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Modified R/S and DFA Analyses of Foreign Exchange Market Efficiency under Two Exchange Rate Regimes: A Case Study of Iran

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Abstract

Abstract: Based on efficient market hypothesis, financial markets are impossible to forecast. The purpose of this paper is to examine the weak-form efficiency of the Iranian foreign exchange rate (defined by the Rial/Dollar) during time period 1999:25:01 to 2010:17:06 from long memory viewpoint. For this, we have employed three methods of scaling analysis including classical rescaled range (R/S) analysis, modified rescaled range (M-R/S) analysis and detrended fluctuation analysis (DFA). We have divided the time period into two sub-periods, 1999:25:01-2002:21:03 and 2002:21:03-2010:17:06. In the former time period, Iran had a fixed exchange rate regime and in the latter period, the country followed a managed floating exchange rate regime. The obtained results from these methods are not the same. To achieve more explicit conclusions, we've used two more widely applied econometric tests namely augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test to determine whether or not the time series under consideration behave as random walk consistent with the weak-form efficiency. The findings indicate that the result of DFA is in line with the econometric approach. We conclude that the Iranian foreign currency market at the first sub-period is less efficient relative to the second sub-period. Another important result is that relying on only one method to make a conclusion about market efficiency may be very misleading. Therefore, one should first carefully select more reliable methods and then compare their results to achieve a reliable conclusion.

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1. INTRODUCTION

The Efficient Market Hypothesis (EMH) originally proposed by Fama (1970) states that prices fully reflect all available information. In an informationally efficient market, the relevant information is not ignored, and systematic errors are not made (Neely and Weller, 2011). The EMH is in direct contrast to Keynes's belief that a freely flexible market price system can generate psychological beliefs creating volatility in market evaluations of financial assets which can then violently depress the real economy (Davidson, 2003).

The analysis of the foreign exchange market efficiency has been a predominant subject for financial economists. The question of currency market efficiency is important. Exchange rates have a penetrating effect on all other prices. If the currency market is inefficient, currencies are often incorrectly priced. This distortion will spread overall other markets, and it causes misallocation of resources that leads eventually to welfare losses. On the other hand, inefficiency in currency markets can lead to excessive exchange rate volatility. Exchange rate volatility is inevitable whenrates float, but excess exchange rate volatility increases the exchange rate risk and may decrease the flow of trade and investment(Boulter, 2007).

From a practical point of view if the foreign exchange market is inefficient, the speculators can engage in profitable foreign exchange transactions and use various tools such as trading rules and statistical techniques to forecast the future exchange rates. The weak-form EMH, which is the focus of this paper, asserts that a speculator or an arbitrageur cannot make use of past exchange rates to predict future exchange rates.

According to empirical studies it is clear that after decades of research, the literature has not reached to an explicit conclusion concerning the validation of weak-form efficiency. Some studies contradict the weak-form of currency market efficiency and imply that the past exchange rates can be used to predict future returns of the exchange rates(e.g. Fama, 1984; Baillie and Bollerslev, 1989; Ajayi and Karemera, 1996; Lee andMathur, 1996; Neelyet al., 1997; Zivot, 2000;Strozzi and Zaldivar, 2005; Wickremasinghe, 2008; Gradojevic et al., 2010). On the other side, there are another studies that confirm the validity of the weak-form of the efficient market hypothesis for foreign exchange market as an evidence against the predictability of exchange rates(e.g. *Cornell* and *Dietrich*, 1978; Mac Donald and Taylor, 1989; Coleman, 1990; Copeland 1991; Lajaunie and Naka, 1992; Wu and Chen, 1998; Rapp and Sharma, 1999; Noman and Ahmed, 2009; Serbinenko and Rachev, 2010; *Wong*and Ahmad, 2011).

There are at least two reasons for this. First reason is the diversity of empirical methods to test market efficiency. It has seen that different methods some times lead to different results about market efficiency even for one market. For example, Naka and Whitney(1995) studied the EMH for seven exchange rates (against US dollar) from 1974:1 to 1991:4. OLS estimation rejected the EMH; but in contrast, Non-Linear Least Square estimation accepted this hypothesis. Therefore, it is necessary that the researcher carefully select methods and then control key parameters in selected methods, and compare the result obtained from alternative methods to achieve a reliable conclusion.

Another reason is related to the different degree of markets development. In most of the empirical studies, emerging markets show weaker evidence of informational efficiency than developed markets (See Crato, 1994; Cheung et al., 1995; Panas, 2001; Wright, 2001; Podobnik et al., 2006). It's not surprising, because emerging markets differ from developed ones in some important categories such as size, liquidity, transparency, trading costs and operational efficiency (Levich, 2001). For example Oh et al. (2007) investigated the relative market efficiency in foreign exchange markets using the global foreign exchange market indices for 17 countries two periods from 1984 to 1998 and from 1999 to 2004. The results suggested that the foreign exchange markets with a larger liquidity such as European and North American markets have higher market efficiency than those with a smaller liquidity such as the African and Asian markets except Japan.

The structure of the paper is as follows. Section 2 reviews literature. Section 3 outlines the methodology and data. Specifically, R/S, M-R/S, DFA techniques and unit root tests are presented in this section. Section 4 presents empirical results and some discussions about the validity of the EMH in weak-form for Iranian foreign exchange market (US Dollar against Iranian Rial) and section 5 concludes the paper.

2. Literature review

The origin of efficient market literature can be traced back to French mathematician, Louis Bachelier (1900). However, the organized presentation of EMH has been attributed to Eugene Fama. In 1970, Fama published his now-famous paper, "Efficient Capital Markets: A Review of Theory and Empirical Work". He helped to the focus and direction of future research by defining three different forms of market efficiency depending on the specification of the information set: weak-form, semi-strong form, and strong form.

Weak-form efficiency: The weak-form of market efficiency states that all past prices are reflected in the today's price on the market. This basically means that it is not possible to get any significant advantage on the market by analyzing past prices only, as it is done in the case of technical analysis[1].

1.Technical analysis is the use of past price behavior to guide trading decisions in asset markets. These decisions are often generated by the application of simple rules to historical

However, fundamental analysis[1] can be successfully applied(Serbinenko and Rachev, 2009).

In fundamental analysis one try to forecast future price trends by studying macroeconomic fundamentals such as inflation, interest rate, GDP and money supply.

The weak-form foreign exchange market efficiency can be investigated in forward market and spot market.

According to forward market efficiency, the forward exchange rate should be an unbiased predictor of the future spotexchange rate. The forward rate unbiasedness can be tested by regressing the change in exchange rate on the difference between the forward and spot rate such that using the following equation:

$$\Delta r_{t+k} = \alpha + \beta(f_{t,k} - r_t) + \varepsilon_{t+k} \quad (1)$$

Δr_{t+k} denotes the change in the logarithm of the spot price over *k* period. $f_{t,k}$ is the logarithm of the k-period forward rate, i.e. the rate agreed now for an exchange of currencies k-periods ahead. r_t isthe logarithm of the spot exchange rate at time *t* and ε_{t+k} is a disturbance term. foreign exchange market efficiency is considered to hold if estimates of α and β are not significantly different from zero and unity [4].

Since a forward market has not yet been developed in Iran and as a result the forward exchange rate is absent, so this category cannot be used for testing the efficiency of the foreign exchange market of Iran. Spot market efficiency can easily be tested using historical data and studying the predictability in asset returns through correlations (Couillard and Davison, 2005). The null hypothesis is that changes in spot exchange rates are serially uncorrelated. In other words, the question is whether the spot exchange rate behaves as a random walk.

The weak-form tests are concerned with the forecast power of past returns (fama, 1991). If it is found out that the market is weak-form efficient, investors can examine the history of past exchange rates to predict future exchange rates and reap profits simply by purchasing currencies that are predicted to increase in price and by selling those currencies that are predicted to fall in price.

*Semi strong-form efficiency:*In a semi-strong efficient market, prices reflect all publicly available information about economic fundamentals.

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price data. Although modern technical analysis was originally developed in the context of the stock market, but since the era of floating exchange rates began in the early 1970s, this approach has been widely adopted by foreign currency traders (Beechey et al, 2000).

1. In fundamental analysis one try to forecast future price trends by studying macroeconomic fundamentals such as inflation, interest rate, GDP and money supply.

Therefore, it is not possible for any investor to earn abnormal returns using any publicly available information. In this level of efficiency, neither fundamental nor technical analysis can systematically produce abnormal returns.

Strong-form efficiency: In highest level of efficiency, no investor can earn excess return by using any information available, whether it is private or public information. In another words, while semi-strong form efficiency precludes the profitability of both technical and fundamental analysis, strong form implies that even with privileged information one cannot expect to earn excess returns. This extreme form serves mainly as a limiting case. *Grossman and Stiglitz*(1980) asserted that *strong form* efficient markets are not possible. They identified a major theoretical problem with the hypothesis termed the *paradox of efficient markets*, which they developed in the context of equity markets. As applied to the foreign exchange market, the Grossman and Stiglitz argument starts by noting that expectations about fundamentals like national price levels, interest rates and public debt levels determine exchange rate returns but that information about these fundamentals is costly for traders to gather and analyze. On the other hand, the traders would not be able to make excess returns on fundamental information in perfectly efficient markets(Neely and Weller, 2011). In this situation, they will have no incentive to gather and analyze information. It follows that if no agent is willing to pay for the information, then the exchange rates will not reflect all available information. Hence, markets cannot be perfectly efficient and exchange rates will not always be exactly where fundamentals suggest they should be (Neely and Weller, 2011).

Since the early 1970s there has been a global trend for governments to replace the Bretton Woods system of fixed exchange rates with a system of floating exchange rates. Indeed, if the value of exchange rates is fixed the currency market will be efficient in weak-form, since expected profits are on average equal to zero; but the exchange rate dynamics is disconnected from its fundamentals, and so (semi)strong version of the EMH does not hold in the fixed exchange rate market (Bouveret and Filippo, 2009).

The market efficiency (especially in the weak form) usually holds in many highly developed economies but usually has been violated in transition (developing) economics (Tenenbaum et al., 2010). Even if an emerging market is efficient, the reason for this efficiency is likely to be different than for an efficient developed market. Two implications for foreign exchange market efficiency are cited in the academic literature. First reason related to informed traders. Many suppose there to be two types of trader in the market: informed traders and noise traders. Informed traders are rational agents that decide by their expectations about future underlying fundamentals and so keep the exchange rate in line with macroeconomic fundamentals and help stabilize markets around a new equilibrium. Noise traders make their decisions on the basis of trends and/or fads unrelated to fundamentals. Noise traders are not able to distinguish between real and pseudo signals, and therefore they are destabilizing speculators. Currency market efficiency in developed markets may result from the dominant position of informed traders. In developed markets, informed traders are usually more numerous relative to noise traders.Consequently, the noise traders lose money to informed traders and so eventually disappear from the market1.

In contrast to developed markets that efficiently functions without any intervention, efficiency in emerging currency markets (if it holds) is likely due to official intervention. When the noise traders are more active than the informed traders, the currency market cannot function efficiently. In this case, a central bank may play the role of informed traders, act as a stabilizing speculator and lead the market to efficiency(Abounoori et al., 2012).The efficiency caused by official intervention could be temporary and when for any reason this intervention is put aside inefficiency appears again.

3. Data and Methodology

3.1. Data

Data used in this paper includes daily spot exchange rates between US dollar (USD) and Iranian Rial (IRR) for the period from 1999:25:01 to 2010:17:06. The number of observations is 3400. The time period has been divided into two sub-periods including 1999:25:01-2002:21:03 that is period of fixed exchange rate regime and 2002:21:03-2010:17:06 that is period of managed floating exchange rate regime. The data has been collected from the Economic Statistics Department of the Central Bank of Iran as the most reliable source of major economic statistics in Iran. For the former period that official exchange rates were fixed, unofficial Rial/Dollar Exchange Rate series have been used. Also, in the latter one there was no considerable difference between official and unofficial Rial/Dollar exchange rates.

Let y_t denote the Rial/Dollar exchange rate at time t. The return r_t at time t is given by the logarithmic difference between consecutive daily exchange rates:

$$r_t = \ln\left(\frac{y_t}{y_{t-1}}\right) \quad (2)$$

Fig. 1and Fig. 2 show Rial/Dollar daily exchange rates and log returns of Rial/Dollar daily exchange rates during sub-periods 1999:25:01-2002:21:03 and 2002:21:03-2010:17:06 respectively. As shown in Fig. 1(a), over the

1. For more detail see Kaltenbrunner and Nissanke, 2009.

first time period, the Rial/Dollar exchange rate at first increases, then decreases and finally remain almost constant. According to Fig. 2(a) the series generally increases during the second time period. Although these observations don't give any information about the market efficiency, but through them one may identify recurring patterns. For more details, Fig. 1(b) shows the return of exchange rate during the considered period. Based on this figure, it seems that whenever the exchange rate increases, it is more likely that it will decrease in the close future, but in contrast, according to Fig. 2(b) it does not seem any recurring patterns. One may not able to identify this from two latter Figures, but if carefully examined, the time series of exchange rate returns, the validity of this statement is clear. This may indicate that the Iranian foreign currency market at the first period is rather inefficient but at the second period it has become more efficient. However, more exact judgment is deferred to section 4.

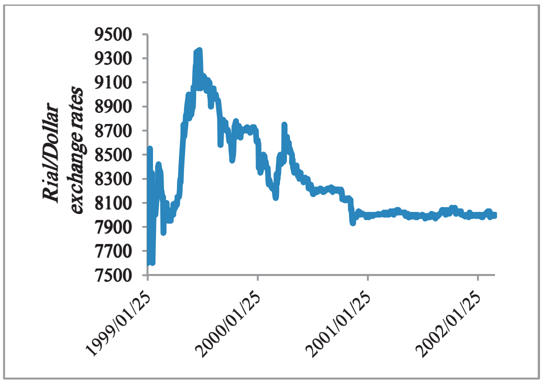

Figure 1(a): Rial/Dollar daily exchange rates from 1999:25:01 to 2002:21:03

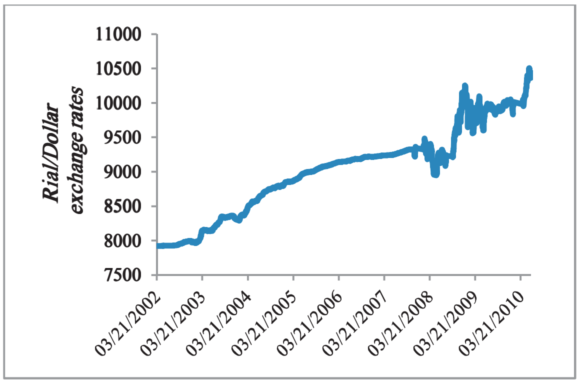

Figure 2(a): Rial/Dollar daily exchange rates from 2002:21:03 to 2010:17:06

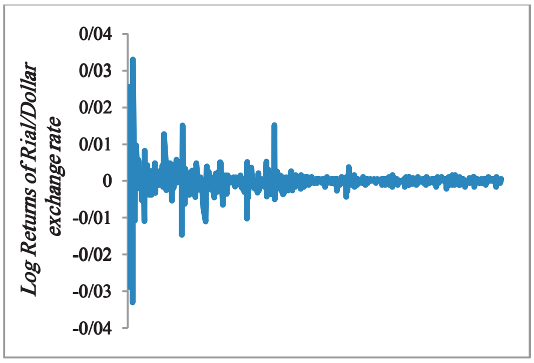

Figure 1(b): log returns of Rial/Dollar dailyexchange ratesfrom 1999:25:01 to 2002:21:03

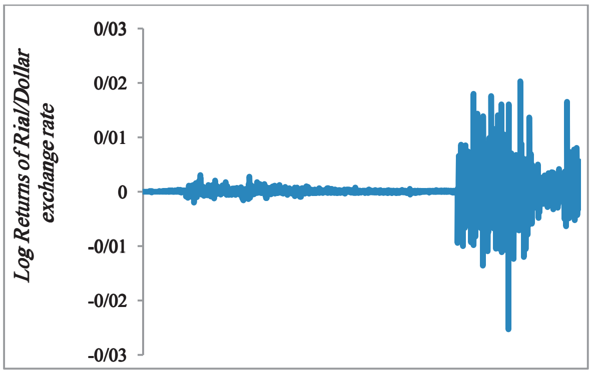

Figure 2(b): log returns of Rial/Dollar daily exchange rates from 2002:21:03 to 2010:17:06

3.2. Methodology

In this paper, we first employ three methods that are common in econophysics literature, namely, Rescaled Range Analysis (R/S), Modified Rescaled Range Analysis (M-R/S) and Detrended Fluctuation Analysis (DFA), to evaluate market efficiency from long memory viewpoint. Then, to achieve more explicit conclusion, we carry out two widely applied econometric approaches, namely, Augmented Dickey-Fuller (ADF) and Phillips-Perron(PP) to examine whether or not the studied time series behave as a random walk.

3.2.1. Rescaled Range Analysis (R/S analysis)

The Rescaled Range Analysis or R/S Analysis is a technique to test presence of long-range correlations in empirical time series and was developed by Hurst (1951)while working as a water engineer in Egypt. The Presence of long memory widely used as an evidence against weak-form of market efficiency (e.g. Barkoulas and Baum, 1996; Cajueiro and Tabak, 2004; Jagric et al., 2005; Podobnik et al., 2006; Tabak and Cajueiro, 2007; Wang et al., 2009; Onaliand Goddard, 2011). It implies that the market does not immediately respond to an amount of information flowing into the financial market and past price changes can be used as significant information for the prediction of future price changes (Oh et al., 2006).

We first start with a time series in prices of length M. This time series is then converted into a time series of logarithmic returns of length N=M-1such that

$$N_i = \log\left(\frac{M_{i+1}}{M_i}\right) \qquad i = 1,2,3,...,M-1 \tag{3}$$

We divide this time period into A contiguous sub-periods of length nsuch that A.n=M. Each sub-period is labeled I_a with $a = 1,2,...,A$. Then, each element in I_a is labeled $N_{k,a}$ such that $k = 1,2,...,n$. For each sub-period I_a the average is calculated as

$$e_a = \frac{1}{n}\sum_{k=1}^{n} N_{k,a} \tag{4}$$

Then, we calculate the time series of *accumulated departures from the mean* $X_{k,a}$ for each sub-period I_a, defined as

$$X_{k,a} = \sum_{i=1}^{k}\left(N_{i,a} - e_a\right) \qquad k = 1,2,...,n \tag{5}$$

The range R_{I_a} is defined as the difference between the maximum and minimum $X_{k,a}$:

$$R_{I_a} = \max(X_{k,a}) - \min(X_{k,a}) \qquad 1 \le k \le n \tag{6}$$

The next step is to calculate the standard deviation for each sub-period I_a,

$$S_{I_a} = \sqrt{\frac{1}{n}\sum_{k=1}^{n}\left(N_{k,a} - e_a\right)^2} \tag{7}$$

Each range R_{I_a} is standardized by corresponding standard deviation S_{I_a} and forms the rescaled range as

$$\left(R/S\right)_{I_a} = \left(\frac{R_{I_a}}{S_{I_a}}\right) \tag{8}$$

The process is repeated for each sub-period of length *n*. The average R/S value for length n is

$$\left(R/S\right)_n = \frac{1}{A}\sum_{a=1}^{A}\left(\frac{R_{I_a}}{S_{I_a}}\right) \quad (9)$$

Hurst found that the observed rescaled range, R/S, is very well described for a large number of natural phenomena by the following empirical relation:

$$\left(R/S\right)_n \propto n^H \quad (10)$$

H is called *Hurst exponent*(Matos et al., 2004). By performing a least-squares regression with $Log\left(R/S\right)_n$ as the dependent variable and $Log\ n$ as the independent one, where a straight line is observed we find the slope of regression which is the estimate of Hurst exponent (Skjeltorp, 2000). H can be interpreted as:

- If $H = 0.5$ the time series is independent and there is no correlation at all and the time series represent a random walk. This is an evidence for market efficiency.
- If $0.5 < H < 1$, persistent long-range correlations are present in the time series. This implies that if the series have been up or down in the last period then the chances are that it will continue to be up or down, respectively.
- If $0 < H < 0.5$, anti-persistent long-range correlations are present in the time series. This means that whenever the time series have been up in the last period, it is more likely that it will be down in the next period. Like any empirical technique, Rescaled range analysis has shortcomings. The most well-knownweakness of Rescaled range analysis is that it is sensitive to short-range correlations which can bias the estimate of H. Financial time series of high frequency (daily or more frequent observations) generally exhibit significant autoregressive tendencies. The effect of short-term dependence upwardly biases the empirical estimates of the Hurst exponent and then it is accumulated to accept that there is a long-term dependence process in a time series(Skjeltorp, 2000).

3.2.2. Modified Rescaled Range Analysis(M-R/S Analysis)

As classical R/S analysis presented above is biased by a presence of short-term memory, Lo and MacKinlay (1991) proposed Modified Rescaled Range (M-R/S) Analysisand indicated that M-R/S is *able* to *distinguish* between *short*-range and long-range dependence. (M-R/S) differs from (R/S) only in its denominator, which includes the autocovariances and is the square root of a consistent estimator of the partial sum's variance (Lo and MacKinlay, 1999). The proposed rescaled range is:

$$\left(M-R/S\right)_{I_a}=\frac{1}{\sigma_a(q)}\left(\max\sum_{j=1}^{k}(N_{j,a}-e_a)-\min\sum_{j=1}^{k}(N_{j,a}-e_a)\right)\qquad 1\le k\le n \tag{11}$$

Where

$$\sigma_a{}^2(q)=\frac{1}{n}\sum_{j=1}^{n}(N_{j,a}-e_a)^2+\frac{2}{n}\sum_{j=1}^{q}w_j(q)\left(\sum_{i=j+1}^{n}(N_{j,a}-e_a)(N_{i-j,a}-e_a)\right) \tag{12}$$

$$w_j(q)=1-\frac{j}{q+1}\qquad q<n$$

where q is the number of lags. For q = 0, one get the original definition of the rescaled range.

3.2.3. Detrended Fluctuation Analysis (DFA)

Detrended fluctuation analysis (DFA) is a scaling analysis method used to quantify long-range power-law correlations in signals (Chen et al., 2002). The DFA was firstly proposed by Peng et al. (1994) while examining series of DNA nucleotides. The advantage of DFA over older method of R/S is that it removes local trends through the least-squares regression fit and is relatively immune to non-stationarity(Peng et al., 1995). Therefore, DFA permits the detection of long-range correlations embedded in non-stationary series, avoiding the spurious detection of apparent long-range correlations that are artifacts of non-stationarity(Hu et al., 2001).

In DFA technique one divides a time series *y(t)* of length *N* into *N/n* equal size non overlapping boxes. The variable *t* is discrete, evolves by a single unit at each time step between *t=1* and *t=N*. Let each box contains n points and *N/n* be an integer. The local trend in each *n*-size box is assumed to be linear, i.e. it is taken as

$$z(t)=at+b \tag{13}$$

In each *n*-size box one next calculates the root mean square deviation between *y(t)* and *z(t)*. Detrended fluctuation function $F^2(n)$ is then calculated as follows:

$$F^2(n)=\frac{1}{n}\sum_{t=kn+1}^{(k+1)n}\left|y(t)-z(t)\right|^2\qquad k=0,1,2,...,(\frac{N}{n}-1) \tag{14}$$

Averaging $F^2(n)$ over all *N/n* box sizes centered on time *n* gives the fluctuations $\left\langle F^2(n)\right\rangle$ as a function of *n*. The calculation is repeated for all possible different values of *n* (Vandewalle et al., 1997). According to Peng et al. (1994) an empirical relation is expected as

$$\left\langle F^2(n)\right\rangle^{\frac{1}{2}}\sim n^H \tag{15}$$

By performing a least-squares regression with $\log(\langle F^2(n)\rangle^{\frac{1}{2}})$ as the dependent variable and $\log n$ as the independent one, where a straight line is observed we find the slope of the regression which is the estimate of the scaling exponent. Scaling exponent from DFAcan be interpreted exactly similar to Hurst exponents from R/S and M-R/S as mentioned above.

3.2.4. Augmented Dickey-Fuller test

Unit root tests can be used to determine if the series is nonstationary as a necessary condition for a random walk (Worthington et al., 2004). ADF and PP *tests widely* applied to investigate whether a time series behave as a *random walk or not (e. g.* Worthington, 2004; Chaudhuri et al., 2003; Serbinenko and Rachev, 2009; Noman and Ahmed, 2009*).*

The weak-form of the efficient market hypothesis is associated with the *random walk theory*, which is used in the finance literature to characterize a price series where subsequent price represent random departures from previous price(Malkiel, 2003).

Formally, an asset price time series y_t is described as simple random walk as follows:

$$y_{t+1} = y_t + \mu_{t+1} \qquad \mu_{t+1} \sim i.i.d.(0,\sigma^2) \qquad (16.a)$$

$$E(y_{t+1}) = y_t \qquad (16.b)$$

where y_{t+1} and μ_{t+1} respectively are the price and random error term at time *t+1*. Equation (16) states that the best forecast of the asset price at time *t*+1 is the price at time *t*, which in turn implies that the expected gain or loss for any holding period is zero. Therefore, analysis of past prices is meaningless because patterns observed in the past occurred purely by chance.

On the other hand, weak-form efficiency states that the current information set I_t is immediately reflected in asset prices and *since* future *information* is presently *unknown* and unpredictable, the best predictor of tomorrow's price, which can be made on the information set I_t, is today's price. In other words, Expected value of the asset price at time t+1 is equal to the asset value at time t.

Thus, price movements in a weak-form efficient market occur randomly and successive price changes are independent of one another. The Augmented Dickey-Fuller (ADF) test proposed by Dickey and Fuller (1979) is carried out by estimating the following equation:

$$\Delta x_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 T + \sum_{i=1}^{k} \beta_i \Delta x_{t-i} + \varepsilon_t \qquad (17)$$

Where Δ is first difference operator, X is time series variable, T is time trend, k is the number of lags and ε is the error term. The null Hypothesis that the series contain unit root ($H_0 : \beta_1 = 0$) is tested against the alternative Hypothesis ($H_1 : \beta_1 < 0$) that the series is stationary. If one can't *reject*the *null hypothesis*, the series follows random walk.

3.2.5. Phillips-Perron test

Phillips and Perron (1988) have suggested an alternative to the ADF test. The Phillips-Perron (PP) unit root test differs from the ADF test mainly in how they deal with serial correlation and heteroskedasticity in the errors. In particular, where the ADF tests use a parametric autoregression to approximate the ARMA structure of the errors in the test regression, the PP tests ignore any serial correlation in the test regression (Zivot and Wang, 2003). The PP test is done by estimating the following regression:

$$\Delta x_t = \alpha_0 + \alpha_1 x_{t-1} + \alpha_2 T + \mu_t \qquad (18)$$

Where Δ is the first difference operator, X is the time series variable, T is time trend, α_0, α_1 and α_2 are the parameters and μ is the error term. Similar to ADF, The null and alternative hypotheses are respectively $H_0 : \alpha_1 = 0$ and $H_1 : \alpha_1 < 0$.

4. Empirical results and discussions

In this section, we present the results of R/S, M-R/S, DFA techniques and Unit root tests.Fig. 3 and Fig. 4 show the estimation of the Hurst exponents for the periods 1999:25:01-2002:21:03 and 2002:21:03-2010:17:06, respectively.

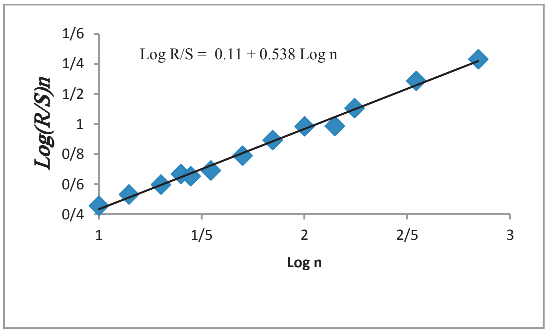

Figure 3(a): Estimation of the Hurst exponent based on the R/S technique for the period: 1999:25:01-2002:21:03

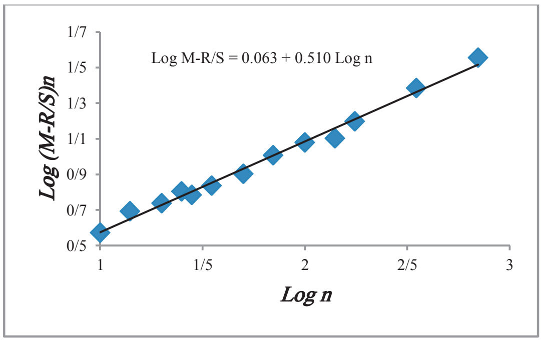

Figure 3(b): Estimation of the Hurst exponent based on the M-R/S technique for the period: 1999:25:01-2002:21:03

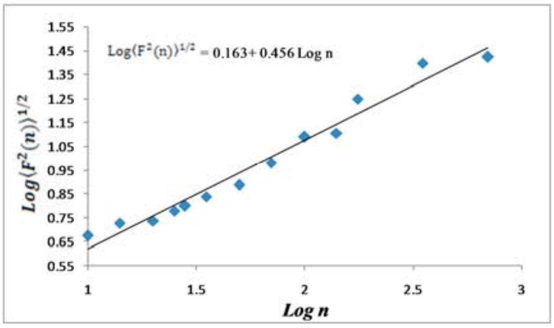

Figure 3(c): Estimation of the Hurst exponent based on the DFA technique for the period: 1999:25:01-2002:21:03

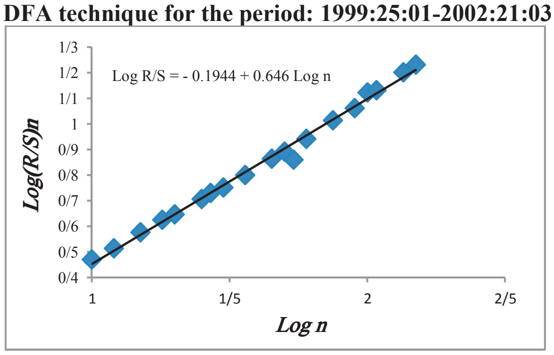

Figure 4(a): Estimation of the Hurst exponent based on the R/S technique for the period: 2002:21:03-2010:17:06

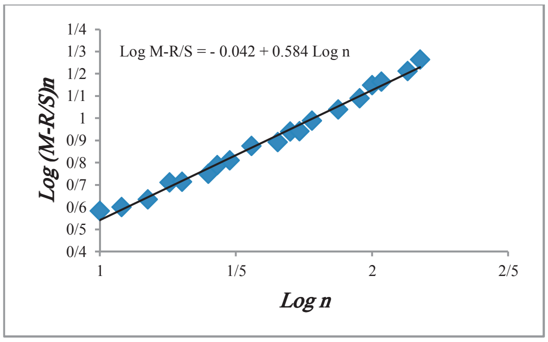

Figure 4(b): Estimation of the Hurst exponent based on the M-R/S technique for the period: 2002:21:03-2010:17:06

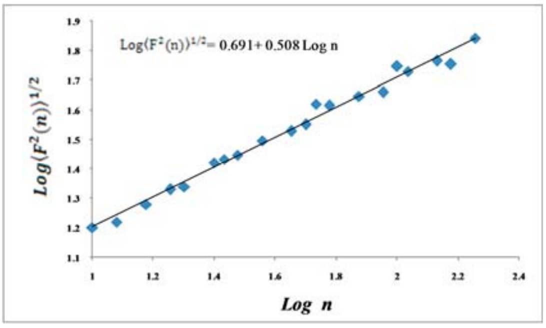

Figure 4(c): Estimation of the Hurst exponent based on the DFA technique for the period: 2002:21:03-2010:17:06

By using a linear regression, we've obtained $H_{R/S} = 0.538 \pm 0.016$, $H_{M-R/S} = 0.510 \pm 0.018$, $H_{DFA} = 0.456 \pm 0.024$ for the first period and $H_{R/S} = 0.646 \pm 0.013$, $H_{M-R/S} = 0.584 \pm 0.014$, $H_{DFA} = 0.508 \pm 0.013$ for the second period.

Then, we test the null hypothesis of H=0.5 by using Wald test. Wald statistic is given by $W = (\frac{H - 0.5}{\sigma_H})^2$ where H is the estimated Hurst exponent and σ_H is its standard error(De Souza et al., 2008).The Wald test results show that for the first period $H_{M-R/S} = 0.510$ is not statistically different from 0.5, but $H_{R/S} = 0.538$ and $H_{DFA} = 0.456$ have a significant difference from 0.5.Also,for the second period we cannot reject the null hypothesis of H=0.5 for $H_{DFA} = 0.508$ while this hypothesis strongly rejected for

$H_{R/S} = 0.646$ and $H_{M-R/S} = 0.584$. These results are presented in Tables 1 and 2.

Table 1: Results of the R/S, M-R/S & DF analysis of the Rial/Dollar exchange rate series from1999/25/01 to 2002/21/03 andWald test for the null hypothesis of H= 0.5.

Technique	Hurst exponent	Wald statistic(P-value)
R/S	**0.538**	**6.116 (0.033)**
M-R/S	0.510	0.319 (0.585)
DFA	0.456	3.482 (0.089)

Table 2: Results of the R/S, M-R/S & DF analysis of theRial/Dollar exchange rate series from2002/21/03to 2010/17/06 andWald test for the null hypothesis of H= 0.5.

Technique	Hurst exponent	Wald statistic(P-value)
R/S	**0.646**	**117.845 (0.000)**
M-R/S	0.584	37.860 (0.000)
DFA	0.508	0.469 (0.502)

According to table 1,the implications on long-range correlation based on various methods are quite different for the first period, asR/S, M-R/S and DFA show positive long-range correlation,no correlation and negative long-range correlation, respectively. Also, according to table 2,R/S and M-R/S suggest long-range correlation but DFA don’t show any correlation between Rial/Dollar exchange rate series in the second period.

To get more explicit conclusion we employ ADF test and PP test to see whether or not the series behave as a random walk. The results are presented in tables 3 and 4. According to Table 3 both the ADF test and PP test reject the *null hypothesis* that the series *have a unit root* at 5% significance level. *This means that the* Rial/Dollar exchange rate series do not follow random walk and therefore, based on ADF test and PP test the market is inefficient over the first period. In contrast, according to Table 4 the null hypothesis is not rejected. Therefore, based on ADF test and PP test the market is weekly efficient over the second period.

Table 3: Unit root Tests for Random Walk in Rial/Dollar exchange rate series from 1999/25/01 to 2002/21/03.

	Augmented Dickey-Fuller	Phillips –Perron
Test statistic	-4.4666	-4.2057
P-value	0.0018	0.0046

Table 4: Unit root Tests for Random Walk in Rial/Dollar exchange rate series from 2002/21/03to 2010/17/06.

	Augmented Dickey-Fuller	Phillips –Perron
Test statistic	-2.9197	-3.1589
P-value	0.1562	0.0931

Thus, our results confirm this statement that different methods sometimes lead to different results about market efficiency (see table 5). Our findings clearly indicate thatrelying on only one method to *make a conclusion on market efficiency may be very misleading.* Therefore,one must first carefully select more reliable methods and then compare their results. In particular, as shown in Table 5, the results of DFA, ADF test and PP test are similar; inefficiency over the first period and weak-form efficiency over the second period. Also, the results of these methods accord with our visual observations presented in section 3(Figures 1(b) and 2(b)).The result of M-R/S is quite different from those of DFA, unit root tests and our visual observations. Furthermore, as mentioned earlier, it is well known that the R/S is a biased estimator of long range dependence and likely lead us to wrong conclusion. Hence, we can cautiously conclude that the Iranian currency market (the Rial/Dollar case) at the first period ismore inefficient relative to the second period.However, the improvement of market efficiency is not because of informed traders; it's because of official intervention and strong management of exchange rate. When for any reason this intervention is put aside a higher degree of inefficiency may appears again. Transparency and the improvement of available information reduce transaction costs and increase the number of informed traders and market depth. Hence, quantitative and qualitative promotion of information services is necessary for a permanent efficiency.

Table 5: the conclusion of various methods about weak-form efficiency over two periods: 1999/25/01- 2002/21/03 and 2002/21/03-2010/17/06.

method	First period 1999/25/01 to 2002/21/03	Second period 2002/21/03to 2010/17/06
R/S	inefficient	inefficient
M-R/S	weak-formefficient	inefficient
DFA	inefficient	weak-formefficient
ADF test	inefficient	weak-formefficient
PP test	inefficient	weak-form efficient

Finally, it seems that after shifting the exchange rate regime from fixed to managed floating and filling up the gap between official and unofficial exchange rates, the market has become more efficient, although regarding to existing literature, there is no theoretical basis for the effect of exchange rate regime on market efficiency and also empirical evidence are very limited in this field (e.g. Booth et al., 1982; Kyaw et al., 2006).

5. Conclusion

The weak-form of the efficient market hypothesis implies that future prices are unpredictable from past prices. The long memory is evidence against the weak-form of EMH and a potentially predictable component in the series dynamics. The presence of the long memory means that the market does not immediately respond to an amount of information flowing into the financial market. Therefore, past price changes can be used as significant information for the prediction of future price changes.

In this paper, we investigated validity of the EMH in weak-form for Iranian foreign exchange market (US Dollar against Iranian Rial) from 1999:25:01 to 2010:17:06.We divided this time period into two sub-periods, 1999:25:01-2002:21:03and 2002:21:03-2010:17:06. In the former period Iran followed the fixed exchange rate regime but a managed floating exchange rate regime in the latter period.

We first employed three methods that are common in econophysics literature, namely, Rescaled Range Analysis (R/S), Modified Rescaled Range Analysis (M-R/S) and Detrended Fluctuation Analysis (DFA), to evaluate market efficiency from long memory viewpoint.The obtained findings were quite different. Specifically, for the first period, R/S, M-R/S and DFA respectively show positive long-range correlation($H_{R/S} = 0.538$), no correlation($H_{M-R/S} = 0.510$) and negative long-range correlation ($H_{DFA} = 0.456$). But, for the second period, R/S and M-R/S suggest long-range correlation ($H_{R/S} = 0.646$ and $H_{M-R/S} = 0.584$) while DFA don't show any correlation between Rial/Dollar exchange rate series ($H_{DFA} = 0.508$).We also testedthe null hypothesis of H=0.5 by using the Wald test to see whether or not obtained the Hurst exponents have significant difference from 0.5.

Then, to achieve more explicit conclusion we carried out two widely applied econometric approaches, namely, Augmented Dickey-Fuller (ADF) and Phillips-Perron(PP) to examine whether or not the studied time series behave as a random walk. For the first period both tests of ADF and PP reject the *null hypothesis* which is the series *have a unit root. This means that the*Rial/Dollar exchange rate series do not follow random walk and therefore, the market seems to be inefficient. In contrast, for the second period the null hypothesis is not rejected at 5% significance level, which is an evidence for weak-form market efficiency over the period.

According to the calculations, only DFA is exactly in line with ADF test and PP test. The result of M-R/S is quite in contrast with the results obtained from these two econometric tests. Also, it is well known that the R/S is a biased estimator of long range dependence. Moreover, the result of DFA is more consistent with our visual observations. Consequently, we conclude that the Iranian currency market (the Rial/Dollar case) at the first period was inefficient and predictable but at the second period it became more efficient. However, the improvement of market efficiency is not because of informed traders; it's because of official intervention and strong management of exchange rate.Whenfor any reason thisintervention is put aside a higher degree of inefficiency may appears again. Hence, help to Increasing informed agents by quantitative and qualitative promotion of information services is necessary for a permanent efficiency.

Finally, Based on the obtained results from this paper it seems that after shifting the exchange rate regime from fixed to managed floating and filling up the gap between official and unofficial exchange rates the market has become more efficient, although concerning to the existing literature, a theoretical basisfor this assertion has not been presented yet and empirical evidence is not enough too.

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