# Dynamics of Indian Foreign Exchange Market Efficiency : An Adaptive Market Hypothesis Approach

* *Sashikanta Khuntia*
** *J. K. Pattanayak*

## Abstract

Adaptive market hypothesis (AMH), a recent evolution in the field of finance, advocates that market efficiency is a time-variant element. In the present study, we empirically verified the time-varying degrees of market efficiency as per the propositions of AMH in the Indian foreign exchange market, which is assumed to provide an evolutionary alternative to the efficient market hypothesis (EMH). For the purpose, we used daily bilateral exchange rate between Indian rupee/United States dollar from January 1999 to December 2015. Statistical tests with linear and nonlinear approaches and better power properties unlike previous studies were used to trace the market efficiency. All tests employed unanimously supported time-varying nature of efficiency in foreign exchange returns, which adhere to the premise of AMH. The findings of the study confirmed market efficiency as an element which evolves with different market conditions, and thereby suggested for adoption of active portfolio management strategies for currency traders.

*Key words :* efficient market hypothesis, adaptive market hypothesis, nonlinear tests, foreign exchange market

JEL Classification : C12, F31, G14, G15

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Efficient market hypothesis (EMH) has been a key linchpin in neoclassical school of finance since the seminal work of Fama (1970). EMH defines a financial market as an efficient market where aggregation of past information by investors has no value in predicting future movement. Thus, an efficient market eliminates chances for speculation. Fama (1970) distinguished market efficiency to three forms (weak, semi-strong, and strong)[1] on the basis of market's absorption to different information. The weak form of EMH as a basic form asserts adjusting power of asset price to past price and information as very high. So, in an information based efficient market, prediction of future market movement through technical analysis is a futile task. In practice, existence of an informational efficient market is quite unrealistic (Grossman & Stiglitz, 1980) because of behavioural biases. Therefore, traders in financial markets show interest in the EMH to explore possible periods of inefficiency to get abnormal returns.

**[1]** Fama (1970) defined semi-strong and strong form of efficiency of financial markets where all publicly available information and privately held or all anticipated information is reflected over the market price of an asset, ruling out abnormal profit.

**Junior Research Fellow,* Department of Management Studies, Indian Institute of Technology (Indian School of Mines) Dhanbad - 826 004, Jharkhand. Email : sashikanta@ms.ism.ac.in
***Professor,* Department of Management Studies, Indian Institute of Technology (Indian School of Mines), Dhanbad - 826 004, Jharkhand.

The weak form of EMH has been investigated substantially in literature for stock markets and foreign exchange markets (FEMs). Focusing on FEMs, a good number of studies have reported mixed results for developed and developing countries (Ajayi & Karemera, 1996 ; Alvarez-Ramirez, Rodriguez, & Espinosa-Paredes, 2012 ; Baillie & Bollerslev, 1989 ; Katusiime, Shamsuddin, & Agbola, 2015). Most of the studies followed a conventional framework while testing weak form EMH for a specific period which has two major constraints. Firstly, this approach tests market efficiency as all-or-nothing conditions. Secondly, time-varying and evolving nature of efficiency created with different market events is overlooked. This is very unlikely as changing dynamics of markets like economic, technological, behavioral, regulatory, and institutional changes can cause changes in degrees of market efficiency (Lim & Brooks, 2011). To reconcile the paradigms, Lo (2004) offered an alternative analytical structure by proposing AMH, derived from the evolutionary principles of competition, adaptation, and natural selection. This alternative explanation to the market theory of EMH represents the behavioral perspective, which interprets financial markets as adaptable and switches between efficiency and inefficiency in due course of time (Hiremath & Kumari, 2014 ; Lo, 2004 ; Urquhart & Hudson, 2013). AMH portrays a number of practical implications on investment management perspectives (Lo, 2005). First, the risk premium in the equity market varies according to the different market conditions and demographic compositions of investors. Second, evolving nature of market efficiency leads to creation of arbitrage opportunities from time to time. Third, due to adaptability of investors, change in business conditions and number of competitors' financial asset price undergoes a bearish and bullish trend. Therefore, believing a perfectly efficient market is perverse.

The practical implications of AMH motivate us to explore whether Indian FEM is adaptive or not to different market conditions. Numbers of convincing factors about India and its FEM persuaded us to undertake this study. To list a few, (a) following major reforms and technological advancements, the Indian FEM witnessed an increase in foreign direct investment (FDI) about 48% in April 2015 and consequently, ranked 17th in terms of daily market turnover (Bank for International Settlements, 2016) ; (b) the heat of global financial and Eurozone crises are also reflected from the worsening macroeconomic fundamentals; and (c) multifold increase in foreign exchange reserves over the period. Given the backdrop of ups and downs, reforms, shocks and integration with global markets, the study on Indian FEM is considered to have strategic importance.

Also, the contributions of the present study to the existing literature are threefold. First, we test whether the market efficiency is time variant or not as per the AMH framework, which is the main objective of this study. In earlier studies, market efficiency was portrayed as a static condition, but looking into reality, we suspect that with different market microstructures and changing macroeconomic environment, the market efficiency evolves and the same was also endorsed by Jeon and Seo (2003) and Ito and Sugiyama (2009). Thus, market efficiency cannot be concluded with either yes or no term, rather it is something which emerges with different market frictions and disappears when market adapts equilibrium. Second, unlike previous studies, we take the cognizance of nonlinear dependence in exchange rate returns in the Indian context. A mere rejection of linear dependence does not hold true to conclude that market is efficient if there is the presence of nonlinear dependence. Third, despite its practical importance, literature exclusively dealing with AMH in FEMs are limited to only three specific studies (Charles, Darné, & Kim, 2012 ; Katusiime et al., 2015 ; Neely, Weller, & Ulrich, 2009). Thus, our effort will strengthen the literature base of AMH, which is at the nascent stage.

## Related Literature

The concept of market efficiency can be traced back to the study of Bachelier (1900), who first theorized the same. Subsequently, the seminal work of Fama (1970) instilled scientific approach to it by suggesting independent market movements. Irrespective of different nature and type of financial markets, prolonged efforts of researchers across the globe have dispensed sizeable studies, which are mostly referred to stock markets. FEMs are an important constituent of financial markets and are also associated with a good number of literature over the period (Ajayi & Karemera, 1996 ; Azad, 2009 ; Chen, 2008 ; Charles et al., 2012 ; Katusiime et al., 2015 ; Liu & He, 1991). Extant research in the line of EMH probed the existence of efficiency in exchange rate series using low and medium density of data (Ajayi & Karemera, 1996 ; Fong, Koh, & Ouliaris, 1997 ; Wright, 2000). On the other hand, Liu and He (1991), using variance ratio test, reported rejection of random walk in exchange rate of five developed markets with weekly data (British pound, Canadian dollar, French franc, German mark, and Japanese yen). In subsequent years, Belaire - Franch and Opong (2005) and Chen (2008) using daily data, reported mixed results on efficiency by rejecting it for Canadian and Singaporean dollar and accepting it for U.S. dollar, Australian dollar, New Zealand dollar, Japanese yen, British pound, Norwegian kroner, Swedish krona, and Swiss franc.

The mixed results of efficiencies and inefficiencies in the FEMs of both developed and developing countries question validity of EMH, as outcomes are silent about time-varying nature of market efficiency. However, the support EMH enjoyed until 1970s got cracked when behaviorists observed that heterogeneous behavior and psychological bias obstructed market participants to react rationally, in turn autocorrelation emerged for short-horizon (Hong & Stein, 1999). To reconcile both the proponents of EMH and behaviorists view, Lo (2004) proposed AMH, which could co-exist with EMH. The fundamental notion of AMH is that market efficiency is not a static approach, rather a time-varying phenomena. The AMH, which is based on the concept of bounded rationality, states that market participants compete, commit mistakes, and then learn to adapt to different market conditions. Thus, informational efficiency and inefficiency (predictability) coexisted over the period of time. Hence, the effectiveness of technical trading strategy to make more than average returns by currency traders depends on different market conditions. The AMH, because of its practical implications, started gaining attention of researchers around the globe and mostly evidenced from stock markets (Ghazani & Araghi, 2014 ; Hiremath &Kumari, 2014 ; Popovic, Mugosa, & Durovic, 2013 ; Verheyden, De Moor, & Van den Bossche, 2015). In the context of FEMs, Neely et al. (2009), using entropy approach, revealed predictability of exchange rate returns in different periods for 10 developed markets, which confirmed AMH. The empirical study of Charles et al. (2012) confirmed inefficiency in five developed FEMs. The authors also explored possible nonlinear dependence in exchange rate returns due to the emergence of market frictions like crises and central bank interventions. In a recent study, Katusiime et al. (2015) linked AMH in Ugandan FEM using variance ratio tests and identified that events like regulatory imposition and central bank intervention in the currency market lead to pockets of efficiency.

For the emerging markets, a study on their FEM efficiency is quite imperative due to their precarious financial system and enormous vulnerability to financial shocks. Although some literature for emerging markets in Europe and Asian FEMs are available, the Indian FEM is still under represented in comparison to its counterparts and its own stock market. The Indian stock market has witnessed a standard base of literature (Hiremath & Kamaiah, 2010 ; Mehla & Goyal, 2012 ; Poshakwale, 1996; Ryaly, Kumar, & Urlankula, 2014 ; Sharma & Chander, 2011 ; Vigg, Nathani, Kaur, & Holani, 2008). Whereas, it is surprising to note that, the study of EMH on Indian FEM is relatively limited to few studies only. Oh, Kim, and Eom (2007) revealed that efficiency of Indian FEM increased following Asian currency crises, but while comparing it with the Western market, it stood down. Vats and Kamaiah (2011) reported serial dependence in rupee - dollar exchange rate for the period from 1991 - 2010 using parametric and non-parametric methods. In subsequent studies, Chaudhry and Javid (2012) also found efficiency in Indian FEM. Though the studies available in the Indian context touch multiple aspects with different data sets and methods, still none of the studies have addressed nonlinear dependence and time-varying predictability. The present study is an attempt to bridge the existing research gap in the form of testing AMH in the Indian FEM market as identified from the review of above literature.

## Data and Methods

We have used daily spot exchange rate data of Indian rupee (INR) to U.S. dollar (USD) for the period of 15 years, starting from January 1999 to December 2014. The said period coincides with multiple economic events (viz. global financial and Eurozone crises, corporate scams, major macroeconomic changes, central bank intervention, and significant depreciation of exchange rate) and non-economic events (viz. war, political changes, and terrorist attacks). Existence of these market frictions may contribute towards the evolving nature of market efficiency. All data were sourced from the official database of the Reserve Bank of India.

A set of statistical tests with linear (LB-Q statistics, Run test, and Wild bootstrap automatic variance ratio test) and nonlinear (ARCH-LM and BDS test) features were used in this study to trace the market efficiency. Use of such mixed statistics can make our findings more robust. More specifically, to verify the vital objective of this study, that is, time - varying degrees of market efficiency in Indian FEM, the whole sample is segregated into non-overlapping moving sub-sample window of one year each [2].

**(1) Ljung-Box (LB) Q - Statistic Test :** Ljung-Box (1978) Q-statistic is the derived version of Box-Pierce (1970) Q-statistic and is used to test the joint hypothesis that all autocorrelation coefficients up to certain lags are simultaneously equal to zero. Autocorrelation estimates are used to check the independent and identical distribution *(iid)* of random variables . The LB Q-statistic is defined as :

$$LB = n\,(n+2)\sum_{k=1}^{m}\left(\frac{\rho_k^2}{n-k}\right) \qquad (1)$$

where, $n$ is the number of observations, $m$ refers to lag length, and $\rho k$ is autocorrelation coefficient at lag $k$. The LB Q-statistic follows chi-square distribution with $m$ degrees of freedom.

**(2) Run Test :** This is used to check whether successive value change in the time series is independent or not. A run is defined as a continuous trend. As per the sequence of trend, a run can be positive, negative, and zero. A data set is said to be random, if there is no significant difference between expected and actual run. Expected run *(ER)* is calculated as :

$$ER = \frac{K(K\text{-}1) - \Sigma_{i=1}^{3} T_i^2}{K} \qquad (2)$$

where, $K$ is the total number of runs, $T_i$ refers to different kinds of run ($i$ = 1, 2, 3). A large $K$ follows approximate normal distribution and standard $Z$ statistics is followed to test the null hypothesis.

**(3) Wild Bootstrap Automatic Variance Ratio Test :** Automatic variance ratio (AVR) test of Choi (1999) is an advancement to the VR and MVR test. The vital statistical properties of AVR test allows for automatic and optimal selection of holding period *(k)*, which is based on data dependent procedure. Under the null of no autocorrelation at all lags, the AVR test statistics is expressed as :

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**[2]** Chiang, Lee, Su, and Tzou (2010) suggested for 250 observations and our yearly samples are almost close to the required observation of 250 days. Urquhart and Hudson (2013) viewed that implementation of rolling window instead of conventional subsampling could lead to certain wrong inferences, that is, one extreme event could affect the results for many subsamples.

$$AVR(\hat{K}) = \sqrt{\frac{T}{k}} \frac{[VR(\hat{K}) - 1]}{\sqrt{2}} \xrightarrow{d} N(0,1) \quad (3)$$

Further, Kim (2009) and Charles, Darné, and Kim (2012) suggested a wild bootstrap version of AVR test, which is robust to heteroscedasticity.

**(4) Engle ARCH - LM Test :** This test is used to test the ARCH (auto regressive conditional heteroscedasticity) effect in residuals of $AR$ (ρ) model. Lagrange multiplier (LM) test detects heteroscedasticity using an auxiliary test regression. It is defined as :

$$r^2_t = \theta_0 + \sum_{i=1}^{p} \theta_1 r^2_{t-i} + u_t \quad (4)$$

where, $r_t$ is the residuals from $AR$ (ρ) model. The test statistics of this regression $NR^2$ follow asymptotically $\chi^2$ *(p)* distribution under the null hypothesis of linear generating mechanism. ARCH effect in the data is evident if the null hypothesis is rejected.

**(5) BDS Test :** It is a test named after Brock, Scheinkman, Dechert, and LeBaron (1996) and is used to check time based dependence in a series. This test identifies linear and nonlinear dependence as well as variety of possible deviation from independence. Grassberger and Procaccia (1983) observed that correlation dimension needed to be followed while testing a null, that is, data series are independent and identically distributed *(iid)*. Rejection of null hypothesis leads to dismissal of random walk and presence of nonlinear dependence. We follow the procedure of Hiremath and Kumari (2014) to estimate the correlation integral $C_m(n, \varepsilon)$.

$$C_m(\text{n}, \varepsilon) = \frac{2}{(n-m)(n-m+1)} \sum_{S=1}^{n-m} \sum_{t=S+1}^{n-m+1} I_m(x_s, x_t, \varepsilon) \quad (5)$$

where, $n$ implies sample size, $m$ is defined as embedding dimension, and ε refers to the difference between two pairs of observation at maximum level. The BDS test statistic can be identified as:

$$W_m(\varepsilon) = \sqrt{\frac{n}{\hat{U}_m}} (c_m(n,\varepsilon) - c_1(\text{n}, \varepsilon)^m) \quad (6)$$

## Empirical Analysis and Results

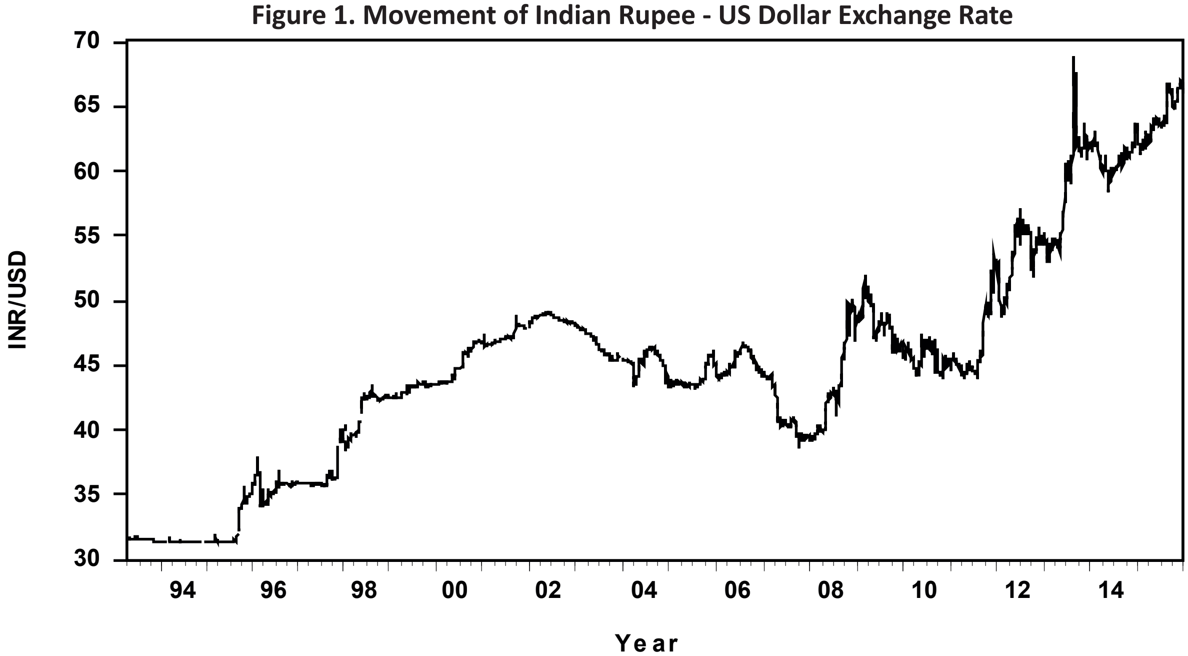
**(1) Descriptive Statistics :** Descriptive statistics shown in the Table 1 indicate that mean exchange rate return is positive for full sample and is mixed for sub-samples. Since 1999, maximum exchange rate return of 4.02 % and minimum return of -3.01 % were recorded in the years 2013 and 2008, respectively. The standard deviation (0.78%) observed in 2013 signifies volatility more than the full sample period. The skewness stands 'positive' for full sample and 'mixed' for sub-samples. Positive skewness denotes that exchange rate returns are flatter to the right of normal distribution, indicating greater magnitude of positive returns. Whereas, the negative skewness implies that exchange rate returns are flatter to the left of normal distribution, signifying a tendency of depreciation in INR to USD. The kurtosis value documented shows sharp peak to normal distribution for full and sub-sample. Further, significant Jarque-Bera statistics confirms that exchange rate returns are not normally distributed (except for in 2012).

**Table 1. Descriptive Statistics of Exchange Rate Returns**

| Sample | Mean | Maximum | Minimum | *SD* | Skewness | Kurtosis | Jarque-Bera |
|---|---|---|---|---|---|---|---|
| **FS** | 0.011 | 4.019 | -3.006 | 0.423 | 0.250 | 11.163 | 11469.91* |
| **1999** | 0.010 | 0.488 | -0.352 | 0.098 | 0.138 | 7.357 | 189.84* |
| **2000** | 0.030 | 0.803 | -0.669 | 0.147 | 1.261 | 10.030 | 567.040* |
| **2001** | 0.012 | 1.001 | -0.332 | 0.128 | 2.699 | 20.397 | 3304.14* |
| **2002** | -0.001 | 0.602 | -0.850 | 0.101 | -1.017 | 27.055 | 5997.82* |
| **2003** | -0.021 | 0.528 | 0.923 | 0.139 | -0.888 | 10.987 | 680.61* |
| **2004** | -0.019 | 1.343 | -1.668 | 0.321 | -0.342 | 8.820 | 350.53* |
| **2005** | 0.014 | 0.780 | -0.744 | 0.218 | 0.494 | 5.074 | 53.45* |
| **2006** | -0.008 | 1.007 | -0.855 | 0.264 | 0.265 | 4.035 | 13.86* |
| **2007** | -0.047 | 1.161 | -1.622 | 0.376 | -0.395 | 5.396 | 64.7* |
| **2008** | 0.086 | 2.490 | -3.006 | 0.682 | -0.159 | 5.660 | 71.7* |
| **2009** | -0.016 | 1.990 | -2.825 | 0.596 | -0.265 | 4.722 | 32.0* |
| **2010** | -0.017 | 1.617 | -2.189 | 0.515 | -0.028 | 4.392 | 19.8* |
| **2011** | 0.072 | 1.924 | -2.656 | 0.523 | 0.093 | 7.380 | 192.1* |
| **2012** | 0.011 | 1.886 | -1.839 | 0.617 | -0.075 | 2.821 | 0.550 |
| **2013** | 0.049 | 4.020 | -2.679 | 0.781 | 0.647 | 6.832 | 166.9* |
| **2014** | 0.010 | 1.207 | -1.261 | 0.380 | -0.098 | 3.873 | 7.870* |
| **2015** | 0.019 | 1.027 | -0.912 | 0.313 | 0.120 | 3.999 | 10.513* |

Note: The * denotes significant at the 1% level. FS denotes full sample.

**Figure 1. Movement of Indian Rupee - US Dollar Exchange Rate**



The Figure 1 shows an upward trend in the rupee-dollar exchange rate over the period, which signifies depreciation of INR.

**(2) Results from Linear and Nonlinear Tests :** The data series must be serially uncorrelated and simultaneously equal to zero to satisfy the condition of market efficiency as per EMH. The Table 2 shows results of linear tests employed in the study. We use Ljung-Box Q test as a preliminary statistics to capture serial autocorrelation in exchange rate returns. In column 2-4 of Table 2, LB Q statistics documented for all conventional lag indicate absence of efficiency for the full sample. Whereas, on the other hand, the years 2001, 2005, 2006, 2008, 2009, and 2013 post support of efficiency in exchange rate returns at any level of lag, rejecting null of random walk at any conventional level of significance. It is inferred from LB-Q statistics that Indian FEM passes through pockets of efficiency and inefficiency which is in consonance with the tenets of AMH of Lo (2004). Subsequently, the Run test, a widely used test in traditional literature, reports efficiency for the whole sample and subsample (see fifth column of Table 2). However, the years 2000, 2008, 2009, and 2014 are few exceptions where inefficiency is detected due to some economic and non-economic events. Positive value of *Z* statistics indicates negative autocorrelation in exchange rate returns and its reverse is also true. The mixed evidence of efficiency and inefficiency describes time-varying nature of Indian FEM and clearly indicates that the market is adaptive as per the proposition of AMH.

**Table 2. Results of Linear Test Statistics**

| Sample | LB Q (lag 5) | LB Q (lag 10) | LB Q (lag 15) | Run Test | WBAVR Test |
|---|---|---|---|---|---|
| **FS** | 0.012(31.38)* | 0.038(41.90) | -0.037(60.00)* | 1.498 | 1.018(0.530) |
| **1999** | 0.199(15.85)* | 0.025(17.96)** | -0.126(22.23) | 0.937 | -0.769(0.388) |
| **2000** | -0.173(13.93)** | 0.051(20.20)** | 0.083(24.58)*** | -2.409** | 0.289(0.730) |
| **2001** | -0.49(3.28) | -0.036(5.62) | 0.025(9.95) | -0.181 | 0.695(0.502) |
| **2002** | 0.126(27.26)* | 0.094(33.97)* | 0.006(42.67)* | 0.485 | -3.710(0.028)* |
| **2003** | -0.053(6.52) | 0.063(13.93) | 0.036(25.13)** | -0.799 | 0.597(0.498) |
| **2004** | 0.185(11.90)** | 0.059(17.4)*** | -0.084(21.11) | 0.581 | 0.453(0.648) |
| **2005** | 0.037(3.19) | -0.006(5.92) | 0.013(13.53) | -0.256 | 0.509(0.564) |
| **2006** | 0.015(6.16) | -0.002(8.59) | -0.027(9.98) | -0.102 | -0.436(0.532) |
| **2007** | 0.015(6.18) | -0.039(19.9)** | 0.028(29.35)* | 0.009 | 0.002(0.992) |
| **2008** | -0.033(5.16) | 0.057(13.03) | -0.046(15.97) | -3.848* | 0.604(0.450) |
| **2009** | 0.018(1.14) | 0.061(4.95) | 0.058(7.29) | 2.156** | -0.406(0.590) |
| **2010** | -0.082(17.55)* | 0.101(22.20)* | -0.158(32.37)* | -0.382 | -0.027(0.886) |
| **2011** | -0.049(0.89) | 0.002(2.53) | -0.075(7.54) | -0.480 | 0.426(0.598) |
| **2012** | 0.089(5.84) | 0.044(16.55)*** | -0.028(18.64) | -0.506 | 0.706(0.290) |
| **2013** | 0.033(7.28) | -0.019(13.08) | -0.071(18.70) | 1.102 | -0.016(0.938) |
| **2014** | -0.036(4.13) | -0.053(11.23) | -0.032(16.23) | 1.960** | -0.833(0.294) |
| **2015** | 0.095(4.624) | -0.014(5.751) | 0.083(14.649) | 1.106 | 0.987(0.210) |

Note: The values in main row are auto correlation coefficients and LB Q statistics in the parenthesis. * , ** , and *** denote significance at 1%, 5%, and 10 % level, respectively. FS denotes full sample.

**Table 3. Results of Engle LM Statistics**

| Sample | AR(ρ) | Lag 5 | Lag 10 | Lag 15 | Lag 20 |
|---|---|---|---|---|---|
| **FS** | 5 | 587.0(0.000)* | 691.0(0.000)* | 755.7(0.000)* | 774.7(0.000)* |
| **1999** | 5 | 17.03(0.004)* | 21.69(0.016)* | 28.60(0.018)* | 30.3(0.064)** |
| **2000** | 14 | 14.34(0.013)* | 17.0(0.073)** | 21.77(0.113) | 23.37(0.270) |
| **2001** | 2 | 12.6(0.026)** | 12.74(0.238) | 13.11(0.593) | 13.12(0.872) |
| **2002** | 8 | 8.67(0.122) | 52.20(0.000)* | 111.9(0.000)* | 135.60(0.000)* |
| **2003** | 5 | 15.93(0.007)* | 28.02(0.001)* | 32.99(0.004)* | 34.70(0.021)** |
| **2004** | 13 | 52.33(0.000)* | 54.02(0.000)* | 57.9(0.000)* | 66.5(0.000)* |
| **2005** | 20 | 55.88(0.000)* | 52.97(0.000)* | 54.21(0.000)* | 59.65(0.000)* |
| **2006** | 2 | 19.16(0.001)* | 30.53(0.000)* | 32.01(0.006)* | 36.43(0.013)* |
| **2007** | 8 | 20.53(0.001)* | 37.28(0.000)* | 38.16(0.000)* | 37.66(0.009)* |
| **2008** | 16 | 29.16(0.000)* | 35.36(0.000)* | 40.12(0.000)* | 45.05(0.001)* |
| **2009** | 3 | 6.99(0.221) | 11.81(0.297) | 12.12(0.669) | 22.21(0.329) |
| **2010** | 12 | 29.82(0.000)* | 39.19(0.000)* | 49.41(0.000)* | 50.51(0.000)* |
| **2011** | 18 | 12.40(0.029)* | 17.22(0.069)* | 19.56(0.189) | 30.80(0.056)** |
| **2012** | 9 | 7.54(0.183) | 11.22(0.340) | 22.19(0.102) | 22.99(0.289) |
| **2013** | 16 | 34.01(0.000)* | 46.76(0.000)* | 66.51(0.000)* | 74.88(0.000)* |
| **2014** | 11 | 13.99(0.015)* | 19.9(0.029)** | 26.7(0.030)** | 30.90(0.055)** |
| **2015** | 7 | 16.08(0.002)* | 33.37(0.000)* | 36.06(0.003)* | 35.09(0.000)* |

Note: The values in parenthesis are *p* - values. *, ** , and *** denote significance at 1%, 5 %, and 10 % level, respectively. *AR*(ρ) indicates auto regression of order ρ.

Finally, we conduct an estimation to check linear dependence in exchange rate returns via WBAVR test, which has better statistical prediction power properties and robust to heteroscedasticity. Test results reported in the final column of Table 2 show some contradiction to the results of LB Q statistics and run test. The WBAVR test reveals that the Indian FEM is efficient for the full sample period and sub-sample period except the year 2002. In a nutshell, it can be implied here that the informational efficiency of Indian FEM is not at all a constant phenomenon ; rather, it is a time-varying element. It evolves with different market frictions. The presence of no serial correlation detected through linear techniques does not guarantee independence and may give wrong inference of market predictability if there is existence of nonlinear dependence (Hiremath & Kamaiah, 2010). To measure nonlinear dependence in exchange rate returns, we have estimated ARCH-LM and BDS test statistics. Before considering these methods, we first removed linearity of our data sets by running a pth order auto regression (AR).

The standard residuals generated are used for the nonlinear estimation. The result of ARCH-LM test reported in Table 3 indicates predictability of exchange rate returns for full sample period. As far as sub-samples are concerned, the year 2001 shows inefficiency in shorter time horizon (lag 5) but in long horizon, the market behaves randomly. A surprising result is evidenced in the year 2002, where predictability is evidenced in longer horizon only. The years 2009 and 2012 are the only sub-samples where serial dependence in exchange returns are rejected. The presence of this nonlinear independence and dependence contradicts EMH and accords the market as an adaptive market as per the proposition of AMH of Lo (2004). Then, we have estimated the BDS test, the results of which are reported in the Table 4. The outcomes of the test evidence nonlinearity dependence in data

**Table 4. Results of BDS Test Statistics**

| Dimension | *m* = 2 | | *m* = 4 | | *m* = 8 | | *m* = 10 | |
|---|---|---|---|---|---|---|---|---|
| **Sample** | **ε = 0.5σ** | **ε = 0.75σ** | **ε = 0.5σ** | **ε = 0.75σ** | **ε = 0.5σ** | **ε = 0.75σ** | **ε = 0.5σ** | **ε = 0.75σ** |
| **Full Sample** | 0.060* | 0.039* | 0.113* | 0.129* | 0.097* | 0.212* | 0.083* | 0.217* |
| **1999** | 0.038* | 0.036* | 0.046* | 0.092* | 0.020* | 0.125* | 0.011* | 0.117* |
| **2000** | 0.048* | 0.041* | 0.081* | 0.136* | 0.054* | 0.196* | 0.044* | 0.195* |
| **2001** | 0.024* | 0.024* | 0.025* | 0.068* | 0.009* | 0.079* | 0.005* | 0.070* |
| **2002** | -3.35E-05 | -3.35E-05 | -0.0002 | -0.0002 | -0.0009 | -0.0009 | 0.014 | 0.014 |
| **2003** | 0.027* | 0.036* | 0.098* | 0.098* | 0.013* | 0.013* | 0.127* | 0.127* |
| **2004** | 0.044* | 0.043* | 0.086* | 0.135* | 0.063* | 0.168* | 0.048* | 0.161* |
| **2005** | 0.021* | 0.025* | 0.030* | 0.064* | 0.013* | 0.103* | 0.007* | 0.095* |
| **2006** | 0.015* | 0.022* | 0.019* | 0.059* | 0.003* | 0.061* | 0.001* | 0.048* |
| **2007** | 0.038* | 0.027* | 0.050* | 0.082* | 0.018* | 0.011* | 0.009* | 0.104* |
| **2008** | 0.030* | 0.023* | 0.049* | 0.063* | 0.032* | 0.094* | 0.024* | 0.104* |
| **2009** | 0.008* | 0.008** | 0.001* | 0.028* | 0.006* | 0.041* | 0.003* | 0.036* |
| **2010** | 0.012* | 0.014* | 0.020* | 0.051* | 0.002* | 0.063* | 0.006* | 0.052* |
| **2011** | 0.019* | 0.20* | 0.032* | 0.084* | 0.010* | 0.110* | 0.004* | 0.109* |
| **2012** | 0.006*** | 0.009* | 0.003* | 0.032* | 0.015* | 0.034* | 0.002* | 0.026* |
| **2013** | 0.009* | 0.013** | 0.002* | 0.062* | 0.007* | 0.085* | 0.003* | 0.081* |
| **2014** | 0.010** | 0.009** | 0.020* | 0.041* | 0.008* | 0.052* | 0.004* | 0.039* |
| **2015** | 0.008* | 0.005** | 0.030* | 0.052* | 0.003* | 0.089* | 0.006* | 0.028* |

Note : The table represents results of BDS statistics where AR (ρ) represents auto regression at *p*th order to remove linearity in data. Here, dimension and distance are denoted by '*m*' and 'ε' , respectively and 'ε' equals to various multiples (0.5, 0.75) of standard deviation 'σ'. BDS statistics with *, **, and *** represent significance at 1%, 5%, and 10% , respectively.

series, interpreting inefficiency in movements of exchange rate returns for full sample and subsample except 2002, which supports independence in exchange rate returns. The test carried out with different dimensions strongly supports nonlinearity dependence and explains the market as informational inefficient. The results of the BDS test indicate that the market movement is evolving, though there is only one period of independence. It describes the market as an adaptive market, supporting the results of ARCH-LM test. Overall, the presence of nonlinear dependence and independence supports the time-varying notion of market efficiency and strongly support the AMH.

## Discussion

In this study, we have made an attempt to empirically verify the existence of time-varying efficiency as per AMH in Indian FEM with linear and nonlinear statistics. Extant literature suggests that there is no formal test existing to empirically verify AMH. Our approach of using both linear and nonlinear tests can generalize the findings and reduce the risk of spurious results from a single test (Hiremath & Kumari, 2014). Investigating the market efficiency with exclusive description to the AMH, the present study confirms that the Indian FEM is adaptive.

The results of this study are in congruence with the outcomes of several similar studies undertaken internationally, even though the methodology and region of our study are different (Charles et al., 2012 ; Katusiime et al., 2015 ; Neely et al., 2009). On the other hand, our study contradicts the findings of the studies undertaken on some other FEMs (Al - Khazali, Pyun, & Kim, 2012 ; Kisaka & Rose, 2008 ; Lee, Pan, & Liu, 2001; Vats & Kamaiah, 2011). Surprisingly, results reported in our study are not in consonance with the outcomes of the study undertaken on Indian FEM by Vats and Kamaiah (2011). The study by Vats and Kamaiah (2011) evidenced no random walk for INR and USD over the study period of July 1991 to June 2010. The contradiction of results of both the studies can be attributed to the time varying approach and methodology adopted in the present study. The reasons of such episodes of efficiency and inefficiency can be linked to different economic and non-economic market events.

More specifically, domestic and international events can be attached to the reasons of inefficiency during 2001, 2002, 2005, 2008, 2009, and 2013 (reported in our test results). Inefficiency that occurred during 2001-02 could be attributed to the period following dot-cum bubble bust, Enron scam, and terrorist attack on the World Trade Center. The period of inefficiency in 2005 and 2008-09 coincided with events like stock market downturn, depreciation in exchange rate, and heavy selling pressure by foreign institutional investors (FIIs) in response to the fear of sub-prime mortgage crisis. The year 2013 also witnessed inefficiency following Federal Reserve Bank's hint to early tapering of Fed rate. The major inference which can be drawn here is that market efficiency emerges with changes in market conditions and it cannot be considered as all-or-nothing conditions.

## Conclusion and Research Implications

Broadly, this study examines the evolving efficiency in Indian FEM. Overall, the empirical findings confirm the series of efficiency and inefficiency over the period. This follows the proposition of AMH. It also implies that both EMH and AMH co-exist. The period of inefficiency which has been created due to several market frictions like financial crisis, stock market crashes, political and macroeconomic changes lead to profit opportunity. Consequently, the market tried to exploit it economically, by adopting it and finally, the profit opportunities disappeared. To get robustness of linear statistics results, the study conducted two nonlinear statistics after fitting an AR (ρ) model which removes linearity from actual data. Both the nonlinear statistics support the result of linear techniques and find time-varying nature of market efficiency. It explains the evolving nature of Indian FEM to different market frictions, suggesting Indian FEM's resemblance to the conditions of AMH. The major inference which can be drawn here is that formulation of trading strategies with technical analysis is not always fruitful. Traders engaged in FEM need to wait for the movements to generate the required returns when exchange rate returns get correlated with different market frictions.

Regardless of the test employed and the mixed results reported, it is apparent that shocks in Indian FX market arise out of economic or non-economic events that cause alteration in market efficiency. Given the back drop of these events (viz. domestic and global financial catastrophes, political tensions, monetary policy change, trade imbalances, etc.), the relevant authorities need to act prepensely to curb any significant shift in the behaviour of the FX market. The recent fear of U.S. monetary policy changes and economic slowdown is a credible evidence of vulnerability of Indian FX market to economic shocks (May-August, 2013). Therefore, an understanding of evolving nature of market efficiency holds importance for different market agents. To policy makers, the dynamic behavior of market efficiency sends a strong message to deal with speculation while restoring the unstable macroeconomic environment. Apart from this, the policy makers need to correct the existence of non-linear dependence. Usually, non-linear dependence emerges when the reactions of market participants are homogeneous to different events, and it is mostly evident from EMEs. The policy direction in this regard is to strengthen the information dissemination system. For investors and FX traders, passive trading strategies can be evolved and implemented to book abnormal returns as the Indian FX market behaves with frequent formations and departures of efficiency, which emerge due to several market frictions.

## Limitations of the Study and Scope for Further Research

The present study uses sub-samples which are non-overlapping in nature. The major shortcoming of the non-overlapping sub-sample approach is that it assumes the movements of market efficiency following a discrete trend over time. However, practically, it is more rational to believe that market efficiency moves with time and ,therefore, the dynamic characteristics of market efficiency cannot be traced with chosen sub-sample which are non-overlapping in nature. From the methodological perspective, the present study does not address long memory or long range dependence in the movement of FX rate.

A further research in this area could use overlapping sample or rolling window approach to capture evolving pattern of efficiency. Use of more recent methods to capture nonlinear dependence can further improve the findings. Moreover, assessment of long memory persistence, degrees of efficiency, and its determinants are left for further research.

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## About the Authors

**Sashikanta Khuntia is a full - time research scholar at IIT Dhanbad. His area of research interest is Financial Economics and Behavioural Finance. He has a number of publications and conference presentations to his credit. He is also awarded with University Grant Commission Junior Research Fellowship (UGC-JRF).**

**J.K. Pattanayak is a Professor in the Department of Management Studies, IIT Dhanbad. He has more than 20 years of teaching and research experience. His prime area of research includes Corporate Finance, Earnings Management, Behavioural Finance, and Financial Economics. There are a number of national, international publications, and conference presentations to his credit.**