ICIC Express Letters
Part B: Applications
Volume **7**, Number **4**, April **2016**

ICIC International ©2016 ISSN 2185-2766
pp. 895–901

STRUCTURING INTERACTIVE ARTIFICIAL BEE COLONY FORECASTING MODEL IN FOREIGN EXCHANGE RATE FORECASTING WITH CONSUMER CONFIDENCE INDEX AND CONVENTIONAL MICROECONOMICS FACTORS

Pei-Wei Tsai[1,2], Chia-Han Liu[3], Jilin Zhang[4] and Jui-Fang Chang[3,*]

[1]College of Information Science and Engineering
[2]Key Laboratory for Automotive Electronics and Electric Drive of Fujian Province
[4]Department of Mathematics and Physics
Fujian University of Technology
No. 3, Xueyuan Road, University Town, Minhou, Fuzhou 350118, P. R. China
pwtsai@fjut.edu.cn; jilinzhang1976@126.com

[3]Department of International Business
National Kaohsiung University of Applied Sciences
No. 415, Chien-Kong Road, Kaohsiung City 80778, Taiwan
imilk1314@hotmail.com; *Corresponding author: rose@cc.kuas.edu.tw

Received September 2015; accepted November 2015

Abstract. *Existing methods used in the foreign exchange rate forecasting are mostly in the branch of the time series methods. The time series models usually do not focus on the short-term forecasting, but the chronic forecasting. Models for the short-term forecasting still remains blank. In addition, conventional foreign exchange rate forecasting methods only consider the factors in microeconomics. No psychological factors are collected in the forecasting process. The forecasting method, which simultaneously considers both the technical and the psychological factors, is not revealed. Answering the needs of short-term foreign exchange rate forecasting and the comprehensive consideration of technical and psychological factors, the new foreign exchange rate forecasting model based on Interactive Artificial Bee Colony (IABC) is proposed. In this paper, IABC algorithm is employed to create a foreign exchange rate forecasting model. Our proposed forecasting model not only utilizes the conventional factors in microeconomics, but also includes the Consumer Confidence Index (CCI) in the consideration as one of the reference data for estimating the foreign exchange rate. In our proposed forecasting model, the reference data include indices announced daily, weekly, and monthly. The output is composed of all reference indices and a set of weighting, which is corresponding to the indices. In our design, IABC plays the role to properly rate the significance of each index and to provide a set of weighting to combine the indices, together, to form a single forecasting value. The final output of our proposed forecasting model is the forecasted foreign exchange rate for the next day. In order to test the accuracy of our proposed method, 4 years of the historical data in 2011 to 2014 are included in the experiments. The forecasting error is about* 0.07‰ *in average, the maximum forecasting error over all test periods is* 0.21‰, *and the minimum forecasting error over all test periods is zero. In addition, the standard deviation of the forecasting error over all test periods is 0.004. The experimental results indicate that our proposed method presents high accuracy in the forecasting capacity in the foreign exchange rate.*
Keywords: Interactive Artificial Bee Colony, Foreign exchange rate forecasting, Optimization, Time series

1. **Introduction.** The foreign exchange rate is the conversion rate of the domestic currency into a foreign currency. It can also be regarded as the currency value of one country in terms of another foreign currency. The foreign exchange rate is determined in the foreign exchange market [11]. It is open to different types of venders and consumers. In

addition, the mechanism it has is a free market system. The price of currencies is decided by the demand and the supply.

The foreign exchange rate forecasting is a popular topic for the investors. It is also a hot topic for researchers to work on. Researchers not only focus on improving the existing forecasting models and designing new forecasting models, but also focus on finding powerful reference factors, which are highly correlated with the foreign exchange rate. Since the foreign exchange rate forecasting is not a new topic in economics, there exist many forecasting modes. The most popular and commonly used model is the time-series model. It includes the Autoregressive Conditional Heteroskedasticity (ARCH) model [3], Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model [4], Exponential Generalized Autoregressive Conditional Heteroscedastic (EGARCH) model [1], and GJR-GARCH [9]. Most of the models are improvements based on the ARCH model. The core theorem is based on the time-series analysis. On the other hand, the conventional foreign exchange rate forecasting methods usually refer to 10 factors such as the price index, the interest rates, the money supply, the balance of trade, and so forth. It is known that these indices are highly related to the foreign exchange rate. However, the factors mentioned above are all statistically collected in the macroeconomics. None of the psychological factors is taken into consideration in the conventional foreign exchange rate forecasting models. In addition, the accuracy of a foreign exchange rate forecasting model suffers from the selection of the referenced information collected from the considered factors. If the selected reference factor is not strong in providing proper information for the forecasting, the accuracy will drop, significantly. Furthermore, the existing literature usually focus on the long-term forecasting rather than the short-term forecasting. It implies that the existing methods are not sharp at the short-term forecasting ability. However, the short-term forecasting accuracy is much more important for the investors involving in the foreign exchange market. Hence, the urgent need of new foreign exchange rate forecasting model with strong short-term forecasting ability is revealed.

Answering this demand, a new foreign exchange rate forecasting model based on Interactive Artificial Bee Colony (IABC) [15] algorithm, which is a method in the field of swarm intelligence, is proposed in this paper. Furthermore, a psychological factor called the Consumer Confidence Index (CCI) is also included in our forecasting model with the conventional macroeconomic factors as the reference information. Our proposed forecasting model not only provides the foreign exchange rate forecasting result for the next day, but also produces a set of weighting for revealing the ranking of the importance of the referenced information. In order to test the usability, the accuracy, and the performance of our proposed method, a set of historical data including the actual exchange rate in 2011 to 2014 between US dollars and New Taiwan dollars is used in our experiments. The forecasting error between the forecasted foreign exchange rate and the actual foreign exchange rate is revealed in the experimental results.

The rest of the paper is composed as follows: a brief review in IABC algorithm and the macroeconomic indices are given in Section 2, our proposed model and the designed fitness function are explained in Section 3, the experiments and the experimental results are given in Section 4, and the conclusion is presented at last.

2. **Review on Interactive Artificial Bee Colony Optimization.** IABC [15] is proposed by Tsai et al. in 2009. At the beginning, it is proposed for solving numerical optimization problems. Soon after it is proposed, different applications of IABC is proposed one after another in recent years. For instance, it is employed in assisting the passive authentication system [13], optimizing the stock investment portfolio [6], and analyzing the impact in the stock market caused by the international trade agreements [14]. The artificial agents in IABC play exactly the same roles as in Artificial Bee Colony (ABC) optimization [10]. However, the movement of the onlooker bees refers to a more flexible

reference information from the employed bees. This movement in IABC provides the artificial agents the chance of gaining higher diversity. The searching result is more accurate than the original ABC. The process of IABC can be summarized as follows.

Step 1. Initialization: Randomly deploy n_e percent of the artificial agents into the solution space. When these agents stand on a position in the solution space, they are defined as the employed bees. The employed bees are responsible for providing information, i.e., the fitness values corresponding to the position they stand on, to the rest of artificial agents, which are called the onlookers, in the upcoming steps.

Step 2. Movement of the Onlookers: Calculate the probability of food sources, which are provided by the employed bees, by Equation (1).

$$P_i = \frac{F(\theta_i)}{\sum_{k=1}^{S} F(\theta_i)} \tag{1}$$

where θ_i is the position of the employed bee, S stands for the total number of employed bees in the solution space, and P_i means the probability for the onlookers to choose the employed bee to follow.

Let N be a predetermined constant, which indicates the number of employed bees that the onlooker refers to in the movement. Base on the universal gravitation theorem, the onlooker is gravitated toward every selected employed bees. The movement of the onlookers is processed by Equation (2).

$$\theta_q(t+1) = \theta_q(t) + \sum_{p=1}^{N} \tilde{F}_{qp} \cdot [\theta_q(t) - \theta_p(t)] \tag{2}$$

where θ_q denotes the position of the onlooker, t is the iteration number, $\tilde{F}_{qp}$ stands for the normalized gravitation force of the employed bee to the onlooker, and the gravitation force can be simply adopted from the probability of the food source.

Step 3. Movement of the Scouts: If a scout bee occurs, move the scout by Equation (3).

$$\theta_k(t+1) = \theta_k(t) + r \cdot (\theta_{k_{\max}}(t) - \theta_{k_{\min}}(t)) \tag{3}$$

where θ_k represents the position of a scout, r is a random vector in the range of $[0, 1]$, the max and the min stand for the maximum and the minimum value occuring in all dimensions of θ_k, respectively.

Step 4. Update the Near best Solution Found So Far: If the newly found solution is better than the original stored solution, update the near best solution.

Step 5. Termination Checking: Check whether the termination condition is satisfied. If it is satisfied, terminate the program and output the stored near best solution. Otherwise, go back to Step 2 and repeat the process.

On the other hand, the foreign exchange rate determination theory includes many elements in the macroeconomics. Because of the length limitation of the paper, we only select parts of the elements for review in this section, e.g., the Purchasing Power Parity (PPP) theory and the monetary model [8], the Interest Rate Parity (IRP) [5], the Balance of Payment Model (BPM) [12], and the Portfolio Balance Model (PBM) [7]. Moreover, the Consumer Confidence Index (CCI) [2] is also briefly introduced for the later use in our proposed method.

The PPP theory claims that the exchange rate between currencies from different countries are equal to the ratio of their price levels because the purchasing ability of a country's currency is reflected in the country's price level and the money price of a reference basket of goods and its services. The PPP theory is proposed based on the concept of the arbitrage across goods markets and the Law of One Price (LOP). It is also the foundation of many other economic models. The IRP theory establishes the joint between the spot currency market and the forward currency market with foreign and domestic market. The BPM indicates that the equilibrium exchange rate should make the surplus and the deficit of balance from the payment of the country equals zero. If the surplus and the deficitare are not equal to zero, the exchange rate must be fluctuated. The PBM is a type of extension from the monetary model. It claims that people having different assets should undertake different returns and risks. This model also treats the expected returns of different financial assets existing in different countries as the primary factors which affect the exchange rate. The CCI is an improvement factor in the macroeconomics because it is an index which quantitates the psychological status of consumers into scales.

3. **Our Proposed Method.** In this paper, IABC is employed to construct the foreign exchange rate forecasting model. In our design, the foreign exchange rate forecasting problem is defined as the optimization problem which optimizes the combination and weighting of the reference information to produce the forecasted foreign exchange rate for the next day. The reference information used in our forecasting model is composed of 10 factors, which include 8 regular macroeconomic factors, namely, Consumer Price Index (CPI), M1, M1B, Commercial Paper Rate (CPR), Federal Fund Rate (FFR), Balance of Trade (BT), Foreign Investment (FI), and Stock Return (SR), the actual exchange rate of New Taiwan Dollars to US Dollars, and the CCI. These factors include the historical data announced monthly, weekly, and daily. To maximize the usage of all available information, the date provided by the daily data is extracted as the reference base. Our proposed forecasting model uses 30 days of the historical data as the reference information, and IABC is in charge of providing a set of weighting mask for identifying the importance of every factor. To achieve this goal, we design a fitness function, which is listed in Equation (4), for IABC to determine the weighting.

$$\min f(W) = \sum_{d=1}^{D} \left| \left(\sum_{m=1}^{M} w_m \cdot v_{d,m} \right) - R_{actual,d} \right| \tag{4}$$

where $f(\cdot)$ stands for the fitness function, D is the total number of reference days of the historical data, M represents the total number of factors referenced in our forecasting model, w_m and $v_{d,m}$ are the weighting mask and the value of the referenced factor, respectively, and $R_{actual,d}$ is the actual foreign exchange rate on day d.

Finally, a linear accumulation is used to combine all reference data with the weighting for producing the forecasted foreign exchange rate for the next day. The sliding window strategy is employed to shift the forecasting period forward from the beginning of the year to the end.

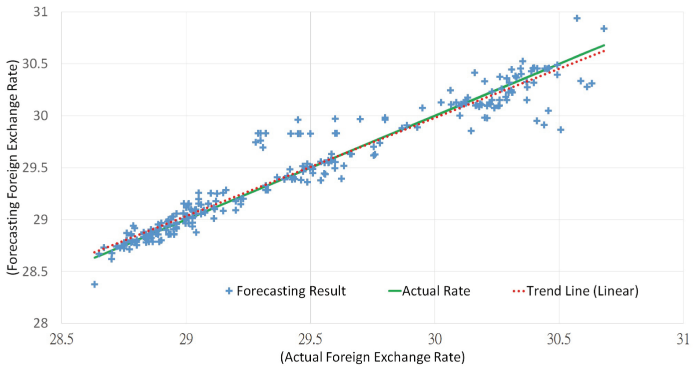
The forecasted foreign exchange rate is calculated by Equation (5):

$$R_{f,d} = \sum_{m=1}^{M} w_m \cdot v_{d-1,m} \tag{5}$$

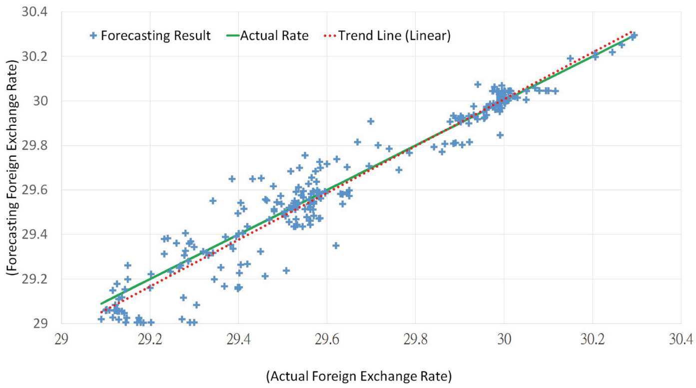
where $R_{f,d}$ is the forecasted foreign exchange rate for day d.

4. **Experiments and Experimental Results.** To test the forecasting accuracy of our proposed foreign exchange rate forecasting model, the historical data in 2011 to 2014 are used in our experiments. The forecasting results of our proposed method are shown in Figure 1.

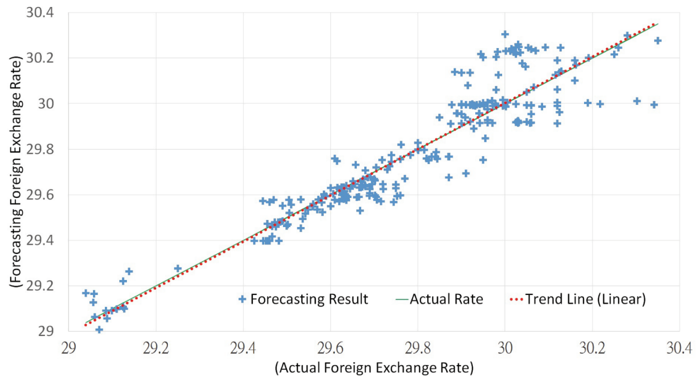
The horizontal axis in Figure 1 is the actual foreign exchange rate, the vertical axis in Figure 1 is the forecasted exchange rate, the orange dots are the actual exchange rates, and the dot line is the trend line of the forecasting results. The statistical information of the test periods are listed in Table 1.



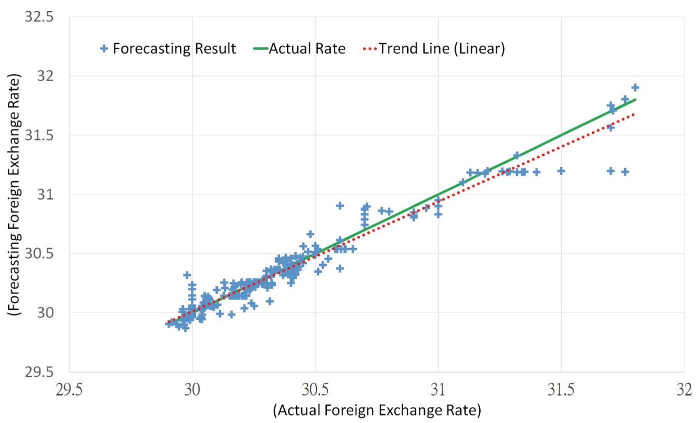
(a)



(b)



(c)



(d)

FIGURE 1. The forecasting result for: (a) 2011, (b) 2012, (c) 2013, and (d) 2014

Table 1. The statistical information of the experimental results

	Maximum Error	Minimum Error	Mean Error	Standard Deviation
2011	0.21‰	0	0.003‰	0.005
2012	0.10‰	0	−0.005‰	0.003
2013	0.11‰	0	0	0.003
2014	0.18‰	0	−0.005‰	0.003

According to the results given in Table 1, our proposed forecasting model presents a very precise forecasting result. Moreover, the standard deviation (STD) indicates that the forecasting result obtained by our proposed model is very stable.

5. **Conclusions.** In this paper, we use IABC with CCI and other factors in macroeconomics to construct the foreign exchange rate forecasting model. In order to test the accuracy of our proposed method, 4 years of the historical data in 2011 to 2014 are included in the experiments. The forecasting error is about 0.07‰ in average, the maximum forecasting error over all test periods is 0.21‰, and the minimum forecasting error over all test periods is zero. In addition, the standard deviation of the forecasting error over all test periods is 0.004. The experimental results indicate that our proposed method is stable and presents high accuracy in the forecasting capacity. In the future work, we plan to take the monitoring indicator into consideration factor in the forecasting model to further include psychological influence in the foreign exchange rate.

Acknowledgment. The authors gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

REFERENCES

[1] G. Ali, EGARCH, GJR-GARCH, TGARCH, AVGARCH, NGARCH, IGARCH and APARCH models for pathogens at marine recreational sites, *Journal of Statistical and Econometric Methods*, vol.2, no.3, pp.57-73, 2013.

[2] R. Batchelor and P. Dua, Improving macro-economic forecasts: The role of consumer confidence, *International Journal of Forecasting*, vol.14, no.1, pp.71-81, 1998.

[3] A. K. Bera and M. L. Higgins, ARCH models: Properties, estimation and testing, *Journal of Economic Surveys*, vol.7, no.4, pp.307-366, 1993.

[4] T. Bollerslev, Generalized autoregressive conditional heteroskedasticity, *Journal of Econometrics*, vol.31, pp.307-327, 1986.

[5] W. H. Branson, Flow and stock equilibrium in a dynamic metzler model, *Journal of Finance*, vol.31, no.5, pp.1323-1339, 1976.

[6] J.-F. Chang, T.-W. Yang and P.-W. Tsai, Applying interactive artificial bee colony to construct the stock portfolio, *Proc. of the 2nd International Conference on Robot Vision and Signal Processing*, Kitakyushu, Japan, pp.129-132, 2013.

[7] Y. W. Cheung, M. D. Chinn and A. G. Pascual, Empirical exchange rate models of the nine-ties: Are any fit to survive? *Journal of International Money and Finance*, vol.24, pp.1150-1175, 2005.

[8] J. A. Frenkel, Flexible exchange rates, prices, and the role of news: Lessons from the 1970s, *Journal of Political Economic*, vol.89, no.4, pp.665-705, 1981.

[9] M. Gherman, R. Terebes and M. Borda, Time series analysis using wavelets and GJR-GARCH models, *Proc. of the 20th European Signal Processing Conference*, Bucharest, Romania, pp.2138-2142, 2012.

[10] D. Karaboga and B. Basturk, On the performance of artificial bee colony (ABC) algorithm, *Applied Soft Computing*, vol.8, no.2008, pp.687-697, 2008.

[11] M. Levinson, *Guide to Financial Markets*, The Economist in Association with Profile Books LTD, Great Britain, 2005.

[12] R. MacDonald and M. P. Taylor, The monetary model of the exchange rate long-run relationships, short-run dynamics and how to beat a random walk, *Journal of International Money and Finance*, vol.13, no.3, pp.276-290, 1994.

[13] P.-W. Tsai, M. K. Khurram, J.-S. Pan and B.-Y. Liao, Interactive artificial bee colony supported passive continuous authentication system, *IEEE Systems Journal*, pp.1-11, 2012.
[14] P.-W. Tsai, C.-J. Liu and J.-F. Chang, Quantitative analysis of effect in trade agreements upon Taiwan stock market, *Proc. of the 5th International Conference on Engineering and Applied Sciences*, Hokkaido, Japan, 2015.
[15] P.-W. Tsai, J.-S. Pan, B.-Y. Liao and S.-C. Chu, Enhanced artificial bee colony optimization, *International Journal of Innovative Computing, Information and Control*, vol.5, no.12(B), pp.5081-5092, 2009.