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Evaluation of Long Memory on the Malaysia Exchange Rate Market

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Abstract

This research evaluates the presence of long memory or long-term dependence on the Malaysian exchange rate. Daily, weekly and monthly data are evaluated against the US dollar (USD) covering from January 2005 to March 2018. Evaluation of long memory is based on the Geweke and Porter-Hudak estimation and the Maximum Likelihood Estimation. The result suggests the presence of long memory on all the daily, weekly and monthly data. Results show that shock on the Malaysian exchange rate persist longer than expected. The forecast capability also concludes that addition of the long memory presence from ARIMA model to ARFIMA model could improve the model forecast.

Keywords: Maximum likelihood; Geweke and porter hudak estimation; ARIMA; ARFIMA.

1. Introduction

Exchange rate has always been a keen interest for economist for both its direct and indirect implication toward the country's economy. Analysis by the Bank Negara Malaysia in 2015 shows how the depreciation of the exchange rate affect the inflation rate substantially over the year 1997 to 1998 caused by the 1997 Asian Financial Crisis. The crisis leads Malaysia to peg their currency to 3.80 MYR per US Dollar before reverting it back into free-float regime in July 2005. The Malaysia decision to revert the exchange rate regime from fixed regime to the free-floating regime after it recovered from the 1997 Asian Financial Crisis has open it currency market for speculations and forecasting. Rege and Martín (2011) express that the first step in building a proper model is upon knowing whether the time series exhibit long, short or no memory hold at all. Long memory is defined as the capability of the shock in the time series to be retained longer than commonly expected. Fractional integration which allow the differencing parameter to take on non-integer value is able to capture the long memory presence in a time series if long-range dependence exist.

Previous studies as observed by HummelAl-Shboul and Anwar (2016) discovers a gap on multi-country studies where less focus on the actual state and financial affair of individual countries deterred the research to be more profound. This study aims to evaluate the presence of long memory that focus on the Malaysian exchange rate. Forecasting of the exchange rates are done using two models ARIMA and ARFIMA to evaluate and compare the performance between the models that incorporate long memory against the conventional model. The scope of the research are the daily, weekly and monthly exchange rate from January 2005 to March 2018 against the US Dollar.

2. Literature Review

Long memory is not a new concept in statistics as the study on the phenomena are first introduced back in the 1950s in the field of hydrology. Hurst wrote articles pertaining to long memory of the Nile River's water levelin year1951 . Unfortunately, only around the 1980s that econometricians start to adopt the long memory theory into the financial field (Baillie, 1996). Long memory behaviour on the exchange rates do have it basis as studies by several researches had proven the presence of long memory in their study. Researchersfor example (Cheung, 1993) observes long memory in Deutsche Mark, Swiss Franc, Japanese Yen and French Franc using the Geweke and Porter-Hudak (GPH) estimator. Cheng (2001) evaluates the exchange rate of 6 Asia-Pacific countries, and the weekly exchange rate of 30 less developed countries. He discovers 8 out of 30 of the countries show the presence of long memory.

Among the researchers that study the long memory on the Malaysian exchange rate include Soofi *et al.* (2006) and Floros (2008). However, both studies involve comparison between countries which would have weaknesses as

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the countries' financial affairs might not be thoroughly considered. On both of these researches, the observations were done from the year 1998 to 2005 which during the period, Malaysia had pegged it currency to RM3.80 per 1 USD. Having included the observation through the pegged period raise a question on the validity of the results from the long memory test conducted as it is unknown what effect of those flat rate would do to the model. Recent studies on long memory topic would include less countries in a single study or focus on a single financial market like the research by Erer *et al.* (2016) which covers only the Turkey Financial Market but with a broader scope, covering the exchange rate and the stock market to see if long memory exist and the fractional integration of both market in Turkey.

Previous study on the ARFIMA forecast capability include Kamil *et al.* (2014) who compares the out of forecast ability of ARFIMA, modified ARFIMA and a random walk model using Root Mean Square Error (RMSE) and on testing fifteen (15) exchange rate, they prove that for some cases, ARFIMA is a better predicting model than the random walk model. Latest study by Jibrin *et al.* (2017) concludes that ARIMA is relatively a better model than ARFIMA for at least three out of four countries exchange rate that they have tested including Malaysia based on the Akaike Information Criterion (AIC).

3. Methodology

The daily, weekly and monthly data of the Malaysia exchange rate are taken from the PACIFIC Exchange Rate Service that cover the period from January 2005 until March 2018. The evaluation of the long memory fractional parameter involves the period up until December 2017 while the rest of the period is set up to evaluate the forecast performance of the models. The research evaluates the presence of long memory using one parametric approach: Maximum Likelihood (ML) Estimator and one semi-parametric approach: the Geweke& Porter-Hudak (GPH) Estimator. The forecast model chosen is between ARIMA and ARFIMA model as ARIMA model would validate if long memory could improve the model.

Geweke and Porter Hudak are two researchers in 1983 that produce an article proposing their own semi-parametric method of testing the long memory. The method revolves on evaluating the spectral density function around the zero frequency. The low frequency ordinates around the zero frequency thus be estimate with a simple least square regression

$$\ln\left[I\left(\omega_j\right)\right] = \alpha + \beta \ln\left[4\sin^2\frac{\omega_j}{2}\right] + \upsilon_j \qquad (1)$$

Where:

$$\upsilon_j = \ln\left[\frac{I(\omega_j)}{f(\omega_j)}\right], \text{ the error term.}$$

$$\alpha = \ln\left[\frac{\sigma^2 f_u(0)}{2\pi}\right], \text{ the constant parameter.}$$

The GPH's differencing parameter, $\hat{d}_{GPH}$ is denotes by $-\beta$ in the above equation. The estimate $\hat{d}_{GPH}$value that are larger than 0 shows that long memory is presence. The first difference of the time series is usually used in the estimation method to ensure stationary and reversibility of the model.

Maximum Likelihood (ML) is a parametric estimation method that, given a time-series observation, estimate and choose the parameters that maximize the likelihood of producing the same observations. The model that is being considered is the ARFIMA (*p*,*d*,*q*) which is a generalize version of the ARIMA model where the only difference is the differencing parameter, *d* which is allowed to take on a non-integer values. This 'fractional' differencing process is said to contain long memory process in the time series. The other two parts of the ARFIMA model are the Autoregressive AR(*p*) and the Moving Average Ma(*q*). Autoregressive model links the value of the dependent variable as a function of the lagged values plus the error term while the Moving Average model define the current values as the mean value plus the error term of the current and previous values. The best parameters for the model are selected based on the Akaike Information Criterion (AIC) for ARFIMA model.

Through the ML estimation method, the order of the parameter *p* and *q* in the ARFIMA (*p*,*d*,*q*) is considered to be an integer value between 0 and 3. There are 16 combinations of ARFIMA model being considered and each model is evaluated in term of their AIC value. The AIC will measure the quality of the model relative to other models and the lowest AIC is chosen as the best model. The fractional differencing parameter, *d* for both estimationsare compared to see if they would come to the same conclusion. Table 1 describes the possible *d* value and its interpretations on the exchange rate data. For long memory to be proven exist, the *d* value must be in the range between 0 and 0.5.

Table-1. Interpretations of the *d* value

***d* value**	**Interpretations**
$-0.5 < d < 0$	The series has intermediate memory since autocorrelation is always negative
$d = 0$	Short memory and the series is stationary
$0 < d < 0.5$	Long memory, the series is stationary and mean-reverting
$0.5 \leq d < 1$	Non-stationary long memory and mean-reverting
$d \geq 1$	The series is not stationary and not mean-reverting

4. Results

The unit root test is performed on all three data sets through Augmented Dickey Fuller Test to ensure stationarity. The same test is done on the first difference of the three data sets when the time series is not stationary. The null hypothesis of the presence of the unit root are able to be rejected on the first difference data at 5% significance level. Table 2 shows that the time series data are not stationary until a first difference is performed.

Table-2. Unit root test for the original time series

	ADF Test	Lag Value	p-value	ADT Test on First Difference	Lag Value	p-value
Daily	-1.5139	14	0.7842	-13.798	14	<0.01
Weekly	-2.6782	7	0.2907	-6.2657	7	<0.01
Monthly	-2.0519	5	0.5547	-3.4948	5	0.04523

The first difference data of the exchange rate is interchangeably known as the rate of return of the exchange rate. Since GPH test and Maximum Likelihood estimation of the fractional difference parameter are done on the first difference where the stationarity is achieved, the evaluation of the long memory on the first difference is said also to be the evaluation of the long memory on the rate of return of the exchange rate.

The result seen of Table 3 shows that for GPH, the fractional difference, d lies between $0 < d < 0.5$ which prove the time series to be affected by long memory, stationary and mean-reverting. The result from Maximum Likelihood estimation on Table 4 seems to be in line with the GPH estimation. The value on Table 5 for each three data sets are based on the lowest AIC value. Noted that even it is the lowest AIC value, the difference between the lowest and the second lowest for example for the daily data differ only by less than 0.002%. Since AIC taking account the likelihood versus the penalty on additional term of the p and q and as we see the difference are extremely small, it is arguable to say which model exceed another in significant way.

Table-3. GPH estimation and Maximum Likelihood estimation (ARFIMA)

Data	GPH d	ARFIMA(p,d,q)	Phi	D	theta	AIC
Daily	0.07368	(0,d,0)	-	**0.0499204**	-	**-34928.51**
Weekly	0.02184	(0,d,0)	-	**0.0337867**	-	**-3325.704**
Monthly	0.35018	(0,d,1)	-	**0.0393545**	**-0.372995**	**-1237.822**

The performance of the long memory forecast model is evaluated against the similar model minus the long-range dependence assumption. In this case, we take the ARIMA model because ARFIMA basically ARIMA model added with long memory theory into it. The same step on Maximum Likelihood estimation is applied in search of the best ARIMA model. As seen in Table 4, only for daily data the AR(p) and MA(q) order is similar to the ARFIMA model while weekly and monthly ARIMA model chose a slightly different order as their best according to the AIC values.

Interpreting the ARIMA and ARFIMA model, it could be said that the order (0,d,0) implies a random walk process which is the general theory that exchange rate best follow the random walk model. The order (0,d,1) is said to be a basic exponential smoothing model with growth.

Table-4. Maximum Likelihood estimation (ARIMA)

Data	ARIMA(p,d,q)	AIC
Daily	(0,1,0)	-17665.93
Weekly	(0,1,1)	-2904.51
Monthly	(1,1,0)	-432.16

We compare the predictive capability for both ARIMA and ARFIMA model to see if adding long memory into consideration would yield a better result. For daily observations we forecast for 21 steps ahead in proportion to 21 daily exchange rate observation in January 2018, for weekly we forecast for 13 step proportion to the weekly observation from January 2018 to March 2018 while monthly forecast is taken up to 3 steps meaning 3 months of observation starting from January 2018.

The evaluation of the forecast capability between ARIMA and ARFIMA shows that ARFIMA models improve the forecast capability when dealing with daily and weekly data while ARIMA model perform better in forecasting the monthly rate. The result implies that long memory process could better explain the exchange rate model than the model that assumes short memory process. Theseresults encouragefutureresearches to incorporate the long memory effect on other predicting models as compare to ARFIMA and ARIMA.

Table-5. Mean Squared Error on Forecast Data

Data	ARIMA MSE	ARFIMA MSE
Daily	0.010443	0.009644
Weekly	0.020273	0.014462
Monthly	0.012544	0.015495

5. Conclusions

The results indicate that the Malaysian exchange rate or can be said as the rate of return on the Malaysian exchange rate against the US Dollar are affected by the long memory effect. Although concluding to that, based on the best selected model, the study still could not eliminate the function of the random walk theory in the exchange rate model. The study hopes that by proving that shocks to the Malaysian exchange rate last longer hinting that there is a bit of inefficiency on the market would aid the financial sector to better forecast by incorporating the long memory into their calculations. Further study on modelling and forecasting on the exchange rate is needed as other model are also capable of incorporating the same long memory effect to their existing model and from there we can comparethe results.

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