CHAPTER SEVEN

COINTEGRATION, VECTOR ERROR CORRECTION MODELING AND GRANGER CAUSALITY

7.1 Introduction

This chapter endeavors the relationship between narrow money supply and price level, and broad money supply and price level during the study period from $1976Q_1$ to $2012Q_2$ through Johansen's Cointegration test, Vector Error Correction Modeling (VECM) and Granger Causality test. First, we analyze the relationship between money supply (both M_1 and M_2) and price level employing the Johansen's Cointegration test. If variables under study are found to be cointegrated, we can use VECM to examine the relationship between money supply and price level. After developing VECM, we apply the stability and diagnostic test to examine the robustness of the VECM. And, this chapter ends with the verification of relationship between the variables through Granger Causality test.

7.2 Selection of Suitable Lags

Before employing the Johansen's Cointegration test, it is necessary to select suitable lags to be used for the endogenous variable in regression. There are various criteria for selecting the lag length. Table 7.1 reveals the selection of lag length through VAR technique.

From Table-7.1 it is observed that Schwarz and Hannan-Quinn statistics are significant at lag 5 and LR, FPE and Akaike information statistics are significant at lag 9. Lag 9 is very high lag to use in regression for analyzing the relationship between two endogenous variables. Lag 5 under SC and HQ is somewhat suitable as compared to lag 9. So, we use lag 5 as the suitable lag for each endogenous variable in regression of cointegration and VECM narrow money supply and price level.

Table-7.1: VAR Lag Order Selection Criteria

Endogenous variables: $LnCPI_t$ & LnM_{1t} Exogenous variable: constant

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-37.2880	NA	0.006334	0.6138	0.6584	0.6319
1	541.9674	1131.358	7.91e-07	-8.3744	-8.2408	-8.3201
2	548.2865	12.14455	7.63e-07	-8.4107	-8.1879	-8.3201
3	587.4708	74.08278	4.40e-07	-8.9604	-8.6485	-8.8337
4	604.0081	30.74902	3.62e-07	-9.1563	-8.7553	-8.9934
5	637.6478	61.49757	2.28e-07	-9.6194	-9.1293*	-9.4203*
6	640.2768	4.723981	2.33e-07	-9.5980	-9.0187	-9.3626
7	641.0406	1.348537	2.45e-07	-9.5475	-8.8790	-9.2759
8	648.5259	12.98244	2.32e-07	-9.6019	-8.8443	-9.2941
9	661.9428	22.85054*	2.01e-07*	-9.7491*	-8.9024	-9.4050
10	664.3007	3.942221	2.06e-07	-9.7234	-8.7876	-9.3432
11	667.2347	4.813567	2.10e-07	-9.7067	-8.6818	-9.2903
12	670.5016	5.257646	2.13e-07	-9.6953	-8.5812	-9.2426
13	674.2848	5.970366	2.15e-07	-9.6919	-8.4887	-9.2030
14	674.8269	0.838576	2.27e-07	-9.6379	-8.3455	-9.1128
15	676.3154	2.255934	2.37e-07	-9.5986	-8.2172	-9.0373
16	679.2294	4.325580	2.42e-07	-9.5817	-8.1111	-8.9842
17	682.4068	4.617140	2.46e-07	-9.5688	-8.0091	-8.9351
18	685.3474	4.181069	2.52e-07	-9.5523	-7.9034	-8.8823

*[26]

7.3 Johansen's Cointegration Test between $LnCPI_t$ and LnM_{1t}

The Johansen method of cointegration is based on Maximum-Eigen and Trace statistic value. The following results have been revealed between $LnCPI$ and LnM_{1t} for Johansen approach.

*[26] Indicates significant level

Table 7.2: Test Based on Maximum Eigen Value ($\lambda_{\max}$)

Endogenous Variables: $LnCPI\ and\ LnM_1$ Order of VAR = 5
Trend Assumption: No Deterministic Trend (Restricted Constant)

Null Hypothesis	Alternative Hypothesis	Eigen-values (λ_i)	Max-Eigen Statistics($\lambda_{\max}$)	0.05 Critical Value	Probability
r = 0*	r = 1	0.1231	18.3993	15.8921	0.0198
r ≤ 1	r = 2	0.0478	6.8626	9.1645	0.1338

* Denotes the rejection of the hypothesis at 0.05 levels.

Table-7.3: Test Based on Trace Statistic (λ_{trace})

Endogenous Variables: $LnCPI\ and\ LnM_1$ Order of VAR = 5
Trend Assumption: No Deterministic Trend (Restricted Constant)

Null Hypothesis	Alternative Hypothesis	Eigen-values (λ_i)	Trace Statistics ($\lambda_{\max}$)	0.05 Critical Value	Probability
r = 0*	r = 1	0.1231	25.2620	20.2618	0.0094
r ≤ 1	r = 2	0.0478	6.8626	9.1645	0.1338

Using fifth order VAR of the two variables under investigation, the hypothesis of r = 0 is uniformly rejected in favor of the alternative hypothesis r = 1 employing the maximum Eigen-value test as reported by the 4th column of Table-7.2. The maximum Eigen-value test of r = 1 versus r = 2 fails to reject the null hypothesis of k = 1 implying one cointegrating vector. Thus, on the basis of maximum Eigen-value test, $LnCPI\ and\ LnM_1$ are found to be cointegrated.

Turning to the trace test as reported by Table-7.3, the null hypothesis r ≤ 1 cannot be rejected while the hypothesis r = 0 can be rejected at 5 percent significant level. Moreover, there appears to be single cointegrating vector, that is: $r = 1$. Consequently, this test indicates that $LnCPI_t\ and\ LnM_{1t}$ are cointegrated.

Both maximum Eigen-value test and trace test indicate that $LnCPI\ and\ LnM_1$ are cointegrated to each other, that is, there is found to be long run equilibrium relationship between narrow money supply and price level during the study period from $1976Q_1$ to $2012Q_2$.

7.4 Vector Error Correction Modeling (VECM) [$\boldsymbol{LnCPI_t}$ & $\boldsymbol{LnM_{1_t}}$]

Once the variables $LnCPI\ and\ LnM_1$ are cointegrated, our next job is to employ the VECM to capture the long run equilibrium relationship by allowing the short run shocks. "A vector error correction (VEC) model is a restricted VAR designed for use with nonstationary series that are known to be cointegrated. The VEC has cointegration relations built into the specification so that it restricts the long run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the *error correction* term since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments". (Quantitative Micro Software, 2009: Eviews 7, User's Guide II)

Table-7.4 shows the regression results from VECM with $LnCPI$ as dependent variable. The estimated VECM with $LnCPI$ as dependent variable is given by equation (7.1).

$$\begin{aligned} dLnCPI_t = {} & \rho_1 Z_{1_{t-1}} + \alpha_1 dLnM_{1_{t-1}} + \alpha_2 dLnM_{1_{t-2}} + \alpha_3 dLnM_{1_{t-3}} + \alpha_4 dLnM_{1_{t-4}} \\ & + \alpha_{5d} LnM_{1_{t-5}} + \beta_1 dLnCPI_{t-1} + \beta_2 dLnCPI_{t-2} + \beta_3 dLnCPI_{t-3} \\ & + \beta_4 dLnCPI_{t-4} + \beta_5 dLnCPI_{t-5} + \varepsilon_{1t} \end{aligned} \tag{7.1}$$

The coefficients of independent variables, standard error, t-statistic and probability value of equation (7.1) are presented through Table-7.4.

Table-7.4: Results from VECM with $dLnCPI_t$ as Dependent Variable

(Lag:1 to 5)

Trend Assumption: No Deterministic Trend (Restricted Constant:$\gamma = 0$)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Z_{1t-1}	$\rho_1 =$ -0.0085	0.0045	-1.8579	0.0655
LnM_{1t-1}	$\alpha_1 = 0.1006$	0.0613	1.6403	0.1034
LnM_{1t-2}	$\alpha_2 = 0.1404$	0.0548	2.5604	0.0116
LnM_{1t-3}	$\alpha_3 = 0.0532$	0.0591	0.8998	0.3699
LnM_{1t-4}	$\alpha_4 =$- 0.1136	0.0575	-1.9738	0.0505
LnM_{1t-5}	$\alpha_5 = 0.0448$	0.0633	0.7072	0.4807
$dLnCPI_{t-1}$	$\beta_1 =$ 0.0847	0.0873	0.9707	0.3335
$dLnCPI_{t-2}$	$\beta_2 = 0.0191$	0.0813	0.2361	0.8137
$dLnCPI_{t-3}$	$\beta_3 =$ -0.1224	0.0799	-1.5318	0.1280
$dLnCPI_{t-4}$	$\beta_4 = 0.3383$	0.0776	4.3578	0.0000
$dLnCPI_{t-5}$	$\beta_5 =$ -0.2140	0.0818	-2.6152	0.0100

R^2=0.532329 Adj. R^2=0.496076 S.E. of regression= 0.018283 Log likelihood=367.3262
Durbin-Watson stat=1.987960

From the Table-7.4, it is observed that

i) The coefficient of error correction term ($Z_{1_{t-1}}$), ρ_1 =-0.0085 is significant at 10% level, which indicates that the short run shocks significantly affect the long run relationship between the variables $dLnCPIP_t$ and $dLnM_{1_t}$. The speed of convergence of equilibrium of (0.0085) 0.85 % implies that inflations are adjusted by 0.85 % of the past five quarters' deviation from equilibrium.

ii) The negative value of ρ_1 =-0.0085 indicates that $dLnCPI_t$, following any positive short run shocks, declined. Consequently, the short run shocks appeared to pull down the $dLnCPIP_t$ below the long run equilibrium level.

iii) The absolute value of the coefficient of Z_{t-1} to be lower than unity, i.e. $|\rho_1| < 1$, which implies that $dLnCPIP_t$ converged to the long run equilibrium level following a short run shocks. Thus, long run relationship between $dLnCPIP_t$ as dependent variable and $dLnM_{1_t}$ independent variables is found to be stable. Consequently, the short run dynamics defined an 'equilibrium' process.

iv) The coefficient of $dLnM_{1_{t-2}}$ is α_2 =0.1404. It is positive and significant at 5% level implying the current inflation is caused by two period's (quarter) back narrow money supply. More clearly, a ten percent rise of change in M_1 money supply in two periods back causes the change in price level to rise by 1.4%.

v) The coefficient of $dLnM_{1_{t-4}}$ is $\alpha_4 =$ - 0.1136. It is significant at 10% level, but the algebraic sign is negative which violates the theoretical norms of 'Quantity Theory of Money'. So this coefficient is disregarded from the analysis of money-price relation.

vi) The coefficient of $dLnCPI_{t-4}$ is $\beta_4 =$ 0.3383. It is significant at less than 1% level and positive, meaning the change in current price level is positively affected by the change in price level of four periods back. It implies that a 10% rise in change in price of four periods/quarters back has caused the change in current price level by 3.3%.

The values of coefficient of determination and adjusted coefficient of determination of estimated VECM of equation (7.1) are R^2=0.5323, Adj. R^2=0.4960 respectively. This implies that approximately 50% of the variation of dependent variable $dLnCPI_t$ is explained by the set of independent variables. This represents the satisfactory goodness of the fit of VECM with $dLnCPI_t$ as dependent variable. Likewise, the low value of standard error of regression and high value of Log likelihood ratio also represent that the estimated VECM is reasonably fitted. Since, the Durbin-Watson statistic is 1.98 (close to 2), the estimated VECM of equation (7.1) does not suffer from positive autocorrelation problem.

The estimated VECM with $dLnM_{1t}$ as dependent variable is given by equation (7.2) as:

$$dLnM_{1t} = \rho_2 Z_{1_{t-1}} + \delta_1 dLnM_{1_{t-1}} + \delta_2 dLnM_{1_{t-2}} + \delta_3 dLnM_{1_{t-3}} + \delta_4 dLnM_{1_{t-4}} + \delta_5 dLnM_{1_{t-5}} + \theta_1 dLnCPI_{t-1} + \theta_2 dLnCPI_{t-2} + \theta_3 dLnCPI_{t-3} + \theta_4 dLnCPI_{t-4} + \theta_5 dLnCPI_{t-5} + \varepsilon_{2t} \quad (7.2)$$

The coefficients of independent variables, standard error, t-statistic and probability value of equation (7.2) are presented through Table-7.5.

Table-7.5: Results from VECM with $dLnM_{1_t}$ as Dependent Variable (Lag: 1 to 5)

Trend Assumption: No Deterministic Trend (Restricted Constant: $\gamma = 0$)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Z_{2t-1}	ρ_2 = -0.0241	0.0063	-3.7868	0.0002
LnM_{1t-1}	δ_1=0.0192	0.0852	0.2253	0.8221
LnM_{1t-2}	δ_2=-0.3187	0.0762	-4.1794	0.0001
LnM_{1t-3}	δ_3=-0.0424	0.0822	-0.5164	0.6065
LnM_{1t-4}	δ_4=0.4097	0.0800	5.1209	0.0000
LnM_{1t-5}	δ_5=0.0447	0.0880	0.5076	0.6126
$dLnCPI_{t-1}$	θ_1=0.2608	0.1213	2.1493	0.0335
$dLnCPI_{t-2}$	θ_2=0.0750	0.1130	0.6640	0.5079
$dLnCPI_{t-3}$	θ_3=0.1312	0.1110	1.1816	0.2395
$dLnCPI_{t-4}$	θ_4=-0.2969	0.1079	-2.7521	0.0068
$dLnCPI_{t-5}$	θ_5=-0.0599	0.1137	-0.5267	0.5992

R^2=0.6989 Adj. R^2=0.6756 S.E. of regression= 0.0254 Log likelihood=321.2465
Durbin-Watson stat=1. 9781

From the Table-7.5, it is observed that

i) The coefficient of error correction term ($Z_{2_{t-1}}$), ρ_2= -0.0241 significant at less than 1% level, which indicates that the short run shocks significantly affect the long run relationship between the variables $dLnCPI_t$ and $dLnM_{1_t}$. The speed of convergence of equilibrium of (0.0241) 2.4 % implies that money supplies (narrow money) are adjusted by 2.4 % of the past five quarters' deviation from equilibrium.

ii) The negative value of ρ_2 =-0.0241 indicates that $dLnM_{1_t}$, following any positive short run shocks, declined. Consequently, the short run shocks appeared to pull down the $dLnM_{1_t}$ below the long run equilibrium level.

iii) The absolute value of the coefficient of Z_{2t-1} to be lower than unity, i.e. $|\rho_2|$< 1, which implies that $dLnM_{1_t}$ converged to the long run equilibrium level following a short run shocks. Thus, long run relationship between $dLnM_{1_t}$as dependent variable and $dLnCPI_t$ independent variables is found to be stable. Consequently, the short run dynamics defined an 'equilibrium' process.

iv) The coefficient of $dLnM_{1_{t-4}}$, $\delta_4 = 0.4097$. It is positive and significant at 1% level implying the current narrow money supply is caused by four period's (quarter) back narrow money supply. More clearly, a ten percent rise of change in M_1 money supply in four periods back causes the change in M_1 money supply level to rise by 4.04%.

v) The coefficient of $dLnCPI_{t-1}$ is $\theta_1 = 0.2608$. It is positive and significant at 5% level. This implies that current M_1 money supply is positively caused by the price level of one period back. A ten percent rise in price level in previous period causes M_1 money supply to rise by 2.6%.

The values of coefficient of determination and adjusted coefficient of determination of estimated VECM of equation (7.2) are R^2=0.6989 Adj. R^2=0.6756 respectively. This implies that more than 65% of the variation of dependent variable dM_{1_t} is explained by the set of independent variables. This represents the satisfactory goodness of the fit of VECM with dM_{1_t} as dependent variable. Likewise, the low value of standard error of regression and high value of Log likelihood ratio also represent that the estimated VECM is reasonably fitted. Since, the Durbin-Watson statistic is 1.97 (close to 2); the estimated VECM of equation (7.2) does not suffer from positive autocorrelation problem.

Thus, the estimated VECMs imply that there is cointegration between M_1 money supply and price level. The long run equilibrium relationship between these two variables imply that there is bi-directional Granger causality between M_1 money supply and price level in Nepalese economy during the study period.

7.4.1 Residuals Diagnostic of VECM

In order to examine the consistency of fitted VECM of equation (7.1), it is necessary to apply Residual Diagnostic through the test such as Correlogram-Q statistic, Correlogram Squared Residuals, Serial Correlation LM Test and Heteroscedasticity Test. With the help of these tests, we can conclude whether or not estimated VECM is consistent.

7.4.1.1 Correlogram –Q-Statistics of Residuals

The Correlogram-Q-statistic of the residuals of estimated VECM of equation (7.1) is presented through Table-7.6. The ACFs and PACFs of correlogram of the residual are nearly zero at all lags and the Q-statistics at all lags are not significant with large p-values. This indicates that there is no evidence of rejecting the null hypothesis of no serial correlation. This implies that the residuals of the fitted VECM of equation (7.1) are not correlated with their own lagged values. Hence, there is strong evidence of goodness of fit of the VECM of equation (7.1).

Table-7.6: Correlogram-Q-statistics of Residual of VECM Equation (7.1)

Lag	AC	PAC	Q-Stat	Prob	Lag	AC	PAC	Q-Stat	Prob
1	-0.014	-0.014	0.0284	0.866	11	0.069	0.010	14.735	0.195
2	-0.009	-0.009	0.0388	0.981	12	-0.047	0.002	15.074	0.237
3	0.140	0.140	2.8983	0.408	13	0.064	0.016	15.705	0.265
4	-0.119	-0.117	4.9613	0.291	14	-0.111	-0.121	17.644	0.223
5	0.050	0.053	5.3322	0.377	15	-0.057	-0.014	18.162	0.254
6	-0.077	-0.103	6.2100	0.400	16	0.102	0.053	19.828	0.228
7	-0.152	-0.121	9.6500	0.209	17	-0.062	-0.001	20.449	0.252
8	0.148	0.126	12.957	0.113	18	0.024	0.017	20.545	0.303
9	-0.083	-0.058	14.007	0.122	19	-0.049	-0.087	20.940	0.340
10	0.003	0.027	14.008	0.173	20	0.113	0.160	23.045	0.287

7.4.1.2 Correlogram of Squared Residuals

The Correlogram-Q-statistic of the residuals squared of estimated VECM of equation (7.1) is presented through Table-7.7. The ACFs and PACFs of correlogram of the residual squared are nearly zero at all lags and the Q-statistics at all lags are not significant with large p-values. This indicates that there is no evidence of rejecting the null hypothesis of no serial correlation. This implies that the residuals of the fitted VECM of equation (7.1) are not correlated with their own lagged values. Hence, there is strong evidence of goodness of fit of the VECM of equation (7.1).

Table-7.7: Correlogram-Q-statistics of Squared Residual of VECM Equation (7.1)

Lag	AC	PAC	Q-Stat	Prob	Lag	AC	PAC	Q-Stat	Prob
1	-0.039	-0.039	0.2231	0.866	9	0.006	0.001	3.6192	0.122
2	-0.012	-0.013	0.2434	0.981	10	-0.041	-0.030	3.8746	0.173
3	-0.021	-0.022	0.3075	0.408	11	0.007	0.007	3.8830	0.973
4	0.133	0.131	2.8779	0.291	12	0.010	-0.003	3.8972	0.985
5	0.022	0.032	2.9480	0.377	13	-0.023	-0.028	3.9812	0.991
6	-0.043	-0.039	3.2260	0.400	14	-0.021	-0.011	4.0538	0.995
7	0.005	0.007	3.2293	0.209	15	-0.099	-0.103	5.6008	0.986
8	0.050	0.034	3.6129	0.113	16	-0.034	-0.051	5.7888	0.990

7.4.1.3 Breusch-Godfrey Lagrange Multiplier Test for Serial Correlation

The results of Breusch-Godfrey Lagrange Multiplier test for serial correlation have been presented through Table-7.8. As reported by F-statistic and $T \times R^2$ value and their corresponding probabilities of B-G LM test of Table-7.8, the null hypothesis of no autocorrelation cannot be rejected. The B-G LM test implies that residuals are not serially correlated. Due to the non-presence of serial correlation, the estimated VECM of equation (7.1) is considered as the consistent model for representing the long run equilibrium relationship between M_1 money supply and price level.

Table-7.8: Breusch-Godfrey Serial Correlation LM Test

F-statistic	1.1067	Prob. F(2,127)	0.3338
$T \times R^2$	2.3864	Prob. Chi-Square(2)	0.3032

7.4.1.4 VEC Residuals Heteroscedasticity Test

The null hypothesis of White's (1980) is:H_0: there is homoscedasticity in the residuals. The null hypothesis is not rejected if the F-statistic and χ^2 –statistic are not significant. No rejection of null hypothesis confirms that residuals of estimated VECM do not suffer from heteroscedasticity problem and estimated VECM is claimed to be consistent. Table-7.9 presents the VEC Residual Heteroscedasticity test.

Looking at the individual component (lower part of Table-7.9), R^2 of all dependent variables are not significant as implied by F-statistic and χ^2-statistic not rejecting the null hypothesis. Likewise, the χ^2-statistic of Joint test also implies that the null hypothesis is not rejected, which means residuals are homoscedastic. Thus, the VEC Residual Heteroscedasticity test confirms that there is no heteroscedasticity problem in the residuals of estimated VECM of equation (7.1). Thus, the estimated VEC model is econometrically meaning full and sound

Table-7.9: VEC Residual Heteroscedasticity Test

Joint Test

χ^2	Degree of Freedom	Probability
64.69036	66	0.5226

Individual Components

Dependent	R-squared	F(22,117)	Prob.	Chi-sq(22)
res1×res1	0.1511	0.9469	0.5355	21.1597
res2×res2	0.1383	0.8537	0.6536	19.3656
res2×res1	0.1934	1.2759	0.2023	27.0891

7.4.2 Stability Test

To examine the stability of the estimated VECM of equation (7.1), we apply some test such as Ramsey's RESET test, Recursive Residual test, CUSUM test, CUSUM of Squares test etc.

7.4.2.1 Ramsey's RESET Test

Ramsey (1969)[27] introduced Regression Specification Error Test (RESET) to examine whether the functional form of the regression is appropriate. In this test, we examine whether the relationship between dependent variable and the independent variable in the regression model bears the linear relationship or non-linear relationship is appropriate. The test involves the addition of powers of the fitted values from the regression into a second regression. If the appropriate model was a linear one, then the powers of the fitted values would not be significant in this second regression.

The classical normal linear regression model is estimated as[28]:

[27] Ramsey, J.B. (1969). Tests for specification errors in classical linear least-squares analysis, Journal of the Royal Statistical Society, Series B, 71, 350–371.

[28] See QMS (2009), Eviews 7: User's Guide II.

$y = X\beta + \varepsilon$ (7.3)

Where, ε is the white noise error term and it is $iid(0, \sigma^2)$, that is, it follows the multivariate distribution.

The null and alternative hypotheses for Ramsey's RESET are:

$H_0: \varepsilon \sim N(0, \sigma^2)$ &

$H_1: \varepsilon \sim N(\mu, \sigma^2) \qquad \mu \neq 0$

The test is based on the augmented regression,

$y = X\beta + Z_\gamma + \varepsilon$ (7.4)

The test of specification error evaluates the restriction,

$\gamma = 0$

In equation (7.3) there is no entry of matrix *Z*. So we are very curious that what variables enter the *Z* matrix so that there exists an omitted variable,

$\gamma = 0$

In testing whether the functional form is incorrect, the non-linear part of the regression model will be some function of the regressors included in equation (7.3).

$y = \beta_0 + \beta_1 X + \varepsilon$ (7.3a)

&

$y = \beta_0 + \beta_1 X + \beta_2 X^2 + \varepsilon$ (7.3b)

So, two regressions are estimated where the latter is the former with squared fitted values obtained from the first regression. Note that the squared fitted values introduce the non-linearity into the specification. We will test for *functional form* with an F-test. The null hypothesis is that "the correct specification is linear"**.** The alternative hypothesis is the correct specification is "non-linear".

If the null hypothesis is not rejected as reported by F-statistic[29], the true specification is linear and the equation passes the Ramsey Reset test. Contrary to this, if null hypothesis is rejected, the specification is not linear and it requires including the squared fitted values to the original model. In such a situation, the model represents non-linear relationship between the variables under study.

[29] t-statistic as well as likelihood ratio can also be used.

Table-7.10 demonstrates the results from Ramsey's RESET test. In the upper part of Table-7.10, f-statistic, t-statistic and likelihood ratio are not significant as reported by the corresponding probability values. The null hypothesis 'correct specification is linear' is not rejected even by including the $Fitted^2$ term in to the VECM of equation (7.1). It means the estimated VECM is linear and there is no need of non-linearity in the estimated VECM (7.1). Likewise, in lower part of Table-7.10, H_0: $\gamma = 0$ is not rejected as reported by the t-statistic. Hence, the Ramsey's RESET test implies that the estimated VECM (7.1) is stable model consisting the properties of linearity and non-misspecification of the model.

Table-7.10: Ramsey's RESET Test of VECM of Equation (7.1)

(a)

Test-statistic	Value	Degree of Freedom	Probability
t-statistic	0.3727	128	0.7099
F-statistic	0.1389	(1, 128)	0.7099
Likelihood ratio	0.1518	1	0.6967

Unrestricted Test Equation (b)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Z_{1t-1}	ρ_1 =-0.0088	0.0046	-1.8879	0.0613
LnM_{1t-1}	α_1 = 0.1082	0.0648	1.6692	0.0975
LnM_{1t-2}	α_2 = 0.1529	0.0644	2.3733	0.0191
LnM_{1t-3}	α_3 = 0.0610	0.0629	0.9698	0.3339
LnM_{1t-4}	α_4 = -0.1262	0.0669	-1.8867	0.0615
LnM_{1t-5}	α_5 = 0.0464	0.0637	0.7287	0.4675
$dLnCPI_{t-1}$	β_1 =0.0903	0.0889	1.0167	0.3112
$dLnCPI_{t-2}$	β_2 =0.0258	0.0835	0.3100	0.7571
$dLnCPI_{t-3}$	β_3 =-0.1359	0.0879	-1.5449	0.1248
$dLnCPI_{t-4}$	β_4 =0.3691	0.1135	3.2520	0.0015
$dLnCPI_{t-5}$	β_5 =-0.2269	0.0890	-2.5469	0.0120
$Fitted^2$	γ =-1.6273	4.3657	-0.3727	0.7099

7.4.2.2 CUSUM Test

"The CUSUM test (Brown, Durbin, and Evans, 1975) is based on the cumulative sum of the recursive residuals. This option plots the cumulative sum together with the 5% critical lines. The test finds parameter instability if the cumulative sum goes outside the area between the two critical lines". (QMS,2009)

[30]The CUSUM test is based on the statistic:

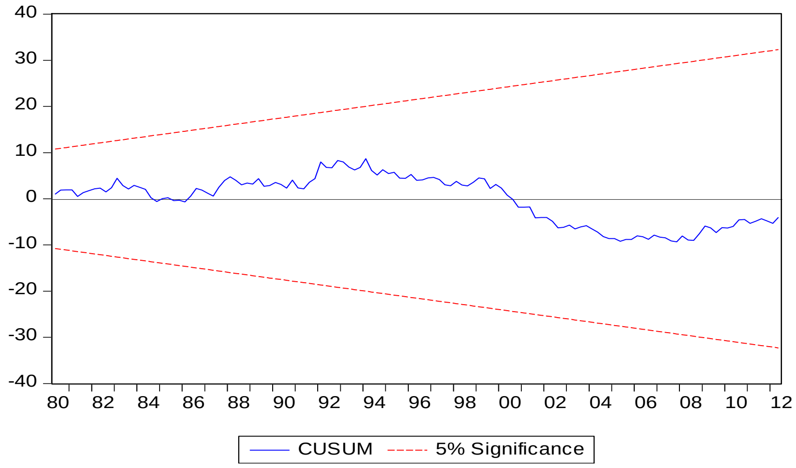
$$W_t = \sum_{r=k+1}^{t} {w_r}/{s} \tag{7.5}$$

For $t = k + 1, \ldots T,$ where w is the recursive residual defined above, and s is the standard deviation of the recursive residuals w_t. If the β vector remains constant from period to period, $E(W_t = 0)$, but if β changes, W_t will tend to diverge from the zero mean value line. The significance of any departure from the zero line is assessed by reference to a pair of 5% significance lines, the distance between which increases with . The 5% significance lines are found by connecting the points:

$$\left[k, \pm - 0.948(T-k)^{1/3}\right] \text{ and, } \left[T, \pm 3 \times 0.948(T-k)^{1/3}\right] \tag{7.6}$$

Movement of W_t outside the critical lines is suggestive of coefficient instability. But if W_t lies within the critical lines, there is stability of coefficient of estimated model. In Graph 7.1, W_t line lies within the critical lines. This clearly confirms the stability of coefficient of estimated VECM (7.1).

Figure-7.1: Graphical Presentation of CUSUM Test



[30] See QMS (2009), Eviews 7: User's Guide II.

7.4.2.3 CUSUM of Squared Test

[31]The CUSUM of squares test (Brown, Durbin, and Evans, 1975) is based on the test statistic:

$$S_t = \left(\sum_{r=k+1}^{t} w_r^2\right) \Big/ \left(\sum_{r=k+1}^{T} w_r^2\right) \tag{7.7}$$

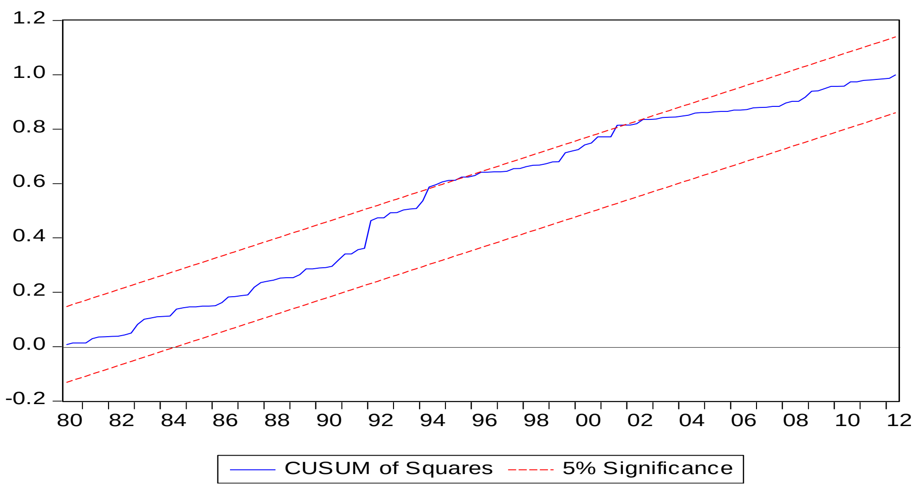
The expected value of S_t under the hypothesis of parameter constancy is:

$$E(S_t) = (t-k) \big/ (T-k) \tag{7.8}$$

Which, goes from zero at $t = k$ to unity at $T = k$. The significance of the departure of S_t from its expected value is assessed by reference to a pair of parallel straight lines around the expected value.

The CUSUM of squared test provides a plot of S_t against t and the pair of 5 percent critical lines. As with the CUSUM test, movement outside the critical lines is suggestive of parameter or variance instability. Figure-7.2 shows the graphical presentation of CUSUM of squares test. In the graph, since S_t line lies within the critical lines, the estimated VECM (7.1) has stable parameter and variance.

Figure-7.2: Graphical Presentation of CUSUM of Squared Test



7.4.2.4 Recursive Coefficient Test

This view enables us to "trace the evolution of estimates for any coefficient as more and more of the sample data are used in the estimation. The view will provide a plot

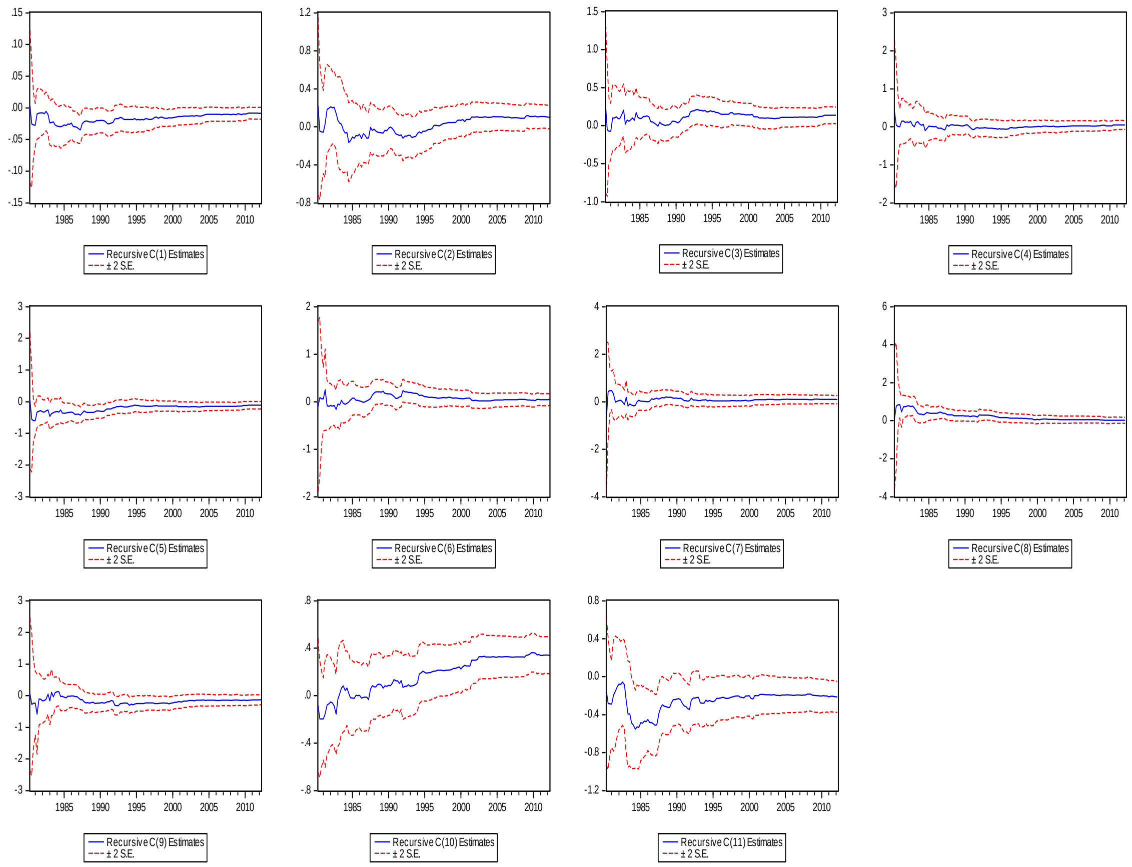
[31] See QMS (2009), Eviews 7: User's Guide II.

of selected coefficients in the equation for all feasible recursive estimations. Also shown are the two standard error bands around the estimated coefficients". (QMS, 2009: Eviews 7)

QMS (2009: Eviews 7), adds that "If the coefficient displays significant variation as more data is added to the estimating equation, it is a strong indication of instability. Coefficient plots will sometimes show dramatic jumps as the postulated equation tries to digest a structural break". Contrary to this, if the coefficient displays no or negligible variation as more data is added to the estimating equation, it can be claimed that there is stability of coefficient of the estimated equation.

Graph-7.3 represents the Recursive Coefficient test of estimated VECM (7.1). The graph of most of the coefficients represents either no or negligible variation with respect to change in time. The slight variation is observed only in case of C(10). But of other coefficients except C(10) have more or less no variation. Thus, the Recursive Coefficient test also represents the stability of coefficients of estimated VECM (7.1).

Graph-7.3: Graphical Presentation of Recursive Coefficients Test



7.5 Johansen's Cointegration Test between $LnCPI_t$ and LnM_{2_t}

Before carrying out the Johansen's Cointegration test between broad money supply and price level, it is necessary to select the suitable lags to be used for each endogenous variable in regression. Table-7.11 shows the selection of suitable lags using different criteria through VAR technique.

From Table-7.11 it is observed that the Schwarz statistics are significant at lags 5 and LR, FPE, HQ and Akaike information statistics are significant at lag 9. Lag 9 is very high lag to use in regression for analyzing the relationship between two endogenous variables. Lag 5 under SC and HQ is somewhat suitable as compared to lag 9. So, we use lag 5 as the suitable lag for each endogenous variable in regression of cointegration and VECM for the endogenous variables $LnCPI$ and LnM_2.

Table-7.11: VAR Lag Order Selection Criteria

Endogenous variables: $LnCPI_t$ & LnM_{2t} Exogenous Variable: constant

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-77.3305	NA	0.011509	1.2111	1.2550	1.2289
1	572.4997	1269.897	6.01e-07	-8.6488	-8.5171	-8.5953
2	576.1597	7.040449	6.04e-07	-8.6436	-8.4241	-8.5544
3	589.3071	24.88982	5.26e-07	-8.7833	-8.4760	-8.6584
4	594.9274	10.46842	5.13e-07	-8.8080	-8.4129	-8.6475
5	628.0603	60.70138	3.29e-07	-9.2528	-8.7699*	-9.0566
6	632.0103	7.115996	3.29e-07	-9.2520	-8.6814	-9.0201
7	634.9120	5.138896	3.35e-07	-9.2352	-8.5768	-8.9677
8	640.2715	9.328061	3.28e-07	-9.2560	-8.5098	-8.9528
9	654.3319	24.04213*	2.82e-07*	-9.4096*	-8.5756	-9.0707*
10	656.3744	3.430251	2.91e-07	-9.3797	-8.4579	-9.0051
11	660.8251	7.338492	2.90e-07	-9.3866	-8.3770	-8.9763
12	663.9000	4.976228	2.94e-07	-9.3725	-8.2751	-8.9265
13	666.8685	4.713289	3.00e-07	-9.3567	-8.1715	-8.8751
14	671.5004	7.213093	2.98e-07	-9.3664	-8.0934	-8.8491
15	671.8438	0.524172	3.16e-07	-9.3105	-7.9498	-8.7576

The Johansen method of cointegration is based on Maximum-Eigen and Trace statistic value. The following results have been revealed between $LnCPI$ and LnM_2 for Johansen approach.

Table 7.12: Test Based on Maximum Eigen Value ($\lambda_{\max}$)

Endogenous Variables: $LnCPI\ and\ LnM_1$ Order of VAR = 5

Trend Assumption: No Deterministic Trend (Restricted Constant)

Null Hypothesis	Alternative Hypothesis	Eigen-values (λ_i)	Max-Eigen Statistics($\lambda_{\max}$)	0.05 Critical Value	Probability
r = 0*	r = 1	0.08837	12.9532	11.2248	0.0246
r ≤1	r = 2	0.01976	2.79471	4.1299	0.1118

Table-7.13: Test Based on Trace Statistic (λ_{trace})

Endogenous Variables: $LnCPI\ and\ LnM_1$ Order of VAR = 5

Trend Assumption: No Deterministic Trend (Restricted Constant)

Null Hypothesis	Alternative Hypothesis	Eigen-values (λ_i)	Trace Statistics ($\lambda_{\max}$)	0.05 Critical Value	Probability
r = 0*	r = 1	0.08837	15.7479	12.3209	0.0128
r ≤1	r = 2	0.01976	2.7947	4.1299	0.1118

Using fifth order VAR of the two variables under investigation, the hypothesis of r = 0 is uniformly rejected in favor of the alternative hypothesis $r = 1$ employing the maximum Eigen-value test as reported by the 4th column of Table-7.12. The maximum Eigen-value test of $r = 1$ versus $r = 2$ fails to reject the null hypothesis of $k = 1$ implying one cointegrating vector. Thus, on the basis of maximum Eigen-value test, $LnCPI\ and\ LnM_2$ are found to be cointegrated. Turning to the trace test as reported by Table-7.13, the null hypothesis r ≤1 cannot be rejected while the hypothesis r = 0 can be rejected at 5 percent significant level. Moreover, there appears to be single cointegrating vector $(r = 1)$. Consequently, this test indicates that $LnCPI\ and\ LnM_2$ are cointegrated.

Both maximum Eigen-value test and trace test indicate that $LnCPI\ and\ LnM_2$ are cointegrated to each other, that is, there is found to be long run equilibrium relationship between broad money supply and price level during the study period from $1976Q_1$ to $2012Q_2$.

7.6 Vector Error Correction Modeling (VECM) [$\boldsymbol{LnCPI_t \text{ and } LnM_{2_t}}$]

After the variables $LnCPI \text{ and } LnM_1$ are cointegrated, our next job is to employ the VECM to capture the long run equilibrium relationship by allowing the short run shocks. An error correction model is not a model that corrects the error in another model. Error Correction Models (ECMs) are a category of multiple time series models that directly estimate the speed at which a dependent variable Y returns to equilibrium after a change in an independent variable X. ECMs are theoretically-driven approach useful for estimating both short term and long term effects of one time series on another. Table-7.4 shows the regression results from VECM with $LnCPI$ as dependent variable. The estimated VECM with $LnCPI$ as dependent variable is given by equation (7.9).

$$dLnCPI_t = \rho_1 Z_{1_{t-1}} + \alpha_1 LnM_{2_{t-1}} + \alpha_2 LnM_{2_{t-2}} + \alpha_3 LnM_{2_{t-3}} + \alpha_4 LnM_{2_{t-4}} + \alpha_5 LnM_{2_{t-5}} + \beta_1 LnCPI_{t-1} + \beta_2 LnCPI_{t-2} + \beta_3 LnCPI_{t-3} + \beta_4 LnCPI_{t-4} + \beta_5 LnCPI_{t-5} + \varepsilon_{1t} \tag{7.9}$$

The coefficients of independent variables, standard error, t-statistic and probability value of equation (7.9) are presented through Table-7.14. From the Table-7.14, it is observed that

i) The coefficient of error correction term ($Z_{1_{t-1}}$), ρ_1 =-0.0097 is significant at 5% level, which indicates that the short run shocks significantly affect the long run relationship between the variables $dLnCPIP_t \text{ and } dLnM_{2_t}$. The speed of convergence of equilibrium of (0.0097) 0.97% implies that inflations are adjusted by 0.97 % of the past five quarters' deviation from equilibrium.

ii) The negative value of ρ_1 =-0.0097 indicates that $dLnCPI_t$, following any positive short run shocks, declined. Consequently, the short run shocks appeared to pull down the $dLnCPIP_t$ below the long run equilibrium level.

iii) The absolute value of the coefficient of Z_{t-1} to be lower than unity, i.e. $|\rho_1| < 1$, which implies that $dLnCPIP_t$ converged to the long run equilibrium level following a short run shocks. Thus, long run relationship between $dLnCPIP_t$ as dependent variable and $dLnM_{2_t}$ independent variables is found to be stable. Consequently, the short run dynamics defined an 'equilibrium' process.

iv) The coefficient of $dLnM_{2_{t-2}}$, α_2 =0.1259. It is positive and significant at 5% level implying the current inflation is caused by two period's (quarter) back broad money supply. More clearly, a ten percent rise of change in M_2 money supply in two periods back causes the change in price level to rise by 1.2%.

v) The coefficient of $dLnM_{2_{t-4}}$ is $\alpha_4 =$ -0.1058. It is significant at 10% level, but the algebraic sign is negative which violates the theoretical norms of 'Quantity Theory of Money'. So, this coefficient is disregarded in the analysis of money-price relation.

vi) The coefficient of $dLnCPI_{t-4}$ is $\beta_4 =$ 0.4873. It is significant at less than 1% level and positive, meaning the change in current price level is positively affected by the change in price level of four periods back. It implies that a 10% rise in change in price of four periods/quarters back has caused the change in current price level by 4.8%. Likewise, the coefficient of $dLnCPI_{t-5}$ is $\beta_5 =$ -0.2562. It is significant at 1% level but negative and nothing can be interpreted with the help of this value.

Table-7.14: Results from VECM with $dLnCPI_t$ as Dependent Variable (Lag:1 to 5)

Trend Assumption: No Deterministic Trend (Restricted Constant:$\gamma = 0$)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Z_{1t-1}	ρ_1 =-0.0097	0.0040	-2.3962	0.0180
LnM_{2t-1}	α_1 =0.0559	0.0579	0.9649	0.3364
LnM_{2t-2}	α_2 =0.1259	0.0575	2.1860	0.0306
LnM_{2t-3}	α_3 =-0.0328	0.0591	-0.5548	0.5800
LnM_{2t-4}	α_4 =-0.1058	0.0582	-1.8166	0.0716
LnM_{2t-5}	α_5 =0.0857	0.0578	1.4815	0.1409
$LnCPI_{t-1}$	β_1 =0.1377	0.0834	1.6510	0.1012
$LnCPI_{t-2}$	β_2 =-0.0754	0.0689	-1.0942	0.2759
$LnCPI_{t-3}$	β_3 =-0.1567	0.0683	-2.2919	0.0235
$LnCPI_{t-4}$	β_4 = 0.4873	0.0654	7.4504	0.0000
$LnCPI_{t-5}$	β_5 =-0.2562	0.0768	-3.3335	0.0011

R^2=0.5145 Adj. R^2=0.4769 S.E. of regression= 0.01828

Log likelihood=364.7136 Durbin-Watson stat=2.077961

The values of coefficient of determination and adjusted coefficient of determination of estimated VECM of equation (7.9) are R^2=0.5145 Adj. R^2=0.4769 respectively. This implies that nearly 50% of the variation of dependent variable $dLnCPI_t$ is explained by the set of independent variables. This represents the satisfactory goodness of the fit of VECM with $dLnCPI_t$ as dependent variable. Likewise, the low value of standard error of regression and high value of Log likelihood ratio also represent that the estimated VECM is reasonably fitted. Since, the Durbin-Watson statistic is 2.07 (approximately 2), the estimated VECM of equation (7.9) does not suffer from positive autocorrelation problem.

The estimated VECM with LnM_{1t} as dependent variable is given by equation (7.10)

$$LnM_{2t} = \rho_2 Z_{1_{t-1}} + \delta_1 LnM_{2_{t-1}} + \delta_2 LnM_{2_{t-2}} + \delta_3 LnM_{2_{t-3}} + \delta_4 LnM_{2_{t-4}} + \delta_5 LnM_{2_{t-5}} + \theta_1 LnCPI_{t-1} + \theta_2 LnCPI_{t-2} + \theta_3 LnCPI_{t-3} + \theta_4 LnCPI_{t-4} + \theta_5 LnCPI_{t-5} + \varepsilon_{2t} \quad (7.10)$$

The coefficients of independent variables, standard error, t-statistic and probability value of equation (7.10) are presented through Table-7.15.

Table-7.15: Results from VECM with $dLnM_{2_t}$ as Dependent Variable (Lag: 1 to 5)

Trend Assumption: No Deterministic Trend (Restricted Constant:$\gamma = 0$)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Z_{2t-1}	ρ_2 =-0.0152	0.0062	-2.4416	0.0160
LnM_{2t-1}	δ_1 =0.1179	0.0883	1.3345	0.1844
LnM_{2t-2}	δ_2 =-0.2122	0.0877	-2.4180	0.0170
LnM_{2t-3}	δ_3 =0.0427	0.0902	0.4735	0.6366
LnM_{2t-4}	δ_4 =0.2084	0.0887	2.3482	0.0204
LnM_{2t-5}	δ_5 =0.1051	0.0882	1.1924	0.2353
$LnCPI_{t-1}$	θ_1 =0.2066	0.1271	1.6248	0.1066
$LnCPI_{t-2}$	θ_2 =0.1966	0.1050	1.8725	0.0634
$LnCPI_{t-3}$	θ_3 =0.1386	0.1041	1.3310	0.1855
$LnCPI_{t-4}$	θ_4 =-0.0311	0.0996	-0.3126	0.7551
$LnCPI_{t-5}$	θ_5 =0.0354	0.1171	0.3022	0.7629

R^2=0.2118 Adj. R^2=0.1507 S.E. of regression= 0.0283
Log likelihood=305.7439 Durbin-Watson stat=1.9764

From the Table-7.15, it is observed that

i) The coefficient of error correction term ($Z_{2_{t-1}}$), ρ_2 =-0.0152 significant at 1% level, which indicates that the short run shocks significantly affect the long run relationship between the variables $dLnCPI_t$ and $dLnM_{2_t}$. The speed of convergence of equilibrium of (0.0152) 1.5 % implies that money supplies (broad money) are adjusted by 1.5 % of the past five quarters' deviation from equilibrium.

ii) The negative value of ρ_2 =-0.0152 indicates that $dLnM_{1_t}$, following any positive short run shocks, declined. Consequently, the short run shocks appeared to pull down the $dLnM_{2_t}$ below the long run equilibrium level.

iii) The absolute value of the coefficient of Z_{2t-1} to be lower than unity, i.e. $|\rho_2|<$ 1, which implies that $dLnM_{2_t}$ converged to the long run equilibrium level following a short run shocks. Thus, long run relationship between $dLnM_{2_t}$as dependent variable and $dLCPI_t$ independent variables is found to be stable. Consequently, the short run dynamics defined an 'equilibrium' process.

iv) The coefficient of $dLnM_{1_{t-4}}$, $\delta_4 = 0.2084$ It is positive and significant at 5% level implying the current broad money supply is caused by four period's (quarter) back broad money supply. More clearly, a ten percent rise of change in M_2 money supply in four periods back causes the change in M_2 money supply level in current time to rise by 2.08%.

v) The coefficient of $LnCPI_{t-2}$, θ_2 =0.1966 is positive and significant at 10% level, implying that a ten percent rise in change of price level in previous second quarter/period causes the change in broad money supply in current period to rise by 1.96%.

The values of coefficient of determination and adjusted coefficient of determination of estimated VECM of equation (7.10) are R^2= 0.2118 and Adj.R^2=0.1507 respectively. This implies that the variation in dependent variable is not so much satisfactorily explained by the set of independent variables. However, the values of standard error of regression, log likelihood ratio and Durbin-Watson statistic imply that VECM of equation (7.10) is reasonably fitted.

Thus, the estimated VECMs imply that there is cointegration between M_2 money supply and price level. The long run equilibrium relationship between these two variables imply that there is bi-directional Granger causality between M_1 money supply and price level in Nepalese economy during the study period.

7.6.1 Residual Diagnostic of VECM of Equation (7.10)

In order to examine the consistency of fitted VECM of equation (7.10), it is necessary to apply Residual Diagnostic through the test such as Correlogram-Q statistic, Correlogram Squared Residuals, Serial Correlation LM Test and Heteroscedasticity Test. With the help of these tests, we can conclude whether or not estimated VECM (7.10) is consistent.

7.6.1.1 Correlogram –Q-Statistics of Residuals

The Correlogram-Q-statistic of the residuals of estimated VECM of equation (7.10) is presented through Table-7.16. The ACFs and PACFs of correlogram of the residual are not nearly zero at all lags. Besides, the Q-statistics up to lag 3 are not significant and above lag 3 these are significant with less p-values. This indicates that there is no evidence of accepting the null hypothesis of no serial correlation. This implies that the residuals of the fitted VECM of equation (7.10) are not uncorrelated with their own lagged values. Hence, there is no evidence of goodness of fit of the VECM of equation (7.10). However, correlogram-Q-statistics alone is not sufficient criterion for diagnostic of residuals. The presence or absence of serial correlation of the residual can be examined with the help of further other tests like Correlogram of Squared Residuals, B-G LM test and Residual Heteroscedasticity test.

Table-7.16: Correlogram-Q-statistics of Residual of VECM Equation (7.10)

Lag	AC	PAC	Q-Stat	Prob	Lag	AC	PAC	Q-Stat	Prob
1	-0.049	-0.049	0.3411	0.559	7	-0.166	-0.102	19.464	0.007
2	0.061	0.059	0.8740	0.646	8	0.176	0.127	24.109	0.002
3	0.188	0.195	6.0284	0.110	9	-0.098	-0.030	25.558	0.002
4	-0.229	-0.222	13.668	0.008	10	-0.047	-0.064	25.899	0.004
5	0.073	0.036	14.460	0.013	11	0.099	0.014	27.413	0.004
6	-0.076	-0.085	15.322	0.018	12	-0.016	0.086	27.451	0.007

7.6.1.2 Correlogram of Squared Residuals

The Correlogram-Q-statistic of the residuals squared of estimated VECM of equation (7.10) is presented through Table-7.17.

Table-7.17: Correlogram-Q-statistics of Residuals Squared of VECM Equation (7.10)

Lag	AC	PAC	Q-Stat	Prob	Lag	AC	PAC	Q-Stat	Prob
1	-0.062	-0.062	0.5557	0.456	7	-0.015	-0.019	1.1873	0.991
2	-0.018	-0.022	0.6000	0.741	8	0.092	0.087	2.4648	0.963
3	0.004	0.002	0.6027	0.896	9	-0.021	-0.012	2.5337	0.980
4	0.054	0.054	1.0310	0.905	10	-0.023	-0.020	2.6142	0.989
5	0.014	0.021	1.0580	0.958	11	-0.009	-0.011	2.6280	0.995
6	-0.025	-0.021	1.1514	0.979	12	-0.019	-0.030	2.6825	0.997

The ACFs and PACFs of correlogram of the residual squared are nearly zero at all lags and the Q-statistics at all lags are not significant with large p-values. This indicates that there is no evidence of rejecting the null hypothesis of no serial correlation. This implies that the residuals of the fitted VECM of equation (7.10) are not correlated with their own lagged values. Hence, there is strong evidence of goodness of fit of the VECM of equation (7.10).

7.6.1.3 Breusch-Godfrey Lagrange Multiplier Test for Serial Correlation

The results of Breusch-Godfrey Lagrange Multiplier test for serial correlation have been presented through Table-7.18. As reported by F-statistic and $T \times R^2$ value and their corresponding probabilities of B-G LM test of Table-7.18, the null hypothesis of no autocorrelation cannot be rejected at 5% level of significance. The B-G LM test implies that residuals are not serially correlated. Due to the non-presence of serial correlation, the estimated VECM of equation (7.10) is considered as the consistent model for representing the long run equilibrium relationship between M_2 money supply and price level.

Table-7.18: Breusch-Godfrey Serial Correlation LM Test

F-statistic	2.2869	Prob. F(2,127)	0.1057
$T \times R^2$	4.8580	Prob. Chi-Square(2)	0.0881

7.6.1.4 VEC Residuals Heteroscedasticity Test

Table-7.19 presents the VEC Residual Heteroscedasticity test. Looking at the individual component (lower part of Table-7.19), R^2 of all dependent variables are not significant as implied by F-statistic and χ^2-statistic not rejecting the null hypothesis. Likewise, the χ^2-statistic of Joint test also implies that the null hypothesis is not rejected, which means residuals are homoscedastic. Thus, the VEC Residual Heteroscedasticity test confirms that there is no heteroscedasticity problem in the residuals of estimated VECM of equation (7.10). Thus, the estimated VEC model is econometrically meaning full and sound.

Table-7.19: VEC Residual Heteroscedasticity Test

Joint Test

χ^2	Degree of Freedom	Probability
72.6275	66	0.2689

Individual Components

Dependent	R-squared	F(22,117)	Prob.	Chi-sq(22)
res1*res1	0.0860	0.5006	0.9685	12.0457
res2*res2	0.1104	0.6601	0.8694	15.4596
res2*res1	0.3015	2.2959	0.0024	42.2157

7.7 Stability Test

To examine the stability of the estimated VECM of equation (7.10), we apply some test such as Ramsey's RESET test, CUSUM test, CUSUM Squares test, Recursive Residual test etc.

7.7.1 Ramsey's RESET Test

Table-7.20 demonstrates the results from Ramsey's RESET test. In the upper part of Table-7.20, F-statistic, t-statistic and likelihood ratio are not significant as reported by the corresponding probability values. The null hypothesis 'correct specification is linear' is not rejected even by including the $Fitted^2$ in to the VECM of equation (7.10). It means the estimated VECM is linear and there is no need of non-linearity in the estimated VECM (7.10).

Likewise, in lower part of Table-7.10, H_0: $\gamma = 0$ is not rejected as reported by the t-statistic. Hence, the Ramsey's RESET test implies that the estimated VECM (7.10) is stable model containing the properties of linearity and non-misspecification of the model.

Table-7.20: Ramsey's RESET Test of VECM of Equation (7.10)

(a)

Test-statistic	Value	Degree of Freedom	Probability
t-statistic	0.5748	128	0.5664
F-statistic	0.3304	(1, 128)	0.5664
Likelihood ratio	0.3609	1	0.5480

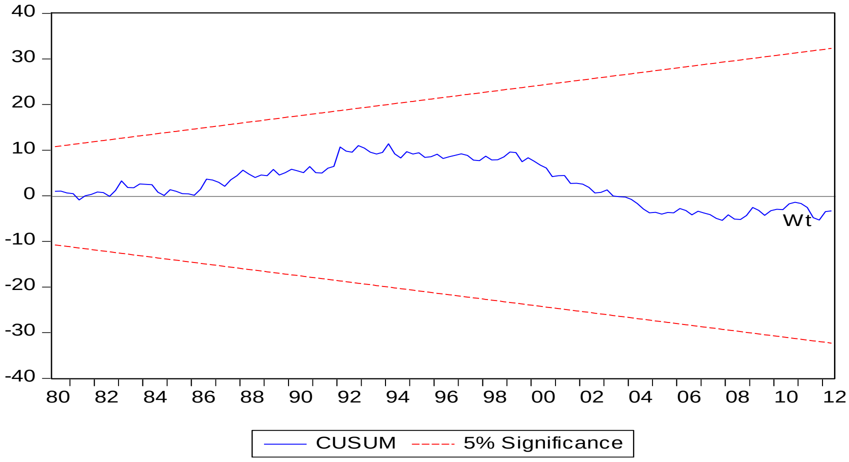
Unrestricted Test Equation (b)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Z_{1t-1}	ρ_1 =-0.0099	0.0041	-2.4175	0.0170
LnM_{1t-1}	α_1 = 0.0595	0.0584	1.0187	0.3102
LnM_{1t-2}	α_2 = 0.1590	0.0816	1.9488	0.0535
LnM_{1t-3}	α_3 = -0.0382	0.0601	-0.6371	0.5252
LnM_{1t-4}	α_4 = -0.1134	0.0599	-1.8944	0.0604
LnM_{1t-5}	α_5 = 0.0965	0.0610	1.5829	0.1159
$LnCPI_{t-1}$	β_1 =0.1535	0.0880	1.7438	0.0836
$LnCPI_{t-2}$	β_2 =-0.0793	0.0694	-1.1427	0.2553
$LnCPI_{t-3}$	β_3 =-0.1919	0.0919	-2.0868	0.0389
$LnCPI_{t-4}$	β_4 =0.5576	0.1387	4.0186	0.0001
$LnCPI_{t-5}$	β_5= 0.2805	0.0878	-3.1921	0.0018
$Fitted^2$	γ =-2.6724	4.6492	-0.5748	0.5664

7.7.2 CUSUM Test

Figure-7.4 shows the graphical presentation of CUSUM test. In the graph, W_t line lies within the critical lines. This clearly confirms the stability of coefficients of estimated VECM (7.10).

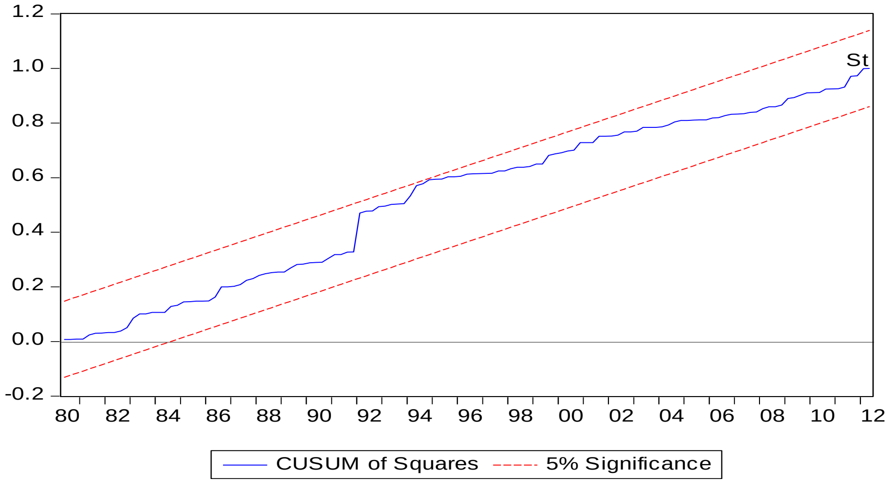
Figure-7.4: Graphical Presentation of CUSUM Test



7.7.3 CUSUM of Squared Test

Figure-7.5 shows the graphical presentation of CUSUM of squares test. In the graph, since S_t line lies within the critical lines, the estimated VECM (7.1) has stable parameter and variance.

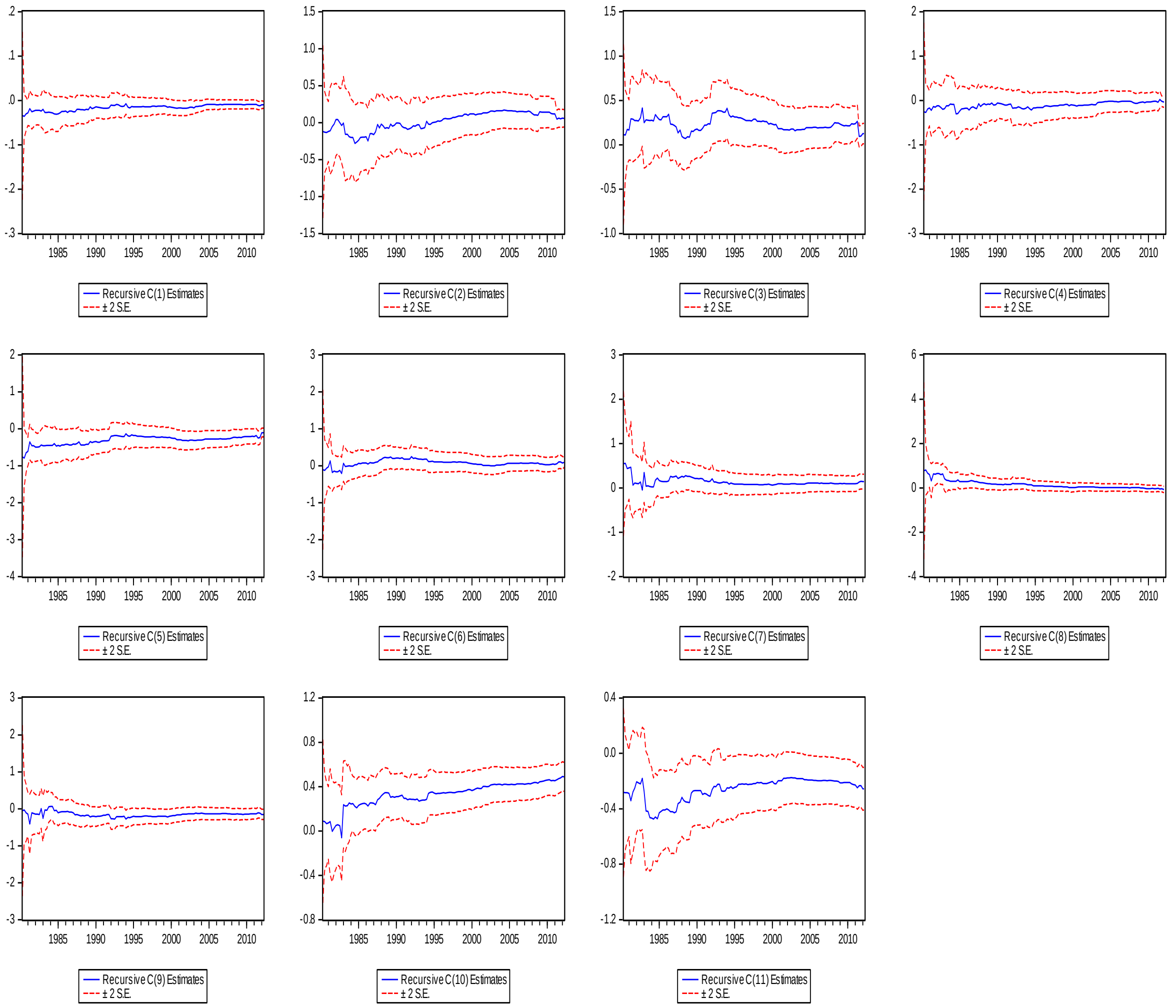
Figure-7.5: Graphical Presentation of CUSUM of Square Test



7.7.4 Recursive Coefficient Test

Figure/Graph-7.6 represents the Recursive Coefficient test of estimated VECM (7.1). The graph of most of the coefficients represents either no or negligible variation with respect to change in time. The slight variation is observed only in case of C(11). But other coefficients except C(10) have more or less no variation. Thus, the Recursive Coefficient test also represents the stability of coefficients of estimated VECM (7.10).

Figure-7.6: Recursive Coefficient Test of VECM (7.10)



7.8 Granger Causality Test

Since the variables ($LnCPI_t \& LnM_{1t}$; $LnCPI_t \& LnM_{2t}$) under investigation are found to be cointegrated, the Granger causality test can be used to obtain the causal relationship between $LnCPI_t$ *and* LnM_{1t} as well as $LnCPI_t$ *and* LnM_{2t}. The Granger causality test is based on F-statistic and it requires the stationary variables. Therefore, the stationary series $dLnCPI_t and\ dLnM_{1t}$ as well as $dLnCPI_t and\ dLnM_{2t}$ have been used for Granger Causality Test. The results of Granger causality test have been portrayed in following Table=7.21.

Table-7.21: Pair Wise Granger Causality Test

Endogenous variables: $\begin{Bmatrix} dLnCPI_t and\ dLnM_{1t} \\ dLnCPI_t\ and\ dLnM_{2t} \end{Bmatrix}$

Null Hypothesis (H_0:$\alpha = 0$) ($dLnCPI_t and\ dLnM_{1t}$)	Lags	F-statistic	Probability
$dLnM_{1t}$ does not Granger Cause $dLnCPI_t$ $dLnCPI_t$ does not Granger Cause $dLnM_{1t}$	1	10.7724 0.0134	0.0013 0.9080
$dLnM_{1t}$ does not Granger Cause $dLnCPI_t$ $dLnCPI_t$ does not Granger Cause $dLnM_{1t}$	2	25.0991 6.18836	5.E-10 0.0027
$dLnM_{1t}$ does not Granger Cause $dLnCPI_t$ $dLnCPI_t$ does not Granger Cause $dLnM_{1t}$	3	21.6135 10.3106	2.E-11 4.E-06
$dLnM_{1t}$ does not Granger Cause $dLnCPI_t$ $dLnCPI_t$ does not Granger Cause $dLnM_{1t}$	4	8.2210 4.4006	6.E-06 0.0023
$dLnM_{1t}$ does not Granger Cause $dLnCPI_t$ $dLnCPI_t$ does not Granger Cause $dLnM_{1t}$	5	5.2248 3.4992	0.0002 0.0053
$dLnCPI_t$& $dLnM_{2t}$			
$dLnM_{2t}$ does not Granger Cause $dLnCPI_t$ $dLnCPI_t$ does not Granger Cause $dLnM_{2t}$	2	7.1088 3.9165	0.0012 0.0222
$dLnM_{2t}$ does not Granger Cause $dLnCPI_t$ $dLnCPI_t$ does not Granger Cause $dLnM_{2t}$	3	6.5207 3.7888	0.0004 0.0120
$dLnM_{2t}$ does not Granger Cause $dLnCPI_t$ $dLnCPI_t$ does not Granger Cause $dLnM_{2t}$	4	4.0642 1.7163	0.0039 0.1501

Upper part of Table-7.21 displays the Granger causality between narrow money supply (M_1) and price level, and lower part of the table shows the Granger causality between broad money supply (M_2) and price level. In the upper part of the Table-7.21, the null hypothesis "$dLnM_{1t}$ does not Granger cause $dLnCPI_t$" is strongly rejected at lag 1,2,3,4 and 5 at less than 1% level of significance as reported by F-statistic and the corresponding probability values. It means the price level is Granger caused by narrow money supply, i.e. the causality runs from narrow money supply to price level. Likewise, the null hypothesis "$dLnCPI_t$ does not Granger cause $dLnM_{1t}$" is also rejected at lag 2,3,4 and 5 at less than 1% level of significance. It implies that narrow money supply is also Granger caused by price level. It is clearly examined that there is bi-directional Granger causality between narrow money supply and price level. The change in narrow money supply has caused price level to change and change in price level has also caused narrow money supply to change. It means not only price level changes by narrow money supply but also narrow money supply changes due to the change in price level in Nepal during the study period.

From lower part of the Table-7.21, it is observed that the null hypothesis "$dLnM_{2t}$ does not Granger Cause $dLnCPI_t$" is strongly rejected at lag 2,3 and 4 at less than 1% level of significance representing that broad money supply Granger causes price level. The change in broad money supply definitely brings about the change in price level. Likewise, the null hypothesis "$dLnCPI_t$ does not Granger cause $dLnM_{2t}$" is also rejected at lag 2 and 3 at 5% level of significance, which means the change in price level definitely brings about the change in broad money supply. It is examined that not only price level is Granger caused by broad money supply but also broad money supply is Granger caused by price level. This clearly implies that there is bi-directional Granger causality between broad money supply and price level in the economy of Nepal during the study period.

7.9 Conclusion of Chapter Seven

Following conclusions are drawn from Chapter Seven.

- As reported by Johansen's Cointegration test, M_1 money supply and price level have long run equilibrium relationship with one cointegrating vector.
- The VECM with $dLnCPI_t$ as dependent variable and lagged $dLnCPI_t$ and $dLnM_{1t}$ with independent variables of equation (7.1) implies that short run shocks significantly affect the long run relationship between M_1 money supply and price level. The inflations are adjusted by 0.85% of the past five quarters' deviation from equilibrium. A ten percent increase in change of M_1 money

supply of two quarters back causes the change in price level to increase by 1.4%.

- Not only M_1 money supply causes price to change but also price is caused by price itself. A ten percent increase in change of price of four periods back causes the change in price of current time to increase by 3.38%.
- The VECM, with $dLnM_{1t}$ as dependent variable and lagged $dLnCPI_t$ and $dLnM_{1t}$ as independent variables, implies that M_1 money supplies are adjusted by 2.4% of the past five quarters' deviation from equilibrium.
- The change in M_1 money supply at current time is caused by the change in M_1 money supply of four periods back itself. A ten percent increase in change of M_1 money supply of four periods back causes the change in current M_1 money supply by 4.04%.
- A ten percent rise in change of price level of preceding period causes change in M_1 money supply of current period to increase by 2.6%.
- As reported by VECM, there is bi-directional Granger causality between M_1 money supply and price level.
- As reported by various residuals diagnostic tests such as correlogram of squared residuals, B-G LM test and heteroscedasticity test, the VECM with $dLnCPI_t$ as dependent variable and lagged $dLnCPI_t$ and $dLnM_{1t}$ with independent variables of equation (7.1) does not suffer serial/autocorrelation and heteroscedasticity problems. There is goodness of fit of the estimated VECM.
- The VECM of equation (7.1) bears the property of stability as reported by Ramsey's RESET test. This VECM is linear with no misspecification while building the model.
- The CUSUM test, CUSUM of squares test and recursive coefficient test imply that the coefficients and parameters of estimated VECM of equation (7.1) are stable.
- The M_2 money supply and price level have the long run equilibrium relationship as confirmed by Johansen's Cointegration test. There is one

cointegrating vector as indicated by maximum Eigen-value test and Trace statistic of Johansen's Cointegration test.

- The VECM with $dLnCPI_t$ as dependent variable and lagged $dLnCPI_t$ and $dLnM_{2t}$ as independent variables of equation (7.9) implies that short run shocks significantly affect the long run relationship between M_2 money supply and price level. The inflations are adjusted by 0.97% of the past five quarters' deviation from equilibrium. A ten percent increase in change of M_2 money supply of two quarters back causes the change in price level to increase by 1.2%.

- The change in price level is not only affected by the change in M_2 money supply but also by the change in price itself. A ten percent increase in change of price level of four periods back causes the change in price level at current time to increase by 4.87%.

- The VECM, with $dLnM_{2t}$ as dependent variable and lagged $dLnM_{2t}$and $dLnCPI_t$ as independent variables, shows that there is short run as well as long run equilibrium relationship between the variables under study. The short run shocks significantly affect the long run equilibrium relationship between $dLnCPI_t$ and $dLnM_{2t}$. The M_2 money supply is adjusted by 1.5% of the past five quarters' deviation from equilibrium.

- The change in M_2 money supply at current time is affected by the change in M_2 money supply itself. A ten percent increase in change of M_2 money supply at four periods back causes the change in M_2 money supply at current time by 2.08%.

- The change in M_2 money supply at current time is affected by the change in price level of two periods back. A ten percent increase in change of price of two periods back causes the current change in M_2 money supply to increase by approximately 2%.

- The VECM, with $dLnM_{2t}$ as dependent variable of equation (7.10) as reported by residuals diagnostic tests, is efficiently fitted. It does not suffer autocorrelation and heteroscedasticity problems.

- The VECM of equation (7.10) satisfies the parameter stability condition as reported by Ramsey's RESET test, CUSUM test, CUSUM of square test and Recursive coefficient test.
- The Granger causality test implies that there is bi-directional Granger causality between M_1 money supply and price level as well as M_2 money supply and price level.