The Role of Improved Neural Network Algorithm in Convertible Bond Market Analysis

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ABSTRACT. *In order to accurately analyze the convertible bond market, reasonably determine its interest rate and volatility, reduce the risk of convertible bond buyers, and improve their purchase rate, the current convertible bond algorithm is analyzed. Combined with Black-Scholcs pricing model, Radial Basis Function (RBF) neural network algorithm is improved, and RBF neural network is used for orthogonal least squares calculation. The central position of RBF neural network is guaranteed to remain unchanged while the algorithm remains unchanged. The least square method is used to calculate the weight vector of the network again, and the width of the RBF network is set according to the obtained data, in order to find the optimal width. Relevant data samples of convertible bonds are collected by Tonghuashun Ifind Financial Data System and other systems, and the data are simulated and calculated by Matlab software, and the pricing simulation results of convertible bonds under three neural networks are compared. The results show that the modified RBF neural network algorithm can evaluate the price of convertible bonds. And its calculation error is less than the other two neural network algorithms. This indicates that the RBF neural network algorithm designed by us can accurately predict the pricing of convertible bonds in combination with Black-Scholcs pricing, which provides guidance and data support for the pricing of convertible bonds and market investment in the future.*

KEYWORDS: *Neural network; Convertible bond; Simulation model; Pricing; Black-Scholcs model*

1.Introduction

With the continuous development of science and technology, people are pursuing more and more efficient and accurate solutions, in order to simplify the current excessive data calculation. In the 1980s, with the continuous development of artificial intelligence, an intelligent operation method is explored, namely artificial neural network [1]. Its operation mode is similar to the neuron network of human body, and it builds relatively simple models through different links to process and analyze big data. It has the characteristics of large-scale parallel processing,

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distributed information storage, fault tolerance, organization and so on [2], which provides a crucial method for breaking through the existing science and technology and in-depth exploration of non-linear complex problems. In recent years, with the continuous in-depth research, artificial neural network has made great breakthroughs, which has been put into use in many fields and greatly improved the operational efficiency of the industry [3, 4]. Convertible bonds are special corporate bonds that can be converted into common stock at a specific time and under specific conditions [5]. Generally speaking, its value can be divided into three parts, namely, pure debt value, conversion value and option value. The former two can be obtained through ordinary operation, but there is no relatively accurate method to calculate option value [6].

With the continuous development of China's economy, many enterprises begin to use convertible bonds when issuing financing, but in order to reduce risks and increase income, enterprises want to know the accurate pricing of convertible bonds in advance [7]. At present, cost method and discount method are mostly used to evaluate convertible bonds, but these two methods cannot predict the impact of market fluctuations on convertible bonds. In 2010, Dcnck Zmcskal [8] put forward black-scholcs scheme for this problem, which could effectively solve this problem. However, its premise assumption was very strict, with too strong subjectivity and ambiguity, so it could not accurately evaluate this problem. Therefore, at present, some scholars use BP neural network algorithm to optimize the black-Scholcs model of Dcnck Zmcskal, but the evaluation effect is still poor due to the defects of BP algorithm [9]. Therefore, most scholars focus on the RBF neural network algorithm. Compared with BP neural network, it has an excellent approximation function in calculation, and its application in the evaluation of convertible bonds can effectively improve the accuracy of evaluation [10]. However, pure RBF network still has its limitations, which need to be further studied and improved to improve the accuracy of its evaluation of convertible bonds [11].

To sum up, as China's convertible bond market is still in the development stage and the market is not perfect, most companies have low debt ratio, less new capital financing, and the accuracy of convertible bond evaluation is low. Therefore, the traditional RBF neural network calculation is improved and its difference with BP neural network and traditional RBF neural network evaluation is compared through simulation experiment, so as to analyze whether the improved RBF neural network algorithm can be used to evaluate the pricing of convertible bonds in the future. This provides experimental guidance for convertible bond pricing and data guarantee for domestic financial investors.

2 Methods

2.1 Pricing of convertible debt ratios

The value of convertible bond consists of three parts (pure bond, conversion and option), which mainly depends on the conditions of conversion, duration of

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conversion, discount rate, volatility, and existing market price. However, some scholars believe that its value can't include conversion value, and the value of pure debt is equivalent to the value of ordinary bonds. Therefore, the theoretical equation of convertible bond is:

$$V_{convertible} = V_{debt} + V_{option} \tag{1}$$

Assuming that the starting time of the bond is zero, the pure bond value of the convertible bond can be expressed as:

$$B = \sum_{t=1}^{r} \frac{C_i}{(1+r)^l} + \frac{M}{(1+r)^l} \tag{2}$$

When the interest rate is continuous, the above equation becomes:

$$B = \sum_{t=1}^{r} C_i \ell^{-rT} + M \ell^{-rT} \tag{3}$$

After a stable development, all companies holding convertible bonds will fluctuate according to the market share price. When the company's stock goes up, they can get more benefits correspondingly, and the conversion value will measure the benefits they get. It is to evaluate the value of the enterprise after converting relevant convertible equity into shares, and its calculation equation is as follows:

$$V_c = \mathrm{S} \times \mathrm{N} \tag{4}$$

If the conversion price of the market is not changed and the conversion rate is constant, the fluctuation of the stock price of the target company will cause the change of convertible bond.

The current calculation model used in China's financial market is Black-Scholcs model. It is widely used because it is simple, easy to understand and easy to calculate. At the same time, Black-Scholcs model can effectively calculate and analyze the market changes of convertible bonds. The Black-Scholcs option pricing equation is as follows:

$$\mathrm{p}(S, \mathrm{t}) = K \ell^{-r(T-t)} N(-d_2) - \mathrm{SN}(-d_1) \tag{5}$$

The above equation assumes that the stock price (p) and the moment variable (N) of the bid company have a linear relationship with the corresponding option value. Table 1 shows the meanings of the corresponding letters in the above equation. Because the previous assumptions of Black-Scholcs method are relatively strict, it can't effectively evaluate the volatility of convertible bonds. Therefore, the current research is to combine Black-Scholcs method with neural network algorithm, which can effectively solve the limitations of Black-Scholcs model and achieve the desired results.

Table 1 meaning of letter in equation

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Letter of equation	Meaning
$V_{convertible}$	The total value of convertible bonds
V_{debt}	The value of the bond portion
V_{option}	The value of the option portion
B	Theoretical value of pure debt
C_i	Interest for each period
M	Face value of convertible bonds
r	Discount rate
T	The duration of the convertible bond
N	Convertible ratio
S	Underlying share price
C	Value of option
K	Stock prices
δ	The volatility of corporate stocks
t	Current time point
T	Term to Maturity
T-t	The remaining time of the option

2.2 Operation principle of neural network BP

BP neural network estimates the error of the direct leading layer of the output layer according to the error after output. And then this error is used to estimate the error of the previous layer, so that the error estimation of the other layers can be obtained after passing down one layer after another. Figure 1 is the structure diagram of BP neural network, which is divided into two parts: forward transmission of signals and back propagation of errors. It uses the steepest descent method and continuously adjusts the weights and thresholds of the network through back propagation so as to minimize the average and minimum errors of the network. The basic BP neural network includes input layer, hidden layer, and output layer. It has the advantages of reliable basis, rigorous derivation and good universality. But at the same time, it has poor convergence, easy to fall into the local minimum and difficult to determine the number of hidden layers and the number of hidden layers.

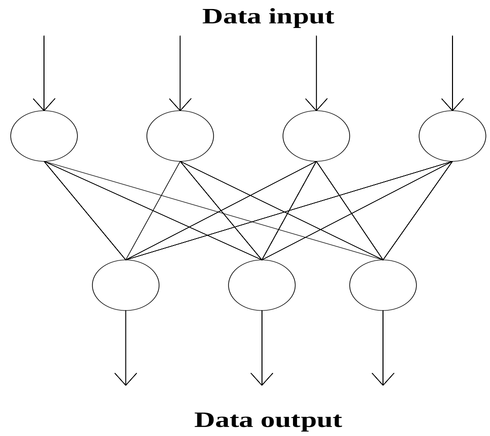

Figure 1 BP neural network diagram

2.3 Operation principle of neural network RBF

RBF neural network is a three-layer forward network: the first layer is the input layer, which is composed of signal source nodes. The second layer is the hidden layer. The transformation function of the hidden element is a kind of locally distributed non-negative nonlinear function. It is radial symmetric to the central point and it has a debilitating function, and the number of units is confirmed by the problem described. The third layer is the output layer, and the output of the network is the linear weighting of the output of the hidden cell. The spatial transformation of RBF neural network from the input space to the hidden space is nonlinear, while from the hidden space to the output space is linear. Figure 2 is the working flow chart of RBF neural network. It overcomes some problems of BP neural network and has the best approximation performance. Global data can be approximated by local approximation.

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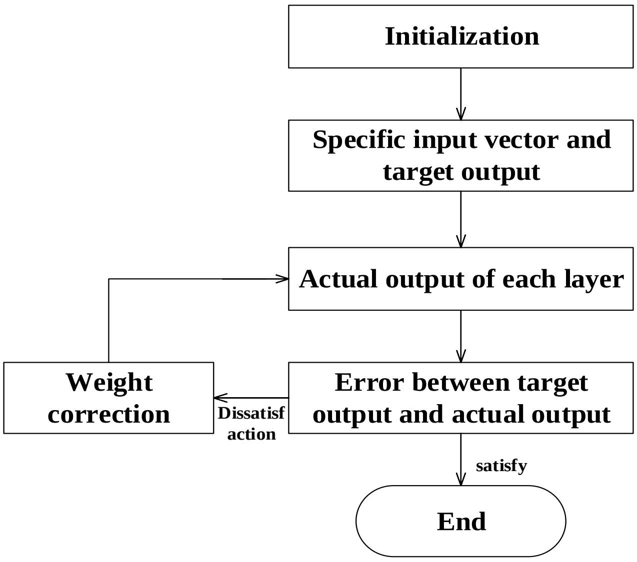

Figure 2 RBF flow chart of neural network calculation

As a non-negative nonlinear function, RBF is usually used as a gaussian function for its hidden layer, and its equation is as follows:

$$R(X_p\text{-}C_i)\text{-}\exp(-\frac{1}{2\sigma^2}\left\|X_p-C_i\right\|^2) \tag{6}$$

This equation is obviously biased. The transformation from the input space to the hidden space of RBF neural network is non-linear, while the transformation from the hidden space to the output space is linear. Therefore, if the nonlinear function is used to calculate the error, the network center, width and weight of RBF determine its relevant performance. Through the network center and width, its specific weight can be gotten. By studying its center and width the algorithm of RBF neural network is improved. Under the condition that the training of orthogonal least squares is good, the center position is kept the same and the width of the network is changed to find a more suitable width to accurately evaluate the pricing of convertible debt ratio. The value equation of its width is:

$$\delta=\frac{d_{max}}{\sqrt{2m}} \tag{7}$$

Among them, δ is the width, dmax is the maximum distance between each cluster center, and m is the number of NBF neural network centers.

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2.4 The empirical calculation

The Black-Scholcs model under BP network, the Black-Scholcs model under RBF neural network, and the Black-Scholcs model under improved RBF network are established and simulated. The obtained structure is then compared and analyzed. The five variables S (the underlying stock price), X (exercise price), T-t (holding period), δ (volatility) and the price of the equation in the issuance bulletin are taken as input variables. And the data of stock market closing in recent years are selected, and the value of daily return by using the equation is calculated. The equation is as follows:

$$\mu_i = \text{In}\frac{S_i}{S_{i-1}} \tag{8}$$

At the same time, the target sample comes from the convertible bonds issued by China's securities exchanges. Relevant parameters are estimated, and three basic values of convertible bonds are calculated according to the above equation. The present value and strike price of the underlying assets are obtained according to the relevant financial statements of the underlying company. Market related trading data are collected to calculate volatility. The risk-free interest rate is obtained through the interest rate of Treasury bonds during the option execution period, and relevant data of the above company are calculated by Matlab software.

3 Results

3.1 RBF network algorithm improvement analysis

The improvement of RBF neural network algorithm is executable. An allowable value A is set, which represents the mean square error between the actual output and the expected output when using RBF neural network. An appropriate algorithm is selected to obtain W. At the same time, it's necessary to figure out the arithmetic mean square of the actual output of RBF neural network and the expected output. D is calculated by subtracting the allowed value from the obtained arithmetic mean square. It is judged whether D is positive or negative. If it is negative, the algorithm stops and records the width value set at this time. After several tests and calculations, the group width with the smallest difference from the specified error value B is selected as the final network width. Figure 3 is the flow chart of the improved RBF neural network algorithm. The improved RBF neural network combined with Black-Scholcs pricing model can effectively evaluate the pricing of convertible bonds. Moreover, the limitation of single Black-Scholcs pricing model can be solved, so that the pricing of convertible bonds can be evaluated more accurately and efficiently.

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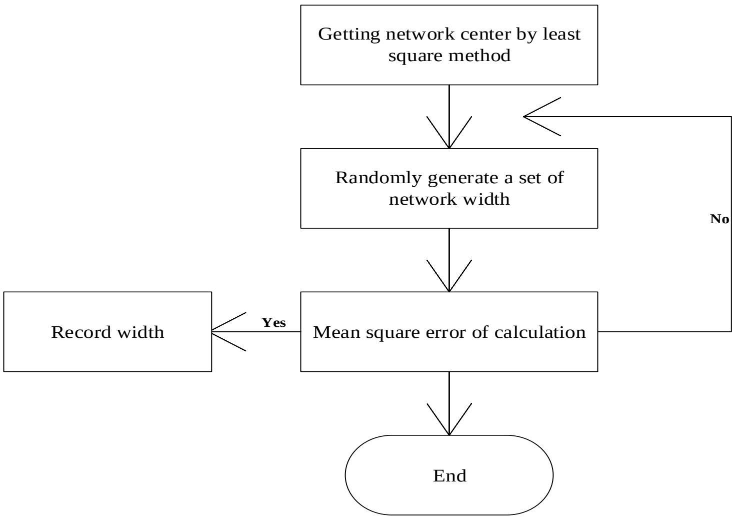

Figure 3 Improved RBF neural network flowchart

3.2 Simulation effect analysis

The obtained data of convertible bonds issued by Shenzhen and Shanghai are calculated by using the above convertible bond pricing equation and Black-Scholcs pricing model equation. After that, BP neural network, RBF neural network, and improved RBF neural network are created by Matlab, and their simulation training effects are analyzed. After several experimental tests, the optimal number of neurons is shown in table 2. According to the table, the optimal neuron of BP neural network is 10. RBF neural network works best when the number of neurons is 5. When the number of neurons is 26, the improved RBF neural network has the best effect, which provides data support for the following calculation and error calculation of the three algorithms.

Table 2 Three neural network algorithms optimal number of neurons

Neural network algorithm	Number of optimal neurons
BP neural network	10
RBF neural network	5
Improved RBF neural network	25

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3.3 Sorting out Matlab data and comparing three models to analyze errors

The obtained data of Shenzhen and Shanghai are calculated and sorted out. The mean error, mean square error, mean absolute error and mean relative error are used to evaluate the errors of the three algorithms. Figure 5 shows the error analysis results of the four indexes in BP network, RBF network, and improved RBF network model. According to the figure, the volatility deviation of RBF neural network and the improved RBF neural network is significantly lower than that of BP neural network, and its error is the highest under the calculation of MAE index. The minimum error of the improved RBF neural network is smaller than the minimum error of the other two. Therefore, the improved RBF neural network has the smallest error in the pricing analysis of convertible bonds, which provides a feasible method for the pricing of convertible bonds in the future market.

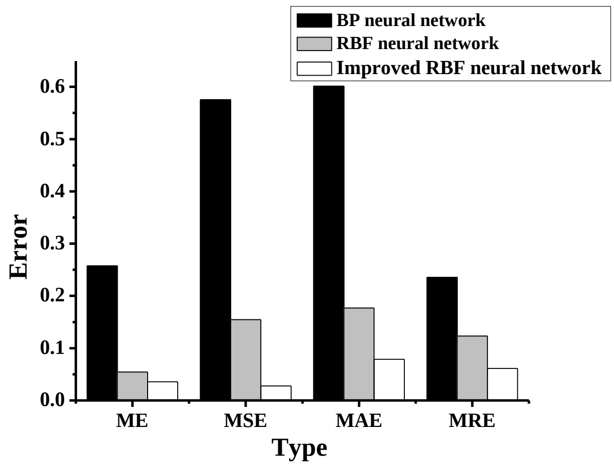

Figure 4 Error comparison of three neural network models

4 Conclusion

According to China's current financial market, market volatility and interest rate have a great impact on convertible bonds. This shows that when the price of fixed bonds in the market changes, the price of convertible bonds will also be affected. Therefore, the current pricing method of convertible bonds is relatively limited and quite unreasonable. At the same time, the current algorithm in China is not accurate enough to evaluate the pricing, which increases the risk of investors. Therefore, accurate pricing can reduce the loss caused by unknown factors and improve the earnings of financing enterprises, which is crucial to the development of domestic capital market in the future.

Because the Black-Scholcs pricing model is simple and easy to operate and has a linear functional relationship with the assumed interest rate and volatility, the Black-

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Scholcs model is chosen to evaluate the pricing of convertible bonds. Under the former's study of BP neural network, the algorithm of RBF neural network is analyzed, and its limitations are modified. The results show that the improved RBF network can effectively improve the accuracy of prediction. This improved algorithm is applied to the pricing of convertible bonds. Combined with Guotai 'an database, wind data system and other data, Matlab software is used for simulation calculation. Finally, Black-Scholcs convertible bond pricing model based on three neural networks is compared and analyzed. The results show that the pricing error of Black-Scholcs convertible bonds under improved RBF neural network is smaller and the results obtained are more effective. This provides a feasible calculation scheme for the evaluation of convertible bond pricing and data support for the development of China's capital market in the future.

References

[1] Xiao L, Guo B, and Shen Y. "(2012)Application of Improved BP Neural Network in Software Energy Consumption Analysis." Computer Engineering, , vol 38.no 10, pp. 185-187.

[2] Simões S. S, Silva I, Ajenjo A C, & Dias M J (2014). Optimization of cultural conditions using response surface methodology versus artificial neural network and modeling of l-glutaminase production by bacillus cereus mtcc 1305. Glutaminase isoenzymes as key regulators in metabolic and oxidative stress aga. Forensic Science International, vol 243. no 6, pp. 117-125.

[3] Chattopadhyay M, Dan P K, Mazumdar S, et al (2012). Application of Neural Network in Market Segmentation: A Review on Recent Trends[J]. Management Science Letters, vol 2. no 2, pp. 425-438.

[4] Fajä• ÃKovą̃, K., Stehlą̃Kovą̃, B., Cveä Kovą̃, V(2017)., & Rapant, S. Application of artificial neural network in medical geochemistry. Environmental Geochemistry & Health, , vol 39. no 6, pp. 1-17.

[5] Cheng K, Guo L M, Wang Y K, & Zafar M T (2017). Application of clustering analysis in the prediction of photovoltaic power generation based on neural network. IOP Conference Series: Earth and Environmental Science, vol 93, pp. 012024.

[6] Moayedi H, Mosallanezhad M, Rashid A S A, Jusoh W A W, & Muazu, M A.(2019) A systematic review and meta-analysis of artificial neural network application in geotechnical engineering: theory and applications. Neural Computing and Applications, vol 6, pp. 1-24.

[7] Botsis T, Foster M, Arya N, Kreimeyer K, Pandey A, & Arya D (2017). Application of natural language processing and network analysis techniques to post-market reports for the evaluation of dose-related anti-thymocyte globulin safety patterns. Applied Clinical Informatics, vol 08. no 02, pp. 396-411.

[8] Seifollahi, Saeed, and Shajari M (2018). "Word sense disambiguation application in sentiment analysis of news headlines: an applied approach to FOREX market prediction." Journal of Intelligent Information Systems, pp. 1-27.

[9] Bektić, Demir, and Regele T. (2017)"Exploiting uncertainty with market timing in corporate bond markets." Journal of Asset Management, pp. 1-14.

ISSN 2616-5902 Vol.1, Issue 3: 26-35, DOI: 10.25236/AJBM.2019.010304

[10]Berna Simsek, & Tüysüz F. (2018) An application of network data envelopment analysis with fuzzy data for the performance evaluation in cargo sector. Journal of Enterprise Information Management, vol 31.no 4, pp. 00-00.
[11]Pan X Q, Chen Y, and Kuo C J J.(2017) "Design, analysis and application of a volumetric convolutional neural network. "Journal of Visual Communication & Image Representation .vol 46, pp. 128-138.