International Journal of Management Studies, Business & Entrepreneurship Research
ISSN: 2545-5893(Print) 2545-5877 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Intervention Analysis of Daily South African Rand/Nigerian Naira Exchange Rates

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ABSTRACT: Time series plot of a realization of daily exchange rates of South African Rand and Nigerian Naira from April 2017 to December, 2017shows the occurrence of an intervention on 4th August, 2017. This research work has an aim of proposing an intervention model to explain the impact of this intervention believed to be due to the economic recession in Nigeria. Pre-intervention series is observed to be stationary by the Augmented Dickey Fuller Test. Following the shown autocorrelation structure of the series, an adequate subset ARMA (12, 2) model is fitted to it. On the basis of this model forecasts are made for the post-intervention period. Difference between these forecasts and their corresponding actual observations are modeled to obtain the intervention transfer function and the desired overall intervention model. Management of these exchange rates may be made on the basis of this model.
Keywords: South Africa, Nigeria, Exchange Rate, ARIMA Modeling, Interrupted Time Series, Forecasting.

INTRODUCTION

The legal tender of South African is the Rand which has an acronym ZAR (Rand). On the other hand, Naira is the Nigerian currency and is denoted by NGN (for Nigerian Naira). An investigation of the daily exchange rates of South Africa and Nigeria from April 2017 to December, 2017, shows an unforeseen jump in the amount of NGN per ZAR on August 4^{th}, 2017. In finance, an exchange rate is the value of one country's currency in relation to another currency. Exchange rate between the two currencies are the basis for international trade between the two nations and may be used as proxy for relative performance of their economies. The aim of this work is to propose an intervention model for the exchange rate between South African Rand and Nigerian Naira.

The intervention situation in the ZAR/NGN exchange is believed to be due to the current economic recession in Nigeria. The approach to the intervention model of the exchange rate, shall be the Autoregressive Integrated Moving Average (ARIMA) approach which was introduced by Box and Tiao (1975) [1]. This approach is well tested and efficaciously applied by many scholars. For instance, Masukawa et al. (2014) studied the impact of the introduction of a rotavirus vaccine on rates of hospitalization of children less than 5 years old for acute diarrhea [2]. Valadkhani and Layton (2004) examined the effect of goods and services tax on inflation in Australia. The observed a transitory effect [3]. Etuk et al. (2017) has fitted an intervention model of the Euro/British pound exchange rate occasioned by BREXIT [4]. Udoudo and Etuk (2018) conducted an intervention study on daily exchange rate of Thailand Thai-Bath/Nigerian Naira, still due to the current economic recession in Nigeria [5]. Ebhuoma et al., (2017) studied the positive effect of the re-introduction of dichlorodiphenyltrichloroethane in the lowering of malaria incidence using ARIA intervention analysis [6]. Michael et al. (2004) studied the impact of illicit drug supply

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reduction on health and social outcomes: the heroin shortage in the Australian Capital Territory. They observed that a sustainable decline in the supply of heroin, as measured by indicators such as drug purity, is related to changes in drug-related health indicator such as ambulance callouts to heroin overdoses [7].

MATERIALS AND METHOD

Data

The data used in this work are of secondary sources. The data analyzed in this work are daily ZAR/NGN exchange rates from 8th April, 2017 to 26th December, 2017 from the website www.exchangerates.org.uk/ZAR-NGN-exchange-rate-history.html. They are read as the amounts of NGN per ZAR. The used data is listed in the appendix.

Intervention Modeling

Let X_t be a time series encountering an intervention at time $t = T$. Box and Tiao (1975) proposed that the pre-intervention part of the series be modeled by ARIMA techniques. That is, for $t < T$, suppose that the $ARIMA(p,\ d,\ q)$ model.

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

$(where \nabla X_t = X_t - X_{t-1})$ is fitted. Model (1) may be put as

$$\Phi(L)(1-L)X_t = \Theta(L)\varepsilon_t \qquad (2)$$

Where $L^k X_t = X_{t-k}, L^k \varepsilon_t = \varepsilon_{t-k}, \Phi(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \ldots - \alpha_p L^p$ is the autoregressive (AR) operator and $\Theta(L) = 1 + \beta_1 L + \beta_1 L^2 + \ldots + \beta_q L^q$ is the moving average (MA) operator. The α's and β's are chosen such that the zeros of $\Theta(L) = 0$ are outside of the unit circle for model stationarity and the zeros of $\Theta(L) = 0$ are outside of the unit circle for model invertibility.

From (2), the noise part of the intervention model is

$$V_t = \frac{\Theta(L)\varepsilon_t}{\Theta(L)(1-L)^d} \qquad (3)$$

On the basis of the model forecasts are obtained for the post-intervention part of the time series. Suppose these are $F_t, t \geq T$. Then for $t \geq T$

$$Z_t = X_t - F_t = \frac{c(1)*\left(1-c(2)^{t-T+1}\right)}{\left(1-c(2)\right)} \qquad (4)$$

(The Pennsylvania State University, 2016 [8]).

This is the transfer function of the intervention model. The model is then obtained by combining (3) and (4) to have

$$V_t = \frac{\Theta(L)\varepsilon_t}{\Theta(L)(1-L)^d} + I_t Z_t \qquad (5)$$

Where I_t is an indicator variable that $I_t = 1$ is the post-intervention period and zero otherwise. Secondly still on the basis of the model, forecast are obtained for the post-intervention part of the time series. Suppose these are $F_t, t \geq T$. Then for $t \geq T$

$$Z_t = X_t - F_t = c(1) + c(2)*(t - T + 1) + c(3)*(t - T + 1)^2 \qquad (6)$$

This is the transfer function of the intervention model. The model is given by combining (3) and (6) to have

$$Y_t = \frac{\Theta(L)\varepsilon_t}{\Theta(L)(1-L)^d} + I_t Z_t \qquad (7)$$

Where I_t is an indicator variable that $I_t = 1$ is the post-intervention period and zero otherwise. In practice the model (2) is fitted first by the determination of the orders, p, d and q. The differencing order is determined sequentially stating from 0 if the series is stationary. If not, with d = 1, the series is tested for stationary. If non-stationary, d = 2. Stationary may be tested with the Augmented Dickey Fuller (ADF) unit root test procedure. The autoregressive (AR) order may be determined by the lap at which the partial autocorrelation function (PACF) cuts off. The moving average (MA) order may be estimated as the lap at which the autocorrelation function (ACF) cuts oft. Estimation of X's and β's may be done by the method of lest squares.

Computer Package: Eviews 10 was used to do all computations in this work.

RESULTS AND DISCUSSION

The time plot of the realization of the time series used in this work is shown in figure 1. After three spikes, there is a sudden sharp increase on 4th August 2017 after which there is no fall in the series. This is the point of intervention. Prior to this point the exchange rates, apart from three spikes the exchange rates point 33 and 56 exhibit a fairly flat trend (see figure 2). They are adjudged stationary by the Augmented Dichey Fuller Test (SeeTable 1). Their correlogram of figure 3 shows evidence of seasonality of MA(2) and AR(2). This inform the fitting of an ARMA (2, 2) model estimated in table (2) as:

$$X_t = 0.664041 X_{t-2} - 0.401345\varepsilon_{t-2} + \varepsilon_t$$

The autocorrelation structure of its residuals shown in Figure 4 looks like that of white noise, an indication of model adequacy. On its basis the noise component of the model is

$$V_t = \frac{(1 - 0.401345^2)}{(1 - 0.664041L^2)}\varepsilon_t$$

The estimate in Table (2) $\alpha_2 = 0.664041$ and $\beta_2 = -0.401345$ are highly statistically significant.

On the basis of these estimate, forecast have been made for the post intervention period. The observed/forecast is modeled using equation (4) and obtained from Table (3), c (1) = 8.490537 and c (2) = 0.681409. Clearly we see that c (1) and c (2) are statistically significant indicating that the model is adequate for forecasting.

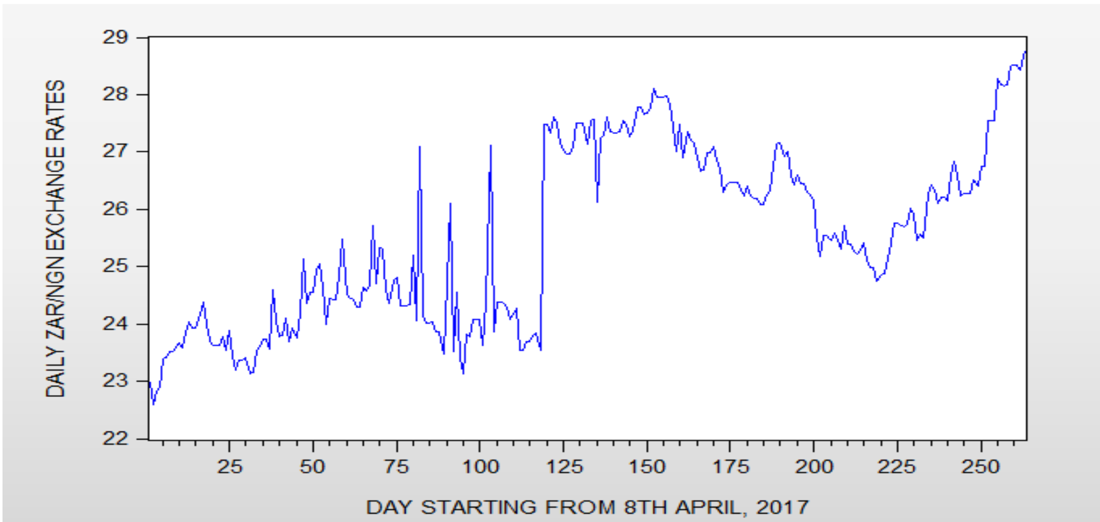

Fig.1: Time plot of daily ZAR/NGN Exchange rate

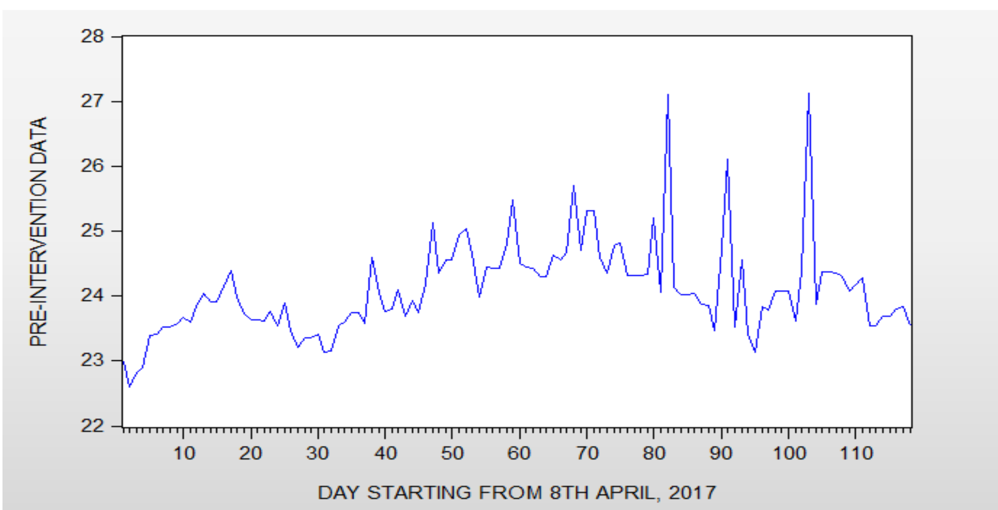

Fig. 2: Time plot of the pre-intervention model

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Table 1: Stationarity Test for Pre-intervention Data

Null Hypothesis: SERIES01 has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=12)

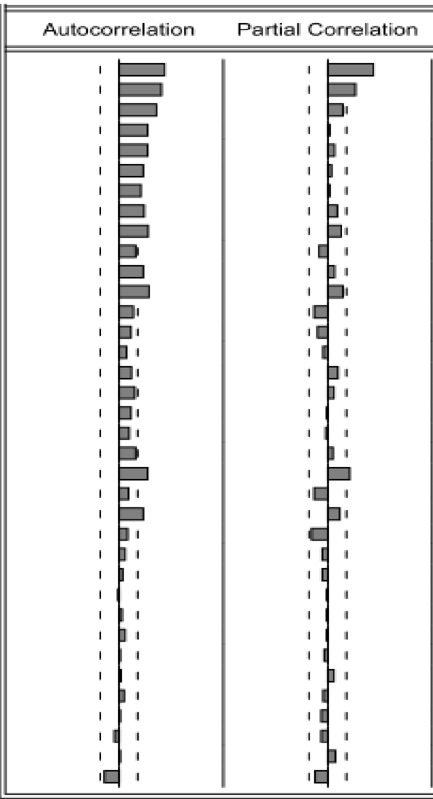
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.453163	0.0004
Test critical values:	1% level	-3.487550	
	5% level	-2.886509	
	10% level	-2.580163	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SERIES01)
Method: Least Squares
Date: 12/03/18 Time: 12:20
Sample (adjusted): 3 118
Included observations: 116 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SERIES01(-1)	-0.412232	0.092571	-4.453163	0.0000
D(SERIES01(-1))	-0.285462	0.088279	-3.233632	0.0016
C	9.953103	2.233143	4.456994	0.0000

R-squared	0.351856	Mean dependent var	0.008145
Adjusted R-squared	0.340384	S.D. dependent var	0.749080
S.E. of regression	0.608378	Akaike info criterion	1.869482
Sum squared resid	41.82402	Schwarz criterion	1.940695
Log likelihood	-105.4299	Hannan-Quinn criter.	1.898390
F-statistic	30.67199	Durbin-Watson stat	2.116784
Prob(F-statistic)	0.000000		



	AC	PAC	Q-Stat	Prob
1	0.451	0.451	24.611	0.000
2	0.419	0.271	46.083	0.000
3	0.373	0.152	63.176	0.000
4	0.283	0.021	73.157	0.000
5	0.281	0.068	83.066	0.000
6	0.244	0.036	90.610	0.000
7	0.215	0.019	96.493	0.000
8	0.250	0.091	104.56	0.000
9	0.294	0.139	115.82	0.000
10	0.172	-0.090	119.68	0.000
11	0.241	0.070	127.34	0.000
12	0.298	0.154	139.24	0.000
13	0.140	-0.133	141.89	0.000
14	0.119	-0.103	143.83	0.000
15	0.076	-0.047	144.62	0.000
16	0.131	0.102	147.00	0.000
17	0.158	0.060	150.48	0.000
18	0.122	-0.012	152.60	0.000
19	0.100	-0.017	154.01	0.000
20	0.166	0.054	157.97	0.000
21	0.284	0.220	169.74	0.000
22	0.091	-0.136	170.96	0.000
23	0.240	0.120	179.57	0.000
24	0.088	-0.162	180.73	0.000
25	0.064	-0.055	181.36	0.000
26	0.035	-0.056	181.55	0.000
27	-0.009	-0.009	181.56	0.000
28	0.032	-0.015	181.72	0.000
29	0.060	-0.016	182.29	0.000
30	0.014	-0.039	182.32	0.000
31	0.018	0.064	182.37	0.000
32	0.052	-0.043	182.82	0.000
33	0.010	-0.063	182.83	0.000
34	-0.047	-0.059	183.21	0.000
35	0.009	0.076	183.22	0.000
36	-0.142	-0.123	186.71	0.000

Fig 3: Correlogram of the Pre-intervention Data

International Journal of Management Studies, Business & Entrepreneurship Research
ISSN: 2545-5893(Print) 2545-5877 (Online)
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http://www.casirmediapublishing.com

Table 2: Estimate of the Pre-intervention model showing that the AR (2) MA (2) are the only significant components of the model.

Dependent Variable: SERIES01
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 12/03/18 Time: 12:36
Sample: 1 118
Included observations: 118
Convergence achieved after 388 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(1)	0.335933	0.234475	1.432706	0.1550
AR(2)	0.664041	0.326915	2.031236	0.0448
MA(1)	-0.034668	0.161103	-0.215192	0.8300
MA(2)	-0.401345	0.130968	-3.064454	0.0028
MA(3)	-0.005994	0.143699	-0.041715	0.9668
MA(4)	-0.140887	0.160434	-0.878161	0.3819
MA(5)	-0.067029	0.157434	-0.425760	0.6712
MA(6)	-0.019104	0.170422	-0.112100	0.9110
MA(7)	-0.084369	0.150683	-0.559911	0.5768
MA(8)	0.018290	0.122378	0.149452	0.8815
MA(9)	0.005159	0.078090	0.066068	0.9475
MA(10)	-0.119376	0.099013	-1.205653	0.2307
MA(11)	0.021779	0.161118	0.135171	0.8927
MA(12)	0.201793	0.117343	1.719683	0.0885
SIGMASQ	0.339598	0.036780	9.233293	0.0000

R-squared	0.335957	Mean dependent var	24.10502
Adjusted R-squared	0.245699	S.D. dependent var	0.718179
S.E. of regression	0.623742	Akaike info criterion	2.087148
Sum squared resid	40.07258	Schwarz criterion	2.439354
Log likelihood	-108.1418	Hannan-Quinn criter.	2.230154
Durbin-Watson stat	2.039278		

Inverted AR Roots	1.00	-.66		
Inverted MA Roots	.89+.12i	.89-.12i	.64+.58i	.64-.58i
	.25+.84i	.25-.84i	-.25+.85i	-.25-.85i
	-.66+.53i	-.66-.53i	-.86-.19i	-.86+.19i

Table 3: Estimate of the Intervention transfer function

Dependent Variable: Z
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 12/04/18 Time: 11:25
Sample: 119 263
Included observations: 145
Convergence achieved after 10 iterations
Coefficient covariance computed using outer product of gradients
Z=C(1)*(1-C(2)^(T-118))/(1-C(2))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	8.490537	0.315539	26.90804	0.0000
C(2)	0.681409	0.012018	56.69802	0.0000

R-squared	0.799833	Mean dependent var	26.24924
Adjusted R-squared	0.798433	S.D. dependent var	2.204589
S.E. of regression	0.989776	Akaike info criterion	2.831022
Sum squared resid	140.0910	Schwarz criterion	2.872080
Log likelihood	-203.2491	Hannan-Quinn criter.	2.847705
Durbin-Watson stat	0.337881		

Fig 5: Graph of Intervention Transfer Function

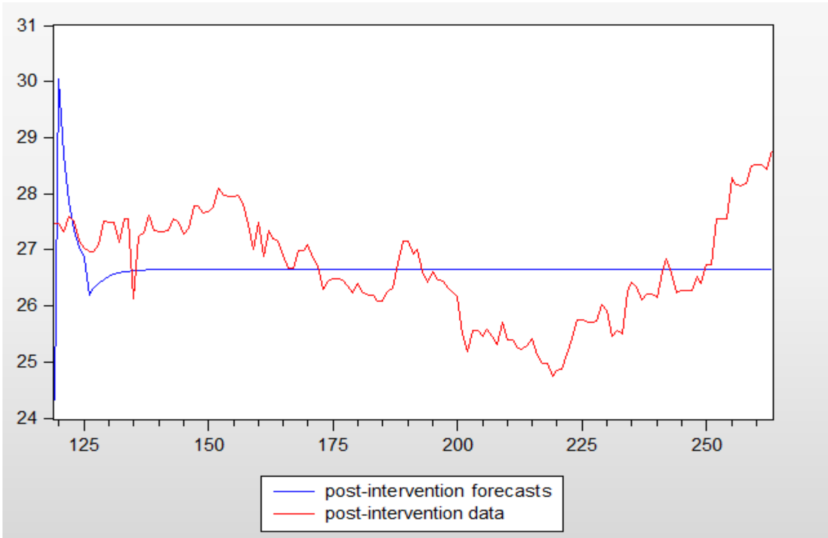

Fig.5: Post-intervention Observations and Intervention Forecast of Model 1

CONCLUSION

From Fig 5 above, we observe that there is a close agreement between post-intervention observations and the forecast. Hence the intervention model (7) is adequate. The model explains the effect of the economic recession on the amount of Naira which is exchanged for a Rand. This is certainly going to assist the Nigerian Government as well as managers in the private sector to establish and maintain adequate intervention measures to remedy the situation for better trade relationship between Nigeria and South Africa.

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APPENDIX
DATA

April, 2017 (From 8th)

22.9825	22.5949	22.8233	22.8872	23.3938	23.4175	23.5195	23.5289	23.5787	23.669	23.5908	23.8318
24.0345	23.9172	23.9172	24.1594	24.3869	23.9853	23.7188	23.6305	23.629	23.6237	23.7681	

May, 2017

23.5492	23.8868	23.4604	23.2021	23.3659	23.3659	23.4115	23.1335	23.1521	23.546	23.5951	23.7439
23.7439	23.5709	24.5963	24.0614	23.7668	23.8092	24.1028	23.6935	23.9378	23.7486	24.1943	25.1348
24.3583	24.5584	24.5621	24.9419	25.0445	24.6481	23.9868					

June, 2017

24.4448	24.4273	24.4318	24.8244	25.4841	24.5018	24.4439	24.4284	24.2915	24.2898	24.6364	24.5645
24.6745	25.709	24.7103	25.3182	25.3104	24.5916	24.3556	24.7777	24.8158	24.321	24.3159	24.3233
24.3309	25.2022	24.0523	27.101	24.1359	24.0143						

July, 2017

24.0146	24.0382	23.8657	23.8568	23.4679	24.7274	26.1048	23.5249	24.5589	23.4084	23.1287	23.8288
23.7874	24.0755	24.0755	24.0801	23.6156	24.3837	27.1174	23.867	24.3793	24.3701	24.3485	24.2944
24.0763	24.1721	24.2736	23.5482	23.5471	23.6938	23.6923					

August, 2017

23.8031	23.8368	23.5397	27.475	27.475	27.3212	27.6022	27.5007	27.1538	27.035	26.9673	26.9677
27.0885	27.5085	27.498	27.494	27.1319	27.5555	27.5604	26.1284	27.2352	27.2911	27.6126	27.3427
27.3211	27.3211	27.3424	27.5523	27.4856	27.2707	27.3757					

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September, 2017

27.7879	27.7879	27.6565	27.6696	27.7573	28.0961	27.9646	27.9558	27.9533	27.9753	27.8304	27.4451
27.0086	27.4882	26.8915	26.8915	27.3531	27.1941	27.1584	26.9013	26.6634	26.6821	26.9874	26.9874
27.0868	26.8636	26.7126	26.3026	26.4343	26.4765	26.4765					

October, 2017

26.4603	26.3501	26.2365	26.2256	26.1884	26.1818	26.0848	26.0761	26.2458	26.3173	26.7492	27.1473
27.1493	26.9207	27.0052	26.6054	26.4282	26.6015	26.4566	26.4446	26.3065	26.258	26.1655	25.4991
25.1871	25.5526	25.5526	25.4486	25.5791	25.4497						

November, 2017

25.3041	25.7172	25.3881	25.3881	25.2533	25.2306	25.2872	25.4208	25.1191	24.9753	24.9753	24.7446
24.8523	24.8668	25.1427	25.4155	25.7576	25.7576	25.7136	25.6997	25.7271	26.0196	25.9093	25.4562
25.5674	25.5065	26.2483	26.4214	26.332	26.1048						

December, 2017

26.201	26.201	26.1487	26.5993	26.8359	26.5933	26.2383	26.2673	26.283	26.2746	26.5158	26.395
26.7416	26.7392	27.5546	27.5546	27.5428	28.2873	28.1655	28.1476	28.1808	28.4985	28.5145	28.5092
28.4271	28.765										