CHAPTER 10

GRANGER CAUSALITY TEST BETWEEN RUPEE/DOLLAR EXCHANGE RATE AND MONEY SUPPLY - Study With A Restricted VAR Model

10.1 Introduction

Period after 1970 is marked by the growth of plethora of theories on the determination of exchange rate. Many of these theories stress upon a causal link between the change in the money supply and the change in the exchange rate. It, therefore, becomes pertinent to examine if money supply has been an important factor behind the exchange rate variation in India. More specifically, it is important to examine if variation in exchange rate has been caused by variation in money supply. This is the issue of our study in this chapter.

The estimated **Unrestricted VAR** model in chapter 7 gives a hint about the direction and nature of causality between variables concerned. However, in the VAR model the specification of lags structures for both the variables is required to be uniform. Consequently, the model is **'over parameterized'**. Such an ***'Unrestricted VAR Model'***, therefore, appears to be less informative about the causality between variables. In such case ***'Restricted VAR Model'*** may be of great help. A variant of such ***'Restricted VAR Model'*** is used in ***'Granger Causality Approach'***. We seek, therefore, to study the causality between exchange rate and money supply in this chapter through ***'Granger Causality'*** Method with a **Restricted VAR Model**. The model is presented below.

10.2 The Model

Following *'Granger Causality'* test procedure, we have formulated the following **Restricted VAR** model. It may be noted that the dataset is quarterly in nature. So the infinite lag structure has been discarded in favor of the finite lag structure. Consequently, the model is:

$$E_t = \alpha + \beta E_{t-1} + \gamma_1 M_{t-1} + \gamma_2 M_{t-2} + \gamma_3 M_{t-3} + \gamma_4 M_{t-4} + \vartheta_t \qquad (10.1)$$

$$M_t = \varphi + \mu M_{t-1} + \theta_1 E_{t-1} + \theta_2 E_{t-2} + \theta_3 E_{t-3} + \theta_4 E_{t-4} + \omega_t \qquad (10.2)$$

where, E_t is the Rupee/Dollar exchange rate in period t

E_{t-1} is the Rupee/Dollar exchange rate in period t-1

M_t is the money supply of India in period t

M_{t-j} is the money supply of India at period t-j, j = 1,2,3,4

E_{t-j} is the Rupee/Dollar exchange rate of India at period t-j, j = 1,2,3,4

$\vartheta_t \sim$ i i d N $(0, \sigma_u^2)$ and $\omega_t \sim$ i i d N $(0, \sigma_\omega^2)$

10.3 Estimation and Result

The estimated equation (10.1) is presented below

Table 10.1
Results of Estimated Equation 10.1
Dependent Variable E_t
Sample (adjusted): 1976(II) - 2006(IV)
Included observations: 123 (after adjusting endpoints)

Variable	Coefficient	SE	t-statistic	Prob.
Constant	**0.258**	**0.101**	**2.549**	**0.01**
E_{t-1}	**0.196**	**0.093**	**2.107**	**0.03**
M_{t-1}	0.026	0.076	0.344	0.73
M_{t-2}	**0.173**	**0.068**	**2.544**	**0.01**
M_{t-3}	**-0.263**	**0.077**	**-3.414**	**0.00**
M_{t-4}	0.024	0.094	0.258	0.79
$R^2 = 0.137$, Adjusted $R^2 = 0.104$, AIC = 2.507, SC = 2.644, F-statistic = 3.728, DW = 2.04				

10.4 Findings From the Table (10.1)

It is observed from the estimated equation (10.1) that

(i) $\hat{\beta}$ is statistically significant at 5% level.

(ii) $\hat{\beta} = 0.196 < 1$ and the system is stable.

(iii) $\sum_{i=1}^{4} \hat{\gamma}_{t-j} < 1$. So the distributive lag structure is consistent.

(iv) D.W. = 2.04 indicates that the equation is free from autocorrelation.

(v) $\hat{\gamma}_2$ and $\hat{\gamma}_3$, the coefficient of M_{t-2} and M_{t-3} respectively are statistically significant at 1 % level.

(vi) All other coefficients such as $\hat{\gamma}_1$ and $\hat{\gamma}_4$ are insignificant even at 10% level.

However, in view of the results of estimation, the Equation 10.1 may be modified through the exclusion of variables the coefficient of which are found to be statistically insignificant. The modified equation is:

$$E_t = \eta + \lambda E_{t-1} + \hat{\pi}_1 M_{t-2} + \hat{\pi}_2 M_{t-3} + v_t \qquad (10.3)$$

The estimable equation (10.3) is expected to provide better estimation in view of the gain in degrees of freedom resulting from exclusion of insignificant variables from equation (10.1).

10.5 Results of Estimation of the Modified Estimation (10.2)

This equation (10.3) is estimated and results are being presented through the Table 10.2

Table 10.2
Results of Estimated Equation 10.3
Dependent Variable: E_t
Sample (adjusted): 1976(I) - 2006(IV)
Included observations: 124(after adjusting endpoints)

Variable	Coefficient	S.E.	t-Statistic	Prob.
C	0.265	0.093	2.85	0.00
E_{t-1}	0.168	0.087	1.923	0.05
M_{t-2}	0.182	0.067	2.711	0.00
M_{t-3}	-0.240	0.069	-3.477	0.00
$R^2 = 0.128$, Adjusted $R^2 = 0.106$ AIC = 2.49, SC = 2.58, F-statistic = 5.907, DW = 1.976				

10.6 Findings of the Modified Estimation (Equation 10.3)

It is observed from the estimated Equation 10.2, shown in the Table 10.2 that

(i) $\hat{\lambda}$, the coefficient of E_{t-1} is significant at 5% level.

(ii) $\hat{\lambda}$ is positive and less than one $(0 < \lambda < 1)$.

(iii) $\hat{\pi}_1$ and $\hat{\pi}_2$, the coefficient of M_{t-2} and M_{t-3} respectively are significant even at 1% level.

(iv) $\hat{\pi}_1$ is positive and less than unity, $\hat{\pi}_2$ is negative and $\left|\hat{\pi}_2\right| < 1$.

(v) $\sum_{i=1}^{2} \hat{\pi}_i < 1$.

(vi) DW = 1.976 means that the model is free from autocorrelation.

10.7 Economic Interpretations of Findings in Section 10.7

Economic implications of these findings are as follows

(i) *Positive and significant* $\hat{\lambda}$, *the coefficient of* E_{t-1} *implies a rise in Rupee/Dollar exchange rate following a rise in Rupee/Dollar exchange rate in the previous period (quarter). This feature of exchange rate indicates continuous depreciation of Indian Rupee against US Dollar which occurred over the period of study.*

(ii) *Significant* $\hat{\pi}_1$ *and* $\hat{\pi}_2$ *indicate that* M_1 *money supply of India in two and three quarter back affected the current Rupee/Dollar exchange rate significantly even in the presence of lagged exchange rate in the vector of regressors. It, therefore, appears that, in Indian economy,* ***variations of Rupee/Dollar exchange rate were Granger caused by variations in money supply over the period concerned.***

(iii) *Moreover,* $\hat{\pi}_1 = 0.182$ *implies that variation in the current exchange rate is positively related to the variation of money supply in the previous quarter. Any rise in money supply causes a rise in Rupee/Dollar exchange rate. In other words, rise in the money supply leads to depreciation of exchange rate (i.e., rise in Rupee/Dollar Exchange rate).* ***This finding supports the main proposition of the Dornbush model of exchange rate determination (1976) and the monetary model of exchange rate determination etc.***

(iv) $\hat{\pi}_1 = 0.18$, $\hat{\pi}_2 = -0.24$ *indicate that the exchange rate underwent appreciation after initial depreciation. This feature of exchange rate variation is known as* ***'Overshooting'*** *of exchange rate. It, therefore, appears that* ***the process of dynamic adjustment of Rupee/Dollar exchange rate follows 'Overshooting' phenomenon in respect of monetary shock.***

10.8 Tests for Reverse Causation

We have observed that Indian money supply *Granger caused* Rupee/Dollar exchange rate variation. It does neither confirm nor neglect the possibility that the variation in money supply was caused by variation in exchange rate. This is possible if money supply was *'activist'* with respect to exchange rate variation. So there exists a possibility of reverse causation. We seek to address this issue henceforth. With this end in view, we perform the Granger Causality Test with money supply as the dependent variable as given in equation (10.2).

10.9 The Model

The model used for the study of reverse causation is presented below through the equation (10.2).

$$M_t = \varphi + \mu M_{t-1} + \theta_1 E_{t-1} + \theta_2 E_{t-2} + \theta_3 E_{t-3} + \theta_4 E_{t-4} + \omega_t \qquad (10.2)$$

where, M_t = money supply in period t

M_{t-1} = money supply in period t-1

E_t = exchange rate in period t

E_{t-j} = Rupee/Dollar exchange rate in period t-j, j = 1, 2, 3, 4.

and $\omega_t \sim \text{iidN}(0, \sigma_\omega^2)$

10.10 Estimation and Results

The model (10.2) has been estimated with differenced data set for variables concerned over the period of the study. The results of estimation are being given by the Table 10.2.

Table 10.3
Results of Estimated Equation 10.2
Dependent Variable: M_t
Sample (adjusted): 1976(II) – 2006(IV)
Included observations: 123 after adjusting endpoints

Variable	Coefficient	S.E.	t-statistic	Prob.
c	**0.503**	**0.146**	**3.426**	**0.00**
M_{t-1}	**0.313**	**0.096**	**3.248**	**0.00**
E_{t-1}	**0.219**	**0.132**	**1.651**	**0.10**
E_{t-2}	0.023	0.129	0.180	0.85
E_{t-3}	**-0.277**	**0.129**	**-2.146**	**0.03**
E_{t-4}	-0.016	0.130	-0.125	0.90
$R^2 = 0.11$, Adjusted $R^2 = 0.08$, AIC = 3.25, SC = 3. 92 F-statistic = 3.82, DW = 2.07				

10.11 Findings

It is observed from the estimated equation (10.3) that

(i) $\hat{\mu} = 0.459 < 1$ and the system is stable.

(ii) $\sum_{i=1}^{4} \hat{\theta}_j < 1$. So the lag structure is consistent.

(iii) D.W. = 2.07 indicates that the system is free from autocorrelation.

(iv) $\hat{\mu}$, the coefficient of M_{t-1}, is significant even at 1% level.

(v) $\hat{\theta}_1$ and $\hat{\theta}_3$, the coefficients of E_{t-2} and E_{t-2} are significant at 10% and 5% level respectively.

However, in view of the results of estimation, the equation (10.2) may be modified through the exclusion of variables, the coefficient of which are found to be statistically insignificant. The modified equation is

$$M_t = \kappa + \psi M_{t-1} + \phi_1 E_{t-1} + \phi_3 E_{t-3} + \tau \qquad (10.4)$$

10.12 Results of the Modified Estimation

This modified equation is estimated by using the stationary dataset for the variables concerned and the results are being presented below.

Table 10.4
Results of Estimated Equation 10.4
Dependent Variable M_t
Sample (adjusted): 1976(I) – 2006(IV)
Included observations: 124 (after adjusting endpoints)

Variable	Coefficient	SE	t-Statistic	Prob.
C	0.498	0.137	3.631	0.00
M_{t-1}	0.317	0.093	3.387	0.00
E_{t-1}	0.219	0.129	1.691	0.09
E_{t-3}	-0.277	0.125	-2.218	0.02
$R^2 = 0.12$, Adjusted $R^2 = 0.09$, AIC = 3.21, SC = 3.30, F-statistic = 5.45, DW = 2.07				

10.13 Economic Interpretations

It is observed from the Table 10.4 that

(i) M_t was a function of M_{t-1} since $\hat{\psi}$ is significant. It indicates that M_t, in its univariate structure represented an AR(1) process.

(ii) $\hat{\psi} > 0$ indicates that current money supply was positively related to the money supply of the previous period. A rise in money supply in the previous period was followed by a rise in the current money supply. Consequently, money supply in the next period registered rise. Thus the overall money supply seem to display a nature which failed to conform to Friedman's K% point rule. The univariate probability structure underlying the distribution process for money supply, therefore, indicated an underlying inclination for maintaining a stable mean value over the period concerned.

(iii) significant coefficients $\hat{\phi}_1$ and $\hat{\phi}_3$ essentially indicate that two period and three period lagged exchange rates affected current money supply significantly even in the presence of lagged money supply in the vector of regressors. Thus **exchange rate '*Granger caused*' money supply over the period concerned.**

(iv) $\hat{\phi}_3 < 0$ deserves further explanation. It may be noted that E_t essentially represents *'spot exchange rate'* (the rupee price of one unit of dollar). So a rise in exchange rate indicates depreciation of Indian rupee against dollar. Now, $\hat{\phi}_3 < 0$ indicates that money supply declined following three quartet back depreciation of rupee. This is indicative of the *'Activists'* nature of the monetary policy in Indian economy. Since $\hat{\phi}_3 < 0$, it further seems to indicate that monetary policy was *'counteracting'* with respect to exchange rate variation.

(v) $\phi_1 + \phi_3 = -0.058$. Consequently, the variations in money supply in t-1 and t-3 periods led to only 0.06% decline in money supplies. This is very insignificant

by any standard and it indicates that, ***though money supply appeared to 'Granger Cause' exchange rate, the strength of the causal effect was very insignificant.***

10.14 Overview of Findings in Sections 10.8 – 10.14

It is observed from our study in sections 10.8 – 10.14 that over the period of study

(i) *exchange rate was **'Granger Caused'** by money supply.*

(ii) *money supply was also **'Granger Caused'** by exchange rates. However, the strength of such causal effect was very insignificant.*

(iii) *there did exist, therefore, **'Bi-directional Causality'** between exchange rate and money supply.*

This finding of *'Bi-directional Causality'* is in striking contrast with the finding of *'Uni-directional causality'* running from money supply to exchange rate in our study with the **Unrestricted VAR Model** in Chapter 7. We, therefore, seek to enquire further into the nature and direction of causality through ***'Spectral Analysis'*** in the next chapter. The ***'Frequency Domain'*** study is expected to supplant and supplement the ***'Time Domain'*** study.
