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INTERRUPTED TIME SERIES MODELLING OF DAILY MALAYSIAN RINGITT MYR / LIBERIAN DOLLAR LRD EXCHANGE RATES

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ABSTRACT
This work is about proposing an intervention model for the exchange rates of Malaysian Ringitt MYR and the Liberian Dollar LRD. The intervention point was observed to be November 8, 2019. A pre-intervention ARIMA model of order (0, 1, 7), $\nabla X_t + 0.3397\varepsilon_{t-7} = \varepsilon_t$ was fitted and forecasts were obtained for the post-intervention data on the basis of it. The difference between the forecast and the original post-intervention data was modeled for the transfer function. The resultant model was observed to adequately represent the data.
Keywords: MYR, LRD, Arima modeling, Intervention modelling

INTRODUCTION
The Malaysian Ringitt MYR is the currency of Malaysia. It has the symbol RM denoting it. It is divided into 100 sen. Banknotes include RM100, RM20, RM5, RM 50, RM10 and RM1. The coins include 20 sen, 50 sen, 5 sen and 10 sen (Wikipedia, 2020). There is published research work on seasonal autoregressive integrated moving average (SARIMA) modeling of daily exchange rates of MYR and the Nigerian naira (NGN) (Etuk, 2014). The Liberian Dollar LRD has been the currency of Liberia since 1943. It is made up of 100 cents (c). It is denoted by the symbol $. The banknotes are $5, $10, $20, $50, $100 and $500. The coins are 5c, 10c, 25c, 50c and $1 (Wikipedia, 2020). Wai (1987) has compared the LRD system with that of Panama balboa (PAB). Any trade relationship between Malaysia and Liberia is based on the exchange rates of MYR and LRD.

Interest here is in developing an intervention model for the Malaysian Ringitt (MYR) / Liberian Dollar (LRD) exchange rates. The Malaysian Ringitt is a stronger currency than the Liberian dollar as evident from the time plot of figure 1 before November 8, 2019. However, when the Liberian government embarked upon an intervention, the trend was reversed in favour of the LRD. The Liberian President George Weah said this on 27 January 2020 as he presents his annual speech to the third session of the fifty-fourth national legislature of the republic of Liberia.

"The domestic macroeconomic environment was difficult in 2019. It was characterized by low economic growth of less than 1 percent, annual inflation of more than 20 percent and depreciation of the Liberian dollar by more than 20 percent. However, in the last quarter of the year under review, inflationary pressure was contained, reflecting some modest appreciation of the Liberian dollar. End-of-period inflation was projected to fall from Thirty point six percent (30.6%) in May 2019 to Twenty five point Eight percent (25.8%). Madam Vice President, Mr Speaker, Mr President Pro-Tempore and Honourable Members of the 54th Legislature Liberian-dollar inflation has undermined the income of the poor and the income of those earning in Liberian dollars. Inflation reduction therefore remains a significant goal of Government planning. ... Consequently, the Liberian dollar has persistently weakened in recent years, stabilizing only briefly during November and December 2019, due largely to a scarcity of Liberian dollars in the banking system and weak business activity." (Weah, 2020).

The approach of intervention modeling adopted here is that proposed by Box and Tiao (1975). This approach has been successfully and widely applied to model intervention situations. For instance, Etuk and Udoudo (2018) analyzed the daily exchange rates of Indian rupee and the Nigerian Naira and proposed an intervention model for the data. This approach to intervention was applied to model the intervention by legislation on reported cases of crimes reporting (Sridharan *et al.*, 2010).

MATERIALS AND METHODS

Data

The data for this work are daily exchange rates of MYR and LRD from 1st September 2019 to 31st December 2019 from the website: https://freecurrencyrates.com/en/exchange-rate-history/MYR-LRD/2019. They are to be read as "the amount of LRD per MYR". They are given in the appendix. The data item for 30th November 2019 was missing. An estimate of the missing value by linear interpolation given by the mean of the 29th November 2019 and the 1st December 2019 values is used to replace the missing value.

Interrupted Time Series Analysis

Let $X_1, X_2, \ldots, X_n$ be a set of time series. If the series is not stationary, let $\nabla^k(X_t)$ be the k^{th} difference of the series $\{X_t\}$ that is stationary assuming that for $m = 0, 1, 2, \ldots, k-1$, $\nabla^m(X_t)$ is not stationary. Then the series $\{X_t\}$ is said to follow an autoregressive integrated moving average model of order (p, d, q), denoted by ARIMA(p, d, q), if

$$\nabla^d(X_t) - \alpha_1\nabla^d(X_{t-1}) - \alpha_2\nabla^d(X_{t-2}) - \ldots - \alpha_p\nabla^d(X_{t-p}) = \varepsilon_t + \beta_1\varepsilon_{t-1} + \beta_2\varepsilon_{t-2} + \ldots + \beta_q\varepsilon_{t-q} \qquad (1)$$

where $\{\varepsilon_t\}$ is a white noise process and the α's and the β's are constants chosen such that model (1) is both stationary and invertible.

Model (1) may be written as

$$A(L)\nabla^d(X_t) = B(L)\varepsilon_t \qquad (2)$$

where $A(L) = 1 - \alpha_1L - \alpha_2L^2 - \ldots - \alpha_pL^p$ and $B(L) = 1 + \beta_1L + \beta_2L^2 + \ldots + \beta_qL^q$ and $L^k\nabla^d(X_t) = \nabla^d(X_{t-k})$ and $L^k\varepsilon_t = \varepsilon_{t-k}$.

Let there be an abrupt change in the mean level of the series at time $t = T$ we say that there is an intervention at that point if there does not seem to be a return to the former level after some time.

Suppose that an ARIMA(p, d, q) has been fitted to the pre-intervention part of the series. It means that the pre-intervention part of the serie can be written in the form (2). Let the post-intervention forecasts be $F(t)$, $t > T$. Let $Z(t) = X_t - F(t)$, $t > T$. Then the transfer function for the intervention for the intervention might be modeled as

$$Z(t) = \frac{c_1(1 - c_2^{(t-T+1)})}{(1-c_2)} \tag{3}$$

where c_1 and c_2 are constants. The intervention model is then given by

$$Int(X_t) = I_t\,F(t) + Z(t) \tag{4}$$

where $I_t = 1$ if $t > T$ and zero otherwise.

Computer Software

Eview 10 was used in all computational work in this research. It is based on the maximum likelihood approach to estimation of parameters.

RESULTS AND DISCUSSION

The time plot of Figure 1 is such that the exchange rates rise slowly unitl November 8, 2019, after which there is an abrupt decline which was never reversed. This is an intervention pattern with November 8, 2019 as the point of intervention. The pre-intervention time plot in Figure 2 shows a positive trend from the beginning to the intervention point.

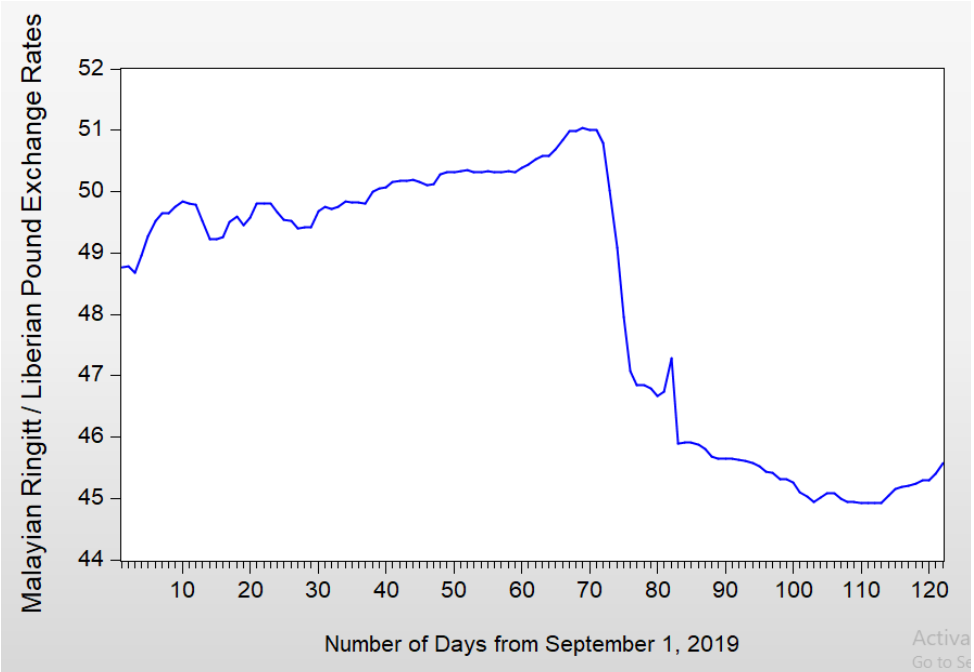


Figure 1: Time Plot of daily exchange rates of MYR and LRD

The Augmented Dickey Fuller unit root test of Table 1 shows that the pre-intervention series is not stationary. This calls for a differencing of the series which has been done. The time plot of the difference of the pre-intervention data shows a horizontal trend which is an indication of stationarity. The figure 4 correlogram of the difference shows two significant spikes on the partial autocorrelation function and two significant spikes on the autocorrelation function at lags 1 and 7, the lag 7 value being bordered by comparative spikes giving an indication of a seasonal component.

Table 2 summarizes the estimation of the ARIMA model over the original series. By the table the model fitted is the ARIMA(0, 1, 7) model

$$\nabla X_t + 0.3397\varepsilon_{t-7} = \varepsilon_t \qquad (5)$$

This means that the noise part of the intervention model is

$$F(t) = (1 - 0.3397L^7)\varepsilon_t/(1-L) \qquad (6)$$

This ARIMA model is used to obtain forecasts F(t) of the pre-intervention model. Then $Z(t) = X_t - F(t)$, $t > T$. The transfer function constants c_1 and c_2 have been estimated in Table 3 as $c_1 = -0.6034$ and $c_2 = 0.8989$. Therefore the transfer function of the intervention model is from (3)

$$Z(t) = (-0.6034)(1 - 0.8989^{t-69})/0.1011 \qquad (7)$$

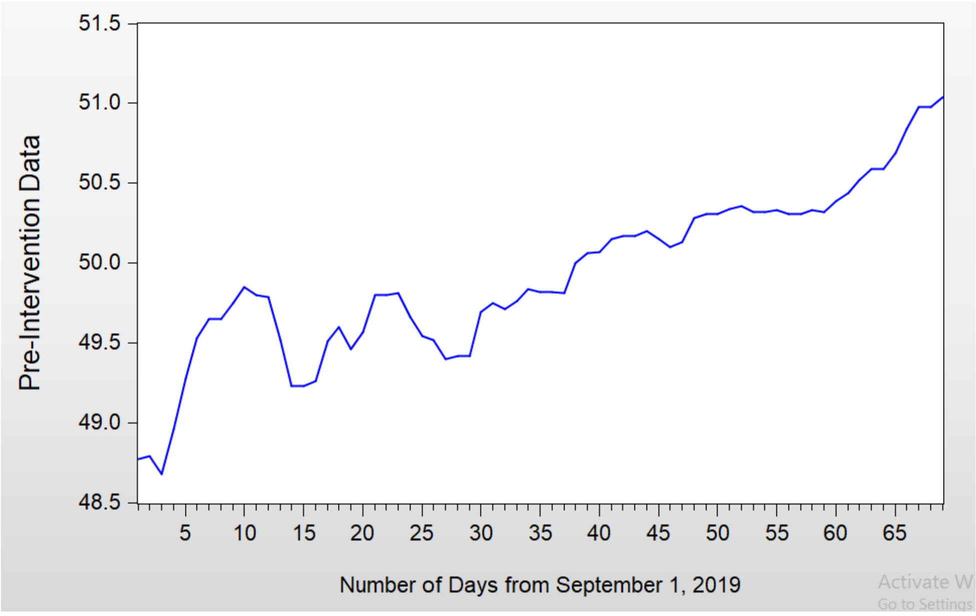


Figure 2: Time plot of the pre-intervention series

Table 1: Unit Root Test of pre-intervention series

Null Hypothesis: The pre-intervention series has a unit root

		t-Statistic	Probabilty
Augmented Dickey Fuller test statistic		-1.447695	0.5538
Test critical values	1% level	-3.531592	
	5% level	-2.905519	
	10% level	-2.590252	

The intervention model is given by

$Int(X_t) = F(t) + Z(t)$

When superimposed on the plot of X_t the plot of $Int(X_t)$ is comparable to it (See Figure 5). Therefore the intervention model is from (6) and (7)

$$Int(X_t) = (1\text{-}0.3397L^7)\varepsilon_t/(1 - L) - 0.6034(1\text{-}0.8989^{t-69})/0.1011 \quad (8)$$

for $t > T = 69$.

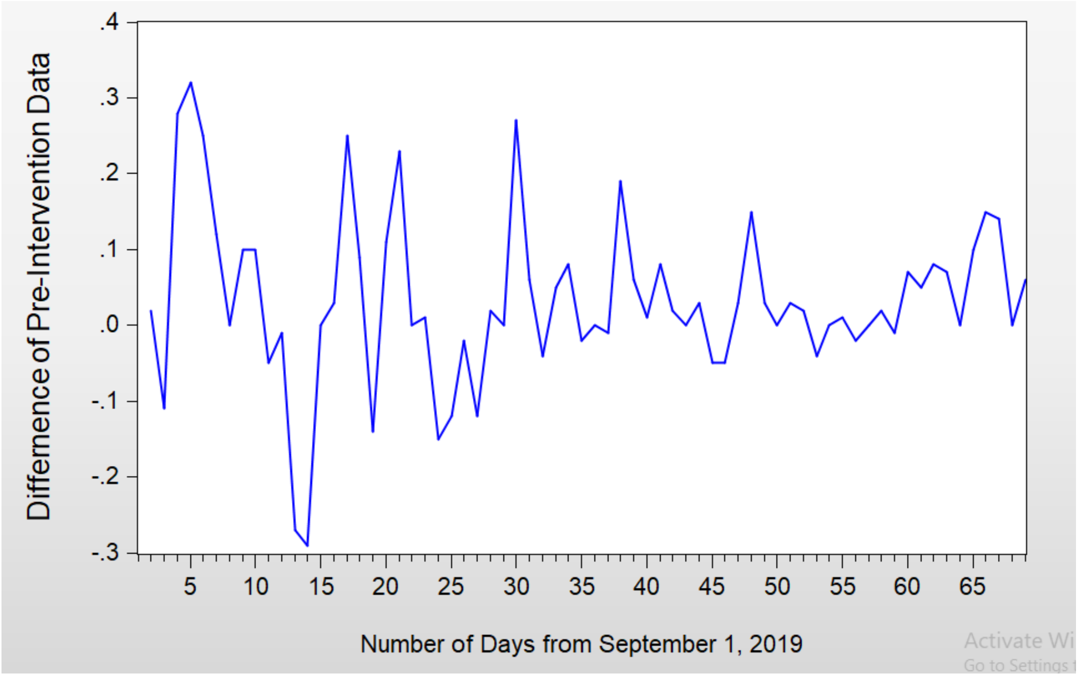
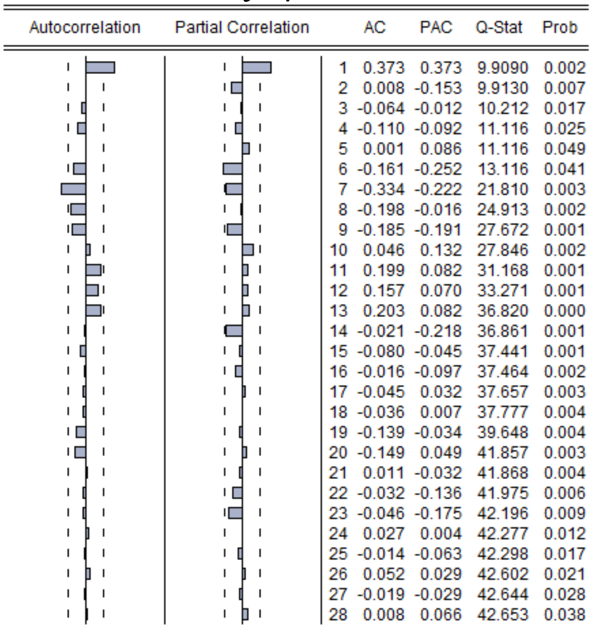


Figure 3: Time plot of the difference of pre-intervention series

CONCLUSION

Therefore model (8) is an adequate representation of the intervention. Planners from Malaysia shall do well to take advantage of it to redress the imbalance engendered in the situation.



	AC	PAC	Q-Stat	Prob
1	0.373	0.373	9.9090	0.002
2	0.008	-0.153	9.9130	0.007
3	-0.064	-0.012	10.212	0.017
4	-0.110	-0.092	11.116	0.025
5	0.001	0.086	11.116	0.049
6	-0.161	-0.252	13.116	0.041
7	-0.334	-0.222	21.810	0.003
8	-0.198	-0.016	24.913	0.002
9	-0.185	-0.191	27.672	0.001
10	0.046	0.132	27.846	0.002
11	0.199	0.082	31.168	0.001
12	0.157	0.070	33.271	0.001
13	0.203	0.082	36.820	0.000
14	-0.021	-0.218	36.861	0.001
15	-0.080	-0.045	37.441	0.001
16	-0.016	-0.097	37.464	0.002
17	-0.045	0.032	37.657	0.003
18	-0.036	0.007	37.777	0.004
19	-0.139	-0.034	39.648	0.004
20	-0.149	0.049	41.857	0.003
21	0.011	-0.032	41.868	0.004
22	-0.032	-0.136	41.975	0.006
23	-0.046	-0.175	42.196	0.009
24	0.027	0.004	42.277	0.012
25	-0.014	-0.063	42.298	0.017
26	0.052	0.029	42.602	0.021
27	-0.019	-0.029	42.644	0.028
28	0.008	0.066	42.653	0.038

Figure 4: Correlogram of the difference of pre-intervention series

Table 2: Estimation of the ARIMA model of the pre-intervention series
Dependent Variable: Difference of the pre-intervention series
Method: ARMA maximum likelihood

Variable	Coefficient	Std. Error	t-Statistic	probability

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AR(1)	0.079824	0.256785	0.310851	0.7569
AR(5)	0.014525	0.179222	0.081047	0.9357
MA(1)	0.437929	0.247423	1.769964	0.0817
MA(7)	- 0.339654	0. 155083	-2.199142	0.0323
MA(8)	-0.072071	0.150237	-0.479714	0.5331

Table 3: Estimation on the intervention transfer function
Dependent Variable: Z

	Coefficient	Std, Error	t-Statistic	probability
C(1)	-0.603362	0.030628	-19.69988	0.0000
C(2)	0.898879	0.006130	146.6463	0.0000

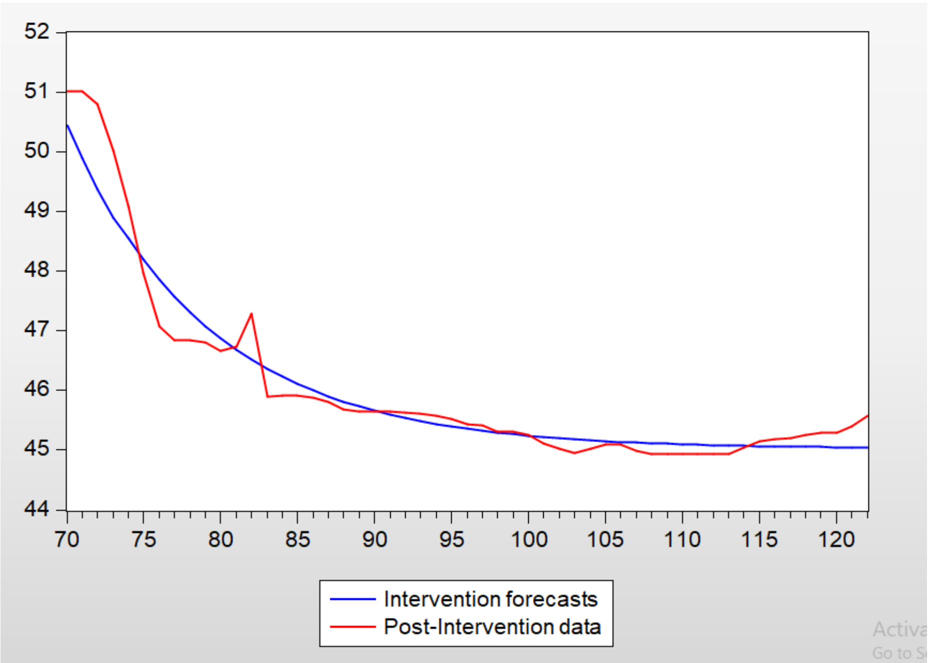

Figure 5: Superimposition of the post-intervention data with the forecasts

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APPENDIX

DATA

September 2019

48.77 48.79 48.68 48.96 49.28 49.53 49.65 49.65 49.75 49.85 49.80 49.79 49.52 49.23 49.23 49.26 49.51 49.60 49.46 49.57 49.80 49.80 49.81 49.66 49.54 49.52 49.40 49.42 49.42 49.69

October 2019

49.75 49.7149.76 49.84 49.82 49.82 49.81 50.00 50.06 50.07 50.15 50.17 50.17 50.20 50.15 50.10 50.13 50.28 50.31 50.31 50.34 50.36 50.32 50.32 50.33 50.31 50.31 50.33 50.32 50.39 50.44

November 2019

50.52 50.59 50.59 50.69 50.84 50.98 50.98 51.04 51.01 51.01 50.79 50.02 49.09 47.96 47.08 46.84 46.84 46.80 46.67 46.74 47.28 45.90 45.92 45.92 45.88 45.80 45.69 45.65 45.65 ____

December 2019

45.63 45.61 45.58 45.53 45.44 45.42 45.31 45.31 45.26 45.11 45.03 44.95 45.02 45.09 45.09 44.99 44.94 44.94 44.93 44.93 44.93 44.93 45.05 45.15 45.19 45.20 45.25 45.30 45.30 45.40 45.57

Source: https://freecurrencyrates.com/en/exchange-rate-history/MYR-LRD/2019