Predicting Manager’s Behaviour with BP Neural Network

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Abstract. There have been many researches on stock trend forecasting in existing literatures, however, there is little research on the actions which managers will take basing on stock price change. This article is based on this point to study the stock market and the actions that manager will take. Based on the proposed automatic selection model, we put it on the stock market to study whether the managers will sell shares in the company with the change of stock price. The results is that the selection of model has good generalization ability, and when the predicted value is higher than the actual value, the manager will sell off the company's shares, and vice versa. However, the accuracy of prediction will be further improved by combining factors such as company size and policy environment.

1. Introduction

Exploring the implied intrinsic relationship in the stock market data has been a matter of great concern to scientists. Based on the study of stock market data in developed countries, a number of literature had shown that stock returns are predictable to some degrees, and studying the existence of the implied laws of China’s stock market with the experience in developed countries is very meaningful. Different scientists have diverse methods on researching the prediction of stock market earnings. Among them, with good self-learning ability and strong anti-interference ability, artificial neural network (ANN) proved to one of the greatest methods which had made great progress on studying dynamic stock, and widely used in the financial fields, such as the price of stock, interest rate, exchange rate, risk analysis and forecasting finance.

The previous literature mainly focused on the application of a series of methods which predict the trend of stock price as well as the point of stock trading or the transaction point, and so on. However, the research on the manager’s behaviour which be acquired from the change of price is relatively less. Richard Seiler, the winner of 2017 Nobel laureate in economics as well as the professor of University of Chicago promoted that "big need irrational, information is extremely closed, willing to hold the price is too high Asset investors "which was written in his book that called "Behavioural Finance Advanced". Based on this theory, a lot of research have found that: (1) We can manipulate the media by hiring psychologists and neurologists making individual investors are trapped in "irrational and unaware" stage; (2) The anxiety or fear of investors’ will increase transaction as a result of promoting investors to buy or throw; (3) Weaken investors’ confidence and mislead their long-term investment plans. We can spread the suspicions through the use of neurological techniques, and people will doubt about the existing beliefs, and have wrong investment. In addition, the encourage of a large number of investors carrying out high-frequency trading is also a major reason for investors to follow investment, which results the stock market deviating from the normal law. According to the above points without considering the abnormal phenomenon, we can easily see that hiring psychologists and

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neurologists to manipulate the media or promoting investors to buy, as well as aggravating anxiety and so on are all managers’ behaviours under the hope of increasing their interests which will affect the stock price. All of these phenomena show that there is a close relationship between the manager’s behaviour and the stock price.

2. Existing model

2.1 Predicting stock market by using artificial neural networks

Researchers have come up with a number of scientific models for studying the forecasts of stock market. Among them, artificial neural network (ANN) is one of the greatest technologies that research dynamic stock market. With good self-learning ability and strong anti-interference ability, ANN has been widely used in researching stock prices or interest rates, as well as exchange rate and so on. Multilayer perceptron (MLP) is one of the most popular neural networks with the ability to complex mapping between input and output which makes it possible to approximate nonlinear functions. We can integrate a variety of methods after analysis to research data. For example, we can use the artificial neural network as a vector autoregressive fractional complement analysis method to study the relationship between the data, where Lara Khansa et al. promoted the delay time of the artificial neural network model, where the accuracy of prediction can up to 95 % while others can only up to 85% (Lara Khansa, 2011).[3] Lu et al. predicted the series of financial with using SVM neural network algorithm and independent component analysis (ICA) supporting vector regression ensemble (SVR).[4] Pei et al. proposed an evolution model of partial connection neural network (EPCNN) to predict the trend of stock price, which greatly improves the expression of neural network by random link between neurons and hidden layers which learn from the knowledge stored in historical time series data (Pei, 2012).[5] Chang et al. used the dynamic time windows of neural network and case-based reasoning (CBR) to predict stock trading (Chang, 2009).[6] In 2010, Multisensor Neural Network (MLP) was used by researchers Mostafa to predict the closing trend of Kuwaiti securities transactions (Mostafa, 2010).[7] Kim and Chun et al. predicted multiple discrete values and found a double-clicked probabilistic neural network (Kim, 1992).[8] Chen et al. used a mixed method containing probabilistic neural networks, rough sets and C4.5 to establish a better model for forecasting the stock market timing (Chen, 2010).[9] Kamijo and Tanihana et al. predicted the trend of the stock market by using a cyclic neural network in 1990 (Kamijo, 1990).[10] In that year, Ahmadi predicted the stock market using back propagation neural networks and generalized delta rules (Ahmadi, 1990).[11] In 2007, Miao et al. and Ritanjali, Panda et al. predicted stock prices by using bacterial foraging optimization (BFQ) under the help of the bacterial colony radial basis function neural network (RBFNN) (Miao, 2007).[12] Zhang et al. introduced the IBCO-BP model and improved bacterial chemotaxis optimization (IBCO) which can predict the short-term (second day) and long-term (fifteen days) stock price trend (Zhang, 2009).[13]

Previous study has shown that artificial neural networks (ANN) is superior to statistical regression model as well as discriminant analysis. Although the existing neural network applications had used a number of technical indicators, the impact of qualitative factors were rarely taken into account, and had no satisfactory results. Therefore, Zadeh and Marmer et al. proposed an integrated system which combined wavelet transform with neural network basing on artificial bee colony algorithm (ABC) where technical indicators and qualitative factors were both taken into account, and as a result, this method eased the handle and decreased the cost by allowing inaccuracies, uncertainties, and local real tolerances when merging metrics.[14]

Firstly, wavelet analysis is a relatively new field of research in signal processing.[15] It is highly closely related to the fluctuation and time-varying characteristics of time series in the reality. The transformations decompose the processes into different scales so that the seasonal nature can be divided to reveal structural faults and volatility clusters then identify the local and global dynamic properties of the process at a particular time scale. The Haar wavelet was used to preprocess data which was used as input for the system.[16] In order to reduce the risk of overworking during the training phase, the authors performed two preprocessing. Secondly, there is considerable data
redundancy in realistic research and eliminating redundancy and reducing the dimension of data may improve the predictability of system predictive performance as well as the interpretability of the results. In this study, stepwise regression-related selection (SRCS) was selected to screen high-quality input eigenvalues among technical and basic factors.\[17\] Besides, the ABC algorithm has the advantages of memory, multi-character, local search and solution improvement mechanisms, therefore it is often used to identify high-quality optimal solutions. The optimization of the parameter matrix in this integrated system is the ABC algorithm and optimizing the cyclic neural network (RNN). Finally, the performance was measured by using the methods such as RMSE, mean absolute error (MAE), average absolute percentage error (MAPE) and Theil's inequality coefficient (Theil U).

The brief steps of the whole system can be expressed as:

![Figure 1. The steps of the whole system](image)

The ABC algorithm, which was inspired by the artificial foraging behaviour of bees, has the ability to find the optimal solution with relatively moderate calculation.\[18\] Therefore, the author chose the ABC algorithm to optimize the structural neural network. The structure is:

![Figure 2. The structure of network](image)
Compared with other models, the simulation results showed that the model based on wavelet analysis preprocessing was superior to other methods.

2.2 Autoshaped choice in artificial neural networks

In this article, the author Jose E. Burgos creatively proposed a model simulation method.\(^{[19]}\) As we all know, in the past analysis of economic behaviour, auto-shaping and automatic maintenance can be obtained through the experiment of Bashirov's accident. Few non-operative accidents were taken into account in the analysis of economic behaviour, the automatic selection model proposed by the author creatively solved this problem. In this paper, the author only focused on the network portion of the model.

As we all know, when facing choices, we all make choice on the account of value. The basis of choice is our internal neural mechanism. McSweeney and Bierley (1984) studied the relationship between auto-shaping and consumer behaviour, but they did not clarify how automation acted on economic behaviour and the mechanisms by which automation operates.\(^{[20]}\) However, we know the strong correlation between automation and economic behaviour by their research.

The model for the first time interpreted the relationship between economic behaviour and neural mechanisms, however, the human brain is often complex, an economic choice is often made by multiple brain regions, and other related brain regions are not considered in this model.\(^{[21]}\) This model discussed that stimulus had an impact on people's economic behaviour.

2.3 Using neuroeconomics to understand economic valuation and decision

In the above, we mainly discussed the main research methods used in the neural mechanism of people's economic behaviour, and we will focus on the following: it is not difficult to find that most studies used case analysis to focus on the relationship between certain behavioural factors and decision-making results or to summarize the performance of specific psychological phenomena. For most of the explanations of behavioural reasons, most studies used only one behavioural factor, and could be explained.

The United States every four years conducts a large-scale questionnaires and in-depth interviews to understand the company's investment decision-making behaviours. Some countries in Europe have also carried out a similar study in recent years, and China has scholars to conduct similar research as well. Since 2002, behavioural decision maker Kahneman won the Nobel Prize in Economics, the theory of behavioural decision-making has been paid attention to and widely used: Kahneman and Tversky's "three types of heuristic cognitive bias". Hsee's "Measurement Capability Hypothesis"; Linda Babcock and George Loewenstein's "proof of bias"; Kahneman and Tversky's "theory of the future", Thaler's "psychological accounts" and other actions behind the explanation, accounted for behaviour basis.

Jenson et al. pointed out that independent directors can supervise managers, thus effectively inhibiting the company's excessive investment.\(^{[22]}\) Pawlina and Renneboog thought that the holdings of external institutions will help reduce the investment cash flow sensitivity.\(^{[23]}\) Hadlock found that the impact of managerial shareholding on the sensitivity of the company's investment cash flow was non-linear, as it depended on the existence of a convergence of interests or a manager's defensive effect.\(^{[24]}\) These studies examined the governance effect of the company's over-investment from different aspects of the corporate governance mechanism and deepen the understanding of the role of corporate governance mechanism. It can be seen that the behaviour of the listed company manager is a significant result of the company's excessive investment, and is not static.

3. Proposed model

In the past model studies, research scholars focused on the trend of stock prices, and didn't involve the actions of managers. In the literature explored above, we tend to judge things based on our analysis of things and choose more valuable options. Therefore, the manager will take different actions to predict
the stock price, the company’s operating conditions as well as problems that the stock price reflects. In the next section, we further elaborate the study of managers’ actions based on neural networks.

In the test sample, we use $X_1, X_2, \ldots, X_{36}$ to respectively represent the 36 indicators in the table, and save in the corresponding table. In this study, as a result of concerning the manager’s behaviours used for the management of the company, we take the weekly line as the time unit for the study, and select the first 611 lines of the sample data as the training set, the data of the 612-815 lines interval as the test set.

The BP neural network algorithm used in this paper will find the optimal solution of the network by adjusting the weight of the links between forward and reverse links constantly, and then use the resulting optimal solution to predict the future data. The process of network operation is: Using the algorithm to read the data in the table to get the feature vector of the sample, then get the input value of the algorithm according to the weight vector, and then use the sigmoid function to calculate the output value. We use $X_1, \ldots, X_{36}$ for the system’s 36 inputs; $w_1, \ldots, w_{35}$ for the corresponding input link weights; $\sum W_iX_i$ for the input sum.

In this article, we choose S-type activation function for the activation function of neurons; and its output characteristics are relatively soft, we choose the output state of the range of $(0,1)$, as it is shown in the follow:

$$f(\text{net})$$

![Figure 3. The state of range](image)

Because the sigmoid function has a non-linear amplification factor function, it can transform the input signal from negative infinity to positive infinity into an output between 0 and 1.\cite{25} For larger input signals, the amplification factor is smaller, while for smaller input signals, the amplification factor is larger, so the S-type activation function can handle and approximate the non-linear input and output relationships.

In this article, the main idea of the BP algorithm is: the 36 input values for the sample are denoted $p_1, p_2, \ldots, p_{36}$ respectively, and its output is known as $T_1, T_2, \ldots, T_{36}$, the purpose of the algorithm is to modify the weight of each of the outputs $A_1, A_2, \ldots, A_{36}$ and therefore the target value is as close as possible to the actual value. We first initialize the weights in the algorithm first and then find the sum of squared differences in the output nodes to further adjust the weights, where:

- $X_i$ is the input of the algorithm;
- $Z$ is the output of the algorithm;
- $W_{ij}$ is the link weight of node $i$ to node $j$;
- $t_k$ is the actual output value of input node $k$;
- $O_k$ is the expected output value at node $k$ of the output layer.

So, the error formula we can say:

$$E(w) = \frac{1}{2} \sum_{k\in\text{outputs}}(t_k - o_k)^2$$  \hspace{1cm} (1)

The derivative is:
\[ \delta_k = a_k (1 - a_k) (t_k - a_k) \]

For each hidden layer \( h \), its error is:
\[ \delta_h = a_h (1 - a_h) \sum_{k \text{ outputs}} w_{hk} \delta_k \]

Finally, update each weight:
\[ w_{ji} = w_{ji} + \eta \delta_j x_{ji} \]

The \( x_{ji} \) is the input of node \( i \) to \( j \), and \( \eta \) is the learning rate.

There are many kinds of managers' actions, but we actually classify them into two groups that have the most influence on the company's stock price. One is market penetration and the other is organization building. Therefore, for the output layer, we divide the output into \( z \in [0, 0.500] \) (market penetration); \( z \in [0.501, 1] \) (organizational construction). In this article, we construct the neural network graph as follows:

![Neural network architecture diagram](image)

Figure 4. Neural network architecture diagram

The process of BP network we designed is shown in the follow:

![BP network learning architecture](image)

Figure 5. BP network learning architecture
4. Results and discussion
In the process of empirical verification, 36 technical indicators (such as ARBR, BIAS, CCI, PSY, etc.) in the energy Internet part were selected as the input values of the model. The time period selected was from May 19, 2014 to Nov 17 2017, and totally had 815 data. First, we chose the data without Shun Feng's board as an example. \( X \) represented the data of each column, with the data of rows 1 to 611 as the training set, and the data from 612 to 815 as the test set, and \( Z \) as the algorithm of the final output value. The range of values obtained represented the action taken by the manager. In this study, we used MATELAB as the experimental tool to import data into the algorithm. After adjusting the parameters several times, we found that when the number of hidden was 2.5 times, the parameter of epochs was 40000, and the goals is \( 10^{-10} \), this model performed very well. As a result, we will use these parameters to conduct the experiment, and the final results are shown in the below:

![Figure 6. Training chart](image1)

![Figure 7. Forecasting chart](image2)

As we can see, the predicted data is slightly lower than the actual data, which represents the undervalued stock price. According to the efficient market hypothesis, manager of companies will not reduce their stock holdings when the stock price is undervalued, but will sell it when the stock price is overvalued. As a result of the above experiment, the stock price is undervalued, so we predict that the manager will continue to hold the shares of the company without any change, and will not sell the shares of the company.
5. Conclusion
Although we have selected better parameters for the experiment, there are still many deficiencies for the experiment itself. We mainly consider several aspects:

(1) Selection of time period. We only collected 815 data as a training set from Shun Feng which were small, and the improvement of the link weight was not accurate enough to improve. Besides, Shun Feng stocks, with larger listing funds, still belong to the new shares, and can’t fully reflect the inherent law of the stock market. Therefore, we ought to improve the selection of the stock that have larger listing and longer time for analysis and forecast.

(2) Sample data. For large-cap stocks, individual stocks are more likely to be hyped. At this moment, stocks will receive more speculation instead of inherent laws of stock market. Therefore, we should analyse and forecast stocks with many stocks or even large stocks that are less affected by external factors in the future.

(3) Data period. Managers' actions have a significant impact on the company, but the effects are all latency, and the impact of this action on the stock price is lengthy. In the future research, we should expand the research cycle, such as half a month, a month, as well as a quarter as a data period to adjust the prediction performance of the algorithm.

(4) Indicator. In this paper, we selected 36 indicators, and these indicators may have no decisive influence on the stock that we can’t know. Therefore, we ought to optimize these indicators, and select appropriate indicators as well as the appropriate number of indicators in the future research. In addition, besides the technical indicators that had an impact on the company's stock price, there are also basic factors, such as the size of the company, the government's policy, the manager's emotions and so on. So we have to further consider these basic factors.

If we take these factors into account and conduct a good analysis of the forecasting model, we will have a model with good generalization ability. Therefore, researching a model with good generalization ability is going to be another important task in the research of the stock market system. Only with a precise prediction model, managers can take timely and accurate actions and take appropriate actions to manage the company. As a result, the company's operations will achieve high-yield, and keep healthy operating conditions, which we have a long way to do in this job.

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