Modelling & Forecasting of Re/$ Exchange rate – An empirical analysis

Surendra babu Gadwala(IIT K) and Somesh K Mathur(Associate Professor,HSS,IITK)

April 2014
## CONTENTS

1. Introduction ........................................................................................................................................3
2. Evolution of exchange rate policy in last 50 years ........................................................................4
3. Theoretical Framework ..................................................................................................................6
   4.1 Purchasing power parity theorem (PPP): ..................................................................................6
   4.2 Harrod balassa samuelson model [1]: ......................................................................................7
   4.3 Open interest differential: ........................................................................................................8
   4.4 Theory : capital flows, forward premium , order flows, rbi intervention ............................10
4. Literature review ..........................................................................................................................11
   5.1 Literature on modelling and forecasting of exchange rate ....................................................11
   5.2 Literature on Methodology (ARDL, ARIMA) .........................................................................12
5. Model and hypothesis ..................................................................................................................13
6. Econometric Methodology ..........................................................................................................14
7. Results ...........................................................................................................................................23
   8.1 Results: Modelling of Exchange Rate ....................................................................................23
   8.2 Results: Forecasting of Exchange rate ...................................................................................29
8. Conclusions ...................................................................................................................................33
9. Data sources and its definitions ....................................................................................................34
10. References ....................................................................................................................................35
11. Appendix .....................................................................................................................................36
1 INTRODUCTION

The exchange rate is price of one currency in terms of other. It is a key financial variable that effects decisions made by foreign exchange investors, exporters, bankers, financial institutions, policy makers. Exchange rate fluctuations affect the value of international investment portfolios, competitiveness of exports and imports, value of international reserves, currency value of debt payments, and the cost to tourists in terms of the value of their currency. Movements in exchange rates thus have important implications for the economy’s business cycle, trade and capital flows and are therefore crucial for understanding financial developments and changes in economic policy. Exchange rate virtually determines the terms of trade with other countries. Stable Exchange Rate is one of the requirements for stable Economy. India follows the Liberalized Exchange Rate Management System (LERMS), under which it is absolutely necessary to understand how the exchange rate moves, and why? The market or the day-today exchange rates, however, are subject to fluctuations in response to the changes to the supply and demand for international money transfers. There are a host of factors which influence to the supply and demand for foreign exchange and thus are responsible for the fluctuations in the rate of exchange Timely forecasts of exchange rates can therefore provide valuable information to decision makers and participants in the spheres of international finance, trade and policy making. Nevertheless, we have enough empirical literature is skeptical about the possibility of accurately predicting exchange rates.

This study attempts to develop a model for the rupee-dollar exchange rate taking into account the different monetary models and variables. The focus is on the exchange rate of the Indian rupee vis-à-vis the US dollar, i.e., the Re/$ rate. This study covers topics: modelling and forecasting the exchange rate. There are a host of factors which influence to the supply and demand for foreign exchange and thus are responsible for the fluctuations in the rate of exchange.

With Liberalization and development of foreign exchange and assets markets variables such as capital inflows, forward premium have also become important in determining exchange rate. From the paper by Medeiros, 2005; Bjonnes and Rime 2003 it was evident that agents in
the foreign exchange market have access to private information about fundamentals or liquidity which is reflected in the buying and selling transactions they undertake that is termed as order flows which is also show impact on exchange rate. Another important variable in determining exchange rate is central bank intervention in the foreign exchange market.

After studying the factors affecting the exchange rate in the first part, then in the second part attempts to examine the forecasting performance of this developed model using simple Ordinary least squares, Vector auto regression and Autoregressive Integrated Moving average models. This Study also evaluates the forecasting performance of OLS, VAR, ARIMA models using different error statistics. We used monthly data of all variables from January 1999 to December 2012 while out of sample forecasting performance evaluated from January 2013 to December 2013 and compared with actual data of exchange rate. Using the best forecasting model out of all the three models we forecasted exchange rate for future coming months January 2014 to June 2014.

Against this backdrop, Section II the economic theory and review of literature would be covered. In Section III, theoretical background for variables in determining exchange rate Review of literature related to modelling of exchange rate and literature on methodology are covered in Section IV. Model for this study is in Section V while the econometric methodology is discussed in Section VI. The estimation and results is done in Section VII. The Section VIII presents some concluding observations.

2 EVOLUTION OF EXCHANGE RATE POLICY IN LAST 50 YEARS

India’s exchange rate policy has evolved from last 50 years with the gradual opening up economy since 1990s. In the post-independence period, India’s exchange rate policy has seen a shift from a par value system to basket peg and further to a managed float exchange rate system. From 1947 to 1977, India followed par value system where Rupee’s external par value fixed at 4.15 grains of gold. RBI used to maintain this values using Pound sterling as intervention currency. The Exchange control measures in this fixed exchange rate regime were guided by the Foreign Exchange Regulation Act that was initially enacted in 1947 and placed on a permanent
basis in 1957[1]. Based on the provisions of the Act, the Reserves Bank of India in certain cases in the central government, controlled and regulated the dealing in foreign exchange payment outside India, export and import of currency notes and bullion, transfers of securities between residents and nonresidents, acquisition of foreign securities, etc.[1]

With the breakdown of Bretton woods system in 1971 and floatation of major currencies, to stabilize the exchange rate rupee was linked to pound sterling. Later in order to overcome the weakness associated with single currency peg and to ensure the stability of the exchange rate, the rupee was pegged to basket of currencies in 1975. By the late eighties and early nineties it was recognized that both macroeconomics policy and structural factors had contributed to balance of payment difficulties. The two-step adjustment of July 1991 effectively brought to a close the period of pegged exchange rate. Following the recommendations of Rangarajan Committee to move towards the market determined exchange rate, the Liberalized Exchange Rate Management System (LERMS) was put in place in March 1992 involving dual exchange rate system in the interim period [1]. The dual exchange rate system was replaced by unified exchange rate system in March 1993. From 1993 till now we are in a mixture of these both policy called Managed floating with Market determining Structure to make country stable. The unification of the exchange rate of the Indian rupee was an important step to current account convertibility. The experience with the market determined exchange rate system in India, since 1993 is generally described as satisfactory as orderliness prevailed in the Indian
market during most of the period. The chronology of evolution of exchange rate policy in India over a timeline is given in below Table 2.1

<table>
<thead>
<tr>
<th>Year</th>
<th><strong>Foreign exchange market and Exchange rate</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1947-1971</td>
<td>Par Value system of exchange rate. Rupee’s external par value was fixed in terms of gold with the pound sterling as the intervention currency</td>
</tr>
<tr>
<td>1971</td>
<td>Breakdown of the Bretton-Woods system and floatation of major currencies. Rupee was linked to the pound sterling in December 1971.</td>
</tr>
<tr>
<td>1975</td>
<td>To ensure stability of the Rupee, and avoid the weaknesses associated with a single currency peg, the Rupee was pegged to a basket of currency. Currency selection and weight assignment was left to the discretion of the RBI and not publicly announced.</td>
</tr>
<tr>
<td>1978</td>
<td>RBI allowed the domestic banks to undertake intra-day trading in foreign exchange.</td>
</tr>
<tr>
<td>1990-92</td>
<td>Balance of Payments crisis</td>
</tr>
<tr>
<td>July 1991</td>
<td>To stabilize the foreign exchange market, a two-step downward exchange rate adjustment was done (9% and 11%). This was a decisive end to the pegged exchange rate regime.</td>
</tr>
<tr>
<td>March 1992</td>
<td>To ease the transition to a market determined exchange rate system, the Liberalized Exchange Rate Management System (LERMS) was put in place, which used a dual exchange rate system. This was mostly a transitional system</td>
</tr>
<tr>
<td>March 1993</td>
<td>The dual rates converged, and the market determined exchange rate regime was introduced. All foreign exchange receipts could now be converted at market determined exchange rates</td>
</tr>
</tbody>
</table>

Source: Reserve Bank of India  
Table 2.1

3 THEORETICAL FRAMEWORK

3.1 PURCHASING POWER PARITY THEOREM (PPP):

It states that the exchange rate between one currency and another is in equilibrium when their domestic purchasing powers at that rate of exchange are equivalent. PPP says currency with higher inflation rate is expected to depreciate relative to currency with lower inflation
Purchasing Power Parity suggests that Real exchange rate should be constant, so if there is a large difference in price between two countries for the same product after exchange rate adjustment, an arbitrage opportunity is created, because the product can be obtained from the country that sells it for the lower price. Hence the exchange rate is adjusted to keep the real exchange rate constant.

\[ RER = \frac{e p^*}{p} \]

Where, \( RER \) = real exchange rate, \( e \)=exchange rate expressed as the number of foreign currencies per one unit of home currency, \( p^* \)=price in foreign country (US), \( p \)=price in home country.

Taking Log and differentiating, exchange rate will depend on differential inflation rate

\[ \frac{d e}{e} = \frac{d p}{p} - \frac{d p^*}{p} \frac{d p}{p} = \text{inflation in India}, \quad \frac{d p^*}{p} = \text{inflation in US} \]

PPP theory provided a point of reference for the long run exchange rate in many of the modern exchange rate theories. It was observed that there were deviations from the PP in short run, but in the long run, PPP holds equilibrium. The reasons for the failure of the PPP have been attributed to the heterogeneity in the baskets of goods considered for construction of prices indices in various countries, the transportation cost, and the imperfect competition of goods market which led to sharp deviation in PPP theory.

### 3.2 HARROD BALASSA SAMUELSON MODEL [1]:

It rationalized the long run deviations from PPP. According to this model, productivity differentials are important in explaining exchange rates. They relax PPP assumption and allow real exchange rates depend on relative price of non-tradable which are function of productivity differentials. The Purchasing power parity (PPP) condition and the money demand functions of domestic and foreign countries are assumed to take the forms as below
\[ \frac{M}{P} = L(Y, i) \]

\[ \frac{M^*}{P^*} = L(Y^*, i^*) \]

\[ E = \frac{P}{P^*} \]

where \( M \) represents domestic money balances; \( P \) is domestic price level; \( Y \) is domestic real income; \( i \) denotes domestic interest rate; \( E \) is the exchange rate of domestic currency per unit of foreign currency; and the corresponding variables for foreign country are denoted by asterisks.

Therefore, we have the monetary approach of exchange rate determination as follows

\[ E = \frac{M}{L(Y, i)} \frac{L(Y^*, i^*)}{M^*} \]

i.e. exchange rate is depending on money supply and output of both domestic and foreign country.

### 3.3 OPEN INTEREST DIFFERENTIAL:

A theory in which the interest rate differential between two countries is equal to the differential between the forward exchange rate and the spot exchange rate. Given the assumptions of capital mobility and perfect substitutability. Interest Rate Parity suggests that for there to be no arbitrage opportunities, two assets in two different countries should have similar interest rates, as long as the risk for each is the same. The basis for this parity is also the law of one price, in that the purchase of one investment asset in one country should yield the same returns as the exact same asset in another country, otherwise exchange rates would have to adjust to make up for the difference.

\[ \frac{F}{S} = \frac{(1 + I_h)}{(1 + I_f)} \]
Where, $F =$ forward exchange, $S =$ spot exchange rate, $I_h =$ interest rate in home country
$I_f =$ interest rate in foreign country (US)

If you invest a unit of domestic currency in the domestic bond, you can expect to come out with
$1+r$ unit of that currency after a year. If you invest a unit of domestic currency in a foreign bond,
you will obtain $1/\pi$ foreign currency units of that bond and can therefore expect to come out
with $(1+r^*)$ $1/\pi$ units of foreign currency after a year. This is where exchange rate expextations
will come in to equation. To compare the two returns you must forecast the exchange rate that
is likely to prevail a year from now. Denote that expected exchange rate by $\pi^*$ and use it convert
the foreign currency return on the foreign bond. It is $(1/\pi) (1+r^*) \pi^e$ units of domestic currency.
Then use $u$ to define the difference between the two returns

$$\frac{1}{\pi} (1+r^*) \pi^e - (1+r) = u;$$

$\pi^e =$ expected nominal exchange rate after 1 year

$r^* =$ interest in foreign country,

$r =$ interest rate in home country,

$(1/\pi) (1+r^*) \pi^e =$ revenue that home country gets after 1 year of investment in foreign country, $u$

= open interest rate differential

$$\hat{\Pi} = \frac{\Pi^e - \Pi}{\Pi} = \text{expected rate of change of exchange rate}$$

$$\Rightarrow \frac{1}{\Pi} (1+r^*) (\hat{\Pi} \Pi + \Pi) - (1+r) = u$$

$$\Rightarrow (1+r^*) (1+\hat{\Pi}) - (1+r) = u$$

$$\Rightarrow \hat{\Pi} + r^* - r = u$$

Higher interest rates attract foreign capital and cause the domestic currency to appreciate and
lower interest rates tend to depreciation. That how the relation between interest rate and
exchange rate was given.
3.4 THEORY: CAPITAL FLOWS, FORWARD PREMIUM, ORDER FLOWS, RBI INTERVENTION

With the evolution of exchange rate policy brings more variables that affect exchange rate because of increase in liberalization and opening up of capital accounts the world over, capital flows become important variable to consider in analysis. The relations between capital flows and exchange rate is hypothesized to be negative because capital inflows as purchase of domestic assets by foreigners and capital outflows means as purchase of foreign assets by residents. Exchange rate is determined by supply and demand for foreign and domestic assets, purchase of foreign assets drives of foreign currency. So, an increase of capital inflows lead to appreciation of the domestic currency when there is no government intervention in the foreign market exchange.

The forward premium measured by the difference between forward and spot exchange rate. According to the covered interest parity, the interest rate differential between two countries equals the premium on forward contracts. So if domestic interest rates rise foreign currency appreciate. The relation between exchange rate and forward premium is expected to be positive.

Order flow is the cumulative flow of transactions, signed positively or negatively depending on whether the initiator of the transaction is buying or selling. Order flow takes positive values if the agent purchases foreign currency and takes negative values if it sells at the dealer's bid. Conventionally, order flow is taken as purchase minus sales of foreign currency. Hence an increase in order flow will generate forces in the foreign exchange market such that there is pressure on the domestic exchange rate to depreciate. Hence the order flow and the exchange rate are positively related (Evans and Lyons, 2005).

Intervention by the central bank in the foreign exchange market is also important variable that show effect on exchange rate. The motive of central bank intervene is to maintain export competiveness; to reduce volatility and to protect the currency from speculative attacks. Intervention also influences exchange rate through different channels through portfolio balance, through monetary channel, intervention accompanies by open market operations, so different
channel intervention gives different signs on exchange rate so the overall effect of intervention on exchange rate is ambiguous.

4 LITERATURE REVIEW

4.1 LITERATURE ON MODELLING AND FORECASTING OF EXCHANGE RATE

Early studies which modelled exchange rates using flexible price model such as Bilson(1978), Woodbury(1980) and Dornbusch (1984) support the performance of the flexible price monetary model in modelling of exchange rate. Studies by Driskill and sheffrin (1981) failed to support the flexible price monetary model and real interest differential model in modelling exchange rate.

Rakesh mohan(2001)in which he explains various aspects of the capital flows and it policy implications and explained the capital flow as determinant of exchange rate modelling. Dua and Sen (2009) develop a model which examines the relationship between the real exchange rate, level of capital flows, volatility of the flows, fiscal and monetary policy indicators and the current account surplus, and find that an increase in capital inflows and their volatility lead to an appreciation of the exchange rate. The theoretical sign on volatility can, however, be positive or negative.

Kenen(1994), in his book he discusses in how exchange rate of a country is determined by a host of factors which includes GDP, Inflation, Interest rate, Money supply along with these there are other’s countries exchange rate which also affects Indian Rupee Exchange Rate. Numerous factors determine exchange rates, and all are related to the trading relationship between two countries. Kenen gave a theoretical garphs and relations between variables differential inflation, interest rate, output, money supply and variables like pound sterling, euro , yen etc.
Pami Dua and Rajiv Ranjan (2012), recent work where they covered the topics various facets of economic policy with respect to the exchange rate, second the recent global financial crisis and the role of exchange rate in that; third the pattern of capital flows and capital account liberalization; fourth modelling and forecasting exchange rate in which they discussed the exchange rate policy of India in background of capital flows, order flows, central bank intervention. At latter part they attempted to gauge the ability of economics to forecast using VAR and BVAR framework and then evaluated the forecast performance.

4.2 **LITERATURE ON METHODOLOGY (ARDL, ARIMA)**

In recent years, although the long run model of exchange rate determination has been the subject of interest for many researchers, there have been only limited studies conducted for the case of Asian countries. To our knowledge, those studies are Makrydakis (1998) and Miyakoshi (2000) for Korea, Chin et al. (2007) for the Philippines, Husted and MacDonald (1999) and Chinn (2000a, b) for selected Asian countries. However, these studies adopted the conventional likelihood-based approach to cointegration proposed by Johansen and Julius (1990). This approach requires the same order of integration of all variables in the system, which is hardly satisfied. The purpose of this paper is to fill the gap in the literature by contributing another study for the case of the Philippines using a state-of-the-art econometric technique, namely Autoregressive Distributed Lag (ARDL) to cointegration. In particularly we followed a paper by M. Pesaran, Shin, J. Smith “Bounds testing approaches to the analysis of level relationships”- in which they proposed tests are based on standard F- and t-statistics used to test the significance of the lagged levels of the variables in a univariate equilibrium correction irrespective of variables in I (0) or I (1) through which one can test for whether there is long run relationship between variables exists or not.

Long and Samreth (2008), examined the validity of both short and long run monetary model of exchange rate using method Auto regressive distributed lag model to cointegration. Pankaj Sinha, Randev, Sushant gupta (2010) analyzed the state of Indian economy pre, during and post-recession by taking factors such as GDP, Exchange rate, inflation, capital markets and
fiscal deficit. They also forecasted some of the major economic variables using ARIMA model. They found that GDP, foreign investments, fiscal deficit and capital markets to rise in 2010-11 period where as ruppe–dollar exchange rate will not change much during this period of study.

In sum, several exchange rate models available in the literature have been tested the last two and half decades. Literatures suggest that different papers considered different monetary models in modelling the exchanges rate however considering more variables giving better results than the random walk. Keeping all results and variables that past studies taken into account, this study tries to re model the exchange rate and forecasted for period January 2014- June 2014.

5 Model and Hypothesis

For estimating the degree of dependence of Indian exchange rates (against USD) on market factors, we have developed a regression model with USD-India exchange rate on left hand side and a number of economic/market variables on the right hand side.

Our model is as follows

\[ EX_t = \beta_0 + \beta_1 Pound_t + \beta_2 Euro_t + \beta_3 Yen_t + \beta_4 DINF_t + \beta_5 DREIR_t + \beta_6 MSIND_t + \beta_7 GDPIND_t + \beta_9 CF_t + \beta_{10} OF_t + \beta_{11} FP_t + \beta_{12} TRB_t + \beta_{13} RIH_t \]

Where,

\[ EX = \text{Price of US dollar in terms of Indian Rupee} \]
\[ Pound = \text{Exchange rate between Pound and USD} \]
\[ Euro = \text{Exchange rate between Euro and USD} \]
\[ Yen = \text{Exchange rate between Yen and USD} \]
\[ DINF = \text{Differential in inflation rate} \]
\[ DREIR= \text{Differential in interest rate} \]
\[ MSIND = \text{Money Supply in India} \]
\[ GDPIND = \text{GDP in India} \]
\[ CF= \text{Capital Inflows} \]
OF= Order Flows
FP= Forward premium
TRB= Trade balance
RBII= Central bank Intervention

Definition of each variable and their data sources were given in appendix. Based on theory that we have seen in theoretical framework section and also by previous paper results one can hypothesis the relation between explanatory variables and dependent variable.

The expected signs of variables can be summarized as follows:

<table>
<thead>
<tr>
<th>Variables</th>
<th>Expected Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Money supply (MSIND)</td>
<td>+</td>
</tr>
<tr>
<td>Output (GDPIND)</td>
<td>-</td>
</tr>
<tr>
<td>Capital Inflows (CF)</td>
<td>-</td>
</tr>
<tr>
<td>Forward Premium (FP)</td>
<td>+</td>
</tr>
<tr>
<td>Order Flows (OF)</td>
<td>+</td>
</tr>
<tr>
<td>Trade Balance (TRB)</td>
<td>-/+</td>
</tr>
<tr>
<td>Intervention (RBII)</td>
<td>-/+</td>
</tr>
</tbody>
</table>

Table 5.1: Expected hypothesis of variables

6 ECONOMETRIC METHODOLOGY

1. Method of least square - Least squares means that the overall solution minimizes the sum of the squares of the residuals made in solving every single equation.

   Since we are dealing here with non-stationary data results produces unreliable t-statistics of the estimated coefficients and Durbin Watson Test statistic goes to zero which is evidence of presence of Postive autocorrelations. So we have to overcome these two problems to get efficient estimates.
2. **Cochrane-Orcutt – Feasible Generalized Least Squares**

Four Steps to carry out this FGLS method as remedy for serial positive auto correlation

- Run OLS on original equation
- Regress residuals on lagged residuals to estimate rho.
- Transform variables using this estimate of rho.
- Run OLS on the transformed variables

1. Begin with a model of a dependent variable $Y$ as a function of $s$ set of independent variables $X_1, \ldots, X_k$

   \[ Y_t = b_0 + b_1 X_{1t} + b_2 X_{2t} + b_3 X_{3t} + \ldots + b_k X_{kt} + e_t \quad [1] \]

2. Regress $e_t$ on $e_{t-1}$ to estimate rho, the impact of lag 1 errors on contemporary errors.

   \[ e_t = \rho (e_{t-1}) + u_t \quad [2] \]

3. The "trick" in creating this pseudo-GLS estimator is to create a new estimating equation, transforming the original variables in the process of eliminating the (first order) serial correlation.

   a. Multiple equation 1 by $\rho$, estimated in equation 2.

   \[ \rho Y_t = \rho b_0 + \rho b_1 X_{1t} + \rho b_2 X_{2t} + \rho b_3 X_{3t} + \ldots + \rho b_k X_{kt} + \rho e_t \quad [3a] \]

   b. Lag equation 3a one time period,

   \[ \rho Y_{t-1} = \rho b_0 + \rho b_1 X_{1,t-1} + \rho b_2 X_{2,t-1} + \rho b_3 X_{3,t-1} + \ldots + \rho b_k X_{k,t-1} + \rho e_{t-1} \quad [3b] \]

   c. Subtract equation 3b from equation 1.

   \[ Y_t - \rho Y_{t-1} = \{b_0 + b_1 X_{1t} + b_2 X_{2t} + b_3 X_{3t} + \ldots + b_k X_{kt} + e_t\} - \{\rho b_0 + \rho b_1 X_{1,t-1} + \rho b_2 X_{2,t-1} + \rho b_3 X_{3,t-1} + \ldots + \rho b_k X_{k,t-1} + \rho e_{t-1}\} \quad [3c] \]

   d. Simplify by combining terms on the right side.

   \[ Y_t - \rho Y_{t-1} = (1-\rho) b_0 + b_1 (X_{1t} - \rho X_{1,t-1}) + \ldots + (e_t - \rho e_{t-1}) \quad [3d] \]

   e. Remember by equation 2, $e_t = \rho e_{t-1} + u_t$

   \[ Y_t - \rho Y_{t-1} = (1-\rho) b_0 + b_1 (X_{1t} - \rho X_{1,t-1}) + \ldots + u_t \quad [3e] \]

We no longer have a serially correlated error term.

f. Simplify 3e by redefining each transformed variable to the right side of the equation.

\[ Y^* = Y_t - \rho Y_{t-1} \]
\[ X_i^* = X_{it} - \rho X_{i,t-1} \]

\[ k^* = 1 - \rho \]

\[ Y^* = b_0 k^* + b_1 X_1^* + b_2 X_2^* + \ldots + u_t[3f] \]

4. Using equation 3f, regress \( Y^* \) on \( k \) and the \( X_i \). The Prais-Winston Estimator will give the Co-FGLS estimates in STATA in which it improves the Durbin Watson statistic.

Unit root tests are used to test for stationarity or order of integration of each series of the variables (second problem that simple OLS estimates have in case of time series variable)

3. Unit Root Test

The first step of testing cointegration is to test all the time series variables for stationarity. Therefore, we conducted the Augmented Dickey-Fuller unit root test on each of the variables and verify that each of these series is integrated of order one.

4. Augmented Dickey-Fuller test

The greater the ADF test statistic value than the critical t-statistical value, stronger the hypothesis that there is a unit some level of confidence. Non-stationary data used in estimation produces unreliable t-statistics of the estimated coefficients in method of Least Squares. Unit root tests are used to test for stationarity or order of integration of each series of the variables. There are three types of ADF methods to check unit root problem.

Without Constant and Trend \[ \Delta Y = \delta Y_{(t-1)} + \epsilon_t \]

With Constant \[ \Delta Y = \alpha + \delta Y_{(t-1)} + \epsilon_t \]

Without Constant and Trend \[ \Delta Y = \alpha + \delta Y_{(t-1)} + \beta T + \epsilon_t \]

Decision rule:

If \( t^* > \) ADF critical value \( \Rightarrow \) not reject null hypothesis, i.e., unit root exists.

If \( t^* < \) ADF critical value \( \Rightarrow \) reject null hypothesis, i.e., unit root does not exist.

If every series is in either I(0) or I(1) we would have apply Johansen cointegration test and we would have get a non redundant estimates but if series are in different order of integration I mean some series are I(0), some are I(1), some are I(2) so we will end up doing Pesaran’s Autoregressive distributed lag (ARDL) approach for cointegration.
5. **ARDL approach to cointegration**

The basic form of an ARDL regression model is:

\[ y_t = \beta_0 + \beta_1 y_{t-1} + \cdots + \beta_k y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \cdots + \alpha_q x_{t-q} + \epsilon_t, \quad (1) \]

Where \( \epsilon_t \) is a random "disturbance" term, which we'll assume is "well-behaved" in the usual sense. In particular, it will be serially independent.

Proof:

A conventional ECM for cointegrated data looks like. It would be of the form:

\[ \Delta y_t = \beta_0 + \sum \beta_i \Delta y_{t-i} + \sum \gamma_j \Delta x_{1t-j} + \sum \delta_k \Delta x_{2t-k} + \phi z_{t-1} + e_t \quad (2) \]

Here, \( z \), the "error-correction term", is the OLS residuals series from the long-run "cointegrating regression"

\[ y_t = \alpha_0 + \alpha_1 x_{1t} + \alpha_2 x_{2t} + v_t \quad (3) \]

The ranges of summation in (2) are from 1 to \( p \), 0 to \( q_1 \), and 0 to \( q_2 \) respectively.

Formulate the following model:

\[ \Delta y_t = \beta_0 + \sum \beta_i \Delta y_{t-i} + \sum \gamma_j \Delta x_{1t-j} + \sum \delta_k \Delta x_{2t-k} + \theta_0 y_{t-1} + \theta_1 x_{1t-1} + \theta_2 x_{2t-1} + e_t \quad (4) \]

Notice that this is almost like a traditional ECM. The difference is that we've now replaced the error-correction term, \( z_{t-1} \) with the terms \( y_{t-1}, x_{1t-1}, \) and \( x_{2t-1} \). From (3), we can see that the lagged residuals series would be \( z_{t-1} = (a_0 - a_1 x_{1t-1} - a_2 x_{2t-1}) \), where the a's are the OLS estimates of the \( \alpha \)'s. So, what we're doing in equation (4) is including the same lagged levels as we do in a regular ECM, but we're not restricting their coefficients.

This is why we might call equation (4) an "unrestricted ECM", or an "unconstrained ECM". Pesaran et al. (2001) call this a "conditional ECM".

6. **Bounds Testing**

Here's equation (4), again:
\[ \Delta y_t = \beta_0 + \sum \beta_i \Delta y_{t-i} + \sum \gamma_j \Delta x_{1t-j} + \sum \delta_k \Delta x_{2t-k} + \theta_0 y_{t-1} + \theta_1 x_{1t-1} + \theta_2 x_{2t-1} + e_t \]

All that we're going to do is preform an "F-test" of the hypothesis, \( H_0: \theta_0 = \theta_1 = \theta_2 = 0 \); against the alternative that \( H_0 \) is not true. As in conventional cointegration testing, we're testing for the absence of a long-run equilibrium relationship between the variables. This absence coincides with zero coefficients for \( y_{t-1} \), \( x_{1t-1} \) and \( x_{2t-1} \) in equation (4). A rejection of \( H_0 \) implies that we have a long-run relationship.

There is a practical difficulty that has to be addressed when we conduct the F-test. The distribution of the test statistic is totally non-standard even in the asymptotic case where we have an infinitely large sample size. (This is somewhat akin to the situation with the Wald test when we test for Granger non-causality in the presence of non-stationary data. In that case, the problem is resolved by using the Toda-Yamamoto (1995) procedure, to ensure that the Wald test statistic is asymptotically chi-square.

Exact critical values for the F-test aren't available for an arbitrary mix of \( I(0) \) and \( I(1) \) variables. However, Pesaran et al. (2001) supply bounds on the critical values for asymptotic distribution of the F-statistic. For various situations (e.g., different numbers of variables, \( (k + 1) \)), they give lower and upper bounds on the critical values. In each case, the lower bound is based on the assumption that all of the variables are \( I(0) \), and the upper bound is based on the assumption that all of the variables are \( I(1) \). In fact, the truth may be somewhere in between these two polar extremes. If the computed F-statistic falls below the lower bound we would conclude that the variables are \( I(0) \), so no cointegration is possible, by definition. If the F-statistic exceeds the upper bound, we conclude that we have cointegration. Finally, if the F-statistic falls between the bounds, the test is inconclusive.

As a cross-check, we should also perform a "Bounds t-test" of \( H_0: \theta_0 = 0 \), against \( H_1: \theta_0 < 0 \). If the t-statistic for \( y_{t-1} \) in equation (4) is less than the "\( I(1) \) bound" tabulated by Pesaran et al. (2001; pp.303-304), this would support the conclusion that there is a long-run relationship between the variables. If the t-statistic is greater than the "\( I(0) \) bound", we'd conclude that the data are all stationary.
Assuming that the bounds test leads to the conclusion of cointegration, we can meaningfully estimate the long-run equilibrium relationship between the variables:

\[ y_t = \alpha_0 + \alpha_1 x_{1t} + \alpha_2 x_{2t} + v_t (5) \]

as well as the usual ECM:

\[ \Delta y_t = \beta_0 + \Sigma \beta_i \Delta y_{t-i} + \Sigma \gamma_j \Delta x_{1t-j} + \Sigma \delta_k \Delta x_{2t-k} + \phi z_{t-1} + e_t \] (6)

Where \( z_{t-1} = (y_{t-1} - a_0 - a_1 x_{1t-1} - a_2 x_{2t-1}) \), and the \( a \)'s are the OLS estimates of the \( \alpha \)'s in (5).

We can "extract" long-run effects from the unrestricted ECM. Looking back at equation (4), and noting that at a long-run equilibrium, \( \Delta y_t = 0, \Delta x_{1t} = \Delta x_{2t} = 0 \), we see that the long-run coefficients for \( x_1 \) and \( x_2 \) are \(-\theta_0 / \theta_1\) and \(-\theta_0 / \theta_2\) respectively.

### 7. Vector auto regression

Vector auto regression (VAR) is an econometric model used to capture the linear interdependencies among multiple time series. VAR models generalize the univariate auto regression (AR) models by allowing for more than one evolving variable. All variables in a VAR are treated symmetrically in a structural sense; each variable has an equation explaining its evolution based on its own lags and the lags of the other model variables.

A VAR model describes the evolution of a set of \( k \) variables (called endogenous variables) over the same sample period \( t = 1, ..., T \) as a linear function of only their past values. The variables are collected in a \( k \times 1 \) vector \( y_t \), which has as the \( i \) th element, \( y_{i,t} \), the time \( t \) observation of the \( i \) th variable. For example, if the \( i \) th variable is GDP, then \( y_{i,t} \) is the value of GDP at time \( t \).

A \( p \)-th order VAR, denoted \( \text{VAR}(p) \), is

\[ y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + ... + A_p y_{t-p} + e_t \]

where the \( l \)-periods back observation \( y_{t-l} \) is called the \( i \)-th lag of \( y \), \( c \) is a \( k \times 1 \) vector of constants (intercepts), \( A_i \) is a time-invariant \( k \times k \) matrix and and it can also express in the following form:
\[ (1 - L - L^2 - L^p)X_t = \alpha + e_t \]
\[ A(L)X_t = \alpha + e_t e_t \sim N(0, \Omega) \]

In a VAR, we are often interested in obtaining the impulse response functions. Impulse responses trace out the response of current and future values of each of the variables to a one-unit increase (or to a one-standard deviation increase, when the scale matters) in the current value of one of the VAR errors, assuming that this error returns to zero in subsequent periods and that all other errors are equal to zero. The implied thought experiment of changing one error while holding the others constant makes most sense when the errors are uncorrelated across equations, so impulse responses are typically calculated for recursive and structural VARs.

\[ z_t = A^{-1}Bz_{t-1} + A^{-1}u_t \]

We calculate the IRF’s to a unitshock of u once we know \( A^{-1} \). We also used VAR model to forecast out of sample.

8. **Auto Regressive Integrated Moving Average Model**

An autoregressive integrated moving average (ARIMA) model is a generalization of an autoregressive moving average (ARMA) model. These models are fitted to time series data either to better understand the data or to predict future points in the series (forecasting). They are applied in some cases where data show evidence of non-stationarity, where an initial differencing step (corresponding to the "integrated" part of the model) can be applied to remove the non-stationarity.

The model is generally referred to as an ARIMA(p,d,q) model where parameters p, d, and q are non-negative integers that refer to the order of the autoregressive, integrated, and moving average parts of the model respectively. ARIMA models form an important part of the Box-Jenkins approach to time-series modelling.

Given a time series of data \( X_t \) where \( t \) is an integer index and the \( X_t \) are real numbers, then an ARMA(p',q) model is given by:
\[ \left\{ 1 - \sum_{i=1}^{p'} \alpha_i L^i \right\} X_t = \left\{ 1 + \sum_{i=1}^{q} \theta_i L^i \right\} \varepsilon_t \]

where \( L \) is the lag operator, \( \alpha_i \) the are the parameters of the autoregressive part of the model, the \( \theta_i \) are the parameters of the moving average part and the \( \varepsilon_t \) are error terms. The error terms \( \varepsilon_t \) are generally assumed to be independent, identically distributed variables sampled from a normal distribution with zero mean.

Assume now that the polynomial \( \left\{ 1 - \sum_{i=1}^{p'} \alpha_i L^i \right\} \) has a unitary root of multiplicity \( d \). Then it can be rewritten as:

\[ \left\{ 1 - \sum_{i=1}^{p'} \alpha_i L^i \right\} = \left\{ 1 + \sum_{i=1}^{p' - d} \phi_i L^i \right\} (1 - L)^d \]

An ARIMA\((p,d,q)\) process expresses this polynomial factorisation property with \( p = p' - d \), and is given by:

\[ \left\{ 1 + \sum_{i=1}^{p' - d} \phi_i L^i \right\} (1 - L)^d X_t = \left\{ 1 + \sum_{i=1}^{q} \theta_i L^i \right\} \varepsilon_t \]

and thus can be thought as a particular case of an ARMA\((p+d,q)\) process having the autoregressive polynomial with \( d \) unit roots. (For this reason, every ARIMA model with \( d > 0 \) is not wide sense stationary.)

The above can be generalized as follows.

\[ \left\{ 1 + \sum_{i=1}^{p' - d} \phi_i L^i \right\} (1 - L)^d X_t = \delta + \left\{ 1 + \sum_{i=1}^{q} \theta_i L^i \right\} \varepsilon_t \]

This defines an ARIMA\((p,d,q)\) process.
9. **Forecast Error Statistics**

Thiel's inequality coefficient, also known as Thiel's U, provides a measure of how well a time series of estimated values compares to a corresponding time series of observed values. The statistic measures the degree to which one time series \(\{X_i\}, i = 1, 2, 3, \ldots, n\) differs from another \(\{Y_i\}, i = 1, 2, 3, \ldots, n\). Thiel's U is calculated as:

\[
U = \frac{\frac{1}{n} \sum (X_i - Y_i)^2}{\sqrt{\frac{1}{n} \sum X_i^2 + \frac{1}{n} \sum Y_i^2}}
\]

Thiel's inequality coefficient is useful for comparing different forecast methods: for example, whether a fancy forecast is in fact any better than a naïve forecast repeating the last observed value. The closer the value of \(U\) is to zero, the better the forecast method. A value of 1 means the forecast is no better than a naïve guess. The \(U\)-statistic measures the ratio of the Root Mean Square Error (RMSE) of the model forecasts to the RMSE of naïve, no-change forecasts.

The RMSE is given by the following formula, if \(A_{t+n}\) denotes the actual value of a variable in period \(t+n\), and \(F_{t+n}\) the forecast made in period \(t\) for \((t+n)\), then for \(T\) observations:

\[
RMSE = \left[ \sum_t (A_{t+n} - F_{t+n})^2 / T \right]^{0.5}
\]

A comparison with the naïve model is, therefore, implicit in the \(U\)-statistic. A \(U\)-statistic of 1 indicates that the model forecasts match the performance of naïve, no-change forecasts. A \(U\)-statistic >1 shows that the naïve forecasts outperform the model forecasts. If \(U\) is <1, the forecasts from the model outperform the naïve forecasts. The \(U\)-statistic is, therefore, a relative measure of accuracy and is unit-free.

**Summary of Steps in Econometric Estimation**
In this study, First we run simple Ordinary Least squares and we checked for autocorrelation and to overcome the problem of positive auto correlation we adopted Cochrane-Orcutt – Feasible Generalized Least Squares. Since we are dealing with time series, we checked for presence of unit root using augmented Dickey-Fuller test. We then moved to estimation using either Johansen cointegration or Auto regressive distributed lag methods based on integrated levels of series.

Second, we forecast the exchange rate using three methods OLS, VAR, ARIMA by considering the variables which comes significant in the first step. We forecasted for three different out of sample periods and then we evaluated the forecasting methods by comparing actual data of exchange rate using Error statistics

7 RESULTS

The Models that we discussed in last section were used to estimate exchange rate in this section. We will discuss the results in two parts, first part modelling and second part forecasting

7.1 RESULTS: MODELLING OF EXCHANGE RATE

We estimated the model given in section 5 using simple ordinary least squares, it was found that Durbin Watson test (test for presence of autocorrelation) was less than 2 which indicates that there is presence of positive autocorrelation in simple OLS. In order to overcome autocorrelation we employed the Feasible Generalized least squares. The results were show in table below.

<table>
<thead>
<tr>
<th>Variables</th>
<th>OLS</th>
<th>Nonlinear OLS</th>
<th>CO- FGLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pound</td>
<td>0.269311*</td>
<td>0.280878*</td>
<td>0.28037*</td>
</tr>
<tr>
<td></td>
<td>Simple</td>
<td>Co FGLS</td>
<td>( * is significant at 5% level of significance  )</td>
</tr>
<tr>
<td>------------------</td>
<td>--------</td>
<td>---------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Euro</td>
<td>-0.187405*</td>
<td>-0.112224</td>
<td>-0.11725</td>
</tr>
<tr>
<td>Yen</td>
<td>0.127715*</td>
<td>0.076823</td>
<td>0.08196</td>
</tr>
<tr>
<td>DINF</td>
<td>-5.71E-05</td>
<td>9.73E-06</td>
<td>5.64E-06</td>
</tr>
<tr>
<td>DREIR</td>
<td>0.002852</td>
<td>0.002295</td>
<td>0.0023059</td>
</tr>
<tr>
<td>MSIND</td>
<td>0.728961*</td>
<td>0.673365*</td>
<td>0.67589*</td>
</tr>
<tr>
<td>GDPIND</td>
<td>-0.818727*</td>
<td>-0.758652*</td>
<td>-0.7611358*</td>
</tr>
<tr>
<td>CF</td>
<td>-0.000561*</td>
<td>-0.000174</td>
<td>-0.000172</td>
</tr>
<tr>
<td>OF</td>
<td>-0.002259*</td>
<td>-0.001430*</td>
<td>-0.00138*</td>
</tr>
<tr>
<td>FP</td>
<td>-0.018669</td>
<td>-0.36885*</td>
<td>-0.36724*</td>
</tr>
<tr>
<td>TRB</td>
<td>0.000135</td>
<td>0.000088</td>
<td>0.000074</td>
</tr>
<tr>
<td>RBII</td>
<td>-0.000214*</td>
<td>-0.0000617*</td>
<td>-0.0000583*</td>
</tr>
<tr>
<td>AR(1)</td>
<td>--------</td>
<td>0.542795*</td>
<td>0.5194*</td>
</tr>
<tr>
<td>R- Squared</td>
<td>0.997017</td>
<td>0.997536</td>
<td>0.9895</td>
</tr>
<tr>
<td>Durbin- Watson</td>
<td>1.202654</td>
<td>1.775138</td>
<td>1.74182</td>
</tr>
</tbody>
</table>

Table 7.1.1: Empirical results of OLS, Co FGLS ( * is significant at 5% level of significance )

Simple OLS results are given in first column of Table 7.1.1 where pound, Euro, Money supply India, GDP India, Capital flows, Order flows, central bank intervention found significant at 5% level of significance whereas the estimates are redundant in nature as R-squared value is almost one and Durbin Watson Test is 1.2 (going to 0) which indicates that there is presence of unit root problem and auto correlation in simple Ordinary least squares.

If we see the sign of significant variables that is price of USD in terms of Rupee appreciates if pound, yen appreciates and depreciates if euro appreciates (negative sign for Euro variable). Money supply in India is positively related to exchange rate which means, excess supply of money leads to reduction in savings its equivalent to excess demand for goods and securities leads to BOP deficit, if there is deficit then there is flexible exchange rate and you will see the depreciation of Indian rupee and appreciation of USD. GDP of our country – it comes with a negative sign because higher the GDP, larger is the demand for money ,more is the savings, lesser is the demand for goods and securities, there will be BOP surplus, leading to appreciation of Indian rupee or the depreciation of USD – That’s why we see a negative sign for GDPIND. Differential inflation rate and real interest rate, Money supply and GDP of US found insignificant in simple OLS.
Capital flows found to be negative which is same as theory suggests that is if there is more purchase of foreign assets by foreigners then there will more demand for our Indian rupee which means appreciation of our currency and depreciation of USA dollar. Conventionally order flows and exchange rate are positively related but OLS results found that it is negative relationship. By definition Order flows is taken as purchase minus sales of foreign currency so with the negative sign it implies that if incase there is sales of foreign currency is more than the purchase than with increase of order flows there will be appreciation of our currency. Variables forward premium and trade balance found insignificant in simple OLS but, forward premium found to be significant if we remove the autocorrelation problem (column 2, 3).

After removing problem of autocorrelation the Durbin Watson static increased from 1.2 to 1.7. In Nonlinear, COFGLS methods coefficients of explanatory variables were changed but their relation with exchange rate was still same as ordinary least squares except for forward premium. Since all these variables were time dependent variables there may be a unit root problem in series Co-FGLS coefficients are redundant as data series have unit root problem so we don’t consider coefficient value here. So before we estimate the impact of each variable on exchange rate we need to check for unit problem.

In order to check stationarity test, we employed Augmented Dickey Fuller test to see the integrated level of all series so based on this test we found the following integrated levels for each variable (results were given in Appendix)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Integrated levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>I(1)</td>
</tr>
<tr>
<td>Pound</td>
<td>I(2)</td>
</tr>
<tr>
<td>Euro</td>
<td>I(1)</td>
</tr>
<tr>
<td>Yen</td>
<td>I(1)</td>
</tr>
<tr>
<td>DINF</td>
<td>I(0)</td>
</tr>
<tr>
<td>DREIR</td>
<td>I(0)</td>
</tr>
<tr>
<td>MSIND</td>
<td>I(1)</td>
</tr>
<tr>
<td>GDPIND</td>
<td>I(1)</td>
</tr>
</tbody>
</table>
Table 7.1.2 shows the results of Augmented Dickey Fuller Test which conveys that some variables are stationary whereas some variables have unit root problem. The variables differential inflation rate, differential interest rate, capital flows, order flows, central bank intervention found to be stationary and all other variables are non stationary. Except pound testing for differences of each non stationary variables are integrated of order one.

One can know the linear interdependencies among multiple time series using Vector Auto Regressive Method in which we consider two things that Variance Decomposition and Impulse Response functions

Variance Decomposition: If pound changes how much impact will be there on dependent variable and in how many time periods

Impulse Response Functions: If you give a shock to system How is my variables affected to after certain time period – Impulse response functions

<table>
<thead>
<tr>
<th>CF</th>
<th>I(0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OF</td>
<td>I(0)</td>
</tr>
<tr>
<td>FP</td>
<td>I(1)</td>
</tr>
<tr>
<td>TRB</td>
<td>I(1)</td>
</tr>
<tr>
<td>RBII</td>
<td>I(0)</td>
</tr>
</tbody>
</table>

Table 7.1.2. Results of ADF test for each independent variable
In Table 7.1.3, after 10 periods pound rupee exchange rate is explaining 25.6% variability which is highest among all independent variables, differential interest rate explains 16.8% and so on. Likewise one can notice which variable will explain the dependent variable more after certain periods. Similarly we want to know suppose if there is any shock in one of the variable then how exchange rate react that shock will capture by impulse response graphs. It was found from following graph is that for any shock, exchange rate will deviate from equilibrium level and it will fluctuate for many periods

From the ADF test results, some variables stationary and some are integrated to order one. If we would have get all the series integrated to order I(1) then we would have applied Johansson cointegration. Since some are I(0) and some are I(1), so we will end up doing Pesaran’s Autoregressive distributed lag (ARDL) approach for cointegration. A series of steps has to do to reach final ARDL results, one of the step is to do Bound’s test to check whether the variables are have long run relationship or not. The following figure is the result of bound test where we compare the F-static with the Pesaran, Shin, Smith calculated critical values.
Figure 7.1.2. Bounds test results (wald test)

Wald test gives us with F static value 1.19 at 8 degrees of freedom, and Bounds test gives us the conditions that If F test > Pesaran Critical higher bound at degrees of freedom then we reject $H_0$ implies that there is a long-run relationship between exchange rate and variables. If F-Value < Pesaran Critical Lower bound then there is no Long run relationship. If F value is in between Lower and Higher pesaran critical values that is Inconclusive

<table>
<thead>
<tr>
<th>Test Statistic</th>
<th>Value</th>
<th>df</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-statistic</td>
<td>1.192806</td>
<td>(8, 93)</td>
<td>0.3119</td>
</tr>
<tr>
<td>Chi-square</td>
<td>9.542449</td>
<td>8</td>
<td>0.2986</td>
</tr>
</tbody>
</table>

Null Hypothesis: $C(1)=0$, $C(2)=0$, $C(3)=0$, $C(4)=0$, $C(5)=0$, $C(6)=0$, $C(7)=0$, $C(8)=0$

At 5% level of significance, for k=8 degree of freedom Pesaran(2001) critical value Lower bound is 2.55 and higher bound is 3.68 (from Table 7.1.4). From Wald test, F static is 1.19 which is less than lower critical bound (2.55) suggests that there is no long run relationship between variables. Same analysis was done to yearly data and it was found that there is long run relationship between money supply and output of India with exchange rate. By considering the fact that there is no long run relationship between variables and we further proceeded to steps of ARDL we left with following variables with significant results
After overcoming the autocorrelation and unit root problem we left with order flows, trade balance, money supply, output, forward premium which are significantly affecting exchange rate. All the variables were significant at 5% level of significance and R-squared value is greater than 50 percent which means these results are just considerable. Durbin Watson Statistic confirms that there is no autocorrelation. The variables show same relations as we expected based on theory that GDP, trade balance with positive sign and order flows, money supply, forward premium with positive sign. All variables have very small impact on exchange rate that is 1% change in variables like money supply, trade balance ,order flows show only 0.05 % percent or less change in exchange rate. Only lagged forward premium show 25 % change in exchange rate.

7.2 RESULTS: FORECASTING OF EXCHANGE RATE

We forecasted exchange rate from January 2013- December 2013 using methods Ordinary Least Squares (OLS), Vector Auto Regression (VAR), Autoregressive Integrated Moving Average (ARIMA). We forecasted exchange rate in three samples to see accuracy of forecasting and then we evaluated the forecasting methods in all these samples by comparing with actual data of exchange rate. Exchange rate forecasted to 3 months, 6 months, and 12 months ahead from
dec-2012. The following figures are forecasting graphs of different methods in three different samples

![3-Month Ahead Forecast](image1)

**Figure 7.2.1.** 3-months ahead forecast using different methods

![6-Month Ahead Forecast](image2)

**Figure 7.2.2.** 6-months ahead forecast using different methods
In all these three figures all these forecasting methods were compared with actual data of exchange rate. Based on graphs, ARIMA and OLS forecasted data show completely different pattern from actual data. Especially in 3 months and 12 months sample period ARIMA and OLS graphs shows distinct pattern respectively. Out of all forecasting methods we used we found that in all the three sample period only VAR shows a similar pattern like actual data. We cannot say that VAR is best method to forecast the exchange rate but compare to OLS and ARIMA method VAR is good method to forecast.

Empirically also one can evaluate the performance of forecast of all the three methods using error statistics. We calculated root mean square error (RMSE) and Theil’s U statistic to check which method is best in forecasting. The following table gives the values of RMSE and U statistic for 3 months sample period.

**Sample Period for 3- months**

<table>
<thead>
<tr>
<th>Error Statistics</th>
<th>OLS</th>
<th>VAR</th>
<th>ARIMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theil’s U statistic</td>
<td>0.008979</td>
<td>0.00827996</td>
<td>0.017449802</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.9790815</td>
<td>0.89930765</td>
<td>1.916647719</td>
</tr>
</tbody>
</table>

Table 7.2.1: Error Statistics for OLS, VAR, ARIMA : 3 Month Sample Period
From above table the both error statistics suggest that error in VAR forecasting in 3 month sample is low which means Vector Auto regression is accurate method of forecasting compare to OLS and ARIMA which has forecasting error (RMSE) near to 1. The closer the value of U is to zero, the better the forecast method so here VAR has very low U so VAR is better method than OLS and ARIMA. The same is true even in case of 6-Months and 12-Months sample period, VAR has low U and low RMSE suggests that in all sample periods VAR is better forecast method.

**Sample Period for 6- months**

<table>
<thead>
<tr>
<th>Error Statistics</th>
<th>OLS</th>
<th>VAR</th>
<th>ARIMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theil’s U statistic</td>
<td>0.0153298</td>
<td>0.00965468</td>
<td>0.016072373</td>
</tr>
<tr>
<td>RMSE</td>
<td>1.6904903</td>
<td>1.06683362</td>
<td>1.796323082</td>
</tr>
</tbody>
</table>

Table 7.2.2: Error Statistics for OLS, VAR, ARIMA : 6 Month Sample Period

<table>
<thead>
<tr>
<th>Error Statistics</th>
<th>OLS</th>
<th>VAR</th>
<th>ARIMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theil’s U statistic</td>
<td>0.00459194</td>
<td>0.02111697</td>
<td>0.024336637</td>
</tr>
<tr>
<td>RMSE</td>
<td>5.2375421</td>
<td>2.45467368</td>
<td>2.840344455</td>
</tr>
</tbody>
</table>

Table 7.2.3: Error Statistics for OLS, VAR, ARIMA : 12 Month Sample Period

One more interesting observation from all these tables is if we compare the VAR error statistics between these three sample periods, the VAR errors were very low for 3- Month sample period than the other two sample periods. That gives us an interesting conclusion that forecast accuracy depends not only the method you are using but also how long you are forecasting. The lesser the period you forecast the more accuracy in forecasting.

The overall conclusion for this section of forecasting of exchange rate is that by empirically and by graphs Vector Auto Regressive yield accurate forecasts than their OLS and ARIMA for all samples.
We also forecasted for time period January 2014 to June 2014 out of sample period using three methods.

![Figure 7.2.4. 5-months ahead forecast using different methods (Jan2014- June2014)](image)

Since we concluded that VAR gives accurate forecast so forecast for period Jan 2014- June 2014(Fig.7.2.4) suggest that exchange rate will be fluctuate between 58-60rs per dollar for coming two months. It is partially true that from January 2014 to May 2014 rupee was appreciated and settled to below 60 in these months. So, based on this fact in coming May, June-2014 months the rupee- dollar exchange rate will be around 60rs.

## 8 CONCLUSIONS

This study covers two main topics: first modelling, where we discussed about the importance of variables like capital inflows, order flows, central bank intervention in modelling exchange rate. We empirically estimated the coefficients of explanatory variables after overcoming autocorrelation and unit root problems. It was found that only variables order flow, forward premium, trade balance, money supply and output has significant effect on exchange rate. We also checked for any long term relationship between variables, found that only money supply and output has long run relationship with exchange rate. All significant variables shows
very small impact on exchange rate except forward premium. Empirical relations between variables and exchange rate support the theoretical relations.

Second forecasting of exchange rate, we forecasted exchange rate using VAR, OLS, ARIMA model for three different sample period. Evaluated the forecasting performance of models by graphs and by error statistics. We found that VAR model yield more accurate forecasts than the OLS and ARIMA as it has very low Theil’s U and RMSE for all periods. Using VAR model we also forecasted out of sample for periods from January 2014- June 2014.

9 DATA SOURCES AND ITS DEFINITIONS

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>Rupee/ dollar exchange rate</td>
<td>Hand book of statistics on the Indian Economy and RBI bulletin</td>
</tr>
<tr>
<td>GDPIND</td>
<td>Index of Industrial Production of India</td>
<td>CEIC data source</td>
</tr>
<tr>
<td>MSIND</td>
<td>Money supply (M3) for India</td>
<td>CEIC data source</td>
</tr>
<tr>
<td>TRB</td>
<td>Trade balance ( export – imports )</td>
<td>RBI Bulletin</td>
</tr>
<tr>
<td>CF</td>
<td>Capital flows ( FDI +FPI in India )</td>
<td>CEIC data source</td>
</tr>
<tr>
<td>OF</td>
<td>Purchase – sales of Foreign currency</td>
<td>CEIC data source</td>
</tr>
<tr>
<td>FP</td>
<td>3-month forward premium</td>
<td></td>
</tr>
<tr>
<td>RBII</td>
<td>Intervention ( Purchase –sale of US dollars by RBI)</td>
<td>CEIC data source</td>
</tr>
</tbody>
</table>
10 REFERENCES


11 APPENDIX

Dependent Variable: EX
Method: Least Squares
Date: 11/07/13   Time: 02:56
Sample: 1971 2012
Included observations: 42

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>2.425558</td>
<td>0.993310</td>
<td>2.441894</td>
<td>0.0203</td>
</tr>
<tr>
<td>POUND</td>
<td>0.269311</td>
<td>0.085750</td>
<td>3.140650</td>
<td>0.0036</td>
</tr>
<tr>
<td>EURO</td>
<td>-0.187405</td>
<td>0.066830</td>
<td>-2.804205</td>
<td>0.0085</td>
</tr>
<tr>
<td>YEN</td>
<td>0.127715</td>
<td>0.059995</td>
<td>2.128752</td>
<td>0.0411</td>
</tr>
<tr>
<td>DINF</td>
<td>-5.71E-05</td>
<td>0.001155</td>
<td>-0.049542</td>
<td>0.9608</td>
</tr>
<tr>
<td>DREIR</td>
<td>0.002852</td>
<td>0.001843</td>
<td>1.547042</td>
<td>0.1317</td>
</tr>
<tr>
<td>MSIND</td>
<td>0.728961</td>
<td>0.097588</td>
<td>7.469790</td>
<td>0.0000</td>
</tr>
<tr>
<td>MSUS</td>
<td>-0.304661</td>
<td>0.209328</td>
<td>-1.545249</td>
<td>0.1553</td>
</tr>
<tr>
<td>GDPIND</td>
<td>-0.818727</td>
<td>0.098689</td>
<td>-8.296032</td>
<td>0.0000</td>
</tr>
<tr>
<td>GDPUS</td>
<td>0.213050</td>
<td>0.185169</td>
<td>1.150566</td>
<td>0.2584</td>
</tr>
</tbody>
</table>

R-squared 0.997017
Mean dependent var
Adjusted R-squared 0.996178
S.D. dependent var
S.E. of regression 0.019980
Akaike info criterion
Sum squared resid 0.012774
Schwarz criterion
Log likelihood 110.4629
F-statistic
Durbin-Watson stat 1.202654
Prob(F-statistic)

Dependent Variable: EX
Method: Least Squares
Date: 11/07/13   Time: 02:58
Sample(adjusted): 1972 2012
Included observations: 41 after adjusting endpoints
Convergence achieved after 56 iterations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>2.120038</td>
<td>1.499562</td>
<td>1.413771</td>
<td>0.1677</td>
</tr>
<tr>
<td>POUND</td>
<td>0.280878</td>
<td>0.104960</td>
<td>2.676053</td>
<td>0.0120</td>
</tr>
<tr>
<td>EURO</td>
<td>-0.112224</td>
<td>0.070550</td>
<td>-1.590706</td>
<td>0.1222</td>
</tr>
<tr>
<td>YEN</td>
<td>0.076823</td>
<td>0.077313</td>
<td>0.993653</td>
<td>0.3283</td>
</tr>
<tr>
<td>DINF</td>
<td>9.73E-06</td>
<td>0.001017</td>
<td>0.009575</td>
<td>0.9994</td>
</tr>
<tr>
<td>DREIR</td>
<td>0.002295</td>
<td>0.001594</td>
<td>1.440043</td>
<td>0.1602</td>
</tr>
<tr>
<td>MSIND</td>
<td>0.673365</td>
<td>0.129672</td>
<td>5.192825</td>
<td>0.0000</td>
</tr>
<tr>
<td>MSUS</td>
<td>-0.347023</td>
<td>0.246551</td>
<td>-1.407507</td>
<td>0.1699</td>
</tr>
<tr>
<td>GDPIND</td>
<td>-0.758652</td>
<td>0.123145</td>
<td>-6.160622</td>
<td>0.0000</td>
</tr>
<tr>
<td>GDPUS</td>
<td>0.275731</td>
<td>0.229549</td>
<td>1.201186</td>
<td>0.2391</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.542795</td>
<td>0.233691</td>
<td>2.322702</td>
<td>0.0272</td>
</tr>
</tbody>
</table>

R-squared 0.997536
Mean dependent var
Adjusted R-squared 0.996178
S.D. dependent var
S.E. of regression 0.018299
Akaike info criterion
Sum squared resid 0.010045
Schwarz criterion
Log likelihood 112.2655
F-statistic 1214.521
Unit root tests for variables

EX - I1
Null Hypothesis: D(EX) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-4.229308</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -4.205004
- 5% level: -3.526609
- 10% level: -3.194611


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(EX,2)
Method: Least Squares
Date: 07/11/13   Time: 22:45
Sample (adjusted): 1973 2012
Included observations: 40 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(EX(-1))</td>
<td>-0.666578</td>
<td>0.157609</td>
<td>-4.229308</td>
<td>0.0001</td>
</tr>
<tr>
<td>C</td>
<td>0.016280</td>
<td>0.011726</td>
<td>1.388291</td>
<td>0.1734</td>
</tr>
<tr>
<td>@TREND(1971)</td>
<td>-8.10E-05</td>
<td>0.000453</td>
<td>-0.179053</td>
<td>0.8589</td>
</tr>
</tbody>
</table>

R-squared 0.326432
Mean dependent var 0.001089
Adjusted R-squared 0.290022
S.D. dependent var 0.039043
S.E. of regression 0.032897
Akaike info criterion -3.918809
Sum squared resid 0.040043
Schwarz criterion -3.792143
Log likelihood 81.37619
Hannan-Quinn criter. -3.873011
F-statistic 8.965657
Durbin-Watson stat 1.972901
Prob(F-statistic) 0.000668

Pound – I2
Null Hypothesis: D(POUND,2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-5.900016</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -4.211868
- 5% level: -3.529758
- 10% level: -3.196411

Date: 07/11/13   Time: 22:41
Sample (adjusted): 1974 2012
Included observations: 39 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(POUND(-1),2)</td>
<td>-0.987105</td>
<td>0.167305</td>
<td>-5.90016</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>-0.000290</td>
<td>0.010895</td>
<td>-0.026591</td>
<td>0.9789</td>
</tr>
<tr>
<td>@TREND(1971)</td>
<td>7.85E-05</td>
<td>0.000441</td>
<td>0.177956</td>
<td>0.8598</td>
</tr>
</tbody>
</table>

S.E. of regression 0.030984
Akaike info criterion 4.036919
Sum squared resid 0.034559
Schwarz criterion 3.908953
Log likelihood 81.71993
Hannan-Quinn criter. 3.991006
Durbin-Watson stat 1.972657

---

Euro- I1
Null Hypothesis: D(EURO) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-5.724108</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -4.205004
- 5% level: -3.526609
- 10% level: -3.194811


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(EURO,2)
Method: Least Squares
Date: 07/11/13   Time: 22:47
Sample (adjusted): 1973 2012
Included observations: 40 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(EURO(-1))</td>
<td>-0.939424</td>
<td>0.164117</td>
<td>-5.724108</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>0.041001</td>
<td>0.021344</td>
<td>1.920950</td>
<td>0.0625</td>
</tr>
<tr>
<td>@TREND(1971)</td>
<td>-0.000311</td>
<td>0.000825</td>
<td>-0.377043</td>
<td>0.7083</td>
</tr>
</tbody>
</table>

S.E. of regression 0.060152
Akaike info criterion 2.711847
Sum squared resid 0.133876
Schwarz criterion 2.585181
Log likelihood 57.23694
Hannan-Quinn criter. 2.666048
Durbin-Watson stat 1.960827

---

Yen- I1
Null Hypothesis: D(YEN) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-4.371190</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -4.205004
- 5% level: -3.526609
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(YEN,2)
Method: Least Squares
Date: 07/11/13   Time: 22:48
Sample (adjusted): 1973 2012
Included observations: 40 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(YEN(-1))</td>
<td>-0.684751</td>
<td>0.156651</td>
<td>-4.371190</td>
<td>0.0001</td>
</tr>
<tr>
<td>C</td>
<td>0.025000</td>
<td>0.017264</td>
<td>1.448107</td>
<td>0.1560</td>
</tr>
<tr>
<td>@TREND(1971)</td>
<td>-5.92E-05</td>
<td>0.000659</td>
<td>-0.089784</td>
<td>0.9289</td>
</tr>
</tbody>
</table>

S.E. of regression 0.047988
Sum squared resid 0.085204
Log likelihood 66.27411

Augmented Dickey-Fuller test statistic -4.592507  0.0006
Test critical values:
1% level  -3.600987
5% level  -2.935001
10% level -2.605836


DINF-I0
Null Hypothesis: DINF has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-4.592507</td>
</tr>
<tr>
<td>Test critical values:</td>
<td></td>
</tr>
<tr>
<td>1% level</td>
<td>-3.600987</td>
</tr>
<tr>
<td>5% level</td>
<td>-2.935001</td>
</tr>
<tr>
<td>10% level</td>
<td>-2.605836</td>
</tr>
</tbody>
</table>


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DINF)
Method: Least Squares
Date: 07/11/13   Time: 22:50
Sample (adjusted): 1972 2012
Included observations: 41 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DINF(-1)</td>
<td>-0.693663</td>
<td>0.151042</td>
<td>-4.592507</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>2.878034</td>
<td>0.843916</td>
<td>3.410332</td>
<td>0.0015</td>
</tr>
</tbody>
</table>

R-squared 0.350986  Mean dependent var 0.132867
Adjusted R-squared 0.334344  S.D. dependent var 4.675350
S.E. of regression 3.814512  Akaike info criterion 5.563053
Sum squared resid 567.4696  Schwarz criterion 5.646642
Log likelihood -112.0426  Hannan-Quinn criter. 5.593492
F-statistic 21.09112  Durbin-Watson stat 1.913406
Prob(F-statistic) 0.000045
DREIR- I0

Null Hypothesis: DREIR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-4.869044</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.600987
- 5% level: -2.935001
- 10% level: -2.605836


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DREIR)
Method: Least Squares
Date: 07/11/13   Time: 22:51
Sample (adjusted): 1972 2012
Included observations: 41 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DREIR(-1)</td>
<td>-0.755179</td>
<td>0.155098</td>
<td>-4.869044</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>1.190176</td>
<td>0.481055</td>
<td>2.474097</td>
<td>0.0178</td>
</tr>
</tbody>
</table>

R-squared: 0.378066
Mean dependent var: 0.014772
S.D. dependent var: 3.335941
S.E. of regression: 2.664331
Akaike info criterion: 4.845334
Schwarz criterion: 4.928923
Log likelihood: -97.32935
Hannan-Quinn criter.: 4.875772
F-statistic: 23.70759
Durbin-Watson stat: 2.042907
Prob(F-statistic): 0.000019

MSIND-I1

Null Hypothesis: D(MSIND) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-5.360588</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.605593
- 5% level: -2.936942
- 10% level: -2.606857


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(MSIND)
Method: Least Squares
Date: 07/11/13   Time: 22:52
Sample (adjusted): 1973 2012
Included observations: 40 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
</table>
D(MSIND(-1)) -0.924860 0.172530 -5.360588 0.0000
C 0.063615 0.012060 5.274965 0.0000

R-squared 0.430591 Mean dependent var -0.000417
Adjusted R-squared 0.415607 S.D. dependent var 0.013735
S.E. of regression 0.010500 Schwarz criterion -6.141704
Sum squared resid 0.004190 Hannan-Quinn crite. -6.195616
Log likelihood 126.5230 Durbin-Watson stat 1.830099
F-statistic 28.73591
Prob(F-statistic) 0.000004

MSUS-I2

Null Hypothesis: D(MSUS,2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=6)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-6.021815</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -4.211868
- 5% level: -3.529758
- 10% level: -3.196411


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(MSUS,3)
Method: Least Squares
Date: 07/11/13 Time: 22:54
Sample (adjusted): 1974 2012
Included observations: 39 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(MSUS(-1),2)</td>
<td>-0.994513</td>
<td>0.165152</td>
<td>-6.021815</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>-0.001779</td>
<td>0.004693</td>
<td>-0.379109</td>
<td>0.7068</td>
</tr>
<tr>
<td>@TREND(1971)</td>
<td>7.37E-05</td>
<td>0.000190</td>
<td>0.388526</td>
<td>0.6999</td>
</tr>
</tbody>
</table>

S.E. of regression 0.013273 Akaike info criterion -5.732357
Sum squared resid 0.010500 Schwarz criterion -5.604391
Log likelihood 114.7810 Hannan-Quinn crite. -5.686444
Durbin-Watson stat 2.015565

GDPIND-I1

Null Hypothesis: D(GDPIND) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-5.733226</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -4.205004
- 5% level: -3.526609
- 10% level: -3.194611

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GDPIND,2)
Method: Least Squares
Date: 07/11/13   Time: 22:55
Sample (adjusted): 1973 2012
Included observations: 40 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(GDPIND(-1))</td>
<td>-0.959427</td>
<td>0.167345</td>
<td>-5.733226</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>0.030323</td>
<td>0.012920</td>
<td>2.346881</td>
<td>0.0244</td>
</tr>
<tr>
<td>@TREND(1971)</td>
<td>0.000154</td>
<td>0.000496</td>
<td>0.311137</td>
<td>0.7574</td>
</tr>
</tbody>
</table>

S.E. of regression 0.035945
Sum squared resid 0.047806
Log likelihood 77.83222
Durbin-Watson stat 1.917953

GDPUS-I1
Null Hypothesis: D(GDPUS) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-5.060891</td>
</tr>
<tr>
<td>Test critical values: 1% level</td>
<td>-4.205004</td>
</tr>
<tr>
<td>5% level</td>
<td>-3.526609</td>
</tr>
<tr>
<td>10% level</td>
<td>-3.194611</td>
</tr>
</tbody>
</table>


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GDPUS,2)
Method: Least Squares
Date: 07/11/13   Time: 22:58
Sample (adjusted): 1973 2012
Included observations: 40 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(GDPUS(-1))</td>
<td>-0.821875</td>
<td>0.162397</td>
<td>-5.060891</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>0.037508</td>
<td>0.008084</td>
<td>4.639766</td>
<td>0.0000</td>
</tr>
<tr>
<td>@TREND(1971)</td>
<td>-0.000691</td>
<td>0.000181</td>
<td>-3.828381</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

S.E. of regression 0.008479
Sum squared resid 0.002660
Log likelihood 135.6072
Durbin-Watson stat 1.920272

Dependent Variable: EX
### Sample (adjusted): 2004:10 2012:12
Included observations: 99 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>58.26540</td>
<td>3.511630</td>
<td>16.59212</td>
<td>0.0000</td>
</tr>
<tr>
<td>MSIND</td>
<td>5.06E-07</td>
<td>6.52E-08</td>
<td>7.762642</td>
<td>0.0000</td>
</tr>
<tr>
<td>GDPIND</td>
<td>-0.247175</td>
<td>0.047815</td>
<td>-5.169447</td>
<td>0.0000</td>
</tr>
<tr>
<td>CF</td>
<td>-0.000561</td>
<td>0.000231</td>
<td>-2.435048</td>
<td>0.0168</td>
</tr>
<tr>
<td>OF</td>
<td>-0.002259</td>
<td>0.000969</td>
<td>-2.330536</td>
<td>0.0220</td>
</tr>
<tr>
<td>FP</td>
<td>-0.018669</td>
<td>0.180980</td>
<td>-0.103156</td>
<td>0.9181</td>
</tr>
<tr>
<td>TRB</td>
<td>0.000135</td>
<td>9.20E-05</td>
<td>1.464469</td>
<td>0.1465</td>
</tr>
<tr>
<td>RBII</td>
<td>-0.000214</td>
<td>6.21E-05</td>
<td>-3.451817</td>
<td>0.0008</td>
</tr>
</tbody>
</table>

R-squared: 0.710616
Mean dependent var: 46.09847
Adjusted R-squared: 0.688355
S.D. dependent var: 4.023093
S.E. of regression: 2.245898
Akaike info criterion: 4.533444
Schwarz criterion: 4.743150
Log likelihood: -216.4055
F-statistic: 31.92295
Prob(F-statistic): 0.000000

Dependent Variable: EX
Method: Least Squares
Date: 04/12/14   Time: 23:11
Sample (adjusted): 2004M11 2012M12
Included observations: 98 after adjustments
Convergence achieved after 28 iterations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>34.06170</td>
<td>5.072725</td>
<td>6.714675</td>
<td>0.0000</td>
</tr>
<tr>
<td>MSIND</td>
<td>2.16E-07</td>
<td>8.36E-08</td>
<td>2.579553</td>
<td>0.0115</td>
</tr>
<tr>
<td>GDPIND</td>
<td>0.030345</td>
<td>0.025692</td>
<td>1.181100</td>
<td>0.2407</td>
</tr>
<tr>
<td>CF</td>
<td>-0.000174</td>
<td>0.000112</td>
<td>-1.558787</td>
<td>0.1226</td>
</tr>
<tr>
<td>OF</td>
<td>-0.001430</td>
<td>0.000514</td>
<td>-2.782253</td>
<td>0.0066</td>
</tr>
<tr>
<td>FP</td>
<td>-0.368885</td>
<td>0.137225</td>
<td>-2.688173</td>
<td>0.0086</td>
</tr>
<tr>
<td>TRB</td>
<td>8.83E-05</td>
<td>4.47E-05</td>
<td>1.974677</td>
<td>0.0514</td>
</tr>
<tr>
<td>RBII</td>
<td>-6.17E-05</td>
<td>2.89E-05</td>
<td>-2.137524</td>
<td>0.0353</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.927394</td>
<td>0.038846</td>
<td>23.87337</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared: 0.934178
Mean dependent var: 46.10509
Adjusted R-squared: 0.928262
S.D. dependent var: 4.043236
Akaike info criterion: 3.088457
Schwarz criterion: 5.321972
Hannan-Quinn criter.: 3.180599
F-statistic: 157.8925
Durbin-Watson stat: 1.622126
Prob(F-statistic): 0.000000

Inverted AR Roots: .93
d(ex) c msind gdpind cf of fp trb rbii ar(1) ma(1)

Dependent Variable: D(EX)
Method: Least Squares
Date: 04/13/14   Time: 00:56
Sample (adjusted): 2004M11 2012M12
Included observations: 98 after adjustments
Convergence achieved after 40 iterations
MA Backcast: 2004M10

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-0.731625</td>
<td>1.848021</td>
<td>-0.395896</td>
<td>0.6931</td>
</tr>
<tr>
<td>MSIND</td>
<td>2.85E-09</td>
<td>3.45E-08</td>
<td>0.082504</td>
<td>0.9344</td>
</tr>
<tr>
<td>GDPIND</td>
<td>0.007266</td>
<td>0.024965</td>
<td>0.291027</td>
<td>0.7717</td>
</tr>
<tr>
<td>CF</td>
<td>-4.57E-05</td>
<td>0.000118</td>
<td>-0.368353</td>
<td>0.6987</td>
</tr>
<tr>
<td>OF</td>
<td>-0.001801</td>
<td>0.000503</td>
<td>-3.576961</td>
<td>0.0006</td>
</tr>
<tr>
<td>FP</td>
<td>-0.192543</td>
<td>0.098743</td>
<td>-2.105857</td>
<td>0.0357</td>
</tr>
<tr>
<td>TRB</td>
<td>-4.51E-05</td>
<td>4.81E-05</td>
<td>-0.919217</td>
<td>0.3627</td>
</tr>
<tr>
<td>RBII</td>
<td>-3.12E-07</td>
<td>3.09E-05</td>
<td>-0.176203</td>
<td>0.8615</td>
</tr>
<tr>
<td>AR(1)</td>
<td>-0.538002</td>
<td>0.259759</td>
<td>-2.081188</td>
<td>0.0377</td>
</tr>
<tr>
<td>MA(1)</td>
<td>0.743377</td>
<td>0.206441</td>
<td>3.582754</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

R-squared 0.283665  Mean dependent var 0.095173
Adjusted R-squared 0.210404  S.D. dependent var 1.151294
S.E. of regression 1.093186  Akaike info criterion 3.112521
Sum squared resid 105.1650  Schwarz criterion 3.376294
Log likelihood -142.5135  Hannan-Quinn criter. 3.219124
F-statistic 3.871956  Durbin-Watson stat 2.050198
Prob(F-statistic) 0.000363

Inverted AR Roots -.54
Inverted MA Roots -.74

d(ex) ex(-1) msind(-1) gdpind(-1) cf(-1) of(-1) fp(-1) trb(-1) rbii(-1) d(ex(-1)) d(msind(-1)) d(gdpind(-1)) d(cf(-1)) d(of(-1)) d(fp(-1)) d(trb(-1)) d(rbii(-1))

Dependent Variable: D(EX)
Method: Least Squares
Date: 04/14/14   Time: 12:53
Sample(adjusted): 1999:03 2013:12
Included observations: 178 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX(-1)</td>
<td>-3.88E-05</td>
<td>0.014666</td>
<td>-0.002647</td>
<td>0.9979</td>
</tr>
<tr>
<td>MSIND(-1)</td>
<td>-8.83E-09</td>
<td>1.30E-08</td>
<td>-0.067829</td>
<td>0.4985</td>
</tr>
<tr>
<td>GDPIND(-1)</td>
<td>-0.000752</td>
<td>0.009198</td>
<td>-0.081717</td>
<td>0.9350</td>
</tr>
<tr>
<td>OF(-1)</td>
<td>-0.000563</td>
<td>0.000530</td>
<td>-1.061307</td>
<td>0.2901</td>
</tr>
<tr>
<td>FP(-1)</td>
<td>0.044751</td>
<td>0.049021</td>
<td>0.912891</td>
<td>0.3626</td>
</tr>
<tr>
<td>TRB(-1)</td>
<td>-7.75E-05</td>
<td>4.97E-05</td>
<td>-1.560076</td>
<td>0.1207</td>
</tr>
<tr>
<td>RBII(-1)</td>
<td>9.51E-06</td>
<td>3.89E-05</td>
<td>2.448088</td>
<td>0.0869</td>
</tr>
<tr>
<td>D(EX(-1))</td>
<td>0.005232</td>
<td>0.086148</td>
<td>0.060730</td>
<td>0.9516</td>
</tr>
<tr>
<td>D(MSIND(-1))</td>
<td>-3.48E-07</td>
<td>2.39E-07</td>
<td>-1.453006</td>
<td>0.1481</td>
</tr>
<tr>
<td>D(GDPIND(-1))</td>
<td>-0.052070</td>
<td>0.019908</td>
<td>-2.615498</td>
<td>0.0097</td>
</tr>
<tr>
<td>D(OF(-1))</td>
<td>-0.000872</td>
<td>0.000564</td>
<td>-1.545516</td>
<td>0.1241</td>
</tr>
<tr>
<td>Variable</td>
<td>Coefficient</td>
<td>Std. Error</td>
<td>t-Statistic</td>
<td>Prob.</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
<td>-------------</td>
<td>-------------</td>
<td>--------</td>
</tr>
<tr>
<td>EX(-1)</td>
<td>-3.88E-05</td>
<td>0.014666</td>
<td>-0.002647</td>
<td>0.9979</td>
</tr>
<tr>
<td>MSIND(-1)</td>
<td>-8.83E-09</td>
<td>1.30E-08</td>
<td>-0.081717</td>
<td>0.9350</td>
</tr>
<tr>
<td>GDPIND(-1)</td>
<td>-0.000752</td>
<td>0.009198</td>
<td>-0.081717</td>
<td>0.9350</td>
</tr>
<tr>
<td>OF(-1)</td>
<td>-0.000563</td>
<td>0.000530</td>
<td>-1.061307</td>
<td>0.2901</td>
</tr>
<tr>
<td>FP(-1)</td>
<td>0.044751</td>
<td>0.049021</td>
<td>0.912891</td>
<td>0.3626</td>
</tr>
<tr>
<td>TRB(-1)</td>
<td>-7.75E-05</td>
<td>4.97E-05</td>
<td>-1.560076</td>
<td>0.1207</td>
</tr>
<tr>
<td>RBII(-1)</td>
<td>9.51E-06</td>
<td>3.89E-05</td>
<td>0.244808</td>
<td>0.8069</td>
</tr>
<tr>
<td>D(EX(-1))</td>
<td>0.005232</td>
<td>0.086148</td>
<td>0.060730</td>
<td>0.9516</td>
</tr>
<tr>
<td>D(MSIND(-1))</td>
<td>-3.48E-07</td>
<td>2.39E-07</td>
<td>-1.453006</td>
<td>0.1481</td>
</tr>
<tr>
<td>D(GDPIND(-1))</td>
<td>-0.052070</td>
<td>0.019908</td>
<td>-2.615498</td>
<td>0.0097</td>
</tr>
<tr>
<td>D(OF(-1))</td>
<td>-0.000872</td>
<td>0.000564</td>
<td>-1.545516</td>
<td>0.1241</td>
</tr>
<tr>
<td>D(FP(-1))</td>
<td>-0.216391</td>
<td>0.107981</td>
<td>-2.003969</td>
<td>0.0467</td>
</tr>
<tr>
<td>D(TRB(-1))</td>
<td>-6.79E-05</td>
<td>4.65E-05</td>
<td>-1.459167</td>
<td>0.1464</td>
</tr>
<tr>
<td>D(RBII(-1))</td>
<td>-1.85E-05</td>
<td>3.07E-05</td>
<td>-0.601586</td>
<td>0.5483</td>
</tr>
</tbody>
</table>

R-squared 0.225982
Adjusted R-squared 0.164627
S.E. of regression 1.031869
Sum squared resid 174.6195
Log likelihood -250.8646
Forecast: EXF_3M_OLS
Actual: EX
Forecast sample: 2012M12 2013M03
Included observations: 4

Root Mean Squared Error 0.979081
Mean Absolute Error 0.922068
Mean Absolute Percentage Error 1.711053
Theil Inequality Coefficient 0.008979
Bias Proportion 0.886928
Variance Proportion 0.044332
Covariance Proportion 0.068740