Neural network technologies for analysis and risk assessment in forecasting the market of industrial financial instruments

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Abstract. The issues of risk analysis and assessment in forecasting the dynamics of prices on the stock exchange and the OTC market have always been a difficult task for many researchers and analysts. Successful investment is largely determined by knowledge of the future situation in the financial market. The article deals with the issues of search and development of technical tools for risk analysis and assessment in forecasting the market of derivative financial instruments under conditions of uncertainty. A recurrent network with a long-term short-term memory cell LSTM, which is one of the most powerful prediction models, was chosen as the architecture of neural networks. The development of technical tools for solving this problem was carried out on the basis of the C# programming language. An additional TA-Lib library served as a mathematical base for technical analysis, from which 42 technical analysis indicators were used during the development process, and for working with the LSTM recurrent network, the library Keras.NET. The ability to efficiently link memory and input remote data using these network memory cells provides a dynamic understanding of the data structure over time. The estimates of the accuracy of the forecast for the cost indicators of a derivative financial instrument obtained as a result of computer experiments showed the high efficiency of the constructed neural network model.

1. Introduction
The stock market is one of the key mechanisms that ensures the functioning of the economy of the whole country. At the moment, it has become an integral part of the financial system of any state. The levels of investment and trade turnover are constantly growing. Only in Russia, according to the Moscow Stock Exchange [1], the number of investors has tripled relative to 2020. With the increase in the number of investors, trade turnover also increases. Traders are constantly in search of new tools and methods that can affect profits and minimize the risks from invested funds.

In recent years, the theory of risk management has attracted even more attention from representatives of business, finance, management, banking, insurance, and has become the subject of research in the scientific world. In the specialized literature, risk is considered as "the product of the probability of an adverse event and the severity of its consequences" [2], as "a form of uncertainty and a way of understanding uncertainty" [3], as "an activity related to overcoming uncertainty" [4], as the probability of loss of a process or project. The ideas embedded in risk management are to detect and eliminate potential dangers and threats for any social object that can affect its successful functioning, as well as to develop mitigation strategies — action plans to eliminate these adverse events long before they can occur.
Risk management is carried out in order to reduce the impact of potential hazards on a dynamic system of any level of complexity and industry affiliation to an acceptable level, which can include the financial market. Minimizing unplanned chaos, the cascade of negative consequences of the COVID-19 epidemic and reducing future uncertainties - an indicator of risk in the post-pandemic period - have further actualized the issues of risk management theory for financial markets, and in particular, for its leading segment - the derivatives market.

A derivative or derivative instrument is a financial contract, the value of which depends on one or more underlying assets, an interest rate or an index. Derivative in finance is understood as the dependence of two quantities, while at least one of which is directly or indirectly related to a fixed-term agreement. An urgent transaction is a preliminary agreement between the market participants of a certain asset regarding the terms of a future exchange. The need for a preliminary agreement is due to market uncertainty – uncertainty of demand, uncertainty of supply and the result of the first two uncertainties - uncertainty of the asset price. When concluding a fixed-term contract, the seller of the asset transfers the risk of price reduction to the buyer of the asset, and the buyer transfers the risk of price increase. Markets with a high degree of uncertainty historically include markets for agricultural products, fuel and energy resources, and metal.

The object of this study was determined by a futures contract for coffee. The choice of this derivative instrument is justified by the fact that, firstly, coffee ranks second in terms of international transactions after oil transactions, therefore, since the formation of the global coffee industry as a market commodity, interest in coffee research and forecasting its price has only been growing. Secondly, coffee prices are quite difficult to determine in the long term, since its pricing is influenced by many fundamental factors — weather, yield, harvest month, rainfall, geographical factors, investment volume and others. Another important mechanism for forming the price of coffee after the exchange is the correction differential, which is formed from the production costs and profits of all participants in the grain production chain. It also depends on the security of doing business with a particular country. The differential is affected by: geography of growth; processing; farm expenses (wages, expenses for the establishment and maintenance of the farm, capital expenses); administrative expenses.

Analysis of the dynamics of the Russian derivatives market, its forecasting, limitation and risk analysis of the use of derivative financial instruments on the example of a coffee futures contract in world practice is the most important and urgent problem in the economic sphere. The purpose of the research is to search and develop technical tools for risk analysis and assessment in forecasting the derivatives market under conditions of uncertainty.

2. Methodological foundations and tools for risk analysis and assessment in forecasting the derivatives market

To cope with the growing variety and complexity of risk assessment tasks in forecasting, many methods have been developed in recent years. Financial analysts should know the technique of choosing forecasting methods: the better they understand the range of forecasting possibilities, the more likely it is that forecasting activities will bring results. The choice of the method depends on many factors — the context of the forecast, the relevance and availability of empirical data, the desired degree of accuracy, the time period to be predicted, the costs/benefits (or value) of the forecast for the company, and the time available for analysis. With all the diversity of the spectrum of mathematical methods of quantitative forecasting, analysts often use the following basic methods: time growth curves, moving averages, simple and multiple linear regression and autoregression. However, earlier [5] it was shown that the methods of mathematical statistics and probability theory do not show efficiency when working with the stock market. Moreover, many analysts express their doubts about the usefulness of these tools. Neural networks have replaced classical forecasting methods. The relevance of their application is due to the ability of neural networks to detect nonlinear relationships in input data, making them ideal for modeling nonlinear dynamic systems such as the stock market.
2.1. Neural network approach in risk management

With the development of neural network methodology, works began to appear describing the use of this device in various applied fields, including in the analysis of financial markets. These are the studies of both Russian scientists — I.Y. Atnabaev [6], V.N. Bugorsky, A.G. Sergienko [7], E.Y. Shechetinin [8], and foreign ones, in particular, J. Agrawal, V. Chourasia, A. Mittra [9], Sh. Banik, F.H. Chanchary [10], K. Daigo, N. Tomoharu [11], D. Jayasuriya [12], Ju. Wang, Ji. Leu [13], etc. With the increasing complexity of the mathematical tools of market analysis, traders find themselves in a situation where they need to track an increasing number of different indicators and indicators, to identify the significance of these criteria in the overall analysis model, and, accordingly, it becomes increasingly difficult for them to make a final decision. Existing decision support systems, such as trading advisors and multifunctional trading platforms, provide the trader with recommendations for entering into a transaction to a greater extent, without taking into account the risk of increased volatility under the influence of changes in macroeconomic indicators, economic news and events. In this situation, it is difficult for a trader to build a profitable trading strategy, since the risk of making unprofitable trades is high, and even when concluding a potentially profitable trade on a trading signal, recommendations, untimely closing it can lead to loss of expected profits. Thus, the existing methods and decision support systems based on data mining do not provide the user with information about the risks of increased volatility under the influence of economic events and news. This aspect is relevant and needs additional research for the market of derivative financial instruments.

2.2. Mathematical methods of financial analysis in risk management

Technical analysis tools are best suited as the material base of an artificial neural network, since they allow us to consider the price movement chart in the market for the past period and predict prices for the future. When considering the market movement, several main parameters are taken into account: price, trading volume and open interest. These parameters are not equivalent. For example, open interest can be found mainly only when trading commodity futures, and when trading other financial instruments, this indicator cannot be determined at all. Many technical analysis tools and indicators are already embedded on trading platforms, and they greatly simplify their interaction with the exchange. The use of technical analysis to predict financial risks is due to some of its advantages:

- technical analysis has a wide range, its tools work absolutely on all types of exchanges. The use of technical analysis is not limited only to financial markets, its tools are quite applicable for forecasting animal populations or presidential elections of a certain country.;
- technical analysis can be applied to any period, since its tools do not place restrictions on the forecasting period.

Let's classify the technical analysis indicators that were used in forecasting financial risks for trading futures contracts.

*Momentum indicators.* These indicators are mainly used to measure market dynamics. For example, the Kaufman Adaptive Moving Average (KAMA) is a moving average designed to account for market noise or volatility. This indicator corrects prices when price fluctuations expand and follow prices from a greater distance. There are 10 more indicators that allow you to analyze and adjust the predicted price dynamics: the stunning oscillator, the percentage price oscillator (PPO), the percentage volume oscillator (PVO), the measurement rate (ROC), the relative strength index (RSI), stochastic RSI, stochastic oscillator, the true strength index (TSI), the final oscillator, the Williams parameter.

*Volume indicators.* This type of indicators takes into account volumes. The volume refers to the number of bets that have passed over a certain interval. For example, the Chaikin Cash Flow Index (CMF) — measures the amount of cash flow for a certain period. Volume indicators also include: accumulation index, ease of movement, strength index, cash flow index (MFI), negative volume index (NVI), balance volume (OBV), volume and price trend (VPT), Weighted Average Price by volume (VWAP), accumulation/distribution index (ADI).

*Volatility indicators.* This type of indicators is based on volatility, the faster the price changes, the higher the volatility. For example, Keltner channels are a trend-following indicator used to determine
reversals with channel breakouts and channel direction. Such indicators also include: the average true range (ATR), Bollinger Bands (BB), Donchian bands (DC), indicators of the upper and lower ranges of the Kelbner channel and the Donchin and Bollinger bands.

**Trend Indicators.** These indicators represent the averaging of the price. Based on them, it is possible to assume the direction of price movement in the future. For example, the Commodity Channel Index (CCI) measures the difference between the price change of a security and its average price change. High positive values indicate that prices are much higher than average, which indicates strength. Low negative values indicate that prices are much lower than average, which indicates weakness. These types of indicators include: Average Directional Movement Index (ADX), Trend-free price Oscillator (DPO), Exponential moving average (EMA), KST oscillator, Moving average convergence Divergence (MACD), Mass index, simple moving average, etc.

**Other indicators.** There are also indicators that do not belong to any of the listed types. These include: total income (CR), return of the daily journal (DLR), daily income (DR).

3. **Research results**

3.1. **Neural network architecture**

As the architecture of neural networks, recurrent neural networks LSTM (Long Short Term Model – LSTM) are best suited, which are the most powerful and well-known tool for recognizing patterns in data sequences, such as numerical time series data coming from sensors, stock markets, etc. This network allows you to take into account time and sequence.

Previously, the most effective tool in forecasting tasks was an RNN-type network, but after the publication of the first article on LSTM [15], most researchers came to the consensus that LSTM can solve the main problem of RNN – to avoid long-term dependence. Memorizing information for long periods of time this is the basic behavior of this type of neural network, which is why at the moment this architecture is the most powerful tool in forecasting tasks [14]. This reason was the main factor in choosing this type of network to solve the task.

3.2. **Development of technical tools for risk analysis and assessment in forecasting the derivatives market**

The development of technical tools for solving this problem was carried out on the basis of the C# programming language. An additional TA-Lib library served as a mathematical base for technical analysis, from which 42 technical analysis indicators were used during the development process, and for working with the LSTM recurrent network, the library Keras.NET.

As a result of the development of technical tools, a forecast was made for the March coffee commodity futures (Figure 1) related to the New York Stock Exchange. The segment from 01.02.2021-01.01.2022 was chosen as the forecast period. The forecast is made in real time after the user sets the required period. As training data, data from the period from 01.01.1999 to 01.01.2013 were uploaded, since in this interval there were two critical situations in the coffee market, which made it possible to predict the current critical situation.
As can be seen from Figure 1, the forecast is as close as possible to the real values of the graph, which confirms the effectiveness of using recurrent neural networks such as LSTM as a basis for forecasting the derivatives market, and a set of technical analysis indicators as an effective mathematical base.

4. Conclusion
In this study, a model of a recurrent neural network with deep learning is proposed to predict the price dynamics of coffee futures contracts. The novelty of the proposed approach consists in the application of the LSTM recurrent network model trained using 42 indicators of technical analysis in the derivatives market. This tool has demonstrated high accuracy for forecasting the derivatives market in comparison with traditional statistical methods, in particular, in the context of a sharp increase in the price of coffee on the world market since March 2021. The study established the possibility of applying the developed algorithms in the real sector of the economy, in particular, for enterprises where derivative financial instruments allow effective financial risk management, reduce the spread of income, and guarantee a minimum level of return on invested funds.

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