International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Bayesian Model Averaging in Exchange Rate of Malaysia Ringgit to China Yuan Renminbi

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Abstract: The depreciation of Malaysia Ringgit (MYR) value since 2013 until 2016 have brought many negative impacts on Malaysia's economy such as the depreciation of export value and the appreciation of import value. Such impacts are getting more severe when the exchange rate of MYR to the currency of Malaysia's biggest trading partner, China Yuan Renminbi (CNY) is increasing. The study is conducted to explain the movement in the exchange rate of Malaysia Ringgit to China Yuan Renminbi (MYR/CNY). The four macroeconomic factors used to build the estimation models for the exchange rate of MYR/CNY in this study are relative current account balance, relative trade openness, relative sovereign debt, crude oil price. The estimation models are built using two different methods, Bayesian Model Averaging (BMA) and Multiple Linear Regression (MLR). The comparison of the results from the two models in the context of model accuracy shows that BMA model has better performance capability than MLR model in estimating the exchange rate of MYR/CNY.

Keywords: Exchange rate; estimation; MYR/CNY; BMA; MLR.

I. INTRODUCTION

Exchange rate of currency is the value of a currency compared to the currency of another country. The exchange rate of most currencies fluctuated from time to time and are affected by various factors such as political and economic factors.

Malaysia's export value has increased by 8.2% because of the regional economic cooperation with ASEAN countries [1]. This causes exchange rate of currency to play a more important role as currencies of different countries are used in the transaction for international trading. Volatility of exchange rate of currency has negative impact towards the export activity of a country [2]. According to Malaysia External Trade Statistics 2018, Malaysia's biggest trading partner in 2018 is China with a total trade of RM313.81 billion or 16.7% of the total trade of Malaysia in 2018.

Revised Manuscript Received on December 30, 2019.
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If the exchange rate of MYR/CNY is unstable, then the trading value will also be unstable, and this may affect the income of Malaysia. The great fluctuation of the exchange rate has negative impacts towards the international trade which in turn will affect the economy of a country [3].

This study is conducted with two objectives: (i) to construct the estimation model for the exchange rate of Malaysia Ringgit to the currency of Malaysia's biggest trading partner in 2018 using Bayesian Model Averaging (BMA) method and multiple linear regression method (MLR) and (ii) to compare the performance of BMA model and MLR model from the context of model accuracy.

II. DATA

China was Malaysia's biggest trading partner in 2018 therefore the exchange rate of MYR/CNY is the dependent variable in this study. There are four macroeconomic factors used as independent variables as these four variable are proven significant to the exchange rate of MYR/CNY [4]. The equation used to compute each independent variable is shown in Table 1.

Table 1: Formula for computation for data of macroeconomic factors

Macroeconomic Factors	Formula
Relative current account balance (BATR)	$\frac{\text{Current account balance of Malaysia (\% of GDP)}}{\text{Current account balance of China (\% of GDP)}}$
Relative trade openness (KPR)	$\frac{\text{Total trade of Malaysia (\% of GDP)}}{\text{Total trade of China (\% of GDP)}}$
Relative sovereign debt (HKAR)	$\frac{\text{External Debt of Malaysia (\% of GDP)}}{\text{External Debt of China (\% of GDP)}}$
Crude oil price (HMM)	Crude oil price index

Data obtained were from the first quarter of 2009 until the third quarter of 2018, with the sample size of 39. The sources of data are the websites of International Monetary Fund (IMF), CEIC Data, XE.com and Malaysia External Trade Statistics 2018. Data cleaning and Z-transformation are carried out to add relevancy to the sample data.

A. Multicollinearity

Prior to the construction of regression models, the multicollinearity test is conducted to detect the existence of multicollinearity between the independent variables. Multicollinearity may cause the correlated independent variables to appear as insignificant variables and therefore affect the accuracy of the regression models. There are two methods to detect the existence of multicollinearity: (i) correlation matrix and (ii) variance inflation factor (*VIF*).

Pearson correlation test is conducted to build the correlation matrix. The correlation matrix contains correlation coefficient for each pair of variables. Equation (1) is used to calculate the Pearson correlation coefficient.

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - \sum(x^2)][N\sum y^2 - \sum(y^2)]}} \quad (1)$$

Where, r = Pearson correlation coefficient, N = number of data, x = value of a variable and y = value of another variable. Generally, multicollinearity is considered as severe when one of the correlation coefficient is greater than 0.9.

The variance inflation factor, VIF_j for each independent variable, x_j is calculated using the equation below:

$$VIF_j = \frac{1}{1-R_j^2} \quad (2)$$

where R_j^2 is the multiple determination coefficient for the regression model which relate x_j to other independent variables. Multicollinearity is said to be severe if (i) the largest VIF_j is greater than 10 or (ii) the mean VIF is substantially greater than 1.

B. Regression Models

In this study, regression analysis explains the changes to the exchange rate of MYR/CNY when one of the independent variables changes while others remain constant. The changes are explained through the regression parameter β. If the β of an independent variable is positive, then the value of exchange rate of MYR/CNY will increase (or decrease) when the value of that particular independent variable increases (decreases).

Regression analysis will be used in this study to build two different models named Bayesian Model Averaging model (BMA model) and multiple linear regression models (MLR model). There are some differences between these two models. First, MLR model is a single model while BMA model is a composite model, which is made up from the combination of few single models with different weightage. The second difference is MLR model only considers the significant independent variables while BMA model considers all the independent variables in different combination for each single model.

$$\text{Residual ratio at time } t = \frac{\text{BMA model residual at time } t}{\text{MLR model residual at time } t} \quad (6)$$

i. Multiple Linear Regression Model (MLR Model)

The regression equation for MLR model is as below:

$$y_t = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \beta_3 x_{3t} + \beta_4 x_{4t} + \varepsilon_t \quad (3)$$

$$\text{Overall perfomance of BMA model} = \frac{\text{Number of (residual ratio} < 1)}{39} \quad (7)$$

where y_t = standard value of exchange rate of MYR/CNY, x_{1t} = standard value of relative current balance account, x_{2t} = standard value of relative trade openness, x_{4t} = standard value of crude oil price and ε_t = error.

ii. Bayesian Model Averaging Model (BMA Model)

There are four macroeconomic factors used as the independent variables for the construction of estimation model for the exchange rate of MYR/CNY, and therefore the number of potential models is 2^4=16. The estimation results from all these models will be collected with respective weightage. The weightage of each single model in the BMA model is represented by their posterior probability that is driven by the performance of that particular model. The equation for BMA model is as below:

$$E(e_t|I) = y_t = \sum_{i=1}^{n} E(e_{t,i}|M_i, I)\, p(M_i|I) \quad (4)$$

where $E(e_t|M_i, I)$ = estimation value of exchange rate of MYR/CNY at time = t by M_i model using equation shown in (5), $p(M_i|I)$ = posterior probability of M_i model, I = data set, i = model index $1, 2, \ldots, n$.

$$E(e_{t,i}|M_i, I) = y_{t,i} = \beta_0 + \beta_{1,i}x_{1t} + \beta_{2,i}x_{2t} + \beta_{3,i}x_{3t} + \beta_{4,i}x_{4t} + \varepsilon_t \quad (5)$$

where $y_{t,i}$ = standard value of exchange rate of MYR/CNY by M_i model, x_{1t} = standard value of relative current balance account, x_{2t} = standard value of relative trade openness, x_{4t} = standard value of crude oil price and ε_t = error.

C. Validation Test

Validation test is required to check the efficiency of the models. Validation test is carried out using two different methods, (i) R^2 and adjusted R^2 and (ii) residual analysis.

R^2 is the proportion of total variance in n real values of dependent variable which can be explained by the overall regression model. Adjusted R^2 avoid the overestimation of the values of the independent variables in the regression model [5].

Residual regression is carried out to examine whether the MLR model and BMA model conform to the regression assumptions. The assumptions must be obeyed to verify the efficiency of the regression models. If the regression assumptions are obeyed, then the residual of the model is normally distributed and independent, with the mean of residual $\mu = 0$ and constant variance, σ^2. Shapiro-Wilk test is ran to check the normality of the residual. Residual plot is used to check the remaining regression assumptions.

D. Comparison between MLR Model and BMA Model

The estimation results from BMA model and MLR model are compared in the context of model accuracy using residual ratio. If the residual ratio is less than one, then the estimation value from model BMA is more accurate than model MLR. The residual ratio is as follow:

The overall performance of BMA model is evaluated using equation (7). If the ratio is greater than 0.5, it means that the overall performance of BMA is better than model MLR in the context of model accuracy.

III. RESULTS AND DISCUSSION

A. Existence of Multicollinearity

Pearson correlation matrix in Table 1 explains the relationship between the variables.

Table 2 shows the variance inflation factors (*VIF*) for each independent variable.

Table 2. Pearson correlation matrix

	BATR	KPR	HKAR	HMM	KP
BATR	1	0.12	0.08	0.15	-0.12
KPR	0.12	1	-0.41	-0.76	0.77
HKAR	0.08	-0.41	1	0.58	-0.59
HMM	0.15	-0.76	0.58	1	-0.72
KP	-0.12	0.77	-0.59	-0.72	1

The Pearson correlation matrix in Table 2 shows that all the correlation coefficient is less than 0.9, meaning that the multicollinearity between the independent variables is not severe.

Table 3. Variance inflation factors (*VIF*) for each independent variable

Independent variables	R_j^2	VIF_j
Intercept	-	-
BATR	0.15	1.18
KPR	0.63	2.71
HKAR	0.34	1.52
HMM	0.70	3.39
	Mean *VIF*	2.20

Refe

rring to Table 3, the highest *VIF* is 3.39 (less than 10) and the mean of *VIF* is 2.20 (not substantially greater than 1), thus it can be concluded that the multicollinearity between the independent variables is not severe.

B. MLR and BMA models

Table 4 shows the results of regression analysis for model MLR.

Table 4. Results of regression analysis for model MLR

Independent Variables	Regression Parameter	*p* value
Intercept	0.0000	1.0000
BATR	-0.1637	0.1100
KPR	0.6348	0.0002
HAKR	-0.2826	0.0178
HMM	-0.0536	0.7532

Referring to Table 4, the two significant independent variables are relative trade openness (KPR) and relative sovereign debt (HAKR). Thus, model MLR that is built using equation 3 is shown in equation 8. The estimations of exchange rate of MYR/CNY using MLR model are obtained using this equation:

$$y_t = 0.6348x_{2t} - 0.2826x_{3t} + \varepsilon_t \qquad (8)$$

In this study, BMA model is constructed based on the best five single models with different weightage and combination of independent variables. Table 5 shows the results of regression analysis for model BMA.

Table 5. Results of regression analysis for model BMA

Independent Variables	Mean	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	0	0	0	0	0	0
BATR	0.0874	-0.1746	.	.	-0.1637	.
KPR	0.643	0.6702	0.6382	0.5477	0.6348	0.523
HAKR	0.2863	-0.2986	-0.3251	-0.2757	-0.2826	.
HMM	0.0286	.	.	-0.1501	-0.05356	-0.3274
Posterior probability		0.4	0.374	0.096	0.068	0.032

Model BMA is constructed using equation 8 and 9. Model BMA is as below:

$$E(e_t|I) = \frac{0.4000E(e_{t,1}|M_1,I) + 0.3740E(e_{t,2}|M_2,I) + 0.0960E(e_{t,3}|M_3,I) + 0.0680E(e_{t,4}|M_4,I) + 0.0320E(e_{t,5}|M_5,I)}{0.9670} \qquad (9)$$

where

$$E(e_t|M_1,I) = y_t = -0.1746x_{1t} + 0.6702x_{2t} - 0.2986x_{3t} + \varepsilon_t \qquad (10)$$

$$E(e_t|M_2,I) = y_t = 0.6382x_{2t} - 0.3251x_{3t} + \varepsilon_t \qquad (11)$$

$$E(e_t|M_3,I) = y_t = 0.5477x_{2t} - 0.2757x_{3t} - 0.1501x_{4t} + \varepsilon_t \qquad (12)$$

$$E(e_t|M_4,I) = y_t = -0.1637x_{1t} + 0.6348x_{2t} - 0.2826x_{3t} - 0.0536x_{4t} + \varepsilon_t \qquad (13)$$

$$E(e_t|M_5,I) = y_t = 0.5230x_{2t} - 0.3274x_{4t} + \varepsilon_t \qquad (14)$$

C. Validation Test

Table 6 shows the R^2 and adjusted R^2 for both MLR model and BMA model.

Table 6. R^2 dan R^2 terlaras bagi model MLR dan model BMA

Model	Sub-model	R^2	Adjusted R^2
MLR	-	0.7128	0.6790
BMA	(Model 1)	0.7120	-
	(Model 2)	0.6830	-
	(Model 3)	0.6900	-
	(Model 4)	0.7130	-
	(Model 5)	0.6400	-

Referring to Table 6, the independent variables in MLR model are able to explain 71.28% of the variance in the real value of the exchange rate of MYR/CNY. The independent variables in model BMA are able to explain between 64.00% to 71.30% of the variance in the real value of the exchange rate of MYR/CNY. Results of BMA model indicate that variable in a single model increases, the R^2 of the single model will increase.

Table 7 shows the results from Shapiro-Wilk test which tests the normality of the model's residual. The hypothesis of Shapiro-Wilk test is as follow:

H_0: Model residual is normally distributed

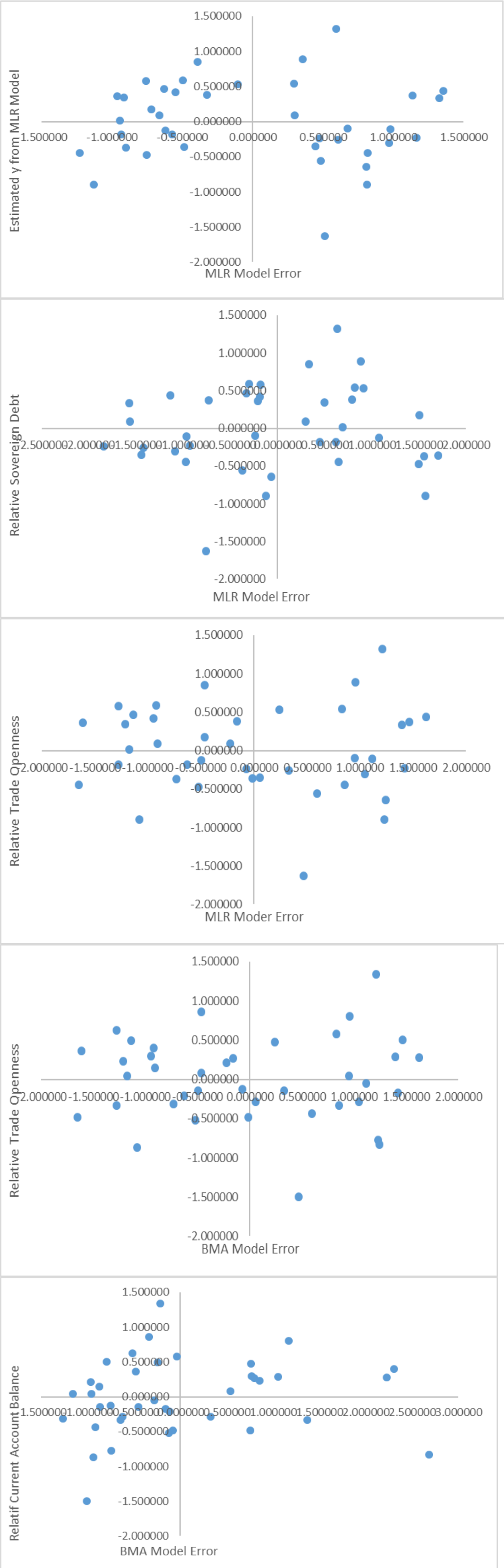
H_1: Model residual is not normally distributed

Table 7. Results of Shapiro-Wilk test

Model	Coefficient *W*	Degree of freedom	*p* value
MLR	0.977	39	0.5957
BMA	0.9873	39	0.9317

Referring to Table 7, H_0 is not rejected at the confidence level of 5% for both MLR and BMA model. This indicates that the residual of both models are normally distributed. Both MLR and BMA models obey the normality assumption.

Figure 1 shows the residual plot which is used to examine the other regression assumptions. Residual plot is used to check the independence of the residual, the constant variation and the mean of residual $\mu = 0$.



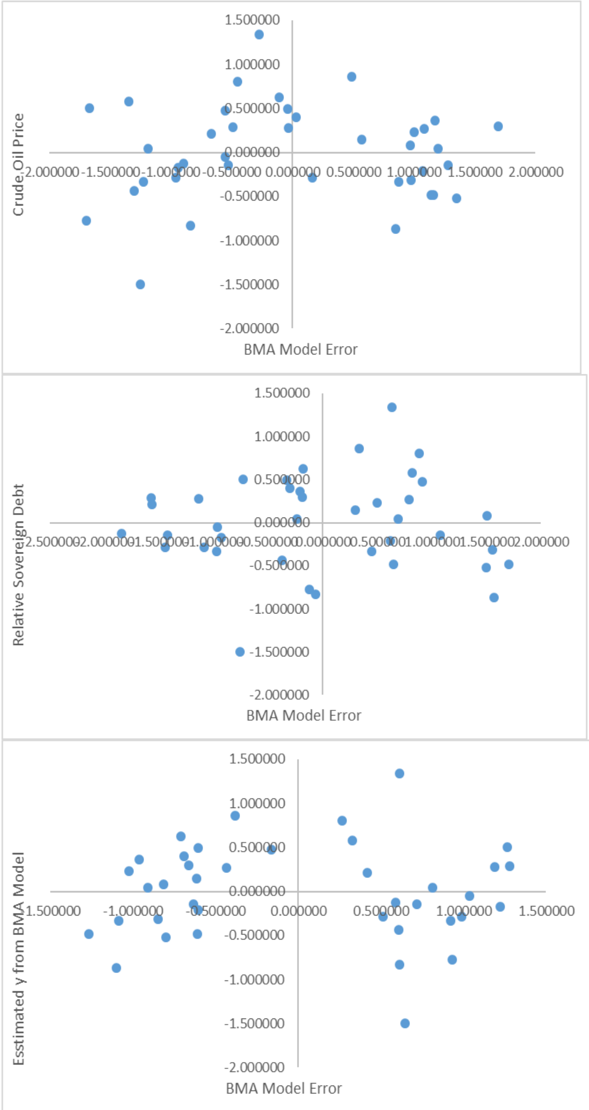


Fig. 1. Residual plot

Referring to Figure 1, the dotted line which is almost static at $y = 0$ indicates that the mean of the residual is zero, except for the residual plot of BMA model versus relative current balance account. This means that MLR model obeys the assumption of mean residual $\mu = 0$ however BMA model does not obey this assumption perfectly. The scattered patterns of all the residual plots indicate the independence of residual for both MLR and BMA models. However, the variances for both models are not constant, contrarily they are actually increasing. Therefore, it can be concluded that both MLR and BMA model in this study is less efficient to estimate the exchange rate of MYR/CNY.

D. Comparison between MLR Model and BMA Model

Overall, the estimation result from BMA model is better than MLR model in 22 estimations from the total of 39 estimations. In the other words, BMA model gives more accurate estimation value of 56.41% at a time. Thus, it can be concluded that the performance of BMA model is superior to MLR model in the context of model accuracy. This outcome is the same as [6] who found that BMA model has better performance than Bayesian Model Winner (BMW) model, which is a single model.

IV. CONCLUSIONS

MLR model is a single model that is built using only two significant independent variables, relative trade openness and relative sovereign debt. BMA model is a composite model made up of five single models that consider all the independent variables in different combination and different weightage. Since both MLR model and BMA model do not pass the validation test ideally, hence both models are considered less efficient to estimate the exchange rate of MYR/CNY. Overall, findings of this study indicates that BMA model gives superior performance than MLR model.

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