(First Draft)

Testing Predictability and Nonlinear Dependence of Indian Rupee/U.S. Dollar Exchange Rate in the Framework of Appropriate Specification

Rituparna Kar

Nityananda Sarkar

Indian Statistical Institute

Kolkata-700108

ABSTRACT

The opening of economies to trade has eventually led the exchange rate to be a very important variable in economics. With demise of post war Bretton Woods system of exchange rate, large industrialized countries floated their exchange rates. Such floating regimes provided economists with empirical data sets to resolve various academic debates which were related to suitable modeling of exchange rates. There has been considerable interest in the time series properties of exchange rates under the floating rate regime, especially after it has been established by a wide number of studies that a simple martingale model has better forecasting ability than complex structural models. Though there exists, a vast literature in this area involving exchange rate data of mainly advanced countries, there are very few such works on exchange rate in India. The focus of our work is to advocate a systematic approach to studying predictability of returns of Indian Rupee/US Dollar exchange rate with due consideration to possible sources of misspecification of conditional mean i.e., serial correlation, seasonal effects, parameter instability, omitted time series variables and any other remaining nonlinear dependences. Since structural change is pervasive in economic time series relationships and may result in inaccurate forecasts and incorrect inferences about economic relations, we have studied this aspect of the exchange rate series and accordingly divided the entire period into sub periods of constant parameters. Thereafter we have studied the aforesaid aspects of modeling and have found that the predictability of exchange rate also depends on day of the week effects, call money rate, BSESENSEX (in some sub-periods only) and conditional heteroscedasticity and some dynamics in the higher moments.

JEL Classification: C22 ; F31

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1. INTRODUCTION

Recent years have seen a renewed interest in issues relating to trade and the exchange rate is considered as one of the most important economic variables. With demise of post war Bretton Woods system of exchange rate, large industrialized countries floated their exchange rates. Such floating regimes provided economists with empirical data sets to resolve various academic debates which were related to suitable modeling of exchange rates. A comprehensive review of the literature which focuses primarily on exchange rate determination and prediction can be found in the existing surveys of Boughton (1988), Dornbusch (1987), Kenen (1988), MacDonald (1990a,b), MacDonald and Taylor (1989,1992,1993b),Meese(1993) and Mussa (1990). Earlier the focus was on the structural models to explain exchange rate behavior. The earliest structural model is the monetary model of exchange rate, which was considered as the workhorse of the international finance, but its empirical failure became swiftly apparent (Frankel and Rose (1995)). Other than the two versions of monetary models –flexible and sticky price models- there is the portfolio-balance model (c.f. Backus (1984),Frankel(1993) and Golub (1989)). Meese and Rogoff (1983a,b) compared forecasting performances of the structural models with non-structural models both univariate and vector-autoregressions only to find that a simple martingale process forecasts better than more complex structural models. Such a revelation propelled the use of time series modeling for exchange rates.

When we are fitting a model taking data for a reasonably long period, using one stable relation (i.e. parameters fixed all throughout the entire sample period) does not seem to be appropriate. Structural changes including changes in the values of the parameters of an assumed model over time is an important problem in time series and this affects modeling inferences if not accounted for appropriately. An implicit assumption for unit root test is that the deterministic trend is correctly specified. Perron (1989) argued that in presence of break in deterministic trend the unit root tests lead to misleading conclusion that there is unit root when in fact there is not. There has been an enormous literature on structural change which can be traced back to 1960 (c.f Chow (1960) and Quandt(1960)) followed by Andrews(1993), Andrews and Ploberger(1994) , Bai and Perron(1998) and Hansen(1997,2001)). These researches have led to the development of a testing procedure to determine whether there is structural break in a time series. Further, Bai (1994,1997a,b) and Chong (1995) have found methods of estimating break points. We have used this methodology to determine break points in the time series and then partition the time period into sub-periods of stable parameters. Thereafter we have tried to specify the mean properly for each sub-period. In this context it is important to note that inferences drawn from models suffering from misspecification due to inappropriate conditional mean can be misleading as well as incorrect. Lumsdaine and Ng (1999) have shown that the Lagrange Multiplier (Rao's score) test for testing the null of homoscedasticity leads to overrejection of the null hypothesis if there is misspecification of conditional mean. Thus we need to account for any misspecification in the conditional mean. The possible sources of misspecification in the conditional mean are existence of serial correlations, seasonal effects and non-inclusion of contemporaneous independent variables. After accounting for these we suggest using functions of recursive residuals to make the specification of conditional mean as correct as possible.

Several studies have applied Engle’s (1982) autoregressive conditional heteroscedastic (ARCH) model and Bollerslev’s (1986) extension to a generalized ARCH (GARCH) model to estimate changing conditional variances in exchange rates. There have been a large number of extensions and generalizations of the original GARCH model. For instance, Higgins and Bera (1992) proposed a nonlinear ARCH (NARCH) while Nelson (1991) in an attempt to capture the so called leverage effect suggested a conditional variance function which is known as exponential GARCH (EGARCH). Similarly, Glosten, Jagannathan and Runkle (1991) and Zakoian (1990) suggested a nonlinear extension called threshold ARCH (TARCH). In most of the empirical studies concerning time series data on exchange rate of developed economies, the form of conditional heteroscedasticity has been found to be GARCH. To the best of our knowledge there is only a few empirical evidences in favor of EGARCH. One such paper is the one, which is concerned with modeling of Canadian dollar, Swiss franc and the Deutsche mark data with respect to US dollar (c.f. Hsieh (1989)). In the modeling approach that we suggest in this paper, attention is also given to proper specification of conditional variance function.

With advent of floating rate regime since 1993, India has emerged as an important economy and is having its share of discussions and debates on issues relating to appropriate exchange rate systems, policies on intervention and capital control. Most of the empirical research that have taken place in context of India deal with the characteristics of explicitly managed exchange rates (Bhaumik and Mukhopadhyay (2000), Ghosh(2002), Kohli(2000,2002), Pattnaik et al(2003), Rao(2000), Unnikrishnan and Mohan (2001)). Empirical evidence on foreign exchange market efficiency and uncovered interest rate parity have been tested for India by Joshi and Saggar (1998) and Pattanaik and Mitra (2001). Kohli (2002) has carried a time series analysis of real exchange rate of India during the recent float period to test for mean reversion property. In these studies unit root tests and variance ratio tests have been applied. These early time series analysis of exchange rate for India are, in our opinion, inadequate as these studies have not considered possible sources of misspecification like structural breaks in the conditional mean and then testing predictability and nonlinear dependence in the model with appropriately specified conditional mean and variance.

The focus of our work is to advocate a systematic approach to testing predictability and nonlinearity of nominal exchange rate return with due consideration to possible sources of misspecification of conditional mean i.e., serial correlation, seasonal effects, parameter instability, omitted time series variables and any other remaining nonlinear dependences.

2. MODEL AND METHODOLOGY

To start with, it may be pointed out that there is an enormous amount of work on structural change, and the predominant conclusion is that structural change affects inferences concerning the underlying model and its predictability.

The first classical test of structural change in the economic literature is due to Chow (1960). The testing procedure splits the sample into two sub-periods, estimates the parameters for each sub-period, and then tests the equality of the two sets of parameters using F statistic. But this traditional test essentially tests the null hypothesis of parameter constancy against the alternative of a known break point a priori under the assumption of constant variance. Quandt(1960) discusses testing the null hypothesis of constant parameters against a more general alternative. Quandt considers a structural change at some unknown time and allows for change in error variance, i.e. he proposes taking the largest Chow statistic over all possible break dates. If the break date is known a priori, then chi-square distribution with appropriate *degrees of freedom* can be used to assess statistical significance. However, if the break date is unknown a priori, then it is obvious that the chi–square critical values are inappropriate. It was after three decades that the problem of obtaining appropriate critical values, was solved by Andrews (1993).

Andrews (1993) used a parametric model indexed by parameters $(\boldsymbol{b}_t, \boldsymbol{d}_0)$[1] for $t = 1,2,......$

The null hypothesis is one of parameter stability $H_0 : \boldsymbol{b}_t = \boldsymbol{b}_0$ for all $t \geq 1$ for some $\boldsymbol{b}_0 \in B \subset R^p$. Considering a one-time structural change alternative with change point $\boldsymbol{p} \in (0,1)$, where T is the sample size, $T\boldsymbol{p}$ is the time of change, and $\boldsymbol{p}$ is referred to as the

[1] In case of tests of pure structural change, no parameter $\boldsymbol{d}_0$ appears (Andrews (1993)).

change point or point of structural change. The one–time change alternative with change point $\boldsymbol{p}$ is given by

$$H_{1T}(\boldsymbol{p}) : \boldsymbol{b}_t = \boldsymbol{b}_1(\boldsymbol{p}) \qquad \text{for } t = 1,\ldots\ldots, T\boldsymbol{p}$$

$$H_{1T}(\boldsymbol{p}) : \boldsymbol{b}_t = \boldsymbol{b}_2(\boldsymbol{p}) \qquad \text{for } t = T\boldsymbol{p} + 1,\ldots\ldots$$

for some constants $\boldsymbol{b}_1(\boldsymbol{p}), \boldsymbol{b}_2(\boldsymbol{p}) \in B \subset R^p$.

For the case where $\boldsymbol{p}$ is known, one can form a Wald, LM, LR-like test for testing H_0 versus $H_{1T}(\boldsymbol{p})$ (Andrews and Fair (1988)). For sake of specificity let $W_T(\boldsymbol{p}), LM_T(\boldsymbol{p}),$ and $LR_T(\boldsymbol{p})$ respectively, denote the test statistics that correspond to these tests. In case of a normal linear regression, these tests are equivalent F tests, which are referred to as Chow tests. However we are considering change point $\boldsymbol{p}$ to be unknown. Constructing test statistics that do not take $\boldsymbol{p}$ as given is complicated since the problem of testing for structural change with an unknown change point does not fit into the regular testing framework, the reason being the presence of $\boldsymbol{p}$ only in the alternative hypothesis and not the null. In consequence, Wald, LM, and LR-like tests constructed with $\boldsymbol{p}$ treated as a parameter, does not possess their standard large sample asymptotic distributions. Andrews (1993) considered test statistics of the form: $\sup_{p \in \Pi} W_T(\boldsymbol{p})$, $\sup_{p \in \Pi} LM_T(\boldsymbol{p})$ and $\sup_{p \in \Pi} LR_T(\boldsymbol{p})$, where Π is some pre-specified subset of $[0,1]$ whose closure lies in (0,1). A natural choice of the set of change points Π for use with these statistics is (0,1) when one has no information regarding the change point. This choice is not desirable because when $\Pi = (0,1)$, the statistics $\sup_{p \in \Pi} W_T(\boldsymbol{p}),\ldots\ldots\ldots, \sup_{p \in \Pi} LR(\boldsymbol{p})$ can be shown to diverge to infinity in probability, whereas when Π is bounded away from zero and one, the statistics converge in distribution. Thus the use of the full interval (0,1) results in a test whose concern for power against alternatives with a change point near zero or one leads to much reduced power against alternatives with change points anywhere else in (0,1). Thus it can be suggested, when no knowledge of the change point is available, the restricted interval $\Pi = [.15,.85]$.

Critical values have been provided for the test statistics $\sup_{p \in \Pi} W_T(p), \ldots\ldots\ldots, \sup_{p \in \Pi} LR_T(p)$ in Table 1 (Andrews (1993) p.840 and Andrews (2003) p. 396). Table 1 covers a wider range of intervals Π, other than the symmetric intervals $[p_0, 1 - p_0]$. For $\Pi = [p_1, p_2]$ for $0 < p_1 \leq p_2 < 1$ then the critical values depend on p_1 and p_2 only through the parameter $l = p_2(1 - p_1)/(p_1(1 - p_2))$. Table 1 provides the value of l corresponding to each value of p_0 considered (*viz.*, $l = (1 - p_0)^2 / p_0{}^2$). This allows one to obtain critical values for all intervals $\Pi = [p_1, p_2]$ whose corresponding value of $l = p_2(1 - p_1)/(p_1(1 - p_2))$ either is tabulated or can be interpolated from the table.

With the Andrews test suggesting structural break we need to estimate the breakpoints. Bai (1994,1997a,b) argued that the appropriate method to estimate breakpoint(s) is least squares and that this is to be applied by splitting the sample at each possible break date, the parameters of the model are then estimated by ordinary least squares and the sum of squared errors calculated. The least squares break date estimate is the date that minimizes the full-sample sum of squared errors. Chong (1995) and Bai (1997b) show how to estimate multiple break dates sequentially. In presence of multiple structural breaks, the sum of squared errors can have a local minimum near each break date. Thus the global minimum can be used as a break date estimate and the other local minima can be viewed as candidate breakpoints. However this needs to be done cautiously. A process of iterative refinements have been used by Bai (1997b) which is the re-estimation of break dates based on refined sample and results in improvement in the estimation procedure.

Model misspecification can arise if the functional form and /or the conditioning information set are misspecified. For linear dynamic models, notable examples are omitted shifts in the trend function, selecting a lag length in an autoregression which is lower than the true order, failure to account for parameter instability, residual autocorrelation, and omitted time series variables. Lumsdaine and Ng (1999) discuss possibilities for guarding against misspecification in the mean function. The approach used by them is to approximate any non-linearities by functions of the recursive residuals. The motivation is that any unobserved non-linearities will be manifested in the recursive residuals. They have suggested a two-step estimation procedure. First step is to start from the $(k+1)^{th}$ observation for some predetermined k and perform recursive estimation of the dependent variable y_t on the set of independent variables z_t over the remaining $T-k$ observations where T is the total number of observations. This leads to a set of estimates $\hat{g}_t$ of g, the coefficients associated with the independent variables, and a set of recursive residuals $\hat{w}_t = y_t - z_t'\hat{g}_{t-1}$. These recursive residuals contain the information used to update $\hat{g}_t$ from $\hat{g}_{t-1}$ and cannot be predicted by the regression model given information at time $t-1$. They are serially uncorrelated by construction if the model is correctly specified. But when the model is misspecified, $\hat{w}_t$ will contain information about true conditional mean not captured by the regression function. In the following step we estimate the equation:

$$y_t = z_t'\boldsymbol{g} + g(\hat{w}_{t-1}) + \boldsymbol{n}_t \tag{2.1}$$

where $g(\hat{w}_{t-1})$ is a (possibly nonlinear) function of the recursive residuals $\hat{w}_{t-1}$.The role of $g(\hat{w}_{t-1})$ is to orthogonalize u_t in $y_t = z_t'\boldsymbol{g} + u_t$ so that the conditional mean of the resulting regression error v_t shrinks towards zero. The use of recursive residuals are appealing as they are easy to compute and $\hat{w}_{t-1} \in I_{t-1}$ and hence is in econometrician's information set at time t. Thus we use $\hat{w}_{t-1}$ instead of $\hat{w}_t$. Given that the objective of the exercise is to guard against misspecification in functional form and the conditioning information set, the natural candidate for $g(.)$ is a flexible function of the recursive residuals. A suitable candidate is a polynomial in the recursive residual of the form $g(\hat{w}_{t-1}) = \sum_{i=1}^{m} \boldsymbol{b}_i \hat{w}_{t-1}^{i}$ for a series expansion of length m in $\hat{w}_{t-1}$. This is appealing since the polynomials have a nonparametric interpretation. Furthermore, significance of $\hat{\boldsymbol{b}}_i$ can be interpreted as a diagnostic for the misspecification in the conditional mean.

3. DATA AND SOFTWARE

In India partial convertibility of the Rupee was introduced through a dual exchange rate system known as the Liberalized Exchange Rate Management System (LERMS) in March 1992.The stability imparted by LERMS resulted in a smooth change over to a regime under which the day-to-day movements in exchange rates were market determined. The movement to market determined exchange rate was accompanied by convertibility on current account and a cautious approach to capital account liberalization. Restrictions on current account convertibility were relaxed in a phased manner till August 20,1994. With a view to promoting orderly development of foreign exchange markets and facilitating external payment in a liberalized regime, the Foreign Exchange Management Act (FEMA) was introduced from June 1, 2000 replacing the earlier Foreign Exchange Regulation Act (FERA). The FEMA is consistent with full current account convertibility and contains provisions for progressive liberalization of capital account.

We now apply the systematic methodology that has been reported in the previous section. We have taken daily level data of spot exchange rate (RBI reference rate) spanning from 1st November 1994 to 13th February 2004, a total of 2287 data points, for the analysis. These data have been collected from the RBI site (www.rbi.org.in). Although there were data on other foreign exchanges but our interest has been on the foreign currency of the US. The spot exchange rate is the price of one unit of the US dollar in rupee terms. Though the floating regime started from March 1993 but the period from March 1993 till November 1994 was a prolonged phase of near constant exchange rate. Even though the exchange rate system in India is supposed to be full float, the reality is that RBI intervenes in the Foreign exchange market at regular intervals to direct the movement in rupee values. In our daily level analysis we could not use data on intervention because RBI publishes only monthly intervention data and like most central banks keeps its daily intervention a closely guarded secret. Further macro economic variables like inflation, money growth, balance of payments couldn’t be included due to their non- availability on a daily basis. However we have used the daily call money rate which is the rate at which the commercial banks borrow money from other banks to maintain a minimum cash reserve requirement .The call money market and foreign exchange markets are closely linked as there exists arbitrage opportunities between the two markets. When call rates increase, banks borrow dollars from their overseas branches, swap them for rupees and lend them in call money market. The other variable considered is the Bombay stock exchange sensitive index (BSESENSEX) downloaded from site www.bseindia.com. In many studies dollar exchange rate has been used to analyze stock prices in the belief that corporate earning are significantly affected by fluctuations in currency value. However it has been established that there is bi-directional relations between the two. Ajayi and Mougoue (1996) found that increases in stock prices have a long run positive effect on the domestic currency value while currency depreciation has a negative long run effect on stock market. The study by Abdalla and Murinde (1997) on India has shown that there are significant connections between exchange rate and stock prices. Ki –ho Kim (2003) showed the presence of price and portfolio adjustment channels through which exchange rates and stock prices are related.

We have used E-VIEWS 3.1 and SAS 8.02 for carrying out the empirical analysis.

4. EMPIRICAL ANALYSIS

For the purpose of this study the observations have been changed to their logarithmic values. Now, we need to first check whether the series of logarithmic values of spot exchange rate is stationary or not. The Augmented Dickey Fuller (ADF) regression is used for this purpose.

$$\Delta y_t = \underset{(0.411)}{.002} - \underset{(0.377)}{(9.5\times 10^{-8})}\,t - \underset{(0.328)}{0.0003}\,y_{t-1} + \underset{(4.709)^{**}}{0.099}\,\Delta y_{t-1} + \underset{(1.066)}{0.022}\,\Delta y_{t-2} - \underset{(3.303)^{**}}{0.069}\,\Delta y_{t-3} + \underset{(6.446)^{**}}{0.135}\,\Delta y_{t-4} - \underset{(2.375)^{*}}{0.05}\,\Delta y_{t-5} \tag{4.1}$$

Here the significance of the coefficient associated with y_{t-1} is tested .The computed value is compared with the tabulated value of t^* statistic due originally to Fuller(1976) and later extended by Guilkey and Schmidt(1989) and MacKinnon (1990).

Here the absolute value of t^* is 0.328, which is compared to MacKinnon tabulated values viz., 3.4144 and 3.967 at 5 percent and 1 percent levels of significance. Hence we conclude that the underlying null hypothesis of presence of unit root cannot be rejected. Thus the series has a unit root. When studying the Ljung –Box statistics Q, we see that the null of no autocorrelation cannot be rejected at 5% level of significance. The optimum value of k is determined using Hall's (1994) procedure and has been found to be 5. The value of $Q(m)$ test statistic is computed for lag m upto 36 and the null of Gaussian white noise for errors is strongly supported by Ljung-Box test.

Since the presence of unit root has been established we need to take the first difference of the series for further analysis. But this can be done only after applying ADF test (1985) on the differenced series to find out whether it is stationary. Carrying out the ADF test for the differenced series, we have the following estimated regression:

$$\Delta y_t = \underset{(3.0632)^{**}}{0.0003} + \underset{(2.095)}{(1.79\times 10^{-7})}\, t - \underset{(19.328)^{**}}{0.894}\, y_{t-1} - \underset{(0.2123)}{0.009}\,\Delta y_{t-1} + \underset{(0.445)}{0.0174}\,\Delta y_{t-2} - \underset{(1.61)}{0.054}\,\Delta y_{t-3} + \underset{(2.866)^{*}}{0.08}\,\Delta y_{t-4} \tag{4.2}$$

The absolute value of t^* is compared to Mackinnon tabulated value which is 3.967 at 1% level of significance. We say that the null of unit root can be rejected at 1% level of significance.

Our study focuses on a systematic approach to studying predictability of exchange rate return with due consideration to possible sources of misspecification. We have tried to account for existence of serial correlations by incorporating lags of exchange rate returns and used dummies to capture the day-of-the-week effects in the conditional mean. Another possible source of misspecification of the conditional mean is exclusion of contemporaneous variables. The two contemporaneous independent variables used by us are call money rate and BSESENSEX.

Taking these into consideration, we propose the following specification:

$$r_t = \sum_{k=1}^{m} V_k r_{t-k} + \sum_{j=1}^{d} \boldsymbol{b}_j D_{jt} + \boldsymbol{v} i_t + \boldsymbol{h} b_t + \boldsymbol{e}_t, t = 1,2,......,n \tag{4.3}$$

where r_t is the difference of log of exchange rate, D_j's $(j = 1,2,...d)$ denote the seasonal 0-1 dummies, i_t is the call money rate, b_t is the difference of log of BSESENSEX (return of stock price index) .m is the appropriate lag value of r_t capturing its autocorrelations. Using the AIC, BIC criteria the number of lags of r_t is found to be 5, while using Hall's criterion the number of lags is found to be15. But most of the lags between 6 and 14 turn out to be insignificant, and hence we use the lag value obtained by AIC, BIC criteria. The estimated model for the entire period is:

$$r_t = \underset{(4.506)^{**}}{0.094}\, r_{t-1} + \underset{(0.966)}{0.02}\, r_{t-2} - \underset{(3.642)^{**}}{0.075}\, r_{t-3} + \underset{(6.233)^{**}}{0.129}\, r_{t-4} - \underset{(2.69)^{**}}{0.056}\, r_{t-5} - \underset{(4.397)^{**}}{(4.64\times 10^{-5})}\, i_t - \underset{(4.597)^{**}}{0.016}\, b_t$$
$$+ \underset{(2.197)^{*}}{0.0003}\, D_1 + \underset{(5.046)^{**}}{0.0008}\, D_2 + \underset{(2.349)^{*}}{0.0004}\, D_3 + \underset{(3.845)^{**}}{0.0006}\, D_4 + \underset{(3.795)^{**}}{0.0006}\, D_5 \qquad (4.4)$$

[The values in parenthesis indicate corresponding absolute values of t-statistic; * indicates significance at 5% level and ** indicates significance at 1% level of significance]

Using this relation Andrews's test is performed over the entire data. The relevant statistic is constructed in the following way. A sequence of Wald statistics is calculated as a function of candidate break-dates. We have considered $\Pi = [.15,.85]$, which means that the candidate breakpoints are the points eliminating the first and last 15 percent of the data points. The candidate break-dates are plotted on the x-axis; the values of the Wald statistics are on the y-axis.

Since the total number of parameters is 12 and $l = .15$, the Andrews 5 percent critical value is 30.43.The maximum value of the sequence of statistics is 70.2, which clearly exceeds the Andrews's critical value and we can reject the hypothesis of no structural break. Thus we can say that the series has a structural break. It now becomes essential to estimate the break date and decide on basis of the results, whether there is more than one break.

The methods discussed in the previous section, of estimating the multiple breaks, is best illustrated in Hansen (2001). Using the same procedure, in Figure 2, we plot the residual variance as a function of a single break date. The sample is split at each break date and regression parameters are estimated separately on each sub-sample .The sum of squared errors is calculated and the residual variance is plotted on the y-axis while the break dates are on the x-axis. In case the true parameters are constant, the sub-sample estimates and hence the sum of squared errors will vary randomly and erratically across candidate break dates. If however there is a structural break then the sub-sample estimates will vary systematically across candidate break dates, and the plot of sum of squared errors will show a well-defined minimum near the true break date.

Insert Fig1

The minimum is found at 357 and the full sample is split into two sub-samples [1,357] and [358,2287] and test for structural breaks is carried out on the two sub-samples. Fig.3A gives the plot of Wald statistics across the candidate break dates for the period [358,2287]. The maximum value is 84.072, which exceed the Andrews critical value of 30.43, and we can reject the hypothesis of no structural break. Fig. 3B gives the plot of residual variance as a function of break date and the estimated break date is 720.Using the sequential method in Hansen (2001) we split the sample into two sub-samples [1,720] and [721,2287]. Both the periods show parameter instability and the estimated breakpoints are 396 and 962 respectively. Andrews's test finds evidence for parameter instability in the period [962, 2287] and the estimated breakpoint is 1429. There appears to be structural break in the period [1,962] and the global minima is found to be 357 while the local minima is around 750. Next considering sub sample [1430,2287] Andrews test fails to find evidence for structural break. The maximum value of Wald statistic is found to be 31.15 while the Andrews critical value is 35.67 at 1 percent level of significance.

We have also carried out a sequential estimation method where the breakpoint is estimated using the full sample .The point is 357, next we have taken [358,2287] and using the estimation procedure discussed above determined the breakpoint 720 .The estimated break point for the region [721,2287] comes out to be 962 and the period used for estimation of breakpoint is [963,2287]. The last breakpoint determined is 1429 since stability test (Andrews) suggests that there is no further break in the region [1430,2287]. Based on this evidence, the tentative breakpoints have been identified, as May 1996, August 1997, August 1998 and August 2000. Based on these break dates we have identified five periods. However, testing for stability using Andrews test we found that instability persists in the regions [Nov 94,May 96], [May 96,Aug 97], [Aug 97,Aug 98] while [Aug 98,Aug 00] and [Aug 00,Feb 04] are found to be stable .We divide the whole sample into five sub-periods [Nov 94,May 96], [May 96,Aug 97], [Aug 97,Aug 98], [Aug 98,Aug 00] and [Aug 00,Feb 04].

Once the partitioning of the entire time period in sub-periods of stable parameters is done we search for an appropriate specification of the conditional mean.

<u>Sub-Period 1 (10/8/95-14/5/96)</u>

The first 200 observations of this sub-period are found to be near constant, so we consider the observations after that to determine the conditional mean.

$$r_t = \underset{(2.842)^{***}}{0.202}\, r_{t-1} + \hat{e}_t \tag{4.5}$$

Sub-Period 2 (15/5/96-22/8/97)

$$r_t = -\underset{(7.027)^{**}}{0.383} r_{t-1} - \underset{(2.410)^{*}}{0.133} r_{t-2} + \hat{e}_t \qquad (4.6)$$

Sub-Period 3 (25/8/97-25/8/98)

$$r_t = \underset{(3.035)^{***}}{0.185} r_{t-1} + \underset{(3.759)^{***}}{0.237} r_{t-4} - \underset{(3.654)^{***}}{0.056} b_t + \hat{e}_t \qquad (4.7)$$

Sub-Period 4 (27/8/98-1/8/00)

$$r_t = -\underset{(3.378)^{**}}{0.156} r_{t-1} + \underset{(2.451)^{*}}{0.122} r_{t-7} + \underset{(2.82)^{**}}{0.144} r_{t-9} + \underset{(2.873)^{**}}{0.148} r_{t-10} - \underset{(2.474)^{*}}{0.126} r_{t-15} - \underset{(2.26)^{*}}{0.116} r_{t-16} + \underset{(2.041)^{*}}{0.0002} D_3 + \underset{(2.949)^{**}}{0.0003} D_4 + \hat{e}_t$$

(4.8)

Sub-Period 5 (2/8/00-13/2/04)

$$r_t = \underset{(2.287)^{*}}{0.077} r_{t-1} + \underset{(2.349)^{*}}{0.075} r_{t-17} + \underset{(3.373)^{**}}{0.00003} i_t - \underset{(5.558)^{**}}{0.016} b_t - \underset{(3.373)^{**}}{0.0004} D_1 - \underset{(3.388)^{**}}{0.0004} D_3 - \underset{(2.183)^{*}}{0.0002} D_5 + \hat{e}_t$$

(4.9)

[The values in parenthesis indicate corresponding absolute values of *t*-statistic; * indicates significance at 5% level and ** indicates significance at 1% level of significance]

The Ljung-Box Q statistics have been reported in Table1 .We find from this table that the null hypothesis of no serial correlation in the residuals cannot be rejected for all the five sub-periods. We now report the results of the recursive residual based test of misspecification of conditional mean. This test is carried out to see whether the mean is misspecified.

Sub-Period 1

$$r_t = \underset{(4.176)^{**}}{0.4495} r_{t-1} - \underset{(1.142)}{6.293} \hat{w}_{t-1}^2 - \underset{(1.914)}{569.157} \hat{w}_{t-1}^3 + \hat{e}_t \tag{4.10}$$

Sub-Period 2

$$r_t = \underset{(0.522)}{0.029} r_{t-1} - \underset{(0.013)}{0.0006} r_{t-2} + \underset{(1.887)}{25.25} \hat{w}_{t-1}^2 - \underset{(5.567)^{**}}{1481.386} \hat{w}_{t-1}^3 - \underset{(4.246)^{**}}{179183.1} \hat{w}_{t-1}^4 + \hat{e}_t \tag{4.11}$$

Sub-Period 3

$$r_t = \underset{(1.19)}{0.109} r_{t-1} + \underset{(3,947)^{**}}{0.253} r_{t-4} - \underset{(3.69)^{**}}{0.058} b_t - \underset{(1.137)}{6.046} \hat{w}_{t-1}^2 + \underset{(1.187)}{553.58} \hat{w}_{t-1}^3 + \hat{e}_t \tag{4.12}$$

Sub-Period 4

$$\begin{aligned} r_t = {} & \underset{(2.541)^{*}}{0.161} r_{t-1} + \underset{(2.358)^{*}}{0.113} r_{t-7} + \underset{(2.85)^{*}}{0.139} r_{t-9} + \underset{(2.641)^{**}}{0.131} r_{t-10} - \underset{(2.395)^{*}}{0.117} r_{t-15} - \underset{(1.544)}{0.076} r_{t-16} + \underset{(2.423)^{*}}{0.0002} D_3 + \underset{(2.893)^{**}}{0.0003} D_4 \\ & - \underset{(2.504)^{*}}{38.91} \hat{w}_{t-1}^2 - \underset{(7.108)^{**}}{30315.73} \hat{w}_{t-1}^3 + \hat{e}_t \end{aligned} \tag{4.13}$$

Sub-Period 5

$$r_t = \underset{(4.087)^{**}}{0.174} r_{t-1} + \underset{(2.495)^{*}}{0.082} r_{t-17} - \underset{(4.984)^{**}}{0.014} b_t + \underset{(4.099)^{**}}{.00004} i_t - \underset{(3.767)^{**}}{0.0004} D_1 - \underset{(3.81)^{**}}{0.0004} D_3 - \underset{(2.759)^{**}}{0.0003} D_5 - \underset{(1.402)}{12.072} \hat{w}_{t-1}^2$$
$$- \underset{(3.614)^{**}}{4997.735} \hat{w}_{t-1}^3 + \hat{\boldsymbol{e}}_t \tag{4.14}$$

[The values in parenthesis indicate corresponding absolute values of t-statistic; * indicates significance at 5% level and ** indicates significance at 1% level of significance]

It is evident from the estimated equations that the conditional mean is properly specified in sub-periods 1 and 3. However for sub-periods 2 and 4 the coefficients of $\hat{w}_{t-1}^2$ and $\hat{w}_{t-1}^3$ are significant indicating misspecification in conditional mean. For sub-period 5 however the coefficient of $\hat{w}_{t-1}^3$ is significant. We include r_{t-1}^3 in the mean and carry out the test of misspecification only to find that the coefficients of $\hat{w}_{t-1}^2$ and $\hat{w}_{t-1}^3$ are insignificant.

We need to specify the conditional variance after the conditional mean has been properly specified. For sub-periods 2 and 4 we include the nonlinear functions of recursive residuals in the conditional mean function and estimate the model along with the GARCH formulation for conditional heteroscedasticity h_t i.e.,

$$h_t = \boldsymbol{a}_0 + \boldsymbol{a}_1 \boldsymbol{e}_{t-1}^2 + \ldots + \boldsymbol{a}_q \boldsymbol{e}_{t-q}^2 + \boldsymbol{b}_1 h_{t-1} + \ldots + \boldsymbol{b}_p h_{t-p} \tag{4.15}$$

where the stochastic error $\boldsymbol{e}_t$ conditional on the realized values of the set of variables $\boldsymbol{y}_{t-1} = [y_{t-1}, z_{t-1}, y_{t-2}, z_{t-2}, \ldots\ldots]$ is assumed to be normally distributed i.e. $\boldsymbol{e}_t \mid \boldsymbol{y}_{t-1} \sim N(0, h_t)$. The inequality restrictions $\boldsymbol{a}_0 > 0$, $\boldsymbol{a}_i \geq 0$ for i=1,….q, $\boldsymbol{b}_i \geq 0$ for i=1,…p are imposed to ensure that the conditional variance is strictly positive.

Bollerslev (1986) gave the necessary and sufficient condition $\sum_{i=1}^{q} \boldsymbol{a}_i + \sum_{i=1}^{p} \boldsymbol{b}_i < 1$ for existence of variance. To avoid nonnegativity restrictions on parameters, Nelson used logarithmic specification and proposed

$$\log(h_t) = \boldsymbol{a}_0 + \sum_{i=1}^{q} \boldsymbol{a}_i g(\boldsymbol{h}_{t-i}) + \sum_{i=1}^{p} \boldsymbol{b}_i \log(h_{t-i}), \tag{4.16}$$

where $g(\boldsymbol{h}_t) = \boldsymbol{q}\boldsymbol{h}_t + \boldsymbol{g}[|\boldsymbol{h}_t| - E|\boldsymbol{h}_t|]$

This is known as exponential GARCH or EGARCH. $g(\boldsymbol{h}_t)$ is independent with mean zero and constant finite variance. It may be noted that unlike GARCH, exponential GARCH does not require any nonnegative restrictions on the parameters involved in h_t.

We used the standard GARCH model but found that the condition $\sum_{i=1}^{q} \boldsymbol{a}_i + \sum_{i=1}^{p} \boldsymbol{b}_j < 1$ was not being satisfied. We then used EGARCH form for h_t and it was found out to be appropriate for conditional variance for returns of spot exchange rate in India. There are some empirical evidence in favor of EGARCH with studies on Canadian dollar, Swiss franc and the Deutsche mark and it is found to perform reasonably well (Hsieh (1989)).

In our case *viz*. in case of Indian Rupee, EGARCH has been found to be the appropriate volatility model for all the sub-periods, as evidenced from equations (4.17) through (4.26) below.

<u>Sub-Period 1 (10/8/95-14/5/96)</u>

$$r_t = \underset{(2.08)^*}{0.154} r_{t-1} + \hat{\boldsymbol{e}}_t \tag{4.17}$$

$$\log(h_t) = \underset{(5.2)^{**}}{-3.132} + \underset{(3.98)^{**}}{0.584}\, g(\boldsymbol{h}_{t-1}) + \underset{(3.59)^{**}}{0.52}\, g(\boldsymbol{h}_{t-2}) + \underset{(12.42)^{**}}{0.696} \log(h_{t-1}) \tag{4.18}$$

The value of $\boldsymbol{q} = \underset{(3.52)^{**}}{0.352}$

<u>Sub-Period 2 (15/5/96-22/8/97)</u>

$$r_t = \underset{(3.17)^{**}}{0.209}\, r_{t-1} - \underset{(4.35)^{**}}{0.182}\, r_{t-2} + \underset{(156.62)^{**}}{26.979}\, \hat{w}_{t-1}^2 - \underset{(5203.8)^{**}}{1481}\, \hat{w}_{t-1}^3 - \underset{(781467)^{**}}{179183}\, \hat{w}_{t-1}^4 + \hat{\boldsymbol{e}}_t \tag{4.19}$$

$$\log(h_t) = \underset{(5.91)^{**}}{-3.386} + \underset{(13.07)^{**}}{1.268}\, g(\boldsymbol{h}_{t-1}) + \underset{(17.75)^{**}}{0.739} \log(h_{t-1}) \tag{4.20}$$

The value of $\boldsymbol{q} = \underset{(2.00)^{*}}{-0.127}$

<u>Sub-Period 3 (25/8/97-25/8/98)</u>

$$r_t = \underset{(2.75)^{**}}{-0.158}\, r_{t-1} + \underset{(3.76)^{**}}{0.158}\, r_{t-4} - \underset{(7.62)^{**}}{0.064}\, b_t + \hat{\boldsymbol{e}}_t \tag{4.21}$$

$$\log(h_t) = \underset{(8.00)^{**}}{-7.94} + \underset{(7.26)^{**}}{1.4}\, g(\boldsymbol{h}_{t-1}) + \underset{(3.12)^{**}}{0.273} \log(h_{t-1}) \tag{4.22}$$

The value of $\boldsymbol{q} = \underset{(2.97)^{**}}{0.261}$

<u>Sub-Period 4 (27/8/98-1/8/00)</u>

$$r_t = \underset{(2.11)^{*}}{0.083}\, r_{t-4} + \underset{(2.25)^{*}}{0.085}\, r_{t-5} + \underset{(3.89)^{**}}{0.138}\, r_{t-9} + \underset{(3.16)^{**}}{0.103}\, r_{t-10} - \underset{(2.09)^{*}}{0.063}\, r_{t-15} + \hat{\boldsymbol{e}}_t \tag{4.23}$$

$$\log(h_t) = \underset{(4.22)^{**}}{-1.838} + \underset{(15.81)^{**}}{0.725}\, g(\boldsymbol{h}_{t-1}) + \underset{(6.92)^{**}}{0.657} \log(h_{t-1}) + \underset{(2..31)^{*}}{0.213} \log(h_{t-2}) \tag{4.24}$$

The value of $\boldsymbol{q} = \underset{(3.72)^{**}}{0.287}$

Sub-Period 5 (2/8/00-13/2/04)

$$r_t = \underset{(2.52)^*}{0.087} r_{t-1} + \underset{(2.48)^*}{0.035} r_{t-17} - \underset{(24221)^{**}}{3716} r_{t-1}^3 + \hat{e}_t \tag{4.25}$$

$$\log(h_t) = -\underset{(5.68)^{**}}{3.019} + \underset{(8.86)^{**}}{0.568} g(h_{t-1}) + \underset{(20.04)^{**}}{0.778} \log(h_{t-1}) \tag{4.26}$$

The value of $q = \underset{(6.03)^{**}}{0.451}$

[The values in parenthesis indicate corresponding absolute values of t-statistic; * indicates significance at 5% level and ** indicates significance at 1% level of significance]

The values of $Q(.)$ and $Q^2(.)$ statistics have been provided in Table 2 and these indicate that there is no significant autocorrelation present in the standardized residuals and the squared standardized residuals at 5 percent significance level.

Finally, we carry out an exercise to check whether there is any remaining higher order, say 3rd or 4th order dependence in the standardized residual, $\tilde{e}_t$. Here we regress $\tilde{e}_t^3$ and $\tilde{e}_t^4$ separately on their respective lags and then test the significance of these lag terms. The regressions for all the 5 sub-periods show that none of the lag terms are significant indicating that there are no 3rd or 4th order dependences in the standardized residual.

Sub-Period 1

$$\tilde{e}_t^3 = \underset{(1.391)}{1.218} + \underset{(0.104)}{0.008} \tilde{e}_{t-1}^3 - \underset{(0.0003)}{0.00002} \tilde{e}_{t-2}^3 - \underset{(0.065)}{0.005} \tilde{e}_{t-3}^3 \tag{4.27}$$

$$\tilde{e}_t^{\,4} = \underset{(2.12)}{8.867} - \underset{(0.243)}{0.018}\tilde{e}_{t-1}^{\,4} - \underset{(0.28)}{0.02}\tilde{e}_{t-2}^{\,4} - \underset{(0.288)}{0.021}\tilde{e}_{t-3}^{\,4} \tag{4.28}$$

Sub-Period 2

$$\tilde{e}_t^{\,3} = \underset{(0.276)}{0.14} - \underset{(1.625)}{0.092}\tilde{e}_{t-1}^{\,3} - \underset{(0.02)}{0.001}\tilde{e}_{t-2}^{\,3} + \underset{(0.508)}{0.031}\tilde{e}_{t-3}^{\,3} \tag{4.29}$$

$$\tilde{e}_t^{\,4} = \underset{(3.505)}{6.871} + \underset{(0.768)}{0.043}\tilde{e}_{t-1}^{\,4} - \underset{(0.739)}{0.042}\tilde{e}_{t-2}^{\,4} + \underset{(0.038)}{0.002}\tilde{e}_{t-3}^{\,4} \tag{4.30}$$

Sub-Period 3

$$\tilde{e}_t^{\,3} = \underset{(1.163)}{0.949} - \underset{(0.039)}{0.003}\tilde{e}_{t-1}^{\,3} - \underset{(0.228)}{0.015}\tilde{e}_{t-2}^{\,3} - \underset{(0.614)}{0.041}\tilde{e}_{t-3}^{\,3} \tag{4.31}$$

$$\tilde{e}_t^{\,4} = \underset{(2.843)}{10.201} - \underset{(0.495)}{0.033}\tilde{e}_{t-1}^{\,4} - \underset{(0.466)}{0.031}\tilde{e}_{t-2}^{\,4} - \underset{(0.27)}{0.018}\tilde{e}_{t-3}^{\,4} \tag{4.32}$$

Sub-Period 4

$$\tilde{e}_t^{\,3} = \underset{(1.83)}{0.782} + \underset{(0.712)}{0.034}\tilde{e}_{t-1}^{\,3} - \underset{(0.004)}{0.0002}\tilde{e}_{t-2}^{\,3} - \underset{(0.11)}{0.005}\tilde{e}_{t-3}^{\,3} \tag{4.33}$$

$$\tilde{e}_t^{\,4} = \underset{(3.377)}{6.179} - \underset{(0.122)}{0.006}\tilde{e}_{t-1}^{\,4} + \underset{(0.021)}{0.001}\tilde{e}_{t-2}^{\,4} - \underset{(0.243)}{0.011}\tilde{e}_{t-3}^{\,4} \tag{4.34}$$

Sub-Period 5

$$\tilde{e}_t^{\,3} = \underset{(1.869)}{1.081} + \underset{(0.11)}{0.004}\tilde{e}_{t-1}^{\,3} - \underset{(0.093)}{0.003}\tilde{e}_{t-2}^{\,3} - \underset{(0.892)}{0.031}\tilde{e}_{t-3}^{\,3} \tag{4.35}$$

$$\tilde{e}_t^{\,4} = \underset{(2.19)}{8.823} - \underset{(0.116)}{0.004}\tilde{e}_{t-1}^{\,4} - \underset{(0.102)}{0.003}\tilde{e}_{t-2}^{\,4} + \underset{(0.153)}{0.005}\tilde{e}_{t-3}^{\,4} \tag{4.36}$$

5.Conclusion

Structural change is important in studying time series relationships, and if we ignore it while modeling the inference is very likely to be misleading and improper. We have applied modern econometric methods to systematically determine the breakpoints in nominal Rupee/US dollar exchange rate series and have used an adequate modeling exercise, incorporating ARCH/GARCH to study predictability of exchange rate return with due consideration to possible sources of misspecification of conditional mean, i.e. serial correlation, seasonal effects, parameter instability, omitted time series variables and any other remaining nonlinear dependences. The break dates identified are 14/5/96,22/8/97,25/8/98 and 1/8/2000 for this series

The period from March 1993 till November 1994 was a prolonged phase of near constant exchange rate .The exchange rate fluctuated little till August 1995. The Indian Economy experienced surges of capital inflow during 1993-94, 1994-95 and first half of 1995-96, which coupled with robust export growth, exerted an upward pressure on the exchange rate. At this point the Reserve Bank intervened to ensure the market correction of overvalued exchange rate. The monetary and other measures succeeded in restoring orderly conditions and the rupee traded in range of Rs 34-35 per US Dollar over the period March-June 1996. However our empirical exercise identifies in this period, a structural break.

In consideration of the international developments, a high level of activity was noted in the second quarter of 1997, supported by an accommodating monetary stance in the major economies and subdued inflation. However, currency and country risk factors were given greater consideration in the wake of financial turbulence observed in certain Eastern European and Asian countries. There was uncertainty surrounding the introduction of the single European currency. Changes in market sentiments were reflected in a movement away from core continental European currencies and towards the US dollar, reflecting large interest differentials and renewed concerns with respect to the implementation of European Economic and monetary union. India experienced a period of heightened volatility from August 1997 till January 1998. At this point it is important to mention that the second break point is identified. This crisis marked the beginning of innovative measures used by RBI to ward off speculation (see Ghosh (2002)). The most important feature of the intervention used by RBI is that they were indirect measures.

Following some easing of market tensions in Asia in the earlier part of 1998, some internal developments were marked which included the economic sanctions in the aftermath of nuclear tests during May 1998.

There was renewed financial turbulence in the second quarter of 1998. Nervousness about the economic and financial conditions of Japan accentuated the coolness toward yen-denominated assets. Problems of policy credibility in several Asian countries put downward pressures on currencies in the region, with markets paying increasing attention to the risk of a devaluation of the Chinese yuan. These events, together with the weakness of commodity prices and, in some countries, political uncertainty, initiated a new wave of contagion to other emerging market economies, triggering a flight towards the perceived safe markets of United States and Europe. The resurgence of financial turbulence in the second quarter of 1998 lent a new sense of urgency to addressing issues of crisis, prevention and resolution. Despite the numerous initiatives that have been spurred by the Asian crisis, national and international authorities continue to face difficult trade-offs. These events underlined the need to reconsider architecture of world financial system. Indian financial markets were also plagued by turmoil in August 1998, the devaluation of Russian rouble and fears of devaluation of Chinese yuan being held responsible, these sentiments were further fueled by domestic political compulsions. A package of measures was announced on August 20. But this crisis was reported as short-lived (see Ghosh(2002))and found not to affect the monetary market though our empirical application has found a break at this point. Another internal development in 1999 was the border conflict during May-June 1999.The year 1999 has been marked by a subsequent increase in crude prices especially May 2000 onwards.

In this study E-GARCH model has been found to be most appropriate in modeling volatility for all the sub-periods.

TABLE 1

Ljung –Box Test of Autocorrelation for residuals

Lag m	Sub-Period 1		Sub-Period 2		Sub-Period 3		Sub-Period 4		Sub-Period 5	
	Q-Stat	Prob.	Q-Stat	Prob.	Q-Stat	Prob.	Q-Stat	Prob.	Q-Stat	Prob.
1	0.116	0.734	0.002	0.969	0.062	0.804	0.065	0.799	0.293	0.588
2	2.346	0.309	0.273	0.872	5.024	0.081	0.208	0.901	1.965	0.374
3	4.788	0.188	2.082	0.556	7.095	0.069	0.301	0.96	2.079	0.556
4	8.243	0.083	2.607	0.626	7.221	0.125	2.527	0.64	2.103	0.717
5	9.529	0.09	2.667	0.751	9.346	0.096	5.157	0.524	2.707	0.745
6	10.777	0.096	2.667	0.849	10.032	0.123	5.158	0.524	2.707	0.845
7	10.902	0.143	2.883	0.896	10.307	0.172	5.419	0.609	3.312	0.855
8	11.536	0.173	4.578	0.802	11.052	0.199	5.945	0.653	8.497	0.386
9	11.567	0.239	5.048	0.83	11.252	0.259	5.968	0.743	8.724	0.463
18	17.252	0.506	7.625	0.984	17.332	0.5	9.761	0.939	12.595	0.815
36	43.598	0.18	31.023	0.704	30.086	0.745	30.187	0.741	24.621	0.924

All the test values indicate that there are no significant autocorrelations.

TABLE 2

Ljung-Box Test of Autocorrelation for standardized residuals and squared standardized Residuals

Lag m		1	2	3	4	5	6	7	8	9	18	36
Sub-Prd 1	Q	1.381	3.8	3.83	5.563	5.799	5.973	5.977	10.51	10.51	20.99	33.23
	P	0.24	0.15	0.28	0.234	0.326	0.426	0.542	0.231	0.311	0.28	0.601
	Q^2	0.032	0.322	0.465	1.925	2.297	2.337	2.38	5.214	5.736	17.11	26.89
	P	0.859	0.851	0.926	0.749	0.807	0.886	0.936	0.735	0.766	0.515	0.864
Sub-Prd 2	Q	4.711	4.833	4.833	4.864	5.074	7.353	7.621	9.713	9.716	16.74	40.51
	P	0.03*	0.089	0.184	0.302	0.407	0.289	0.367	0.286	0.374	0.541	0.278
	Q^2	0.008	1.132	1.456	1.694	1.712	2.714	3.053	4.378	4.429	18.54	40.49
	P	0.929	0.568	0.692	0.792	0.887	0.844	0.88	0.821	0.881	0.421	0.279
Sub-Prd 3	Q	2.052	4.077	5.509	5.7	5.87	6.495	6.563	9.033	9.786	15.63	25.21
	P	0.152	0.13	0.138	0.223	0.319	0.37	0.476	0.34	0.368	0.615	0.911
	Q^2	0.463	0.588	0.613	2.629	2.959	3.215	3.249	3.74	4.161	13.01	27.21
	P	0.495	0.745	0.893	0.622	0.706	0.781	0.861	0.88	0.9	0.791	0.854
Sub-Prd 4	Q	0.156	0.302	0.307	0.316	0.342	0.703	0.786	0.801	0.879	10.88	34.58
	P	0.693	0.86	0.959	0.989	0.997	0.994	0.998	0.999	1.00	0.899	0.536
	Q^2	0.17	0.494	0.495	1.265	2.104	2.919	3.284	3.293	3.528	9.538	17.33
	P	0.68	0.781	0.92	0.867	0.835	0.819	0.858	0.915	0.94	0.946	0.996
Sub-Prd 5	Q	1.464	2.466	2.472	2.99	3.132	3.719	3.749	4.727	4.808	14.63	35.64
	P	0.226	0.291	0.48	0.559	0.68	0.715	0.808	0.786	0.851	0.687	0.486
	Q^2	0.192	0.194	0.455	0.55	0.967	0.984	2.049	2.285	2.331	6.335	13.02
	P	0.661	0.907	0.929	0.968	0.965	0.986	0.957	0.971	0.985	0.995	1.000

All test values indicate that there are no significant autocorrelations.

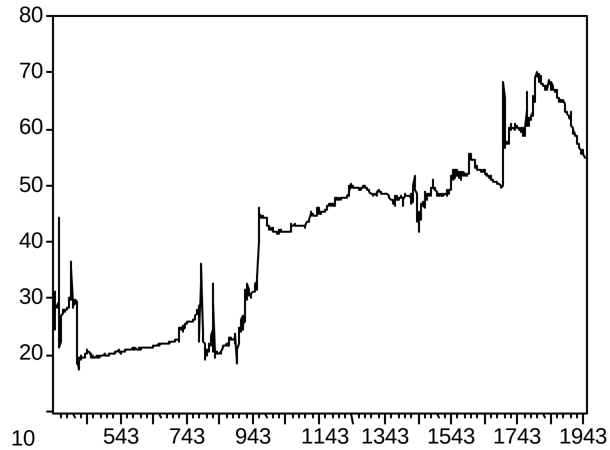


Fig 1. Plot of Wald statistics for each candidate break point

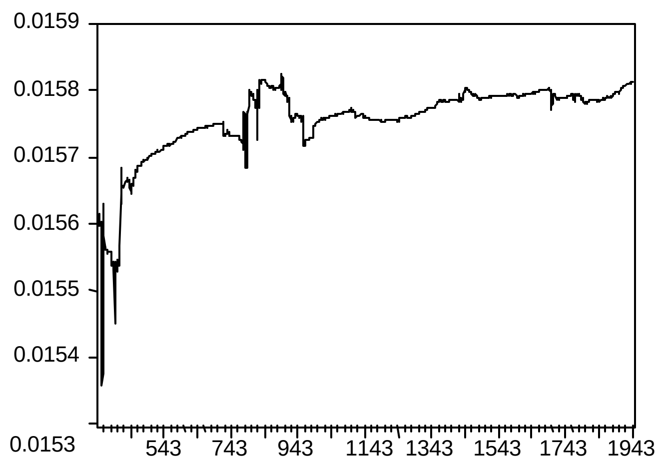


Fig2. Plot of residual variance for each candidate breakpoint.

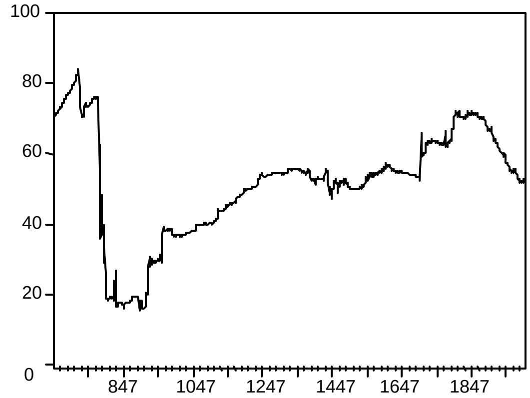


Fig 3A. Andrews Test for [358,2287]

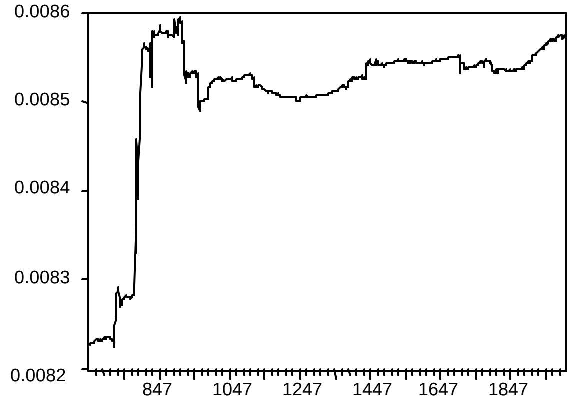


Fig 3B. Estimation of break point for [358,2287]

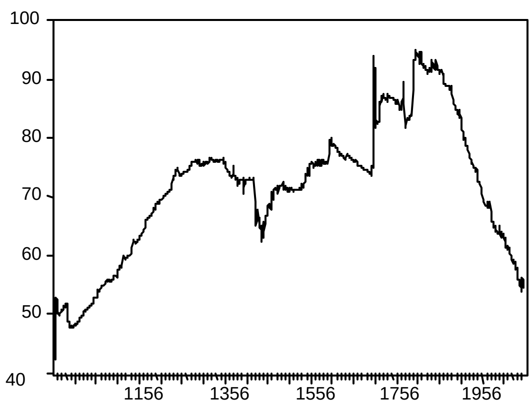


Fig 3C. Andrews Test for [721,2287]

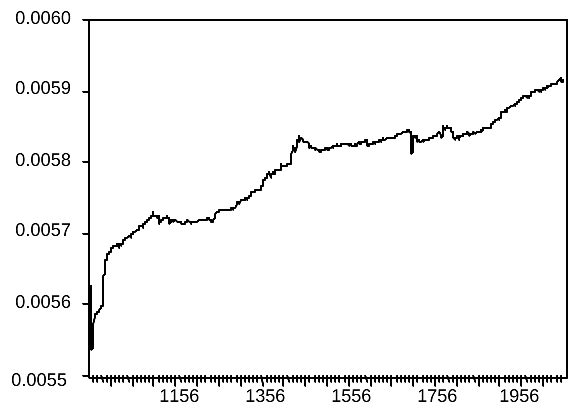
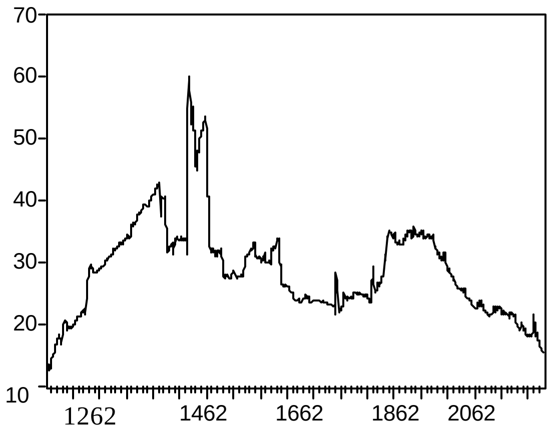


Fig 3D. Estimation of break date for [721,2287]



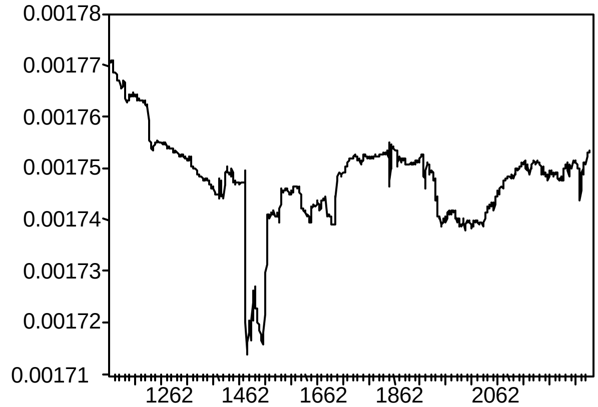
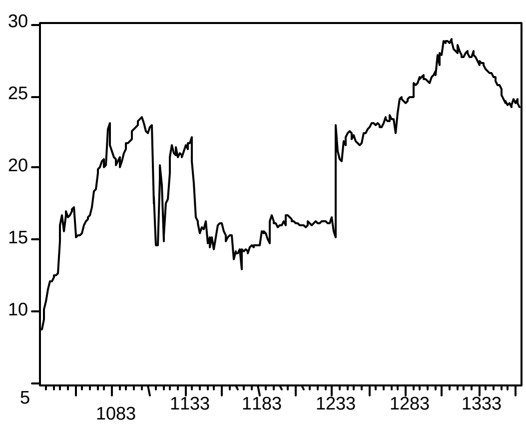


Fig 3E. Andrews Test for [963,2287]

Fig 3F. Estimation of break point for[963,2287]



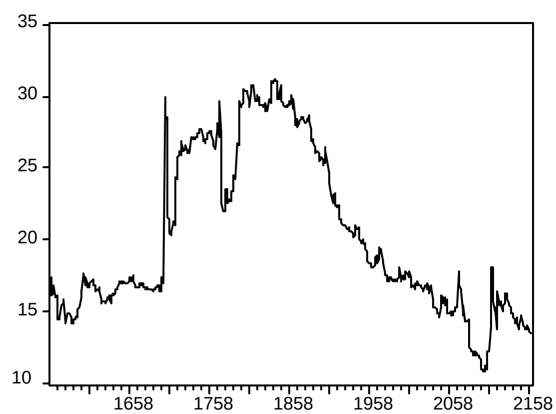


Fig 3G. Andrews Test for [963,1429]

Fig 3H . Andrews Test for [1429,2287]

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