Machine Learning Algorithm Applications in Empirical Finance: A Review of the Empirical Literature

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Abstract. The modern finance industry has many challenges to handle, so advanced tools are applied to assist people in trying to find a solution to those complex problems. Machine learning is a powerful tool that can help researchers tackle difficult issues, including those in the financial industry. In this paper, I reviewed literature focusing on machine learning algorithm applications in empirical finance. I divide the literature review into three sub-sectors: financial market prediction, bankruptcy prediction and credit risk analysis, and other notable aspects. It is found that researchers widely use algorithms like support vector machines and neural networks. Finally, based on my review of the literature, I provide my insights in this area.

Keywords: machine learning · financial market prediction · bankruptcy prediction · literature review

1 Introduction

Machine learning has been evolving over the past few decades. It has been applied in many industries, including finance, to help people research complex problems. The algorithms can be applied to various aspects of financial research, such as stock prediction, bankruptcy prediction, and risk management. The modern financial market is complex and volatile. From the 2008 financial crisis to the Silicon Valley Bank bankruptcy in 2023, there are always significant challenges in the market. To become a better participant in the market, taking advantage of more advanced tools is necessary. Nowadays, artificial intelligence, and its subset, machine learning (ML), are under the spotlight, especially after the release of the ChatGPT developed by OpenAI since they have proved their ability to assist human beings in solving problems efficiently.

Many researchers are aware of using machine learning to handle real-world financial problems. According to the publication statistics, there has been a rising amount of literature focusing on machine learning applications in the finance industry since 2015 [1]. In this paper, I reviewed empirical literature focusing on applying machine learning in empirical finance. As there are many sub-sectors in finance where machine learning can be utilised, some issues like financial market prediction and bankruptcy prediction are popular among researchers. However, some areas need more attention since the current studies in those sectors are not sufficiently comprehensive. The remaining part

S. Tehseen et al. (Eds.): ICEDBC 2023, AEBMR 258, pp. 311–316, 2024.
https://doi.org/10.2991/978-94-6463-246-0_38

of this paper is separated into two sections. The selected literature that has already been published on the applications of machine learning in finance is reviewed in Sect. 2, and Sect. 3 gives the conclusions and insights.

2 Review of the Extant Literature

2.1 Financial Market Prediction

The financial market is full of uncertainties and can be affected by various factors. The non-stationary characteristic makes forecasting movements in the financial market difficult. The non-linear, dynamic and chaotic time series data is considered to be a major factor that affects the prediction [2]. So, to make better predictions, it is necessary to use more effective models. Nowadays, with the development of more reliable techniques, machine learning is often used by researchers to make predictions of the financial market, and models including support vector machines (SVM) and neural networks are commonly adopted.

Kara, Acar Boyacioglu attempted to predict the Istanbul Stock Exchange (ISE) National 100 Index movement with the application of two machine learning models based on artificial neural networks (ANN) and SVM. Their research result showed that ANN outperformed SVM in index prediction [3]. However, in some research, SVM showed superior predictability. The survey conducted by Kumar and Thenmozhi showed that the SVM model performed better in handling complex data, which is prevalent in the financial market [4]. Their SVM model is used to predict S&P CNX NIFTY Index returns, and compared with other models used in the research, the SVM model has a greater prediction accuracy. Prior to the survey mentioned above, Cao and Tay chose a data set consisting of five futures contracts gathered from the Chicago Mercantile Market to investigate the viability of using SVM in financial forecasting [5]. They concluded that SVM is considered to have a more satisfactory financial forecasting performance than back-propagation (BP) neural networks. Their conclusion is among the earliest ones that declare the outstanding prediction performance of the SVM model. Moreover, the SVM model's performance can be considerably enhanced by developing a hybrid genetic algorithm–SVM (GA-SVM) model because it can successfully choose the ideal subset of input features that are most pertinent to the stock price forecast [6].

Apart from the previously mentioned machine learning algorithms, some researchers showed interest in using long short-term memory networks (LSTM) to help predict stock prices. Using S&P 500 data, Ghosh, Neufeld found that LSTM can help investors trade with a higher possibility of gaining positive returns, and it has a better intraday return compared with random forests. Shen and Shafiq developed a deep learning model consisting of a convolutional neural network (CNN) layer, an LSTM layer, and a fully connected layer to forecast stock market price trends using data from the Chinese stock market. Their proposed system can predict short-term stock market price trends with great accuracy [7, 8].

Unlike predicting stock movement to gain a positive return which is mainly concerned by investors, forecasting stock market crisis events is a topic that central banks are interested in. Chatzis, Siakoulis combined different machine learning algorithms to help them predict the stock market crisis, and they declared that deep learning and boosting

approaches were applied for the stock market crisis prediction. They found that deep neural networks can promote accuracy tremendously [9]. So, it is suggested that effective machine learning techniques can help central banks take action to stabilise the financial market.

Many other works of literature have researched market forecasting with their models mainly based on machine learning algorithms, and their empirical results indicate the noticeable performance of machine learning models [10–13].

2.2 Bankruptcy Prediction and Credit Risk Analysis

Traditional methods were used to predict bankruptcy. However, since the advantages of machine learning algorithms have been discovered by research, the algorithms' performance is more encouraging in many situations. There is literature focusing on bankruptcy prediction with machine learning techniques, and they compare accuracy with traditional models. In one study, the data related to selected North American firms were analysed by using random forest models to predict bankruptcy, and the result showed that machine learning models have more accuracy than traditional models [14].

Huang, Chen used the backpropagation neural network (BNN) model as a benchmark in their credit rating analysis, and they also applied the SVM model to make a comparison with the BNN model [15]. The result indicated that both models have good accuracy, but SVM is slightly better. There are also other researchers gains the conclusion that SVM can have a better bankruptcy prediction performance. Min and Lee employed a grid-search technique with 5-fold cross validation to identify the ideal SVM kernel function parameter values. As a result, their model has a high level of predictability [16]. Wu, Tzeng also recognised the importance of determining the parameters in the SVM model. Their genetic-based SVM (GA-SVM) model can help find the optimal parameters which should be dedicatedly selected to improve the performance of the model [17].

Many researchers applied their bankruptcy prediction models in a specific country or region, and they did not predict at a global level. Since globalisation has made the connection between different countries closer, turmoil in one region can create a ripple reaction worldwide. Alaminos, Del Castillo recognised that there are few studies concentrating on global bankruptcy forecasting, so they developed a global model of bankruptcy prediction, which had better predictive power than localised models [18].

Son, Hyun believed the previous machine learning models had drawbacks [19]. First off, the findings were not comprehensible, and secondly, the prediction accuracy did not significantly outperform the statistical models in some research. So, using financial statement data and machine learning methods, particularly XGBoost, their research suggested a unique bankruptcy prediction model. The study assessed their model using an extensive dataset of US corporations from 2000 to 2017 and contrasted it with models like random forests, logistic regression, and SVM. It claimed that their model achieved high accuracy and interpretability by applying proper pre-processing steps and analysing feature importance scores and partial dependence plots, and their essay contributed to the field of bankruptcy prediction by addressing the issue of financial data skewness and by clearly articulating the model's findings.

2.3 Other Notable Aspects

Over the last decade, cryptocurrency has become an emerging financial product which attracted great interest. Compared with most traditional financial assets, the price of cryptocurrencies has greater volatility, and it is considered extraordinarily risky by many investors. Assisted by machine learning algorithms, the traders may be more likely to gain profits in the cryptocurrency market. A study conducted by Alessandretti, ElBahrawy used daily data from November 2015 to April 2018 and a variety of machine learning methods, including support vector machines, random forests, and XGBoost, to forecast the price changes of cryptocurrencies [20]. Their paper asserted that moving average and buy-and-hold strategies don't perform as well as basic trading techniques supported by machine learning algorithms. By utilising machine learning as a cutting-edge method to foresee the short-term evolution of the cryptocurrency market, they contributed to the field of cryptocurrency trading. It is also noteworthy that to predict the price of a cryptocurrency, some novel information sources can be accepted. Colianni, Rosales developed trading strategies for cryptocurrencies, particularly Bitcoin, by using Twitter sentiment analysis. Their study used Twitter data to predict the price trend of cryptocurrencies using supervised machine learning methods like SVM, logistic regression, and Naive Bayes. According to the result, their strategy surpassed existing approaches that did not involve Twitter sentiment analysis and achieved high accuracy for forecasting hour-to-hour and day-to-day price fluctuations. Since more reliable machine learning algorithms help handle different data sources, the researchers might discover better models that can analyse combined data sources and relieve the bad impact of poor data quality to gain a higher prediction accuracy [21].

Financial market investing is a difficult and time-consuming process that demands investors and traders to constantly watch market actions. So, the use of machine learning is noticed since it can help automate trading activities and relieve traders' stress. Alsulmi, Al-Shahrani applied combined machine learning methods and risk management techniques to automate stock trading in the Saudi Stock Exchange (Tadawul). They got a positive result, and their framework's performance beat a number of hedge funds managed by renowned investment banks in Saudi Arabia. Although their research had shown a promising outcome, enhancements could be made by incorporating sentiment analysis into future research [22].

3 Conclusions

The applications of machine learning in financial market prediction have been widely explored. Researchers applied the models in different scenarios and used different algorithms. Although there is a difference between the performance of algorithms, and it is still controversial to decide which algorithm is better, machine learning is still a more advanced tool for stock prediction in most cases. Bankruptcy prediction using machine learning is also an outstanding issue, and with the development of machine learning techniques, its better accuracy presents a promising future for credit risk management. There are also many other financial segments, such as cryptocurrency trading and automated trading, where machine learning can be taken advantage of.

It is found that different machine learning algorithms are used by researchers, and each of them can have its advantage in a specific scenario. Still, sometimes it can be hesitant to distinguish which algorithm is the best under certain circumstances. Moreover, the existing academic studies are not always satisfied with the models developed so far, and many researchers have tried to optimise models in ways like finding more suitable parameters to gain better results. Apart from that, machine learning applications in some comparatively new or complicated topics in finance still lack a comprehensive study. Finally, different data sources can be combined and analysed to help achieve better model performance, but it also requires applying more advanced machine learning techniques.

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