

# Stochastic behavior of South African Rand exchange rate

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## Abstract

The study of fluctuations of exchange rates is one of many active research areas in the international finance. This paper is concerned with modeling of exchange rates of the South African Rand, through which the Namibian Dollar accesses the international market. It uses some standard models and tools of quantitative analysis, such as Random walk, Martingale hypothesis, Auto Regressive model (AR), Auto regressive polynomial model (PN), Feed forward artificial neural network (NN), functional coefficient model and non-parametric regression model (NP), to closely look at stochastic behaviors of the South African Rand exchange rates against thirteen currencies of countries that are major trade partners to and within Southern African nations. Due to increasing international trade volumes, Southern African nations are more and more exposed to the international community, and trading in both goods and services that are affected to a large extent by movements in exchange rates.

**Keywords:** Martingale, Hedging, Variance ratio tests, Random-walk, Depreciation, Appreciation, Exchange rates, Market efficiency.

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## 1 Introduction

Several methods and models have been employed to closely observe the stochastic nature of the exchange rates such as random walk and martingale properties. Such studies have been

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performed mostly for forex markets of developed economies but such studies are rarely done for emerging economies forex markets, in particular Southern African regions. However with increasing development in this region Exchange rate movements has been affecting the foreign demand for firm's products. When the local currency appreciates, products in that currency become expensive to foreign customers, which may cause a decline in exports resulting decrease in the current account. However, Some of the motives in forecasting exchange rates are of advantage to foreign direct investments, this includes:

- *To exploit monopolistic advantage.* Firms become more internationalized if they possess unique skills or advance technology that is not available to competing firm.
- *Seek superior profit possibilities.* Firms would go global to maximize their expected profit. This is successfully attainable with appropriate exchange rate forecasting, for excessive earnings to be realized.
- *To attract new sources of demand.* A corporation may get to a point where its growth is limited in its home country, due to competitions. Hence, a rational solution would be to begin operations in the foreign markets where potential demand exists.
- *Earning assessments and capital budgeting decisions.* Firms may perform exchange rate forecast to determine on how to capitalize its scarce resources to maximize profit, enhance its value and assess its earning that it may realize in the future.

## 1.1 Literature review

Quite a number of studies have examined the hypothesis that exchange rate changes follow a martingale or related hypothesis of random walk. As observed by Liu and He (1991), this hypothesis has two important implications: a unit root and un-associated increments. Because unit root tests does not detect all deviations from a martingale and the chance of auto-correlation has interesting implications with regards to alternative exchange rate models (Liu and He, 1991), most recent studies stressed the analysis of un-associated increments using the Variance Ratio test[1]. Thus far, there is no sufficient statistical evidence to fall in with the random walk model, many investigations have paid more attention to linear predictability of exchange rate movements. At best, the data suggest that exchange rate movements are un-associated, in the light of normality [6].

Lo and MacKinlay (1988) mocked the typical random walk tests of asset returns and introduced a more robust volatility-based specification test. Commonly, asset returns usually possess time-varying volatilities and deviations from normality, the significance of a test which is robust to heteroskedasticity and non normality becomes very important[10].

Hong (2003) brought forth a model-free omnibus statistical principles to outline if the direction of changes in an economic variable is predictable using the history of its past changes. A class of separate inference rules are as well provided to measure possible sources of directional predictability. They can provide information about whether the direction of future changes is predictable using the historical directions, level, volatility, skewness, and kurtosis of past changes. A crucial component of the proposed principle is that they test many lags at the same time, which is specifically suitable for detecting the alternatives whose directional dependence is small at each lag but it carries over a long distributional lag. At the same time, the tests naturally discount higher order lags, which is on par with the conventional intelligence that financial markets are more affected by the recent past than by the remote past occurrences[5].

Yil-maz(2003) find out that daily exchange rates satisfies the martingale properties most of the times, with an exclusion of periods marked by central bank interventions. Studies using the Variance ratio test only presents in-sample evidence, which is of no greater importance to decision makers as out-of-sample evidence. Moreover, previous studies did not look into potential non-linearity in-mean with respect to exchange rates [8].

Theoretically two typical hypothesis play a huge important role. These are, the Purchasing Power Parity (PPP) and the Uncovered Interest rate Parity (UIP). The main purpose of the PPP hypothesis is that exchange rates and national price indices are proportional so as to keep any given currency's purchasing power across the borders which means that under the assumption of strict PPP the true values of any given currency will be the value of other currencies in all countries at any point in time (The law of one price). UIP hypothesis states that, in equilibrium, the interest rate differential among countries must be equal to the expected rate of change of exchange rate [3]. The Efficient Market Hypothesis (EMH) states that in an efficient market, asset under PPP, exchange rate is proportional to a ratio of external and internal price levels:

$$L_t = Q_t^* - Q_t$$

where  $L_t$  is the logarithm of the exchange rate (the foreign price of domestic currency) and  $Q_t$  and  $Q_t^*$  are the internal and external price levels, respectively. The typical property of deviations from PPP can be seen through the exchange rates since the logarithm of the exchange rate,  $q_t$ , can be defined as the deviation from PPP:

$$q_t = L_t + Q_t - Q_t^*$$

If PPP is kept continuously,  $q_t$  would be a constant showing differences in units of measurement. However, the sample variance of major exchange rates over the recent float is

very huge, creating concrete and clear evidence against continuous PPP. As noted above, failure to reject the hypothesis of non stationarity in the exchange rate has often been seen as evidence against future PPP. Prices fully reflect all available information about the asset, and investors therefore cannot consistently earn abnormal returns.

Liu and He (1991) applied Variance test ratio based and provided evidence that rejected the random walk hypothesis for five pairs of daily exchange rates, their report results suggested that auto correlations are present in weekly increments in daily exchange rates [4].

In the past decade, there has been a consensus that nominal exchange rates exhibit a random walk process. Since a unit root and independent increments are all needed for a random walk process, the random walk is normally entertained in the existing studies either because a unit root component is realized in the exchange rate series else because the increment in the exchange rate is found to be strongly independent.

The study by Lo and MacKinlay (1988) is the foundation of the variance ratio test approach. It is thus far an important study and commonly used on the random-walk hypothesis. However, the test specialized on testing one variance ratio at a time for a unit observation interval. Which became an individual hypothesis test. However, Other scholars (Chow and Denning 1993) have proposed that an effective test of the random-walk hypothesis should be based on multiple set of variance ratios in order to have a correct overall size of the test by comparisons, which requires a joint hypothesis test. This methodology is not common because it is valid only if sample auto correlations of the random-walk increments are asymptotically independent, which might not be valid due to some natural dependent time series. While many other tests have been developed over the years to try and remedy the possible shortcomings of earlier tests[2].

The use of the VR statistic can be of great advantage when testing against certain interesting alternatives to the random walk model, a lot of those hypotheses associated with mean reversion. In fact, a number of authors (e.g., Lo and MacKinlay, 1989; Faust, 1992; Richardson and Smith, 1991) discovered that the Variance Ratio statistic optimal against such alternatives. Moreover, while the intuition behind the variance ratio test is rather simple, conducting a statistical inference using the variance ratio test is less focused. What makes things complicated is that the variance ratio test traditionally uses overlapping data in computing the variance of long term returns[9].

In Yilmaz (2003) its debated that tests of the martingale property in exchange rates need to look out for the sensitivity of the results to the specific period used. Then, the movements of daily exchange rates is linked to the interventions of Central Banks, during the period of coordinated central bank interventions, exchange rates move away from the martingale property. The main issue is that Yilmaz did not test the martingale property of exchange rates, but the linear correlation of the returns. Hence, in his terminology, when he can not

reject the null hypothesis of no correlation for a set variance ratio horizons, he declared that exchange rates follow a martingale. However, this is not very true, because there can be nonlinear complex items which could provoke a violation of the null hypothesis of martingale for exchange rates.

## 1.2 Significance of the study

Traditionally the most famous used technical trading rules in financial markets are based on the prediction of the direction of the market movement. Having the knowledge of the direction of exchange rate trends, is of practical value to investors and other decision makers, particularly from the perspective of decision making under uncertainty to maximize economic welfare. Therefore, research such as this paper is useful to investors in currency trading in determining the currency which is safe to invest especially those engaged in Foreign Direct Investment and those that run Multinational Corporations (MNCs).

Country risk analysis is a matter of importance to Multinational corporations because of the following reasons, as a screening tool to prevent MNCs from creating subsidiaries in countries with excessive risks, it can be used for short and long term investments decisions. MNCs should assess country risks not only in the countries where they are currently operating but also wherever they expect to export or create subsidiaries. One of the extreme form of country risks is the political risk, there are several characteristics that help MNCs identify the level of political risk such as attitude of government, currency convertibility restrictions, level of corruption, consumers attitude, and restriction on fund transfers.

Macro and micro assessments can be applied to assess the country risks since macro assessment of country risk involve all variables that influence country risk, excluding those unique to a specific firm and industry, while micro assessment of country risk serves as an indicator of the country's overall status, instead of assessing the country risk from a perspective of specific business concern.

Understanding of exchange-rate behavior is important in establishing policies aimed at achieving macroeconomic stability in an economy, as exchange-rate uncertainty tends to disturb set macroeconomic goals. Currency trading has become a major source of revenue for the banking sector. Understanding exchange-rate trends will not only help in shaping macroeconomic policy, but also affect other foreign-exchange market players such as currency traders and speculators.

## 2 Methodology and data

In this section we explained each model and give its empirical results and their interpretations. However, the data for the study consists of daily exchange rates for the Australian Dollar, Botswana Pula, British Pound, Canadian dollar, Denmark Krone, Euros, Indian Rupees, Japanese yen, Sweden krona, Switzerland Franc, US Dollar, Zambian Kwacha and SDR, All relative to the Rand from 02 January 2000 to 30 June 2016 (Almost 16 years daily data). The exchange rate data is obtained from South African Reserved bank, Economics and Statistics department. The choice of daily data is consistent with previous studies and for better reality reflecting results. These currencies are chosen because they are some of the major trading partners of South Africa and are floating currencies.

### 2.1 Random walk

A random walk theory suggests that stock price changes are similarly distributed and are not dependent of each other, this means that the previous or past movements or trends of stock prices cannot be used to predict the future movements. In short this is the idea that stock take random or an unpredictable path.

This is a simple definition of a random walk, it did not include probability theory, except in an event where probabilistic ideas explicitly appear. Nevertheless, probability theory will implicitly always run at the back ground of random walk.

#### 2.1.1 Variance ratio test (VR)

The variance ratio test proposed by Lo and Mackinlay (1988,1989) is grounded by the fact that, for a random walk series, the variance of its  $k^{th}$  difference is  $k$  times the variance of its first difference, with respect to the assumption of independent and identically distributed returns.

#### 2.1.2 Reslts and interpretations for VR test

Empirical results of the Variance ratio test are shown in the table below.

Currency	P Value	Test statistics
Australian Dollar	0.1598	1.9758
Botswana Pula	0.0000	0.0000
British Pound	0.3356	0.9269
Canadian Dollar	0.2714	1.2094
Denmark Krone	0.15125	2.0782
Euro	0.6878	0.1614
Indian rupees	0.1494	2.0782
Japanese yen	0.1790	1.8057
Sweden Krona	0.5709	0.3211
Switzerland Franc	0.8750	1.7371
US dollar	0.1430	2.1451
Zambian Kwacha	0.3387	0.9152
SDR	0.0283	4.8071

### Statistics

$H_0$  : The rand exhibits a random walk.

$H_1$  : The rand exhibits no random walk.

Level of significance: 0.05

Clearly, We observe from the table above that for all the currencies the P value is greater than the level of significance except Botswana pula and SDR. Hence, with this information we reject the null hypothesis. This means we have a strong statistical evidence that the rand exchange rates do not follow a random walk. Meanwhile, For Botswana pula and SDR we fail to reject the null hypothesis and conclude that we have sufficient statistical evidence that Rand exhibits a random walk against Botswana pula and SDR.

### 2.1.3 Ranks and signs-based random walk tests(R-S test)

The test based on ranks  $R_1$  and  $R_2$  proposed by Wright (2000) are exact under the no dependence and similar distribution assumptions, whereas the tests based on sign ( $S_1$  is exact under conditional heteroskedasticity). The ranks and signs test is relatively simple, as it avoids distortions in the absence of the need to conform to any asymptotic approximations. The statistical definitions of Wright's ranks and signs are derived as follows: given that  $[y_1, \dots, y_N]$  is a time series of exchange rate returns with a sample size of  $N$ , then we define  $R_1$  and  $R_2$  as:

$$R_1 = \left( \frac{\frac{1}{Nk} \sum_{t=k}^N (r_{1t} + \dots + r_{1t-k+1})^2}{\frac{1}{N} \sum_{t=1}^N r_{1t}^2} - 1 \right) \times \Phi(k)^{-1/2}$$

$$R_2 = \left( \frac{\frac{1}{Nk} \sum_{t=k}^N (r_{2t} + \dots + r_{2t-k+1})^2}{\frac{1}{N} \sum_{t=1}^N r_{2t}^2} - 1 \right) \times \Phi(k)^{-1/2}$$

Where,

$$r_{1t} = (r(y_t) - \frac{N+1}{2}) / \sqrt{\frac{(N-1)(N+2)}{12}}$$

$$r_{2t} = \Phi^{-1}(r(y_t)/(T + 1))$$

$$\Phi(k) = \frac{2(2k-1)(k-1)}{3kN}$$

$r(y_t)$  is the rank of  $y_t$  among  $y_1, \dots, y_N$ , and  $\Phi^{-1}$  is the inverse of the standard normal cumulative distribution function, The series  $r_{1t}$  is a simple linear transformation of the ranks, standardized such that it has a sample mean of 0 and variance 1, whilst  $r_{2t}$  have a sample mean of 0 and variance approximately equal to 1. However the test based on the signs of returns is given by:

$$S_1 = \left( \frac{\frac{1}{Nk} \sum_{t=k}^N (s_t + \dots + s_{t-k+1})^2}{\frac{1}{N} \sum_{t=1}^N s_t^2} - 1 \right) \times \Phi(k)^{-1/2}$$

Where,

$$\Phi(k) = \frac{2(2k-1)(k-1)}{3kN}$$

Given a series  $Y_t$ , let  $u(y_t, q) = (Y_t > q) = 0.5$ , it then follow that  $u(Y_t, 0) = 0.5$  if  $Y_t$  is positive and 0.5 elsewhere.

Wright (2000) further elaborated that letting  $2u(y_t, 0) = 2u(\varepsilon_t, 0)$ , then  $s_t$  is independently and similarly distributed series with a mean of 0 and variance of 1.

### 2.1.4 Results and interpretations of the R-S test

Empirical results of Wright’s Rank and Sign-based test are shown in the mini tables below.

<i>Australian Dollar</i>			
	$R_1$	$R_2$	$S_1$
k=2	-2.1691	-2.3673	-1.0943
k=5	-2.5945	-2.9568	-1.1245
k=10	-2.1774	-2.7689	-1.0445

<i>SDR</i>			
	$R_1$	$R_2$	$S_1$
k=2	-2.3734	-2.4981	0.6734*
k=5	-2.3349	-2.8840	2.9508*
k=10	-2.2983	-2.7689	4.7174*

<i>Botswana Pula</i>			
	$R_1$	$R_2$	$S_1$
k=2	-6.6026	-8.1444	-3.8930
k=5	-5.3596	-6.5513	-3.6994
k=10	-4.0658	-5.0260	-2.4162

<i>Canadian Dollar</i>			
	$R_1$	$R_2$	$S_1$
k=2	-1.0782	-1.3544	-1.0475
k=5	-2.0107	-2.4660	-1.7583
k=10	-1.9535	-2.3482	-1.4716

<i>Euro</i>			
	$R_1$	$R_2$	$S_1$
k=2	-0.7026	-0.8282	-0.9847
k=5	-1.2943	-1.7053	-1.3584
k=10	-1.1985	-1.4860	-1.3249

<i>Japanese Yen</i>			
	$R_1$	$R_2$	$S_1$
k=2	-2.0432	-2.4906	-1.7979
k=5	-2.2336	-2.9088	-1.7012
k=10	-2.4992	-3.2413	-1.7957

<i>Switzerland Franc</i>			
	$R_1$	$R_2$	$S_1$
k=2	-1.6848	-2.0391	-1.0788
k=5	-2.5932	-3.0330	-1.7013
k=10	-2.7242	-3.1483	-1.9735

<i>Zambian Kwacha</i>			
	$R_1$	$R_2$	$S_1$
k=2	-3.2741	-2.9415	-2.6422
k=5	-2.8153	-3.1165	-2.3064
k=10	-2.2653	-2.7719	-2.0847

<i>British Pound</i>			
	$R_1$	$R_2$	$S_1$
k=2	-0.7966	-1.1354	-0.1250
k=5	-1.4886	-1.8921	-0.5879
k=10	-1.4621	-1.6098	-1.0964

<i>Denmark Krone</i>			
	$R_1$	$R_2$	$S_1$
k=2	-0.6927	-1.1856	-1.0787
k=5	-1.3115	-1.9546	-1.4272
k=10	-1.2382	-1.6889	-1.2975

<i>Indian Rupees</i>			
	$R_1$	$R_2$	$S_1$
k=2	-1.9989	-2.1629	-1.2977
k=5	-2.3899	-2.6017	-2.1351
k=10	-2.0711	-2.3623	-1.9902

<i>Sweden Krona</i>			
	$R_1$	$R_2$	$S_1$
k=2	-0.9354	-1.0049	0.0156*
k=5	-2.1116	-2.5457	-1.0732
k=10	-2.5539	-1.8466	-0.6288

<i>US Dollar</i>			
	$R_1$	$R_2$	$S_1$
k=2	-1.8496	-2.1886	-1.3599
k=5	-2.2863	-2.5755	-2.7282
k=10	-1.8336	-2.1902	-2.4934

The results for Wright's ranks and signs-based tests are given in the small Tables above . The ranks  $R_1$  and  $R_2$  and signs  $S_1$  provide strong support for the rejection of Random Walk Hypothesis for all the sampling intervals. Except only for SDR  $S_1$  and Sweden Krona  $S_1$  for  $k=2$ (marked with an \* in the tables).

## 2.2 Martingale

A martingale is a stochastic process  $W_t$  at time  $t$  which satisfies the following conditions.  $E[W_t|W_{t-1}, W_{t-2}, \dots] = W_t$ , This means the process has no tendency of going up neither

down.

If  $E[W_t|W_{t-1}, W_{t-2}, \dots] < W_t$ , then the process is called a super martingale. This means the process has a tendency of decreasing. If  $E[W_t|W_{t-1}, W_{t-2}, \dots] > W_t$ , then the process is called a sub martingale. This means the process has a tendency of increasing. A set  $\pi = [W_{t-1}, W_{t-2}, \dots]$  is called a **Filtration**.

If  $W_t$  is the asset's price at time  $t$ , then it means that tomorrow's price is expected to be equal to today's price, given the historical asset's price. The forecasting meaning following the martingale hypothesis implies that the "best" forecast of tomorrow's price is simply today's price.

### 2.2.1 Benchmark

The Benchmark model is simply the expected value which is:

$$E[W_t|W_{t-1}, W_{t-2}, \dots] = \mu$$

All models will be Benchmarked to this model.

### 2.2.2 Auto regressive model (AR(d))

An AR(d) model represents a time series as a linear function of its past values, The order (d) of an AR model tells how many lagged past values are included.

$$E[W_t|W_{t-1}, W_{t-2}, \dots] = \beta_0 + \sum_{j=1}^d \beta_j W_{t-j}$$

Where  $\beta_0 = W_t - \bar{W}$

and

$\beta_1, \beta_2, \dots, \beta_d$ , are the regression coefficients on lag 1, lag 2, up to lag d.

The number (2) in the model indicates the lags and is determined by the minimization of the information criteria.

### 2.2.3 Auto regressive polynomial model (PN(d,m))

The PN model is almost similar to the AR(d) model discussed above it expresses a time series as a linear function, but with the PN mode it have the order (d) which tells us how many lagged past values are included and an order (m) which tells us the highest order of the exponential.

$$E[W_t|W_{t-1}, W_{t-2}, \dots] = \beta_0 + \sum_{j=1}^d \sum_{i=1}^m \beta_j W_{t-j}^i$$

where  $\beta_0 = W_t - \bar{W}$  and  $\beta_j, j = 1 \dots d$  are the regression coefficients on lag 1, lag2, up to lag d of order m.

The number of lags and the highest order of the exponential term are selected by having relatively more vital parameters and good forecasting performance among preliminary regression.

#### 2.2.4 Artificial neural network (NN(d,q))

In numerous literature the NN(d,q) model have been famous in forecasting financial time series. The basic development of neural network puts together a lot of functions through the multilayer structure, usually there exist a hidden layer between inputs and outputs. In this project we have used a single layer neural networks, which is quite basic and less complicated but widely used in the area of finance and as well as economics.

The logic is that the non-response variable simultaneously activate the units in the intermediate layer via some functions  $\Upsilon$  and the output is produced via some functions  $\varphi$ . the following equations shortens this process:

$$h_{i,t} = \Upsilon(\gamma_{i0} + \sum_{j=1}^m \gamma_{ij} X_{j,t}) \quad i = 1, \dots, q$$

$$W_t = \varphi(\beta_0 + \sum_{i=1}^q \beta_i h_{i,t})$$

where,  $X_{j,t}$  is an independent variable, while  $h_{i,t}$  is the the node or hidden unit in the hidden layer and  $W_t$  is the dependent variable.

The coefficients of the NN(d,q) are estimated using the nonlinear least squares through the Newton-Raphson algorithm.

$$E[W_t|W_{t-1}, W_{t-2}, \dots] = \beta_0 + \sum_{j=1}^d \beta_j W_{t-j} + \sum_{i=1}^q \delta_i G(\gamma_{0i} + \sum_{j=1}^d \gamma_{ji} W_{t-j})$$

where,

$$G(z) = (1 + e^{-z})^{-1}, \text{ which is a function of } \Upsilon.$$

In this model NN(2,5), the number 2 represents lags and the number 5 represents the node in the hidden layer and this number are chosen simply based on preliminary estimations, by preliminary we mean to utilize this combination of parameters to run the estimations on several randomly selected countries for certain periods and this combination produces at least an optimal performance compared to other combinations.

### 2.2.5 Nonparametric regression model (NP(k,m))

The non linearity in the expected value may be very complicated and cannot be showed explicitly, it is pleasing to use the non parametric regression to estimate the model without specifying the forms of functions. In general, can be expressed as,

$$E[W_t|W_{t-1}, W_{t-2}, \dots] = g(W_{t-1}, W_{t-2}, \dots, W_{t-j})$$

As stated earlier with respect to the non parametric estimator  $g(\cdot)$  can be estimated by local linear regression. At each point  $W_t = [W_{t-1}, W_{t-2}, \dots, W_{t-j}]$ , we approximate  $g(\cdot)$  locally by a linear function  $g(W) = a + (W - y)'b$ . Or simply approximating  $g(W)$  locally by a constant function  $g(W) = a$  which is relatively simple to implement and useful in the area of applied research. The local constant estimator at point  $y$  is given by  $g(W) = b$ , where  $b$  minimizes the sum of local weighted squares:

$$\sum_{t=1}^N [W_t - a]^2 \prod_{s=1}^j K_{hs}(W_{t-s} - w_{t-s})$$

Where,

$$\prod_{s=1}^j K_{hs}(W_{t-s} - w_{t-s})$$

Is the product kernel,  $K_{hs}(\cdot)$  is the univariate kernel function and  $h = (h_1, \dots, h_j)$ .

The denotation of the model as NP(k,m), where the parameters (k,m) are crucial to the forecasting performance of this model.

The number (500) is the regression length, this is so because the non-parametric estimation says that the number of observations used in the in-sample estimation must be big enough, so we somehow arbitrarily chose this number which seem reasonable large enough. The number (25) indicates the forecasting evaluation length.

### 2.2.6 Results and interpretation of the AR(d), PN(d,m), NN(d,q), NP(k,m)

The table below shows empirical result from the models and each of the result is compared to the Benchmark model. The interpretations follows right after the table.

Currency	Benchmark	AR(2)	PN(2,4)	NN(2,5)	NP(25,500)
Australian dollar	0.163	0.163	0.161	0.162	0.160
Botswana pula	0.805	0.805	0.801	0.800	0.801
British pound	22.834	22.828	22.877	22.895	22.794
Canadian dollar	0.149	0.149	0.146	0.148	0.146
Denmark krone	0.767	0.765	0.766	0.759	0.767
Euro	10.299	10.299	10.278	10.286	10.288
Indian rupee	5.992	5.973	5.998	6.068	6.018
Japanese yen	13.078	13.059	13.067	13.098	13.121
Sweden krona	0.946	0.945	0.945	0.938	0.953
Switzerland franc	0.148	0.148	0.149	0.152	0.161
US dollar	8.479	8.453	8.466	8.449	8.512
Zambian Kwacha	458.930	458.536	458.546	458.750	458.805
SDR	12.420	12.325	12.521	12.346	12.463

We clearly observe from the table that:

- The Australian dollar satisfies the martingale property only with an AR model, while with PN, NN and NP it satisfies the super martingale property.” **this currency has a tendency of depreciating**”.
- The Botswana Pula satisfies the martingale property with an AR model, while with PN, NN and NP models it satisfies the super Martingale property.” **this currency has a tendency of depreciating**”.
- The British pound satisfies the super martingale property with an AR and NP models, while with PN and NN models its satisfies the sub martingale property.” **this currency has a tendency of appreciating**”.
- The Canadian dollar satisfies the martingale property with an AR model, while with PN, NN, NP models it satisfies the super martingale property.” **this currency has a tendency of depreciating**”.
- Denmark krone satisfies the super martingale property with an AR, NN and PN models, while with NP it satisfies the martingale property.” **this currency has a tendency of depreciating**”.
- The Euro satisfies the martingale property with an AR model, while with PN, NN, and NP models, it satisfies the sub martingale property ”**This currency has a tendency of Appreciating**”.
- The India ruppee satisfies the super martingale property with an AR model, while with the PN, NN, NP models it satisfies the sub martingale property.” **this currency has a tendency of appreciating**”.

- The Japanese yen satisfies the super martingale property with an AR and PN models, while with the NN and NP it satisfies the sub martingale property.” **this currency has a tendency of appreciating”**.
- The Sweden krona satisfies the super martingale with an AR, PN and NN models, while it satisfies the sub martingale property with the NP models.” **this currency has a tendency of depreciating”**.
- The Switzerland franc satisfies the martingale property with an AR model, while it satisfies the sub martingale property with the PN, NN, NP models.” **this currency has a tendency of appreciating”**
- The US dollar satisfies the super martingale property with an AR and PN, NN model, while with NP model it satisfies the sub martingale property.” **this currency has a tendency of depreciating”**
- The Zambian Kwacha satisfies the super martingale property with all the models, that is AR, NP, NN and PN models,”**This currency has a Strong tendency of depreciating”**.
- The SDR satisfies the super martingale property with an AR and NN models, while with the PN and NP it satisfies the sub martingale property.” **this currency has a tendency of depreciating”**.

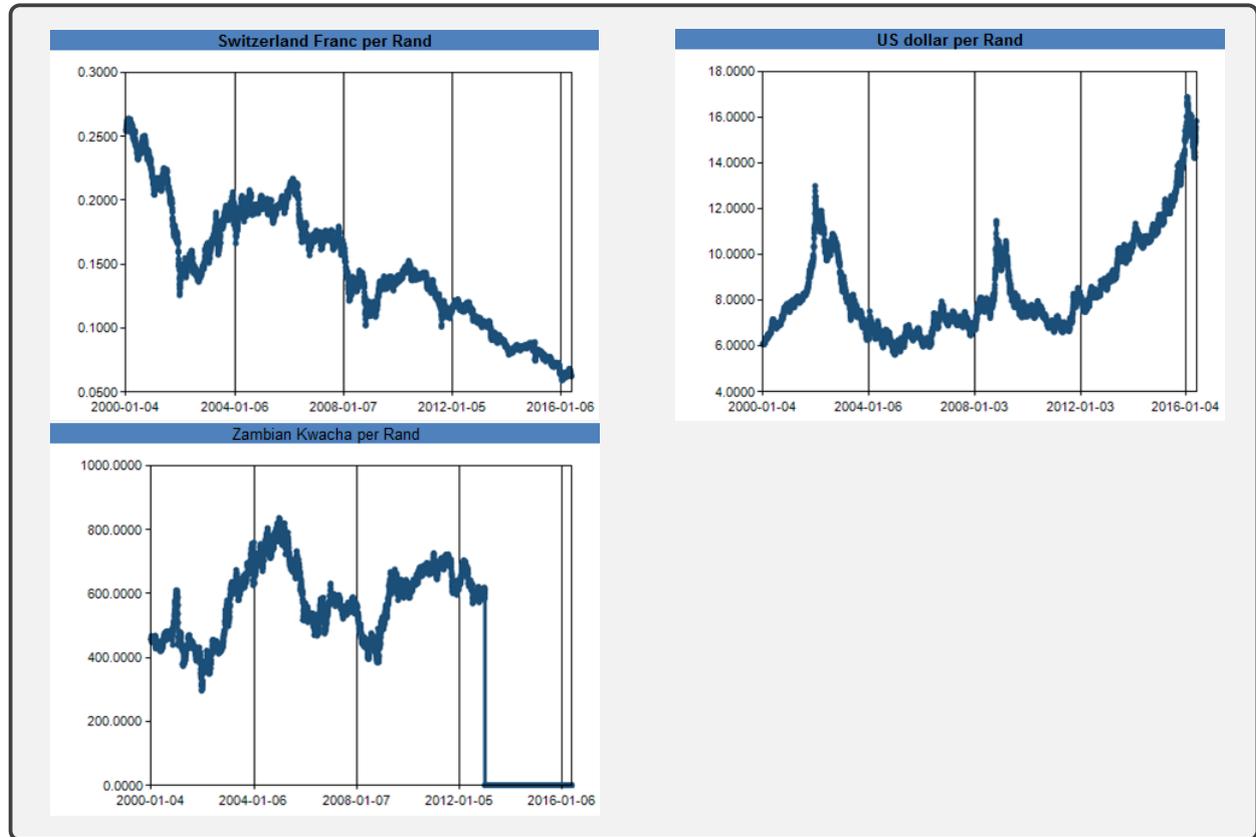
Despite this evidence on the exchange rates, it again remain a possibility that the exchange rates movements may be related to the central bank interventions, its important to note that some central banks my not take part in in all policy interventions. Hence, we do not expect the central bank market intervention to affect all bilateral exchange rates.

### 3 Graphical representations

The graphs below depicts the historical daily movements of the currencies indicated per Rand, since 2000-01-04 to 2016-06-30. The graphs indicate non-stationary time series and martingale properties. How appreciation and depreciation has been occurring among different exchange rates with respect to the Rand.

For example we observe a very drastic depreciation in the Zambian kwacha between the time period interval of [2012,2016], An appreciation in the US Dollar in the time period interval of [2012,2016]. All the graphs show a very high volatility among Rand exchange rate movements.





## 4 Conclusion

In this paper, we have attempted to investigate the stochastic behavior of 13 major rand exchange rates. Quite various models are used to capture the potential behavior of the rand exchange rate, the models includes, the variance ratio test, Rank and sign-based random walk test, Autorgressive model (AR(D)), Autoregressive polynomial model(PN(d,m)), Artificial neural network(NN(d,q)) and non-parametric regression model (NP(d,m)). The data used is the daily exchange rates.

Typical statistical criterion are used to reject or fail to reject the random walk hypothesis, In addition the martingale properties are used to describe the exchange rate tendencies. Exchange rates are simply just prices, like prices of other products. Here, we are just buying currencies with currencies and their prices are likely to change just like prices of other products in the market. However, protecting ourselves from exchange rates movement, we can use financial instruments such as forward contracts, futures contract options, ceilings, floors and swap. All these instruments aim to lock in a price that we will trade or purchase with

in the future irrespective of the changes in currencies that are involved in the transactions. We further discussed the results and interpretations of our empirical findings. We further demonstrated evidence with regards to the previous movement or trends of Rand daily exchange rates by means of line graphs for the past almost 16 years.

Traders and speculators from a number of banks and other financial institutions have probably performed technical-analysis training to acquire the skills needed to benefit from reading foreign-exchange trade volumes and price changes. As stated above, Predictability of asset returns has immediate positive effect for investment practitioners and far reaching ideas for the efficiency of asset prices in capital budgeting and a profitable trading strategy may be realized by a small number of successful forecasts for which huge profits are made.

The application of this study is limited to the Southern African countries, particularly the South African foreign exchange market and Namibian foreign exchange market, due to the one-to-one link of the Namibian Dollar to the South African Rand.

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