Analysis of The Exchange Rate on The Thai Baht Against The Chinese Yuan Using A Support Vector Machine and Firefly Algorithm

การวิเคราะห์อัตราแลกเปลี่ยนระหว่างเงินบาทไทยกับเงินหยวนจีนด้วยแบบจำลองซัพพอร์ตเวกเตอร์แมชชีนและวิธีหิ่งห้อย

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ABSTRACT

This research constructed an optimal model to forecast the exchange rate of the Thai Baht against the Chinese Yuan by Support Vector Machine model and firefly algorithm. The software used for the construction was R program. The data used for modelling was secondary data collected from Bank of Thailand and the Ministry of Commerce, which consisted of *the exchange rate* of the Thai Baht against the Chinese Yuan, *policy interest rate* (per year), *the Thai Baht index*, *import value*, *export value* and *international reserve fund*. The collection of data was monthly records starting from January 2009 to June 2019, 126 data sets. The first 120 data sets were used for constructing the model and the last 6 data sets were used to verify the model. It was found that there were 3 factors which affected the exchange rate of the Thai baht against the Chinese yuan, with 5% statistical significance. The same direction factors were *policy interest rate* and *import value* and the opposite direction factor was *international money fund*. The optimal support vector machine model obtained was *eps-regression* type with *radial basis function* kernel, which had gamma parameter $\boldsymbol{\gamma = 0.43}$, epsilon parameter $\boldsymbol{\epsilon = 0.1}$ and cost value parameter $\boldsymbol{C = 17}$. The model verification showed that the obtained model provided the root mean square error 0.1518 only whereas the classical multiple linear regression model provided the root mean square error 0.2614.

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บทคัดย่อ

ในงานวิจัยนี้มีจุดประสงค์เพื่อสร้างตัวแบบที่มีความเหมาะสมในพยากรณ์อัตราแลกเปลี่ยนระหว่างสกุลเงินบาทไทยต่อสกุลเงินหยวนจีนด้วยแบบจำลองซัพพอร์ตเวกเตอร์แมชชีนและวิธีหิ่งห้อย โดยใช้โปรแกรม R ในการสร้างตัวแบบ สำหรับข้อมูลที่ใช้ในการศึกษาเป็นข้อมูลทุติยภูมิซึ่งเป็นการเก็บรวบรวมข้อมูลจากธนาคารแห่งประเทศไทยและกระทรวงพานิชย์ สำหรับตัวแปรที่ศึกษามีดังนี้ อัตราแลกเปลี่ยนระหว่างสกุลเงินบาทไทยต่อสกุลเงินหยวนจีน อัตราดอกเบี้ยนโยบาย (ร้อยละต่อปี) ดัชนีค่าเงินบาท การนำเข้าและการส่งออกไทย-จีน และเงินสำรองระหว่างประเทศ โดยทำการเก็บข้อมูลเป็นรายเดือนตั้งแต่เดือนมกราคม พ.ศ. 2550 จนถึงเดือนมิถุนายน พ.ศ. 2562 รวมทั้งสิ้น 126 ข้อมูล สำหรับข้อมูล 120 ข้อมูลแรกจะถูกใช้ในการสร้างตัวแบบและข้อมูล 6 ข้อมูลหลังถูกนำมาใช้ในการทดสอบความแม่นยำในการพยากรณ์

จากผลการศึกษาพบว่าปัจจัยที่ส่งผลต่ออัตราแลกเปลี่ยนระหว่างสกุลเงินบาทไทยกับสกุลเงินหยวนจีนอย่างมีนัยสำคัญทางสถิติที่ระดับนัยสำคัญ 0.05 มี 3 ปัจจัย โดยที่ปัจจัยที่ส่งผลในทิศทางเดียวกันได้แก่ อัตราดอกเบี้ยนโยบายและมูลค่าการนำเข้าไทยจีน สำหรับปัจจัยที่ส่งผลต่ออัตราแลกเปลี่ยนในทิศทางตรงกันข้าม ได้แก่ เงินสำรองระหว่างประเทศ สำหรับแบบจำลองที่ใช้ในการพยากรณ์อัตราแลกเปลี่ยนระหว่างสกุลเงินบาทไทยกับสกุลเงินหยวนจีนที่เหมาะสมคือ แบบจำลองซัพพอร์ทเวกเตอร์แมชชีนการถดถอย ที่มีฟังก์ชันเคอร์เนลเป็นฟังก์ชันเรเดียลเบสิส มีค่าพารามิเตอร์แกมมาเท่ากับ 0.43 ค่าพารามิเตอร์แอปไซลอนเท่ากับ 0.1 และค่าพารามิเตอร์ C เท่ากับ 17

จากการทดสอบความแม่นยำของผลพยากรณ์อัตราแลกเปลี่ยนสกุลเงินบาทไทยต่อสกุลเงินหยวนจีน ตั้งแต่เดือนมกราคม พ.ศ. 2562 จนถึงเดือนมิถุนายน พ.ศ. 2562 มีความคาดเคลื่อนรากกำลังสองเฉลี่ยเท่ากับ 0.1518 เมื่อเปรียบเทียบกับการพยากรณ์ค่าอัตราแลกเปลี่ยน โดยทั่วไปที่ใช้วิธีการถดถอยเชิงเส้นพหุคูณบนข้อมูลเดียวกันจะมีค่าความคาดเคลื่อนรากกำลังสองเฉลี่ยเท่ากับ 0.2614

Introduction

Nowadays Thailand has mixed economic system, which is also used in many countries. Government of Thailand uses this system to support in many Thai economic operations in a decreasing economic fluctuation situation. Whenever the government and the private sectors make the amount of international transactions, commerce, product exports, investments and international ministrations, they have to use international currency exchange rate to connect products and services. The international currency exchange rate affects on the currency to distinguish the same value. Global international commerce has many major currencies such as U.S. dollar, Euro, British Pound, Japanese Yen, etc. The U.S. crisis in 2008 and Europe public debt in 2010 affected the economic performance of the United States and Europe badly. In 2009, China promoted Yuan currency to be globaly accepted, called RMB internationalisation, and the next year China became a second largest economic country (Bank of Thailand, 2019). In 2015, The International Monetary Fund (IMF) announced the Chinese currency (Yuan) to be a part of Special Drawing Rights-SDRs (Prajaksitai, 2016). There are more value in international commerce between Thailand and China continuously has a good trend, so transections of Thailand involved the import-export commerce and the investment in china, are affected on the fluctuation of currency exchange rate between Thai currency (Baht) agains Chinese currency (Yuan) It causes a profit-loss return.

From the above mentioned, the factors which affect currency exchange rate of the Thai Baht against the Chinese Yuan are interesting. This research applied multiple linear regression model to analyze the significance of the factors observed. The optimized forecast model to predict currency exchange rate by the analyzed factors was constructed by Support Vector Machine (SVM) and firefly algorithm.

Related Mathematics Background

Multiple Linear Regression

Regression analysis is used to study relation between the dependent variables and the independent variables. This analysis depends on any characteristic of historical information to analyze factors that affect the dependent variables and this analysis can forecast some events because of some characteristic of historical information. Equations for multiple linear regression are as follows,

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \epsilon_i,$$

where Y_i is the dependent variable $(i = 1,2,3,\dots,n)$, n is a number of data, X_{ij} is the ith independent variable at j $(j = 1,2,3,\dots,k)$, k is the number of independent variables, $\beta_0, \beta_1, \cdots, \beta_k$ are parameters of the model and ϵ_i is a random error with index i.

Support Vector Machine-SVM

Support Vector Machine (SVM) model is a kind of self-studied machine which was invented by Vapnik, V. N., (Vapink, 1995). A mechanism of the model depends on statistical learning and it is able to forecast and classify data. Moreover, linear and nonlinear data can be used in SVM (Hamel, 1995; Sanguansut, 2019)

Suppose a training data $T = \{ (x_1, y_1), (x_2, y_2), \cdots, (x_n, y_n) \}$, where $x_i \in R^m, y_i \in R, i = 1,2,3,\dots,n$ and mathematical equation of SVM model is

$$f(x) = (w, x) + b,$$

where $f(x)$ is a predicted function, w is a weight function, b is a bias value and $b \in R$, $(\cdot,\cdot)$ is an inner product and x is an input data. The optimised weight parameter can be found as

$$\min \frac{1}{2} ||w||^2 + C \sum_{i=1}^{n} [\xi_i + \xi_i^*], \tag{1}$$

with constrains

1. $y_i - (w \cdot x_i) - b \le \epsilon + \xi_i;$
2. $(w \cdot x_i) + b - y_i \le \epsilon + \xi_i^*,$ where $\xi_i, \xi_i^*, C \ge 0, \forall i = 1,2,3,\dots,n;$

where ξ_i, ξ_i^* are slack variables and $(\cdot)$ is a scalar product and parameter C is penalty parameter. The dual problem of equation (1) is

$$\min_{\alpha,\alpha^*} \frac{1}{2} (\alpha_i^* - \alpha_i)(\alpha_j^* - \alpha_j)(x_i, x_j) + \epsilon \sum_{i=1}^{n} (\alpha_i^* - \alpha_i) - \sum_{i=1}^{n} y_i (\alpha_i^* - \alpha_i), \tag{2}$$

with constrains

1. $\sum_{i=1}^{n} (\alpha_i^* - \alpha_i) = 0;$
2. $\alpha_i, \alpha_i^* \in [0, C], \quad i = 1,2,3, \dots, n;$

where α_i, α_i^* are Lagrange multipliers. *C*-valued selection affects the SVM model. In the case that value of *C* has excess value, the construction of the model is hard to be fit even for the small error. That affected model is called an over-fitting problem. On the other hand, if value of *C* is not high enough, the model accepts more error and is not accurate. Thus, the optimal parameter *C* can provide the best implement.

Since the major of problems in forecasting occurs in nonlinear form, it is better to change a nonlinear data to a linear data by a kernel function. A kernel function is a function for solving the nonlinear data under Mercer's condition, that is an inner product space multiplication of all possibilities in vector set (Sanguansut, 2019):

$$K(x_i, x_j) = \left(\Phi(x_i), \Phi(x_j)\right), \tag{3}$$

where Φ is a nonlinear transformation function. The kernel function is used to forecast the exchange rate.

A kernel function used in this research is radial basis function which is popular to forecast the nonlinear data space. The equation is

$$K(x_i, x_j) = \exp\left[-\gamma \left|\left|x_i - x_j\right|\right|^2\right], \tag{4}$$

where $\gamma > 0$ is a parameter of the radial basis function, which is also called a gamma parameter value. A mathematical equation of SVM model is

$$f(x) = \sum_{i=1}^{n} (\alpha_i^* - \alpha_i) K(x, x_i) + b,$$

where $f(x)$ is function of prediction. α_i and α_i^* are Lagrange multiplier, $b \in R$ is bias value, $K(x, x_i)$ is kernel function and x is the vector of the input data. The initial value problem of a weight parameter is considered as the dual problem:

$$\min_{\alpha,\alpha^*} \frac{1}{2}(\alpha_i^* - \alpha_i)(\alpha_j^* - \alpha_j)K(x_i, x_j) + \epsilon \sum_{i=1}^{n} (\alpha_i^* - \alpha_i) - \sum_{i=1}^{n} y_i(\alpha_i^* - \alpha_i) \tag{5}$$

with constrains $\sum_{i=1}^{n}(\alpha_i^* - \alpha_i) = 0$ and $\alpha_i, \alpha_i^* \in [0, C], i = 1,2,3, \ldots, n$ are Lagrange multipliers.

Firefly Algorithm

Firefly Algorithm (FA) was first introduced by Xin-She Yang in 2007 (Yang, 2010). It is a nature-inspired metaheuristic algorithm which follows 3 rules as follows:

1. A firefly will be attracted to other fireflies regardless of their sex.
2. Attractiveness is proportional to their brightness which means that the firefly having less brightness will move towards the brighter one. If there is no brighter one than a particular firefly, the move is random. Moreover, more distance makes less brightness, which implies the attractiveness is less.
3. The brightness of firefly is determined by the landscape of the objective function, which is proportional to the value of the objective function.

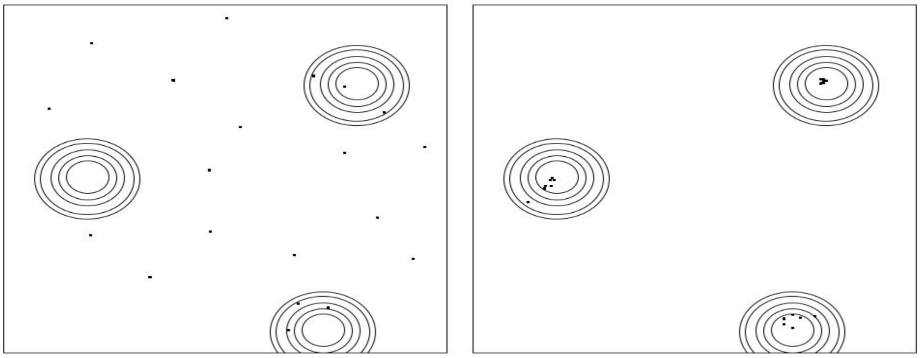

Figure 1 The primal locations of 20 fireflies (left) and their final inert locations after 30 iterations (right).

In this research, the brightness value represents the exchange rate, which is calculated by formula

$$\eta = \eta_0 e^{kr_{i,j}},$$

where

1. η_0 is the sum of initial assigned brightness (exchange rate) of these two fireflies.
2. $r_{i,j}$ is the distance between firefly x_i and x_j which $r_{i,j} = \left|\left|x_i - x_j\right|\right|$;
3. k is a parameter.

Instrument

We used R program version 3.6.3 operated in Microsoft Windows 10 for analysing the factors that affect currency exchange rate of the Thai Baht against the Chinese Yuan and find an optimal model to forecast currency exchange rate of these two currencies with SVM model and firefly algorithm.

Procedure

1. To study the factors that affect the exchange rate of the Thai Baht against the Chinese Yuan with multiple linear regression.

Some previous studies in the literature show that *the inflation rate*, *the interbank rate*, *the montly import-export value of goods*, *Thai business sentiment index*, *real effective exchange rate* and *manufacturing production index* are factors which affect the exchange rate (Avakiat & Prawatrungruang, 2016; Mungmaipol & Boonyanam, 2018). However, by the limitation of the open sources, this reseach considered 1) *policy interest rate* 2) *the Thai Baht index* 3) *import value* 4) *export value* and 5) *international reserve fund* only.

2. To construct the exchange rate model.

In this step, we use factors that significantly affect the exchange rate of the Thai Baht against the Chinese Yuan from multiple linear regression to construct a predicting model by the SVM model (Deng, Tian, & Zhang, 2013). Here, a firefly algorithm will be applied in the process of modelling to adjust the parameters of the predicting model.

3. To evaluate the obtained model.

Finally, the obtained model will be verified by comparing the forecasting result of the exchange rate of the two currencies between 2019 January and 2019 June with the result of the multiple linear regression model.

Results

1. The analysis of parameters' signification by R program found that *policy interest rate*, *import value* and *international reserve fund* were significant factors, with 5% statistical significance. Here, *policy interest rate* and *import value* were same direction factors of the exchange rate whereas *international reserve fund* was an opposite direction factor.

Table 1. The result of analyzing the factors of the exchange rate of the Thai Baht against the Chinese Yuan with multiple linear regression

Attribute	Coefficients	Std.Error	t-Stat
IV	0.102	0.008	12.004
PR	0.060	0.029	2.084
FER	-1.228	0.112	-10.923
Intercept	5.953	0.125	47.065

The coefficients appearing in Table 1 provide the multiple linear regression model as follows:

$$Exchange\ Rate = 5.953 + 0.102\mathbf{IV} + 0.060\mathbf{PR} - 1.228\mathbf{FER}.$$

Remark:
IV is *import value*, **PR** is *policy interest rate* and **FER** is *international reserve fund*.

2. The factors, i.e. import value, international reserve fund and policy interest rate, were appointed to build the model of the exchange rate of the Thai Baht against the Chinese Yuan with SVM model and firefly algorithm.

2.1. With the default value of parameters in R program, gamma parameter $\gamma = 0.33$, epsilon parameter $\epsilon = 0.1$ and cost value parameter C = 1, the result of the analysis showed that the appropriate SVM model was *eps-regression* type with *radial basis function* kernel.

2.2. By the suggestion model type, an *eps-regression* type with *radial basis function* kernel, then R program was applied to calculate and to find appropriate parameter ϵ, C and γ which made the model optimum. The constrains of parameters' range were, $\epsilon \in [0,1], -15 \leq \log_2 C \leq 15$ and $-5 \leq \log_2 \gamma \leq 5$. Note that the ranges of parameters followed (Chao & Horng, 2015) which were also used for the SVM classification using the firefly algorithm. The obtained parameters were $\epsilon = 0.1, C$ = 17 and $\gamma = 0.43$

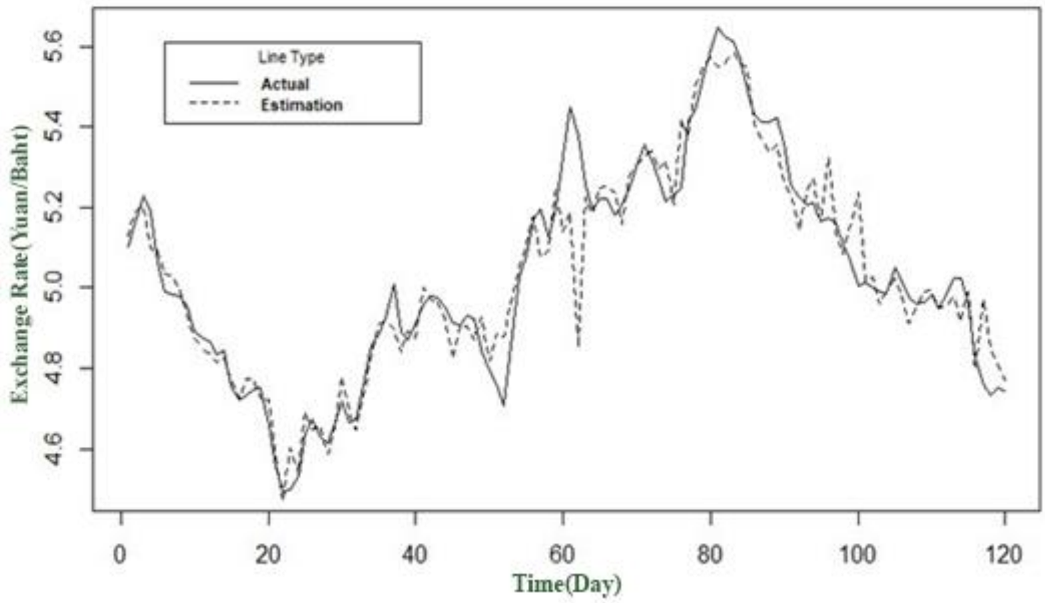

Figure 2 The value of exchange rate of the Thai Baht against the Chinese Yuanand the estimated value calculated by the SVM model with firefly algorithm.

3. The optimal model obtained was verified by the forecasting value of the exchange rate of the Thai Baht against the Chinese Yuan from January 2019 to June 2019. The results showedin Table 2., where the root mean square error is 0.1518.

Table 2. The predicted value of the exchange rate of the Thai Baht against the Chinese Yuan from January 2019 to Jun 2019

Month	Real Value	Predicted value (by the proposed method)	Predicted value (by the MLR method)
2019 Jan	4.6807	4.7627	5.1314
2019 Feb	4.6411	4.1111	4.5411
2019 Mar	4.7231	4.7397	4.7270
2019 Apr	4.7390	4.8095	4.9027
2019 May	4.6292	4.8093	4.9382
2019 Jun	4.5066	4.8116	4.7798
RMSE		**0.1518**	**0.2614**

Conclusion

This research constructed an optimal model to forecast the exchange rate of the Thai Baht against the Chinese Yuan by Support Vector Machine model and firefly algorithm. A part of the factors' analysis shows that there were 3 factors which affected the exchange rate of the Thai Baht against the Chinese Yuan, with 5% statistical significance. The same direction factors were *policy interest rate* and *import value* and the opposite direction factor was *international money fund*. The optimal model obtained was *eps-regression* type with *radial basis function* kernel, which had gamma parameter $\boldsymbol{\gamma = 0.43}$, epsilon parameter $\boldsymbol{\epsilon = 0.1}$ and cost value parameter $\boldsymbol{C = 17}$. The verification by using data of the exchange rate of the two currencies from January 2019 until June 2019 showed that our model provided the root mean square error 0.1518 only whereas the classical multiple linear regression model provided the root mean square error 0.2614 (see the predicted value in Table 2).

Therefore, we claim that the model using the Support Vector Machine model and firefly algorithm has more accuracy in the exchange rate prediction than the multiple linear regression model has.

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