Forecasting ASEAN countries exchange rates using auto regression model based on triangular fuzzy number

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ABSTRACT

Exchange rate forecasting is important to represent the expectation of exchange rates future values. The forecasting task is due to the economic factor and the historical data used to forecast are exposed to uncertainty and observational error during data collection. The existing auto regression model only deals with uncertainty exist in the model, not in the data preparation. Uncertainties may contained in the data input and should be treated during data preparation which is an early stage of forecasting process. To date, only few researches discuss intensely on a fuzzy data preparation. However, data treatment during data preparation is important to reduce model's error due to uncertainty problem. Hence, this paper presents an approach to construct Triangular Fuzzy Number to handle uncertainty in data during data preparation. As the Triangular Fuzzy Number is often used to represent uncertain information in a form of interval, this study proposed a procedure to construct Triangular Fuzzy Number from single point data. In this study, the Triangular Fuzzy Number is built in a form of symmetric triangular with 1%, 3% and 5% spread value. Autoregressive model is then used to forecast the exchange rate of Association of South East Asian Nation (ASEAN) countries. The result in this study shows that the forecasting exchange rate is significantly important to trace the movement of ASEAN countries exchange rates and beneficial in forecasting planning.

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1. INTRODUCTION

Exchange rate is the price of a nation's currency in terms of another currency. The exchange rates play a vital role in facilitating international trade of goods and service and comparison price between countries [1]. Exchange rate forecasting is important to evaluate the benefits and risk in international business environment involving the foreign denominated cash flows in international transaction. Indeed, an expectation of exchange rate future values can be represented by the forecasting approach though it is widely agreed that forecasting exchange rates is definitely a difficult task [2]. Auto regression model is one of a common approach used to forecast the exchange rates since the model can produce reliable solution [2]-[4].

Forecasting task based on auto regression model is depending on the historical data. However, the historical data used for forecasting are exposed to uncertainty and observational error. Currently, existing model did not explain specific data preparation procedure which handled uncertainty contained in the data which are used for forecasting. Uncertainty in the collected data may come from measurement error such as human or machine error, observational error, environmental error, and random errors [4]. Even though fuzzy theory is introduced in the auto regression model, it deals only with uncertainty exists in the model; not in the data preparation which is the early steps of forecasting process. Thus, in this study, a practical phase in handling uncertainty during data preparation for forecasting is presented.

In this paper, the main contribution is to develop a symmetric fuzzy number for auto regression model to forecast exchange rates based on time series dataset of Association of South East Asian Nation (ASEAN) countries. The performance of proposed approach is evaluated with the auto regression model which uses single point data. The result from this study may have significance impact in forecasting planning and decision making while considering errors reduction during data preparation due to uncertain information. Additionally, the forecaster could trace the movement of ASEAN countries exchange rates in particular.

The remainder of this paper is organized as follows. Section 2 describes related works of this study. Section 3 explains the auto regression forecasting with fuzzy data preparation. Section 4 explains the implementation with real dataset. Section 5 draws the conclusions.

2. OVERVIEW OF RELATED WORKS

This section discusses about the related work to this research which are exchange rates, data collection and measurement error, and fuzzy auto regressive model.

2.1. Data Collection and Measurement Error

Data collection is the first step in forecasting process. Relevant data must be available and correct in order to have a reliable forecasting value. Observing, interviewing and questionnaire are several common techniques used in data collection. Certainly, assembling an appropriate data from different sources are often challenging and time-consuming task [5]. Data preparation is the second step which transforms the data according a format to fit the researcher needs. Data preparation is a crucial task and should be accomplished first to prevent mistakes. By organizing the data correctly also can save a lot of time during the step of analysis.

However, it is a common situation where the process in data collection and preparation is exposed to uncertainty and measurement error. Uncertainty may come from expert differences or due to systematic differences within the dataset [5], [6]. Random error and systematic error are included in the measurement error which can affect all measurement [6]. Thus, to overcome the problem in data preparation, triangular fuzzy number (TFN) was introduced and applied in different applications [7]-[11]. The implementations of triangular fuzzy number in these researches show that the fuzzy number is more realistic in describing the physical world than single-valued number.

2.2. Exchange Rates

Any currencies of the actual exchange rate are determined by the buying and selling of foreign currencies on world currency markets [12]. The price of a currency is fixed by the forces of demand and supply. In the exchange rate forecasting literature, a study to construct the forecasting model for exchange rates using robust linear autoregressive and neural network [4]. A robust regression approach was developed to overcome the limitation of regression model in predicting the exchange rate returns. An approach to forecast exchange rates was proposed providing the real-time exchange rates forecast at any forecast horizon [2]. An auto regression model also been proposed to predict the ASEAN exchange rates where it can produce a reliable prediction [3]. Other research on ASEAN exchange rate was developed to examine the exchange rate behaviour [13]. These findings lead to a perception that forecasting exchange rate is necessary in international transaction to analyse the benefits and risks attached in the foreign cash flow.

2.3. Auto Regressive Model

Auto regression model (AR model) is a method in statistical time series to forecast the values of variables based on the previous value of the same variable [14]. The basic formulation of auto regression model is as follows:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \epsilon_t \qquad (1)$$

where β_0 is constant, β_1 is coefficient, ϵ_t is error and y_{t-1} is previous values from the same time series. In practice, auto regression model is a common method use in forecasting and widely applied in different area. It was applied in forecasting the BDT/USD exchange rate in the context or performance measure [15]. Other application of auto regression is in the analysis of pre earthquake to predict the ionospheric anomalies [14]. Various applications of auto regression model show that this method can successfully forecast any values from statistical time series as long as input data are available [14]-[18].

3. RESEARCH METHOD

In this section, the auto regression forecasting with TFN is explained. The procedure to construct the TFN is included as shown in Figure 1 to reduce the forecasting error in data preparation phase.

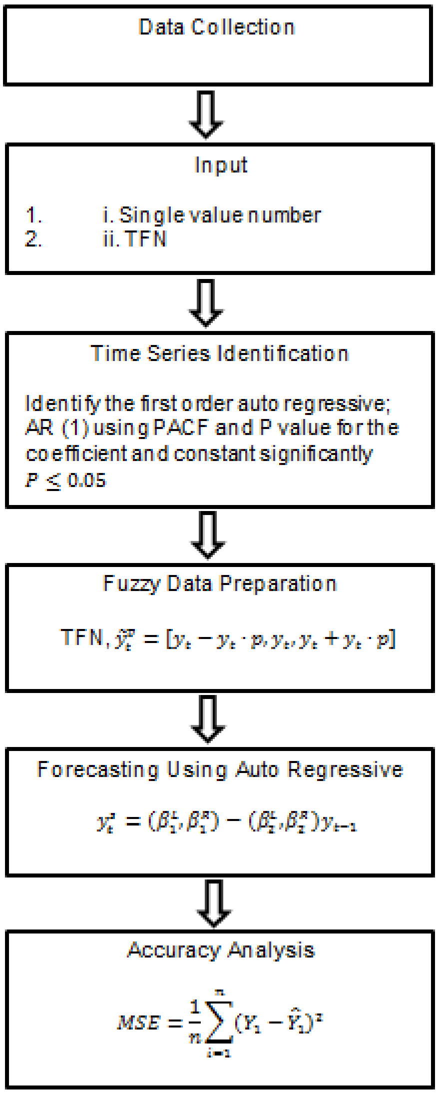

Figure 1. Phases in proposed model

Phase 1: Data collection

The time series data of exchange rates are collected. The types of exchange rates or currency for ASEAN countries are determined.

Phase 2: Time series identification

The estimate parameters for auto regression are tested using statistical software. This study uses the first order auto regressive process; AR (1). The AR (1) process the outcome variable at some point in time t is related only to time periods that are one period apart which mean $t-1$. Partial Autocorrelation Functions (PACF) can be used to identify the AR (1). If there is a significant spike at a lag of 1 and much lower spikes for the subsequent lags, then an AR (1) model would likely be feasible for the dataset. Besides that, the parameters of coefficient, constant and P value are also estimated to identify the AR (1) model. The P value for the coefficient and constant should significantly less than 0.05 for the AR (1) model.

Phase 3: Fuzzy data preparation

To build the TFN, the spread is adjusted from 5%, 3% and 1%. We concern only spread 5% or below is the best spread to be used [19], [20]. The procedures are detailed as follows:

a) Determine the spread, p of TFN using measurement error of 1%, 3% and 5%.
Let p is spread of TFN.
$p = [1\%, 3\%, 5\%]$.

TFN, $\tilde{y}_t^p = [y_t - y_t \cdot p, y_t, y_t + y_t \cdot p]$

where
p = spread in the form of symmetry left right, $y_t 0.01, y_t 0.03\ y_t 0.05$.
y_t = observation value of a time series at period of $t, t = 1,2 \dots \dots T$

b) Build Triangular Fuzzy Number y_t based on (i).
Triangular Fuzzy Number as shown in Figure 2.

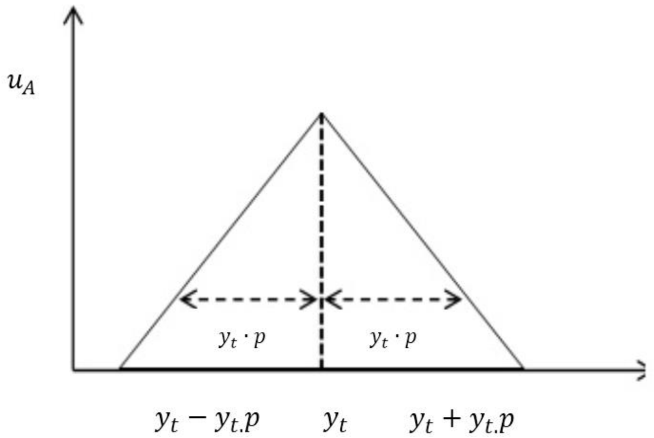

Figure 2. Triangular fuzzy number, $\tilde{y}_t^p = [y_t - y_t \cdot p, y_t, y_t + y_t \cdot p]$

c) Find average from predicted values, $\bar{\tilde{y}}_t^s$.
Phase 4: Forecasting using autoregressive.
The AR can be solve using Ordinary Least Square (OLS) method
d) Forecast original data (single point) and find AR (1) model based on (2)

$$y_t = \beta_1 - \beta_2 y_{t-1} \tag{2}$$

e) Forecast fuzzy data with spread, p and find AR (1) model based on (3)

$$y_t^s = (\beta_1^L, \beta_1^R) - (\beta_2^L, \beta_2^R) y_{t-1} \tag{3}$$

(3) is the AR model with TFN which is built based on confidence interval approach.
Phase 5: Accuracy analysis
The final step is to evaluate the performance between the AR (1) models based on single point (crisp) data and fuzzy data using Mean Square Error (MSE). The formulation to evaluate the forecasting accuracy using MSE is shown in equation as follows:

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (Y_1 - \hat{Y}_1)^2 \tag{4}$$

where
y_1 = actual observation value based on day one, $t = 1$
$\hat{Y}_1$ = predicted observation value based on day on

4. NUMERICAL EXAMPLE

The proposed algorithm to build the fuzzy auto regression model was applied to ASEAN countries exchange rate datasets. The ASEAN exchange rate series considered in this study are Malaysian Ringgit (MYR), Brunei Dollar (BND), Indonesian Rupiah (IDR), Singapore Dollar (SGD), Thailand Baht (THB), Philippine Peso (PHP), Cambodian Riel (KHR), Myanmar Kyat (MMK), Laos Kip (LAK) and Vietnamese Dong (VND). All are denominated in US Dollar (USD) as the USD is well known largest ASEAN trading partners.

Phase 1: Data collection

All ten ASEAN countries exchange rates dataset are been observed and collected [21]. The observations running from 1st January 2018 until 30th April 2018 based on daily observation except weekend due to the closing market. Each series consist of 86 observations considering the price in the exchange rate market. Sample of datasets is shown in Table 1.

Table1. Sample Exchange Rate Dataset

BND	Date	Price
1	Jan 01, 2018	1.336
2	Jan 02, 2018	1.3355
3	Jan 03, 2018	1.3337
4	Jan 04, 2018	1.3355
5	Jan 05, 2018	1.3355
……….	……….	……….
85	Apr 27, 2018	1.3148
86	Apr 30, 2018	1.3381

Table 1 show the Brunei Dollar exchange rate based on 1 US Dollar. In this study, the dataset is divided into two sections of training and testing. The training data is 80% from the observation dataset while testing is 20%.

Phase 2: Time series model identification

Based on Table 1, the dataset is tested using the Partial Auto Correlation Functions (PACF). The PACF is important in time series modelling to identify the order of an auto regressive mode and determine the appropriate lags by plotting the PACF. In this explanation, Malaysian Ringgit (MYR) and Brunei Dollar (BND) are two sample exchange rate series used to explain the identification of time series model.

Figure 3 shows the PACF plot for Malaysian Ringgit and Figure 4 shows PACF plot for Brunei Dollar. Based on these figures, the PACF lag are cut off from lag 1 and the other lag are down sharply. From this PACF result, the possible model that can be made is AR (1). To be more precise, the parameters of coefficient, constant and *P* value are estimated to define the AR (1) model. Figure 5 and Figure 6 show the sample of final estimate parameters.

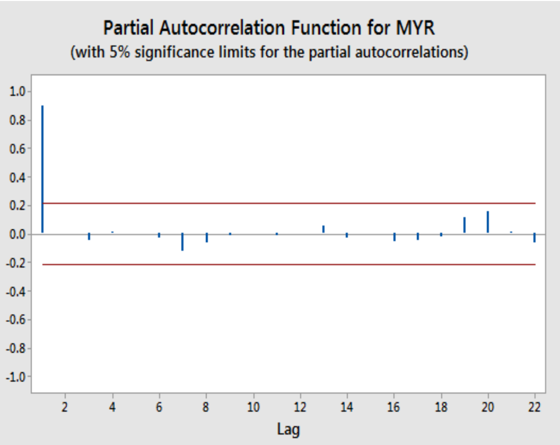

Figure 3. MYR PACF Plot

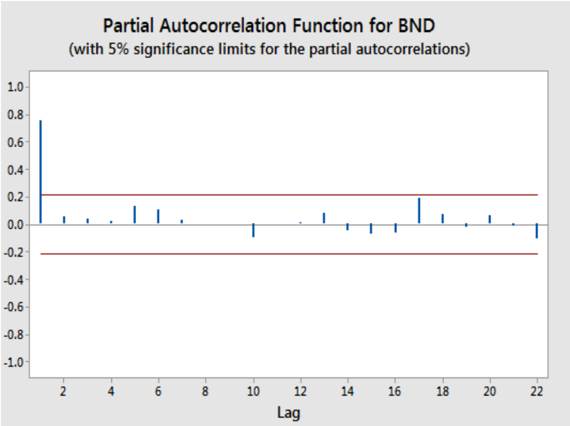

Figure 4. BND PACF Plot

Final Estimates of Parameters					
Type		Coef	SE Coef	T	P
AR	1	0.9994	0.0272	36.70	0.000

Figure 5. Parameters for MYR

Type		Coef	SE Coef	T	P
AR	1	0.8390	0.0664	12.63	0.000
Constant		0.213455	0.000435	491.17	0.000

Figure 6. Parameters for BND

Based on Figure 5, it shows that the constant for MYR exchange rate is 0.002303 and coefficient is 0.9994. However, P values of constant are not significant to $P < 0.05$. Therefore, the model AR (1) of MYR is not suitable to be used. Meanwhile, Figure 6 shows the constant for BND exchange rate is 0.213455 and coefficient is 0.8390. The P values of coefficient and constant are significant to $P < 0.05$. Therefore, the model AR (1) of BND is suitable to be used. From the estimate parameters, AR (1) model is shown in (5) as follows:

$$BND_t = 0.213455 + 0.8390BND_{t-1} \quad (5)$$

Phase 3: Fuzzy data preparation

Confidence interval of 95% is used to generate the spread, p to build the TFN. Particularly, the spread is identified as 1%, 3% and 5%. The possibilities of TFN for the BND dataset are shown in Table 2.

Table 2. The Possibilities of TFN

sample	actual	y_t0.01		y_t0.03		y_t0.05	
		Left	Right	Left	Right	Left	Right
1	1.336	1.32264	1.34936	1.29592	1.37608	1.2692	1.4028
2	1.3355	1.322145	1.348855	1.295435	1.375565	1.268725	1.402275
3	1.3337	1.320363	1.347037	1.293689	1.373711	1.267015	1.400385
4	1.3355	1.322145	1.348855	1.295435	1.375565	1.268725	1.402275
5	1.3355	1.322145	1.348855	1.295435	1.375565	1.268725	1.402275
...	...	...	...	...	...	...	...
85	1.3148	1.301652	1.327948	1.275356	1.354244	1.24906	1.38054
86	1.3381	1.324719	1.351481	1.297957	1.378243	1.271195	1.405005

From Table 2, it shows the value from the symmetry left right spread based on 1%, 3% and 5%. By using these TFN, the possibilities of AR (1) models for BND dataset are presented in Table 3 respectively.

Phase 4: Forecasting using autoregressive

Table 3 shows the observation value of Brunei Dollar (BND) time series at period of t. The values are based on the spread of 1%, 3% and 5% and are presented as $TFN_{0.01}$, $TFN_{0.03}$and $TFN_{0.05}$. In contrast than the actual value, the constant for possible AR (1) model based TFN is considering the value from left and right spread. For example, $TFN_{0.01}$ has the constant value 0.21132 for left spread and 0.21571 for the right spread. The whole processes from step 1 until step 3 are repeated for other exchange rate series.

Table 3. AR (1) Models

TFN	Possibilities of AR(1) model
Actual value (non-fuzzy)	$BND_t = 0.213455 + 0.8390BND_{t-1}$
$TFN_{0.01}$	$BND_t = (0.21132, 0.21571) + 0.8390BND_{t-1}$
$TFN_{0.03}$	$BND_t = (0.205433, 0.219959) + 0.8390BND_{t-1}$
$TFN_{0.05}$	$BND_t = (0.131035, 0.147845) + 0.8390BND_{t-1}$

Phase 5: Accuracy analysis

The final step is to calculate the forecasting accuracy to analyse its performance by using Mean Squared Error (MSE). MSE is a method to evaluate a forecasting technique by squared the error, then summed and divided by the number of observation [5]. The MSE values which closer to zero are better and would be the one that have higher accuracy. In the first stage of data collection, ten ASEAN countries exchange rate series are examined. The results had shown that, only eight exchange rates series meet the requirement of AR (1) model. There are Brunei Dollar, Singapore Dollar, Thailand Baht, Philippine Peso, Cambodian Riel, Myanmar Kyat, Laos Kip and Vietnamese Dong. The MSE results are tabulated in Table 4.

Table 4. MSE Result

TFN	BND		SGD		THB		PHP	
	Training	Testing	Training	Testing	Training	Testing	Training	Testing
y_t	0.041	0.0771	0.0498	0.0685	0.2619	0.333	0.3314	0.4099
5%	0.0408	0.0761	0.0498	0.0689	0.2619	0.333	0.3315	0.403
3%	0.0408	0.0755	0.0497	0.0689	0.2619	0.333	0.3315	0.4026
1%	0.0411	0.077	0.0497	0.0688	0.2619	0.3339	0.3315	0.4026

TFN	KHR		MMK		LAK		VND	
	Training	Testing	Training	Testing	Training	Testing	Training	Testing
y_t	2.2218	2.3658	1.3266	2.5487	2.1383	2.8869	1.8559	4.423
5%	2.2218	2.3658	1.2281	2.553	2.1383	2.8869	1.8559	4.423
3%	2.2219	2.3654	1.1895	2.2159	2.1383	2.8869	1.8559	4.4235
1%	2.2218	2.3658	1.1902	2.2212	2.1383	2.8869	1.8559	4.4235

Table 4 shows the MSE comparison between the proposed model with conventional AR (1) model. All the series of dataset are divided into training and testing. For Brunei Dollar, value of $TFN_{0.03}$ and $TFN_{0.05}$ have smaller MSE value from actual data. For Singapore Dollar, value from training $TFN_{0.01}$ and $TFN_{0.03}$has smaller MSE value from actual data. The testing value of Philippine Peso has smaller MSE value than actual data. While Myanmar Kyat has smaller MSE value from actual data in training, there are testing $TFN_{0.01}$ and $TFN_{0.03}$. As for Thailand Baht, Cambodian Riel, Laos Kip and Vietnamese Dong, they have similarity value with actual data for training and testing. Apparently, we may see that the MSE result of the TFN is quite near to the actual series. Certain training and testing can get smaller error rather than conventional model which mean it has higher accuracy. Thus, from this table, it shows that the proposed model may perform well to forecast the exchange rate time series.

5. CONCLUSIONS

In this study, the forecasting model for ASEAN countries exchange rates is developed using auto regression by incorporating Triangular Fuzzy Number (TFN) while preparing the data for forecasting. As to reducing error during forecasting, data preparation should be accomplished by transforming the data according a format to fit the research need. Commonly, in real application, data collection and data preparation may expose to fuzzy and random uncertainties. In this study, TFN was introduced to overcome the uncertainty in data preparation. The construction of TFN is important to present the uncertain information in a form of interval. The TFN is built from single point data with 1%, 3 % and 5% spread value. Based on the implementation of TFN, it is expected that the proposed procedure is not only able to achieve similar result as existing AR model but also can handle uncertainty issue.

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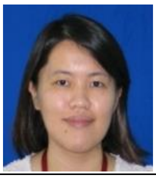	Chai Wen, Chuah is a senior lecturer at Faculty Computer Science and Information Technology, University Tun Hussein Onn Malaysia. Her qualification as below: Bsc(University Tun Hussein Onn), MSc(University Science Malaysia), PhD(Queensland University of Technology). Her research areas are Cryptography, Cryptology, Key Derivation Functions, Stream Ciphers.