1. Introduction

Policy Reforms and the Rate of Interest :

The objective of this study is to examine the role of domestic and external factors in the determination of short term interest rates in India in the period following economic reforms. The period under study is March 1993 to May 2000.

Steps to liberalize interest rates started in the late 1980s. Certificates of deposits were introduced in June 1989 and commercial paper in January 1990. However, the reforms did not gain momentum until mid-1992 when rates of interest in India were gradually decontrolled in a variety of ways. The most important interest rates are now market determined. These include all deposit rates with the exception of fixed deposit rates that account for roughly 15 to 20 percent of bank deposits. Banks are allowed to determine their lending rate for loans above Rs. 2 lakh. Below this amount, a maximum ceiling prevails so that small borrowers are treated on par with large ones. In mid-1992, the Reserve Bank of India also introduced new government securities through auction sale. These included 364-day Treasury bills, and five-year and ten-year bonds.

The year 1993 also marked the beginning of the era of a freely floating exchange rate system. From 1975 to 1992, the rupee exchange rate was officially determined by the Reserve Bank of India and was based on a weighted basket of currencies of India's major trading partners. The 1991 balance of payments crisis resulted in two successive devaluations following which India adopted a dual exchange rate system from March 1992 to February 1993. Subsequently, in March 1993, exchange rates were unified.

Since August 1994, the rupee is convertible on the current account. Capital account convertibility is allowed for foreigners, foreign based corporates and non-resident Indians. Several types of exchange controls have been dismantled and the Indian rupee is no longer pegged. The process of integration of the Indian financial market with the rest of the world is underway. Foreign portfolio investment and direct foreign investment are increasing. Guaranteed repatriation of profits and other returns to foreign based investors are among several factors that have made India a favoured destination for foreign funds. In this changing scenario interest parity conditions can be expected to prevail.

The changing financial and monetary conditions are examined in a global perspective in the post liberalization period. In the following section, a macroeconomic model for an open economy is specified and the model is solved for the real rate of interest. Section 3 reports the econometric methodology and the data sources. The empirical results are reported in Section 4 and the following section concludes the paper

2. Specification of the Model

In modelling a particular rate of interest, the objective is to explain the behaviour of the designated rate on a given financial instrument. Analytically, the rate is taken as the equilibrium yield on the given instrument determined by equilibrating its demand and supply. However, the objective of the present study is to examine the impact of domestic market forces and external factors on interest rate determination in general, in the post - reform period. The importance of such a study can hardly be over - emphasised given the fact that prior to economic reforms not only was the capital account closed, but most of the rates of interest were also administered. As a result, the interest rates were to a great extent immune to both domestic market forces and external factors.

In the post reform period, it has been observed that Indian financial markets are getting more integrated and the movement of various rates of interest in the Indian economy is in "uniform directions"[1]. A market determined rate can therefore be used to indicate the direction of change.

The present study uses a macroeconomic model in which the structural equations specify the relevant relationships reflecting the predominant influences for the period under study. The goods market equilibrium and money market equilibrium are given by

$$Y = C(Y, r) + I(Y, r) + G \quad \text{----------------------} \quad \text{(i)}$$

$$M = M_1(Y, i) + M_2(i) \quad \text{----------------------} \quad \text{(ii)}$$

[1] Bhoi and Dhall (1998) p.378

In equation (i) C_Y , I_Y are both positive
C_r ,I_r are both negative

In equation (ii) M_{1Y} is positive

M_{2i} and M_{1i} are negative

Y = Real output
M = Real Money supply
r = real rate of interest
i = nominal rate of interest
M_1,M_2 = Transactions demand and speculative demand for money
G = Real government expenditure
C = Real consumption expenditure
I = Real investment expenditure

In principle, equation (i) can be solved for Y in terms of the remaining variables i.e. $Y = f_1 (r,G)$, and equation (ii) can be solved in terms of Y, and i as, $M = f_2 (Y,i)$. Assuming linear functional forms and using lower case letters as logarithms of the corresponding upper case letters (except for interest rates which are in percentages) equations (i) and (ii) representing the goods market and money market equilibria can be written in stochastic form as

$$y = b_o + b_1 r + b_2 g + v \qquad (1)$$
$$m = c_o + c_1 y + c_2 i + e \qquad (2)$$

Two predominant influences on the rate of interest during the post reform period have been subdued inflationary expectations and the possibility of interest rate arbitrage with the ROW sector.

In India the post reform period has witnessed a fall in fiscal deficit, with a controlled monetisation of the budget deficit - resulting in subdued inflationary expectations. This calls for examining the relevance of Fisher hypothesis. The equation specified for this is no doubt a definition, but in a regime of market determined rates, it would bring out the impact of domestic inflation and the resultant inflationary expectations on the rate of interest. This equation also relates the nominal with the real rate of interest - the former featuring in money market clearing equation and the latter in the goods market clearing equation. The Fisher equation is :

$r = i - p^e$ (3), where p^e = expected rate of inflation of wholesale prices.

Finally, given the fact that in the post reform period, Indian rupee is now convertible on current account and partially convertible on capital account, resulting in a significant increase in capital inflows an interesting question is how would interest rate arbitrage work.

In the literature, this question has been addressed as an issue of capital mobility in developing countries. Edwards and Khan (1985) model a continuum of countries ranging from those with completely open capital accounts to countries with closed capital accounts. This is done for the period 1969 to 1987. Haque and Montiel (1990,1991) examine the capital mobility issue, while distinguishing between the organised and the informal financial markets. Haque, Lahiri and Montiel (1990) incorporate the extent of capital mobility in a macroeconometric model for a large number of developing countries, with the results showing that on average, capital mobility prevailed in general.

In studies related to specific countries, Blejer and Diaz (1986) for Uruguay and Gochoco (1991) for Phillipines specifically model the interest parity conditions. Blejer and Diaz conclude that given the capital account convertibility, the authorities have little control over the real interest rate in Uruguay. Gochoco finds that capital account in the Phillipines is quite open despite the existence of legal barriers to capital mobility and that domestic monetary policy only indirectly influences interest rates in Phillipines. Using Indian monthly data for the period April 1993 to March 1998, Bhoi and Dhall (1998) examine the extent of financial market integration in India and observe that covered interest parity hypothesis cannot be rejected for the Indian case in the post reform period.

In the present study, we specify a covered interest parity relationship. It is reasonable to acknowledge that foreign and domestic financial assets are not perfect substitutes, due to several kinds of risk. However, the existence of a forward market provides a mechanism for getting a forward cover for the anticipated component of exchange risk. Under such conditions, a covered interest parity would hold -

$$i_t = i_t^* + F_t - S_t$$

$$i_t = i_t^* + FP \qquad (4)$$

F_t = Forward rate of exchange
S_t = Spot rate of exchange
$FP = F_t - S_t$

Now we can put the four equations together

$$y = b_o + b_1 r + b_2 g + v \qquad (1)$$

$$m = c_o + c_1 y + c_2 i + e \qquad (2)$$

$$r = i - p^e \qquad (3)$$

$$i = i^* + FP \qquad (4)$$

y, m, r, i are the endogenous variables while g, p^e, i^* and FP are the exogenous variables in the model. Equations (1), (2) are stochastic behavioural functions, while (3) and (4) are equations or definitions. Adding (3) and (4), we obtain

$$2i = r + p^e + i^* + FP$$
$$i = \frac{1}{2}(r + p^e + i^* + FP)$$

Substituting this value of i in equation (2) we have -

$$m = c_o + c_1 y + \frac{c_2}{2}(r + p^e + i^* + FP) + e \qquad (5)$$

Substituting the value of y from (1) in equation (5)

$$m = c_o + c_1 (b_o + b_1 r + b_2 g + v) + \frac{c_2}{2}(r + p^e + i^* + FP) + e \qquad (6)$$

Equation (6) can be solved for r, the real rate of interest and we would have

$$r = a_o +_{(+)} a_1 g +_{(-)} a_2 p^e +_{(+)} a_3 i^* +_{(-)} a_4 m +_{(+)} a_5 FP \qquad (7)$$

In (7) a_o is the intercept term
a_1 -------- a_5 are response coefficients.
The a priori signs of the variables are given in the brackets.

A priori, we expect higher government spending (g) to be associated with a higher domestic rate of interest. Ceteris paribus, in the short period of a month, higher government spending has to be associated with a larger issue of government bonds - there being no month to month variation in taxes. This would result in a fall in the prices of government bonds and a rise in the rate of interest.

On the other hand higher money supply (m) materialises through open market operations raising bond prices and reducing the rate of interest. Monetary policy interventions in the shape of changes in reserve ratios would reflect in terms of changes in credit availability and thereby in the broad money supply. Money supply variable would thus have a negative coefficient.

A priori considerations imply that higher expected rate of inflation (p^e) would have a negative impact on the real rate of interest. This is as per the Fisher - relationship.

Higher world interest rate (i^*) would be positively associated with the domestic rate (i) simply because higher i^* would lead to an outflow of capital. This would imply a fall in the demand for domestic bonds and a rise in the domestic rate of interest.

Finally, higher the forward premium (FP), higher the expected depreciation of domestic currency - higher the demand for foreign bonds relative to domestic bonds. The result would be lower domestic bond prices and a higher domestic rate of interest. So on the basis of a priori considerations FP ought to bear a positive coefficient in this interest rate model.

The model in equation (7) above has been specified with a view to examine the role of domestic and external factors in the determination of real interest rate in India's open economy in the post-liberalisation period. The structural equations of the model have been solved so as to focus on the predominant influences on the real rate of interest during the period under study. Among the factors influencing the real interest rate, the model focuses on π^e ,g, m, i* and F, and the theoretical considerations explaining their role in the model have been spelt out above.

3. Econometric Methodology

This paper analyzes the empirical relationship between real interest rates, real government expenditure, real money supply, foreign interest rates, forward premium, and inflation rate[2] in the post liberalization period. Cointegration analysis and Granger causality tests in the framework of error correction models are used to examine the relationship

Three alternative measures of the nominal interest rate are used, viz., the commercial paper rate, the 3-month Treasury Bill rate, and the 12-month Treasury bill rate. The paper therefore tests if the relationship is robust to different measures of the interest rate. Since the

[2] The empirical estimations use the actual inflation rate although the theoretical model includes the expected inflation rate. This is because including the expected inflation rate on the right hand side did not yield satisfactory results. This may be since the expected inflation rate is also included in the left hand side.

empirical analysis pertains to the real interest rate, measures of the expected inflation rate are required. First, we assume perfect foresight implying that inflation expected for the next period equals the realized inflation rate for the following period. Second, we generate inflation forecasts using the autoregressive integrated moving average models.

Nominal money supply is measured by M3 and is deflated by WPI to convert to real money supply. Real government expenditure is generated in a similar way. Foreign interest rate is measured by the six months London inter-bank offer rate. The analysis also includes the forward premium (three months).

Tests for Nonstationarity

The first econometric step is to test if the series are nonstationary. The classical regression model requires that the dependent and independent variables in a regression be stationary in order to avoid the problem of what Granger and Newbold (1974) called 'spurious regression.' Nonstationarity or the presence of a unit root can be tested using the augmented Dickey-Fuller (1979, 1981) tests. To test if a sequence y_t contains a unit root, three different regression equations are considered.

$$\Delta y_t = \alpha + \gamma y_{t-i} + \theta t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad (8)$$

$$\Delta y_t = \alpha + \gamma y_{t-i} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad (9)$$

$$\Delta y_t = \gamma y_{t-i} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad (10)$$

The first equation includes both a drift term and a deterministic trend; the second excludes the deterministic trend; and the third does not contain an intercept or a trend term. In all three equations, the parameter of interest is γ. If $\gamma=0$, the y_t sequence has a unit root. The estimated t-statistic is compared with the appropriate critical value in the Dickey-Fuller tables to determine if the null hypothesis is valid. The critical values are denoted by τ_τ , τ_μ , and τ for equations (8), (9), and (10) respectively.

Following Doldado, Jenkinson, and Sosvilla-Rivero (1990), a sequential procedure is used to test for the presence of a unit root when the form of the data-generating process is unknown. Such a procedure is necessary since including the intercept and trend term reduces the degrees of freedom and the power of the test implying that we may conclude that a unit root is present when, in fact, this is not true. Further, additional regressors increase the absolute value of the critical value making it harder to reject the null hypothesis. On the other hand, inappropriately omitting the deterministic terms can cause the power of the test to go to zero (Campbell and Perron, 1991).

The sequential procedure involves testing the most general model first (equation 8). Since the power of the test is low, if we reject the null hypothesis, we stop at this stage and conclude that there is no unit root. If we do not reject the null hypothesis, we proceed to determine if the trend term is significant under the null of a unit root. If the trend is significant, we retest for the presence of a unit root using the standardised normal distribution. If the null of a unit root is not rejected, we conclude that the series contains a unit root. Otherwise, it does not. If the trend is not significant, we estimate equation (9) and test for the presence of a unit root. If the null of a unit root is rejected, we conclude that there is no unit root and stop at this point. If the null is not rejected, we test for the significance of the drift term in the presence of a unit root. If the drift term is significant, we test for a unit root using the standardised normal distribution. If the drift is not significant, we estimate equation (10) and test for a unit root.

We also conduct the Phillips-Perron (1988) test for a unit root. This is because the Dickey-Fuller tests require that the error term be serially uncorrelated and homogeneous while the Phillips-Perron test is valid even if the disturbances are serially correlated and heterogeneous. The test statistics for the Phillips-Perron test are modifications of the t-statistics employed for the Dickey-Fuller tests but the critical values are precisely those used for the Dickey-Fuller tests. The critical values for the Phillips-Perron (PP) statistics are precisely those given for the ADF tests. In general PP test is preferred to the ADF tests if the diagnostic statistics from the ADF regressions indicate autocorrelation or heteroscedasticity in the error terms. Phillips and Perron (1988) also show that when the disturbance term has a positive moving average component, the power of the ADF tests is low compared to the

Phillips-Perron statistics so that the latter is preferred. If, however, a negative moving average term is present in the error term, the PP test tends to reject the null of a unit root and therefore ADF tests are preferred.

If the variables are nonstationary, we test for the possibility of a cointegrating relationship using the Johansen and Juselius (1990) methodology. If the variables are indeed cointegrated, we can construct a vector error-correction model that captures both the short-run and long-run dynamics.

Johansen's Cointegration Test

Consider the p-dimensional vector autoregressive model with Gaussian errors

$$y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + \Psi . D + A_0 + e_t$$

where y_t is an $m \times 1$ vector of I(1) variables, D is a vector of nonstochastic variables, such as seasonal dummies or time trend. The Johansen test assumes that the variables in y_t are I(1). For testing the hypothesis of cointegration the model is reformulated in the vector error-correction form

$$\Delta y_t = -\Pi y_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + A_0 + \Psi D + e_t$$

where

$$\Pi = I_m - \sum_{i=1}^{p} A_i, \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j, \quad i = 1, ..., p-1.$$

If the vector y_t is I(0),   will be a full rank mxm matrix. If the elements of vector y_t are I(1) and cointegrated with rank (   )=r, then $\Pi = ab'$, where   and   are mxr full column rank matrices and there are r<m linear combinations of y_t . The model can easily be extended to include a vector of exogenous I(1) variables.

Under cointegration, the VECM can be represented as

$$\Delta y_t = -ab' y_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + A_0 + \Psi D + e_t$$

where   is the matrix of adjustment coefficients. If there are non zero cointegrating vectors, then some of the elements of   must also be non zero to keep the elements of y_t from diverging from equilibrium.

If two variables are cointegrated, i.e. they have a common trend, causality in the Granger (temporal) sense must exist in at least one direction (Granger, 1986; 1988). However although cointegration indicates presence or absence of Granger causality, it does not indicate the direction of causality. In the two variable VAR model assuming the variables to be stationary, we say that the first variable does not Granger cause the second if the lags of the first variable in the VAR are jointly not significantly different from zero. The concept of Granger causality is extended in the framework of a VECM to include the error correction term in addition to .lagged variables of the variables. Granger-causality can then be tested by (i) the statistical significance of the lagged error correction term by a standard t-test; and (ii) a joint test applied to the significance of the sum of the lags of each explanatory variables, by a joint F or Wald χ^2 test. Alternatively, a joint test of all the set of terms described in (i) and (ii) can be conducted by a joint F or a Wald χ^2 test.

Derivation of the real interest rate: Perfect Foresight and ARIMA Forecasts

Since the paper examines the real interest rate, we estimate alternative measures of the expected inflation rate that are subtracted from the nominal interest rate to yield the real rate. We make two assumptions about the expected inflation rate. The first is the assumption of perfect foresight that is used as the benchmark model. The second set of forecasts are generated from a best-fit ARIMA model. The usual criteria are used to select the forecasting model. These include checking for stationarity, invertibility, AIC, SBC, diagnostic checking of residuals, out-of-sample forecasting accuracy and stability.

4. Empirical Results

The estimates are based on monthly data from April 1993 to May 2000. We first test for the nonstationarity of all the variables, i.e., commercial paper rate; Treasury bill rate – 3 months and 12 months, WPI (all commodities), inflation rate – annual and monthly, LIBOR (6 months), forward premium (3 months), nominal government expenditure deflated by WPI and nominal money supply (M3) deflated by WPI. All variables are specified in logarithmic form. Although the estimations are based on data from 1993 onwards, tests for nonstationarity are carried out from 1985 as well since nonstationarity is a long run concept. After checking for the presence of unit roots, we proceed with the tests for cointegration and Granger causality in the framework of a vector error correction model.

For the unit root tests, the null hypothesis γ=0 in the most general model (equation 8) is tested against the critical value τ_{τ}. The critical values for equations (9) and (10) are τ_{μ} and τ respectively. The critical value for the test for a time trend in the presence of a unit root in equation (8) is ϕ_3. Similarly, the critical value for the test for a drift in the presence of a unit root in equation (9) is ϕ_1. The test statistics are given in Table 1. The sequential procedure is used so that if the null of unit root is rejected for the most general model, we stop at this stage. If the null is not rejected, we look at smaller models (equations 9 and 10).

On the basis of the ADF and PP tests, for the post 1993 period, except for government expenditure, all other variables are nonstationary (Table 1A). For the longer period, i.e. from Jan-85 onwards, the results are unchanged for all variables except for government expenditures. While the ADF test suggests the presence of a unit root, the PP test points otherwise (Table 1B). However, the MA patterns of the disturbances of the series indicates presence of a negative MA term implying that the PP test is not reliable. Moreover even the plot of the correlogram of the government expenditure indicates nonstationarity of the series. We therefore treat government expenditure as nonstationary. First differences of all variables are found to be stationary. Further, we find that monthly inflation is stationary while annual inflation is nonstationary.

Perfect foresight model

To calculate the real rate of interest, we make two assumptions. First, we assume that people have perfect foresight i.e., they know the true value of the future expected variable and second, we assume that forecasts are based on a best-fit ARIMA model.

The assumption of perfect foresight may not be an unreasonable one given that the period under study is one of repressed inflation. Thus the real interest rate is calculated as $r = i - \pi_t$, where we assume $\pi_t^e = \pi_t$ (actual annual inflation rate). In order to differentiate between the perfect foresight and time series models, we denote the perfect foresight real rate as r_1 and the time series rate as r_2. Since we have three different interest rates we denote these as $r_{1(CPR)}$, $r_{1(TB3)}$ and $r_{1(TB12)}$ respectively.

We use Johansen's FIML technique to test for cointegration between domestic real interest rate, real money supply, real government expenditure, forward premium and foreign interest rate, while treating monthly inflation as stationary exogenous variable. After ascertaining that the variables are infact integrated of the same order, we select the order of the VAR. The AIC, SBC, and the likelihood ratio test collectively suggest an optimal lag length of 3.

The next step is the selection of the deterministic terms in VAR. Although the data exhibit a linear trend, there is no reason to expect a quadratic trend. This implies an intercept in VAR but no trend.

Both the maximum and trace eigenvalue statistics strongly reject the null hypothesis that there is no cointegration between the variables (i.e. $r = 0$), but do not reject the hypothesis that there is one cointegrating relation between the variables (i.e. $r = 1$) for all the three interest rates (Table 2A, 2B). We find that all of the variables have the correct signs as suggested by the theoretical model. The cointegrating vector suggests that while the money supply is negatively related to the real interest rate, government expenditure, forward premium and the foreign interest rate have positive signs. The cointegrating equations for the three cases are:

MODEL 1A : $r_{1(CPR)} = -1.27\,m + 1.44\,g + 3.23\,i^* + 0.93\,fp$

MODEL 1B : $r_{1(TB3)} = -0.87\,m + 1.03\,g + 2.23\,i^* + 0.52\,fp$

MODEL 1C : $r_{1(TB12)} = -1.17\,m + 1.39\,g + 2.15\,i^* + 0.65\,fp$

The likelihood ratio tests for zero restrictions on the parameters are reported in Table 3. These show that while the money supply and government expenditure are highly significant, the foreign interest rate is not although it has the correct sign. The forward premium is significant in the equation for the commercial paper rate but is insignificant in the case of 3 and 12-month Treasury bills. The relative importance of the domestic variables such as the money supply and the government expenditure may be due to the short time span covered over which the foreign variables may not have been as important. The importance of the domestic variables is also reflected in the error-correction form of the model (detailed results are not reported for the sake of brevity) where the inflation rate appears as an exogenous stationary variable. It has a negative sign in all the three cases and is also highly significant as indicated by the t-ratios -- (–5.46), (-5.54) and (-5.38) for the three cases respectively.

In all three vector error correction models, the error correction term is negative and statistically significant as indicated by the t-ratios (-2.24), (-2.67) and (-3.16) respectively, but is rather small (-0.011,-0.018,-0.012 respectively). The negative sign implies that if the interest rate today is higher than what it's long term specification suggests, then it should fall. The small size suggests that it will take a long time for the system to return to its equilibrium once it has been given a shock. An alternative explanation for the small magnitude is that given our small time period, the speed of adjustment may not have captured the entire magnitude.

Using the error correction models, we also test whether the variables individually improve the forecasting performance of the model, i.e., we test if the independent variables Granger cause the interest rate. For this, we test for the joint significance of the lagged variables of each variable along with the error correction term in the following equation:

$$\Delta r_t = a_0 + a_1 e_{t-1} + \sum_{i=1}^{2} b_i \Delta m_{t-i} + \sum_{i=1}^{2} g_i \Delta g_{t-i} + \sum_{i=1}^{2} d_i \Delta i^*_{t-i} + \sum_{i=1}^{2} k_i \Delta fp_{t-i} + p\,\dot{p}_t + e_t$$

where, e_{t-1} is the error correction term defined as :

$$e_{t-1} = r_t - mm_{t-1} + hg_{t-1} + l i^*_{t-1} + qfp_{t-1}$$

The money supply, for example, is said to Granger cause the real interest rate if the coefficients α_1, β_1 and β_2 are jointly significant. This test is important especially in light of the insignificance of the foreign variables in the cointegrating vector.

The results reported in Table 4 indicate that the null hypothesis of no Granger causality is strongly rejected in all the cases. This result is significant since it shows that both domestic and external factors play a major role in determining movements in the real rate.

The above results are based on the assumption that inflation rate forecasts are perfect foresight predictions. We now estimate the models using forecasts generated from time series models.

ARIMA Forecast model

Since the series to be predicted, i.e., the annual inflation rate is non-stationary we take its first difference to make it stationary and then forecast the differenced series integrating it back to get the level series (Table 5). The model is selected by initially estimating it from Jan-85 to Mar-93 and making out of sample forecasts. The sample size is then increased by one observation, the model is reestimated and out of sample forecasts are again generated. This continuous updating and reestimation is continued until all observations are utilized. The optimal model is selected on the basis of out of sample accuracy and other test statistics reported in Table 5. The new interest rates are denoted by r_2 to distinguish them from the perfect foresight model. Accordingly we now have three real interest rates denoted as $r_{2(CPR)}$, $r_{2(TB3)}$ and $r_{2(TB12)}$. A comparison of the real rates derived by the two procedures is given in Figures 1A-1C.

Since the real rates based on ARIMA forecasts are integrated of order one (Table 6) cointegration tests are conducted as described for the perfect foresight model. The optimal lag length collectively selected by AIC, SBC, and the likelihood ratio test is three. We estimate a VAR with unrestricted intercepts and no trend.

Both the maximum and trace eigenvalue statistics strongly reject the null hypothesis that there is no cointegration between the variables (i.e. r = 0), but do not reject the hypothesis that there is one cointegrating relation between the variables (i.e. r = 1) for all the three interest rates (Table 7A, 7B). As earlier we find that all the variables have the correct signs. The cointegrating vector suggests that while money supply is negatively related to real interest rate, government. expenditure, forward premium and the foreign interest rate have positive signs.

The cointegrating equations now are:

MODEL 2 A : $\mathbf{r_{2(CPR)} = - 1.09\, m + 1.25\, g + 2.54\, i^* + 0.76\, fp}$

MODEL 2 B : $\mathbf{r_{2(TB3)} = - 1.15\, m + 1.36\, g + 2.27\, i^* + 0.50\, fp}$

MODEL 2 C : $\mathbf{r_{2(TB12)} = - 2.26\, m + 2.66\, g + 3.31\, i^* + 0.79\, fp}$

The likelihood ratio tests for the significance of the variables suggest that all the variables except the forward premium and foreign interest rates are significant (Table 8). Examining the vector error correction form of the model indicates that the error correction coefficients are negative and significant (the t-ratios are (–3.17), (-2.67) and (-2.92) for the three interest rates respectively). Moreover, the magnitude of the speed of adjustment is small (-0.025,-0.021,-0.010 respectively). The exogenous monthly inflation term is also negative and significant (the t-ratio being (–5.43), (-4.49) and (-4.27)). The final check on the specification of the model -- the Granger causality tests, indicate that the included variables do Granger cause the domestic real interest rate (Table 9).

Thus, our conclusions are unchanged even though the forecast generating model is not the same.

5. Conclusions

Our results show that both domestic and external factors have influenced movements in the domestic real interest rates in the post reform period. Furthermore, real money supply, real government expenditure, foreign interest rate, forward premium and the domestic inflation rate have Granger caused the domestic real interest rate. More importantly, these results are robust to three alternative measures of the nominal interest rate and two measures of the expected inflation rate. Our results, however, must be treated with caution because of the short time period (7 years) over which the estimations are conducted.

References

Bhoi, B.K. and S.C. Dhall (1998), " Integration of Financial Markets in India: An Empirical Evaluation" ,*RBI Occassional Papers*,19, 4,pp.345-380.

Blejer, M.I. and J.G. Diaz (1986), " Domestic and External Factors in the Determination of the Real Interest Rate: The case of Uruguay" ,*Economic Develpoment and Cultural Change*,pp.589-606.

Campbell, J. Y. and P. Perron (1991), "Pitfalls and Opportunities: What Macroeconomists Should Know About Unit Roots", *NBER Macroeconomic Annual*, University of Chicago Press, Illiniois.

Dickey, D. A. and W. A. Fuller (1979), "Distribution of the Estimators for Autoregressive Time Series with a Unit Root", *Journal of the American Statistical Association,* 74, pp. 427-31.

______________ (1981), "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root", *Econometrica*, 49, pp. 1057-72.

Dolado, J., T. Jenkinson, and S. Sosvilla-Rivero (1990), "Cointegartion and Unit Roots", *Journal of Economic Surveys*, 4, pp.249-73.

Edwards , S. and M.S. Khan (1985), " Interest Rate Determination in Developing Countries:A Conceptual Framework" ,*IMF Staff Papers*,32,pp.377-403.

Engle, R. E. and C. W. J. Granger (1987), "Cointegration and Error Correction: Representation, Estimation and Testing, *Econometrica*, 55, pp. 251-76.

Gochoco, M.S. (1991) " Financial Liberalisation and Interest Rate Determination: The case of Phillipines 1981-1985", *Journal of Macroeconomics*, Spring 1991,13,2,pp.335-350.

Granger, C. W. J. (1986), “Developments in the Study of Cointegrated Variables”, *Oxford Bulletin of Economics and Statistics*, 48, pp. 213-27.

Granger, C.W.J. and P. Newbold (1974), “Spurious Regressions in Econometrics”, *Journal of Econometrics*, 2, pp. 111-20.

Haque, N.U. and P.J. Montiel (1990), “ How Mobile is Capital in Developing Countries”, *Economics Letters*,33,pp.359-362.

____________________ (1991), : Capital Mobility in Developing Countries: Some Empirical Tests” ,*World Development*,19,pp.1391-1398.

Haque, N.U. , Lahiri K. and P.J. Montiel (1990), “ A Macroeconometric Model for Developing Countries”,*IMF Staff Papers*,pp.537-559.

Johansen, S. and K. Juselius (1990), “Maximum Likelihood Estimation and Inference on Cointegration with Applications to the Demand for Money”, *Oxford Bulletin of Economics and Statistics*, 52, pp. 169-209.

______________ (1992), “Testing Structural Hypothesis in a Multivariate Cointegartion Analysis of PPP and the UIP for UK”, *Journal of Econometrics*, 53, pp. 211-44.

Phillips, P. and P. Perron (1988), “Testing for a Unit Root in Time Series Regression”, *Biometrica*, 75, pp. 335-46.

Table 1A

Unit Root Tests : (Apr 93 – May 2000)

TESTS ***VARIABLE***	**Null: g=0 in equation 3** t_t	**Null: g=0, q=0, equation 3** f_3	**Null: g=0 in equation 2** t_m	**Null: g=0, a=0 equation 2** f_1	**Null: g=0 in equation 1** t	***RESULTS*** ***(UNIT ROOT PRESENT)***
ADF Test **m**	-1.72	1.53	-0.34	11.72		YES*
PP – Test **m**	-3.77	7.17	0.18	83.88		YES*
ADF Test **i***	-2.99	4.51	-2.70	4.19	0.67	YES*
PP – Test **i***	-1.92	2.00	-1.94	3.44	1.39	YES*
ADF Test **g**	-4.56					NO**
PP – Test **g**	-11.39					NO**
ADF Test **fp**	-2.15	2.35	-2.18	2.41	-1.33	YES*
PP – Test **fp**	-2.82	4.01	-2.83	4.07	-1.77	YES**
ADF Test $\mathbf{r_{1(CPR)}}$	-2.60	3.38	-2.39	2.89	-1.41	YES*
PP – Test $\mathbf{r_{1(CPR)}}$	-2.20	2.46	-2.02	2.12	-1.33	YES*
ADF Test $\mathbf{r_{1(TB3)}}$	-1.80	1.63	-1.57	1.23	-1.19	YES*
PP – Test $\mathbf{r_{1(TB3)}}$	-1.95	1.91	-1.69	1.43	-1.27	YES*
ADF Test $\mathbf{r_{1(TB12)}}$	-2.13	2.28	-1.89	1.80	-1.18	YES*
PP – Test $\mathbf{r_{1(TB12)}}$	-1.60	1.31	-1.50	1.14	-0.97	YES*
ADF Test $\dot{p}$	-2.91	4.29	-2.73			NO*
PP – Test $\dot{p}$	-9.69					NO*
Critical Values						
10%	-3.13	5.34	-2.57	3.78	-1.62	
5%	-3.41	6.25	-2.86	4.59	-1.95	

Note : The variable r_1 is the real interest rate defined as r = i- $_1$ where i is the nominal interest rate and assuming perfect foresight $_1$ is the actual annual inflation rate derived from WPI. The three different versions of r_1 are for the different interest rates i.e. commercial paper rate, and the three and twelve months treasury bill rates respectively. $\dot{p}$ is the monthly inflation rate also derived from the WPI.

* and ** denote significance at 10% and 5% levels respectively.

Table 1B

Unit root tests : (Jan 85 – May 2000)

TESTS ***VARIABLE***	**Null: g=0 in equation 3** $\mathbf{t_t}$	**Null: g=0, q=0, equation 3** $\mathbf{f_3}$	**Null: g=0 in equation 2** $\mathbf{t_m}$	**Null: g=0, a=0 equation 2** $\mathbf{f_1}$	**Null: g=0 in equation 1** $\mathbf{t}$	***RESULTS*** ***(UNIT ROOT PRESENT)***
ADF Test **g**	-3.56	6.37	-0.51	10.19		YES*
PP – Test **g**	-15.95					NO*
Critical values						
10%	-3.13	5.34	-2.57	3.78	-1.62	
5%	-3.41	6.25	-2.86	4.59	-1.95	

Note : * and ** denote significance at 10% and 5% levels.

Table 2A

Perfect Foresight Models :Tests for Cointegration

λ_{max} *Tests*

H_0 :	*H_1 :*	*Statistics*	*Critical values* 95%	*Critical values* 90%	*RESULTS*
MODEL 1A : $r_{1(CPR)} = f(m, g, i^*, fp, \dot{p})$					
r = 0	**r = 1**	55.30	33.64	31.02	Reject Null Hypothesis
$r \leq 1$	**r = 2**	19.26	27.42	24.99	Do not Reject Null Hypothesis
$r \leq 2$	**r =3**	13.36	21.12	19.02	Do not Reject Null Hypothesis
MODEL 1B : $r_{1(TB3)} = f(m, g, i^*, fp, \dot{p})$					
r = 0	**r = 1**	51.56	33.64	31.02	Reject Null Hypothesis
$r \leq 1$	**r = 2**	15.60	27.42	24.99	Do not Reject Null Hypothesis
$r \leq 2$	**r =3**	14.18	21.12	19.02	Do not Reject Null Hypothesis
MODEL 1C : $r_{1(TB12)} = f(m, g, i^*, fp, \dot{p})$					
r = 0	**r = 1**	54.68	33.64	31.02	Reject Null Hypothesis
$r \leq 1$	**r = 2**	19.36	27.42	24.99	Do not Reject Null Hypothesis
$r \leq 2$	**r =3**	12.12	21.12	19.02	Do not Reject Null Hypothesis

Note: r is the order of cointegration. The critical values take in to account inclusion of the exogenous variables.

Table 2B

λ_{trace} *Tests*

H_0 :	*H_1 :*	*Statistics*	*Critical values* 95%	*Critical values* 90%	*RESULTS*
MODEL 1A : $r_{1(CPR)} = f(m, g, i^*, fp, \dot{p})$					
r = 0	**r > 0**	92.84	70.49	66.23	Reject Null Hypothesis
$r \leq 1$	**r > 1**	37.54	48.88	45.70	Do not Reject Null Hypothesis
$r \leq 2$	**r > 2**	18.27	31.54	28.78	Do not Reject Null Hypothesis
MODEL 1B : $r_{1(TB3)} = f(m, g, I^*, fp, \dot{p})$					
r = 0	**r > 0**	85.32	70.49	66.23	Reject Null Hypothesis
$r \leq 1$	**r > 1**	33.75	48.88	45.70	Do not Reject Null Hypothesis
$r \leq 2$	**r > 2**	18.15	31.54	28.78	Do not Reject Null Hypothesis
MODEL 1C : $r_{1(TB 12)} = f(m, g, i^*, fp, \dot{p})$					
r = 0	**r > 0**	90.55	70.49	66.23	Reject Null Hypothesis
$r \leq 1$	**r > 1**	35.87	48.88	45.70	Do not Reject Null Hypothesis
$r \leq 2$	**r > 2**	16.50	31.54	28.78	Do not Reject Null Hypothesis

Note: r is the order of cointegration. The critical values take in to account inclusion of the exogenous variables.

Table 3

Perfect Foresight Models :Tests for the Significance of Individual Coefficients

TESTS FOR SIGNIFICANCE	***2 (calculated) p-value in parenthesis***	***Conclusion***
MODEL 1A : $r_{1(CPR)}$ = f (m, g, I*, fp, $\dot{p}$)		
m	20.31 (0.000)	Reject zero restriction
g	29.99 (0.000)	Reject zero restriction
i*	1.023 (0.312)	Do not reject zero restriction
fp	40.71 (0.000)	Reject zero restriction
MODEL 1B : $r_{1(TB3)}$ = f (m, g, I*, fp, $\dot{p}$)		
m	14.28 (0.000)	Reject zero restriction
g	27.34 (0.000)	Reject zero restriction
i*	0.767 (0.381)	Do not reject zero restriction
fp	0.407 (0.523)	Do not reject zero restriction
MODEL 1C : $r_{1(TB12)}$ = f (m, g, I*, fp, $\dot{p}$)		
m	15.19 (0.000)	Reject zero restriction
g	26.40 (0.000)	Reject zero restriction
i*	0.407 (0.523)	Do not reject zero restriction
fp	0.424 (0.515)	Do not reject zero restriction

Table 4

Perfect Foresight Models : Granger Causality Tests

Null Hypothesis	*Number of Lags*	*^{2}(calculated)*	*Conclusion*
MODEL 1A : $r_{1(CPR)}$ = f (m, g, i*, fp, $\dot{p}$)			
$r_{1(CPR)}$ is not granger caused by **m**	3	10.91 (0.012)	Reject null hypothesis*
$r_{1(CPR)}$ is not granger caused by **g**	3	17.23 (0.001)	Reject null hypothesis*
$r_{1(CPR)}$ is not granger caused by **i***	3	7.638 (0.054)	Reject null hypothesis**
$r_{1(CPR)}$ is not granger caused by **fp**	3	22.01 (0.000)	Reject null hypothesis*
MODEL 1B : $r_{1(TB3)}$ = f (m, g, i*, fp, $\dot{p}$)			
$r_{1(TB\ 3)}$ is not granger caused by **m**	3	7.666 (0.053)	Reject null hypothesis**
$r_{1(TB\ 3)}$ is not granger caused by **g**	3	9.012 (0.029)	Reject null hypothesis*
$r_{1(TB\ 3)}$ is not granger caused by **i***	3	7.356 (0.061)	Reject null hypothesis**
$r_{1(TB\ 3)}$ is not granger caused by **fp**	3	10.96 (0.012)	Reject null hypothesis*
MODEL 1C : $r_{1(TB12)}$ = f (m, g, i*, fp, $\dot{p}$)			
$r_{1(TB\ 12)}$ is not granger caused by **m**	3	14.50 (0.002)	Reject null hypothesis*
$r_{1(TB\ 12)}$ is not granger caused by **g**	3	10.39 (0.016)	Reject null hypothesis*
$r_{1(TB\ 12)}$ is not granger caused by **i***	3	10.09 (0.018)	Reject null hypothesis*
$r_{1(TB\ 12)}$ is not granger caused by **fp**	3	16.69 (0.001)	Reject null hypothesis*

Note : p –value in parenthesis. * and ** refer to conclusion at 5% and 10% level of significance.

Table 5

ARIMA Forecast Models : Tests for Model Selection

Variable name : $d\pi_2$

Model	***AR(1) AR(12) MA(12)***	***AR(12) MA(12)***	***AR(12) MA(1) MA(12)***	***AR(1) AR(12) MA(1) MA(12)***
Sum of sq. residuals	38.55	39.52	41.81	40.85
AIC	2.12	2.13	2.20	2.20
SBC	2.24	2.21	2.32	2.35
Ljung-Box - Q for residuals (sig. Level in parenthesis) Q(16), Q(24)	15.8 (0.25) 23.5 (0.31)	15.7 (0.32) 22.4 (0.43)	14.5 (0.33) 23.9 (0.29)	14.6 (0.26) 24.0 (0.24)
Breusch-Godfrey LM test – lags 2, 4 $N*R^2$ (p-value)	2.31 (0.31)	3.66 (0.15)	4.88 (0.08)	2.46 (0.29)
$N*R^2$ (p-value)	1.46 (0.22)	7.13 (0.12)	9.38 (0.05)	6.39 (0.17)
Theil U statistics	0.5190	0.5307	0.4946	0.4971

Note : The variable $d\pi_t$ is the first difference of the annual inflation series. We have taken the difference since the level series was non-stationary. The time-period for estimation is from Jan-85 to Mar-93. The Theil U-statistics to compare the forecast performance of different models are based on out of sample forecasts generated for the period Apr-93 to Mar-94.

Table 6

Unit Root Tests : (Apr 93 – May 2000)

TESTS ***VARIABLE***	**Null: γ=0 in equation 3** τ_τ	**Null: γ=0, θ=0, equation 3** ϕ_3	**Null: γ=0 in equation 2** τ_μ	**Null: γ=0, α=0 equation 2** ϕ_1	**Null: γ=0 in equation 1)** τ	***RESULTS*** ***(UNIT ROOT PRESENT)***
ADF Test $r_{2(CPR)}$	-2.43	2.96	-2.24	2.57	-1.48	YES*
PP – Test $r_{2(CPR)}$	-2.53	3.23	-2.33	2.79	-1.51	YES*
ADF Test $r_{2(TB3)}$	-2.39	2.85	-2.07	2.15	-1.67	YES**
PP – Test $r_{2(TB3)}$	-2.40	2.88	-2.06	2.14	-1.63	YES**
ADF Test $r_{2(TB12)}$	-2.09	2.20	-1.91	1.83	-1.28	YES*
PP – Test $r_{2(TB12)}$	-2.13	2.29	-1.93	1.88	-1.28	YES*
Critical Values						
10%	-3.13	5.34	-2.57	3.78	-1.62	
5%	-3.41	6.25	-2.86	4.59	-1.95	

Note : The variable r_2 is the real interest rate defined as $r = i - {}_2$ where i is the nominal interest rate and ${}_2$ is the forecasted annual inflation series generated with the help of ARIMA forecasts. The three different versions of r_2 are for the different interest rates as earlier i.e. commercial paper rate, and the three and twelve months treasury bill rates respectively. * and ** denote significance at 10% and 5% levels respectively.

Table 7A

ARIMA Forecast Models : Tests for Cointegration

λ_{max} Tests

H_0 :	H_1 :	*Statistics*	*Critical values* 95%	*Critical values* 90%	*RESULTS*
MODEL 2A : $\rho_{2(CPR)} = f(m, g, i^*, fp, \dot{\pi})$					
r = 0	**r = 1**	52.37	33.64	31.02	Reject Null Hypothesis
r ≤ 1	**r = 2**	16.24	27.42	24.99	Do not Reject Null Hypothesis
r ≤ 2	**r =3**	13.49	21.12	19.02	Do not Reject Null Hypothesis
MODEL 2B : $\rho_{2(TB3)} = f(m, g, i^*, fp, \dot{\pi})$					
r = 0	**r = 1**	48.78	33.64	31.02	Reject Null Hypothesis
r ≤ 1	**r = 2**	14.48	27.42	24.99	Do not Reject Null Hypothesis
r ≤ 2	**r =3**	11.97	21.12	19.02	Do not Reject Null Hypothesis
MODEL 2C : $\rho_{2(TB12)} = f(m, g, i^*, fp, \dot{\pi})$					
r = 0	**r = 1**	49.96	33.64	31.02	Reject Null Hypothesis
r ≤ 1	**r = 2**	13.20	27.42	24.99	Do not Reject Null Hypothesis
r ≤ 2	**r =3**	12.21	21.12	19.02	Do not Reject Null Hypothesis

Note: r is the order of cointegration. The critical values take in to account inclusion of the exogenous variables.

Table 7B

λ_{trace} Tests

H_0 :	H_1 :	*Statistics*	*Critical values* 95%	*Critical values* 90%	*RESULTS*
MODEL 2A : $\rho_{2(CPR)} = f(m, g, i^*, fp, \dot{\pi})$					
r = 0	**r > 0**	86.33	70.49	66.23	Reject Null Hypothesis
r ≤ 1	**r > 1**	33.96	48.88	45.70	Do not Reject Null Hypothesis
r ≤ 2	**r > 2**	17.71	31.54	28.78	Do not Reject Null Hypothesis
MODEL 2B : $\rho_{2(TB3)} = f(m, g, i^*, fp, \dot{\pi})$					
r = 0	**r > 0**	79.07	70.49	66.23	Reject Null Hypothesis
r ≤ 1	**r > 1**	30.28	48.88	45.70	Do not Reject Null Hypothesis
r ≤ 2	**r > 2**	15.80	31.54	28.78	Do not Reject Null Hypothesis
MODEL 2C : $\rho_{2(TB12)} = f(m, g, i^*, fp, \dot{\pi})$					
r = 0	**r > 0**	79.56	70.49	66.23	Reject Null Hypothesis
r ≤ 1	**r > 1**	29.59	48.88	45.70	Do not Reject Null Hypothesis
r ≤ 2	**r > 2**	16.39	31.54	28.78	Do not Reject Null Hypothesis

Note: r is the order of cointegration. The critical values take in to account inclusion of the exogenous variables.

Table 8

ARIMA Forecast Models : Tests for the Significance of Individual Coefficients

TESTS FOR SIGNIFICANCE	***2*** ***(calculated)*** ***p-value in parenthesis***	***Conclusion***
MODEL 1A : $r_{2(CPR)}$ = f (m, g, i*, fp, $\dot{p}$)		
m	18.93 (0.000)	Reject zero restriction
g	29.63 (0.000)	Reject zero restriction
i*	0.835 (0.361)	Do not reject zero restriction
fp	0.391 (0.532)	Do not reject zero restriction
MODEL 1B : $r_{2(TB3)}$ = f (m, g, i*, fp, $\dot{p}$)		
m	14.51 (0.000)	Reject zero restriction
g	28.45 (0.000)	Reject zero restriction
i*	0.465 (0.495)	Do not reject zero restriction
fp	0.217 (0.641)	Do not reject zero restriction
MODEL 1C : $r_{2(TB12)}$ = f (m, g, i*, fp, $\dot{p}$)		
m	16.35 (0.000)	Reject zero restriction
g	29.07 (0.000)	Reject zero restriction
i*	0.265 (0.607)	Do not reject zero restriction
fp	0.189 (0.664)	Do not reject zero restriction

Table 9

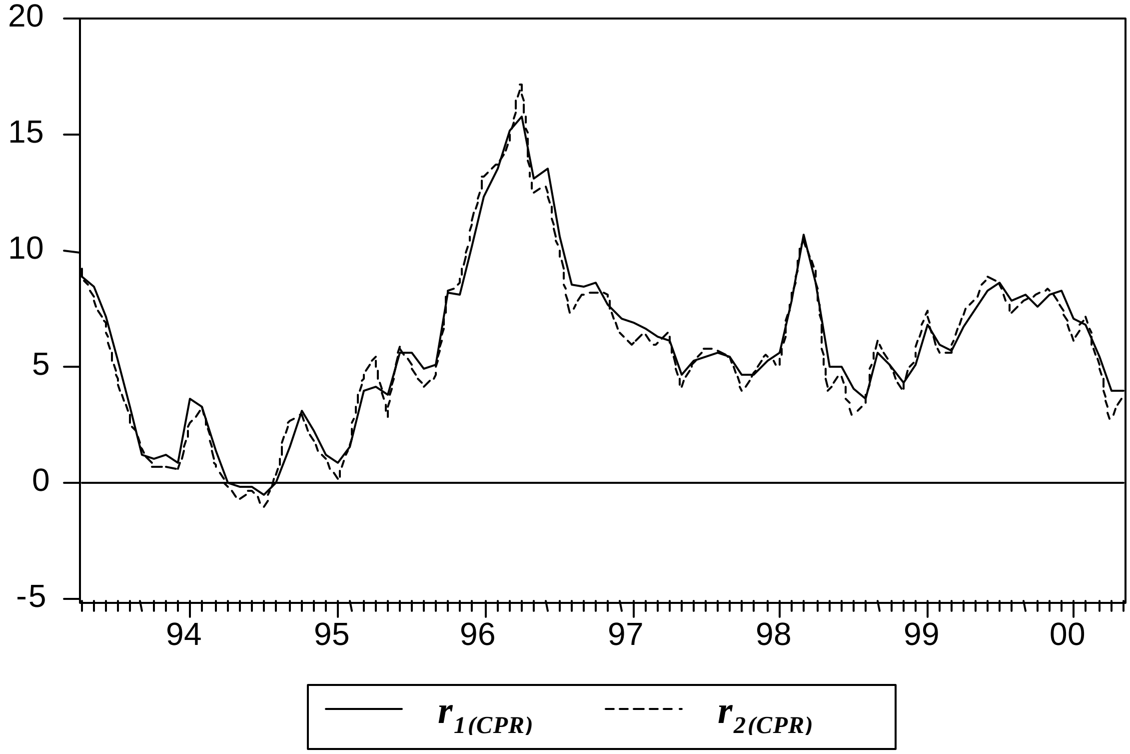
ARIMA Forecast Models : Granger Causality Tests

Null Hypothesis	*Number of Lags*	^{2} *(calculated)*	*Conclusion*
MODEL 1A : $r_{2(CPR)} = f\,(m, g, i^*, fp, \dot{p})$			
$r_{2(CPR)}$ is not granger caused by **m**	3	21.26 (0.000)	Reject null hypothesis*
$r_{2(CPR)}$ is not granger caused by **g**	3	25.43 (0.000)	Reject null hypothesis*
$r_{2(CPR)}$ is not granger caused by **i***	3	13.21 (0.004)	Reject null hypothesis*
$r_{2(CPR)}$ is not granger caused by **fp**	3	28.81 (0.000)	Reject null hypothesis*
MODEL 1B : $r_{2(TB3)} = f\,(m, g, i^*, fp, \dot{p})$			
$r_{2(TB\,3)}$ is not granger caused by **m**	3	7.974 (0.047)	Reject null hypothesis*
$r_{2(TB\,3)}$ is not granger caused by **g**	3	11.61 (0.009)	Reject null hypothesis*
$r_{2(TB\,3)}$ is not granger caused by **i***	3	7.781 (0.051)	Reject null hypothesis**
$r_{2(TB\,3)}$ is not granger caused by **fp**	3	12.06 (0.007)	Reject null hypothesis*
MODEL 1C : $r_{2(TB12)} = f\,(m, g, i^*, fp, \dot{p})$			
$r_{2(TB\,12)}$ is not granger caused by **m**	3	12.40 (0.006)	Reject null hypothesis*
$r_{2(TB\,12)}$ is not granger caused by **g**	3	13.45 (0.004)	Reject null hypothesis*
$r_{2(TB\,12)}$ is not granger caused by **i***	3	9.570 (0.023)	Reject null hypothesis*
$r_{2(TB\,12)}$ is not granger caused by **fp**	3	14.56 (0.002)	Reject null hypothesis*

Note : p –value in parenthesis. * and ** denote conclusion at significance level 5% and 10%.

Figure 1A

Real Interest Rate - CPR



Note : The variable r_1 is the real interest rate defined as $r = i-\pi_1$ where i is the nominal interest rate and assuming perfect foresight π_1 is the actual annual inflation rate derived from WPI. The variable r_2 is the real interest rate defined as $r = i-\pi_2$ where i is the nominal interest rate and π_2 is the forecasted annual inflation series generated from an ARIMA model.

Figure 1B

Real Interest Rate - TB3

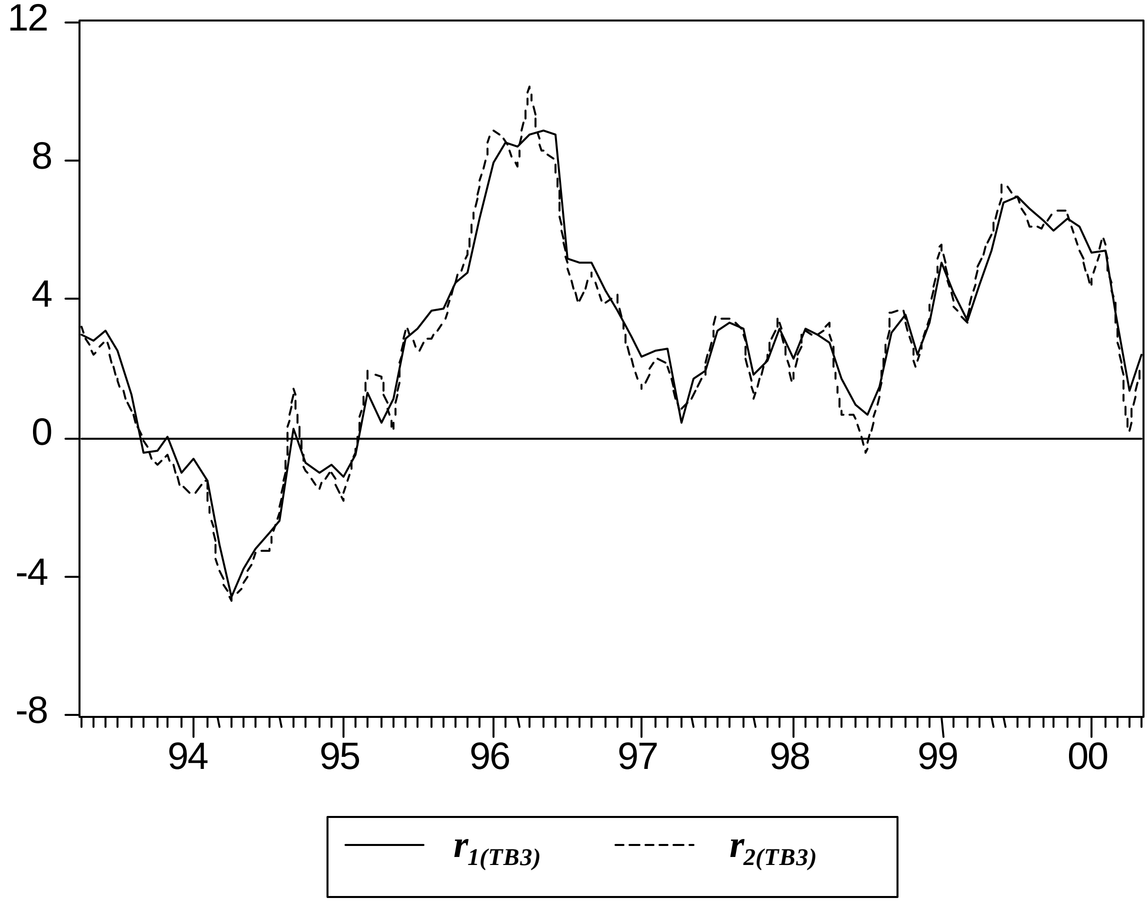


Figure 1C

Real Interest Rate -- TB12