for online processing of exchange information. The following section presents the results of work of the developed indicators.

3. Results and Discussion

Testing the most well-known models of technical analysis (Simple Moving Average (SMA), Moving Average Convergence Divergence (MACD), Relative Strength Index (RSI), Bollinger Bands, Stohastic, Chaikin Oscillator, Ichimoku) using Russian stock market crises as an example shows the following results (Figures 1-3). The obtained results indicate the relative predictability of the crises of 2008–2009 and 2019–2020 using the analyzed technical indicators. At the same time, the currency crisis of 2014–2015 was the least predictable. The application of active investment strategies based on the analyzed technical indicators demonstrates the most enormous capital losses in 2008–2009 and 2014–2015.

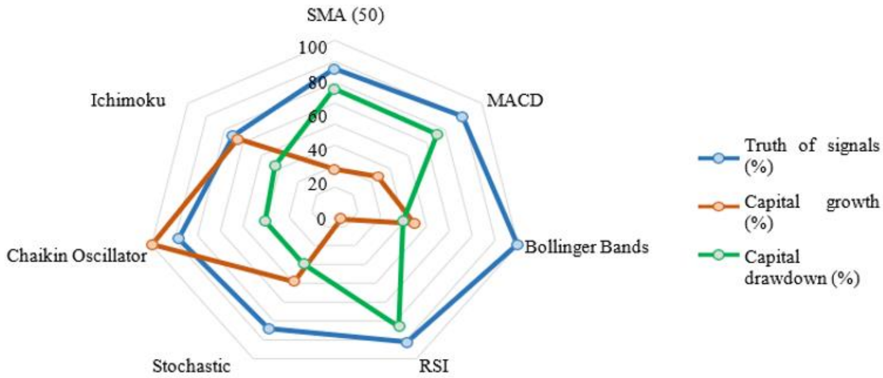


Figure 1 The results of the work of technical analysis indicators during the crisis period from 2008 to 2009

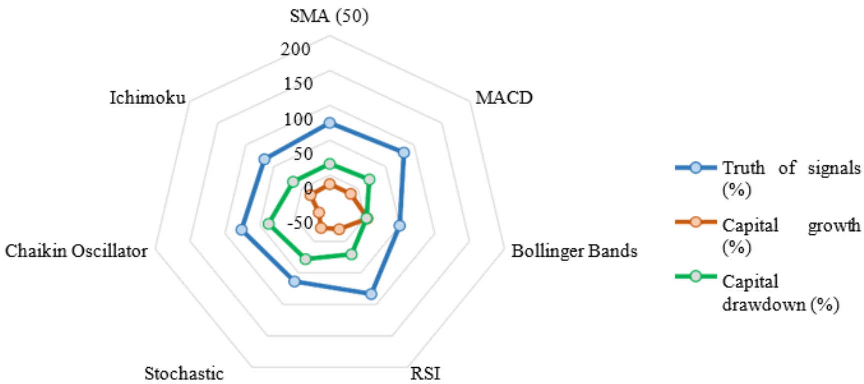


Figure 2 The results of the creation of technical analysis indicators during the crisis period from 2014 to 2015

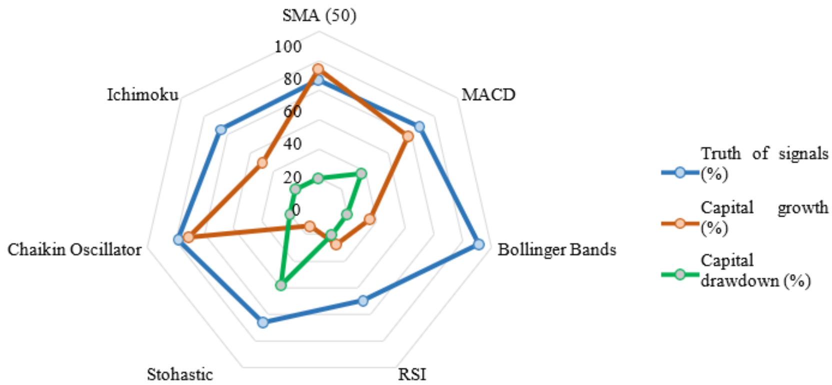
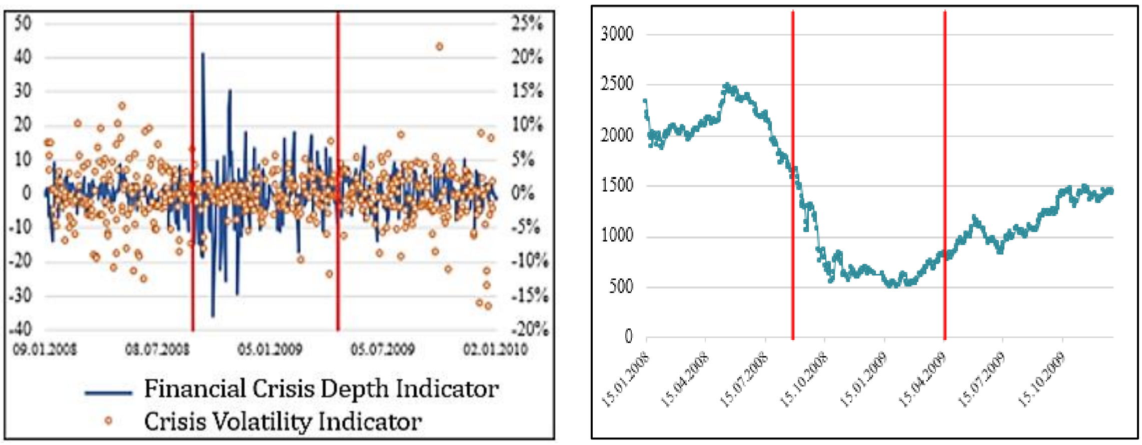


Figure 3 The results of the work of technical analysis indicators during the crisis period from 2019 to 2020

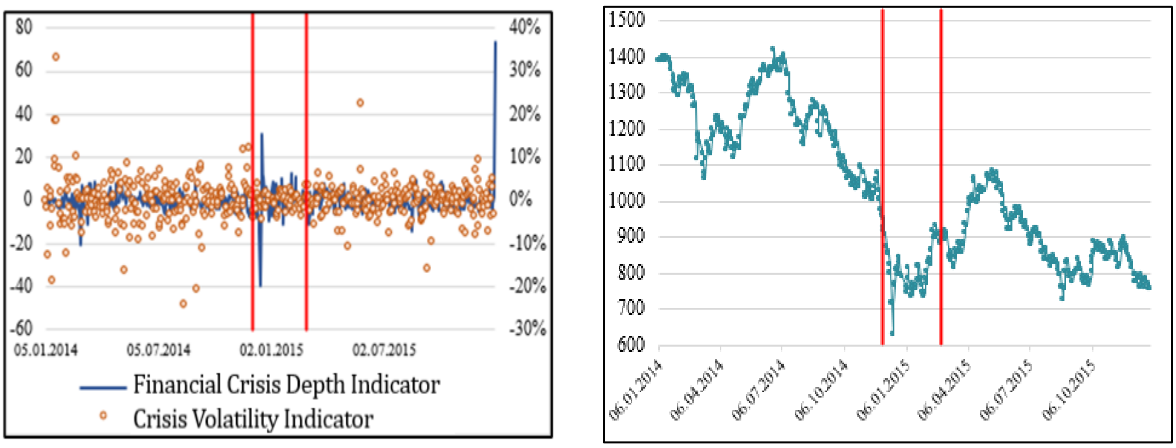
Technical indicators that generate trading signals are valuable tools for predicting the dynamics of financial markets, whereby the results of the research have been confirmed by many authors. The main problem of their application is related to the determination of suitable parameters. This problem takes on the most acute character in the context of financial crises. It is proposed to use a neural network algorithm trading algorithm based on the joint use of the Crisis Volatility Indicator (CVI) and the Financial Crisis Depth Indicator (FCDI). Optimization and algorithmic debugging were carried out according to two criteria: growth and drawdown of the investor's capital. Adjustment of the degree of sensitivity of indicators was necessary when passing through a critical zone of the "bottom" of the crisis, the transition to the period of post-crisis recovery was recorded after this zone. Results testing of the algorithmic trading strategy based on the developed technical indicators was carried out using the example of the Russian stock market crises. In particular, the following periods of severe crisis shocks in the Russian economy have been considered: 2008–2009, 2014–2015 and 2019–2020. The indicator reflecting the state of the Russian stock market (including under conditions of currency crises) is the Russian Trading System (RTS) Index. In this regard, the shares included in this Index and denominated in US dollars at the exchange rate current for the given time served as the testing objects. The studied portfolio is characterized as highly diversified. The historical data on the prices of the shares included in the RTS Index, which were fixed every minute, served as the database.

Figures 4-6 illustrate the applicability and correctness of work of the constructed IDFC and CVI compared with the RTS Index price dynamics for the periods under consideration. The time interval characterizing the bottom of each considered financial crisis is represented by vertical lines in Figures 4-6.



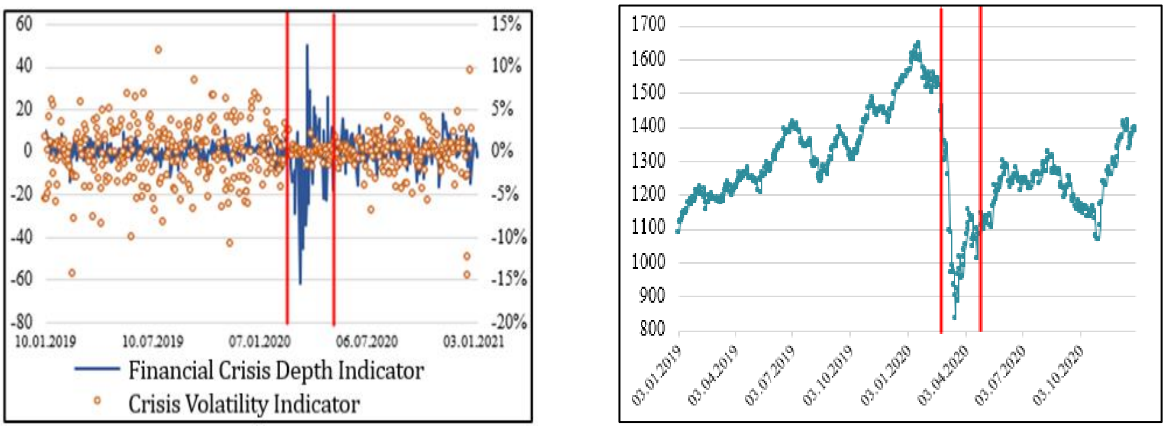
(a) (b)

Figure 4 Joint work of the Financial Crisis Depth Indicator and Crisis Volatility Indicator (a) for 2008-2009 in comparison with the RTS Index price dynamics (b)



(a) (b)

Figure 5 Joint work of the Financial Crisis Depth Indicator and Crisis Volatility Indicator (a) for 2014-2015 in comparison with the RTS Index price dynamics (b)



(a) (b)

Figure 6 Joint work of the Financial Crisis Depth Indicator and Crisis Volatility Indicator (a) for 2019-2020 in comparison with the RTS Index price dynamics (b)

Combining science's advances and technology has indicated positive economic efficiency, leading to the minimization of losses and contributing to the increment of investor capital during the considered crisis periods (Table 1).

Table 1 Results of Implementation of the Anti-Crisis Strategy of Investment Portfolio Management (fragment)

Crisis Periods	2008-2009	2014-2015	2019-2020
Capital growth%	47.88	32.98	10.29
Capital drawdown, %	0.00	0.00	0.00

Table 2 illustrates the results of a simple passive strategy ("buy and hold") portfolio strategy (i.e., its growth and drawdown of capital). Table 2 demonstrates, in particular, that the investor who used such a passive method might have lost nearly 80 percent of their wealth in 2008-2009. At the same time, the process based on the approach described above permitted reducing the drawdown to 0 percent.

Table 2 Results of Implementation of the Passive Investment Strategy (fragment)

Crisis Periods	2008-2009	2014-2015	2019-2020
Capital growth%	-37.10	-45.61	-3.17
Capital drawdown, %	79.98	55.73	49.46

The anti-crisis portfolio management mechanism allows implementing an investment strategy based on technical analysis. It was found that buying or selling financial assets from the index portfolio upon receiving signals following the developed method allowed to maintain and increase the investor's wealth. Testing this trading strategy using the studied crisis periods has shown an increase in the capital invested in the investment portfolio and absence of its drawdown. These results confirm that the developed indicators allow to diagnose the onset of periods of instability and deep declines in the stock market, contributing to minimization of financial losses.

Application of the considered and similar algorithmized strategies allows to realize the following advantages. The use of algorithmic robotic trading systems helps to reduce investment risks and improve the investor's portfolio profitability indicators by preventing subjective errors and increasing the price efficiency of the financial market, significantly accelerating various processes occurring in it. At the same time, the efficiency of algorithmized stock exchange trading is primarily determined by the quality of trading robots making hundreds and thousands of operations with financial assets during a single trading session.

4. Conclusions

Volatility and a prolonged downtrend are the main problems of the effective operation of the standard technical analysis tools in a crisis period. The proposed Crisis Volatility Indicator and Financial Crisis Depth Indicator allow to forecast the approach and onset of the periods of increased volatility associated with significant downtrends in prices, which will enable investors to make appropriate decisions to protect the capital invested in investment portfolios. Testing an anti-crisis investment strategy based on the developed technical indicators allows minimizing the risks of losses. Joint application of the developed technological tools allow for timely fix a moment for the purchasing or selling of financial assets. Thus, active portfolio strategies using the developed technical indicators may yield returns in crisis periods when numerous techniques fail. Monitoring the data transmitted by a trading platform using the developed algorithm based on technical analysis allows to reveal breaking points of crisis phenomena. The proposed tools can be used in robotic trading or automated online processing of exchange information. The practical significance of this study lies in the fact that the proposed recommendations for portfolio investment management using the developed tools can be useful for the activities of investment or brokerage companies, funds, as well as for private investors to increase the efficiency of financial investments. This study can be further developed to study other emerging stock markets. At the same time, the toolkit of anti-crisis indicators can be expanded. Coverage of more existing technical indicators, and research of other crisis periods will allow to modify the models of the developed crisis indicators. The field of technical analysis is quite multifaceted, which determines many possibilities for its application and improvement.

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References

Altarawneh, G., Hassanat, A., Tarawneh, A., Alabadleh, A., 2022. Stock Price Forecasting for Jordan Insurance Companies Amid the COVID-19 Pandemic Utilizing Off-the-Shelf Technical Analysis Methods. *Economies,* Volume 10(2), pp. 1–18

Berawi, M.A., 2021. Innovative Technology for Post-Pandemic Economic Recovery. *International Journal of Technology*, Volume 12(1), pp. 1–4

de Souza, M.J.S., Ramos, D.G.F., Pena, M.G., Sobreiro, V.A., Kimura, H., 2018. Examination of the Profitability of Technical Analysis based on Moving Average Strategies in BRICS. *Financial Innovation*, Volume 4(3), pp. 1–18

Fama, E.F., 2014. Two Pillars of Asset Pricing. *American Economic Review*, Volume 104(6), pp. 1467–1485

Fayek, M., El-Boghdadi, H., Omran, S., 2013. Multi-objective Optimization of Technical Stock Market Indicators using Gas. *International Journal of Computer Applications*, Volume 68(20), pp. 41–48

Feng, Y., Yu, R., Stone, P., 2004. Two Stock-Trading Agents: Market Making and Technical Analysis. *Lecture Notes in Computer Science,* Volume 3048, pp. 18–36

Chan, H., Faff, R.W., Kalev, P.S., Lee, D., 2003. Further Evidence on the Short-Term Contrarian Investment Strategy. *Finance Letters*, Volume 1(2), pp. 41–45

Chong, T., Cheng, S., Wong, E.A., 2010. Comparison of Stock Market Efficiency of the BRIC Countries. *Technology and Investment*, Volume 1(4), pp. 235–238

Inumula, K., Tadamarla, A., Deeppa, K., 2019. Simulation of Technical Indicators for Better Profits in the Indian Stock Market. *International Journal of Recent Technology and Engineering*, Volume 8(3), pp. 1612–1619

Kearns, M., Ortiz, L., 2003. The Penn-Lehman Automated Trading Project. *IEEE Intelligent Systems*, Volume 18(6), pp. 22–1

Kutluk, K.S., 2013. An Early Warming Model with Technical Indicators: The case of Use (Istanbul Stock Exchange). *iBusiness,* Volume 5, pp. 173–183

Lo, A.W., Mamaysky, H., Wang, J., 2000. Foundations of Technical Analysis: Computational Algorithms, Statistical Inference, and Empirical Implementation. *The Journal of Finance*. Volume 4, pp. 1705–1765

Lubnau, T., Todorova, N., 2014. Technical Trading Revisited Evidence from the Asian Stock Markets. *Corporate Ownership & Control*, Volume 11(2), pp. 511–518

Lyukevich, I., Agranov, A., Lvova, N., Guzikova, L., 2020. Digital Experience: How to Find a Tool for Evaluating Business Economic Risk. *International Journal of Technology*, Volume 11(6), pp. 1244–1254

Petrov, S., Yashin, S., Yashina, N., Kashina, O., Pronchatova-Rubtsova, N., Kravchenko, V., 2021. Digital Techniques Share Price Modeling based on a Time-varying Walrasian Equilibrium under Exchange Processes in the Financial Market. *International Journal of Technology*. Volume 12(7), pp. 1557–1567

Polyanin, A., Pronyaeva, L., Pavlova, A., Fedotenkova, O., Rodionov, D., 2020. Integrated Approach for Assessing the Economic Security of a Cluster. *International Journal of Technology*, Volume 11(6), pp. 1148–1160

Teixeira, L.A., Oliveira, A.L.I., 2010. A Method for Automatic Stock Trading Combining Technical Analysis and Nearest Neighbor Classification. *Expert Systems with Applications,* Volume 37(10), pp. 6885–6890

Wong, W., Manzur, M., Chew, B-K., 2003. How Rewarding is Technical Analysis? Evidence from Singapore Stock Market. *Applied Financial Economics*, Volume 13(7), pp. 543–551