CHAPTER - 9
INTERVENTION ANALYSIS THROUGH THE STUDY OF IMPULSE RESPONSE FUNCTIONS

9.1 Introduction:

The VAR model estimated in Chapter 8 consists of two endogenous variables, namely, exchange rate (E_t) and relative price level (P_t). Consequently, the model considers two types of shocks (u_{1t} and u_{2t}). Some shocks (u_{1t}) are transmitted through exchange rate channel while others (u_{2t}) are transmitted through relative price level channel. Both the endogenous variables are subject to such shocks, and these variables exhibit their responses to such shocks.

An *Impulse Response Function* traces the effects of a one-time shock to one of the innovations on current and future values of the endogenous variables concerned. Thus an *Impulse Response Function* traces the responses of a variable over time to an '*anticipated*' change in '*itself*' or other interrelated variables. Consequently, an '*Impulse Response Function*' may be used in any VAR system in order to explain the dynamic behaviour of the whole system with respect to shocks in the residuals of the time series involved.

The study in this Chapter is devoted to examining the response of exchange rate and relative price level to different types of shocks. This will enable us to examine the relative importance of these shocks in explaining variations in Rupee/Nepalese Rupee exchange rate and relative price level over the sub-period 1993:2-2006:1.

9.2 Methodological Issues Concerning Impulse Response Functions

Let y_t be any stationary variable with zero mean and finite variance. Then by the *Wold Representation Theorem* y_t must have an MA(∞) representation such that

$$y_t = b_0\varepsilon_t + b_1\varepsilon_{t-1} + b_2\varepsilon_{t-2} + \ldots\ldots\ldots\ldots \tag{9.1}$$

$$\varepsilon_t \sim GWN\ (0, \sigma^2)$$

Then (9.1) may be written as

$$y_t = (b_0 m)(\frac{1}{m}\varepsilon_t) + b_1 m(\frac{1}{m}\varepsilon_{t-1}) + b_2 m(\frac{1}{m}\varepsilon_{t-2}) + \ldots\ldots\ldots\ \ldots\ldots \tag{9.2}$$

[when m is an arbitrary constant and $\varepsilon_t \sim GWN\ (0, \sigma^2)$]

$$\text{or}\quad y_t = b_0'\varepsilon_t' + b_1'\varepsilon_{t-1}' + b_2'\varepsilon_{t-2}' + \ldots\ldots\ldots\ldots\ldots \tag{9.3}$$

where $b_i' = b_i m$, $\varepsilon_{t-j}' = \frac{\varepsilon_{t-j}}{m}(j = 0,1,\ldots\ldots.)$

and $\varepsilon_t' \sim GWN\ (0, \frac{\sigma^2}{m^2})$

Now let $m = \sigma$

Then from (9.2) we have

$$y_t = (b_0\sigma)(\frac{1}{\sigma}\varepsilon_t) + (b_1\sigma)(\frac{1}{\sigma}\varepsilon_{t-1}) + (b_2\sigma)(\frac{1}{\sigma}\varepsilon_{t-2}) + \ldots\ldots\ldots\ldots \tag{9.4}$$

$$\text{or}\quad y_t = b_0'\varepsilon_t' + b_1'\varepsilon_{t-1}' + b_2'\varepsilon_{t-2}' + \ldots\ldots\ldots\ldots \tag{9.5}$$

where $b_i' = b_i\sigma$

$$\varepsilon_t' = \frac{\varepsilon_t}{\sigma} \quad \text{and} \quad \varepsilon_{t-j}' = \frac{\varepsilon_{t-j}}{m}(j = 1,2,\ldots\ldots.)$$

and $\varepsilon_t' \sim GWN(0,1)$

Therefore, m = σ converts shocks to '*Standard Deviation Unit*' because a unit shock to ε_t corresponds to a '*One-Standard Deviation Shock*' to ε_t.

9.2.1 UNIVARIATE CASE:

Let us consider the *univariate AR(1) process* such that

$$y_t = \phi y_{t-1} + \varepsilon_t \tag{9.6}$$

$$\varepsilon_t \sim GWN(0, \sigma^2)$$

The moving average form dictated by the '*Wold Representation Theorem*' is

$$y_t = \varepsilon_t + \phi \varepsilon_{t-1} + \phi^2 \varepsilon_{t-2} + \ldots\ldots.. \tag{9.7}$$

$$\varepsilon_t \sim GWN(0, \sigma^2)$$

The equivalent representation in standard deviation unit is

$$y_t = b_0 \varepsilon_t' + b_1 \varepsilon_{t-1}' + b_2 \varepsilon_{t-2}' + \ldots\ldots\ldots. \tag{9.8}$$

$$\varepsilon_t' \sim GWN(0,1)$$

where $b_i = \phi^i \sigma$ and $\varepsilon_t' = \dfrac{\varepsilon_t}{\sigma}$

The '*Impulse Response Function*' is

$$\{b_0, b_1, b_2, \ldots\ldots\ldots\ldots.\}$$

The parameter b_0 is the *contemporaneous effect* any of a unit shock ε_t', or equivalently, a one-standard- deviation shock to ε_t. In such case $b_0 = \sigma$. Here b_0 gives the immediate effect any of the shock at time t when it hits.

Again, the parameter b_1, which multiplies ε_{t-1}', gives the effect of the shock one period later and so on. The full set of *Impulse Response Coefficients,* $\{b_0, b_1, b_2, \ldots\ldots\ldots\}$ tracks the complete dynamic response of y to the shock.

9.2.2 MULTIVARIATE CASE:

Let us consider the VAR(2,1) system such that

$$y_{1t} = \phi_{11} y_{1t-1} + \phi_{12} y_{2t-1} + \varepsilon_{1t} \tag{9.9}$$

$$y_{2t} = \phi_{21} y_{1t-1} + \phi_{22} y_{2t-1} + \varepsilon_{2t} \tag{9.10}$$

where $\varepsilon_{1t} \sim GWN(0, \sigma^2_1)$

$\varepsilon_{2t} \sim GWN(0, \sigma^2_2)$

$\text{cov}(\varepsilon_1, \varepsilon_2) = \sigma_{12}$

The *standard moving average representation* are

$$y_{1t} = \varepsilon_{1t} + \phi_{11}\varepsilon_{1t-1} + \phi_{12}\varepsilon_{2t-1} + \ldots\ldots\ldots\ldots \tag{9.11}$$

$$y_{2t} = \varepsilon_{2t} + \phi_{21}\varepsilon_{1t-1} + \phi_{22}\varepsilon_{2t-1} + \ldots\ldots\ldots\ldots \tag{9.12}$$

where $\varepsilon_{1t} \sim GWN(0, \sigma^2_1)$

$\varepsilon_{2t} \sim GWN(0, \sigma^2_2)$

$\text{cov}(\varepsilon_1, \varepsilon_2) = \sigma_{12}$

The multivariate analog of the '*Univariate Normalization*' by σ is called the '*Normalization by the Cholesky Factor*'.

The resulting VAR moving average representation has a number of useful properties that parallel the univariate case precisely.

First, the innovations of the transformed system are in standard deviation units.

Second, the current innovations in the normalized representation have non-unit coefficients.

Third, in the first equation there is one current innovation, ε_{1t}. But the second equation contains both the current innovations. Thus the ordering of the variable can matter a lot. *Consequently, in higher-dimensional VARs, the equation that appears first in the ordering contains only one current innovation,* ε'_{1t}. *The second equation contains two* *current innovations namely,* ε'_{1t} *and* ε'_{2t}. *The third equation has three current innovations like* ε'_{1t}, ε'_{2t}, *and* ε'_{3t} *and so on.*

If y_1 is ordered first, the *normalization representation* is

$$y_{1t} = b^{\circ}_{11}\varepsilon'_{1t} + b'_{11}\varepsilon'_{1t-1} + b'_{2}\varepsilon'_{2t-1} + \ldots\ldots\ldots\ldots \tag{9.13}$$

$$y_{2t} = b^{\circ}_{21}\varepsilon'_{1t} + b^{\circ}_{22}\varepsilon'_{2t} + b'_{21}\varepsilon'_{1t-1} + b'_{22}\varepsilon'_{2t-1} + \ldots\ldots \tag{9.14}$$

where $\varepsilon'_{1t} \sim GWN(0,1)$

$\varepsilon'_{2t} \sim GWN(0,1)$

$\operatorname{cov}(\varepsilon'_{1t}, \varepsilon'_{2t}) = 0$

Alternatively, if y_2 is ordered first, then the normalization representation is

$$y_{2t} = b^{\circ}_{22}\varepsilon'_{2t} + b'_{21}\varepsilon'_{1t-1} + b'_{22}\varepsilon'_{2t-1} + \ldots\ldots\ldots\ldots\ldots \tag{9.15}$$

$$y_{1t} = b^{\circ}_{11}\varepsilon'_{1t} + b^{\circ}_{11}\varepsilon'_{2t-1} + b'_{11}\varepsilon'_{1t-1} + b'_{12}\varepsilon'_{2t-1} + \ldots\ldots\ldots \tag{9.16}$$

where $\varepsilon'_{1t} \sim GWN(0,1)$

$\varepsilon'_{2t} \sim GWN(0,1)$

$\operatorname{cov}(\varepsilon'_{1t}, \varepsilon'_{2t}) = 0$

After normalizing the system, four sets of *'Impulse Response Functions'* are computed for the bivariate model. These are

i. response of y_1 to a unit normalized innovation to y_1 given by y_1,

$[b^{\circ}_{22}, b^{1}_{22}, b^{2}_{22}, \ldots..]$..

ii. response of y_1 to a unit normalized innovation to y_2 given by y_2,

$[b^{1}_{12}, b^{2}_{12}, \ldots\ldots\ldots\ldots]$.

iii. response of y_2 to a unit normalized innovation to y_2, given by

$[b^{\circ}_{22}, b^{1}_{22}, b^{2}_{22}, \ldots..]$.

iv. response of y_2, to a unit normalized innovation to y_1, given by

$$[b^{\circ}_{21}, b^{1}_{21}, b^{2}_{21}, \ldots\ldots].$$

9.3 Impulse Response Functions for Exchange Rate (E_t)

The relevant *Impulse Response Functions* of E_t in response to impulses, transmitted through the channels of exchange rate (E_t) and relative price level (P_t), are being presented through the Figures (9.1) and (9.2). The numerical values of these responses across different forthcoming periods are given by the Table 9.1.

Table: 9.1

Impulse Responses of Exchange Rate (E_t) to

Cholesky (d.f. Adjusted) One S.D. E_t and P_t Innovations (±2S.E)

Response of Et:		
Peri...	Et	Pt
1	0.004853	0.000000
	(0.00053)	(0.00000)
2	-0.003201	5.55E-05
	(0.00084)	(0.00068)
3	0.000102	-0.000889
	(0.00121)	(0.00086)
4	0.001504	0.000702
	(0.00125)	(0.00089)
5	-0.000767	-0.001429
	(0.00125)	(0.00086)
6	-0.000241	0.000350
	(0.00120)	(0.00074)
7	0.000364	0.000351
	(0.00118)	(0.00072)
8	-0.000154	-0.000374
	(0.00109)	(0.00065)
9	-0.000241	-0.000457
	(0.00105)	(0.00064)
10	0.000397	0.000303
	(0.00107)	(0.00056)
11	-0.000190	0.000186
	(0.00098)	(0.00055)
12	-0.000216	-0.000250
	(0.00091)	(0.00043)
13	0.000221	-9.49E-05
	(0.00099)	(0.00047)
14	7.00E-05	7.15E-05
	(0.00089)	(0.00042)
15	-0.000178	9.73E-05
	(0.00091)	(0.00042)
16	-2.25E-06	-3.01E-05
	(0.00091)	(0.00038)
17	9.84E-05	-9.62E-05
	(0.00086)	(0.00033)
18	-1.60E-05	-6.18E-06
	(0.00090)	(0.00040)
19	-3.51E-05	9.78E-05
	(0.00088)	(0.00034)
20	-6.82E-06	7.98E-06
	(0.00086)	(0.00040)

Figure 9.1

Impulse Response of E_t to Cholesky One S.D. E_t Innovation (±2S.E)

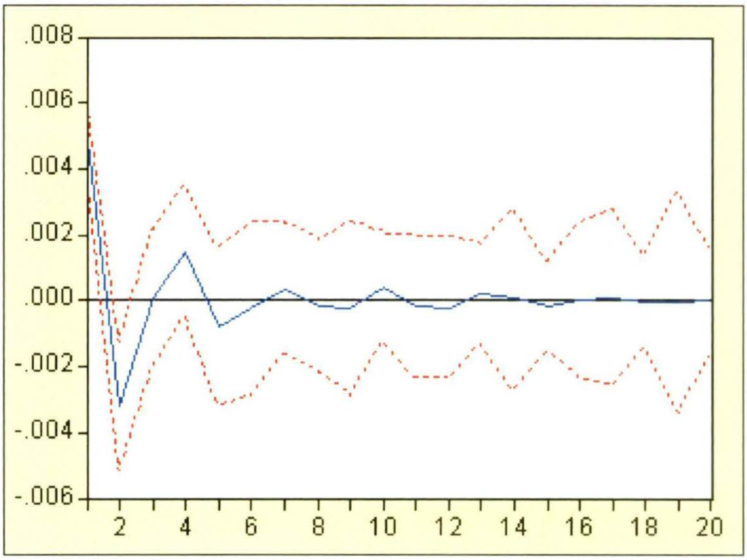
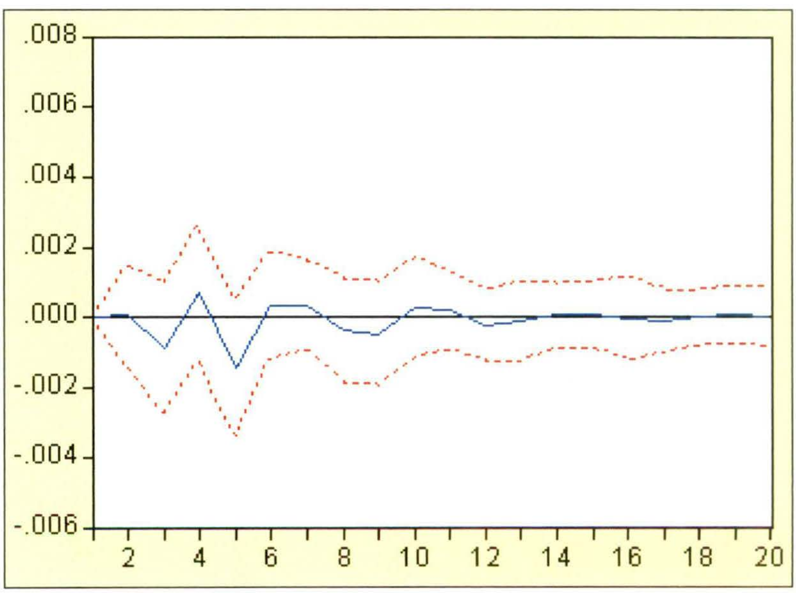


Figure 9.2

Impulse Response of E_t to Cholesky One S.D. P_t Innovation (±2S.E)



9.4 Explanation of Exchange Rate (E_t) Dynamics Through Impulse Response Functions

9.4.1 Observations From the Figure 9.1 and Table 9.1

It is observed from the Figure 9.1 and Table 9.1 that, following a positive impulse transmitted through the exchange rate channel, exchange rate (E_t)

i. responds immediately by rising above the long run base at t=0.
ii. declines subsequently for the next two periods.
iii. responds with a rise at t=3 period followed by almost a steady decline to collapse on the equilibrium base line.

9.4.2 Observations From the Figure 9.2 and Table 9.1

The figure 9.2 and Table 9.1 show that, following a positive impulse transmitted through the relative price level channel, exchange rate

i. exhibits very delayed response. Until t=10 there was no appreciable variations in exchange rate above its equilibrium base.
ii. exhibits minimal variations since t =11 period until it collapses on its equilibrium base at t =14.

9.5 Economic Interpretations of the Findings in Section 9.4

It, therefore, appears from the findings in Section 9.4 that

(a) response of exchange rate (E_t) to any positive impulse transmitted through the exchange rate channel.

i. is *immediate* and marked by a *rise* above its long run equilibrium base.
ii. is significant for the next five periods (quarters). Henceforth, it collapses on the equilibrium base.

Thus any variations in E_t above its long run equilibrium base are mainly due to those in previous period exchange rate.

(b) response of E_t to any positive impulse, transmitted through the relative price level channel

i. is *not immediate* indicating lagged adjustments of exchange rate to relative price variations.

ii. becomes perceptible as an upward adjustment of exchange rate if such impulses could sustain for 10 periods. In that event exchange rate exhibits a rise over its long run value though it ultimately collapses on the long-run equilibrium base within next four periods (quarters).

These features of exchange rate responses to relative price innovations testify for '*Granger Causality*' running from relative price level to exchange rate.

9.6 Impulse Response Functions For Relative Price Level (P_t)

The relevant *Impulse Response Functions* of P_t in response to impulses transmitted through the channels of exchange rate (E_t) and relative price level (P_t) are being presented through the Figures (9.3) and (9.4). The numerical values of these responses across different forthcoming periods are given by the Table 9.2.

Figure 9.3

Impulse Response of P_t to

Cholesky One S.D. E_t Innovation (±2S.E)

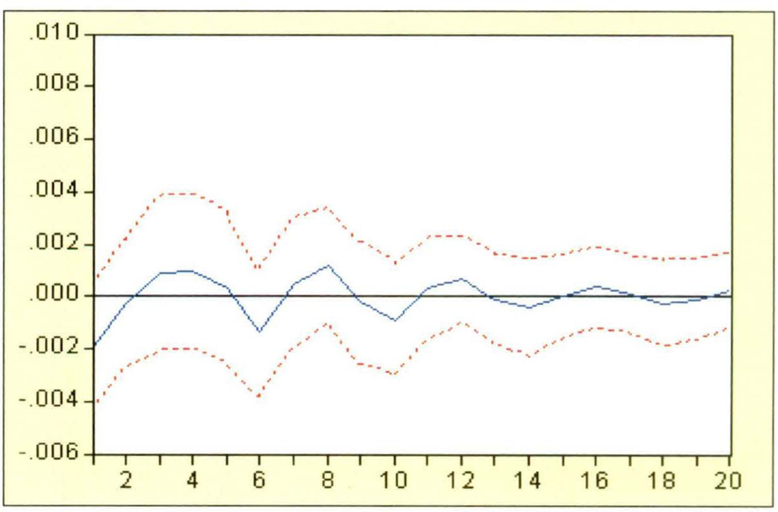


Figure 9.4

Impulse Response of P_t to Cholesky One S.D. P_t Innovation (±2S.E)

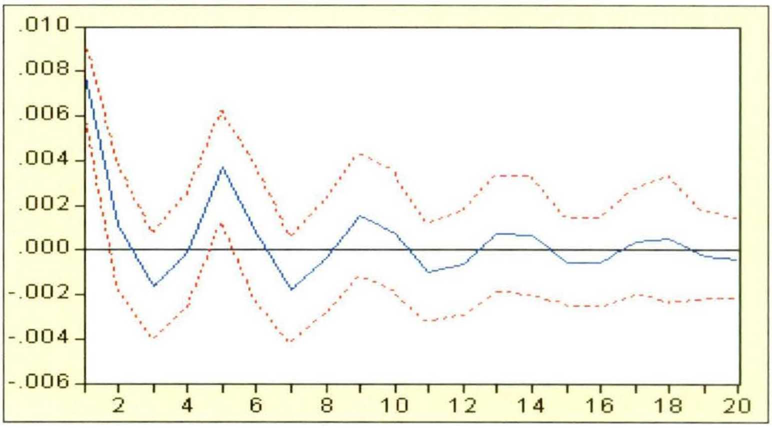


Table: 9.2

Impulse Response of Price Level (P_t) to Cholesky (d. f. Adjusted) One S.D. E_t and P_t Innovations (±2S.E)

Response of Pt:

Peri...	Et	Pt
1	-0.001947	0.007862
	(0.00113)	(0.00069)
2	-0.000257	0.001106
	(0.00129)	(0.00122)
3	0.000885	-0.001613
	(0.00127)	(0.00116)
4	0.000930	-0.000102
	(0.00126)	(0.00115)
5	0.000319	0.003722
	(0.00122)	(0.00126)
6	-0.001373	0.000824
	(0.00134)	(0.00121)
7	0.000485	-0.001764
	(0.00114)	(0.00133)
8	0.001204	-0.000319
	(0.00114)	(0.00122)
9	-0.000203	0.001530
	(0.00100)	(0.00133)
10	-0.000898	0.000748
	(0.00096)	(0.00111)
11	0.000276	-0.001007
	(0.00093)	(0.00134)
12	0.000670	-0.000607
	(0.00087)	(0.00106)
13	-0.000122	0.000741
	(0.00089)	(0.00139)
14	-0.000447	0.000659
	(0.00095)	(0.00096)
15	8.11E-06	-0.000531
	(0.00078)	(0.00148)
16	0.000356	-0.000568
	(0.00088)	(0.00088)
17	6.41E-05	0.000379
	(0.00085)	(0.00156)
18	-0.000277	0.000490
	(0.00090)	(0.00076)
19	-9.68E-05	-0.000249
	(0.00079)	(0.00167)
20	0.000227	-0.000409
	(0.00088)	(0.00074)

9.7 Explanation of Relative Price Level (P_t) Dynamics Through Impulse Response Functions

9.7.1 Observations From the Figure 9.3 and Table 9.2

Figure 9.3 and Table 9.2 show that, following a positive impulse transmitted through exchange rate (E_t) channel, relative price level (P_t)

i. exhibits a delayed response.
ii. exhibits insignificant damped oscillations around the long-run equilibrium level and it collapses on its long-run equilibrium base before-long.

9.7.2 Observations From the Figure 9.4 and Table 9.2

Figure 9.4 and Table 9.2 show that, following a positive impulse transmitted through relative price level(P_t) channel, relative price level (P_t)

i. responds immediately (at $t = 0$) by rising above its long-run equilibrium base.
ii. exhibits pronounced but damped oscillations for successive periods (until $t = 20$ periods).

9.8 Economic Interpretations of the Findings in Section 9.7

It appears from the findings in Section 9.7 that

(a) response of relative price level (P_t) to any positive impulse transmitted through exchange rate channel

i. is delayed and insignificant.
ii. is short-lived by nature since relative price level does not exhibit any adjustment above its long-run equilibrium base at all.

These features of the responses of relative price level to exchange rate impulses testify for the '**absence of Granger Causality**' running from exchange rate (E_t) to relative price level (P_t).

(b) responses of relative price level (P_t) to any positive impulse transmitted through relative price level (P_t) channel

i. are immediate marked by a rise in its value above the long-run equilibrium base.
ii. indicate that such upward adjustments were short-lived since it quickly collapsed on the long-run equilibrium base.

All these features testify for the fact that short-run variations in relative price level above its long-run equilibrium base are mainly due to variations in the price levels prevailing in the countries concerned. Such short-run variations are not linked to those in exchange rates.

9.9 Overview of the Findings From the Study with Impulse Response Functions

These findings give forth some important features of responses of exchange rate (E_t) and relative price level (P_t) to different types of shocks. These are as follows:

(a) Shocks, transmitted through the relative price level channels, induce significant responses from exchange rate. This testifies for the ***'Granger Causality'*** *running from relative price level to exchange rate.*

(b) Relative price level (p_t) exhibits meagre and scanty response to shocks, transmitted through exchange rate channel. This confirms the ***'absence of Granger Causality'*** *running from exchange rate (E_t) to relative price level (P_t).*

(c) Relative price level(P_t) exhibits appreciable responses to shocks, transmitted through relative price level channel. Such responses are marked by temporary upward adjustment of relative price level (P_t) above its long-run equilibrium base. Consequently, these shocks appear to be ***'short-lived'***.