Interest Rate Determination : An Error Correction Model

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Abstract

Integration of the domestic market for funds with foreign money markets is a natural corollary of financial sector liberalisation. For a transition economy like India, therefore, we assume interest rates to be a combination of an autarkic rate as in a closed economy and the uncovered interest parity rate as in a completely open economy. We capture both the long run and the short run dynamics of domestic interest rate behaviour by estimating an error correction model using the Engle-Granger methodology. Econometric analysis suggests that as the Indian financial sector integrates more and more with global markets, returns on foreign assets play a significant and increasing role in the determination of domestic interest rates.

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Contents

1.Introduction

The Indian economy witnessed a regime of complex administered interest rates till the early nineties, when interest rate policy was driven by considerations of promoting overall investment and channeling credit to identified priority sectors. The policy framework underwent a radical change with the initiation of economic reform in 1992, as a consequence of which the financial sector was gradually liberalised and domestic interest rates were substantially deregulated. In the course of the process of financial sector reform the focus has shifted from the impact of interest rate deregulation to the determination of interest rates in a deregulated economy. The factors influencing interest rates would obviously vary with the extent of openness of the economy. In the case of a completely closed economy, nominal interest rates would be determined solely by domestic monetary conditions. A study of interest rates in India for 1951-52 to 1985-86 (a period characterised by low or no interest rate deregulation) reveals that domestic factors like the rate of inflation, balance of payments, government market borrowings and budgetary deficits had a significant effect on interest rates (Bhole, 1988). In contrast, in countries with a completely open economy, some form of interest rate arbitrage would hold, with domestic interest rates depending on world interest rates, expected devaluation and some risk factors. In fact, for a highly open economy with dynamic and sophisticated financial markets, the uncovered interest parity theory states that the differential between the domestic and international interest rate equals the expected rate of depreciation of domestic currency. Domestic factors play an insignificant role in the determination of domestic rates (Edwards and Khan, 1985).

The increasing globalisation of the domestic markets has ensured that India can no longer be considered to be a closed economy. Although domestic monetary factors are found to be highly significant in explaining some domestic market rates (Bhole and Sebastian, 1996), exchange rates seem to play an important role in determining some other interest rates (Trivedi, 1998). In view of India’s status as an economy in transition, some studies have followed the Edwards and Khan methodology (notably Rao and Singh, 1995) to determine interest rates as a function of both closed and open economy factors. Proceeding on similar lines, we attempt to measure interest rates as a weighted average of the autarkic rate as in a completely closed economy and the uncovered interest parity rate as in a completely open economy.

1.1 The closed economy case

It is assumed here that there is no inflow or outflow of capital, or the economy is closed. The demand for money is demand for real money. Money is held to finance transactions and therefore demand for money increases with real output. Holding money has an opportunity cost measured by the nominal rate of interest. Higher interest rates discourage the holding of wealth in the form of money.

If M is assumed to be the nominal stock of money and P is the price level, real money demand is defined as M/P, which is a function of the interest rate, i and the output, Y. Short run equilibrium in the money market exists when the demand for money is equal to the supply of money. Assuming the elasticity of money demand with respect to income is constant, we specify a log-linear form of the money demand function in any period t as

$$\ln M_t^d = \ln\left(\frac{M_t}{P_t}\right) = \alpha_0 + \alpha_1 \ln Y_t - \alpha_2 i_t \tag{1}$$

If in equilibrium the demand for real money is equal to the supply of money which is assumed to be policy determined and therefore exogenous

$$M_t^s = \frac{M_t}{P^t} \quad \textit{(Exogenous)} \tag{2}$$

$$M_t^s = M_t^d \tag{3}$$

Or, $\leftrightarrow \quad \ln \frac{M_t}{P^t} = \alpha_0 + \alpha_1 \ln Y_t - \alpha_2 i_t$ (4)

In the closed economy case equilibrium in the money market exists when

$$\ln \frac{M_t}{P^t} = \alpha_0 + \alpha_1 \ln Y_t - \alpha_2 i_t \tag{5}$$

or, $i_t = \frac{\alpha_0}{\alpha_2} + \frac{\alpha_1}{\alpha_2} \ln Y_t - \frac{1}{\alpha_2} \ln \frac{M_t}{P_t}$ (6)

1.2 The open economy case

If an economy is completely open to the rest of the world, domestic and foreign interest rates will be closely linked and the following uncovered interest rate arbitrage condition will hold:

$$i_t = i_t^* + \dot{e}_t^e \qquad (7)$$

where

i_t^* = world interest rate for a financial asset with the same characteristics as the domestic instrument and

$\dot{e}_t^e$ = expected rate of change of exchange rate

1.3 The general case

If it is assumed that the degree of openness can be measured by Ψ, we can combine the closed and open economy extremes by assuming that the nominal interest rate is a weighted average of the two cases. Therefore, in the mixed case

$$i_t = (1 - \psi)\left[\frac{\alpha_0}{\alpha_2} + \frac{\alpha_1}{\alpha_2}\ln Y_t - \frac{1}{\alpha_2}\ln\frac{M_t}{P_t}\right] + \psi(i_t^* + \dot{e}_t^e)$$

which leads us to a reduced form equation for nominal interest rate in a semi-open economy:

$$i_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln\frac{M_t}{P_t} + \beta_3(i_t^* + \dot{e}_t^e) + \varepsilon_t \qquad (8)$$

where

$$\beta_0 = (1 - \psi)\frac{\alpha_0}{\alpha_2}$$

$$\beta_1 = (1 - \psi)\frac{\alpha_1}{\alpha_2}$$

$$\beta_2 = -(1 - \psi)\frac{1}{\alpha_2}$$

$$\beta_3 = \psi$$

Equation (8) defines the long run relationship between interest rate, output, real money supply and the domestic equivalent of foreign returns.

2. Error correction model

To capture both the long run and the short run dynamics of interest rate behaviour we estimate an error correction model (ECM) using the Engle-Granger methodology. A brief discussion of the methodology follows.

2.1 The Engle-Granger Methodology

If two time series y_t and x_t are both integrated of order d (i.e. I(d)), then, in general, any linear combination of the two series will also be I(d); that is, the residuals obtained on regressing y_t on x_t are I(d). If, however, there exists a vector β, such that the disturbance term from the regression ($\varepsilon_t = y_t - \beta x_t$)is of a lower order of integration I(d-b), where b>0, then Engle and Granger (1987) define y_t and x_t as cointegrated of order (d,b).

The economic interpretation of cointegration is that if two or more series are linked to form an equilibrium relationship spanning the long run, then even though the series themselves may be non-stationary, they will move closely together over time and their difference will be stationary. Their long run relationship is the equilibrium to which the system converges over time, and the disturbance term ε_t can be interpreted as the disequilibrium error or the distance that the system is away from equilibrium at time t.

In order to estimate the long run relationship between y_t and x_t it is necessary to estimate the static model:

$$y_t = \beta x_t + \varepsilon_t \qquad (9)$$

Although the equilibrium long run relationship can be estimated directly using (9), it is also important to consider the short run dynamics of the variables under consideration, since the system may not always be in equilibrium. A simple dynamic model of short run adjustment can be written as:

$$y_t = \alpha_0 + \gamma_0 x_t + + \gamma_1 x_{t-1} + \alpha_1 y_{t-1} + u_t \qquad (10)$$

Reparameterising and rearranging (11) gives the error correction formulation (ECM):

$$\Delta y_t = \gamma_0 \Delta x_t - (1 - \alpha_1)\, [y_{t-1} - \beta_0 - \beta_1 x_{t-1}] + u_t \qquad (11)$$

where β_0 and β_1 are coefficients estimated from equation (9).

The ECM incorporates both short run and long run effects. When equilibrium holds, $[y_{t-1} - \beta_0 - \beta_1 x_{t-1}] = 0$. But in the short run, when disequilibrium exists, this term is non-zero and measures the distance that the system is away from equilibrium during time t. Thus $(1- \alpha_1)$ provides an estimate of the speed of adjustment of the variable y_t. For instance, if $[y_{t-1} - \beta_0 - \beta_1 x_{t-1}] < 0$, that is, y_{t-1} has moved below its equilibrium level, since $-(1- \alpha_1)$ is negative, it will boost Δy_t, thereby forcing it back to its long run path.

Engle and Granger show that two or more variables are cointegrated of order I(1,1) if and only if an ECM exists.

The first stage in the Engle-Granger framework is to test whether the variables are cointegrated. This is accomplished by testing the residuals of equation (9) for stationarity. That is, the null hypothesis of ε_t being I(1) is tested against the alternate of it being I(0). Although any unit root test can be used, Engle and Granger advocated the use of Augmented Dickey Fuller tests on the residuals.

The second stage of the EG procedure comprises of estimating the short run ECM itself from the residuals of the regression of the first stage. That is, having obtained $\varepsilon_{t-1} = y_{t-1} - \beta x_{t-1}$, we estimate equation (11) to determine the dynamic structure of the system.

We expect that there is a long-run relationship between money supply, economic activity, domestic interest rates and foreign interest rates. We therefore test for the existence of a cointegrating relationship. This is done using the above ECM methodology. In the first step we estimate the coefficients by OLS and test for the existence of a unit root in the residuals. The analysis is also supplemented by testing for the number of cointegrating relationships using the Johansen procedure.

The deviations from the long run path are captured at the second stage. When the coefficients of the lagged residual term from the first stage is negative, it suggests that the system comes back to the long run path or adjusts. Therefore, there exists an error correction mechanism.

2.2 Results

The model was estimated using monthly data for the period January 1993 to November 1997. Output was proxied by the Index of Industrial Production since monthly GDP data is not available. Real money supply was measured by M3 deflated by the wholesale price index (for all commodities). Domestic equivalent of foreign returns is measured as the sum of returns on foreign assets and expected depreciation in the exchange rate. The return on foreign assets is measured by the LIBOR, and the expected depreciation by the forward premium. The domestic interest rate is measured by the 364 day secondary market treasury bill rate. The series were found to be non-stationary. The results for the stationarity tests are presented in Table 1 (a).

Table 1(a)

Test Statistics	**Tb364**	**I**	**Call**	**CP**	**Liip**	**Lrm3**	**Lrm1**	**Ifee**
Dickey-Fuller	-2.6	-1.3	-1.8	-1.6	-1.4	-1.3	-2.4	-1.3
Wtd.Symmetric	-1.5	-1.3	-2.3	-1.7	-2.3	-1.9	-1.5	-1.7

Johansen tests revealed the existence of exactly one cointegrating relationship between the 364-day treasury bill rate, IIP, real money supply and expected return on foreign assets (Table 1(b)).

Table 1(b) Johansen Maximum Likelihood Procedure

Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix
56 observations from 1993M4 to 1997M11. Maximum lag in VAR = 3.

List of variables included in the cointegrating vector:
TB364 LIIP LRM3 IFEE Intercept

List of eigenvalues in descending order:
.46670 .31931 .12488 .034953 .0000

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r = 1	35.2061	28.1380	25.5590
r<= 1	r = 2	21.5399	22.0020	19.7660
r<= 2	r = 3	7.4703	15.6720	13.7520
r<= 3	r = 4	1.9924	9.2430	7.5250

Cointegration LR Test Based on Trace of the Stochastic Matrix
56 observations from 1993M4 to 1997M11. Maximum lag in VAR = 3.

List of variables included in the cointegrating vector:
TB364 LIIP LRM3 IFEE Intercept

List of eigenvalues in descending order:
.46670 .31931 .12488 .034953 .0000

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r>= 1	66.2087	53.1160	49.6480
r<= 1	r>= 2	31.0027	34.9100	32.0030
r<= 2	r>= 3	9.4627	19.9640	17.8520
r<= 3	r = 4	1.9924	9.2430	7.5250

The estimation of the long run cointegrating relationship, or step 1 of the Engle-Granger procedure reveals that real money supply has the expected impact and thus a negative sign, while output and foreign returns have the expected positive signs. All coefficients are found to be significant at the 5 % level of significance.

The second step of the Engle-Granger procedure suggests the existence of an error correction mechanism as the coefficient of the lagged residual term is negative. A negative coefficient is to be expected if there exists a cointegrating relationship between the variables (Engle-Granger Theorem). The coefficient of foreign returns again has the expected positive impact on domestic interest rates. This impact is small but significant at 5% level of significance. The results are summarised in Tables 2 and 3.

STEP 1

$$\underset{}{Tb364} = 91.45 + \underset{(3.33)}{13.51\, Liip} - \underset{(-4.41)}{21.26\, Lrm3} + \underset{(5.22)}{.13\, Ifee} + \varepsilon_t$$

STEP 2

$$\Delta Tb364 = \underset{(2.48)}{.06\, \Delta Ifee} - \underset{(-2.61)}{0.25\, \varepsilon_{t-1}}$$

where Tb364 = Secondary market rate on the 364-day treasury bill

Liip = Log of the Index of Industrial Production (General)

Lrm3 = Log of real money supply

Ifee = Expected foreign return: LIBOR plus Rs/$ forward premium

ΔIfee = Ifee – Ifee(-1)

ΔTb364= Tb364 – Tb364(-1)

The ECM was re-estimated using the 91-day treasury bill rate for secondary markets, the call money rate and the commercial paper rate as the domestic interest rate. The results were broadly similar to the results for the 364-day treasury bill rate (see Tables 3 and 4).

Table 2

Stage I : Engle-Granger Procedure

Method of Estimation: Ordinary Least Squares Sample: Jan 93 to Nov 97

Equation	Dependent Variable	Constant	Liip	Lrm3	Lrm1	IFEE	R-squared	DW
1.	Tb364	91.45 (6.19)	13.51 (3.33)	-21.26 (-4.41)	-	0.13 (5.22)	0.68	1.07
2.	I	49.04 (3.60)	-	-	-6.73 (-3.13)	0.29 (7.82)	0.53	.53
3.	Call	89.67 (2.54)	-	-	-13.91 (-2.5)	0.79 (8.10)	0.54	1.09
4.	CP	57.42 (4.20)	-	-6.56 (-3.56)	-	0.43 (13.44)	0.77	0.93

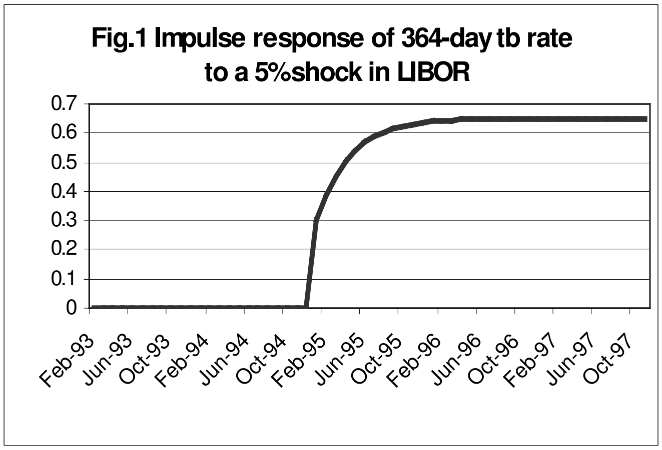
Table 3

Stage II : Engle-Granger Procedure

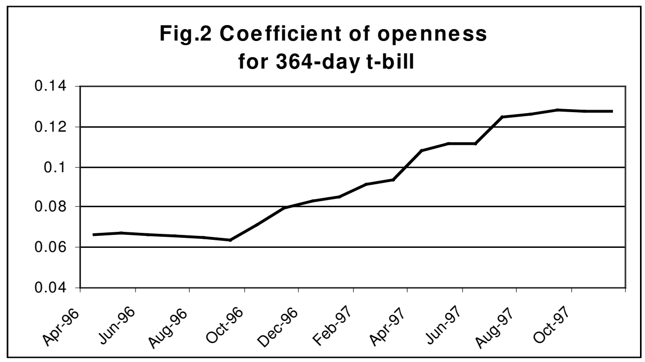
Method of Estimation: Ordinary Least Squares Sample: Feb 93 to Nov 97

Equation	**Dependent Variable**	**Difee**	**Dlscb**	**Res1(-1)**	**R-squared**	**DW**
1.	D364	0.06 (2.48)	-	-.25 (-2.61)	0.17	2.06
2.	Di	0.12 (-2.07)	-9.13 (-2.33)	-0.16 (-2.07)	0.23	2.13
3.	Dcall	1.19 (8.15)	-	-0.59 (-5.24)	0.60	2.30
4.	Dcp	0.15 (3.58)	-	-0.34 (-3.87)	0.30	1.66

D364	tb364 – tb364(-1) = Δtb364
Dcall	call – call(-1)
Dcp	cp – cp(-1)
Di	i – i(-1)
Difee	ifee – ifee(-1)
Dlscb	lscb – lscb(-1)
Res1(-1)	lagged value of residual obtained from corresponding equation of Stage I for each variable



A simulation exercise was undertaken to analyse the response of the domestic interest rate to a 5% positive shock to LIBOR. This provides an estimate of the speed of adjustment of the interest rate to equilibrium. It was observed that domestic interest rates take about 15 months to adjust to the shock (Fig 1).



In order to estimate the change in the parameter of openness as the economy liberalizes we estimate ψ as a time varying parameter. This is done by estimating the equation recursively for the period April 1996 to November 1997. For a recursive estimation the sample first chosen was January 93 to April 96 and then the sample was increased by one month and the model re-estimated. This was done over and over again. The coefficient of the return on foreign capital estimated "recursively" is then plotted. The estimate of the coefficient of openness shows an increasing trend (Figure 2), indicating an increasing level of integration of domestic interest rates with foreign returns.

3. Conclusion

The integration of the domestic market for funds with foreign money markets would be a natural outcome of financial sector liberalisation. Evidence shows that such integration is observed for short-term interest rates in the Indian money market in the post reform period.

An attempt to identify the factors determining interest rates in India led to the establishment of a co-integrating relationship between interest rates, real money supply, output and expected return by foreign investors. Although the relatively short sample period and the specification of the scale variable in terms of the index of industrial production limit the modelling exercise, the results clearly point to the emerging dynamics of interest rate determination. The error-correction model suggests that money supply and industrial output are no longer the sole determinants of interest rates as in a completely closed economy. In addition to these variables, returns on foreign assets play a significant role in the determination of domestic interest rates both in the short-run and the long-run periods. Further, the parameter of openness (as measured by the coefficient of the expected foreign return variable in the co-integrating regression) has increased significantly in the period April 96- November 97. Rising foreign portfolio inflows, greater exposure to Indian markets by foreign institutions and funds and sustained rise in foreign direct investment account for the stronger linkages observed between domestic and foreign interest rates. India is far from being a completely open economy, but the influence of global financial markets in determining domestic financial variables is a significant indication of the increasing globalisation of its financial sector.

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Appendix 1

Data sources

The data for this paper was collected for the period from January 1993 to November 1997. The following section lists the variables used in the paper along with their sources.

Broad money (lrm3)

Log of deseasonalized M3 deflated by the WPI

Source: M3: RBI monthly bulletin, various issues

WPI: Index numbers of Wholesale Prices in India, Ministry of Industry

Narrow money (lrm1)

Log of deseasonalized M1.

Source: RBI monthly bulletin, varoious issues

Bank lending to Government (lscb)

Log of deseasonalized net scheduled bank lending to the government

Source: RBI monthly bulletin, various issues

Prices (Inf)

Inflation estimated as the month-on-month change in the average Wholesale Price Index.

Source: Index numbers of Wholesale Prices in India, Ministry of Industry

Industrial Production (liip)

Log of deseasonalized index of industrial production (general).

Source: Central Statistical Organisation

Expected foreign return (ifee)

Minimum return expected by foreign investors is defined as the sum of return on foreign assets and expected depreciation in the exchange rate. The return on foreign assets is proxied by the dollar LIBOR and expected depreciation by the 3-month forward premium.

Source: LIBOR sourced from International Financial Statistics, IMF and forward premium from RBI annual report, various issues

Interest rates

i 91-day treasury bill secondary market rate

Source: Discount and Finance House of India weekly bulletins

tb364 364-day treasury bill secondary market rate

Source: Discount and Finance House of India weekly bulletins

call Call money rate

Source: RBI Weekly Statistical Supplement, various issues