Configuring an Improved Backpropagation Network for Forecasting Study of Interest Rate in Traditional Money Market and Derivative Commodity Market

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Through dexterously masterminding the interacting characteristics of micro and meso structures for optimizing performance of feedforward networks, the application of neural network on pattern recognition of monetary tools, bond rating, stock price forecasting and loan examination has successfully made a stride. The study concentrates on the mastery of future trend of not yet explored ninety to one hundred eighty day commercial paper interest rate that plays one of the key roles both in traditional secondary money market and innovative derivative commodity market. The outcome shows several encouraging messages: 1.While the result of applying the multi-regressional model on this kind of problem is awkward, the improved backpropagation networks especially the one integrating Nguyen-Widrow Method and Adaptive Learning Rate Method turn out to have great performance without involving in the serious problems of multicollinearity and autocorrelation. 2.With small error of tolerance, the forecasting reliability of network is satisfactory no matter random or moving simulation sampling method is adopted. 3.For avoiding the impact of random walk, we take the average interest rate of day t-2,t-1,t,t+1,t+2 as the target output. In so doing, the network presents an outstanding learning effect with the accuracy of forecast beyond 98%. 4.The performance of improved backpropagation network like momentum is not always better than pure backpropagation network. The excellance of network largely depends on the area of application, structure of network, distributing structure of input data, transfer function, selection and combing effect of various parameters and initial weight matrix. 5.We learned from the study that the fluctuating trend of interest rate may be influenced by different combinations of economic and monetary independent variables in different time period, so rashly gathering the big sample without reviewing the attribute of data may hold down the authentic forecating effect of network.

Key Word : OTC currency options, innovative monetary commodity, LIBOR, variance inflation factors, error of tolerance, random walk, mixed improved backpropagation network.

1 .Background and objective of the research

For the purpose of smoothly achieving the complete monetary openness by the year of 2000 and of being well corresponded with the monetarily developing trends of liberalization , internationalization and multiformity , The Central Bank and Ministry of Finance have ratified the derivative commodity transactions of interest rate swaps , cross currency swaps , forward rate agreements , over-the-counter (OTC) currency options and OTC interest rate options.

Among these newly-opened derivative commodities, we found that four of them take interest rate as the operational object except for the OTC currency options which are solely connected with exchange rate. The fact implies the particular importance and urgency of the interest rate operation both in short-term money market and long-term capital market.Taking the practical transaction of interest rate as an example.The turnover of interest rate swap in the global market is from 1.5 trillion U.S.dollars in the year of 1989 rapidly jumped to 3.8 trillion U.S.dollars in the year of 1992.It shows that the powerful activity and developing potential of interest rate related commodities in Taiwan's monetary market are predictable.

Since derivative commodity belongs to one of the items in off-balance transaction [Tung, 1993], the authentic surplus and debt can not be truly reflected on the financial report. An operational failure may cause tremendous impact to the investors. In addition, since the domestic mid-term and long-term interest rates are lack of indexes[Wang, 1995], the related transactions are more difficult and risky. Hence, for the purpose of providing government organizations, banks, enterprises,

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investment trust companies and civilians a more reliable information or index used as the reference of making decision while dealing with interest rate commodities, the study applies neural network as an analytical and forecasting tool of interest rate. We premeditatedly choose the ninety to one hundred eighty day interest rate of commercial paper in the secondary market as the predicted object among various interest rates. The reasons are as follows: (1)The fluctuating range of interest rate of commercial paper is lower than those of prime rate and loan interest rate of the bank but higher than those of interest rates of treasury bill and deposit[YU,1990]. It means that if the trend of interest rate of commercial paper can be effectively controlled, the trends of interest rates of Central Bank, general banks and various bills and securities can be well understood and managed. (2)The value of commercial paper depends on the market spot interest rate on the particular trading day plus paying the discount interest and certain service charge of its value[Liu and Chen,1993], so the future trend is tremendously difficult to be controlled. (3)The interest rate of commercial paper is taken as an important reference index of upper and lower bound interest rates in the option market. Other than that, the swap transaction between the commercial bank interest rate and LIBOR is one of the major operating tools for hedging. It shows that the commercial paper plays an important role in the operations of derivative commodities.

2.Problem analysis and research tool selection

As tradition, we first try to tackle the problem through regressional model. The outcome shows some of independent variables whose values of variance inflation factors and correlation coefficient are too high reflect the serious problem of multicollinearity. And since we take the three consecutive month data as input column vector, the problem of autocorrelation appears conspicuously. In the process, we put all variables forcibly into the model and come up with the coefficient of determination R^2 equal to 0.77. But with the consideration of degree of freedom, we get the adjusted coefficient of determination R_a^2 only equal to 0.39. Yet we still leave the unprocessed problems of multicollinearity and autocorrelation. We also apply the stepwise regression to exclude the unnecessary variables from the model, but the value of R^2 is so low that the model is not applicable. The above practice and analysis form the main motive of adopting the neural network as the tool of forecasting.

3.The analysis and design of neural network construction

3.1Input Variable: According to the critical factors of influencing interest rate as commodity price, economy, exchange and bank liquidity, ...etc.[Chyn and Wang, 1995], we induced the primary input variables as follows:(1) the spot exchange rate (2) the increasing rate of monetary supply (3) the increasing rate of liquidity debt (4) the increasing rate of loan and investment devided by the increasing rate of deposit (5) Consumer's commodity price index (6) Unemployment rate (7) Business leading barometer (8) the increasing rate of custom export (9) the increasing rate of gross index of industrial production.

We take the newest three consecutive month data of each factor as input for predicting the spot interest rate happened three month later. So there are 27 input variables totally. And due to the differences of the ranges of input variables are too big, we first map the different ranges of all necessary input variables into the interval between 0 and 1 through max-min mapping method[Yeh,1995].

3.2Output variable: Taking the forecasting problem of commercial paper interest rate happened three month later as an example, let t is the month at when the commercial paper will be dealed, t-3 is the current month at when the purchasing

decision of commercial paper is made. We view the interest rate prediction as the problem of sample classification[Baba and Kozaki,1992], so the output can be treated as a rise and fall classification of interest rate that requires three processing units presenting the situations of rise, even and fall. For avoiding the influence of random walk, the average rate of rise and fall of target output vector is decided by comparing the interest rate of current month (t-3) with the average interest rate of the months t-2, t-1, t, t+1, and t+2. Denoted by

$\mathbf{I_p}$:the commercial paper interest rate of secondary market in present month. $\mathbf{I_i}$:the commercial paper interest rate of secondary market in i-th month, where i=t-2, t-1, t, t+1, t+2. $\mathbf{d_i}$:the rise or fall rate obtained from comparing the commercial paper interest rates of present month and the i-th month. **avg_d**:the average rise or fall rate of interest rate from the month t-2 to the month t+2,so

$$d_i = \frac{I_i - I_p}{I_p} \quad , \quad avg\_d = \frac{\sum_{i=t-2}^{t+2} d_i}{(t+2)-(t-2)+1} = \frac{\sum_{i=t-2}^{t+2} d_i}{5}$$

Then the dividing way of output vector can be classified in Table 1.

Table1: The classification standard of output vector

classification	satisfied condition	output vector
rise	avg_d > 1.0%	1 0 0
even	-1.0 ≤ avg_d ≤ 1.0%	0 1 0
fall	avg_d < -1.0%	0 0 1

Data resource: The result of the study

3.3Network training: We take the 91 to 180 day commercial paper interest rate of secondary market from May 1991 to June 1995 as the training and testing data[9] [10] in which the former gets 76%and the latter gets 24%. The sigmoid transfer function is used in both hidden and output layers. Four training ways are adopted as follows: 1.Pure backpropagation network [Alianna, Dan and Stanley,1990](N-1). 2.Improved backpropagation network which combines the advantages of Nguyen-Widrow Method and Adaptive Learning Rate Method (N-2). 3.Improved backpropagation network which only includes Adaptive Learning Rate Method (N-3). 4.Improved backpropagation network which includes the application of Momentum [Sharda and Patil,1990](N-4).

The diagram 1 is the integrated structure of backpropagation network consisting of input vector, output vector, hidden layer and transfer function.

3.4Testing of the network: The testing of the network is carried out based on the weight matrix and bias vector obtained from the previous training process. The random sampling method and moving simulation method are both adopted for testing.The time differentiating way of moving simulation is presented in diagram 2.

4.Outcome of the study

In the learning stage, the result shows that four different training ways can all achieve the tolerance error of 0.01, but the convergent speeds are quite different.The data from Table 2 indicates network N-2, with the lowest average epoch (3113.3) and standard error (310.6) under moving simulation method and with the lowest epoch (3450) under random sampling method, has the best performance. Diagram 3 and 4 show its convergent epoch vs. error and learning rate. The pure backpropagation network N-1 is only inferior to N-2 impling that the improved networks are not always better than the pure ones. Diagram 5 shows the

convergent epoch and error change of pure network combining with the random sampling method. From Table 2 , we learned that the convergent speed of the network has no significant difference no matter random sampling method or moving simulation method is adopted. Secondly, there are three classifications for the output: (100) representing rise, (010) representing even and (001) representing fall. We use the trained N-2 network to test 24 percent of data and the outcome is satisfactory. Except for only one input vector whose target value is supposed to be 1 0 0 (representing rise) but turning out to be the unjustifiable forecasting value (0.814,0.64,0.485), the trained network is capable of making accurate and clear match between forecasting and target values for over 98% of testing data.

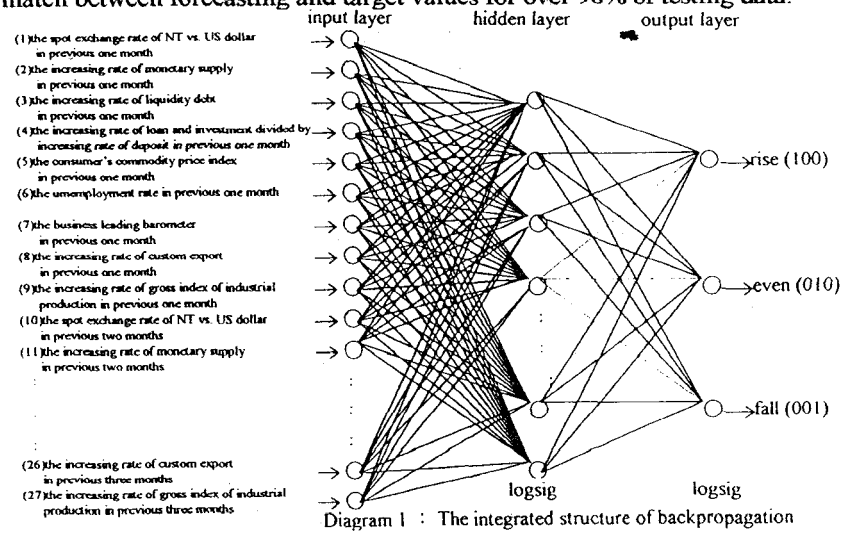

Diagram 1 : The integrated structure of backpropagation

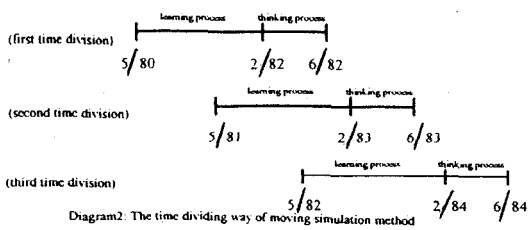

Diagram2: The time dividing way of moving simulation method

Table2: With the maximum error of 0.01, the convergent epochs needed in different training and sampling ways

The sampling of moving simulation	training way / sampling way / epoch	N-1	N-2	N-3	N-4
	I-1	3869	3044	6290	12866
	I-2	3610	3575	5489	10433
	I-3	5806	2846	8113	11242
	I	4428.3	3113.3	6630.7	11573.7
	σ_I	1174.6	310.6	1098	1011.7
	random sampling	3382	3450	7746	13408
	T	4166.7	3228.7	6909	11987

I : the average convergent epoch of network in the training way of moving simulation sampling
σ_I : the standara error of epoch under the training way of moving simulation sampling
T : the average convergent epoch of network under the training ways of moving simulation and random sampling methods
Data resource: The result of the study

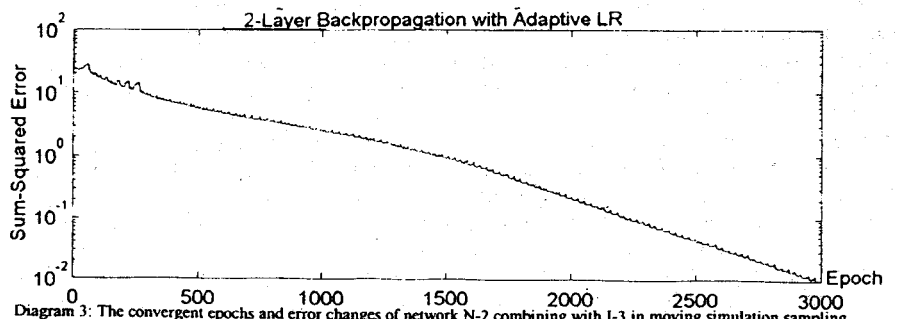

Diagram 3: The convergent epochs and error changes of network N-2 combining with I-3 in moving simulation sampling

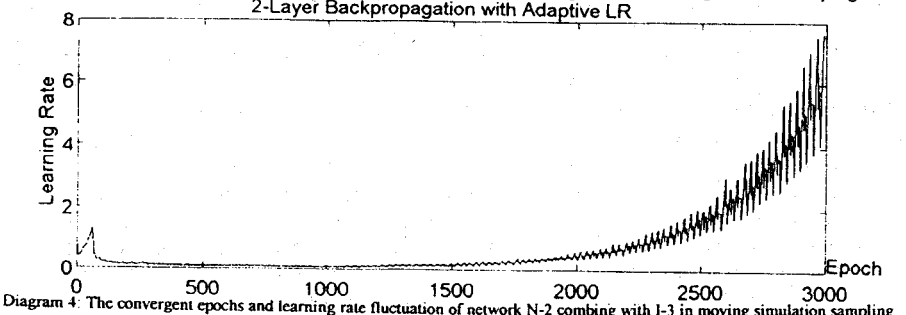

Diagram 4: The convergent epochs and learning rate fluctuation of network N-2 combing with I-3 in moving simulation sampling

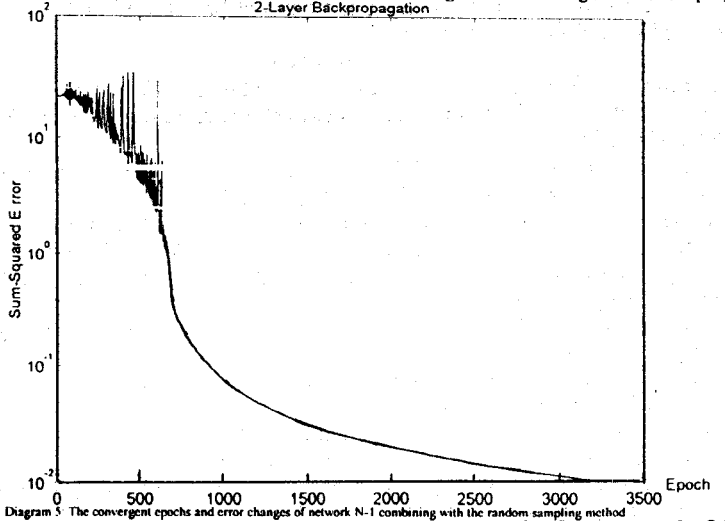

Diagram 5: The convergent epochs and error changes of network N-1 combining with the random sampling method

5. Conclusion

We apply the improved backpropagation network to forecast the future trend of 91 to 180 day commercial paper average interest rate in the secondary market for the purpose of providing the banks, enterprises, investment trust companies and different individual a reliable, effectively controlled and managed tool of capital procurement, investment and hedging. The study points out that network N-2 has the fastest convergent speed with the maximum error being controlled within 0.01 no matter what kind of sampling way is adopted. And its forecasting capability is

over 98%. In the mean time the delicate problems of multicollinearity and autocorrelation existing in regressional model can be effectively avoided of its own accord. We also acquired the following tips from dealing with the problem: 1.The arrangement of two consecutive sigmoid functions for hidden and output layers has the best effectiveness. 2.The network of mixing up the advantages of Nguyen-Widrow Method and Adaptive Learning Rate Method has the best performance. 3.The effectiveness of general improved backpropagation network is not always superior to that of pure backpropagation network, It depends on the application area, network structure, distributed structure of input data, transfer function, initial weight matrix and arrangement of various key parameters. 4.With the maximum error being set up to be 0.01, the forecasting reliability of network is satisfactory no matter random sampling or moving simulation method is adopted. 5.The number of processing units of hidden layer is initially set up to be 15 through the generally-used formula. The outcome of practical operation indicates that both the forecasting effect and convergent speed are able to meet the requirement of network goal with the number of processing unit is 6 or beyond.

Pratically speaking, the experience we obtained from the construction of network, the selection and arrangement of input and output vectors, the synthetic set-up of various parameters in learning stage and the outcome of research should have positive values of reference to the followers in the related area. We also try to broaden the time interval of gathering data which is from 1986 to 1995 in order to collect more samples, but both the learning effect and forecasting reliability will not be conspicuously improved. It reflects that the interest rate may be influenced by different combinations of independent variables in different period of time. We suggested that this kind of phenomenon can not be ignored and should be carefully handled in the following research.

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