EXCHANGE RATE AND PURCHASING POWER PARITY: WITH SPECIAL REFERENCE TO INDIA & NEPAL

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CHAPTER - 1
INTRODUCTION

1.1 Introduction:

The decade of 1970s brought in a turning point in the realm of international economics and finance. The Bretton Woods System broke down and flexible exchange rate system replaced the fixed exchange rate system in 1970s. Determination of exchange rates became the centre-price of deliberations in international economics while the management of balance of payments became almost a non-entity. Consequently, attention of economists was diverted from the Balance of Payments problems to issues relating to exchange rate dynamics. Variability of major world currencies in early seventies drew the attention of economists and they proceeded to provide theoretical explanations for such empirical phenomena. Consequently, over the last three decades a large number of theories on exchange rate grew up. On the other hand, the issues of dynamic adjustment of balance of payments were relegated to the background.

The important theories of exchange rate, developed during the last three decades which excited the imaginations of economists include *Purchasing Power Parity Theory, Portfolio Balance Model, Asset Market Model, Covered and Uncovered Interest Parity Theories, Currency Substitution Theory and Monetary Approaches to Exchange Rate (MAER) Theory.*

The most exciting feature of this period is the growth of renewed interest of economists in the '*Purchasing Power Parity Doctrine*'. As a matter of fact, '*Purchasing Power Parity*' is almost an invariable ingredient of the macroeconomic models of exchange rate whether by itself or in combination with other equilibrium conditions. Thus the '*Purchasing Power Parity Theory*' has emerged as an influential theory of the determination of the exchange rate since 1970s.

The '*Purchasing Power Parity Theory*' is theoretically attractive no doubt. But the empirical support for PPP is mixed. Some authors find in favour of PPP, while others do not. Yet the research on PPP is extensive. That so much research has been reported on this subject indicates, in past, a reluctance to reject PPP, at least in the long-run. The present study is an attempt in this direction with an objective of examining how far the Rupee/Nepalese rupee exchange rates conformed to the '*Purchasing Power Parity Doctrine*' over the period 1976:1-2006:1.

1.2 Purchasing Power Parity: Meaning, Importance in International Trade

1.2.1 Purchasing Power Parity: Meaning

Purchasing Power Parity states that prices of the same good in different countries with their own currencies should be the same when the domestic price of the good is converted to a common currency. Thus *PPP theory* establishes the '*Law of One Price*'(LOOP) across trading nations.

1.2.2 Absolute PPP: Single Good Case

If there was just one internationally traded good with domestic and foreign prices, p_{1t} and p^*_{1t} respectively, then the *PPP exchange rate* (e_t) is

$$e_t = \frac{p_{1t}}{p^*_{1t}} \tag{1.1}$$

This is the Absolute Version of PPP (APPP).

1.2.3 Absolute PPP: Multiple Good Case

When there are multiple goods, PPP states that the nominal exchange rate at time t, E_t, should be equal to the ratio of domestic price level (index) P_t to the foreign price level (index) p^*_t such that

$$e_t = A\frac{P_t}{P^*_t} \tag{1.2}$$

with A = 1,

$$e_t = \frac{P_t}{P^*_t}$$

and this is also known as the *Absolute Version of PPP (APPP).*

1.2.4 Relative Purchasing Power Parity(RPPP):-

If $A \neq 1$, then this is the Relative Version of PPP (RPPP). Even if $A \neq 1$, RPPP indicates that the elasticity of nominal exchange rate with respect to relative price is unity. In such case, 1% change in the ratio of price indices in the home and overseas countries will lead to 1% change in the nominal exchange rate.

Now let $A \neq 1$, Then from equation (1.2) we get

$$\log E_t = \log A + \log p_t - \log p^*_t$$

Differentiating with respect to t,

$$\frac{1}{E_t}\frac{dE_t}{dt} = \frac{1}{p_t}\frac{dp_t}{dt} - \frac{1}{p^*_t}\frac{dp^*_t}{dt}$$

$$\text{or } \dot{E}_t = \dot{\pi}_t - \dot{\pi}^*_t \qquad (1.3)$$

$$\text{or } \dot{\pi}_t = \dot{E}_t + \dot{\pi}^*_t \qquad (1.4)$$

where $\dot{\pi}_t$ and π^*_t are the inflation rates at domestic and foreign countries respectively.

Equation (1.4) states that the home country's inflation rate ($\dot{\pi}_t$) will be equal to the sum of the inflation rate π^*_t and the rate of currency depreciation. Again equation (1.3) states that rate of domestic currency depreciation equals the rate by which domestic inflation rate exceeds that in the foreign country.

Thus the Relative PPP Hypothesis basically states that *one country's inflation rate can only be higher (lower) than another's to the extent that its exchange rate depreciate (appreciates).*

It may be noted that APPP holds when A = 1. In such case also equation (1.3) and (1.4) hold. In that case

$$\log E_t = \log A + \log p_t - \log p^*_t$$

$$or \log E_t = \log p_t - \log p^*_t \qquad [\text{ since } \log 1 = 0] \tag{1.5}$$

Differencing with respect to t, we have

$$\frac{1}{E_t}\frac{dE_t}{dt} = \frac{1}{p_t}\frac{dp_t}{dt} - \frac{1}{p^*_t}\frac{dp^*_t}{dt}$$

$$\text{or } \dot{E}_t = \dot{\pi}_t - \dot{\pi}^*_t \tag{1.6}$$

Thus whether A = 1 or $A \neq 1$, RPPP Doctrine is always valid. This accounts for the widespread use of RPPP in economic literature.

1.2.5 Real Exchange Rate:

Real exchange rate (RE_t) is such that

$$RE_t = E_t . \frac{P^*_t}{P_t} \tag{1.7}$$

It is the ratio of the foreign price level, converted to domestic currency units, to the domestic price level.

If $RE_t > 1$, the domestic currency is *undervalued.*

If $RE_t < 1$, the domestic currency is *overvalued.*

If $RE_t = 1$, domestic currency is *just valued* and APPP holds.

However, in RPPP case the real exchange rate is constant and any changes in domestic and foreign price level must be matched by an exactly compensating movement in the nominal exchange rate.

Given equation (1.7) we have

$$\log RE_t = \log E_t + \log p^*_t - \log p_t \tag{1.8}$$

Differentiating with respect to t, we get

$$\frac{1}{RE_t}\frac{dRE_t}{dt} = \frac{1}{E_t}\frac{dE_t}{dt} + \frac{1}{p^*_t}\frac{dp^*_t}{dt} - \frac{1}{p_t}\frac{dp_t}{dt}$$

$$= \dot{E}_t + \dot{\pi}^*_t - \dot{\pi}_t$$

$$= \dot{E}_t - (\dot{\pi}_t - \dot{\pi}^*_t)$$

$$= \dot{E}_t - \dot{E}_t \quad \text{[from equations (1.3) and (1.4)]}$$

$$= 0 \tag{1.9}$$

Thus real exchange rate is always constant whether APPP holds or not. In case of APPP, $RE_t = 1$ and in case of RPPP, RE_t is a constant (A) where $A \neq 1$.

1.2.6 Importance of PPP in Economic Theory

Purchasing Power Parity has become an attractive theory of exchange rate on the ground that it has a substantial commonsense appeal. It compares the common currency price of identical goods produced in different countries. In case of difference between such prices, arbitrage would occur leading to the removal of the difference in the common currency price by adjustment in nominal exchange rate so that real exchange rate remains unchanged.

As a matter of fact, a key reason behind the popularity of the PPP as the theory of exchange rate is the possibility of 'arbitrage' in commodities. According to PPP, if an imported commodity, identical to any product produced domestically, can be bought at a price, when converted is cheaper than the domestically produced commodity, then it is possible to make profit by trading in that good. If trading continues, then increased demand would raise the price of the imported goods. Finally, arbitrage will establish the *'Law of One Price' (LOOP).*

1.2.7 Importance of PPP in the Expansion of International Trade:

If APPP or RPPP holds, then real exchange rate will remain constant. Consequently, the change in real exchange rate will be zero. This indicates, if exchange rate once ensures long-run equilibrium for the trading nations, then the real exchange rate will remain constant and '*neutral*'. Consequently, exchange rate movements over time, under PPP, would ensure that terms of trade would not favour any trading partner against another. Thus exchange rates, under PPP, never hinders the growth of trade among participating trading partner nations. PPP, therefore, promotes trade and opens up scope for expansion of trade among trading partners.

1.3 Importance of PPP in Trade Among South Asian Countries:

South Asian Countries have been stressing upon, since 1980s, developing stronger economic and culture relations among themselves. The establishment of SAARC in 1987 was the concrete outcome of such effort. With the passage of time, the members of the SAARC put importance on extension of bilateral and multilateral trade relations among themselves. Consequently, trade practices were liberalized, and trade restrictions in many cases have been removed. Reciprocal lifting of tariffs followed in and trade relations were extended as well as strengthened.

India, as a founder leader of the SAARC, further floated the 'Look East' doctrine in order to usher in growing trade relations with South East Asian Countries also. SAFTA is becoming a reality which opened up a scope for expansion of trade among South and South-East Asian Countries.

India, as a leader of the SAARC and a big partner of trade, could expect flourishing trade relations with other South –Asian Countries provided the terms of trade were 'neutral'. If not, then the argument of 'dominant bias' as propounded in '*Prebisch-Singer Hypothesis*' might crop up. This would be detrimental for the expansion of Indian trade relation with other South-Asian Countries.

This indicates that for the expansion of trade, *neutral 'terms of trade'* in exchange is urgently required and PPP can assure such '*neutrality*' in terms of trade. Consequently, even in case of expansion of trade among South Asian Countries, quoted exchange rates among currencies concerned are required to conform to the PPP doctrine.

1.4 Importance of PPP in Indo-Nepalese Trade:

Nepal is a land-locked country and a close neighbour of India. Nepal also happens to be one of the closest political allies for India. Trade relation between India and Nepal had existed more than five hundred years before the Christian era began. By the first half of seventh century when the *Lichhavis* were ruling India, Nepal emerged as a country of transit trade between India and Tibet. During the British Period and even to-day the borders between these two countries are open. Nepal depends on India for most of its importables and India is the country of transit trade between Nepal and her other trade partners.

Given these historical, economic and political relations between India and Nepal, it becomes pertinent to see if expansion of Indo-Nepalese trade in desired proportions would be supported by the '*terms of trade*' arising out of the exchange rates quoted between Rupee and Nepalese Rupee.

In 1990-91 the age-old Indo-Nepalese trade-relation, however, suffered a jolt when Nepal insisted on a bulk diversion of trade form India to China. Such a snag in Indo-Nepalese trade was considered unprecedented. This move of Nepal, with some political connotations, was accounted for by *unfavourable terms of trade* which Nepal experienced in her trade with India at this time.

This indicates that the expansion of Indian trade with other South-Asian Countries like Nepal may be possible and viable provided *terms of trade* remain '*neutral*' over time. Herein comes the role of PPP in the fixation of exchange rate of Indian currency (Rupee) vs Nepalese Currency (Nepalese Rupee). If such quoted exchange rates conform to PPP, terms of trade will be *neutral* contributing to unhindered expansion of Indo-Nepalese trade. Therefore, it becomes pertinent for us to examine the system of exchange rate determination in both the countries in the post Bretton Woods System period.

1.5 Exchange Rate Management in India Since 1971

The *Bretton Woods System* broke down in 1971. This paved the way for the worldwide replacement of *fixed exchange rate system* with *flexible exchange rate system.* In December, 1971 Indian Rupee was linked to Pound-Starling. Under *Smithsonian Agreement* of 1971 value of Starling was fixed in terms of US dollar and, therefore, the value of rupee was stable against dollar. However, in September, 1975 the Reserve Bank of India gave up policy of '*Single Currency Peg*' and, instead, value of rupee was pegged to a '*Basket of Currencies.*

The '*Pegged Exchange Rate System*' was given up in 1991 when India moved towards the adoption of the *Market Determined Exchange Rate System. Liberalized Exchange Rate Management System* (LERMS) initially replaced the *Pegged Exchange Rate System* in 1992. Under *LERMS* initially a *Dual Exchange Rate System* was followed.

Under *Dual Exchange Rate System* all foreign exchange receipts of current accounts transaction were required to be surrendered to the authorized dealers for conversion into domestic currency. 60% of the receipts were converted at the market rate while the rest 40% of the receipts were converted at the RBI quoted official rate. The dealers had to surrender the 40% of their purchase of the foreign currencies to the Reserve Bank of India and they retained the rest 60% of the foreign exchange for selling in the free market. The *Dual Exchange Rate System* was replaced by the '*Unified Exchange Rate System*' in 1993. India finally established the era of *flexible exchange rate system.* Rupee became fully convertible on all current accounts transactions in 1994 and with this *fully flexible exchange rate regime* came into force in Indian economy.

1.6 Evolution of Exchange Rate System In Nepal – A Brief History

Nepal was divided into various states until 1769 and these states had their own metallic currencies. Gold and silver coins were used as means of exchange. Nepal was unified into a state in 1769 and since then Nepal did have a single currency. Evolution of Nepal's exchange rate policy began only after the unification of Nepal in 1769. Over a period of 240 years, Nepal moved from having '*no defined exchange rate*' policy to the *market* *determined* system. Over this period Nepalese exchange rate system passed through eight different phases as stated below.

i. Phase 1(1769-1834): Floating Exchange Rate System

Prior to the establishment of Nepal Rastra Bank, many foreign currencies along with the Nepalese currency were in circulation in Nepal. The exchange rate between Nepalese currency and any other currency in circulation was determined by market forces. Fluctuations in demand and supply of currencies were reflected in the floating rates. However, these currencies were metallic and their values were based on metallic content. It continued until 1834.

ii. Phase II (1835-1956): Dual Currency System

Nepal experienced dual currency system since 1835 to 1956 when both Nepalese currency and Indian currency were in circulation in Nepal. Indian paper currency was acceptable for heavy transactions. Nepalese currency dominated in Kathmandu while Indian currency was heavily circulated in Terai region close to the Indo-Nepal boarder. However, in hilly regions barter system still prevailed.

iii. Phase III (1957-1959): Pegged Exchange Rate System

Nepalese currency-Indian currency exchange rates experienced extreme volatility between 1951 and 1956. Such volatility had adverse effects on the confidence of Nepalese currency and, thereby, on Nepalese economy. Consequently, the dual system was abolished in 1957 under **Nepal Currency Circulation and Expansion Act.** Since then the Nepalese currency has been in circulation as a '*Single Currency*'. Nepalese currency was then pegged to Indian currency at the fixed rate of 160 NC to 100 IC. This rate was revised several times thereafter.

iv. Phase IV (1960-1973): Dual Exchange Rate Phase

In accordance with the *Bretton Woods System*, Nepal Rastra Bank pegged 1 USD to 7.60 Nepalese currency in 1960. Thus Nepal adopted a '**Dual Pegged System**' when Nepalese currency was pegged to US dollar (7.60NC= 1USD) and again Nepalese currency was pegged to Indian currency. This period extended from 1960 to 1973.

v. Phase V (1973-1975): Discrete Pegging Phase

After the collapse of Bretton Woods System in 1971, Nepal revised the pegging rates occasionally over the period 1973- 76, between Nepalese currency and US dollar. At the same time exchange rates between Nepalese currency and Indian currency were revised.

vi. Phase VI (1976-1982): Regular Crawling Peg Phase

Between 1976 and 1982 Nepal practiced *Crawling Peg System* with regular revision of *peg rates* of Nepalese currency vis-à-vis US dollar and Indian currency (Rupee).

vii. Phase VII (1983-1992): Basket of Currency Pegging System

Nepal adopted the ***Basket of Currency System*** from 1983. Since June 1, 1983, Nepalese currency was linked with 'Basket of Currencies' which included number currencies with '*trade weights*'. However, the exact composition of basket of currencies had not ever been divulged by Nepal Rastra Bank. Indian currency was also included in the basket of currency. Consequently, Rupee/Nepalese rupee rates also changed on daily basis during this period. This practice continued until 1992.

viii. Phase VIII (1993): Market Determination Phase

Basket of Currency System was discarded in 1992 and Nepalese currency was floated according to the demand for and supply of relevant currencies in the market since 1993. However, the system was '*Managed Float System*' by nature.

1.7 Objective of the Study

The objective of the present study is to investigate into the nature of Rupee/Nepalese Rupee exchange rate variations over the period 1976:1-2006:1 and to examine if these exchange rates were in conformity with the '*Purchasing Power Parity Doctrine*' at all. More specifically, the objective of the study is to examine.

i. the '*stationarity*' and *integrability*' of Rupee/Nepalese Rupee exchange rate and relative price level time series over the period of study.
ii. if any long-run relationship between these variables did exist.
iii. if the long-run relations, in the event of its existence, were 'stable'.
iv. the nature of the causal relationship between the variable concerned.
v. the responses of these variables to different types of endogenous shocks.
vi. how far the causal relationships, if any, remained invariant under the '*frequency domain*' study.

1.8 Chapter Specification

The study consists of the following Chapters.

Chapter 2 presents the survey of relevant literature and provides the theoretical as well as empirical findings on the relationship between exchange rate and relative price level.

Chapter 3 deals with the nature, source of datasets, period of the study and methodological issues.

Chapter 4 is devoted to the study of '*stationarity*' and '*integrability*' of the relevant time series.

Chapter 5 enquires into the '*cointegration*' between Rupee/Nepalese Rupee exchange rates and relative price levels over the period of study. The study on '*Cointegration*' provides a scope for examining if *Purchasing Power Parity Doctrine* were operative during the period of study.

This chapter also presents the identification of two sub-periods in the historical dataset on the basis of structural shift in the relation between exchange rates and relative price level. Consequently, the study of '*stationarity*' and '*integrability*' on the time series concerned for two different sub-periods would be taken up.

Chapter 6 is devoted to examine the existence of long-run relationship between exchange rate and relative price level in two different sub-periods. This involves the study of '*cointegration*' for the confirmation of RPPP in any of the sub-period identified.

The existence of long-run relationship between exchange rate and relative price level in the sub-period 1993:2- 2006:1 will be confirmed.

Chapter 7 presents the study on the *dynamics of short-run shocks* and the *stability* of the long-run relationship between the variables in the sub-period 1993:2-2006:1.

Chapter 8 is devoted to the examination of the long-run relationship between Rupee/Nepalese Rupee exchange rate and relative price level in the sub-period 1993:2-2006:1 through the study of an *Unrestricted Structural VAR Model.* This allows us to examine the nature and direction of *Granger Causality* between the variables concerned over the period 1993:2-2006:1.

Chapter 9 presents the '*Intervention Analysis*' through the study of the *Impulse Response Functions* of the endogenous variables in the *Unrestricted Structural VAR Model.*

Chapter 10 presents the *Intervention Analysis* through the study of the '*Variance Decomposition*' of *Forecast Errors* of the endogenous variables concerned.

Chapter 11 is devoted to the study of the nature and direction of *Granger Causality* between exchange rate and relative price level over the period 1993:2-2006:1 through the study of an appropriate *Restricted VAR Model.*

Chapter 12 presents the *Spectral Analysis* for the confirmation of '*Granger Causality*' between the variables concerned over the period 1993:2-2006:1. Thus the '*Time Domain Analysis*' is being supplemented with the '*Frequency Domain*' study.

Chapter 13 presents the *Summary, Conclusions* and *Policy Implications* of the study.

CHAPTER - 2
REVIEW OF LITERATURE

2.1 Introduction:

One of the most provocatively debated issues in international macroeconomic literature pertains to whether or not *Purchasing Power Parity* (PPP) holds across borders. The parity condition is the core of many theoretical and empirical models of exchange rate determination. As a matter of fact, the pervasiveness of PPP has gone hand in hand with the literature on the empirical tests of the theory. A plethora of studies has enriched the economic literature on the validity of PPP. Such studies originated in the 16^{th} century and are still continuing in the 21^{st} century. However, the evidences in favour of the PPP are mixed by nature.

The idea of Purchasing Power Parity Theory has been traced to the 16^{th} century. **Salamanca School** of Spain (Officer, 1982). At that time, PPP was an indicator not only of integration of the Spanish and outside economies but also of the importance of monetary influences on exchange rate.

Salamanca invention of PPP theory relates to their empirical observations of the following causal chains:

i. Spain received large inflow of gold and silver from the New World.
ii. Consequently, the Spanish money stock increased.
iii. The Spanish price level also increased.
iv. Exchange rates had become unfavourable to Spain.

Thus exchange rate was found to be inversely and proportionately related to the Purchasing Power of currencies concerned. This led to the formation of the crude form the PPP in the 16^{th} century.

The PPP theory, in its modern form, is credited to **Gustav Cassel,** a Swidish economists. He developed and popularized its empirical version in 1920s (Rogoff, 1996). Cassel held that the nominal exchange rate should reflect the purchasing power of one currency against another. He was of the view that a purchasing power exchange rate existed between any two currencies and such purchasing power could be measured by the reciprocal of one country's price level against another. He concluded his theory with the proposition that exchange rate must adjust to ensure that the '*law of one price*' must hold internationally for identical bundle of goods.

2.2 Review of Theoretical Developments:

In the twentieth century economists reconsidered the PPP Doctrine and provided several theoretical platforms for the theory. Some of the important theoretical works are being cited below.

Officer (1984) considers PPP as a flow model since it traces the flow of goods and services through the current accounts in order to determine the exchange rate.

Taylor (1988) holds that free trade is possible between two countries only when equilibrium real exchange rates remain constant over time. In that case nominal exchange rate movements tends to offset relative price movements. This is possible when the nominal exchange rate between currencies of two countries equals the ratio of price levels in the two countries concerned. Thus PPP sets the basis of free trade among countries.

Protopapadakis and Stoll (1986) hold that existence of arbitrage is the driving force behind the PPP. However, commodity arbitrage takes time. Consequently, the theoretical exchange rates and commodity prices in the '*Law of One Price' (LOOP) are forward or future prices and not spot prices.* This means that study on PPP must involve the examination of the relation between exchange rates and the ratio of forward or future prices. They further hold that use of the spot prices instead of forward or future prices would generally lead to the failure of PPP.

Clark, et al (1994) points out that many countries usually undertake collective measures on their exchange rates on the basis of inflation differentials with trading partner countries. While doing so, countries derive the *Fundamental Equilibrium Exchange Rates* (*FEERs*) from the medium term internal and external balance conditions. These *FEERs* are used to detect misalignment in a country's real exchange rate. Consequently, it has become easier to compute PPPs. However, the empirical studies have not yet been taken up to analyse the deviations between *FEERs* and PPPs. Such analysis is expected to provide a better insight about the economic conditions behind the failure of PPP in exchange rate determination.

Foot and Rogoff (1995) and Rogoff (1996) hold that the existence of trade barriers and transformation costs drives a wedge between prices in different countries. As a results, the Law of One Price (*LOOP*) cannot hold exactly.

Rogoff (1996) argues that the wedge depends on the tradability of the goods. For highly traded goods, the wedge becomes thin and for these goods the law (*LOOP)* holds quite well. On the other hand, for traded goods value-added taxes and profit margins widen the wedge resulting in an environment against the law (*LOOP).*

Foot and Rogoff (1995) further hold that, in empirical *tests*, PPP has been tested usually without comparing identical baskets of goods. *Instead*, in these empirical tests *Consumer Price Indices* (CPIs) and *Wholesale Price Indices* (WPIs) are usually used. The use of these indices to test absolute PPP (APPP) invariably leads to results not supporting this version of the theory. This is due to the fact that different countries use different compositions of goods in the baskets for the construction of price indices. *Again,* the weights assigned to goods are not necessarily uniform across countries. APPP measured with this heterogeneous CPIs, are less likely to hold in the empirical studies.

Engel and Rogers (1996, 1998 and 1999) have shown that nominal exchange rate volatility is the major cause of deviations of exchange rates from the PPP level. These volatilities are nothing but short-run variations of exchange rate around its long-run stable equilibrium level. Consequently, they hold, PPP may be expected to hold good when exchange rates are found to be stable over a considerable period of time.

Jenkins (1995) argues that short-run variations in exchange rates are news-driven phenomena. Announcement about interest rate changes growth rate of GDP in forthcoming periods, and variations in inflation rates etc cause variations in exchange rates in the short-run. However, *such variations* in exchange rates dissipate over years. The time horizon is usually is between 4 and 10 years. When such short-run exchange rate variations wither away, PPP is found to hold good. That's why, empirical studies support the statement that PPP does not determine exchange rate in the short-run.

Bala (1964) and Chinn (2000) give forth several reasons for the deviations of exchange rates from the PPP level. These are as follows:

First, restrictions on trade and capital movements distort the relationship between domestic and foreign prices.

Second, speculative activities and official intervention may create a distortion from the PPP level.

Third, faster productivity growth in the tradable goods sector than that in the non-tradable goods sector, may result in systematic divergence of prices.

Fourth, prices, being usually sticky, do not move rapidly enough to offset frequent changes in nominal exchange rates.

Fifth, non-stationarity of real exchange rate may result in following some real shocks in the economy.

Finally, short-run deviations of exchange rate from the PPP level may arise because of innovations in financial sector, imbalance in government budget, differentials in productivity growth etc in major industrial countries.

Pippenger (2004) questions the conventional idea that the short-run volatility of exchange rate is excessive. The idea is derived from the fact that the variance of monthly changes in exchange rate is much larger than that for monthly changes in relative CPIs. In this connection he points out several problems with these variance ratios.

First, the modern theory of PPP implies such ratios should be larger than one. But more successful the management of monetary policies, the larger will be these variance ratios. As a result, excess volatility will be the largest when flexible exchange rates are working their best.

Second, construction of consumer price indices on the basis of sticky retail prices increases the variance ratios.

Pippenger further argues that the modern theory of PPP suggests that the volatility of exchange rate increased dramatically after the collapse of the Bretton Woods System no doubt. Such rise in volatility was not the effect of the adoption of flexible exchange rate system. But it was because of the fact that pegged exchange rates artificially restricted the movement in exchange rates as compared to the movement that would have been consistent with purchasing power parity.

He concludes by upholding the view that purchasing power parity works at least as well in a stable monetary environment as with hyperinflation. Measurement errors and non-linearities might have caused the misinterpretation of the econometric evidence.

2.3 Review of Empirical Contributions

The empirical studies on PPP may be categorized into three groups on the basis of tests they apply. These are

i. the easily '*correlation*' based studies
ii. the '*Unit Root Test*' based studies where *stationarity* of real exchange rates are examined.
iii. the '*cointegration*' based studies where *cointegration* between exchange rates and relative price level is being investigated into.

The '*correlation*' based studies were prevalent in the late 1970s and early 1980s. These studies found little support for PPP. The '*Unit Root Tests*' based studies were prevalent in 1980s while the '*Cointegration*' based studies have been taken up since the late 1980s. These studies provided mixed results with respect to the validity of the PPP doctrine in the long-run. Some of the important empirical studies are being cited below.

Frankel (1976) examined the validity of the PPP doctrine in Germany's trade during the hyperinflationary period. His estimated time-series model was

$$S_t = \alpha + \beta P_t + u_t$$

He assumed that foreign price levels were insignificant compared to hyperinflated prices in Germany. So he excluded the foreign price levels from his estimable model. In this estimated equation $\hat{\beta}$ was not statistically different from one. This led him to conclude that RPPP held good for German Deutche Mark during the period of hyperinflation.

Frankel (1981) then tested the validity of PPP with the use of data from the USA, UK, France and Germany during 1970s when these economies were more stable. The estimated β's ranged from below -1 to over 2. Thus in each case the null hypothesis of relative PPP was rejected at least in the short-run.

Johansen and Juselius (1992) are the *fore-runners* in testing combined PPP and UIP with the use of time series data for the UK over the period 1972:1-1987:2. They reject the hypothesis that the PPP relation is stationary by itself. However, they find support for combined occurrence of PPP and UIP. Other studies which provide support for the combination of PPP and UIP into a single relationship include Sjoo (1995), and Pesaran et al (2000).

Wu (1996) tested for unit roots in real exchange rate for 18 OECD countries. He used the pooled data on real exchange rates between the US and the OECD countries for the current float. Standard ADF Tests and Phillips and Perron (PP) Tests were performed on monthly individual real exchange rates. Real exchange rates were found to be non-stationary at conventional significance levels. However, when the panel-based tests were performed, the null hypothesis of unit root was rejected at 1% level. Consequently, the real exchange rates were found to be stationary. This provided the support for the validity of long-run PPP for the post-Bretton Woods Period.

Papell (1997) also used the Panel data analysis to test for long-run PPP. The study was designed for examining the evidence against unit roots in real exchange rate during the current float for industrialized countries.

The estimable equation in his study was

$$\Delta e_{jt} = \mu_j + \alpha\, e_{jt-1} + \sum_{i=1}^{k} C_{ji} \Delta e_{jt-1} + \varepsilon_{jt}$$

The equation was estimated by the *Feasible Generalized Least Squares (FGLS) Method.*

where e = exchange rate

j = indices of the countries in the panel.

Monte Carlo methods were used to compute exact finite sample critical values for the test statistics for study. His study found strong evidence against the unit root hypothesis for monthly data but not for quarterly data.

Coakley and Fuertes (1997) also use the *panel unit root test* to analyse real exchange rate data for the G-10 countries and Switzerland. They use monthly data for the period from 1973 to 1996 of bilateral rates, and wholesale as well as consumer prices. They find that in the test involving the use of wholesale price series, the null of a unit root in the real exchange rate is rejected at 5% level. However, the null is rejected at 10% level only when the test is done with the use of consumer price series. Thus they conclude that the real exchange rates in their panel are stationary in all cases. This render support for long-run PPP.

Sarno and Taylor (1998) employ two *multivariate unit root tests* using panel data. Their study provides support for PPP for the post-Bretton Woods Period. They employ the tests on monthly data on bilateral real dollar exchange rates among the G-5 countries for the period 1973 to 1996. From these tests they find evidence of *mean reversion* in all of the real exchange rates examined.

Nagayasu (1998) examines the validity of long-term PPP using data for the 16 African Countries. He uses annual data for the period 1981 to 1994. The study involves the application of a '*Panel Cointegration Technique*' and the '*Panel Unit Roots Test'* to the parallel market exchange rates expressed in US dollars and Consumer Price indices (CPIs). The test for unit root and cointegration in individual countries establishes that PPP is invalid. However, more reliable results are obtained in the panel context, where the null of non-cointegration is rejected. This confirms the *semi-strong form* of long-run PPP in 16 African countries.

Krichene (1998) studies the relationship between exchange rate and relative price level in five East African countries, namely, Burundi, Kenya, Rwanda, Tanzania and Uganda. Monthly data of bilateral real exchange rates for the period ranging from 1979:1 to 1996:12 have been used in the study.

Bilateral real exchange rates have been found to *revert to* long-run equilibrium. Again the tests for the unit roots in bilateral real exchange rates reject the null hypothesis of unit root. Thus APPP has been supported to be valid in case of Burundi and Kenya, Burundi and Rwanda and Kenya versus Rwanda. This result indicates that arbitrage has been operative among these countries because of the importance of bilateral trade, proximity of markets and rapid transmission of information on prices and profit opportunities.

Krichene further holds that the null hypothesis of unit root, in case of Tanzania and Uganda, cannot be rejected for the entire sample period because of exchange rate misalignments. However the null hypothesis of the unit root stands rejected in the sub-period 1986:1-1996:12.

Mollick (1999) employs the standard unit root test in order to examine the nature of real exchange rate in Brazil over the period 1855-1990. He reports a mixed evidence in favour of *mean reverting* behaviour of the real exchange rates for the period of study.

Islam and Ahmed (1999) test the PPP hypothesis for the bilateral exchange rates and relative price level for Korea and US by employing quarterly data for the period 1971-1996. *Dickey-Fuller* and *Phillips-Perron tests* indicate non-stationary at level for both nominal exchange rates and relative price level. However, both the series are found to be stationary upon first differencing.

They employ both the *Engel-Granger Two-Step Method* and *Johansen-Juselius Method* of cointegration in order to examine the presence of long-run relationship between Korea –US bilateral exchange rate and relative price levels in these countries concerned. The findings lend support for the PPP hypothesis as a long-run equilibrium condition.

However, stronger support was provided by the *Johansen-Jesulius Method* than by the *Engel-Granger Method.*

They find that the estimated value of the coefficient of the relative price variable is lower than unity. So the long-run equilibrium relationship appears to be far from being perfect. The ECM estimates testify for the stability of the relationship that exchange rate maintains with relative price level where the speed of adjustment is about 24% over a year.

The *Granger Causality test* without *error correction* indicates the absence of any causal relation between exchange rate and relative price level. However, the *Granger Causality test* with *error correction* testifies for the *uni-directional causality* running from exchange rate to relative price level. The authors hold that the causality result is not unexpected in view of the fact that the exchange rate in Korea has been under government control for most of the time period covered in this study.

Beharamshah, Haw and Fountas (2002) investigate into the validity of PPP hypothesis for Asia-6 currencies using the *ADRL procedure*. The sample was divided into two sub-periods. One sub-period covers the pre-crisis period and the other relates to the post crisis period.

They report the absence of any cointegrating relationship between the nominal exchange rate and relative price level in the pre-crisis sub-period. However, they find a strong evidence for the *weak form of PPP* in the second sub-period.

These findings imply that the *cointegrating relationship* is time dependent and sensitive to changes in the regime. This implicitly indicates that exchange rates of the East Asian countries were possibly '*overvalued*' during the pre-crisis period. Again, the *mean reverting* behaviour of these currencies over the post-crisis period suggests that departures from the equilibrium or the PPP rates are temporary.

Ahmed and Anoruo, Braha (2002) examine the validity of purchasing power parity doctrine for 11 developing countries, namely, Argentina, Bolivia, Columbia, Cote d'

Ivoire, Equador, Guatemala, Kenya, Nigeria, Peru, South Africa and Venezuela. They specify and estimate the *Dynamic Error Correction Models* for this purpose.
The results from the Unit Root Tests fail to provide evidence of PPP in all of the cases. However, the results from the estimated Error Correction Models present evidence in favour of PPP for 9 countries. So the authors broadly conclude that PPP holds in the long-run.

Schweigert (2002) examines the validity of PPP in the economy of Guatemala with respect to peso/dollar exchange rate. The study period ranges from the late 1890s to mid 1920s. He holds that the behaviour of peso/dollar exchange rate over the period of study is consistent with combined monetary and PPP theories.

In PPP literature the usual hypotheses are that the elasticity of exchange rate

i. with respect to domestic money stock is unity and
ii. with respect to foreign price level is minus one.

The author reports that in his study both the hypotheses cannot be rejected. In the study he finds that exchange rate, domestic money stock and foreign price level series define random walk processes with drift. However, these series are cointegrated at level implying a stationary real exchange rate.

Ogawa and Kawasaki (2003) examine the *non mean reverting* bahaviour of the real exchange rate in six East Asian countries which include South Korea, Thailand, Indonesia, Malaysia, Singapore and Philippines. The base currencies were dollar and yen as the USA and Japan happen to be the most important trading partners of Asia 6-countries. They use the pre-crisis period (January, 1976-June, 1997) data to investigate into the *Generalized PPP (G-PPP) hypothesis* developed by Enders (1994). The *G-PPP hypothesises* real exchange rate will share common trends if fundamental variables are sufficiently interrelated. They report the absence of evidence for PPP for these countries over this period of study.

Lopez and Papell (2003) examine the impact on the Euro on the PPP hypothesis in the context of trade among the constituent countries of Europe. They also consider the trade

between Europe and other Non-Europe countries in this context. They report that the evidence for PPP is clearly stronger within the Euro Zone than between the Euro Zone and other countries.
They further report that the evidence of PPP is stronger for the larger countries in Euro-Zone. These countries are France, Germany and Italy.

Wickremassinghe (2004) examine the empirical validity of the PPP hypothesis in Sri Lanka using exchange rates for six foreign currencies. He observes that real exchange rates derived through CPI and WPI with different base currencies are not stationary. These results are not consistent with the PPP hypothesis.

Again estimation results of the *error correction models* reveal that exchange rates have different adjustment patterns for positive and negative gaps from the long-run PPP relationship. However, domestic and foreign price levels do not show any statistically significant adjustment towards positive and negative gaps from the long-run PPP relationship.

Sedaris (2005) tests for the validity of long-run Purchasing Power Parity (PPP) for seventeen European economics. These countries are Estonia, Latvia, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Romania, Slovakia Republic, Slovenia, Georgia, Moldova, Russia, Ukraine and Belarus. Long-run Purchasing Power Parity is initially tested for each economy vis-à-vis the US. Johansen Cointegration Technique and Panel Cointegration Technique have been used for examining the long-run relation between respective bilateral (dollar based) exchange rates and the corresponding relative price level. The analysis provides support for long-run equilibria. However, the coefficients of the estimated cointegrating vectors violate the symmetry and proportionality hypothesizes suggested by Purchasing Power Parity.

CHAPTER - 3
DATA AND METHODOLOGY

3.1 Nature and Period of Dataset

The study is based on secondary dataset. In this study datasets of Rupee/Nepalese Rupee exchange rate and relative price level in India and Nepal have been used. We have used historical datasets on exchange rate and CPIs of both the currencies in our study. The dataset is quarterly by nature. The period covers 1976:1 to 2006:1. The base period is 2000. Specified variables are e_t and p_t where

e_t = Rupee/Nepalese Rupee exchange Rate

p_t = Relative Price Level

3.2 Source of the Dataset

The time series data for Rupee/Nepalese Rupee exchange rate and consumer price index (CPI) for India and Nepal have been used. These datasets have been collected from the different issues of International Financial Statistics (IFS), published by the International Monetary Fund (IMF).

3.3 Rationale Behind the Choice of the Period of Study

Reserve Bank of India adopted the '*Basket Peg System*' in September, 1975. Since then until 1991, value of rupee was being pegged to a '*basket of currencies*'. The adoption of the 'Basket Peg system' virtually marked the initiation of the '*Flexible Exchange rate System*' in India.

The Nepal Rasta Bank, on the other hand, in Nepal resorted to '*Crawling Peg System*' on regular basis since 1976. This marked the era of '*flexible exchange rate system*' in Nepal.

Thus in the year 1976 *'flexible exchange rate system'* became operative in both India and Nepal. This accounts for the choice of 1976 as the starting year of the dataset on Rupee/Nepalese Rupee exchange rates in our present study.

3.3.1 Rationale Behind the Choice of the Consumer Price Index(CPI)

Price Indices in case of Multiple Goods:

In the simplest form of PPP, for a single homogeneous good, the exchange rate would eventually be equal to the ratio of domestic price and foreign price when both are expressed in the same currency units.

However, in practical life there are a large number of goods with different prices. In such case PPP theory involves the comparison of the domestic and foreign price level through the use of an aggregate index number of the many prices in each country. Thus in case of multiple goods, PPP states that the nominal exchange rate (e_t) should be equal to the ratio of domestic price index (p_t) and the foreign price index (p^*_t) such that

$$E_t = A\left(\frac{P_t}{P^*_t}\right) \tag{3.1}$$

With A=1, we have the Absolute version of PPP. If $A \neq 1$, then we have the relative version of PPP.

3.3.2 Price Indices Rationale Behind the Use of Tradable Goods only:

The scope of arbitrage in commodity underlies the PPP theory. According to PPP differences in the prices in the same goods in different countries, when converted to a common currency unit, open up the prospect of profits to be made by buying the good in one country and selling it in other. Thus deviations from PPP represent profitable commodity arbitrage opportunities. Such opportunities exist only for commodities which are traded internationally. However, there are many goods which are not traded internationally. For these goods, there exists no international market in which these can be bought and sold. So these goods do not contribute to the demand for and supply of foreign currency. Consequently, it is argued that the price indices which are used to measure PPP should be constructed from the prices of traded goods. In such case, wholesale price indices for these goods should be chosen.

3.3.3 Arguments Behind the Use of CPI

The alternative view is that exchange rate represents the relative price of national currencies. Currency is held as an asset. It can be converted, like any other form of wealth, into the purchasing power over tradable and non-tradable goods. A Consumer Price Index includes the prices of both traded and non-traded goods. Consequently, CPI can comfortably and reasonably be used as a measure of purchasing power of the currencies concerned.

3.4 Use of CPI in this Study

It, therefore, follows that the ratio of two consumer price indices (CPIs) measures the relative price of domestic currency to foreign currencies. Alternatively, the ratio of two consumer price indices measures the relative purchasing power of currencies concerned. This provides the rationale behind the use of CPI in our study. The ratios of the CPI of India to that of Nepal in any quarter over the period 1976:1-2006:1 have been used to measure the relative price level in the corresponding quarter.

3.5 Tests for PPP

3.5.1 Testability of Absolute Purchasing Power Parity (APPP)

Let e_t be the normal exchange rate between the currencies for the domestic and foreign countries at time t.

Let P_t and p^*_t be the domestic and foreign price indices. Then in case of multiple goods PPP states that the exchange rate at time t should equal the ratio of domestic price index (P_t) and the foreign price index (p^*_t) such that

$$e_t = A.(\frac{P_t}{P^*_t}) \qquad (3.2)$$

With A = 1, then Absolute Purchasing Power Parity (APPP) holds.

However, differences exist in the construction of index numbers in the domestic and foreign countries because the conventions of setting the price index to some commonly member such as 1 or 100 in a particular base are usually different in different countries. Thus in estimations, the finding that $A \neq 1$ simply because of different statistical conventions would have no bearing on the validity of PPP. *APPP, therefore, is not in general a testable proposition especially because P_t and p^*_t are price indices rather than the price of a single good.*

3.5.2 Testability of Relative Purchasing Power Parity (RPPP)

From (3.2) we have

$$RE_t = E_t\left(\frac{P_t}{P^*_t}\right) = A \tag{3.3}$$

A is not necessarily equal to unity if P_t and p^*_t are indices.

Taking logarithm on (3.3)

$$In\ RE_t = In\ E_t + In\ p^*_t - In\ P_t = InA$$

$$or, re_t = e_t + p^*_t - p_t = a \tag{3.4}$$

Where $In\ RE_t = re_t$

$In\ E_t = e_t$

$In\ P_t = p_t$

$In\ p^*_t = p^*_t$

$InA = a$

If APPP holds, then In(A) = a = In 1 = 0.

If RPPP holds, then $re_t \neq 0$

Now taking first differencing of re_t we get

$$\Delta re_t = \Delta e_t + \Delta p^*_t - \Delta p_t \tag{3.5}$$

Then (3.5) states that the rate of change of the real exchange rate is equal to the rate of change of nominal exchange rate plus the inflation in the foreign country minus the inflation in the domestic country.

Again from (3.4) and (3.5)

$$\Delta e_t + \Delta p^*_t - \Delta p_t = 0 \quad \text{[since, } \Delta a\text{]} \tag{3.6}$$

Therefore,

$$\Delta e_t = \Delta p_t - \Delta p^*_t \tag{3.7}$$

(3.7) indicates that nominal exchange rate moves to exactly compensate the relative growth in foreign and domestic price indices. If (3.7) holds, then $\Delta re_t = 0$.

It, therefore, follows that once RPPP holds such that nominal exchange rate moves to reflect exactly the inflation differences in both the trading countries, then there will be no change in real exchange rate over time. This indicates, on the other hand, that RPPP indirectly establishes the '*Constancy*' of real exchange rate. *Thus the testing of PPP relates to testing the constancy of real exchange rate. Such testing of PPP, therefore, constitutes an exercise for testing the RPPP in practice.*

3.6 Basic Format for the Test of RPPP

Let e_t = log of the nominal exchange rate

p_t = log of domestic CPI

p^*_t = log of foreign CPI

Then in RPPP the regression equation is

$$e_t = \alpha + \beta(p_t - p^*_t) + u_t \tag{3.8}$$

where $u_t \sim iidN(0, \sigma^2_u)$

Consequently, $u_t \sim I(0)$.

From (3.8) we have

$$e_t - \alpha - \beta(p_t - p_t^*) = u_t \qquad (3.9)$$

Since $u_t \sim I(0)$, then

$[e_t - \alpha - \beta(p_t - p_t^*)]$ must be I(0).

Therefore, (3.9) indicates that

e_t and $(p_t - p_t^*)$ must be *cointegrated* **at level** if RPPP holds. Consequently, RPPP holds iff exchange rate and the ratio of relative price level are c*ointegrated at level. Thus test of PPP or RPPP relates to examining if exchange rate and relative price level datasets are cointegrated at level.*

3.7 Stationarity:

The study involves the extensive use of time series techniques. *Box-Jenkins techniques* along with the latest developments in theoretical and empirical analysis have been adopted in our study. The time series for exchange rate and relative price level have been subject to tests for stationarity.

In this study the *Dickey-Fuller method* has been adopted for the test of the presence of unit roots in the time series concerned. The detection of the unit root in a time series is undertaken to examine if the time series exhibit random walk processes, i.e. non-stationarity.

Non-stationarity has further been verified through the estimation of the *Autocorrelation Function (ACF)* and *Partial Autocorrelation Function (PACF). Box- Ljung* values, along with the relevant probabilities for significance, have been reported along with the estimated autocorrelation coefficients at different lags. The *ACF* and *PACF* plots showing the estimated coefficients for different lags along with the upper and lower critical values for the confidence limits have been derived.

The detection of non-stationarity in the time series has been followed up through appropriate transformation of the time series concerned for ensuring stationarity. This has mainly been accomplished through first differencing. The first differenced series have then been subject to *Dickey-Fuller tests* in order to examine if stationarity were really obtained in the series concerned. This has further been confirmed through the examination of the relevant *ACF* and *PACF* plots.

3.7.1 Properties of Stationarity Dataset and Unit Root Test

In case of time series analysis unit root tests are important since these tests detect stationarity and non- stationarity of the time series data used for the study. A stationary time series data set has three basic properties.

First, it has a finite mean, which implies that a stationary series fluctuates around a constant long run mean.

Second, a stationary time series has a finite variance. This implies that variance is *time-invariant.*

Third, a stationary time series dataset has finite auto-covariances. This reflects that theoretical autocorrelation co-efficient decay fast as lag length increases.

Regression runs on non- stationary time series produce a spurious relationship. In order to avoid a spurious relationship, it becomes necessary to perform a unit root test on variables. The *Dickey-Fuller (DF)* and *Augmented Dickey-Fuller (ADF)* tests are widely used for performing unit root tests. The ADF test involves the autoregressive AR(1) process. For this we consider the following equation.

$$Y_t = \alpha + \rho Y_{t-1} + \zeta_t$$

In case ρ carries the value $-1<\rho<1$, the variable Y is stationary. If the value of ρ is one, the variable Y is non- stationary. Hence, the unit root test null hypothesis is:

$$H_0 : \rho = 1$$

While testing the null hypothesis of unit root, the following equation is used.

$$\Delta Y_t = \alpha + \gamma Y_{t-1} + \zeta_t \tag{3.10}$$

where, $\gamma = \rho - 1$ and ΔY is the first difference of the series Y. Here the unit root null hypothesis is:

$$H_0 : \gamma = 0$$

3.7.2 Unit Root Test: The Methodology

Let us consider the data generating process

$$Y_t = \varphi Y_{t-1} + \varepsilon_t$$

The associated question is whether $\varphi = 1$. Subtracting Y_{t-1} from both sides we get,

$$\Delta Y_t = (\varphi - 1) Y_{t-1} + \varepsilon_t$$
$$= \gamma Y_{t-1} + \varepsilon_t$$

$\gamma = 0$ implies that $\varphi = 1$ which indicates the presence of a unit root in $\{Y_t\}$.

A drift is allowed by including an intercept

$$\Delta Y_t = \alpha_0 + \gamma Y_{t-1} + \varepsilon_t$$

Allowing for linear trend with a drift gives us

$$\Delta Y_t = \alpha_0 + \gamma Y_{t-1} + \alpha_1 t + \varepsilon_t$$

In any event, the test hypothesis is

H_0: $\gamma = 0$ (Y_t has a unit root)

against

H_1: $\gamma \neq 0$ (Y_t is stationary)

The test statistic $\dfrac{\hat{\gamma}}{\sqrt{\operatorname{var} \hat{\gamma}}}$ is a statistic. The critical values come from a set of tables prepared by Dickey and Fuller. This test is known *'Dickey-Fuller Test'*.

The immense literature and diversity of unit root tests can at times be confusing and present a truly daunting prospect for a researcher. The unit root theory has been examined with an emphasis on testing principles. The summary of the finding is given below:
When time series data are used in econometric analyses, the preliminary statistical step is to test the stationary of each individual series. Unit root tests provide information about

stationarity of the data. Non-stationary data contain unit roots. The main objective of unit root tests is to determine the degree of integration of each individual time series. Various methods for unit root tests have been applied in the study. Some of them are being explained below.

3.7.3 Augmented Dickey Fuller Unit Root Test

In order to test for the existence of unit roots, and to determine the degree of differencing necessary to induce stationarity, the *Augmented Dickey-Fuller test* is used. Dickey and Fuller (1976, 1979), Said and Dickey (1984), Phillips (1987), Phillips and Perron (1988), and others developed modifications of the Dickey-Fuller tests when ε_t is not white noise. The results of the *Augmented Dickey-Fuller test* (ADF) determine the form in which the data should be applied in any econometric analyses. The test is based on the following equations:

$$\Delta y_t = \gamma + \alpha y_{t-1} + \sum_{j=2}^{k} \theta_j \Delta y_{t-j+1} + e_t \qquad (3.11)$$

$$\Delta y_t = \gamma + \delta t + \alpha y_{t-1} + \sum_{j=2}^{k} \theta_j \Delta y_{t-j-1} + e_t \qquad (3.12)$$

$$\Delta y_t = \alpha y_{t-1} + \sum_{j=2}^{k} \theta_j \Delta y_{t-j+1} + e_t \qquad (3.13)$$

where, y_t = Modeled Variables,

Δy_t = First differenced series of y_t.

Δy_{t-j+1} = First differenced series of y_t at $(t-j+1)^{th}$ lags. (j = 2 ----- k)

The equation (3.11) is related to ADF test with constant as exogenous. Equation (3.12) is based on constant and linear trend as exogenous and ADF test with no exogenous is presented in equation (3.13).

3.7.4 The D-F GLS Unit Root Test

The DF-GLS test developed by *Elliott, Rothenberg and Stock (1996),* which has greater power than standard ADF test is also employed in the study. The DF-GLS t-test is performed by testing the hypothesis $a_0=0$ in the regression

$$\Delta y_t^d = a_0 y_t^d + a_1 \Delta y^d_{t-1} + \text{-----} + a_p \Delta y^d_{t-p} + \text{error} \tag{3.14}$$

where y_t^d is the locally de-trended series y_t .The local de-trending depends on whether we consider a model with drift only or a linear trend.

(i) The model for DF-GLS unit root test without time trends i.e., a model with drift only is

$$y_t^\mu = \alpha y^\mu_{t-1} + \sum_{i=1}^{k} \Psi i \, \Delta y^\mu_{t-i} + u_t \tag{3.15}$$

(ii) The model for DF-GLS unit root test with time trends i.e. a model with linear trend is

$$y_t^\tau = \alpha y^\mu_{t-1} + \sum_{i=1}^{k} \Psi i \, \Delta y^\tau_{t-i} + u_t \tag{3.16}$$

3.7.5 Phillips –Perron Unit Root Test

Phillips (1987), Phillips and Perron (1988) have generalized the DF tests to situations where disturbance processes ε_t are serially correlated, without augmenting the initial regression with lagged dependent variables. The PP is intended to add a 'correction factor' to the DF test statistic and the test is designed for examining the presence of any 'structural shift' in the dataset.

Let the AR (1) model be

$$Y_t = \mu + \varphi_1 Y_{t-1} + \varepsilon_t, \ [t = 1, \text{---------}, T] \tag{3.17}$$

with $\quad Var(\varepsilon_t) \equiv \sigma_\varepsilon^2$.

If ε_t is serially correlated, the ADF approach is to add lagged ΔY_t to 'whiten' the residuals. To illustrate the alternative approach, the test statistic $T(\varphi_1\text{-}1)$ has been considered which is distributed as ρ_μ from the maintained regression with an intercept but no time trend. The PP modified version is

$$Z\rho_\mu = T(\varphi_1 - 1) - CF \tag{3.18}$$

where the correction factor CF is

$$CF = 0.5(s^2_{Tl} - s_\varepsilon^2) / (\sum_{t=2}^{T}(Y_{t-1} - \overline{Y}_{-1})^2/T^2) \quad (3.19)$$

and,

$$s_\varepsilon^2 = T^{-1}\sum_{t=1}^{T}\varepsilon_t^2 \quad (3.20)$$

$$s^2_{Tl} = s_\varepsilon^2 + 2\sum_{s=1}^{l}W_{sl}\sum_{t=s+1}^{T}\varepsilon_t\varepsilon_{t-s}/T \quad (3.21)$$

$W_{sl} = 1 - s/(l+1)$ and $\varepsilon_t = Y_t - \mu - \varphi_1 Y_{t-1}$

$$\overline{Y}_{-1} = \sum_{t=2}^{T}\frac{Y_t}{T-1} \quad (3.22)$$

3.8 Cointegration:

Macro-Economic variables, which are used in this study, are of time series by nature. These series are not deterministic variables. On the contrary, these are considered to be generated by some underlying stochastic processes. In any time series (Y_t), each value of Y_1, Y_2.............., Y_t is assumed to be drawn randomly from a probability distribution. To be completely general, the observed series Y_1, Y_2,...................., Y_t is assumed to be drawn from a set of jointly distributed random variables. Thus if the underlying probability distribution function of the series could be specified, then one could determine the probability of one or another future values of the variable concerned.

The complete specification of the probability distribution function for any time series is usually impossible. However, it is possible to construct a simplified model for the time series, which explains its randomness in a manner that is useful for econometric studies. This simple model may be a reasonable approximation of the actual and more complicated underlying stochastic process. The usefulness of such a model depends on how closely it captures the true probability distribution and the true random behavior of the series. Consequently, the validity and usefulness of macroeconomic studies with time series like money supply, price level etc. depends upon the nature of underlying stochastic process and upon approximation of the process.

Specification of the underlying stochastic process is preceded by the identification of the nature of the stochastic process. More specifically, it is necessary to know whether the underlying stochastic process is invariant with time or whether it describes a random walk. If the process is non-stationary, it will be difficult to represent time series over past and future intervals of time by an algebraic model. By contrast, if the stochastic process is fixed in time i.e., if it is 'stationary', then one can model the process via an equation with fixed coefficients that can be estimated from the past data. It is analogous to the single equation regression model in which one variable is related to another variable with coefficients that are estimated under the assumption that the structural relationship described by the equation is 'invariant' over time. The probability of a given fluctuation in the process from the mean level is assumed to be the same at any point of time. In other wards, the stochastic properties of the stationary process are assumed to be invariant with respect of time. For a stationary process both the joint probability distribution and conditional probability distribution are invariant with respect of time.

Cointegration between the time series has been studied for estimating a stable long-run equilibrium relationship between the variables concerned. This concept is very useful in empirical analysis because it allows the research to describe the nature of an equilibrium or stationarity relationship between two time series each of which is individually non-stationary.

For the study of cointegration between the variables concerned, the following procedures have been adopted.

i. The cointegrating equation has been estimated with the OLS Method.
ii. The residuals of the estimated equation have been obtained.
iii. The residuals are subject to Augmented Dickey-Fuller (ADF) test to examine if random walk exists or if the residuals are white noise.
iv. The ADF test results have been further confirmed through the examination of the ACF and PACF plots of the residuals.

v. If the residuals exhibit random walk, the time series are subject to first differencing.
vi. The cointegrating equation has been re-estimated through the use of the differenced dataset.
vii. The residuals of the estimated equation have been obtained.
viii. The residuals again are subject to Augmented Dickey-Fuller (ADF) test and we examine if the residuals are white noise.
ix. The ADF test results have further been confirmed through the examination of the ACF and PACF plots of the residuals.

The procedures have been repeated until the residuals of the estimated co-integrating equation are free from random walk. Thus the order of co-integration has been ascertained.

a. The Basic Problem:

In a provocative study *Charles R. Nelson and C.I. Plosser (1982)* found evidence that macro-economic variables like GNP, exchange rate, interest rate, employment, money supply, price level etc. behave like random walks. As these series follow 'Random Walks', these are not 'trend reverting'. Consequently, these economic variables do not tend to revert back to a long run trend after a shock.

These findings of *Nelson and Plosser (1982)* posed serious problems for econometric studies for macroeconomic variables. The studies so for carried out with the macroeconomic variables were based on the idea that these variables were 'deterministic non-stationary' series. Stationarites in these series were ensured through 'Filtering' like differencing of the series and identifying appropriate *Auto-Regressive Moving Average (ARMA)* processes. Findings of Nelson and Plosser (1982) hit the basic idea underlying these studies and the relevance of the studies was threatened consequently.

b. The Nature of the Problem:

The reason why Nelson-Plosser findings would threaten the basic approach behind the econometric studies with macroeconometric time series and why random walk process for the time series would limit the use of this series in econometric studies need serious consideration.

First, variances of the random walk processes in the joint probability distribution are no longer constant. Instead, the variances expand out with time and the random walk errors are no longer '*Homoscedastic*'. Consequently, the *Gauss- Markov Theorem* would not hold, and *Ordinary Least squares (OLS)* method would not yield consistent estimates of the parameters concerned.

Second, random walk processes fail to posses finite variance. In such case, the regression analysis fails and econometric studies with these series become irrelevant.

Third, detrending the variable before running the regression will not help because even the detrended series still remains non-stationary. Consequently, the random walk process becomes non-deterministic, non-stationary process. In such case detrending fails to ensure stationarity.

Fourth, if a variable follows a random walk, the effects of a temporary shock will not dissipate after several years but instead will be permanent. This occurs because the auto-correlation functions for such variables are 'uniform' by nature and it declines geometrically over time. The random walk process in such case, has an infinite memory. The current value of the process depends on all past values and the magnitude of the effect remains unaltered with time. As a result, the effect of a temporary shock will not dissipate after several years but will remain permanent. This further indicates that, in case of the presence of non-stationarity in the series for the variable describing random walks, the series does not revert back to a long run trend after a shock.

3.8.1 Cointegration: Engel Granger Method

Cointegration is the study concerning the existence of long run equilibrium relationships among variables. The study allows the researcher to describe the existence of an equilibrium or stationary relationship among two or more time series, each of which is individually non-stationary. According to *Engle and Granger (1987)* the variables will be cointegrated when the linear combination of non-stationary variables is stationary.

Cointegration provides a method for elimination of the cost of differencing by rationalizing terms in levels but only in linear combinations, which are stationary.

For example, if there are two variables X (Relative Price Level) and Y (Exchange Rate), the following equation may be considered for cointegrating test.

$$\varepsilon_t = Y_t - \alpha - \beta X_t \tag{3.23}$$

where ε_t is the residual. If ε_t, the residuals are stationary, the series Y_t and X_t are said to be cointegrated.

Here the cointegration study may be based on the estimation of any of the models given below:

$$e_t = \alpha_1 + \beta p_t + \mu_{1t} \tag{3.24}$$

$$p_t = \alpha_2 + \beta e_t + \mu_{2t} \tag{3.25}$$

where, e_t = Exchange Rate,

p_t = Relative Price Level

μ_{1t} & μ_{2t} are residual terms.

3.8.2 Johansen Cointegration Test:

Both the *Johansen (1988) and the Stock and Watson(1988)* methodologies rely heavily on the relationship between the rank of the matrix and the characteristic roots. The *Johansen cointegration* test equation is presented below:

$$\Delta y_t = \gamma + \pi\, y_{t-1} + \sum_{i=1}^{\rho-1} \pi_i \Delta y_{t-i} + \mu_t \tag{3.26}$$

where, γ is the vector of constants, y_t is the m dimensional vector of variables, (i.e., e_t, p_t in our analysis), ρ is the number of lags, μ_t is the error vector, which is multivariate normal and independent across observations.

$$\pi = -(1 - \sum_{i=1}^{p} A_i) \text{ and } \pi = -\sum_{j=i+1}^{p} A_i$$

Here, the rank of the matrix π is equal to the number of independent cointegrating vectors. Specifically,

If π = 0, the matrix is null and is the usual VAR model in first differences.

If π is of rank n, the vector process is stationary.

If π =1, there is a single cointegrating vector.

If $1 < \pi < n$, there are multiple cointegrating vector.

Let the matrix be π and ordered the n characteristics roots be λ_1, λ_2, ...λ_k such that $\lambda_1 > \lambda_2 > \ldots\ldots\ldots \lambda_n$. If the variables in y_t are not cointegrated, the rank of π is zero and all of these characteristic roots will be zero. Since Log (1) = 0 each of the expressions Log(1- λ_i) will equal to zero if the variables are not cointegrated. Similarly, if the rank of π is unity, $0<\lambda_1<1$, so the expression Log(1- λ_1) will be negative and the other $\lambda_i = 0$, so that Log(1- λ_2) = log (1- λ_3) = ...= Log (1- λ_n) = 0.

Here the number of distinct cointegrating vectors can be determined by checking the significance of the characteristic roots of π. The test for the number of characteristic roots that are significantly different from the unity can be obtained by using the following two test statistics:

i. *the Trace Statistic,*
ii. *the Max-Eigen Statistic.*

The Trace Statistic can be calculated in terms of the following expression:

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{n} Log(1 - \hat{\lambda}_i)$$

On the other hand, the Max-Eigen Statistic can be calculated as

$$\lambda_{trace}(r, r+1) = -TLog(1 - \hat{\lambda}_{r+1})$$

where, $\hat{\lambda}_i$ = the estimated values of the characteristic roots (i.e., Eigen values) obtained from the estimated π matrix, T= the number of unstable observations.

The '*Trace Statistic*' is used to test the null hypothesis that the number of distinct cointegrating vector is less than or equal to 'r' against the general alternative. The '*Max-Eigen Statistic*' test the null hypothesis that the number of cointegrating vector is 'r' against the alternative of (r+1) cointegrating vectors. The *critical values* of the λ_{trace} and the λ_{max} statistic are calculated using the *Monte Carlo approach.*

3.9 Correlogram:

One of the simple, intuitive and interesting methods of testing '*stationarity*' is running a *correlogram*. Correlogram is nothing but a graphical representation of *Autocorrelation Function* (ACF) and *Partial Autocorrelation Function* (PACF). The nature of stationarity can also be found almost accurately in most of the cases with the help of *Correlogram.*

3.10 Vector Error Correction Modeling:

Vector Error Correction modeling provides important information on the short-run relationship (short-run dynamics) between any two cointegrated variables. *Vector Error Correction* test has provided empirical evidence on the short run causality among variables concerned.

In the present study the *vector error correction* estimates have been specified using by the following model. The models have been used in both cases i.e. involving exchange rate and relative price level.

$$\Delta e_t = \alpha_1 + \rho_1 z_{t-1} + \beta_{1i} \sum_{i=1}^{m} \Delta e_{t-i} + \gamma_{1i} \sum_{i=1}^{m} \Delta p_{t-i} + \omega_t \qquad (3.27)$$

$$\Delta p_t = \alpha_2 + \rho_2 z_{t-1} + \beta_{2i} \sum_{i=1}^{m} \Delta e_{t-i} + \gamma_{2i} \sum_{i=1}^{m} \Delta p_{t-i} + v_t \qquad (3.28)$$

Δe_{t-i}=First Differenced series of Exchange Rate at time t-i; i=1,2,.............,m

Δp_{t-i}=First Differenced series of Relative Price Level at time t-i; i=1,2,........,m

Z_{t-1} is the *error correction term* since the *Johansen Cointegration Tests* confirm the existence of *only one Cointegration Equation* between e_t and p_t. The lag length (m), in the estimation, is determined through the *Akaike Information Criterion* (AIC) and *Schwartz Information Criterion* (SIC) etc. ω_{1t} and v_{2t} are white noise errors; β_{1i} and β_{2i}

are the coefficients of lagged exchange rates and γ_{1i} and γ_{2i} are the coefficients of relative price levels.

The focus of the *vector error correction* analysis is on the lagged z_t terms. These lagged terms are the residuals from the previously estimated cointegrating equations. In the present case the residuals from two lag specifications of the cointegrating equations have been used in the *vector error correction* estimates. Lagged z_t terms provide an explanation of short run deviations from the long run equilibrium for the test equations above. Lagging these terms means that disturbance of the last period impacts upon the current time period. Statistical significance tests are conducted on each of the lagged z_t term in equations (3.27) and (3.28). In general, finding a statistically insignificant coefficient of the z_t term implies that the system under investigation is in the short run equilibrium as there are no disturbances present. If the coefficient of the z_t term is found to be statistically significant, then the system is in the state of the short run disequilibrium. In such a case the sign of z_t term gives an indication of the causality direction between the two test variables.

3.11 Vector Autoregressive Model

Economic theories sometimes suggest a relationship between two variables, y_t and z_t. In that case modeling each series involves an autoregression of y_t on lagged values of y_t and an autoregression of z_t on lagged values of z_t. However such a separate approach would not capture any interactions between the variables concerned.

However, such interactions between the variable are captured through a *Vector Autoregression (VAR)* model where the time path of $\{y_t\}$ is affected by the current and past realizations of $\{z_t\}$ sequence and the time path of $\{z_t\}$ sequence is allowed to be affected by current and past realizations of $\{y_t\}$ sequence. In a VAR model y_t is related not just to its own lagged values but also those of z_t and similarly, z_t is related to its own lagged values and those of y_t, such that

$$y_t = b_1 + b_{11} y_{t-1} + b_{12} z_{t-1} + \varepsilon_{1t} \tag{3.29}$$

$$z_t = b_2 + b_{21} y_{t-1} + b_{22} z_{t-1} + \varepsilon_{2t} \tag{3.30}$$

The VAR model, consisting of the equations (3.29) and (3.30),
can be written as

$$\begin{pmatrix} y_t \\ z_t \end{pmatrix} = \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}$$

$$\text{or } x_t = b + \pi_1 x_{t-1} + \varepsilon_t \tag{3.31}$$

where, , $b' = (b_1 \quad b_2)$ is the vector of constants usually known as drift

$\varepsilon_t' = (\varepsilon_{1t} \quad \varepsilon_{2t})$ are innovations relative to information

set $x'_{t-1} = (z_{t-1}, z_{t-1})$

The equation (3.31) defines a VAR (1, 2) Model where order (p) = 1 and k (number of variables) = 2.

This form of the VAR is a '*Reduced Form*' system in the sense that no current dated values of y_t and z_t appear in any of the equations. The genesis of the '*Reduced From*' VAR could serve as the solution in a dynamic simultaneous equation model. For example, let us consider a VAR system with contemporaneous relationship between two variables such that

$$y_t = b_{10} + b_{12} z_t + \gamma_{11} y_{t-1} + \gamma_{12} z_{t-1} + \varepsilon_{yt} \tag{3.32}$$

$$z_t = b_{20} + b_{21} y_t + \gamma_{21} y_{t-1} + \gamma_{22} z_{t-1} + \varepsilon_{zt} \tag{3.33}$$

where it is assumed that

i. both y_t and z_t are stationary, and
ii. ε_{yt} *and* ε_{zt} are white noise disturbances

such that $\varepsilon_{yt} \sim$ iid N (0, σ_y^2) , $\varepsilon_{zt} \sim$ iid N (0, σ_z^2)

Now the VAR system consisting of equations (3.32) and (3.33) can be written as

$$y_t + b_{12} z_t = b_{10} + \gamma_{11} y_{t-1} + \gamma_{12} z_{t-1} + \varepsilon_{yt}$$

$$z_t + b_{21}y_t = b_{20} + \gamma_{21}y_{t-1} + \gamma_{22}z_{t-1} + \varepsilon_{zt}$$

$$\text{or } \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix} \begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$$

$$\text{or } Bx_t = \tau_0 + \tau_1 x_{t-1} + \varepsilon_t \qquad (3.34)$$

$$\text{where } B = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}$$

$$x_t = \begin{bmatrix} y_t \\ z_t \end{bmatrix}$$

$$\tau_0 = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix}$$

$$\tau_1 = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}$$

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$$

Pre-multiplying equation (3.34) by B^{-1} we have

$$X_0 = A_0 + A_1 x_{t-1} + e_t \qquad (3.35)$$

where $A_0 = B^{-1}\tau_0$

$A_1 = B^{-1}\tau_1$

$e_t = B^{-1}\varepsilon_t$

Now '*equivalent form*' of (3.35) is

$$y_t = a_{10} + a_{11}y_{t-1} + a_{12}z_{t-1} + e_{1t} \qquad (3.36)$$

$$z_t = a_{20} + a_{21}y_{t-1} + a_{22}z_{t-1} + e_{1t} \qquad (3.37)$$

Thus the '*Structural VAR*' constituted by equations (3.32) and (3.33) is converted to the '*Standard Form*' constituted by equation (3.36) and (3.37)

Here

$$e_{1t} = (\varepsilon_{yt} - b_{12}\varepsilon_{zt})/(1 - b_{12}b_{21})$$

$$e_{2t} = (\varepsilon_{zt} - b_{21}\varepsilon_{yt})/(1 - b_{12}b_{21})$$

Thus e_{1t} and e_{2t} are the composites of the two shocks ε_{yt} and ε_{zt}.

3.11.1 Stability of the VAR Model

The first order VAR model of (3.35) defines a first order difference equation which can be iterated backward to obtain

$$X_t = A_0 + A_1(A_0 + A_1 X_{t-1} + e_{t-1}) + e_t$$

$$= (I + A_1)A_0 + A_1^2 X_{t-2} + A_1 e_{t-1} + e_t$$

where I = 2*2 identity matrix

After n iterations, we have

$$X_t = (1 + A_1 + \ldots + A_1^n)A_0 + \sum_{i=0}^{n} A_1^i e_{t-1} + A_1^{n+1} X_{t-n-1} \tag{3.38}$$

It is observed that the convergence requires that the expression A_1^n vanish as n→∞. Consequently, the stability of the VAR model requires that the roots of $(1- a_{11}L)(1-a_{22}L) - (a_{12}a_{21}L^2)$ lie outside the unit circle. This stability conditions holds if

i. the $\{y_t\}$ and $\{z_t\}$ sequences are jointly covariance stationary
ii. each sequence has a finite and time-invariant mean and a finite time-invariant variance

3.12 Granger Causality: Methodology

3.12.1 Introduction:-

The study of *cointegration* of variables examines if the variables are related or not. The *cointegration* procedure stresses upon estimating distributed lag relationship along with the *error correction* structure. However, the *autoregressive structure* does not play any significant role in the study of *cointegration* between variables concerned.

This particular feature of the *cointegration equations* accounts for the inability of the equation to explain if the variables concerned are '*exogenous*' or '*endogenous*'. *Engel, Hendry and Richard (1983)* define a set of a variable X_t in a parameterized model to be '*weakly exogenous'* if the full model can be written in terms of a marginal probability distribution of X_t and a conditional distribution of Y_t/X_t such that estimation of the parameters of the conditional distribution is no less efficient than estimation of the full set of parameters of the joint distribution. With reference to time series applications variable X_t is said to be predetermined in the model if X_t is independent of all subsequent structural disturbances ε_{t-s} for s>0. Variables that are predetermined in the model can be treated, at least asymptotically, as if they were *exogenous* in the sense that consistent estimates can be obtained when they appear as regressors.

Cointegrating equations cannot establish if any of the variables is *exogenous.* Consequently, *cointegrating equations* cannot be used for forecasting purposes. These equations, therefore, cannot explain if one of the variables could be used for the effective prediction for variation in another variable. This explains why *cointegrating relation* fails to establish 'Granger' causal relationship between variables concerned.

3.12.2 The Methodology

Let us consider a jointly covariance stationary stochastic process y_t, x_t with $E(x_t) = E(y_t) = 0$ and with a *covariance generating function* $g_x(z)$, $g_y(z)$ and $g_{xy}(z)$. It is assumed that x possesses an *autoregressive representation* and that both y and x are linearly indeterministic. Then the projection of x_t on past values of x and past values of y_t is given by

$$X_t = \sum_{j=1}^{\infty} h_j X_{t-j} + \sum_{j=1}^{\infty} v_{t-j} y_{t-j} + u_t \tag{3.39}$$

where the least square residual u_t obeys the *orthogonality condition*

$$E(u_t X_{t-\beta}) = E(u_t y_{t-\beta}) = 0 \text{ for } \beta = 1, 2, \ldots\ldots\ldots\ldots\ldots\ldots$$

Solving (3.39) for u_t permits the *orthogonality condition* to assume the form of normal equations

$$E\{(X_t - \sum_{j=1}^{\infty} h_j X_{t-j} - \sum_{j=1}^{\infty} v_j y_{t-j}) X_{t-\beta}\} = 0, \tag{3.40}$$

$\beta = 1,2, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

$$E\{(X_t - \sum_{j=1}^{\infty} h_j X_{t-j} - \sum_{j=1}^{\infty} v_j y_{t-j}) y_{t-\beta}\} = 0, \tag{3.41}$$

$\beta = 1,2, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

These equations can be written as

$$c_x(\beta) = \sum_{j=1}^{\infty} h_j c_x(\beta - j) + \sum_{j=1}^{\infty} v_j c_{yx}(\beta - j) \tag{3.42}$$

$$c_x(\beta) = \sum_{j=1}^{\infty} h_j c_{xy}(\beta - j) + \sum_{j=1}^{\infty} v_j c_x(\beta - j) \tag{3.43}$$

These equations hold only for positive integer $\beta = 1$

Multiplying both sides of (3.42) and (3.43) by z^{β} and summing over all β, we get the following equations in terms of z transformation

$$g_x(z) + m(z) = h(z) g_x(z) + v(z) g_{yx}(z) \tag{3.44}$$

$$g_{xy}(z) + n(z) = h(z) g_{xy}(z) + v(z) g_y(z) \tag{3.45}$$

where m(z) and n(z) are each unknown series in non-positive power of z only. That m(z) and n(z) series are non-positive powers of z is equivalent with equations (3.42) and (3.43) holding only for $\beta > 1$. Equations (3.44) and (3.45) are the *normal equations* for h(z) and v(z).

Following *Weiner, Granger (1969)* has proposed that *"y causes x" whenever v(z) $\neq 0$ That is, y is said to cause x if, given all past values of x, past values of y help predict x.*

The conditions under which v(z) does or does not equal to zero turn out to be of substantial interest to econometrician and macro- economists.

Let us consider the projection of y_t on the entire x process

$$y_t = \sum_{j=1}^{\infty} b_j X_{t-j} + \varepsilon_t \tag{3.46}$$

where $E(\varepsilon_t X_{t-j}) = 0$ for all j

Let X_t have the ' *Wold Moving Average* ' presentation such that

$$X_t = d(L)\eta_t$$

$$\eta_t = X_t - P[X_t / X_{t-1}, X_{t-2}, \dots\dots\dots]$$

$$\sum_{j=1}^{\infty} d_j^2 < \infty \tag{3.47}$$

Then $\quad g_X(z) = \sigma_n^2 d(z) d(z^{-1})$

It is assumed that x possesses an *autoregressive representation* so that [d(z^{-1})] is *one sided square summable* in non-negative power of z. It is always possible to uniquely factor the cross covariance generating function as

$$g_{yX}(z) = \alpha(z)\phi(z^{-1}) \tag{3.48}$$

where $\alpha(z)$ and $\phi(z)$ are one sided in non-negative power of z .

Substituting (3.46) and (3.47) into the usual relation

$$b(z) = g_{yX}(z) / g_X(z) \tag{3.49}$$

we have

$$b(z) = \alpha(z)\phi(z^{-1}) / \sigma_n^2 d(z) d(z^{-1}) \tag{3.50}$$

Evidently, b(z) is one sided in non-negative powers of z if and only if $\phi(z^{-1}) = kd(z^{-1})$, where k is a constant . Under this condition (3.49) becomes

$$b(z) = k\alpha(z) / \sigma_\eta^2 d(z) \tag{3.51}$$

Here $\alpha(z)$ has an inverse that is one sided in non-negative power of z.

Now if b(z) is one sided in non-negative power of z, the equation (3.44) and (3.45) are both satisfied with v(z) = 0 and

$$h(z) = z[d(z)/z] + d(z^{-1}) \tag{3.52}$$

Consequently, equation (3.45) becomes

$$\phi(z)\alpha(z^{-1})n(z) = z[d(z)/z] + 1/d(z)\alpha(z^{-1})\phi(z) \tag{3.53}$$

Dividing both sides of equation (3.53) by $z\alpha(z^{-1})$ gives

$$\phi(z)/z + n(z)/z\alpha(z^{-1}) = [d(z)/z] + \phi(z)/d(z) \tag{3.54}$$

where $n(z)/z\alpha(z^{-1})$ involves only negative powers of z. Since the right hand side involves only non-negative power of z, (3.54) implies

$$d(z)[\phi(z)/z] = [d(z)/z] + \phi(z) \tag{3.55}$$

This equation (3.55) can be satisfied if $\phi(z) = kd(z)$ where k is a constant.

Now let (x_t, y_t) be a *jointly covariance stationary, strictly indeterministic process* with zero mean. Then $\{y_t\}$ fails to *Granger cause* $\{x_t\}$ if and only if there exists a vector moving average representation

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} C(L)_{11} & 0 \\ C(L)_{21} & c(L)_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_t \\ u_t \end{bmatrix} \tag{3.56}$$

where ε_t and u_t are serially uncorrelated processes with zero means and $E(\varepsilon_t u_s)=0$ for all t and s, and where the one-step-ahead prediction errors $[x_t - p(x_t / x_{t-1}, \ldots\ldots\ldots, x_{t-1}, \ldots\ldots)]$ and $[y_t - p(y_t / y_{t-1}, \ldots\ldots\ldots, y_{t-1}, \ldots\ldots)]$ are each linear combination of ε_t and u_t.

Under these situations Sims (1972) explains the concept of causality through the following theorem:

'*Y_t can be expressed as a distributed lag of current and past x's (with no further x's) with a disturbances process that is orthogonal to past, present and future x's if and only if y does not Granger cause x*'.

Consequently, the test involves estimating the following regressions:

$$y_t = \sum_{i=1}^{n} \alpha_i X_{t-j} + \sum_{j=1}^{n} \beta_j y_{t-j} + u_{1t} \qquad (3.57)$$

$$X_t = \sum_{i=1}^{n} \lambda_i y_{t-j} + \sum_{j=1}^{n} \delta_j X_{t-j} + u_{2t} \qquad (3.58)$$

where it is assumed that the disturbances u_{1t} and u_{2t} are uncorrelated.

Equation (3.57) postulates that current y_t is related to past values of y_t itself as well as of x_t and (3.58) postulates a similar behavior for x_t. Four cases then can be distinguished.

1 Unidirectional causality from x to y

It is indicated if the estimated coefficients on the lagged x in (3.57) are statistically different from zero as a group (i.e. $\Sigma\alpha_i \neq 0$) and the set of estimated coefficients on the lagged y in (3.58) is not statistically different from zero (i.e, $\Sigma\delta_j = 0$).

2 Unidirectional causality from y to x

It exists if the set of lagged x coefficients in (3.57) is not statistically different from zero(i.e, $\Sigma\alpha_i = 0$) and the set of the lagged y coefficient in (3.58) is statistically different from zero (i.e. $\Sigma\delta_j \neq 0$) .

3 Feedback or Bilateral Causal

It is suggested when the sets of x and y coefficient are statistically significantly different from zero in both regressions.

4 Independence

It is suggested when the sets of x and y coefficients are not statistically significant in both the regressions.

3.13 Intervention Analysis: Impulse Response Functions

If the stability condition is met, then the particular solution for x_t in (3.38) can be written as

$$X_t = \mu + \sum_{i=0}^{n} A_1^i e_{t-i} \tag{3.59}$$

where $\mu = [\overline{y}, \overline{z}]'$ and

$$\overline{y} = [a_{10}(1-a_{22}) + a_{12}a_{20}]/\Delta$$
$$\overline{z} = [a_{20}(1-a_{11}) + a_{21}a_{10}]/\Delta$$
$$\Delta = (1-a_{11})(1-a_{22}) - a_{12}a_{21}$$

Equation (3.59) is *Vector Moving Average (VMA)* representation of (3.35) in that the variables, y_t and z_t are represented in terms of the current and past values of two types of shocks (i.e e_{1t} and e_{2t}). Again equation (3.59) can further be simplified as

$$X_t = \mu + \sum_{i=0}^{\infty} \phi_i \varepsilon_{t-i} \tag{3.60}$$

where $$\phi_i = \frac{A_1^i}{(1-b_{12}b_{21})}\begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix}$$

Consequently, we have for (3.60)

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \overline{y} \\ \overline{z} \end{bmatrix} + \sum \begin{bmatrix} \phi_{11(i)} & \phi_{12(i)} \\ \phi_{21(i)} & \phi_{22(i)} \end{bmatrix} \begin{bmatrix} \varepsilon_{yt-i} \\ \varepsilon_{zt-i} \end{bmatrix}$$

The four sets of coefficients $\phi_{11(i)}, \phi_{12(i)}, \phi_{21(i)}\, and\, \phi_{22(i)}$ are called the 'Impulse Response Functions'. Plotting the coefficients of $\phi_{jk(i)}$ against i is a practical way to visually represent the behaviours of the $\{y_t\}$ and $\{z_t\}$ series in response to various shocks. Further elaboration follows in Chapter 9.

3.14 Intervention Analysis: Variance Decomposition of Forecast Errors:

Given the equation (3.60), we have for n^{th} period

$$X_{t+n} = \mu + \sum_{i=0}^{\infty} \varepsilon_{t+n-i} \tag{3.61}$$

where $E(x_{t+n}) = \mu$. Then the unconditions n period ahead forecast error is

$$X_{t+n} - E(X_{t+n}) = \sum_{i=0}^{n-1} \varepsilon_{t+n-1} \tag{3.62}$$

Using (3.62) we can find one-period ahead, two period ahead and thus n period ahead forecast errors. Each of the forecast errors would have variances. It is possible to decompose the n-step ahead forecast error variance owing to shocks in $\{y_t\}$ and $\{z_t\}$ sequences.

Thus the '*Forecast Error Variance Decomposition*' indicates the proportion of variation in a sequence owing to its '*own shock*' versus *shocks to other variables.*

3.15 'Window Finding' of Structural Changes:

The choice of sub-periods objectively involves the identification of structural changes through '*Window Finding*'. The basic procedure is described below.

3.15.1 Methodology

Sometimes researcher seeks to investigate into the stability of the coefficient estimates as the sample size increases. Sometimes researcher also wants to find out whether the estimates will be different in enlarged samples and whether these will remain stable over time. Working with a sample, a researcher may produce a regression which is too closely tailored to his sample by experimenting with too many formulations of his model. In this case, he is not contained that the estimated function will perform equally well outside the sample of data which has been used for the estimation of coefficients. Furthermore, there may have occurred events which change the structure of the relationship like changes in taxation law, introduction of birth control measures and so on. If such structural changes occur, the coefficient may not be stable. They may be sensitive to the changes in the sample compositions.

Testing for structural stability calls for the use of additional observations besides the sample that are used to estimate a given model. Procedures for testing structural stability are given by Rao (1960) and Chow (1952).

The econometric method which involves '*Window Finding*' uses *Chow test* to identify the sub-periods. Here equality between two regression coefficients concerning the relationship over two different periods is tested. This is done by F-test. Let us consider two samples with n_1 and n_2 observations respectively and the general model for data set is

$$Y = X\beta + u \tag{3.63}$$

where
$Y \rightarrow n \times 1$
$X \rightarrow n \times k$
$\beta \rightarrow k \times 1$
$n \rightarrow n_1 + n_2$

Let us rewrite the model for these two individual samples such as

$$Y_1 = (z_1 \quad w_1) \begin{pmatrix} \gamma_1 \\ \delta_1 \end{pmatrix} + u_1 \tag{3.64}$$

$$Y_2 = (z_2 \quad w_2) \begin{pmatrix} \gamma_2 \\ \delta_2 \end{pmatrix} + u_2 \tag{3.65}$$

where
$Y_1 \rightarrow n_1 \times 1$
$Y_2 \rightarrow n_2 \times 1$
$Z_1 \rightarrow n_1 \times 1$
$Z_2 \rightarrow n_2 \times 1$
$W_1 \rightarrow n_1 \times m$
$W_2 \rightarrow n_2 \times m$
$\gamma_1 \rightarrow 1 \times 1$

$\gamma_1 \rightarrow l \times 1$

$\delta_1 \rightarrow m \times 1$

$\delta_2 \rightarrow m \times 1$

By combining (3.64) and (3.65) we have

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} z_1 & 0 & w_1 & 0 \\ 0 & z_2 & 0 & w_2 \end{pmatrix} \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \delta_1 \\ \delta_2 \end{pmatrix} + \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \tag{3.66}$$

and the null hypothesis of interest is

$$H_0 : \gamma_1 = \gamma_2 (= \beta \text{ say})$$

Under the null hypothesis, the model is

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} z_1 & w_1 & 0 \\ z_2 & 0 & w_2 \end{pmatrix} \begin{pmatrix} \beta \\ \delta_1 \\ \delta_2 \end{pmatrix} + \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \tag{3.67}$$

The L.S estimate of the efficient vector in (3.67) is

If we fit (3.64) and (3.65) individually, their LS estimates of the coefficients will be

$$\begin{pmatrix} \hat{\beta} \\ \hat{\delta}_1 \\ \hat{\delta}_2 \end{pmatrix} = \left[\begin{pmatrix} z_1 & w_1 & 0 \\ z_2 & 0 & w_2 \end{pmatrix}' \begin{pmatrix} z_1 & w_1 & 0 \\ z_2 & 0 & w_2 \end{pmatrix} \right]^{-1} \left[\begin{pmatrix} z_1 & w_1 & 0 \\ z_2 & 0 & w_2 \end{pmatrix}' \right] \begin{pmatrix} y_1 \\ y_2 \end{pmatrix} \tag{3.68}$$

$$\begin{pmatrix} c_1 \\ d_1 \end{pmatrix} = \left[\begin{pmatrix} z_1 & w_1 \end{pmatrix}' \begin{pmatrix} z_1 & w_1 \end{pmatrix} \right]^{-1} \begin{pmatrix} z_1 & w_1 \end{pmatrix}' y_1 \tag{3.69}$$

$$\begin{pmatrix} c_1 \\ d_2 \end{pmatrix} = \left[\begin{pmatrix} z_1 & w_1 \end{pmatrix}' \begin{pmatrix} z_1 & w_1 \end{pmatrix} \right]^{-1} \begin{pmatrix} z_1 & w_1 \end{pmatrix}' y_1 \tag{3.70}$$

where c_i is the estimate of γ_i. The sum of squares necessary for computing test statistics can then be obtained by using the results in (3.68), (3.69) and (3.70). The sum of squares measures the distance of individual observations from the common regression plane is

$$Q_1 = \left[\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} - \begin{pmatrix} z_1 & w_1 & 0 \\ z_2 & 0 & w_2 \end{pmatrix} \begin{pmatrix} b \\ \delta_1 \\ \delta_2 \end{pmatrix}\right]' \left[\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} - \begin{pmatrix} z_1 & w_1 & 0 \\ z_2 & 0 & w_2 \end{pmatrix} \begin{pmatrix} b \\ \delta_1 \\ \delta_2 \end{pmatrix}\right] \qquad (3.71)$$

Here Q_1 / δ_2 has χ^2 distribution with (n-2m-1) degrees of freedom where we assume that u_1 and u_2 have a common variance δ_2. Now Q_1 can be decomposed into two sum squares Q_2 and Q_3. Q_2 will measure the distances of observations from the individual estimated regression planes, and Q_3 measures the distance of the individual estimated plane from the common regression plane. Thus,

$$Q_2 = \left[y_1 - \begin{pmatrix} z_1 & w_1 \end{pmatrix} \begin{pmatrix} c_1 \\ \delta_1 \end{pmatrix}\right]' \left[y_1 - \begin{pmatrix} z_1 & w_1 \end{pmatrix} \begin{bmatrix} c_1 \\ \delta_1 \end{bmatrix}\right] + \left[y_2 - \begin{pmatrix} z_2 & w_2 \end{pmatrix} \begin{pmatrix} c_2 \\ \delta_2 \end{pmatrix}\right]' \left[y_2 - \begin{pmatrix} z_2 & w_2 \end{pmatrix} \begin{bmatrix} c_2 \\ \delta_2 \end{bmatrix}\right] \qquad (3.72)$$

and $Q_3 = Q_1 - Q_2$. Here Q_2/δ_2 has a χ^2 distribution with (n-2m -1) degrees of freedom. Again,

$$Q_3 = \left[\begin{pmatrix} z_1 & w_1 \end{pmatrix} \begin{pmatrix} c_1 \\ \delta_1 \end{pmatrix} - \begin{pmatrix} z_1 & w_1 \end{pmatrix} \begin{pmatrix} b \\ \delta_1 \end{pmatrix}\right]' \left[\begin{pmatrix} z_1 & w_1 \end{pmatrix} \begin{pmatrix} c_1 \\ \delta_1 \end{pmatrix} - \begin{pmatrix} z_1 & w_1 \end{pmatrix} \begin{pmatrix} b \\ \delta_1 \end{pmatrix}\right] +$$

$$\left[\begin{pmatrix} z_2 & w_2 \end{pmatrix} \begin{pmatrix} c_2 \\ d_2 \end{pmatrix} - \begin{pmatrix} z_2 & w_2 \end{pmatrix} \begin{pmatrix} b \\ d_2 \end{pmatrix}\right]' \left[\begin{pmatrix} z_2 & w_2 \end{pmatrix} \begin{pmatrix} c_2 \\ d_2 \end{pmatrix} - \begin{pmatrix} z_2 & w_2 \end{pmatrix} \begin{pmatrix} b \\ d_2 \end{pmatrix}\right] \qquad (3.73)$$

It may be noted that c_l is the estimate of γ_l obtained from the first regression and that d_2 is the estimate of δ_2, obtained from pooled regression plane. So the ratio is

$$F = \frac{\frac{Q_3}{l}}{\frac{Q_2}{(n-2m-2l)}} \tag{3.74}$$

So, we have an F-distribution with (l, n-2m-2l) degress of freedom. Here Q_3 is the restricted sum of squares and that Q_2 is the unrestricted sum of squares.

If, however, the new observations n_2 are fewer than the number of parameters in the function we may proceed as follows. First, from the augmented sample we obtain the regression equation.

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 + \ldots\ldots\ldots\ldots + \hat{\beta}_k \hat{X}_k \tag{3.75}$$

From which we calculate the residual sum of squares

$$\Sigma e^2 = \Sigma y^2 - \Sigma \hat{y}^2 \tag{3.76}$$

with $(n_1 + n_2 - k)$ degrees of freedom. Second from the original sample of size n_1 we have

$$\hat{Y}_1 = \hat{\beta}_0 + \hat{\beta}_1 + \hat{\beta}_k \hat{X}_k \tag{3.77}$$

from which the unexplained sum of squares is

$$\Sigma e_1^2 = \Sigma y_1^2 - \Sigma \hat{y}_1^2 \tag{3.78}$$

with n_1 - k degrees of freedom.

Third, subtracting the two sums of residuals we find

$$\Sigma e^2 = \Sigma e_1^2 \tag{3.79}$$

with $(n_1 + n_2 - k) - (n - k) = n_2$ degrees of freedom, where n_2 are the additional observations. Further, we form F* ratio where

$$F^* = \frac{\Sigma e^2 - \Sigma e_{12}/n_2}{\Sigma e_{12}/(n_1 - k)} \tag{3.80}$$

The null hypotheses are

$$H_0 : b_i = \beta_i (i = 0,1,2,..........k)$$
$$H_0 : b_i \neq \beta_i$$

The F* ratio is compared with the theoretical value of F obtained from the F- table with $v_1 = n_2$ and $v_2 = (n - k)$ degrees of freedom.

If F* ratio exceeds the table value of F, we reject the null hypothesis i.e, we accept that the structural coefficients are unstable. This indicates that their values are changing in extended sample period.

CHAPTER - 4

STATIONARITY AND INTEGRABILITY OF TIME SERIES OF EXCHANGE RATE (e_t) AND RELATIVE PRICE LEVEL(p_t)

4.1 Introduction:

Econometric analysis of time series data involves the use of data from the past to quantify historical relationship. If the future is akin to the past, then these historical relationships can be used to forecast the future. If the future differs fundamentally from the past, then these historical relationships might not be reliable guides to the future.

In the context of time series regression analysis, the concept of *stationarity* is used is to examine if such historical relationships can be generalized to the future. A time series Y_t is *stationary* if its probability distribution does not change over time. More formally, Y_t is *stationary* if the joint probability distribution of (Y_{s+1}, Y_{s+2},...................., Y_{s+T}) does not depend on s. Otherwise Y_t is said to be *nonstationary.*

In the event of the time series being non-stationary, future is not like the past. Thus the historical relationship obtained from the past does not remain valid in future. In such case, as Nelson and Ploser (1982) hold, regression analysis becomes '*spurious*'. It, therefore, becomes pertinent to enquire into the nature of the stochastic process of the macroeconomic time series like exchange rate (e_t) and relative price level (p_t) in our study and examine if these series at level were '*stationary*' or if these define some *random walk* non-stationary stochastic processes.

If these series display *random walk* processes, then it would require appropriate filtering through differencing in order to generate stationary series. However, the *order of differencing* or *integration* for the two series involved may not be identical. Thus objective of our study this Chapter is also to enquire into the *integrability* of the series involved. *Stationarity and integrability* of the series will be examined through

i. the time plots of the series and the corresponding trend analysis, and
ii. appropriate stationarity tests like the ADF and Phillips-Perron Tests.
iii. Correlogram study.

4.2 Time plots of the series

Time plots of the exchange rate (e_t) and relative price level (p_t) series are being presented through the Figures 4.1-4.2 for the period 1976:1-2006:1.

Figure: 4.1

Time Plot of Rupee/Nepalese Rupee Exchange rate (e_t)

[Period: 1976:1-2006:1]

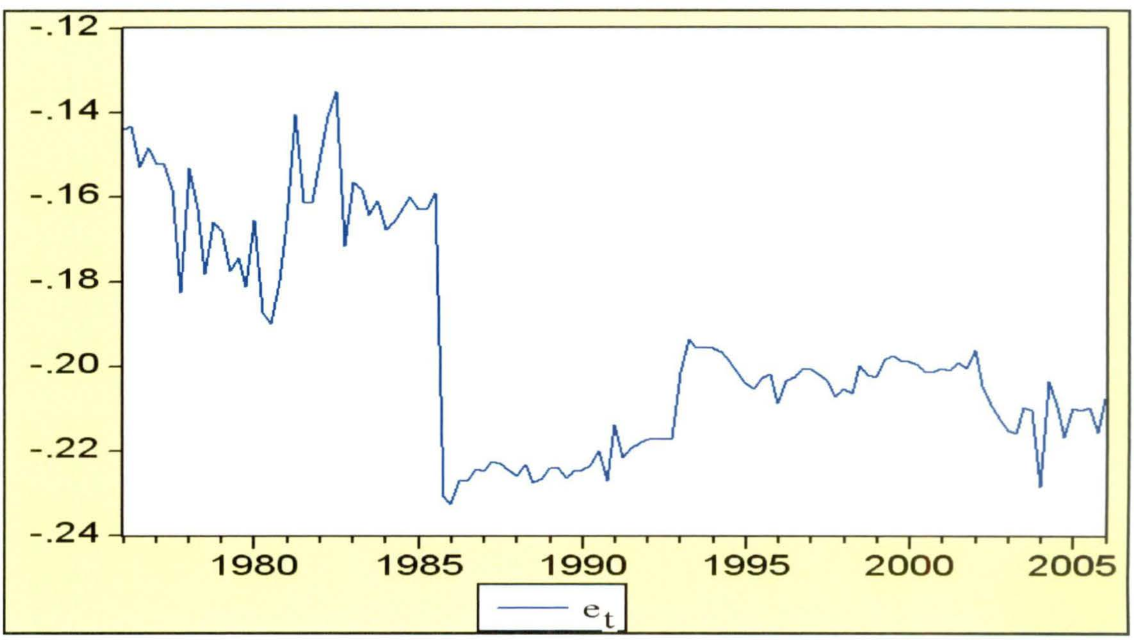
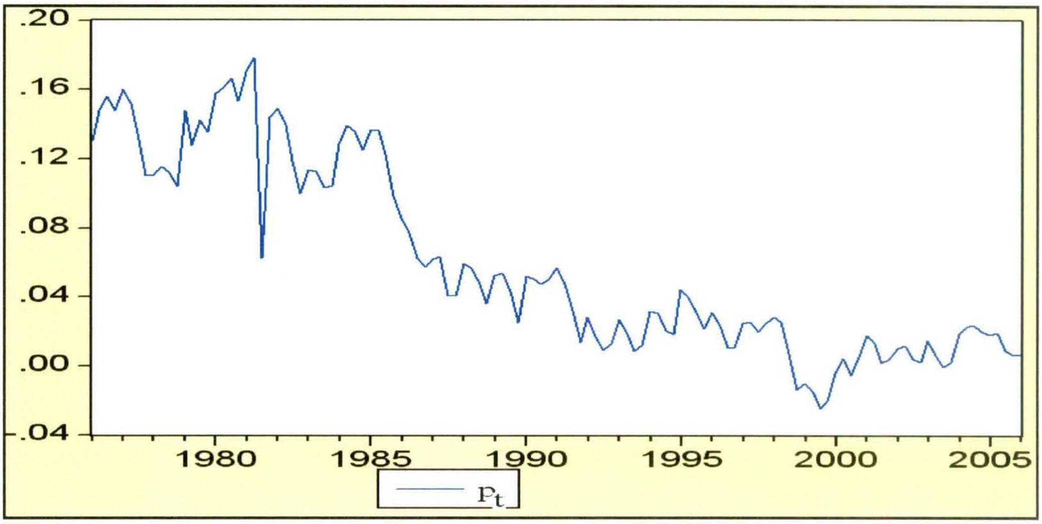


Figure: 4.2

Time Plot of Relative Price level (p_t)

[Period: 1976:1-2006:1]



4.3 Trend Analysis:

4.3.1 Nature of the Time Plot of Rupee/Nepalese Rupee Exchange Rate (e_t)

It is observed from the time plot of e_t as given by the Figure 4.1 that

i. e_t declines steadily (i.e Indian currency appreciated against the Nepalese currency) between 1976 and 1978. However, e_t, with a minimal rise in 1979, declined until 1981.

ii. e_t displayed a rise between 1982 and 1984 with a tendency to reach a level higher than that in 1976. However, e_t fell in 1983 and almost maintained that level until 1985.

iii. in 1986 there was a very sharp fall in e_t (i.e Rupee appreciated strikingly against the Nepalese Rupee in 1986).

iv. since 1987 e_t displayed a rising trend with fluctuations until 1993. These fluctuations are not regular.

v. in 1993 exchange rate (e_t) rises and since then it displayed a tendency to maintain the 1993 level until 2002.

vi. in 2003 e_t fell and maintained that level with some minor fluctuations.

The peculiar feature of fluctuations in e_t observed here relates to the exchange rate practices followed in these two countries concerned during 1970s, especially in India. Both the countries practiced fixed exchange rate management. Since 1975 monetary authorities in both the countries followed multi-currency pegging system in lieu of a link with any single currency. The monetary authorities in both the countries kept on severing, from time to time, its rates for the purchase and sale of major currencies for spot delivery since 1985. Till 1990, in every quarter exchange rate varied though these variations were little.

As both the countries, especially India, were stepping away from fixed exchange rate system, Rupee/Nepalese Rupee exchange rate tended to get related to relative price level. In the very first opportunity in 1986, the exchange rate underwent spectacular depreciation (i.e. Rupee appreciated) in order to be in parity with the relative price level. This is marked by a sharp fall in exchange rate. However, such appreciation of Rupee (Indian currency) is marked by '*overshooting*' since the appreciation of Rupee is followed by a spell of depreciations since 1987 to 1993:1.

Since 1993 India and Nepal steadily moved forward to the '*market determination*' system of exchange rate. By 1994 the exchange rate system become virtually flexible. During the period 1993-2002, exchange rate which was closely related to relative price level, exhibited some minor fluctuations around a stable level.

All these observations indicate that the economic systems and exchange rate practices varied strikingly over the period concerned. Thus the processes generating the exchange rate data did not remain '*stationary* over the period of study implying *non-stationarity* of the data set concerned.

4.3.2 Nature of the Time Plot of the Relative Price Level (p_t)

The time plot of p_t as given in the Figure 4.2, represents some downward movements with fluctuation of higher amplitude between 1976 to 1985. However, between 1985-1986, it exhibited a sharp decline. Since then, there is a visible declining trend with minor fluctuations between 1986-2006. All these observations seem to testify for a possible '*non-stationary*' nature of the series concerned.

4.4 Test of Stationarity: Augmented Dickey-Fuller (ADF) Unit Root Test

Stationarity of exchange rate (e_t) and relative price level (p_t) series has been studied through the Augmented Dickey Fuller (ADF) tests. The basic ADF equation estimated with appropriate changes under different assumptions are

$$\Delta e_t = \alpha_1 + \beta_1 t + \gamma_1 e_{t-1} + \delta_{1i} \sum_{i=1}^{k} \Delta e_{t-1} + \varepsilon_{1t} \qquad (4.1)$$

$$\Delta p_t = \alpha_2 + \beta_2 t + \gamma_2 p_{t-1} + \delta_{2i} \sum_{i=1}^{k} \Delta p_{t-1} + \varepsilon_{2t} \qquad (4.2)$$

where $\Delta e_t = (e_t - e_{t-1})$ and $\Delta p_t = (p_t - p_{t-1})$ etc.

$\varepsilon_{1t} \sim iidN\ (0, \sigma^2_{\varepsilon_1})$ and $\varepsilon_{2t} \sim iidN\ (0, \sigma^2_{\varepsilon_2})$

The optimal lag (k) may be determined through *Akaike Information Criterion, Schwartz Information Criterion, Haunan-Quinn Information criterion* etc.

4.5 Results of the ADF Tests

Results of ADF Unit Root Tests on e_t and p_t series concerned are being presented through the Table 4.1 below.

Table 4.1

Results of ADF Tests on Exchange Rate (e_t) and Relative Price Level (p_t)

[Period: 1976:1-2006:1]

Variable	Null Hypothesis	Lag Length*	ADF Test Stat.	Prob.	Mac-Kinnon Critical Value**		
					1%	5%	10%
e_t	e_t has unit root Exogenous: Constant	0	-2.759	0.067	-3.486	-2.886	-2.580
	e_t has unit root Exogenous: Constant, Linear Trend	0	-3.042	0.125	-4.037	-3.448	-3.149
	e_t has unit root Exogenous: None	0	0.188	0.739	-2.584	-1.943	-1.615
p_t	p_t has unit root Exogenous: Constant	2	-1.467	0.547	-3.486	-2.886	-2.580
	p_t has unit root Exogenous: Constant, Linear Trend	2	-2.207	0.481	-4.038	-3.448	-3.149
	p_t has unit root Exogenous: None	2	-1.947	0.050	-2.585	-1.943	-1.615

**MacKinnon (1996) one-sided p-values. * based on SIC, Max Lag = 12

4.6 Finding from the ADF Tests(Table 4.1)

It is observed from the ADF Unit Root Test results as presented through the Table 4.1 that

i. the hypothesis of '*unit roots*' in e_t and p_t cannot be rejected even at 10% level in the presence of '*intercept*' term and '*time*' variable in the maintained regression equation.
ii. the hypothesis of '*unit root*' in e_t and p_t is accepted in the presence of '*intercept*' term alone without '*linear trend*' and even in the absence of any '*intercept*' term and '*linear trend*' in the maintained regression equations.

All these observations indicate that

i. e_t and p_t series contain '*unit roots*' and, therefore, these series are '*non-stationary*' by nature.
ii. e_t and p_t series do not entail any '*deterministic trends*', and on the contrary,
iii. e_t and p_t series contain '*non-stationary*' stochastic trends.

The ADF tests do not confirm whether the observed '*non-stationarity*' of e_t and p_t series is the '*inherent*' nature of the series concerned or if it is due to any *structural shift* in the process. We, therefore, seek to examine if the observed '*non-stationarity*' of the series concerned is due to '*structural shift*'. *Phillips-Perron Unit Root Tests*' are being performed for this purpose.

4.7 Results of Phillips –Perron Unit Root Tests

Results of Phillips-Perron Unit Root tests are being presented through the Table 4.2

Table 4.2

Results of Phillips –Perron Unit Root Tests on Exchange Rate (e_t) and Relative Price Level (p_t) at Level

[Period: 1976:1-2006:1]

Variable	Null Hypothesis	Lag Length	Phillips-Perron Test Stat.	Prob*.	Mac-Kinnon Critical Value**		
					1%	5%	10%
e_t	e_t has unit root Exogenous: Constant	3	-2.511	0.115	-3.486	-2.886	-2.580
	e_t has unit root Exogenous: Constant,Linear Trend	1	-2.843	0.185	-4.037	-3.448	-3.149
	e_t has unit root Exogenous: None	10	0.502	0.822	-2.584	-1.943	-1.615
p_t	p_t has unit root Exogenous: Constant	6	-1.442	0.559	-3.486	-2.886	-2.580
	p_t has unit root Exogenous: Constant,Linear Trend	7	-3.990	0.011	-4.038	-3.448	-3.149
	p_t has unit root Exogenous: None	5	-1.622	0.099	-2.585	-1.943	-1.615

*Mackinnon(1996) One-sided P-values **Newey-West using Bartlett kernel

4.8 Finding From the Phillips-Perron Test (Table 4.2)

The Table 4.2 shows that

i. the null-hypothesis of '*unit roots with exogenous constant*' in the maintained regression equations for the series e_t and p_t cannot be rejected even at 10% level.

ii. the null-hypothesis of '*unit roots with exogenous constant and linear trend*' in the maintained regression equation is rejected at 5% for p_t series but accepted for e_t series at 5% level.

iii. the null-hypothesis of '*unit roots with 'no intercept term and linear trend*' in the maintained regression equation has also been rejected for p_t even at 10% level but accepted for e_t at 10% level.

These observations indicate that

i. e_t is non-stationary at level,

ii. 'non-stationarity' of p_t series depends on the nature of the maintained regression equation.

a. p_t is '*stationary*' when maintained regression equation is taken with or without intercept along with a linear trend.

b. again p_t is found to be '*non-stationary*' when the maintained regression equation contains only the intercept term.

These observations hint at the existence of *non-stationarity* in p_t because of the presence of '*structural shift*' in it. This seems to confirm our earlier observation on the nature of the time plot of p_t in Section 4.3.2.

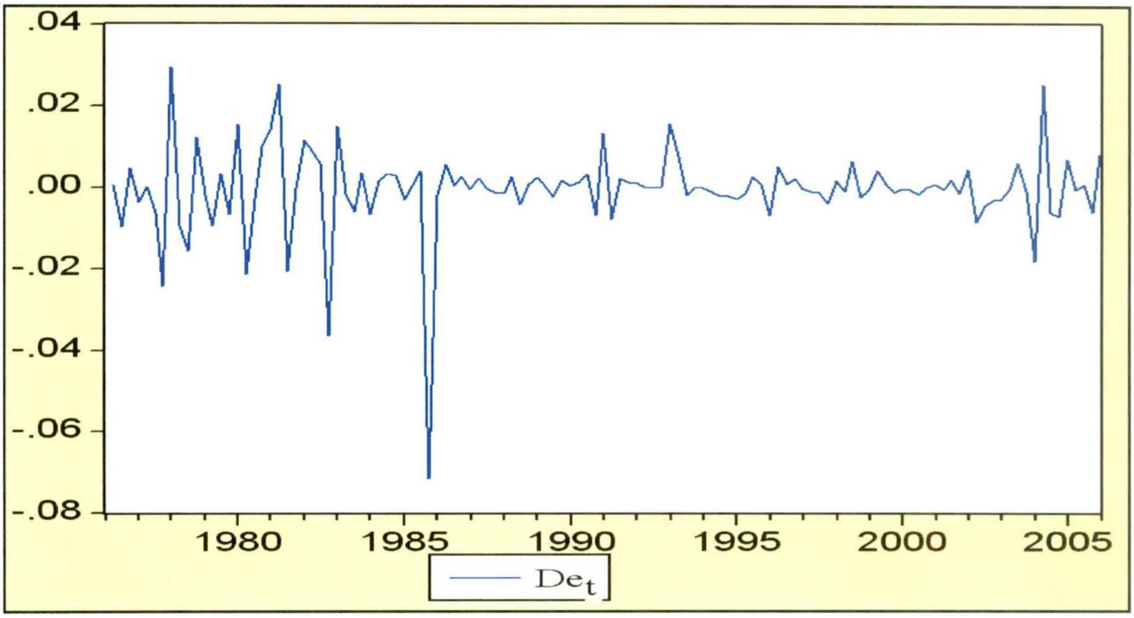
4.9 Integrability of e_t and p_t Series: Time Plots of First Differenced Series:

Time Plots of first differenced series of exchange rate (e_t) and relative price level (p_t) are shown in Figures 4.3-4.4.

Figures 4.3

Time Plot of First Differenced Series of Rupee/Nepalese Rupee Exchange Rate (e_t)

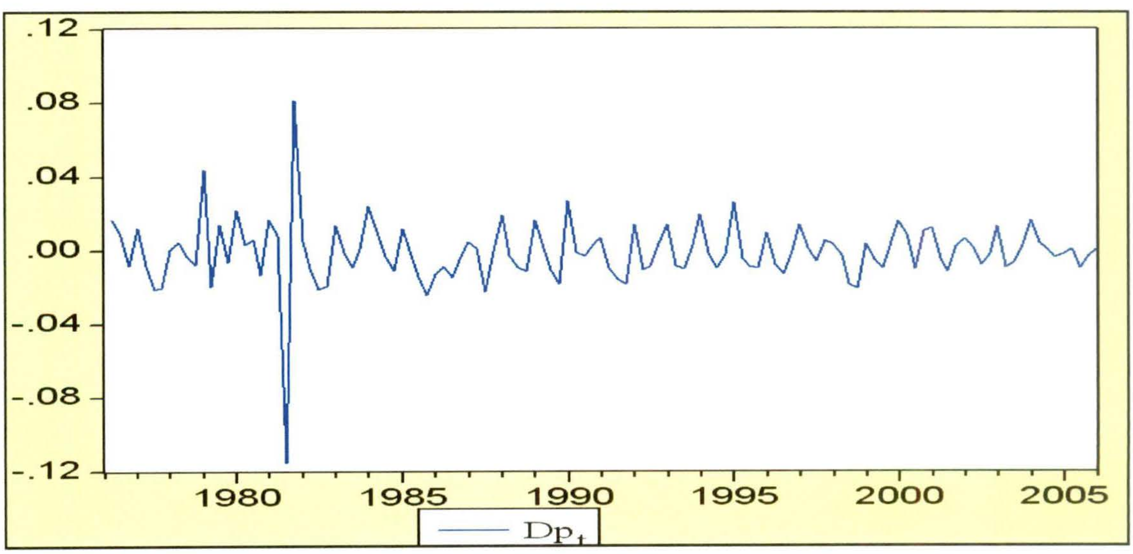
[Period: 1976:1-2006:1]



Figures 4.4

Time Plot of First Differenced Series of Relative Price Level (p_t)

[Period: 1976:1-2006:1]



Time plots of first differenced series for e_t and p_t indicate that

i. the unconditional means of De_t and Dp_t are zero and, therefore, the values of De_t and Dp_t sequences fluctuate around zero. This means of the series are invariant with time. This is a pointer to the *stationarity* of the De_t and Dp_t series.

ii. De_t series exhibit fluctuations around zero mean with high amplitudes until 1986. Since 1987 fluctuations occur with minor amplitudes. This indicates that the stochastic processes for De_t between 1976:1 and 1986:4 differ significantly from that which followed after 1986.

iii. De_t again exhibited high amplitude fluctuations between 1990 and 1992. Nature of fluctuation between 1993 and 2006 differed significantly from those which occurred in 1990-1992.

These observations again hint at the possibility that the stochastic processes behind De_t in 1987-1992 and 1993-2006 were different by nature.

iv. Dp_t series exhibits fluctuations with high amplitudes in 1976-1982. Amplitudes of fluctuations declined a little between 1983-1992. Since 1993 the fluctuations were almost uniform.

These observations also hint at the possibility of structural breaks in p_t series and the stationarity of Dp_t series.

4.10 Integrability of e_t and p_t Series ADF and PP Tests

Stationarity of first differenced series of exchange rate (De_t) and relative price level (Dp_t) has been studied with the Augmented Dickey–Fuller (ADF) test. The basic ADF Test equations are

$$De_t = \alpha_3 + \gamma_3 e_{t-1} + \delta_{3i} \sum_{i=1}^{k} \Delta e_{t-1} + \varepsilon_{3t} \tag{4.4}$$

$$Dp_t = \alpha_4 + \gamma_4 p_{t-1} + \delta_{4i} \sum_{i=1}^{k} \Delta p_{t-1} + \varepsilon_{4t} \tag{4.5}$$

where $De_t = \Delta e_t = (e_t - e_{t-1})$ and $Dp_t = \Delta p_t = (p_t - p_{t-1})$ etc.

$\varepsilon_{3t} \sim iidN(0, \sigma^2_{\varepsilon_3})$ and $\varepsilon_{4t} \sim iidN(0, \sigma^2_{\varepsilon_4})$

These basic equations have been estimated with some maintained alternative assumptions like

i. $\alpha_3 \neq 0, \quad \alpha_4 \neq 0, \quad \gamma_3 = 0, \quad \gamma_4 = 0,$

ii. $\alpha_3 \neq 0, \quad \alpha_4 \neq 0, \quad \gamma_3 \neq 0, \quad \gamma_4 \neq 0,$

iii. $\alpha_3 = 0, \quad \alpha_4 = 0, \quad \gamma_3 = 0, \quad \gamma_4 = 0,$

Results of such ADF tests are being presented through the Table 4.3.

Table:- 4.3

Results of ADF Unit Root Tests on e_t and p_t at First Difference [1976:1-2006:1]

Variable	Null Hypothesis	Lag Length*	ADF Test Stat.	Prob.	Mac-Kinnon Critical Value**		
					1%	5%	10%
De_t	De_t has unit root Exogenous: Constant	0	-13.646	0.000	-3.486	-2.886	-2.580
	De_t has unit root Exogenous: Constant, Linear Trend	0	-13.637	0.000	-4.037	-3.448	-3.149
	De_t has unit root Exogenous: None	0	-13.657	0.000	-2.584	-1.943	-1.615
Dp_t	Dp_t has unit root Exogenous: Constant	1	-11.333	0.000	-3.486	-2.886	-2.580
	Dp_t has unit root Exogenous: Constant, Linear Trend	1	-11.317	0.000	-4.038	-3.448	-3.149
	Dp_t has unit root Exogenous: None	1	-11.230	0.000	-2.585	-1.943	-1.615

**Mac Kinnon (1996) One sided P-Values * Based on SIC, Max Lag = 12

(A) The Table 4.3 shows that

i. the hypothesis of '*unit roots*' for De_t series is rejected even at 1% level in the presence of an '*intercept term*' and a '*linear trend*' in the maintained regression equation.

ii. the hypothesis of '*unit roots*' for De_t series is rejected even at 1% level both in the presence and absence of an '*intercept term*' in the maintained regression equation.

iii. the hypothesis of '*unit root*' in Dp_t series is rejected even at 1% level when the estimated maintained regression equation contains an '*intercept term*' and '*linear trend*' term in it.

iv. the hypothesis of *unit root* for Dp_t is also rejected even at 1% level when the maintained regression equation is estimated with and without an '*intercept*' term given that no '*time*' variable appears in it.

All these observations indicate that

a) De_t and Dp_t are *stationary*. So both De_t and Dp_t are I(0) variables.

b) e_t and p_t are '*Differenced Stationary*' and these are not '*Trend Stationary*' series.

c) e_t and p_t are I(1) variables. Therefore, e_t and p_t represent *First Order Integrable Series,*

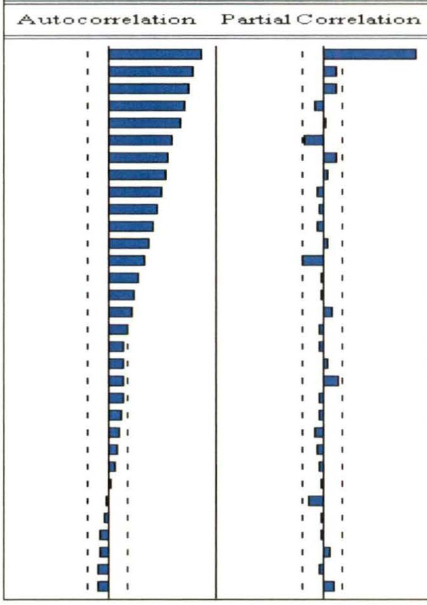
4.11 Test of Stationary Through Correlogram Study:

The nature of *stationarity* and *integrability* of e_t and p_t has further been enquired into through the study of their respective *correlograms.* The Figures 4.5 and 4.6 present correlograms of e_t at level and at first difference respectively. Again Figures 4.7 and 4.8 present the correlograms of the p_t series at level and at first difference respectively.

Figure 4.5

Correlogram of Rupee/ Nepalese Rupee (e_t) Series at Level [Period: 1976:1-2006:1]

Included observations: 121 Sample: 1976:1 2006:1

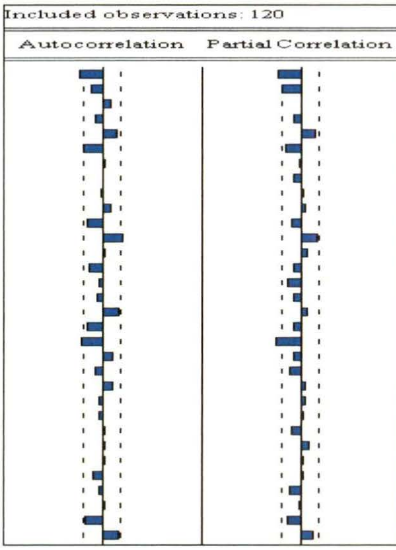


	AC	PAC	Q-Stat	Prob
1	0.896	0.896	99.510	0.000
2	0.829	0.135	185.46	0.000
3	0.790	0.137	264.14	0.000
4	0.733	-0.059	332.44	0.000
5	0.689	0.038	393.38	0.000
6	0.617	-0.171	442.62	0.000
7	0.582	0.127	486.81	0.000
8	0.559	0.050	527.92	0.000
9	0.511	-0.049	562.66	0.000
10	0.474	-0.020	592.79	0.000
11	0.431	-0.046	617.88	0.000
12	0.406	0.044	640.34	0.000
13	0.345	-0.194	656.77	0.000
14	0.289	-0.004	668.36	0.000
15	0.254	-0.005	677.43	0.000
16	0.229	0.094	684.84	0.000
17	0.202	-0.025	690.68	0.000
18	0.160	-0.039	694.37	0.000
19	0.145	0.057	697.44	0.000
20	0.161	0.142	701.26	0.000
21	0.149	-0.028	704.58	0.000
22	0.131	-0.040	707.16	0.000
23	0.105	-0.079	708.84	0.000
24	0.086	-0.055	709.97	0.000
25	0.063	-0.033	710.60	0.000
26	0.030	-0.011	710.74	0.000
27	-0.013	-0.134	710.77	0.000
28	-0.038	-0.007	711.00	0.000
29	-0.059	-0.010	711.58	0.000
30	-0.077	0.060	712.54	0.000
31	-0.096	-0.040	714.06	0.000
32	-0.088	0.111	715.36	0.000

Figure 4.6

Correlogram of Rupee/ Nepalese Rupee (e_t) Series at First Difference [Period: 1976:1-2006:1]

Included observations: 120 Sample: 1976:1 2006:1



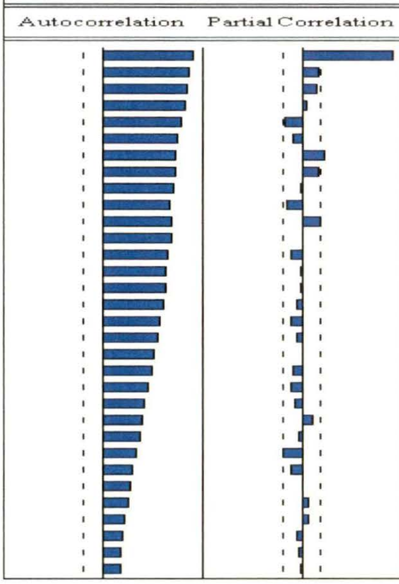
	AC	PAC	Q-Stat	Prob
1	-0.230	-0.230	6.4912	0.011
2	-0.120	-0.182	8.2677	0.016
3	0.083	0.009	9.1278	0.028
4	-0.066	-0.068	9.6710	0.046
5	0.157	0.152	12.810	0.025
6	-0.188	-0.146	17.339	0.008
7	0.026	-0.001	17.430	0.015
8	0.005	-0.069	17.433	0.026
9	-0.008	0.018	17.442	0.042
10	0.093	0.056	18.594	0.046
11	-0.160	-0.084	22.011	0.024
12	0.209	0.168	27.927	0.006
13	0.017	0.069	27.964	0.009
14	-0.139	-0.060	30.638	0.006
15	-0.024	-0.123	30.715	0.010
16	-0.045	-0.059	31.003	0.013
17	0.165	0.079	34.863	0.006
18	-0.147	-0.071	37.966	0.004
19	-0.218	-0.247	44.876	0.001
20	0.107	-0.069	46.554	0.001
21	-0.063	-0.120	47.132	0.001
22	0.120	0.043	49.280	0.001
23	-0.035	0.042	49.464	0.001
24	-0.030	0.021	49.601	0.002
25	0.027	-0.086	49.714	0.002
26	0.037	0.083	49.927	0.003
27	0.025	0.030	50.028	0.005
28	-0.084	0.021	51.153	0.005
29	-0.018	-0.104	51.205	0.007
30	0.035	-0.010	51.404	0.009
31	-0.179	-0.134	56.662	0.003
32	0.173	0.134	61.641	0.001

Figure 4.7

Correlogram of Relative Price Level (p_t) at Level

[Period: 1976:1-2006:1]

Included observations: 121 Sample: 1976:1 2006:1



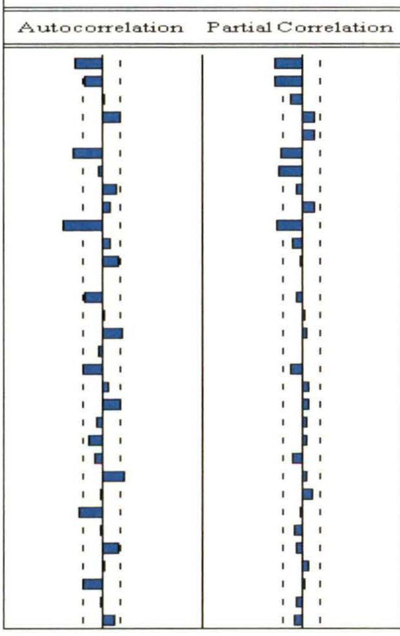
	AC	PAC	Q-Stat	Prob
1	0.940	0.940	109.56	0.000
2	0.903	0.168	211.52	0.000
3	0.881	0.153	309.47	0.000
4	0.859	0.046	403.31	0.000
5	0.815	-0.168	488.64	0.000
6	0.772	-0.091	565.84	0.000
7	0.763	0.225	641.85	0.000
8	0.760	0.173	717.91	0.000
9	0.740	-0.014	790.63	0.000
10	0.708	-0.149	857.78	0.000
11	0.714	0.188	926.78	0.000
12	0.714	0.015	996.31	0.000
13	0.688	-0.105	1061.6	0.000
14	0.664	0.000	1123.0	0.000
15	0.654	-0.002	1183.0	0.000
16	0.643	-0.051	1241.6	0.000
17	0.605	-0.120	1294.0	0.000
18	0.567	-0.044	1340.5	0.000
19	0.547	0.002	1384.2	0.000
20	0.524	-0.090	1424.6	0.000
21	0.478	-0.112	1458.5	0.000
22	0.433	-0.069	1486.8	0.000
23	0.421	0.107	1513.7	0.000
24	0.401	-0.030	1538.4	0.000
25	0.355	-0.182	1557.9	0.000
26	0.310	-0.123	1573.0	0.000
27	0.290	0.007	1586.3	0.000
28	0.275	0.081	1598.5	0.000
29	0.242	0.061	1607.9	0.000
30	0.205	-0.055	1614.8	0.000
31	0.191	-0.035	1620.9	0.000
32	0.181	-0.011	1626.4	0.000

Figure 4.8

Correlogram of Relative Price Level (p_t) at First Difference

[Period: 1976:1-2006:1]

Included observations: 120 Sample: 1976:1 2006:1



	AC	PAC	Q-Stat	Prob
1	-0.271	-0.271	9.0567	0.003
2	-0.170	-0.263	12.634	0.002
3	0.032	-0.112	12.766	0.005
4	0.184	0.135	17.048	0.002
5	0.011	0.133	17.064	0.004
6	-0.298	-0.219	28.496	0.000
7	-0.029	-0.228	28.603	0.000
8	0.163	-0.057	32.090	0.000
9	0.084	0.127	33.027	0.000
10	-0.389	-0.259	53.126	0.000
11	0.091	-0.087	54.227	0.000
12	0.175	-0.013	58.374	0.000
13	0.005	0.006	58.377	0.000
14	-0.167	-0.053	62.214	0.000
15	0.025	0.017	62.302	0.000
16	0.221	0.052	69.162	0.000
17	-0.018	0.006	69.207	0.000
18	-0.197	-0.100	74.786	0.000
19	0.066	0.059	75.415	0.000
20	0.201	0.074	81.344	0.000
21	-0.054	0.048	81.780	0.000
22	-0.124	0.052	84.080	0.000
23	-0.068	-0.086	84.774	0.000
24	0.235	0.054	93.161	0.000
25	-0.015	0.102	93.194	0.000
26	-0.229	-0.010	101.37	0.000
27	-0.003	-0.066	101.37	0.000
28	0.165	-0.042	105.68	0.000
29	0.024	0.066	105.77	0.000
30	-0.190	0.017	111.67	0.000
31	-0.014	-0.045	111.70	0.000
32	0.124	-0.058	114.26	0.000

4.12 Findings From the Figures 4.5 and 4.6

(A) It is observed from the correlogram of p_t given by the Figure 4.5 that

i. the *ACF* of e_t displays a long ladder-like dying out pattern of solid spikes as the lag length increases. Corresponding Q-statistics are found to be significant even at 1% level.

ii. the *PACF* contains only one significant spike (even at 1% level) at lag one and all other lags contain very insignificant spikes.

All these features of the correlogram confirm the *non-stationarity* of the e_t series at level.

(B) The integrability of e_t series is being enquired into through the examination of the correlogram of e_t series at first difference as given by the Figure 4.6. It is observed from the Figure 4.6 that for the first differenced filtered series of e_t.

i. the *ACF* is marked by the absence of any dying out pattern of spikes.

ii. no singularly significant large spike appears at the first lag of the corresponding *PACF*.

These features of the correlogram, as given in the Figure 4.6, confirm that the first differenced series of e_t is stationary. Consequently, e_t series is I (1).

4.13 Findings from the Figures 4.7 and 4.8

(A) It is observed form the Figure 4.7, which presents the correlogram of p_t at level, that

i. the *ACF* exhibits a long dying out pattern of solid spikes over the extending lags.

ii. the *PACF* is marked by the presence of a singular significant spike at lag one with insignificant spikes at all other lags.

These features of the Figure 4.7 confirm the '*non-stationarity*' of the series p_t at level. The *integrability* of the series p_t is being examined through the study of the correlogram of the first differenced series of p_t as given by the Figure 4.8.

(B) It is observed from the correlogram of the first differenced series for p_t as given by the Figure 4.8 that

i. the *ACF* of the series p_t is free from any dying out pattern of spikes, and
ii. the *PACF* of the series is marked by the absence of any singularly significant spike at lag one.

These features of the correlograms of p_t confirm that

i. the first differenced series for p_t (i.e, Dp_t) is *stationary*, and therefore,
ii. p_t attains *stationarity* upon first differencing. Consequently, p_t is also I(1).

4.14 Review of the Findings:

The findings in our study through ADF and Phillips Perron Unit Root Tests and through the examinations of relevant correlograms of the variables confirm that over the period 1976:1-2006:1

i. both the Rupee/ Nepalese Rupee exchange rate (e_t) and the relative price level (p_t) series are non-stationary at level and these, therefore, exhibit random walk processes.

ii. both the series attain stationarity upon filtering through first differencing Consequently, both the series are integrated of order one i.e, $e_t \sim I(1)$ and $p_t \sim I(1)$.

CHAPTER - 5

STUDY OF COINTEGRATION BETWEEN RUPEE / NEPALESE RUPEE EXCHANGE RATE AND RELATIVE PRICE LEVEL

5.1 Introduction:

Rupee/ Nepalese Rupee exchange rate(e_t) and relative price level (p_t) series are non-stationary and both the series are I(1). Since both the series possess the same order of integrability, the possibility of *cointegration* between these series exists. The study of the *cointegration* between e_t and p_t is important in view of the fact that the existence of such *cointegration* implies long-run relationship between exchange rate and relative price level of the two countries concerned. In that case, exchange rates quoted between the currencies will be in parity with the relative prices prevailing at different time sequences of the period of study. This implies, on the other hand, that exchange rates quoted for the currencies are related to and in parity with the relative purchasing power of the currencies over the study-period. Consequently, '*Purchasing Power Parity Doctrine*' becomes a valid phenomenon in the determination of exchange rate of currencies of the countries concerned (viz, India and Nepal). It is, therefore, pertinent to examine if these variables (e_t and p_t) are *cointegrated.* The study in this chapter is devoted to address this issue.

5.2 Johansen Cointegration Test

The Johansen Cointegration Tests are used to examine if Rupee/ Nepalese Rupee exchange rate (e_t) and the relative price level (p_t) series are cointegrated at level over the period 1976:1-2006:1. The results of such tests are being presented through the Table-5.1.

Table-5.1

Results of Johansen Cointegration Tests for

e_t and p_t at level [Period 1976:1-2006:1]

Trend Assumption: Linear Deterministic Trend (Restricted)

Lag Intervals (in first Difference): 1- 4

I Unrestricted Cointegration Rank λ_{trace} Test Variables Involved: e_t and p_t at Level					
Null Hypothesis	Alternative Hypothesis	Eigen Value	Trace Statistics(λ_{trace})	Critical values 5%	1%
r=0	r>0	0.082	14.529	25.32	30.45
r≤1	r≥1	0.039	4.641	12.25	16.26
II Unrestricted Cointegration Rank λ_{max} Test Variables Involved: e_t and p_t at Level					
Null Hypothesis	Alternative Hypothesis	Eigen Value	Maximum Eigen Statistics (λ_{max})	Critical Values 5%	1%
r=0	r=1	0.082	9.888	18.96	23.65
r≤1	r=2	0.039	4.641	12.25	16.26

5.3 Findings From the Table 5.1

It is observed from the Table 5.1 that

i. for the null-hypothesis r=0 against the alternative hypothesis r>0, $\lambda_{trace}(0)$= 14.529 is lower than the corresponding 5% and 1% critical values. Therefore, the null-hypothesis of '*no cointegrating*' relation cannot be rejected even at 5% level.

ii. for the null-hypothesis r≤1 against the alternative hypothesis r>1, the value of λ_{trace} (1) statistic is 4.641 which is lower than 1% and 5% critical values. So the null hypothesis of r≤1 cannot be rejected even at 5% level.

iii. for the null hypothesis r=0 against the alternative hypothesis r=1 under λ_{max} test, λ_{max} (1,0) value is 9.888. It is lower than the corresponding 5% and 1% critical values. It implies that the null hypothesis of '*no cointegration*' cannot be rejected at even 5% level.

iv. for the null hypothesis r =1 against the alternative hypothesis r = 2 under λ_{max} test, λ_{max} (1,2)= 4.641 falls short of the corresponding critical values at 5% and 1% levels. Consequently, the null hypothesis of '*no cointegration*' between the variables appears to be accepted at even 5% level.

5.4 Overview of the Findings of Cointegration Study and Economic Implications

It is observed from the findings in Section 5.3 that

i. there does not exist any '*cointegration*' between Rupee/Nepalese Rupee exchange rate(e_t) and the relative price level (p_t) at level over the period of study (1976:1-2006:1).

ii. though both of e_t and p_t are I(1), these are not CI(I,0).

The absence of *cointegration* between exchange rate (e_t) and relative price level (p_t) at level bears some important economic implications. The '*non-cointegration*' between e_t and p_t implies that the exchange rates quoted between Indian and Nepalese Currency were not related to the relative purchasing power of the currencies over the period of study. Consequently, there did not exist any long-run relationship between exchange rates quoted in international trade and the relative price levels in these countries.

Study of *cointegration* enquires into the existence of equilibrium relationship postulated by the economic theory. In the present context the economic theory refers to the '*Purchasing Power Parity Theory*' which stresses upon the long-run relationship between exchange rate and relative purchasing power of currencies concerned. Under this theory exchange rate, in the long-run, establishes, the *law of one price* (LOOP).

However, the absence of *cointegration* between e_t and p_t, as found in section 5.3, fails to testify for the validity of the '*Purchasing Power Parity Doctrine*' over the period of study concerned. It, therefore, appears that the Rupee/ Nepalese Rupee exchange rates, prevailing over the period of study, were largely determined by some factors other than contemporary relative price levels.

5.5 Limitations of Study with the Historical Dataset (Covering the period 1976:1 – 2006:1)

Lucas (1976) has pointed out that econometric relationships change over time following changes in economic policies, social set-ups, administrative decisions, management considerations, political liabilities and institutional opportunities etc. Thus multiforced changes affect the behaviour of macroeconomic variables leading to changes in their relations as a consequence. Thus historical dataset embodies such varying economic relations. Consequently, the econometric relations among the variables estimated with the historical dataset fail to represent the true econometric relations among the variables concerned.

The historical dataset used in this study covers a period of about thirty-one years (1976:1-2006:1). This period is marked by spectacular changes in economic-social-administrative-political fronts. In this period fixed exchange rate system gave away for '*crawling peg*' system which was finally replaced by '*flexible exchange rate*' system. Thus exchange rate system finally became free from government intervention and varied over time following variations in market forces. Within this period, era of liberalization dawned and globalization was welcome in the realm of trade. Bilateral and multi-lateral trade expansion took place among the South Asian Countries. **SAARC** was established and consequently both India and Nepal took important steps in bringing forth expansion of trade. Thus both the countries experienced changes in economic-social-political fronts and consequently economic relations among variables also underwent changes.

It may also be noted that these changes do not occur everyday. Changes in economic relations occur and continue for some time. Then again such relations change after the passage of some time. Such changes in relations embody '*structural changes*' by nature. Consequently, historical dataset is marked by the presence of '*structural changes*'.

In the historical dataset (1976:1-2006:1) used in our study is found to contain two sub-periods giving forth two distinct relations between exchange rate(e_t) and relative price level(p_t). The first sub period ranges from 1976:1 to 1993:1 and the second sub period extends from 1993:2 to 2006:1.

These two sub periods have been identified through the '*Chow Tests*'. However, the exact period i.e, the coverage of the each of the sub-periods has been identified through laborious '*trial and error*' methods. Identification of the end of the first sub-period and the beginning of the second sub period involved laborious econometric estimations. The justifications of such identifications becomes evident from the econometric findings presented in subsequent chapters.

5.6 Stationarity of e_t and p_t in the Sub-period 1976:1-1993:1: ADF Unit Root Test

The stationarity of e_t and p_t in the sub-period 1976:1-1993:1 has been examined through

i. the ADF Unit Root Test, and
ii. the Correlogram Study.

The results of the ADF Unit Root Tests on e_t and p_t at level and at first difference have been presented through the Tables 5.2 and 5.3 below.

Table: 5.2

Results of the ADF Unit Root Tests for e_t and p_t at Level

(Sub-period: 1976:1-1993:1)

Variable	Null Hypothesis	Lag*	ADF Test Stat.	Prob.	Mac-Kinnon Critical Value**		
					1%	5%	10%
e_t	e_t has unit root Exogenous: Constant	0	-2.010	0.282	-3.530	-2.905	-2.590
	e_t has unit root Exogenous: Constant and Linear Trend	0	-2.719	0.232	-4.099	-3.477	-3.166
	e_t has unit root Exogenous: None	0	0.184	0.737	-2.599	-1.946	-1.614
p_t	p_t has unit root Exogenous: Constant	2	-0.737	0.829	-3.533	-2.906	-2.591
	p_t has unit root Exogenous: Constant and Linear Trend	0	-4.196	0.008	-4.099	-3.477	-3.166
	p_t has unit root Exogenous: None	2	-1.503	0.123	-2.600	-1.946	-1.613

**MacKinnon (1996) one-sided p-values. *Based on SIC, Max Lag =10

Table 5.3

Results of the ADF Unit Root Tests for e_t and p_t at First Difference (De_t and Dp_t)

(Sub-period: 1976:1-1993:1)

Variable	Null Hypothesis	Lag*	ADF Test Stat.	Prob.	Mac-Kinnon Critical Value** 1%	5%	10%
De_t	e_t has unit root Exogenous: Constant	0	-9.953	0.000	-3.530	-2.905	-2.590
	e_t has unit root Exogenous: Constant and Linear Trend	0	-9.917	0.000	-4.099	-3.477	-3.166
	e_t has unit root Exogenous: None	0	-9.971	0.000	-2.599	-1.946	-1.614
Dp_t	p_t has unit root Exogenous: Constant	1	-8.554	0.000	-3.533	-2.906	-2.591
	p_t has unit root Exogenous: Constant and Linear Trend	1	-8.492	0.000	-4.099	-3.477	-3.166
	p_t has unit root Exogenous: None	1	-8.407	0.000	-2.600	-1.946	-1.613

**MacKinnon (1996) one-sided p-values. *Based on SIC, Max Lag = 10

5.7 Findings From The Tables 5.2-5.3

(A) The Tables 5.2 shows that

i. the ADF test statistic for e_t with *intercept term* as well as that for e_t with 'intercept and *linear trend term* in the maintained regression equations fall short of critical values even at 10% level.

ii. the ADF test statistic for e_t with '*no intercept term and linear trend*' term in the maintained regression equation also falls short of the critical values even at 10% level.

All these findings indicate that e_t is 'non-stationary' in the period 1976:1-1993:1.

(B) The Table 5.2 further shows that

i. the ADF test statistics for p_t with '*intercept*' and without '*intercept as well as linear trend*' in the maintained regression equations are lower than the corresponding critical values even at 10% level.

ii. the ADF test statistic for p_t with intercept and linear trend term in the maintained regression equation exceeds 1% critical values.

These findings indicate contradictory status regarding stationarity of p_t. In order to ascertain its stationarity, study of its correlogram becomes necessary.

(C) The Table 5.3 shows that

a. the ADF test statistic for De_t (i.e. e_t at first difference) with *intercept* or '*with intercept as well as linear trend*' or '*without intercept and linear trend*' term in the maintained regression equations exceed the critical values even at 1% level.

b. the ADF test statistic for Dp_t (i.e. p_t at first difference) exceed the critical values even at 1% level when the maintained regression equations are estimated with '*intercept only*' or '*with intercept and linear trend term*' or without '*intercept and linear trend term*'.

These findings indicate that

i. both De_t and Dp_t are stationary even at 1% level, and therefore,

ii. $e_t \sim I(1)$ and $p_t \sim I(1)$.

5.8 Stationarity of e_t and p_t in the Sub-period 1976:1-1993:1 : Correlogram Study

The stationarity of e_t and p_t over the sub-period 1976:1-1993:1 has been examined through the study of their correlograms. The correlogram for e_t *at level* and at *first difference* for this sub-period are given by the Figures 5.1-5.2. The correlograms for p_t *at level* and at *first difference* for this sub-period are being presented through the Figures 5.3-5.4.

Figure 5.1

Correlogram of Rupee/Nepalese Rupee (e_t) Series at level

[Sub-Period: 1976:1- 1993:1]

Included observations: 69 Sample: 1976:1 1993:1

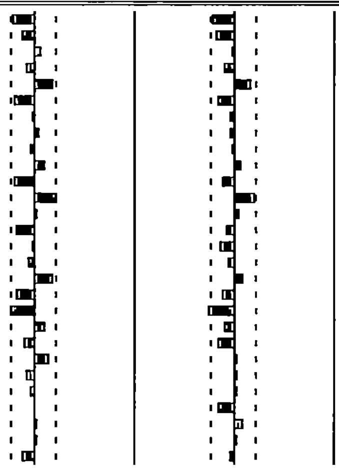
	AC	PAC	Q-Stat	Prob
1	0.898	0.898	58.061	0.000
2	0.828	0.115	108.22	0.000
3	0.785	0.123	153.92	0.000
4	0.727	-0.051	193.80	0.000
5	0.684	0.045	229.59	0.000
6	0.607	-0.195	258.20	0.000
7	0.567	0.126	283.58	0.000
8	0.542	0.053	307.19	0.000
9	0.491	-0.070	326.84	0.000
10	0.448	-0.025	343.54	0.000
11	0.398	-0.055	356.95	0.000
12	0.371	0.057	368.79	0.000
13	0.303	-0.246	376.81	0.000
14	0.237	0.002	381.81	0.000
15	0.197	-0.002	385.34	0.000
16	0.164	0.078	387.82	0.000
17	0.130	-0.058	389.40	0.000
18	0.075	-0.059	389.94	0.000
19	0.050	0.064	390.19	0.000
20	0.061	0.132	390.56	0.000
21	0.042	-0.039	390.74	0.000
22	0.021	-0.024	390.79	0.000
23	-0.013	-0.093	390.80	0.000
24	-0.037	-0.064	390.95	0.000
25	-0.066	-0.065	391.43	0.000
26	-0.104	0.009	392.66	0.000
27	-0.154	-0.172	395.42	0.000
28	-0.186	-0.011	399.57	0.000

Figure 5.2

Correlogram of Rupee/Nepalese Rupee (e_t) at First Difference

[Sub-Period: 1976:1- 1993:1]

Included observations: 68 Sample: 1976:1 1993:1



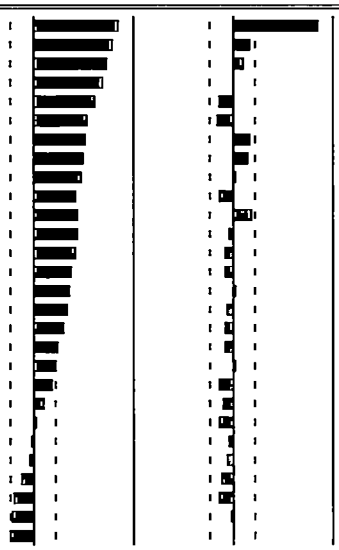
Autocorrelation / Partial Correlation	AC	PAC	Q-Stat	Prob
1	-0.214	-0.214	3.2584	0.071
2	-0.119	-0.173	4.2789	0.118
3	0.058	-0.010	4.5224	0.210
4	-0.070	-0.085	4.8894	0.299
5	0.188	0.174	7.5690	0.182
6	-0.200	-0.152	10.627	0.101
7	-0.003	-0.025	10.627	0.156
8	0.050	-0.029	10.823	0.212
9	-0.038	-0.005	10.938	0.280
10	0.107	0.064	11.886	0.293
11	-0.187	-0.119	14.795	0.192
12	0.240	0.214	19.701	0.073
13	0.017	0.043	19.725	0.102
14	-0.171	-0.072	22.293	0.073
15	-0.013	-0.134	22.308	0.100
16	-0.056	-0.044	22.597	0.125
17	0.190	0.086	25.956	0.075
18	-0.165	-0.110	28.540	0.054
19	-0.244	-0.251	34.319	0.017
20	0.112	-0.089	35.565	0.017
21	-0.090	-0.155	36.394	0.020
22	0.150	0.024	38.719	0.015
23	-0.060	0.025	39.106	0.019
24	-0.027	0.020	39.182	0.026
25	0.016	-0.144	39.212	0.035
26	0.033	0.093	39.332	0.045
27	0.031	0.020	39.445	0.058
28	-0.110	-0.019	40.896	0.055

Figure 5.3

Correlogram of Relative Price Level (p_t) at level

[Sub-Period: 1976:1- 1993:1]

Included observations: 69 Sample: 1976:1 1993:1



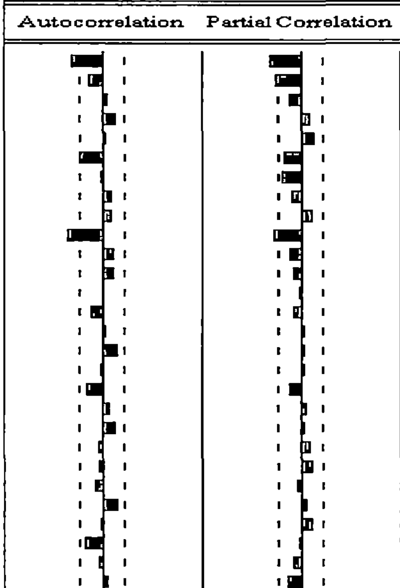
Autocorrelation / Partial Correlation	AC	PAC	Q-Stat	Prob
1	0.880	0.880	55.729	0.000
2	0.814	0.177	104.14	0.000
3	0.768	0.107	147.94	0.000
4	0.718	0.008	186.82	0.000
5	0.644	-0.125	218.56	0.000
6	0.559	-0.144	242.84	0.000
7	0.534	0.172	265.39	0.000
8	0.523	0.156	287.40	0.000
9	0.496	0.034	307.48	0.000
10	0.444	-0.127	323.87	0.000
11	0.464	0.202	342.09	0.000
12	0.465	-0.017	360.67	0.000
13	0.435	-0.078	377.26	0.000
14	0.396	-0.067	391.21	0.000
15	0.382	0.041	404.45	0.000
16	0.366	-0.056	416.82	0.000
17	0.313	-0.073	426.03	0.000
18	0.252	-0.076	432.13	0.000
19	0.222	0.022	436.96	0.000
20	0.183	-0.131	440.31	0.000
21	0.114	-0.093	441.63	0.000
22	0.039	-0.132	441.79	0.000
23	-0.003	-0.026	441.79	0.000
24	-0.039	-0.057	441.96	0.000
25	-0.111	-0.115	443.32	0.000
26	-0.181	-0.133	447.07	0.000
27	-0.211	-0.001	452.29	0.000
28	-0.226	0.003	458.40	0.000

Figure 5.4

Correlogram of Relative Price Level (p_t) at First Difference

[Sub-Period: 1976:1- 1993:1]

Included observations: 68 Sample: 1976:1 1993:1



	AC	PAC	Q-Stat	Prob
1	-0.325	-0.325	7.4976	0.006
2	-0.124	-0.256	8.6035	0.014
3	0.042	-0.110	8.7330	0.033
4	0.123	0.083	9.8576	0.043
5	0.025	0.131	9.9059	0.078
6	-0.243	-0.171	14.449	0.025
7	-0.015	-0.201	14.467	0.043
8	0.098	-0.096	15.234	0.055
9	0.096	0.108	15.985	0.067
10	-0.360	-0.270	26.623	0.003
11	0.108	-0.105	27.601	0.004
12	0.099	-0.069	28.434	0.005
13	0.008	-0.014	28.439	0.008
14	-0.109	-0.062	29.486	0.009
15	0.035	0.030	29.598	0.013
16	0.150	0.027	31.645	0.011
17	-0.007	0.018	31.649	0.017
18	-0.141	-0.108	33.555	0.014
19	0.072	0.054	34.065	0.018
20	0.131	0.035	35.772	0.016
21	-0.030	0.087	35.862	0.023
22	-0.037	0.114	36.006	0.030
23	-0.078	-0.018	36.644	0.035
24	0.161	0.051	39.450	0.024
25	-0.007	0.120	39.456	0.033
26	-0.173	-0.005	42.842	0.020
27	-0.026	-0.064	42.923	0.027
28	0.054	-0.127	43.266	0.033

5.9 Findings From the Correlogram Study (Sub-period: 1976:1-1993:1)

(A) It is observed from the Figures 5.1-5.2 that

i. the *ACF* for e_t *at level* displays a long dying out pattern of spikes.

ii. the *PACF* for e_t *at level* contains a singular significant spike at lag one.

iii. the *ACF* for e_t at *first difference* is marked by the absence of any dying out pattern of spikes.

iv. the *PACF* for e_t at *first difference* contains no singularly significant spike at lag one.

All these observations confirm that

i. e_t *at level* in the sub-period 1976:1-1993:1 is non-stationary.

ii. e_t attains stationarity upon first differencing over the sub-period 1976:1-1993:1.

(B) The Figures 5.3-5.4 show that

i. the *ACF* of p_t *at level* over the sub-period 1976:1-1993:1 is marked by the presence of a long dying out pattern of spikes.
ii. the *PACF* of p_t at *level* over the sub-period 1976:1-1993:1 contains unique significant spike at lag one.
iii. the *ACF* of p_t at *first difference* exhibits no long dying out pattern of spikes.
iv. the *PACF* of p_t at *first difference* is marked by the absence of any singularly significant spike at lag one.

These features of the correlograms of p_t *at level* and at *first difference* indicate that

i. p_t is non-stationary at level, and
ii. p_t is stationary at first difference over the sub-period 1976:1-1993:1.

5.10 Review of the Findings on Stationarity of e_t and p_t Over the Sub-period 1976:1-1993:1

The Finding in Sections 5.7-5.9 confirm that over the sub-period 1976:1-1993:1

i. both e_t and p_t are non-stationary at level.
ii. both e_t and p_t attain stationarity upon first differencing, and, therefore,
iii. $e_t \sim I(1)$ and $p_t \sim I(1)$.

5.11 Stationarity of e_t and p_t in the Sub-period 1993:2-2006:1: ADF Unit Root Tests

Stationarity of e_t and p_t in the sub-period 1993:2-2006:1 has been examined through ADF unit root tests. Results of such tests for e_t and p_t *at level* and *at first difference* are being presented through the Tables 5.4-5.5.

Table 5.4

Results of ADF Unit Root Tests for e_t and p_t at Level:

[Sub-period: 1993:2-2006:1]

Variable	Hypothesis	Lag*	ADF Test Stat.	Prob.	Mac-Kinnon Critical Value** 1%	5%	10%
e_t	e_t has unit root Exogenous: Constant	2	-1.626	0.462	-3.571	-2.922	-2.599
	e_t has unit root Exogenous: Intercept and Linear Trend	2	-1.946	0.615	-4.157	-3.504	-3.182
	e_t has unit root Exogenous: None	2	0.906	0.900	-2.613	-1.948	-1.612
p_t	p_t has unit root Exogenous: Constant	6	-1.383	0.582	-3.585	-2.928	-2.602
	p_t has unit root Exogenous: Intercept and Linear Trend	6	-1.307	0.874	-4.176	-3.513	-3.187
	p_t has unit root Exogenous: None	6	-1.067	0.254	-2.617	-1.948	-1.612

**MacKinnon (1996) one-sided p-values.*Based on SIC, Max Lag = 10

Table 5.5

Results of ADF Unit Root Tests for e_t and p_t at First Difference: [Sub-period: 1993:2-2006:1]

Variable	Null Hypothesis	Lag*	ADF Test Stat.	Prob.	Mac-Kinnon Critical Value**		
					1%	5%	10%
De_t	De_t has unit root Exogenous: Constant	1	-8.977	0.000	-3.571	-2.922	-2.599
	De_t has unit root Exogenous: Intercept and Linear Trend	1	-8.892	0.000	-4.157	-3.504	-3.182
	De_t has unit root Exogenous: None	1	-8.938	0.000	-2.616	-1.948	-1.612
Dp_t	Dp_t has unit root Exogenous: Constant	5	-4.646	0.0005	-3.585	-2.928	-2.602
	Dp_t has unit root Exogenous: Intercept and Linear Trend	5	-4.621	0.003	-4.176	-3.513	-3.187
	Dp_t has unit root Exogenous: None	5	-4.700	0.000	-2.617	-1.948	-1.612

**MacKinnon (1996) one-sided p-values. *Based on SIC, Max Lag = 10

5.12 Findings From the Table 5.4-5.5

(A) Tables 5.4 and 5.5 show that

i. the ADF Test Statistics for e_t at level fall short of the critical values even at 10% level when the maintained regression equations are estimated with an *intercept term* only or with an *intercept term along with a linear trend* or without *an intercept term as well as a linear trend.*

ii. the ADF Test Statistics for De_t (i.e. e_t at first difference) exceed the critical values even at 1% level when the maintained regression equations are estimated with an *intercept* or with *an intercept along with a linear trend* or without *any intercept and linear trend.*

These findings indicate that

a. e_t is *non-stationary* at level even at 10% level of significance, and
b. De_t (i.e. e_t upon first differencing) is *stationary* even at 1% level.

(B) It is further observed from the Tables that

i. the ADF test statistics for p_t at level are lower than the corresponding critical values even at 10% level when estimated regression equations contain an *intercept term* or an *intercept term together with a linear trend* or without *an intercept term and a time trend.*

ii. the ADF test statistic for Dp_t (i.e. p_t at first difference) exceed the corresponding critical values at 1% level when maintained regression equations are estimated with an *intercept term* or with *an intercept term together with a linear trend* or without *any intercept term and a linear trend.*

These findings indicate that in the sub-period 1993:2-2006:1

i. p_t is *non-stationary* at level, and
ii. p_t attains *stationarity* upon first differencing such that Dp_t is *stationary* at level even at 1% level.

5.13 Stationarity of e_t and p_t in the Sub-period 1993:2-2006:1: Correlogram Study

Stationarity of e_t and p_t in the sub-period 1993:2-2006:1 has also been examined through the study of their respective correlograms. The correlograms of e_t *at level* and at *first difference* are being presented through the Figures 5.5-5.6. Moreover, Figures 5.7 and 5.8 present the correlograms of p_t *at level* and at *first difference* respectively.

Figure 5.5

Correlogram of Rupee/Nepalese Rupee (e_t) at Level

[Sub-Period: 1993:2-2006:1]

Included observations: 52 Sample: 1993:2 2006:1

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.622	0.622	21.322	0.000
		2	0.551	0.266	38.344	0.000
		3	0.576	0.280	57.381	0.000
		4	0.419	-0.099	67.643	0.000
		5	0.297	-0.145	72.926	0.000
		6	0.226	-0.114	76.057	0.000
		7	0.244	0.154	79.759	0.000
		8	0.100	-0.106	80.395	0.000
		9	0.115	0.106	81.266	0.000
		10	0.062	-0.130	81.523	0.000
		11	0.008	-0.005	81.528	0.000
		12	-0.039	-0.119	81.636	0.000
		13	-0.116	-0.080	82.612	0.000
		14	-0.153	-0.102	84.350	0.000
		15	-0.233	-0.057	88.483	0.000
		16	-0.213	0.032	92.031	0.000
		17	-0.194	0.131	95.040	0.000
		18	-0.166	0.082	97.324	0.000
		19	-0.104	0.100	98.241	0.000
		20	-0.027	0.088	98.304	0.000
		21	-0.013	-0.047	98.320	0.000
		22	-0.052	-0.153	98.570	0.000
		23	0.015	-0.008	98.590	0.000
		24	-0.011	-0.038	98.603	0.000

Figure 5.6

Correlogram of Rupee/Nepalese Rupee (e_t) at First Difference

[Sub-Period: 1993:2-2006:1]

Included observations: 51 Sample: 1993:2 2006:1

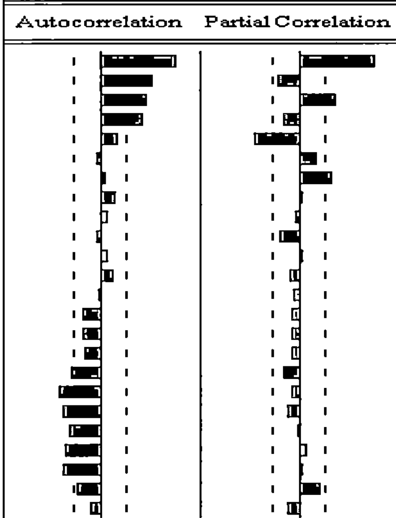
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.444	-0.444	10.664	0.001
		2	-0.130	-0.408	11.599	0.003
		3	0.259	-0.006	15.365	0.002
		4	-0.046	0.089	15.488	0.004
		5	-0.075	0.059	15.819	0.007
		6	-0.097	-0.209	16.389	0.012
		7	0.261	0.100	20.571	0.004
		8	-0.276	-0.176	25.363	0.001
		9	0.118	0.063	26.257	0.002
		10	-0.005	-0.108	26.259	0.003
		11	0.022	0.107	26.290	0.006
		12	0.007	0.025	26.293	0.010
		13	-0.059	0.046	26.541	0.014
		14	0.053	-0.120	26.743	0.021
		15	-0.133	-0.146	28.080	0.021
		16	0.026	-0.257	28.132	0.030
		17	-0.012	-0.102	28.143	0.043
		18	-0.021	-0.145	28.177	0.059
		19	-0.036	-0.085	28.290	0.078
		20	0.099	0.021	29.144	0.085
		21	0.028	0.130	29.213	0.109
		22	-0.135	-0.061	30.914	0.098
		23	0.138	0.000	32.749	0.086
		24	-0.105	-0.261	33.863	0.087

Figure 5.7

Correlogram of Relative Price Level (p$_t$) at Level

[Sub-Period: 1993:2-2006:1]

Included observations: 52 Sample: 1993:2 2006:1



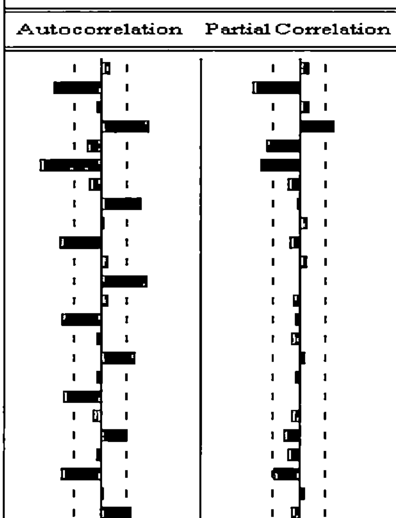
Lag	AC	PAC	Q-Stat	Prob
1	0.779	0.779	33.449	0.000
2	0.525	-0.209	48.951	0.000
3	0.474	0.379	61.853	0.000
4	0.430	-0.163	72.693	0.000
5	0.169	-0.461	74.406	0.000
6	-0.030	0.171	74.462	0.000
7	0.048	0.333	74.603	0.000
8	0.153	0.032	76.093	0.000
9	0.078	-0.038	76.489	0.000
10	-0.016	-0.201	76.507	0.000
11	0.076	0.031	76.905	0.000
12	0.134	-0.088	78.157	0.000
13	-0.006	-0.050	78.160	0.000
14	-0.171	-0.070	80.322	0.000
15	-0.165	-0.058	82.400	0.000
16	-0.148	-0.062	84.114	0.000
17	-0.290	-0.151	90.852	0.000
18	-0.416	-0.062	105.13	0.000
19	-0.381	-0.109	117.49	0.000
20	-0.311	-0.014	125.95	0.000
21	-0.354	0.061	137.31	0.000
22	-0.379	0.020	150.74	0.000
23	-0.229	0.213	155.82	0.000
24	-0.087	-0.117	156.59	0.000

Figure 5.8

Correlogram of Relative Price Level (p$_t$) at First Difference

[Sub-Period: 1993:2-2006:1]

Included observations: 51 Sample: 1993:2 2006:1



Lag	AC	PAC	Q-Stat	Prob
1	0.090	0.090	0.4335	0.510
2	-0.468	-0.480	12.526	0.002
3	-0.030	0.098	12.579	0.006
4	0.500	0.351	26.932	0.000
5	-0.127	-0.339	27.880	0.000
6	-0.630	-0.387	51.743	0.000
7	-0.100	-0.103	52.352	0.000
8	0.414	-0.013	63.130	0.000
9	0.035	0.068	63.207	0.000
10	-0.423	-0.085	74.982	0.000
11	0.075	0.066	75.362	0.000
12	0.475	0.009	91.011	0.000
13	0.057	-0.043	91.246	0.000
14	-0.390	-0.035	102.37	0.000
15	-0.036	-0.062	102.47	0.000
16	0.361	0.053	112.52	0.000
17	-0.037	-0.035	112.63	0.000
18	-0.381	0.008	124.51	0.000
19	-0.074	-0.073	124.97	0.000
20	0.272	-0.155	131.41	0.000
21	-0.035	-0.114	131.52	0.000
22	-0.387	-0.255	145.51	0.000
23	0.027	0.049	145.58	0.000
24	0.315	-0.070	155.53	0.000

5.14 Findings From the Correlogram Study (Sub-Period: 1993:2-2006:1)

(A) It is observed from the figures 5.5-5.6 that in the Sub-Period: 1993:2-2006:1

i. the *ACF* of e_t *at level* exhibits a long dying out pattern of spikes extending beyond 20th lag.

ii. the *PACF* of e_t *at level* exhibits the presence of a '*unique*' significant spike at lag one.

iii. the *ACF* of De_t (i.e. e_t at first difference) is marked by the absence of a dying out ladder like pattern of spikes.

iv. the *PACF* of De_t contains no *singularly significant* spike at lag one.

All these features of the correlograms of e_t *at level* and *first difference* confirm the findings of the ADF unit root tests that over the period 1993:2-2006:1

i. e_t is non-stationary *at level*, and

ii. De_t is stationary at level i.e, e_t attains stationarity upon *first differencing*.

(B) The Figures 5.7 and 5.8 show that in the sub-period 1993:2-2006:1

i. the *ACF* of p_t *at level* contains a long dying out pattern of spikes extending beyond the 20th lag.

ii. the *PACF* of p_t at level is devoid of any such pattern and any *singularly significant* spike at lag one.

iii. the *ACF* of Dp_t (i.e p_t upon first difference) exhibits no dying out pattern of spikes.

iv. the *PACF* of De_t is marked by the absence of any *unique* significant spike at lag one.

All these features of the correlograms of p_t *at level* and at *first difference* testify that over the sub-period 1993:2-2006:1

a. p_t *at level* is non-stationary, and

b. Dp_t is stationary at level and, therefore, p_t attains stationarity upon first differencing.

5.15 Review of Findings on Stationarity and Integrability of e_t and p_t over the Sub-Period 1993:2-2006:1

The findings on *Stationarity* and *Integrability* of e_t and p_t over the sub-period 1993:2-2006:1 in the sections 5.12 through 5.14 confirm that

i. *e_t and p_t at level are non-stationary.*

ii. *e_t and p_t are stationary upon first differencing, and*

iii. *$e_t \sim I(1)$ and $p_t \sim I(1)$.*

5.16 Summary of the Findings and Economic Implications

The findings in this Chapter (Chapter 5) over the subsections 5.7-5.14 confirm that

i. $e_t \sim I(1)$ and $p_t \sim I(1)$ over the sub-period 1976:1-1993:1, and

ii. $e_t \sim I(1)$ and $p_t \sim I(1)$ over the sub-period 1993:2-2006:1.

In both the sub-periods, e_t and p_t are non-stationary while both of them possess the same order of integrability. These are integrated of order one. This indicates that there exist a scope of enquiring into the existence of long-run relationship between these variables in both the sub-periods. Consequently, the study of *cointegration* between e_t and p_t is theoretically justified in both the sub-periods. The *cointegration* between e_t and p_t, if established in any of the sub-periods, would support the doctrine of '*Purchasing Power Parity*' for the quoted exchange rates between the currencies of India and Nepal in that sub-period. The study in the next chapter is devoted to address this issue.

CHAPTER - 6
STUDY OF COINTERGATION BETWEEN RUPEE/ NEPALESE RUPEE EXCHANGE RATE AND RELATIVE PRICE LEVEL IN DIFFERENT SUB-PERIODS

6.1 Introduction:

This chapter entails a study of *cointegration* between exchange rate (e_t) and relative price level (p_t) in two different sub-periods viz 1976:1-1993:1 and 1993:2-2006:1. The sub periods were identified on the basis of the fact that the econometric relationship between e_t and p_t would be strikingly different from each other. Consequently, the nature of the *cointegration* between these two variables is expected to be different in two different sub-periods. The '*Johansen Cointegration Tests*' are being adopted for this purpose.

6.2 The Johansen Cointegration Tests For the Sub-Periods 1976:1-1993:1:

Results of the *Johansen Cointergation Tests* for e_t and p_t at level over the sub-period 1976:1-1993:1 are being presented through the Table 6.1 below.

Table 6.1

Results of the Johansen Cointegration Tests for e_t and p_t at Level

Sub-Period: 1976:1-1993:1

Trend Assumption: Linear Deterministic Trend (Restricted)

Lag Interval in first difference: 1 to 4

I Unrestricted Cointegration Rank λ_{trace} Test Variables Involved: e_t and p_t At Level					
Null Hypothesis	Alternative Hypothesis	Eigen Value	Trace Statistic (λ_{trace})	Critical Values 5%	1%
r=0	r>0	0.101	11.021	25.32	30.45
r≤1	r>1	0.058	3.933	12.25	16.26

II Unrestricted Cointegration Rank λ_{max} Test Variables Involved: e_t and p_t At Level					
Null Hypothesis	Alternative Hypothesis	Eigen Value	Maximum Eigen Statistic (λ_{max})	Critical Values 5%	1%
r=0	r=0	0.101	7.087	18.96	23.65
r=1	r=2	0.058	3.933	12.25	16.26

6.3 Finding From The Table 6.1

Results of the *Johansen Cointegration Test,* as given in the Table 6.1, show that in the sub-period 1976:1-1993:1

i. for the null hypothesis r=0 against the alternative hypothesis r>0, $\lambda_{trace}(0)=11.021$ is lower than the corresponding 5% and 1% critical values. It is not, therefore, possible to reject the *null hypothesis* of '*no cointegration*' between e_t and p_t at level even at 5% level of significance.

ii. for the null hypothesis $r \leq 1$ against alternative hypothesis $r > 1$, the value of $\lambda_{trace}(1)$ statistic is 3.933 which is lower than 1% and even 5% levels of significance. So the *null hypothesis* of $r \leq 1$ cannot be rejected even at 5% level.

iii. for the null hypothesis $r=0$ against alternative hypothesis $r=1$, under λ_{max} test, $\lambda_{max}(0,1)$ value is 7.087. It is clearly lower than the corresponding 1% and 5% critical values. It implies that the *null hypothesis of 'no cointegration'* between e_t and p_t cannot be rejected even at even 5% level.

iv. for the null hypothesis $r=1$ against the alternative hypothesis $r=2$, under λ_{max} test, $\lambda_{max}(1,2)$ =3.933 falls short of the corresponding critical values at 5% and 1% levels. Consequently, the *null hypothesis of 'no cointergation'* between e_t and p_t appears to be accepted at even 5% level.

6.4 Overview of the Findings From the Johansen Cointegration Tests:

It is observed from the findings of the *Johansen Cointegration Test* results, as given in Section 6.3, that in the sub-period 1976:1-1993:1.

i. there does not exist any cointegration between exchange rate (e_t) and relative price level(p_t) at level even at 5% level of significance.

ii. e_t and p_t are, therefore, not CI(1,0).

6.5 Economic Implications of Findings of Cointegration Study:

Absence of *cointegration* between exchange rate(e_t) and relative price level(p_t) *at level* in the sub-period 1976:1-1993:1 implies that there did exist no long-run relationship between exchange rate quoted for the currencies of the countries concerned and the relative price levels prevailing in different quarters of the sub-period. It further implies that the *exchange rates* between the currencies were not linked to their relative *purchasing power*. Thus *purchasing power* of currencies, as revealed by the relative price levels prevailing in the two countries, did not matter at all in the determination of the rate of exchange for the currencies. Thus the '*Law of One Price*' (LOOP) as dictated by the '*Purchasing Power Parity Doctrine*' was not established by the quoted exchange rates between the currencies concerned over the sub-period 1976:1-1993:1.

6.6 The Johansen Cointegration Tests for The Sub-Period 1993:2-2006:1:

The *Johansen Cointegration Test* results for the *level* data of exchange rate (e_t) and relative price level (p_t) over the Sub-Period 1993:2-2006:1 have been presented through the Table 6.2 below.

Table 6.2

Results of the Johansen Cointegration Tests for e_t and p_t At Level

Sub-Period: 1993:2-2006:1

Trend Assumption: Linear Deterministic Trend (Restricted)

Lag Interval in first difference: 1 to 1

I Unrestricted Cointegration Rank λ_{trace} Test Variables Involved: e_t and p_t At Level					
Null Hypothesis	Alternative Hypothesis	Eigen Value	Trace Statistic (λ_{trace})	Critical Values 5%	1%
r=0	r>0	0.332	29.734	25.32	30.45
r≤1	r>1	0.153	8.676	12.25	16.26

II Unrestricted Cointegration Rank λ_{max} Test Variables Involved: e_t and p_t At Level					
Null Hypothesis	Alternative Hypothesis	Eigen Value	Maximum Eigen Statistic (λ_{max})	Critical Values 5%	1%
r=0	r=1	0.332	21.057	18.96	23.65
r=1	r=2	0.153	8.676	12.25	16.26

6.7 Finings From The Table 6.2

It is observed from the Table 6.2 that over the sub-period 1993:2-2006:1 in case of the *Johansen Cointegration Tests*

i. for r=0 against r>1, λ_{trace} (0)=29.734 exceeds the corresponding critical value at 5% level. This implies that the null hypothesis of the '*absence of cointegration*' (r=0) between e_t and p_t at *level* has been rejected at 5% level.
ii. for r≤1 against r>1, λ_{trace} (1)=8.676 falls short of the corresponding critical value even at 5% level. This implies that the '*null hypothesis of not more than 'one cointegrating relation'* is accepted even at 5% level.
iii. for r=0 against r=1, λ_{max} (0,1)=21.057 exceed the corresponding critical value at 5% level of significance. Therefore, *the null hypothesis* of *non-existence* of *cointegration* between the variables (e_t and p_t) is not accepted at 5% level.
iv. for r=1 against r=2, λ_{max} (1,2)=8.676 falls short of the corresponding critical value even at 5% level. Consequently, the *null hypothesis of the existence of only one cointegrating relation* appears to be accepted even at 5% level.

6.8 Overview of the Findings From the Johansen Cointegration Test (for the Sub-period 1993:2 – 2006:1)

It is observed from the section 6.7 that over the Sub-Period 1993:2-2006:1

i. there exists cointegration between e_t and p_t at level.
ii. e_t and p_t are CI (1,0).
iii. there exists one and only one cointegrating relation between e_t and p_t at level.

6.9 Economic Implications of the Findings of Cointegration Study

The existence of *cointegration* between e_t and p_t *at level* implies that there did exist a long run relationship between exchange rate of currencies concerned with the relative price levels prevailing over the sub-period 1993:2 – 2006:1. This further implies that exchange rates for the currencies were in parity with the relative purchasing power of the currencies concerned. Moreover, *existence of one cointegrating relation* between the currencies establishes that exchange rates were uniquely related to their relative purchasing power.

It, therefore, follows that exchange rates in this sub-period 1993:2-2006:1 were so determined as to establish the '*Law of One Price*' (LOOP) in the realm of trade between the countries concerned.

6.10 Summary of Findings in Chapter-6

The study in this Chapter (Chapter-6) is devoted to examining the *cointegration* between exchange rate (e_t) and relative price level (p_t) at level over two sub-periods, namely, 1979:1 – 1993:1 and 1993:2 – 2006 1. It has been confirmed that

(i) *e_t and p_t were I(1) variables in both the sub-periods.*

(ii) *there did exist no cointegration i.e. long-run equilibrium relation between exchange rate and relative price level in the sub-period 1976:1–1993:1. Consequently, exchange rates quoted for the currencies over the sub-period 1976:1-1993:1 were not at all related to the relative purchasing power of currencies concerned. So the doctrine of purchasing power parity did not hold good and the determination of exchange rates for the currencies failed to establish the 'Law of One Price' (LOOP) in international trade between India and Nepal in the sub-period 1976:1-1993:1.*

(iii) *there did exist 'cointegration' i.e. long-run equilibrium relation between exchange rate and relative price level in the sub-period 1993:2 – 2006:1. This implies that the purchasing power of currencies significantly determined the exchange rates quoted for the currencies over this sub-period. Thus exchange rates in this period were so determined as to establish the 'Law of One Price' (LOOP) in international trade in the long-run. Consequently, the 'Purchasing Power Parity Doctrine' seemed to hold good in the determination of exchange rates between Rupee and Nepalese Rupee in the sub-period 1993:2 – 2006:1.*

CHAPTER - 7
DYNAMICS OF SHORT-RUN SHOCKS AND STABILITY OF THE LONG-RUN RELATIONSHIP BETWEEN EXCHANGE RATE AND RELATIVE PRICE LEVEL IN THE SECOND SUB-PERIOD

7.1 Introduction:

Cointegration study in Chapter-6 confirms the existence of long-run relationship between Rupee / Nepalese Rupee exchange rates and relative price levels prevailing in India and Nepal over the sub-period 1993:2 – 2006:1. It becomes then imperative to examine if such relationship were stable. The long-run relationship becomes *stable* if the innovations or shocks transmitted through the channels of exchange rate (e_t) or relative price level (p_t) converge and dissipate before long. The *stability* of the long-run relationship is studied through the estimation of a relevant *Vector Error Correction Model* (VECM) for the variables concerned.

The *Vector Error Correction* term in the VECM allows for a wide range of short-run dynamics and restricts the long-run behaviour of the endogenous variables to converge to this *cointegrating relationship.* The *cointegrating term* acts as the *error correction term* since the deviation from the long-run equilibrium is corrected gradually through a series of *partial short-run adjustments.* Thus the *Vector Error Correction Modeling* provides valuable information about the short-run relationship between the *cointegrated variables.*

7.2 The Vector Error Correction Model (VECM)

The estimable relevant *Vector Error Correction Model* for e_t and p_t over the sub-period 1993:2 – 2006:1 consists of the following equations

$$\Delta e_t = \alpha_1 + \rho_1 z_{t-1} + \beta_{1i} \sum_{i=1}^{m} \Delta e_{t-i} + \gamma_{1i} \sum_{i=1}^{m} \Delta p_{t-i} + \omega_t \tag{7.1}$$

$$\Delta p_t = \alpha_2 + \rho_2 z_{t-1} + \beta_{2i} \sum_{i=1}^{m} \Delta e_{t-i} + \gamma_{2i} \sum_{i=1}^{m} \Delta p_{t-i} + v_t \tag{7.2}$$

Δe_{t-i} = First Differenced Series of e_t at time t-i; i =1,2,............,m

Δp_{t-i} = First Differenced Series of p_t at time t-i; i =1,2,............,m

Z_{t-1} is the *error correction term* since the *Johansen Cointegration Tests* confirm the existence of *only one Cointegration Equation* between e_t and p_t. The lag length (m), in the estimation, is determined through the *Akaike Information Criterion* (AIC) and *Schwartz Information Criterion* (SIC) etc.

7.3 Results of the Estimated VEC Model (Sub-Period 1993:2 – 2006:1)

The VEC Model, consisting of the equations (7.1) and (7.2), has been estimated for the sub-period 1993:2 – 2006:1. Results of the estimation are being presented through the Tables (7.1) and (7.2) below.

Table – 7.1

Results of the VEC Model Estimation (Equation 7.1)

Sub-period : 1993:2 – 2006:1

Sample (adjusted) : 1994:3 – 2006:1

Included Observations : 47 (after adjusting end points)

Dependent Variable	Explanatory Variable/Constant	Coefficient	S.E	t-stat.
Δe_t	Constant	-0.0006	0.0007	-0.832
	Z_{t-1}	-0.018	0.020	-0.906
	Δe_{t-1}	-0.626	0.166	-3.759
	Δe_{t-2}	-0.419	0.199	-2.106
	Δe_{t-3}	0.068	0.199	0.343
	Δe_{t-4}	0.034	0.165	0.207
	Δp_{t-1}	-0.017	0.096	-0.180
	Δp_{t-2}	-0.143	0.097	-1.466
	Δp_{t-3}	0.024	0.089	0.266
	Δp_{t-4}	-0.222	0.090	-2.478

R^2 = 0.445 Adj R^2 = 0.310 F-Stat. = 3.297

Log Likelihood = 189.246 AIC = -7.627 SIC = -7.234

Determinant Residual Covariance = 1.22E-09

Table – 7.2

Results of the VEC Model Estimation (Equation 7.2)

Period : 1993:2 – 2006:1

Sample (adjusted): 1994:3 – 2006:1

Included Observations : 47 (after adjusting end points)

Dependent Variable	Explanatory Variable/Constant	Coefficient	S.E	t-stat.
Δp_t	Constant	-0.0006	0.0007	0.832
	Z_{t-1}	0.095	0.031	3.089
	Δe_{t-1}	-0.156	0.250	-0.623
	Δe_{t-2}	-0.088	0.299	-0.295
	Δe_{t-3}	0.044	0.300	0.148
	Δe_{t-4}	0.310	0.248	1.249
	Δp_{t-1}	0.266	0.145	1.835
	Δp_{t-2}	-0.053	0.147	-0.362
	Δp_{t-3}	0.105	0.135	0.780
	Δp_{t-4}	-0.535	0.135	- 3.968

R^2 = 0.520 Adj R^2 = 0.403 F-Stat .= 4.452

Log Likelihood = 170.049 AIC = -6.811 SIC = -6.417

Determinant Residual Covariance = 1.22E-09

7.4 Stability of the VEC Model

The roots of the *Characteristic Polynomials* corresponding to autoregressive structures in equations 7.1 – 7.2 are given by the Table 7.3.

Table – 7.3

VEC Stability Condition Check

Roots of Characteristic Polynomial

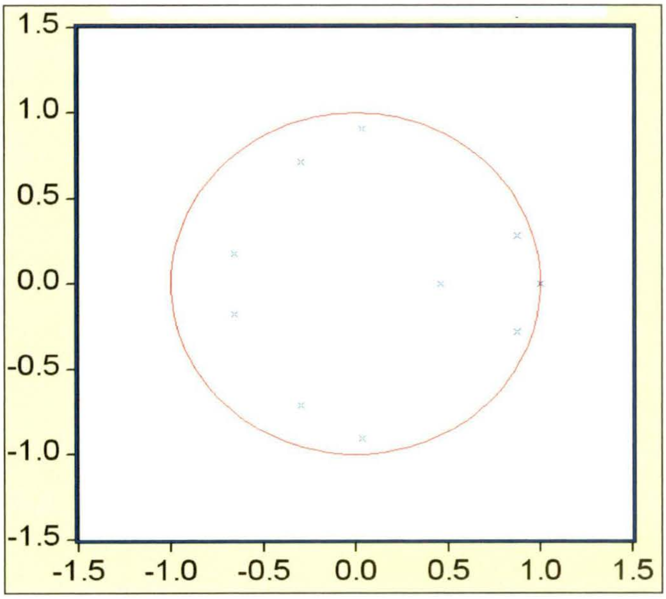
Endogenous Variables: e_t *,* p_t

Exogenous Variable: C

Root	Modulus
1.000000	1.000000
0.871367 - 0.279482i	0.915091
0.871367 + 0.279482i	0.915091
0.033917 + 0.904525i	0.905161
0.033917 - 0.904525i	0.905161
-0.299843 - 0.715164i	0.775477
-0.299843 + 0.715164i	0.775477
-0.656717 + 0.174623i	0.679537
-0.656717 - 0.174623i	0.679537
0.457074	0.457074
VEC specification imposes 1 unit root(s).	

Figure 7.1

Inverse Roots of AR Characteristic Polynomial



7.4.1 Findings From the Table 7.3

It is observed from the Table 7.3 that

i. the absolute values of the characteristic roots are less than unity.

ii. four of the characteristic roots are positive.

iii. four of the characteristic roots are negative.

iv. one of the characteristic roots is not significantly different from zero.

Again the *inverse roots of AR Characteristic Polynomials* lie within the unit circle. This is being shown in the Figure 7.1. *However, VEC specification imposes one unit root.* All these findings confirm the stability of the estimated VEC model consisting of equations (7.1) and (7.2).

7.5 Findings From the VECM Estimation (Table 7.1)

It is observed from the Table 7.1 that

(i) $\hat{\rho}_1$, being insignificant even at 5% level, indicates that short-run shocks, transmitted through the channel of exchange rate, fail to affect the long-run relationship which exchange rate maintained with relative price level.

(ii) $\hat{\gamma}_{14}$, being significant (at 1% level) even in the presence of Δe_{t-i} (i = 1, ...4) in the vector of regressions for Δe_t, indicates that relative price level *Granger Caused* exchange rate in the short-run over the period of study.

(iii) $\hat{\gamma}_{14} < 1$ indicates that the four period back relative price level led to less than proportionate change in exchange rate.

(iv) $\hat{\gamma}_{14} < 0$ again indicates that exchange rate declined following four period back rise in relative price level. This may apparently be in contradiction with the proposition of *Purchasing Power Parity Doctrine.* In PPP theory, e_t is directly related to p_t. So rise in relative price $\frac{P_{India}}{P_{Nepal}}$ means a fall in the purchasing power of Indian currency leading to depreciation of Indian currency. In such case more Rupees are needed to per unit of Nepalese currency. Consequently, e_t must rise.

It may however be noted that $\hat{\gamma}_{14}$ represents change in Δe_t following change in Δp_t. Consequently, $\hat{\gamma}_{14}$ represent the rate of change in exchange rate in response to rate of change in relative prices (i.e. rate of relative inflation). Consequently, $\hat{\gamma}_{14}$ <0 implies that rate of depreciation of Indian currency declines following rise in Indian inflation rate over that in Nepal.

Thus the basic proposition of the *PPP Theory* remains valid when $\hat{\gamma}_{14}$ <0. Moreover, $\hat{\gamma}_{14}$ <0 guarantees that there exists no run-away depreciation of Indian currency following rise in relative inflation rate. Consequently, the *stability* of the long-run relationship between exchange rate and relative price level is being ensured by $\hat{\gamma}_{14}$ <0.

7.6 Findings From the VECM Estimation (Table 7.2)

The Table 7.2 shows that

(i) $\hat{\rho}_2$, the coefficient of Z_{t-1} in the equation 7.2, is significant even at 1% level. This indicates that the short-run shocks, transmitted through the relative price level channel, significantly affected the long-run relationship which exchange rate maintained with relative price level.

(ii) $\hat{\rho}_2$>0 indicates that, given the positive relationship between exchange rate and relative price level, relative price level rises in order to raise exchange rate when it falls below the *target rate*. Thus the adjustment of short-run exchange rate to its *long-run target value* becomes possible because of the positive variation in relative price level.

(iii) $\hat{\rho}_2$ < 1 indicates that relative price level does not make over adjustment in order to ensure adjustment of observed exchange rate to its long-run target value. Thus the long-run equilibrium relationship between exchange rate and relative price level remains *stable* even in the face of short-run variations in exchange rate.

(iv) $0 < \hat{\gamma}_{24} < 1$ is significant at 1% level. This implies that variations in current relative inflation rate are less than proportionately related to those in four period back inflation rates.

(v) $\hat{\beta}_{2i}$ (i=1,2,3,4) are not significant even at 10% level. These imply that variations in relative price level are not '*Granger Caused*' by those in exchange rates in the short-run.

7.7 Economic Interpretations of Results of the Estimated VEC Model

Economic implications of the findings from the estimated equations (7.1) and (7.2) are as follows:

i. Insignificant [even at 10% level] $\hat{\rho}_1$ in the estimated equation (7.1) indicates that exchange rate failed to exhibit any significant adjustment following short-run deviations from its target (i.e. long-run) value.

ii. Significant (even at 1% level) $0 < \hat{\rho}_2 < 1$ in the estimated equation (7.2) indicates that relative price level underwent significant adjustments causing appropriate variations in exchange rate so that exchange rate could adjust to its target (long-run) value. However, $\hat{\rho}_2 < 1$ indicates hat relative price level did not exhibit *'over adjustment'* in this process.

iii. Significant (at 1% level) $\hat{\gamma}_{14}$ indicates short-run *Granger Causality* running from relative price level to exchange rate over the sub-period 1993:2-2006:1.

iv. Insignificant (even at 10% level) $\hat{\beta}_{2i}$ (i=1,2,3,4) imply *absence of Granger Causality* running from exchange rate to relative price level in the short-run over the sub-period 1993:2 – 2006:1.

7.8 Overview of Findings From the Estimated VEC Model

Following inferences may be drawn on the basis of the findings from the study with the estimated VEC Model regarding the relationship between exchange rate (e_t) and relative price level (p_t) over the sub-period 1993:2 – 2006:1.

i. The long-run relationship that exchange rate maintained with relative price level was stable.

ii. Exchange rate exhibited no significant adjustment following its short-run variations from the target (long-run) values.

iii. The shocks, transmitted through the exchange rate channel, had no significant impact on the long-run relationship.

iv. *Relative price level exhibited significant adjustment in order to induce appropriate variations in exchange rate so that short-run deviations of exchange rate from its target (long-run) values could wither away.*

v. *The shocks, transmitted through the relative price level channel, thus had significant impact on the maintenance of long-run relationship (between e_t and p_t). Thus the short-run dynamics of relative price variations defined a* ***'Stable Equilibrium Process'***

vi. *These did exist* **'Uni-directional' short-run 'Granger Causality'** *running from relative price level to exchange rate.*

vii. *Exchange rate failed to* ***'Granger Cause'*** *relative price level in the short-run.*

viii. *Relative price level (p_t), consequently, emerged as an* ***exogenous variable*** *in the VEC model.*

CHAPTER - 8

CAUSAL RELATIONSHIP BETWEEN RUPEE/NEPALESE RUPEE EXCHANGE RATE AND RELATIVE PRICE LEVEL-A STUDY WITH VECTOR AUTOREGRESSIVE MODEL

8.1 Introduction:

'Cointegration' study in Chapter 6 has confirmed the existence of long-run relation between exchange rate(e_t) and relative price level(p_t) over the sub-period 1993:2-2006:1. The study with the estimated *Vector Error Correction Model* (VECM) in Chapter 7 has established the *stability* of such long run relationship between e_t and p_t. It is, therefore, pertinent to examine if the estimated relationship between e_t and p_t or a variant of it could be effectively used for forecasting the future values of the variables concerned.

Granger and Newbold (1977) hold that any *stable* long-run relationship can be effectively used as a forecasting equation provided such relationship entails '*Causality*' of any sort running from any of the variables to another. If e_t, in *Granger's Sense*, causes p_t, then the equation can be used to forecast future values of p_t. If, on the other hand, p_t, in *Granger's Sense*, causes e_t, then the equation may serve as an *effective forecasting equation* for e_t. If there exists *bi-directional causality*, in *Granger Sense*, then the equations can serve as the basis for the forecasting of both e_t and p_t.

We, therefore, seek to examine, the nature and direction of *Granger Causality* between e_t and p_t in their long-run relationship over the sub-period 1993:2-2006:1, as evidenced by the study of *Cointegration* in Chapter 6. The study in this Chapter is devoted to address this issue. The study is carried through the estimation of an appropriate *Vector Autoregressive Model* (VAR) for e_t and p_t over the period 1993:2-2006:1.

8.2 The Vector Autoregressive (VAR) Model

The Vector Autoregressive (VAR) Model for Rupee/Nepalese Rupee Exchange Rate(e_t) and relative price level(p_t) is as follows.

$$E_t = \alpha_1 + \sum_{i=1}^{m} \beta_{1i} E_{t-i} + \sum_{i=1}^{m} \gamma_{1i} p_{t-i} + u_{1t} \quad (8.1)$$

$$p_t = \alpha_2 + \sum_{i=1}^{m} \beta_{2i} E_{t-i} + \sum_{i=1}^{m} \gamma_{2i} p_{t-i} + u_{2t} \quad (8.2)$$

Here $E_t = \Delta e_t$ and $P_t = \Delta p_t$ represent the first differenced stationary time series dataset for e_t and p_t respectively over the sub-period 1993:2-2006:1. Since $e_t \sim I(1)$ and $p_t \sim I(1)$, the stationarity of E_t and P_t is ensured through the first difference filtering of e_t and p_t respectively.

$u_{1t} \sim GWN\ (0, \sigma^2_{u_1})$ and $u_{2t} \sim GWN\ (0, \sigma^2_{u_2})$ are the stochastic error terms which are known as *impulse* or *innovations* or *shocks* in the VAR Model.

The equations (8.1) and (8.2) represent '*Seemingly Unrelated Regression Equations*' (SURE) since the joint estimation of these equations considers and uses the '**Contemporaneous Var-Covariance matrix (Ω)** of the cross equation error terms involved such that **Ω = Var-Covar (u_{1t}, u_{2t})** where **Ω** is a **Positive Definite Matrix.**

8.3 Selection of Lag Length in the VAR Estimation

The *optimum lag length* (m) has been determined on the basis of some *Information Criteria* like *Akaike Information Criterion* (AIC), *Schwartz Information Criterion* (SIC), *Hannan-Quin Information Criterion* (HQIC), *Sequential Modified LR Test Statistic* (SMLST), *Forecast Prediction Error(FPE) Statistic* etc. The Table 8.1.presents the relevant lag length statistics as given by these criteria.

Table 8.1

VAR LAG ORDER SELECTION CRITERIA

Endogenous variables: E_t, P_t Exogenous variables: C

Sample: 1993:2 2006:1 Included observations: 46

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	321.8117	NA	3.14E-09	-13.905	-13.825	-13.875
1	328.3466	12.21741	2.81E-09	-14.015	-13.776	-13.926
2	339.0528	19.08504	2.10E-09	-14.307	-13.909*	-14.158*
3	339.3525	0.508246	2.48E-09	-14.146	-13.589	-13.937
4	**346.4020**	**11.34037***	**2.18E-09**	**-14.278**	**-13.563**	**-14.010**
5	352.4333	9.178141	2.01E-09*	-14.367*	-13.492	-14.039

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final Prediction Error

AIC: Akaike Information Criterion

SIC: Schwarz Information Criterion

HQ: Hannan-Quinn Information Criterion

SIC and HQ statistics suggest for lag 2 as the optimum lag. However, the LR statistics suggest for lag 4 as the optimum lag. The *trial and error* estimations, as suggested by Enders, also conform lag 4 as the optimum lag. So in the VAR model, consisting of equations (8.1) and (8.2), the optimum lag (m) is set to be 4.

8.4 Results of the Estimation of the VAR Model

Results of the estimation of the VAR model are being presented through the Tables 8.2 and 8.3.

Table : 8.2

Results of VAR Model Estimation (Equation 8.1)

Sub-Period: 1993:2-2006:1 Sample (adjusted): 1994:3-2006:1

Included Observations: 47 (after adjusting endpoint)

Dependent Variable	Explanatory Variable/Constant	Coefficient	S.E	t-stat.	Prob.
E_t	Constant	-0.001	0.001	-0.876	0.386
	E_{t-1}	-0.657	0.162	-4.042	0.000
	E_{t-2}	-0.456	0.194	-2.348	0.024
	E_{t-3}	0.030	0.194	0.155	0.877
	E_{t-4}	0.014	0.163	0.088	0.930
	P_{t-1}	0.007	0.092	0.076	0.939
	P_{t-2}	-0.109	0.090	-1.216	0.232
	P_{t-3}	0.035	0.088	0.397	0.694
	P_{t-4}	-0.202	0.087	-2.332	0.025

R^2= 0.433 Adj R^2 = 0.313 F-Stat. = 3.624
Log Likelihood = 188.730 AIC = -7.648 SIC = -7.294
Determinant Residual Covariance = 1.46E-09

Table : 8.3

Results of VAR Model Estimation (Equation 8.2)

Sub-Period: 1993:2-2006:1 Sample (adjusted): 1994:3-2006:1

Included Observations: 47 (after adjusting endpoint)

Dependent Variable	Explanatory Variable/Constant	Coefficient	S.E	t-stat.	Prob.
P_t	Constant	-0.000	0.001	-0.157	0.876
	E_{t-1}	0.003	0.271	0.013	0.990
	E_{t-2}	0.102	0.324	0.314	0.755
	E_{t-3}	0.240	0.324	0.740	0.464
	E_{t-4}	0.410	0.272	1.509	0.139
	P_{t-1}	0.141	0.154	0.914	0.367
	P_{t-2}	-0.225	0.150	-1.497	0.143
	P_{t-3}	0.047	0.148	0.320	0.751
	P_{t-4}	0.432	0.145	2.986	0.005
R^2= 0.396 Adj R^2 = 0.269 F-Stat. = 3.115 Log Likelihood = 164.656 AIC = -6.624 SIC = -6.269 Determinant Residual Covariance = 1.46E-09					

8.5 Essential Features of the VAR Model

The VAR Model consisting of equations (8.1) and (8.2) requires that

i. E_t and P_t be '*Stationary*'.

ii. the model be '*Stable*'.

iii. u_{1t} and u_{2t} be *white noise terms* such that

$$u_{1t} \sim iidN\ (0, \sigma^2_{u_1})$$

$$u_{2t} \sim iidN\ (0, \sigma^2_{u_2})$$

In this model E_t and P_t are '**Stationary**' since

$E_t = \Delta e_t$ and $P_t = \Delta p_t$

where $e_t \sim I(1)$ and $p_t = I(1)$

Therefore $E_t \sim I(0)$ and $P_t = I(0)$

Consequently, the first requirement is satisfied.

Again the *consistence* of the VAR Model requires that the model be *stable*. The conditions of '*stability*' are derived below and then we proceed to examine if these conditions are met by the estimated VAR model. Once the '*stability*' conditions are satisfied, then we would examine if u_{1t} and u_{2t} are *white noise* by nature.

8.6 Conditions of Stability For the VAR Model

From the equation (8.1) we have

$$E_t - \sum_{i=1}^{4} \beta_{1i} E_{t-i} = \alpha_1 + \sum_{i=1}^{4} \gamma_{2i} P_{t-i} + u_{1t}$$

or $E_t(1 - \sum_{i=1}^{4} \beta_{1i} L^i) = \alpha_1 + \sum_{i=1}^{4} \gamma_{2i} P_{t-i} + u_{1t}$

or $A(L) E_t = \alpha_1 + \sum_{i=1}^{4} \gamma_{2i} P_{t-i} + u_{1t}$

or $E_t = [A(L)]^{-1}[\alpha_1 + \sum_{i=1}^{4} \gamma_{2i} P_{t-i} + u_{1t}]$ (8.3)

where $A(L) = (1 - \beta_{11} L - \beta_{12} L^2 - \beta_{13} L^3 - \beta_{14} L^4$

The absolute value of each of the eigen values of the ***Characteristic Polynomial A(L)*** in equation (8.3) must be less than unity for the **stability** of the equation (8.1).

Similarly, from the equation (8.2) we have

$$P_t = [B(L)]^{-1}[\alpha_2 + \sum_{i=1}^{4} \gamma_{2i} E_{t-i} + u_{2t}]$$

where $B(L) = (1 - \sum_{i=1}^{4} \beta_{2i} L^i)$

$= (1 - \beta_{11} L - \beta_{12} L^2 - \beta_{13} L^3 - \beta_{14} L^4)$ (8.4)

The modulus of each of the eigen values of the ***Characteristic Polynomial B(L)*** in equation (8.4) must be less than unity for the *stability* of the equation (8.2). The roots of the AR *characteristic polynomial [A(L) or B(L)]* are being presented through the Table 8.4 while the Inverse Roots of AR characteristic polynomial [A(L) or B(L)] are shown by the Figure 8.1 below.

Table 8.4

VAR Stability Condition Check [Roots of the AR Characteristic Polynomial A(L)]

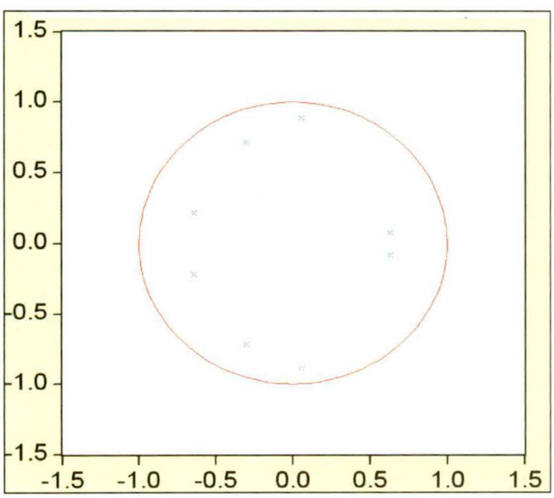
Endogenous Variable: E_t, P_t

Exogenous Variable: C   Lag Specification: 1 4

Root	Modulus
0.055132 - 0.888131i	0.889841
0.055132 + 0.888131i	0.889841
-0.303076 - 0.718820i	0.780101
-0.303076 + 0.718820i	0.780101
-0.640972 - 0.216865i	0.676665
-0.640972 + 0.216865i	0.676665
0.630875 - 0.079582i	0.635874
0.630875 + 0.079582i	0.635874
No root lies outside the unit circle.	

Figure 8.1

Inverse Roots of AR Characteristic Polynomial A(L)



8.7 Examination of the Stability of the VAR Model

(A) The Table 8.4 presents the roots and respective modulus of each of the roots in A(L)

It is observed that

i. four of the eigen values are positive.
ii. four of the eigen value are negative.

Again the Figure 8.1 shows that inverse roots of the **AR** ***Characteristic Polynomial A(L)*** lie within unit circle. Thus the findings from the Figure 8.1 and the Table 8.4 confirm the '*Stability of the estimated VAR* Model.

8.8 Normality of the VAR Residuals $\hat{u}_{1t}$ and $\hat{u}_{2t}$: Jarque-Bera Test

Normality of the $\hat{u}_{1t}$ and $\hat{u}_{2t}$ is being examined through the *Jarque-Bera VAR Residual Normality Tests*. Results of such tests are being reported through the Table 8.5 below.

Table 8.5

VAR Residual Normality Tests
Orthogonalization: Residual Correlation (Doornik-Hansen)
Null Hypothesis: residuals are multivariate normal
Sample: 1993:2- 2006:1
Included observations: 47

Component	Skewness	Chi-sq	df	Prob.
E_t	-0.186	0.337	1	0.561
P_t	-0.026	0.007	1	0.935
Joint		0.344	2	0.842
Component	Kurtosis	Chi-sq	df	Prob.
E_t	1.851	4.519	1	0.033
P_t	1.276	20.364	1	0.000
Joint		2.632	2	0.000
Component	Jarque-Bera	df	Prob.	
E_t	4.856	2	0.088	
P_t	20.371	2	0.000	
Joint	25.227	4	0.000	

It is observed from the Table 8.5 that

i. the JB statistic for $\hat{u}_{1t}$ = 4.856. It implies that the null hypothesis (i.e residuals $\hat{u}_{1t}$ are normal) has been accepted even at 10% level.

ii. the JB statistic for $\hat{u}_{2t}$ = 20.371. The null hypothesis that residuals $\hat{u}_{2t}$ are normal has been accepted even at 1% level.

iii. the JB statistic for the joint test of normality of $\hat{u}_{1t}$ and $\hat{u}_{2t}$ = 25.227. The null hypothesis of normality for both $\hat{u}_{1t}$ and $\hat{u}_{2t}$ has been accepted at 1% level.

These findings confirm the multivariate normality of the residuals ($\hat{u}_{1t}$ and $\hat{u}_{2t}$) of the VAR model consisting of equations (8.1) and (8.2).

8.9 Serial Independence of the VAR Residuals ($\hat{u}_{1t}$ and $\hat{u}_{2t}$)

The correlograms of the VAR residuals $\hat{u}_{1t}$ and $\hat{u}_{2t}$ are given by the Figures 8.2 and 8.3 below.

Figure : 8.2

Correlogram of Residuals $\hat{u}_{1t}$

Included observations: 47   Sample: 1993:2 2006:1

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.080	0.080	0.3231	0.570
		2	0.044	0.037	0.4206	0.810
		3	0.021	0.015	0.4444	0.931
		4	-0.131	-0.137	1.3698	0.849
		5	-0.118	-0.102	2.1371	0.830
		6	-0.208	-0.189	4.5782	0.599
		7	0.006	0.048	4.5806	0.711
		8	-0.287	-0.309	9.4299	0.307
		9	-0.006	0.016	9.4323	0.398
		10	0.128	0.074	10.447	0.402
		11	0.052	0.024	10.617	0.476
		12	0.079	-0.045	11.032	0.526
		13	0.024	-0.027	11.072	0.605
		14	0.038	-0.056	11.175	0.672
		15	-0.209	-0.192	14.320	0.501
		16	-0.108	-0.154	15.184	0.511
		17	-0.081	-0.087	15.685	0.546
		18	-0.099	-0.042	16.464	0.560
		19	0.045	0.010	16.628	0.615
		20	0.153	0.111	18.616	0.547

Figure : 8.3

Correlogram of Residuals $\hat{u}_{2t}$

Included observations: 47 Sample: 1993:2 2006:1

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.193	0.193	1.8713	0.171
		2	0.190	0.158	3.7169	0.156
		3	-0.014	-0.081	3.7272	0.292
		4	-0.201	-0.232	5.9002	0.207
		5	-0.340	-0.287	12.229	0.032
		6	-0.358	-0.242	19.428	0.003
		7	-0.219	-0.077	22.186	0.002
		8	-0.031	0.069	22.244	0.004
		9	0.035	-0.022	22.318	0.008
		10	0.029	-0.206	22.370	0.013
		11	0.226	0.010	25.644	0.007
		12	0.153	0.015	27.191	0.007
		13	0.165	0.089	29.033	0.006
		14	-0.061	-0.156	29.292	0.010
		15	-0.059	-0.132	29.542	0.014
		16	0.140	0.297	30.996	0.013
		17	-0.113	0.035	31.975	0.015
		18	-0.107	-0.130	32.880	0.017
		19	0.033	0.033	32.971	0.024
		20	-0.141	-0.189	34.679	0.022

It is observed from the Figures 8.2-8.3 that

i. the corresponding *ACFs* of $\hat{u}_{1t}$ and $\hat{u}_{2t}$ are free from any from significant spikes in the spread of lags from one through twenty.

ii. the corresponding *PACFs* of the VAR residuals $\hat{u}_{1t}$ and $\hat{u}_{2t}$ are also marked by the absence of any significant spikes in lags 1-20.

These observations indicate that the VAR residuals are serially independent, given that quarterly data for e_t and p_t have been used for the estimation of the VAR model.

8.10 Further Confirmation of Serial Independence: Portmanteau Test

Serial independence of the VAR residuals, $\hat{u}_{1t}$ and $\hat{u}_{2t}$, has further been examined through the '*Portmenteau Tests*'. Results of such tests have been presented through the Table 8.6 below.

Table 8.6

VAR Residual Portmanteau Tests for Autocorrelations

Null Hypothesis: No Residual Autocorrelations up to lag h

Sample: 1993:2- 2006:1 Included observations: 47

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	2.544469	NA*	2.599783	NA*	NA*
2	4.946730	NA*	5.108812	NA*	NA*
3	5.418701	NA*	5.612963	NA*	NA*
4	8.013421	NA*	8.449052	NA*	NA*
5	16.95295	0.0020	18.45281	0.0010	4
6	25.12574	0.0015	27.82162	0.0005	8
7	29.29382	0.0036	32.71911	0.0011	12
8	33.71842	0.0059	38.05132	0.0015	16
9	36.17345	0.0147	41.08781	0.0036	20
10	38.68280	0.0295	44.27536	0.0071	24
11	47.93089	0.0109	56.34925	0.0012	28
12	50.61613	0.0194	59.95515	0.0020	32

*The test is valid only for lags larger than the VAR lag order.

The Table 8.6 shows that

i. the adjusted Q-statistics in the Portmenteau Tests for lag h $(4 < h \leq 12)$ are significant even at 1% level.

ii. the null hypothesis of '*no residual autocorrelation*' up to lag h $(4 < h \leq 12)$ therefore, has been accepted at 1% level.

Thus the *Portmenteau Tests* also confirm *serial independence* of the VAR residuals ($\hat{u}_{1t}$ and $\hat{u}_{2t}$).

8.11 Homoscedasticity of the VAR Residuals ($\hat{u}_{1t}$ and $\hat{u}_{2t}$)

Time plots of the VAR residuals ($\hat{u}_{1t}$ and $\hat{u}_{2t}$) are given by the Figures 8.4 and 8.5 respectively.

Figure : 8.4

Time Plot of VAR Residuals $\hat{u}_{1t}$

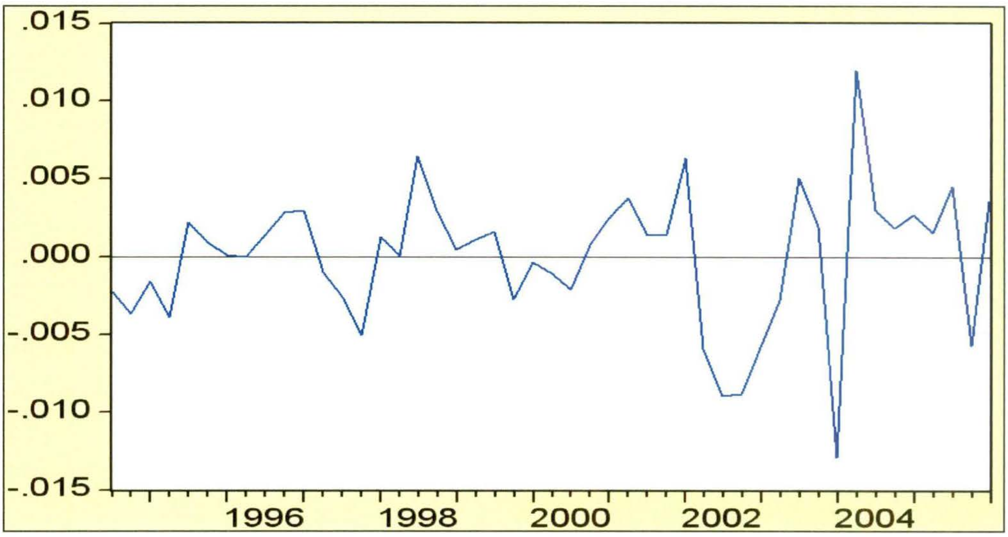
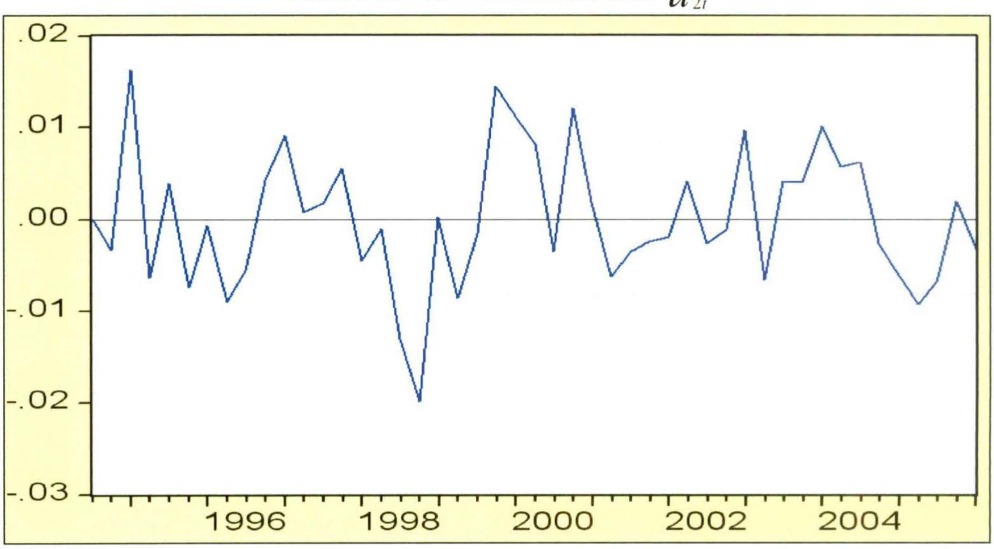


Figure : 8.5

Time Plot of VAR Residuals $\hat{u}_{2t}$



The Figures 8.4 and 8.5 show that

i. time plots of $\hat{u}_{1t}$ and $\hat{u}_{2t}$ exhibit variations around 'zero' mean.

ii. $\hat{u}_{1t}$ exhibits almost uniform variations around the zero-mean over the period concerned.

iii. time plot of $\hat{u}_{2t}$ is devoid of any flutter or concentration of variations at or around any period.

All these observations testify for the 'homoscadasticity' of the VAR residuals $\hat{u}_{1t}$ and $\hat{u}_{2t}$.

8.12 Further Confirmation of Homoscdasticity of VAR Residuals: Correlogram of VAR Residual Variance

The homoscadasticity of VAR residuals $\hat{u}_{1t}$ and $\hat{u}_{2t}$ has further been examined through the study of the correlograms of the variance of the residuals concerned. The relevant correlograms are given by the Figure 8.6 and 8.7.

Figure : 8.6

Correlogram of Variance of VAR Residuals, $\hat{u}_{1t}$

Included observations: 47 Sample: 1993:2 2006:1

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.463	0.463	10.744	0.001
		2	0.037	-0.227	10.812	0.004
		3	0.007	0.122	10.815	0.013
		4	-0.023	-0.099	10.842	0.028
		5	0.169	0.308	12.403	0.030
		6	0.377	0.193	20.400	0.002
		7	0.202	-0.080	22.754	0.002
		8	0.052	0.059	22.916	0.003
		9	-0.030	-0.098	22.970	0.006
		10	-0.129	-0.078	24.000	0.008
		11	-0.067	-0.072	24.291	0.012
		12	-0.035	-0.159	24.374	0.018
		13	-0.069	-0.030	24.698	0.025
		14	-0.054	-0.049	24.898	0.036
		15	-0.049	0.035	25.068	0.049
		16	-0.049	0.058	25.243	0.066
		17	-0.007	0.065	25.247	0.089
		18	-0.037	0.025	25.358	0.115
		19	-0.062	0.027	25.674	0.140
		20	-0.054	-0.024	25.924	0.168

Figure : 8.7

Correlogram of Variance of VAR Residuals, $\hat{u}_{2t}$

Included observations: 47 Sample: 1993:2 2006:1

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.049	0.049	0.1224	0.726
		2	-0.091	-0.094	0.5454	0.761
		3	-0.071	-0.062	0.8072	0.848
		4	0.176	0.177	2.4662	0.651
		5	0.092	0.064	2.9283	0.711
		6	-0.003	0.013	2.9289	0.818
		7	-0.125	-0.095	3.8339	0.799
		8	0.032	0.025	3.8952	0.866
		9	-0.047	-0.096	4.0265	0.910
		10	-0.135	-0.155	5.1543	0.881
		11	-0.138	-0.105	6.3735	0.847
		12	-0.096	-0.122	6.9820	0.859
		13	-0.111	-0.137	7.8218	0.855
		14	0.034	0.054	7.9003	0.894
		15	0.208	0.280	11.024	0.751
		16	-0.200	-0.200	13.988	0.600
		17	0.031	0.155	14.062	0.663
		18	0.014	0.005	14.078	0.724
		19	0.064	-0.092	14.414	0.759
		20	-0.031	-0.074	14.499	0.804

The Figures show that

i. The *ACF* and *PACF* of the variance of $\hat{u}_{1t}$ series contain singularly significant spike at lag one.

ii. The *ACF* and *PACF* of the variance $\hat{u}_{2t}$ series are free from any significant spikes at any lag.

These observations indicate that

i. Variance of the residuals $\hat{u}_{1t}$ defines an ARMA(0,1) process, and

ii. Variance of the residuals $\hat{u}_{2t}$ defines an ARMA(0,0) process.

Consequently, the VAR residuals, $\hat{u}_{1t}$ and $\hat{u}_{2t}$ are found to be free from *Autoregressive Conditional Heteroscadasticity (ARCH).*

8.13 Findings From the VAR Model (Table 8.2)

In the estimated equation (8.1) in the Table 8.2

i. $\sum_{i=1}^{4}\hat{\beta}_{1i} < 1$, $\sum_{i=1}^{4}\hat{\gamma}_{1i} < 1$. So the *autoregressive and distributed* lag structures are *consistent.*

ii. $\hat{\beta}_{11}$ and $\hat{\beta}_{12}$ are significant at 1% and 5% levels respectively.

iii. $-1 < \hat{\beta}_{11} < 0$ and $-1 < \hat{\beta}_{12} < 0$.

iv. $\hat{\gamma}_{14}$ is significant at 5% level.

8.14 Economic Interpretations of Findings in Section 8.13

The economic significance of the findings in Section 8.13 is as follows:

a. Negative and significant value of $\hat{\beta}_{11}$ and $\hat{\beta}_{12}$ indicate that variations in current exchange rate were inversely related to those in one and two period back exchange rates. It again implies that variations in exchange rate beyond the second lag period failed to exert any significant effect on current exchange rate.

b. Again the negative and significant values of $\hat{\beta}_{11}$ and $\hat{\beta}_{12}$ imply that a rise(fall) in Rupee/ Nepalese Rupee Exchange rate at any period led to a fall (rise) in the exchange rate in the next period (quarter). This feature of exchange rate dynamics is a pointer to the existence of a check on the run-away appreciation/depreciation of Indian Rupee against Nepalese Rupee over the period of study. This feature of exchange rate dynamics testifies for the '*Overshooting*' of E_t over the period of study.

c. $\hat{\gamma}_{14}$ being significant, even in the presence of E_{t-i} (i=1,2,3,4) in the vector of regressors in the VAR equation for E_t, indicates that relative price level '*Granger Caused'* exchange rate over the period of study.

8.15 Findings From the Estimated VAR Model (Table 8.3)

It is observe from the estimated equation (8.2) in the VAR model as given in the Table 8.3 that

i. $\sum_{i=1}^{4} \hat{\beta}_{2i} < 1$, $\sum_{i=1}^{4} \hat{\gamma}_{2i} < 1$ $\quad i = 1,2,3,4$

So the *autoregressive and distributed lag* structures are consistent.

ii. $\hat{\beta}_{2i} (i = 1,.........,4)$ are not significant even at 10% level.

iii. $\hat{\gamma}_{24}$ is significant at 1% level.

iv. $0 < \hat{\gamma}_{24} < 1$.

8.16 Economic Interpretations of the Findings in Section 8.15

Economic significance of the findings from the estimated equation (8.2) as given in Section 8.15 is as follows.

(a) $\hat{\gamma}_{24}$, being significant and positive, indicates that current relative price level was positively related to those in past fourth quarter. This is a pointer to the fact that the relative price level (for India and Nepal) exhibited a sustained trend over the sub-period concerned.

(b) again $0 < \hat{\gamma}_{24} < 1$ indicates that in the quarterly dataset, variations in four quarter back relative price level affect the current quarter relative price level directly, non-proportionately.

As a matter of fact, this feature accounts for a declining spell of relative price level over the sub-period concerned. This feature owes its emergence to a lower inflationary rate in India than that in Nepal over the period 1993:2-2006:1.

(c) $\hat{\beta}_{2i} (i = 1, \ldots 4)$ are not statistically significant in the presence of P_{t-i} (i=1,...4) in the vector of regressors for the P_t equation (equation 8.2) in the VAR model. This indicates that exchange rate *'failed to Granger Cause'* relative price level over the sub-period concerned.

(d) $\hat{\beta}_{2i} (i = 1, \ldots 4)$ being insignificant even at 10% level indicate that relative price level (P_t) is an exogenous variable in the VAR model. Consequently, relative price level (P_t) in the economy of India and Nepal appeared to be determined by some other factors than exchange rate. Exchange rate variations, therefore, *'failed to Granger Cause'* variations in relative price level over the period 1993:2-2006:1.

8.17 Summary of Findings in Chapter 8

It is, therefore, observed in Section 8.13 through Section 8.16 that over the sub-period 1993:2-2006:1.

i. *relative price level* **'Granger Caused'** *exchange rate.*
ii. *exchange rate* **'failed to Granger Cause'** *relative price level.*
iii. *there did exist, therefore,* ***'Uni-Directional Causality'*** *running from relative price level to exchange rate.*
iv. *Relative price level appeared to be an* **exogenous** *variable in the VAR model (i.e in the system).*

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

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

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

Then (9.1) may be written as

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

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

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

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

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

Now let $m = \sigma$

Then from (9.2) we have

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

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

where $b_i' = b_i\sigma$

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

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 $\varepsilon_t^{'} = \frac{\varepsilon_t}{\sigma}$

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 $\varepsilon_t^{'}$, 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 $\varepsilon_{t-1}^{'}$, 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

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

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

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

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

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

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

$$y_{1t} = b^{o}_{11}\varepsilon'_{1t} + b'_{11}\varepsilon'_{1t-1} + b'_{2}\varepsilon'_{2t-1} + \ldots\ldots\ldots\ldots \quad (9.13)$$

$$y_{2t} = b^{o}_{21}\varepsilon'_{1t} + b^{o}_{22}\varepsilon'_{2t} + b'_{21}\varepsilon'_{1t-1} + b'_{22}\varepsilon'_{2t-1} + \ldots\ldots \quad (9.14)$$

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

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

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

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

$$y_{2t} = b^{o}_{22}\varepsilon'_{2t} + b'_{21}\varepsilon'_{1t-1} + b'_{22}\varepsilon'_{2t-1} + \ldots\ldots\ldots\ldots\ldots \quad (9.15)$$

$$y_{1t} = b^{o}_{11}\varepsilon'_{1t} + b^{o}_{11}\varepsilon'_{2t-1} + b'_{11}\varepsilon'_{1t-1} + b'_{12}\varepsilon'_{2t-1} + \ldots\ldots\ldots \quad (9.16)$$

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

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

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

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,

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

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

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

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

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

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)

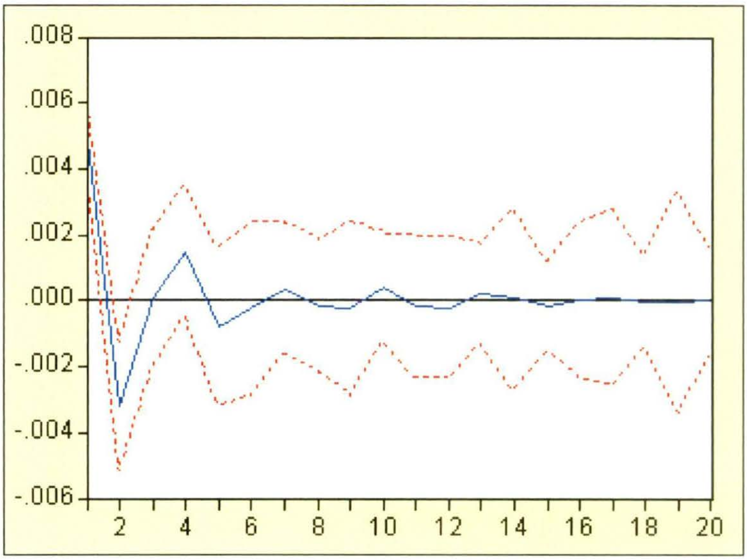
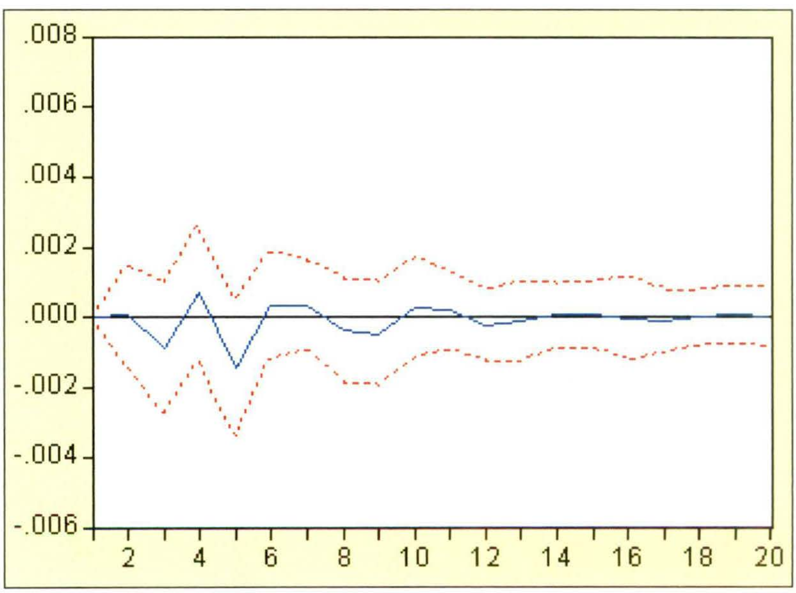


Figure 9.2

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)

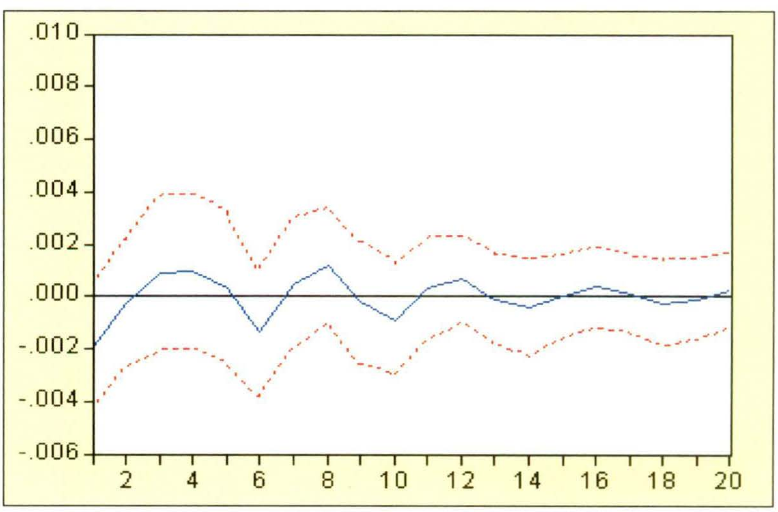


Figure 9.4

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

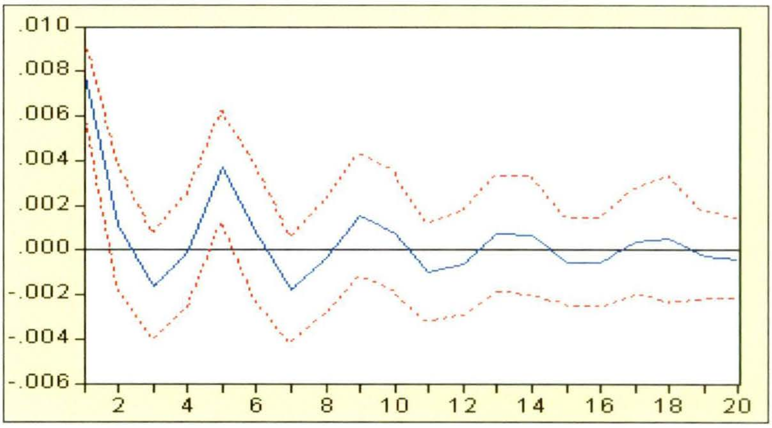


Table: 9.2

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'****.*

CHAPTER - 10

INTERVENTION ANALYSIS THROUGH THE STUDY OF VARIANCE DECOMPOSITION

10.1 Introduction:

One important way of characterizing the dynamics associated with *VAR* is the *Variance Decomposition*. *Variance Decompositions* have an immediate link to forecasting. These actually show how much of the h-step-ahead forecast variance of the variable i is explained by innovations to variable j, for h=1,2,......... Thus the *Forecast Error Variance Decompositions* provides us the proportion of the movement in a sequence owing to its own shocks versus shocks transmitted through other variables in the *VAR System*. In other words, *Variance Decomposition* indicates the relative importance of each innovation in affecting the endogenous variables in the *VAR System*.

The *VAR System* in our study, as given in Chapter 8, consists of two endogenous variables, namely, exchange rate (E_t) and relative price level (P_t). Then it becomes pertinent to examine the relative importance of the endogenous shocks in accounting for the h-step ahead forecast error variances for the variables concerned. The study in this Chapter is confined to this issue.

10.2 Variance Decomposition Tables and Figures For Exchange Rate

The Variance Decompositions of forecast error variance over 20 quarters ahead for exchange rate are being presented through the Table (10.1) shown below. Graphical presentations of such decompositions are shown by the Figures (10.1) and (10.2).

Table :10.1

Variance Decompositions of E_t

Variance Decomposition of E_t :			
Period	S.E.	E_t	P_t
1	0.004853	100.0000	0.000000
		(0.00000)	(0.00000)
2	0.005814	99.99089	0.009114
		(2.97195)	(2.97195)
3	0.005882	97.70685	2.293148
		(5.73403)	(5.73403)
4	0.006112	96.55643	3.443568
		(6.49530)	(6.49530)
5	0.006323	91.67781	8.322191
		(7.94736)	(7.94736)
6	0.006338	91.41095	8.589049
		(8.17130)	(8.17130)
7	0.006358	91.16081	8.839189
		(8.36761)	(8.36761)
8	0.006371	90.85154	9.148459
		(8.50339)	(8.50339)
9	0.006391	90.40040	9.599597
		(8.79170)	(8.79170)
10	0.006411	90.23463	9.765370
		(8.89730)	(8.89730)
11	0.006416	90.16762	9.832379
		(8.98549)	(8.98549)
12	0.006425	90.04204	9.957964
		(9.01275)	(9.01275)
13	0.006429	90.03419	9.965810
		(9.04569)	(9.04569)
14	0.006430	90.02424	9.975761
		(9.14649)	(9.14649)
15	0.006433	90.01130	9.988702
		(9.20432)	(9.20432)
16	0.006433	90.00933	9.990674
		(9.26746)	(9.26746)
17	0.006435	89.99153	10.00847
		(9.31512)	(9.31512)
18	0.006435	89.99151	10.00849
		(9.42047)	(9.42047)
19	0.006436	89.97103	10.02897
		(9.48190)	(9.48190)
20	0.006436	89.97090	10.02910
		(9.55432)	(9.55432)

Figure:10.1

Graphical Presentation of Variance Decompositions of E_t
Percent E_t Variance Due to E_t shocks

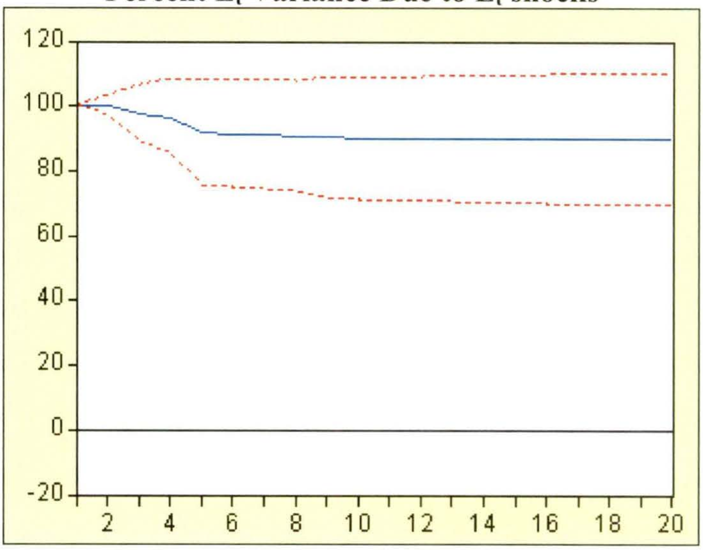
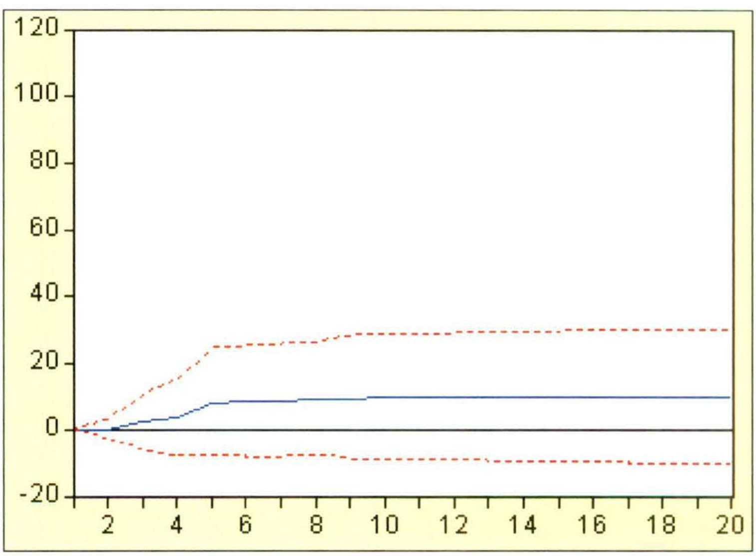


Figure: 10.2

Graphical Presentation of Variance Decompositions of E_t
Percent E_t Variance Due to P_t shocks



10.3 Explanation of Exchange Rate Dynamics Through the Study of Variance Decomposition

The Figures (10.1) and (10.2) together with the Table 10.1 show that, in case of 20 step-ahead forecasts for exchange rate

(A) exchange rate shocks account for

i. at least 95% of forecast error variances for the immediate 4 periods (periods 1 through 4).
ii. at least 90% of forecast error variances for the next 12 periods (period 5 to period 16).
iii. about 90% of forecast error variances for the next 4 periods (periods 16 through 20).

(B) relative price level shocks account for

i. at most 5% of forecast error variances for the immediate 4 periods (periods 1 through 4).
ii. at most 10% of forecast error variances for the next 12 periods (periods 5 through 16).
iii. increasing forecast error variances over extending forecasting horizon.
iv. at least 10% of forecast error variances for the last 3 periods (periods 17 through 20).

10.4 Economic Interpretations of Findings in Section 10.3

These findings indicate that in case of forecasting exchange rate over time

i. exchange rate plays the more dominant role than relative price level.
ii. relative price level gradually assumes important role as forecast distance (h) increases.

Thus relative price level emerges as a significant variable in explaining long-run forecast error variances for exchange rate.

10.5 Variance Decompositions Tables and Figures for Relative Price Level

The variance decompositions of forecast error variances for relative price level over 20 quarter-ahead are being presented through the Figures (10.3) and (10.4) along with the Table 10.2 below.

Figure 10.3

Graphical Presentation of Variance Decomposition of P_t

Percent P_t variance Due to E_t Shocks

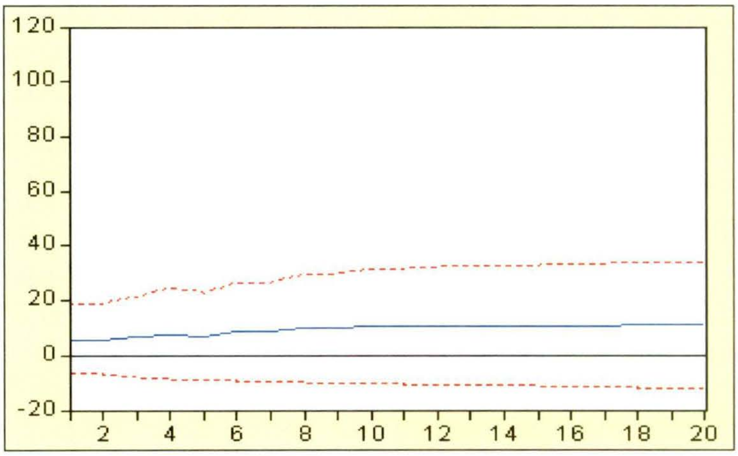


Figure 10.4

Graphical Presentation of Variance Decomposition of P_t

Percent P_t variance Due to P_t Shocks

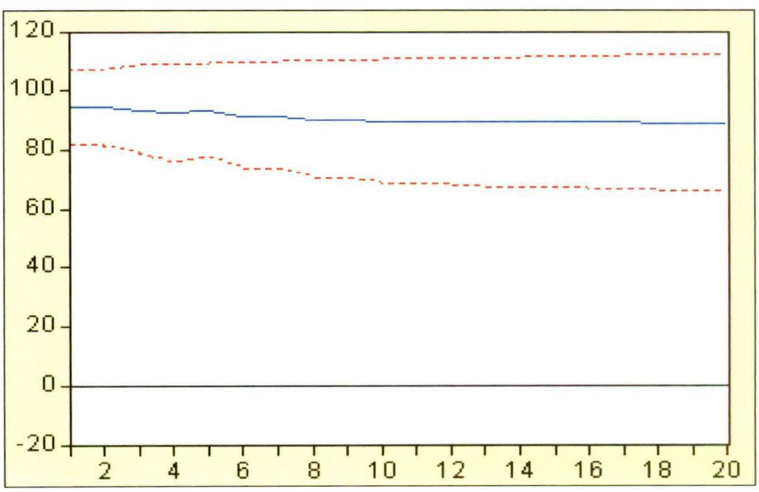


Table 10.2

Variance Decomposition of P_t

Variance Decomposition of P_t: Period	S.E.	P_t	E_t
1	0.008099	100.0000	0.000000
		(0.00000)	(0.00000)
2	0.008178	99.99960	0.000403
		(2.41983)	(2.41983)
3	0.008383	99.68337	0.316626
		(4.78771)	(4.78771)
4	0.008435	98.60411	1.395895
		(6.09453)	(6.09453)
5	0.009225	97.12992	2.870077
		(5.53568)	(5.53568)
6	0.009363	95.74550	4.254501
		(6.48372)	(6.48372)
7	0.009540	95.89945	4.100548
		(6.76711)	(6.76711)
8	0.009621	94.68001	5.319986
		(7.69595)	(7.69595)
9	0.009744	94.78295	5.217047
		(7.73071)	(7.73071)
10	0.009814	94.36009	5.639915
		(8.19544)	(8.19544)
11	0.009869	94.42256	5.577442
		(8.27761)	(8.27761)
12	0.009910	94.20984	5.790159
		(8.34906)	(8.34906)
13	0.009939	94.23923	5.760765
		(8.41291)	(8.41291)
14	0.009971	94.19996	5.800037
		(8.49807)	(8.49807)
15	0.009985	94.20198	5.798018
		(8.56642)	(8.56642)
16	0.010007	94.18428	5.815725
		(8.61257)	(8.61257)
17	0.010015	94.16942	5.830576
		(8.74692)	(8.74692)
18	0.010030	94.16498	5.835017
		(8.75975)	(8.75975)
19	0.010034	94.14561	5.854388
		(8.84678)	(8.84678)
20	0.010045	94.14357	5.856429
		(8.93459)	(8.93459)

10.6 Explanation of Relative Price Dynamics Through the Study of Variance Decomposition

The Figures (10.3)-(10.4) and the Table 10.2 show that, in case of 20-step-ahead forecasts for relative price level (P_t),

i. exchange rate shocks account for at most 4% of forecast variances for the first 7 periods (periods 1 through period 7).
ii. exchange rate shocks account for at most 6% over the entire spread of forecast provided (periods through 20).
iii. relative price level shocks account for uniformly at least 94% of forecast variances over the forecast horizons (periods 1 through 20).

10.7 Economic Interpretations of Findings in Section 10.6

It, therefore, appears that, in case of relative price level forecasts over a long - horizon

i. relative price level in the given VAR system appears to be the only effective variable.
ii. exchange rate fails to play any effective role.

10.8 Overview of Findings in Chapter 10

The main findings from the study of Variance Decompositions in Chapter 10 are as follows:

i. exchange rate is the dominating factor for the forecast of exchange rate over the forecast-horizon (20 quarters).
ii. relative price level also plays a significant in 20 quarter-ahead-forecast for exchange rate.
iii. relative price shocks appear to be the only effective predominant variable in explaining the forecast error variances for relative price level over the forecast horizon.
iv. exchange rate plays no role at all in explaining error variances of forecasts for relative price level.

All these findings testify that over the period of study (1993:2-2006:1)

i. *exchange rate variations were* ***'Granger Caused'*** *by those in relative price level.*

ii. *the VAR system failed to exhibit* ***'Predictive Causality'*** *i.e.* ***Granger Causality'*** *running from exchange rate to relative price level, and*

iii. *relative price level, therefore, appears virtually as an* ***exogenous variable*** *in the VAR system consisting of equations (8.1) and (8.2) which serve as the base for generating forecast error variances for relative price level.*

CHAPTER - 11
GRANGER CAUSALITY BETWEEN RUPEE/NEPALESE RUPEE EXCHANGE RATE AND RELATIVE PRICE LEVEL– STUDY WITH RESTRICTED VAR MODEL

11.1 Introduction:

The **VAR** (2,4) Model estimated in Chapter 8 is *Unrestricted* by nature. In such '*Unrestricted VAR'* model the specification of lag structures for both the variables, E_t and P_t, is required to be uniform. This made the model '*Over Parameterized'*. Such an *Unrestricted VAR model'* therefore, becomes less informative about *the nature* and *direction of causality* between the variable concerned. In such case a *Restricted VAR Model* may be more helpful for the purpose since it allows parsimony of lag structure for both the endogenous variables in the system through the exclusion of insignificant lagged variables from the vector of regressors for each endogenous variable. A variant of such *Restricted VAR model* is usually adopted in the '*Granger Causality Test Procedure'*. We, therefore, seek in this Chapter to examine the nature and direction of '*Granger Causality*' between exchange rate and relative price level through the estimation of an appropriate *Restricted VAR Model* for the variables concerned.

11.2 The Restricted VAR Model

The estimable *Restricted VAR Model* for E_t and P_t, following *Granger Causality Test Procedure*, is being formulated and stated below. The *auto-regressive lag structure* for each endogenous variable is confined to first lag only. However, the *distributed lag structure* is retained unchanged in both the equations. Consequently, the model is

$$E_t = \alpha_1 + \beta_1 E_{t-1} + \gamma_1 P_{t-1} + \gamma_2 P_{t-2} + \gamma_3 P_{t-3} + \gamma_4 P_{t-4} + \omega_t \qquad (11.1)$$

$$P_t = \alpha_2 + \delta_1 P_{t-1} + \theta_1 E_{t-1} + \theta_2 E_{t-2} + \theta_3 E_{t-3} + \theta_4 E_{t-4} + \mu_t \qquad (11.2)$$

where $\omega_t \sim iidN(0, \sigma_\omega^2)$

$\mu_t \sim iidN(0, \sigma_\mu^2)$

11.3 Estimation and Result

The *Restricted VAR Model* consisting of equations (11.1) and (11.2) are being estimated for the sub-period 1993:2-2006:1. Results of the estimation are being presented through the Tables 11.1 and 11.2 below.

Table 11.1

Results of the Estimation of the Restricted VAR Model (Equation 11.1)

Dependent Variable: E_t Sub-Period: 1993:2-2006:1 Sample(adjusted):

Included Observations: 46 (after adjusting endpoints)

Independent Variables	Coefficients	S.E	t-stat.	Prob.
Constant	-0.0004	0.001	-0.535	0.595
E_{t-1}	-0.460	0.142	-3.236	0.002
P_{t-1}	0.030	0.097	0.306	0.761
P_{t-2}	-0.056	0.093	-0.605	0.548
P_{t-3}	-0.001	0.093	-0.008	0.994
P_{t-4}	-0.169	0.091	-1.857	0.071
R^2 = 0.274 Adjusted R^2= 0.186 AIC= -7.529 SIC= -7.293 DW= 2.277 F-Stat.= 3.097 Prob(F-statistic)= 0.018				

Table 11.2

Results of the Estimation of the Restricted VAR Model (Equation 11.2)

Dependent Variable: P_t Sub-Period: 1993:2-2006:1 Sample(adjusted):

Included Observations: 46 (after adjusting endpoints)

Independent Variables	Coefficients	S.E	t-stat.	Prob.
Constant	-0.0002	0.001	-0.114	0.909
P_{t-1}	0.085	0.161	0.528	0.600
E_{t-1}	-0.031	0.324	-0.096	0.924
E_{t-2}	0.224	0.376	0.597	0.554
E_{t-3}	0.361	0.370	0.975	0.335
E_{t-4}	0.349	0.313	1.114	0.272
R^2 = 0.05 Adjusted R^2 = -0.071 AIC = -6.294 SIC = -6.058 DW = 1.882 F-Stat.= 0.393 Prob(F-statistic) = 0.851				

11.4 Findings From the Table 11.1

It is observed from the estimated equation (11.1) that

i. $\hat{\beta}_1$ is significant at 1% level.

ii. $|\hat{\beta}|$ = 0.460<1 and the system is *stable.*

iii. $\sum_{i=1}^{4} \gamma_i < 1$. So the distributive lag-structure is *consistent.*

iv. DW= 2.277 indicates that the estimated equation is free from auto-correlation.

v. $\hat{\gamma}_4$ is significant at 1% level.

vi. all other estimated coefficients $\hat{\alpha}_1, \hat{\gamma}_1, \hat{\gamma}_2$ *and* $\hat{\gamma}_3$ are not significant even at 10% level.

However, the equation (11.1) may be modified through the exclusion of the variables which appears to be statistically insignificant (even at 10% level). The modified equation is

$$E_t = \eta + \phi\, E_{t-1} + \pi\, P_{t-4} + \mu_{1t} \tag{11.3}$$

The estimable modified equation (11.3) is expected to provide better estimation in view of the gain in degrees of freedom resulting from the exclusion of insignificant variables (like p_{t-1}, p_{t-2} and p_{t-3}) from the vector of regressors for the endogenous variable E_t.

11.5 Results of Estimation of the Modified Equation (11.3) in the Restricted VAR System

Results of estimation of the modified equation (11.3) are being presented through the Table 11.3 below.

Table 11.3

Results of the Estimation of the Equation 11.3 in The Restricted VAR System

Dependent Variable: E_t Sub-Period: 1993:2-2006:1 Sample(adjusted):

Included Observations: 47 (after adjusting endpoints)

Independent Variables	Coefficients	S.E	t-stat.	Prob.
Constant	-0.0004	0.001	-0.582	0.562
E_{t-1}	-0.481	0.132	-3.634	0.001
P_{t-4}	-0.143	0.076	-1.879	0.067
R^2 = 0.266 Adjusted R^2= 0.232 AIC= -7.645 SIC= -7.527 DW= 2.279 F-Stat.= 7.963 Prob(F-statistic)= 0.001				

11.6 Findings From the Estimated Modified Equation 11.3

It is observed from the estimated equation 11.3, shown in the Table 10.3, that

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

ii. $\hat{\phi}$ is negative and $|\hat{\phi}| < 1$.

iii. π, the coefficient of P_{t-4}, is significant at 10% level.

iv. DW = 2.279 indicates absence of autocorrelation in the estimated equation.

v. F-statistics = 7.963 registers an improvements over that in the estimated equation (11.1).

11.7 Economic Interpretations of Findings in Section 11.6

Economic implications of the findings are as follows:

i. *negative and significant* $\hat{\phi}$, *the coefficients of* E_{t-1}, *implies a declines in the current Rupee/Nepalese Rupee exchange rate following a rise in Rupee/Nepalese Rupee exchange rate in the previous period (quarter). This feature of the exchange rate testifies for existence of an inhibition to a possibility of run-away depreciation or appreciation of the exchange rate concerned over the period of study (1993:2-2006:1).*

ii. *significant* π, the coefficient of P_{t-4} *in the presence of lagged exchange rate* E_{t-1} *in the vector of regressors for* E_t, *indicates that variations in relative price level* ***'Granger Caused'*** *those in exchange rate.*

iii. $\pi<0$ *indicates that exchange rate appreciates in response to a rise in four quarters back relative price level while cointegration study indicates a depreciation following a rise in the relative price level at the current period.*

The autocorrelations function, being ***'even'*** *by nature, indicates that exchange rate in it's the dynamic path of adjustment in response to a rise in current level of relative price level, exhibits a 'depreciation' first and then it shows a pattern of 'appreciation' with the passage of 4 quarters(one year)(thereafter). These testifies for the fact that the path* *of dynamic adjustment of Rupee/Nepalese Rupee exchange rate exhibits the occurrence of '**Overshooting**' phenomenon in response to a relative price level shock.*

11.8 Findings From the Table 11.2 [Equation 11.2]

It is observed from the estimated equation 11.2 in the Table 11.2 that

i. $\hat{\delta}$, the estimated coefficient of P_{t-1}, is not significant even at 10% of significance.

ii. $\hat{\phi}_i (i = 1,2,3,4)$, the estimated coefficients of E_{t-i} (i=1,2,3,4) are not significant even at 10% level of significance.

iii. DW= 1.882 indicates that the equation is free from autocorrelation.

iv. F-Statistic = 0.393 with F-Probability = 0.852 indicate, that the joint estimation of the equation is not significant at even 10% level of significance.

11.9 Economic Implications of the Findings in Section 10.8

The findings in Section 11.8 show that

*i. variations in relative price level are not at all related to those in exchange rate. Therefore, relative exchange rate is not '**Granger Caused**' by exchange rate.*

*ii. relative exchange rate, therefore, appears as an '**exogenous**' variable in the **Restricted VAR System** consisting of equation (11.1) and (11.2).*

11.10 Overview of the Findings in Chapter 11

It is observed from the findings in our study with the estimated **Restricted VAR System** that, over the sub-period 1993:2-2006:1

*i. exchange rate was **Granger Caused** by relative price level.*

*ii. relative price level was not '**Granger Caused**' by exchange rate.*

*iii. there exists '**Uni-directional Causality**' running from relative price level to exchange rate.*

iv. *relative price appears virtually as an exogenous variable in the* ***Restricted VAR System****. This confirms the findings of* ***exogeneity*** *of relative price level in the* ***Unrestricted VAR System*** *in Chapter 8.*

We seek to enquire further into the nature and direction of causality between exchange rate and relative price level through 'Spectral Analysis' in next chapter. The ***'Frequency Domain'*** *study is expected to supplant and supplement the* ***'Time Domain'*** *analysis.*

CHAPTER - 12
SPECTRAL ANALYSIS ON THE RELATIONSHIP BETWEEN EXCHANGE RATE (E_t) AND RELATIVE PRICE LEVEL (P_t)

12.1 Introduction:

The study in Chapters 4 through 11 constitutes the '*Time Domain*' analysis which considers the evolution of a process through time. The fundamental base of the '*Time Domain*' study is the *Autocovariance (or autocorrelation*) function. A complementary analysis for the '*Time Domain*' study is constituted by the '*Frequency Domain*' study which considers the frequency properties of a time series. The '*Spectral Density Function*' constitutes the natural tool for the study. As a matter of fact, inference regarding the '*Spectral Density Function*' is called an analysis in the '*Frequency Domain*'.

'*Spectral Analysis*' is the name given to the methods of estimating the '*Spectral Density Function*' or '*Spectrum*' of a given time series. The study under '*Frequency Domain*' is concerned with estimating the '*Spectrum*' over the whole range of frequencies in order to identify '*hidden periodicities*'. '*Cross-Spectral*' properties are expected to provide us the relation between relative price level and exchange rate over the sub-period 1993:2-2006:1.

12.2 Spectral Estimation: Methodology

12.2.1 Fourier Series:

Traditional '*Spectral Analysis*' is a modified form of '*Fourier Analysis*' and this modification makes it suitable for *stochastic* rather than *deterministic function. Fourier Analysis* (Priestly, 1981) relates to approximating a function by a sum of *sine* and *cosine* terms which are called the '*Fourier Series Representation'.*

Let a function f(t) be defined on ($-\pi$, π) satisfying the *Dirichlet Conditions* which ensure that f(t) is reasonably '*well behaved*' such that f(t) is absolutely integrable over the range ($-\pi$, π) with a finite number of *discontinuities* and a finite number of maxima and minima. Then f(t) may be approximated by the *Fourier Series.*

$$\frac{a_0}{2} + \sum_{r=1}^{k}(a_r \cos rt + b_r \sin rt) \tag{12.1}$$

where
$$a_0 = \frac{1}{\pi}\int_{-\pi}^{\pi} f(t)dt \tag{12.2}$$

$$a_r = \frac{1}{\pi}\int_{-\pi}^{\pi} f(t)\cos rtdt \tag{12.3}$$

$$(r = 1,2..........\,..)$$

$$b_r = \frac{1}{\pi}\int_{-\pi}^{\pi} f(t)\sin rtdt \tag{12.4}$$

$$(r = 1,2.........\,..)$$

The *Fourier Series* then converges to f(t) as $k \rightarrow \infty$ except at points of discontinuities, where it converges to halfway up the step change.

12.2.2 Fourier Transformations:

Given a function h(t) of a real variable t, the ***Fourier Transform*** of h(t) is

$$H(\omega) = \int_{-\infty}^{\infty} h(t)\, e^{-i\omega t}\, dt \qquad (12.5)$$

provided the integral exists for every real (ω).

A sufficient condition for H(ω) to exist is that

$$\int_{-\infty}^{\infty} | h(t) | dt < \infty \qquad (12.6)$$

Let equation (12.5) be regarded as an integral equation for h(t). Then we may have h(t) from H(ω) such that

$$h(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} H(\omega)\, e^{i\omega t}\, d\omega \qquad (12.7)$$

Then h(t) is called the *Inverse Fourier Transform* of H(ω). The two function h(t) and H(ω) are commonly called a '*Fourier Transform Pair*'.

However, Cox and Miller (1968) find it convenient to put $\frac{1}{2\pi}$ outside the integral in equation (12.5) such that

$$H(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} h(t)\, e^{-i\omega t}\, dt \qquad (12.8)$$

Consequently, in the *Inverse Fourier Transform*

$$h(t) = \int_{-\infty}^{\infty} H(\omega)\, e^{i\omega t}\, d\omega \qquad (12.9)$$

Time series analysis usually involves the use of the variable $f = \frac{\omega}{2\pi}$ rather than ω. Then the resulting *Fourier Transform Pair* is

$$G(f) = \int_{-\infty}^{\infty} h(t)\, e^{-2\pi i f t}\, dt \qquad (12.10)$$

$$h(t) = \int_{-\infty}^{\infty} G(f)\, e^{2\pi i f t}\, df \qquad (12.11)$$

12.2.3 The Spectral Distribution Function

Wiener Khintchine Theorem states that for any real valued stationary stochastic process with autocovariance function γ(k), there exists a monotonically increasing function F(ω) such that

$$\gamma(k) = \int_{0}^{\pi} \cos \omega k dF(\omega) \qquad (12.12)$$

Equation (12.12) is called the '*Spectral Representation of the autocovarince Function*'.

F(ω) is the contribution to the variance of the series accounted for by the frequencies in the range (0, ω) given that

$$F(\omega) = 0 \text{ for } \omega < 0$$

For a discrete time series process measured at unit intervals of time, the highest possible frequency is the *Nyquist Frequency* (π) and so all the variations is accounted for by frequencies less than π. Thus

$$F(\pi) = Var(X_t) = \sigma^2_x \qquad (12.13)$$

In between ω = 0 and ω = π, F(ω) is monotonically increasing. So F(ω) is also called the '*Spectral Distribution Function*'.

12.2.4 The Spectral Density Function (SPECTRUM)

F(ω) is usually a continuous (monotone bounded) function in [0, π]. Therefore, F(ω) may be differentiated with respect to ω in [0, π] such that

$$f(\omega) = \frac{dF(\omega)}{d\omega} \tag{12.14}$$

f(ω) is the '*Spectral Density Function*' or '*Spectrum*'

If f(ω) exists , then equation (12.12) can be expressed as

$$\gamma(k) = \int_0^{\pi} \cos \omega k f(\omega) \quad d\omega \tag{12.15}$$

Now putting k = 0, we have

$$\gamma(0) = \sigma^2{}_x = \int_0^{\pi} f(\omega) d\omega = F(\pi) \tag{12.16}$$

Thus f(ω) dω represents the contribution to variance of components with frequencies in the range (ω, ω + dω).

For a continuous purely indeterministic stationary process, X(t), the *autocovariance function*, $\gamma(\tau)$, is defined for all τ and the *spectral density function*, f(ω) is defined for all positive ω. Then

$$f(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} \gamma(\tau) e^{-i\omega\tau} d\tau \tag{12.17}$$

$$= \frac{2}{\pi} \int_0^{\infty} \gamma(\tau) e^{-i\omega\tau} d\tau \tag{12.18}$$

For 0 < ω < ∞, the *inverse transformation* gives

$$\gamma(\tau) = \int_0^{\infty} f(\omega) \cos \omega\tau d\omega \tag{12.19}$$

12.2.5 The Cross Spectrum

In *Time Domain* analysis the tool for examining the relationship between time series is the *Cross-Correlation Function.* In *Frequency Domain* analysis, a complementary function used as a tool for the same purpose in the *Cross Spectral Density Function* or the *Cross-Spectrum.*

Let X and Y be two discrete-time stationary processes, measured at unit intervals of time. Let $\gamma_{xy}(k)$ represent the relevant *Cross Covariance Function.* Then the *Fourier Transform* of the *cross-covariance function* $\gamma_{xy}(k)$ is

$$f_{xy}(\omega) = \frac{1}{\pi}[\sum_{k=-\infty}^{\infty} \gamma_{xy}(k) e^{-i\omega k}] \tag{12.20}$$

over the range $0 < \omega < \pi$.

Here $f_{xy}(\omega)$ is called the '*Cross- Spectral Density Function*' or the '*Cross-Spectrum*'.

If the *Cross-Spectrum'* is defined over the range $[-\pi,\pi]$, then

$$f_{xy}(\omega) = \frac{1}{2\pi}[\sum_{k=-\infty}^{\infty} \gamma_{xy}(k) e^{-i\omega k}] \tag{12.21}$$

Consequently, the '*inverse transformation*' gives

$$f_{xy}(k) = \int_{-\pi}^{\pi} e^{i\omega k} f_{xy}(\omega) d\omega \tag{12.22}$$

12.2.6 Co-spectrum and Quadrature Spectrum

$f_{ry}(\omega)$, the *Cross –spectrum,* is a complex function since $\gamma_{xy}(k)$ is not an even function. The real part of the '*Cross-spectrum*' is called the '*Co-Spectrum*' which is given by

$$\begin{aligned} c(\omega) &= \frac{1}{\pi}[\sum_{k=-\infty}^{\infty} \gamma_{xy}(k) \cos \omega t] \\ &= \frac{1}{\pi}\{\gamma_{xy}(0) + \sum_{k=1}^{\infty}[\gamma_{xy}(k) + \gamma_{yx}(k)] \cos \omega k \end{aligned} \tag{12.23}$$

The complex part of the *Cross-Spectrums* is called the *Quadrature Spectrum* and it is given by

$$q(\omega) = \frac{1}{\pi}[\sum_{k=-\infty}^{\infty} \gamma_{xy}(k)\sin\omega k]$$

$$= \frac{1}{\pi}\{\sum_{k=1}^{\infty}[\gamma_{xy}(k) - \gamma_{yx}(k)]\sin\omega k\} \tag{12.24}$$

Consequently,

$$f_{xy}(\omega) = c(\omega) - q(\omega) \tag{12.25}$$

12.2.7 Cross Amplitude Spectrum and Phase Spectrum

The *Cross Spectrum* can be expressed as

$$f_{xy}(\omega) = \alpha_{xy}(\omega)e^{i\phi xy(\omega)} \tag{12.26}$$

where $$\alpha_{xy}(\omega) = \sqrt{c^2(\omega) + q^2(\omega)} \tag{12.27}$$

Here $\alpha_{xy}(\omega)$ is the *Cross- Amplitude Spectrum.*

$$\phi_{xy}(\omega) = \tan^{-1}[\frac{-q(\omega)}{c(\omega)}] \tag{12.28}$$

is the *Phase Spectrum.*

12.2.8 Coherency Spectrum and Gain Spectrum

From the Equations (12.23) and (12.26) we obtain

$$c(\omega) = [c^2(\omega) + q^2(\omega) / f_x(\omega) f_y(\omega)]$$

$$= \sigma^2_{xy}(\omega) / f_x(\omega) f_y(\omega) \tag{12.29}$$

where $f_x(\omega)$, $f_y(\omega)$ are the *power spectra* of the individual processes, $\{x_t\}$ and $\{Y_t\}$ such that

$$0 \le c(\omega) \le 1$$

$c(\omega)$ is called the *Coherency Spectrums.*

The estimate of $c(\omega)$ measures the square of the linear correlation between the two components of the bivariate process at frequencies ω and it is analogous to the square of the usual correlation coefficient.

The *Gain Spectrums* is given by

$$G_{xy}(\omega) = \sqrt{[f_y(\omega)c(\omega)]} / f_x(\omega)$$

$$= \frac{\alpha_{xy}(\omega)}{f_x(\omega)}$$

This is essentially the regression coefficient of the process Y_t on the process X_t at frequency ω.

A second *Gain Spectrum* can also be defined by

$$G_{yx}(\omega) = \frac{\alpha_{xy}(\omega)}{f_y(\omega)}$$

This is the regression coefficient of the process X_t on the process Y_t at the frequency ω.

12.3 The 'Cospectral Densities' of E_t and P_t

The '*Cospectral Density by Frequency*' for E_t and P_t is given by the Figure 12.1 while the '*Cospectral Density by Period*' for E_t and P_t is given by the Figure 12.2.

Figure 12.1

Cospectral Density By Frequency Exchange Rate (E_t) and Relative Price Level (P_t)

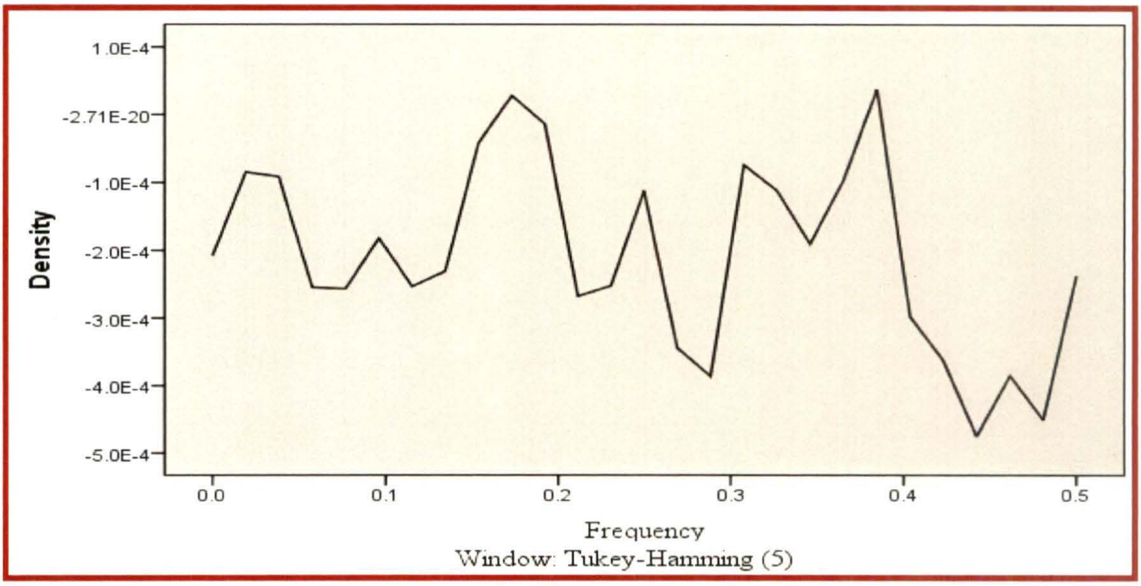
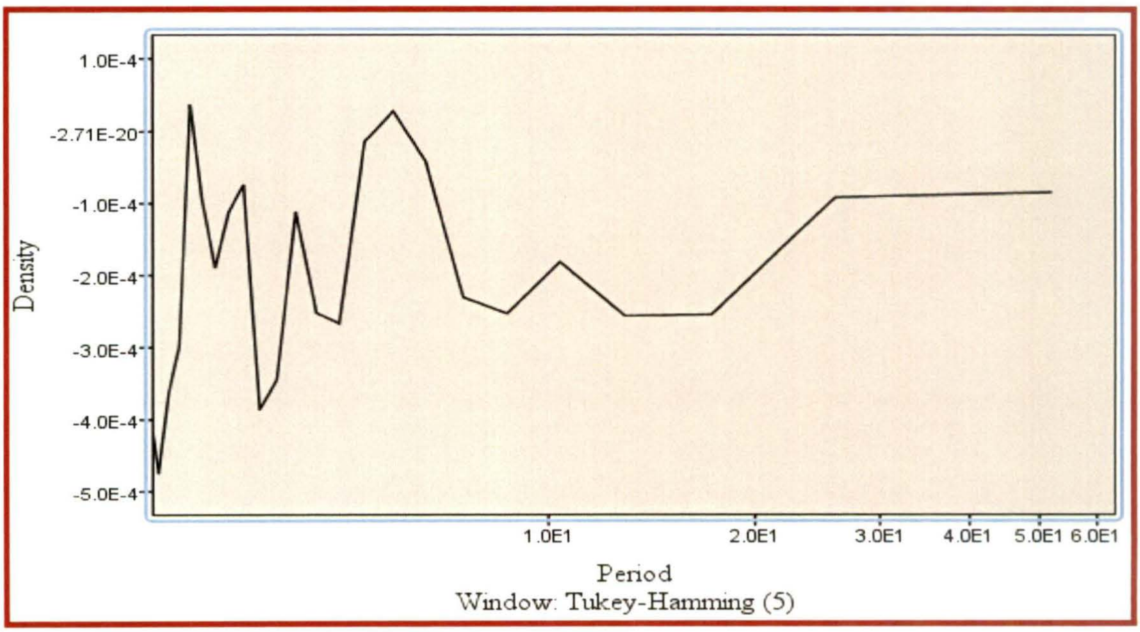


Figure 12.2

'Cospectral Density' by Period for Exchange Rate(E_t) and Relative Price Level (P_t)



The Figure 12.1 shows that the '*Cospectral Density by Frequency*' for E_t and P_t

i. is not a horizental straight line.
ii. is marked by the presence of structural ups and down.
iii. exhibits sharp peaks at frequencies 0.25, 0.35 and 0.4 (approximately).

The Figure 12.2 shows that the *Cospectral Density by Period* for E_t and P_t

i. is far from being a horizontal straight line.
ii. exhibits several prominent ups and down, and
iii. is marked by the presence of prominent peaks at periods 2,3,4,(approximately).

These features of the '*Cospectral Density*' for E_t and P_t indicate that

i. there did exist significant covariations of E_t and P_t over the period of study (1993:2-2006:1).
ii. these co-movements were marked by some 'periodicities'.
iii. there did exist dominant periodicities at periods 2,3 and 4 (approx).

All these observations testify that over the period 1993:2 – 2006:1

i. E_t and P_t were cointegrated, and
ii. the long-run relationship between these variables was 'stable'.

12.4 Features of the 'Gain Spectrum' of Exchange Rate (E_t) and Relative price Level (P_t)

The '*Gain Spectrum*' by *frequency* for E_t and P_t is being presented through the Figure 12.3 while th Figure 12.4 presents the corresponding '*Gain Spectrum*' by *period.*

Figure –12.3

'Gain Spectrum' By Frequency For Exchange Rate(E_t) and Relative Price Level (P_t)

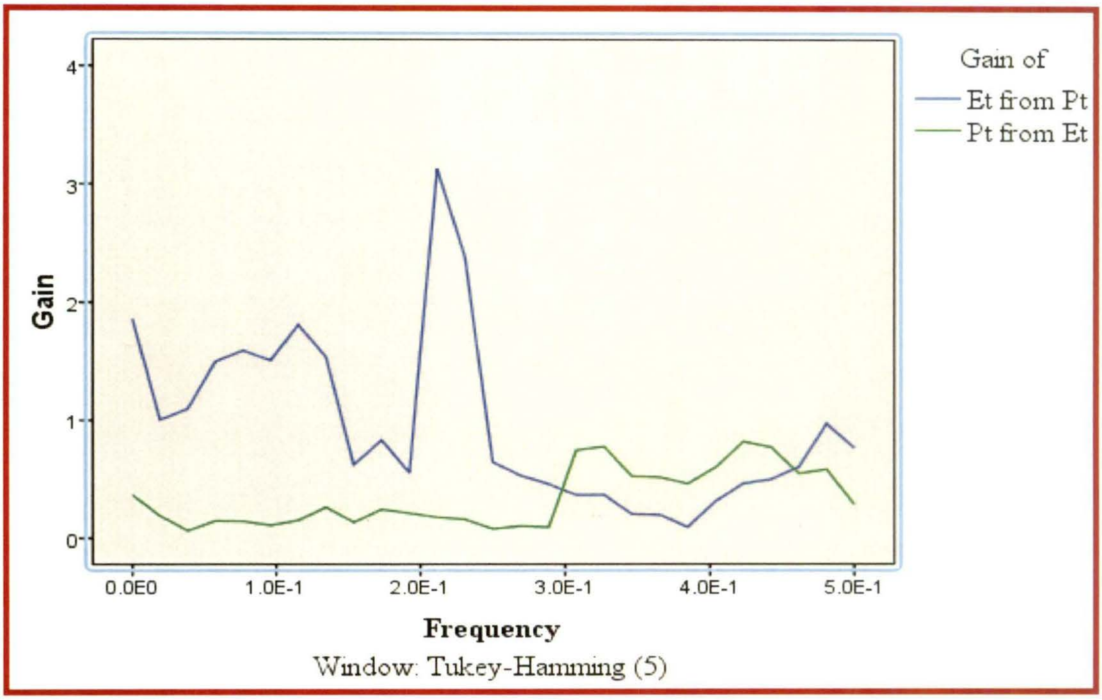
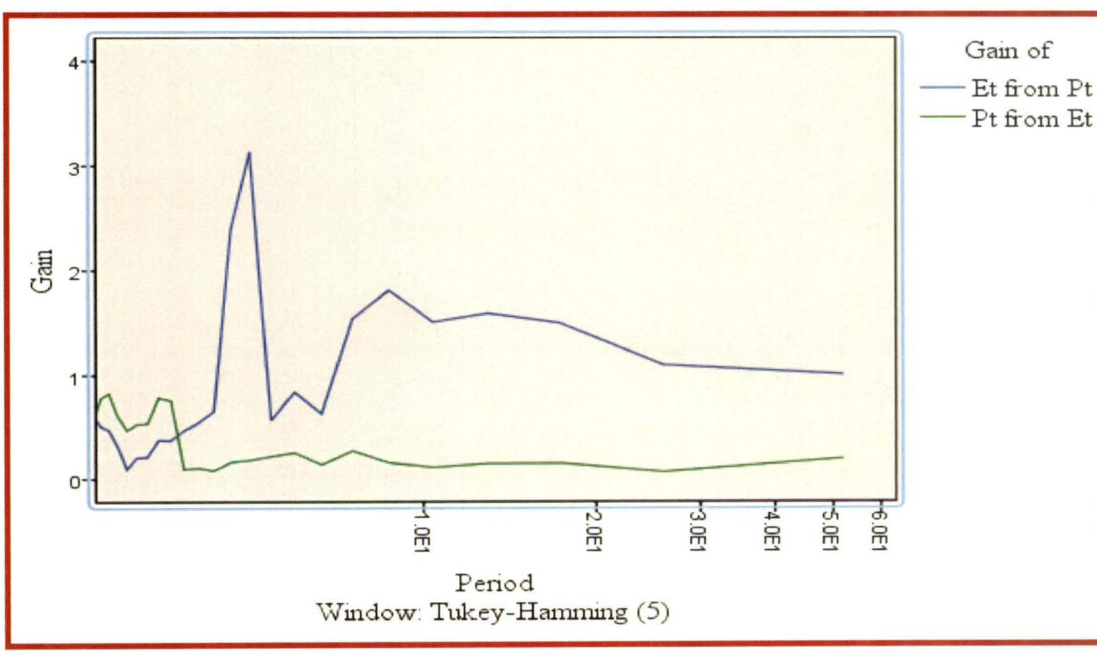


Figure 12.4

'Gain Spectrum' By Period For Exchange Rate (E_t) and Relative Price Level(P_t)



The 'Gain Spectrum' in Figures 12.3 and 12.4 for E_t and P_t for the period 1993:2 – 2006:1 show that

i. *the ' Gains of exchange rate (E_t) from relative price level (P_t) lie over the 'Gains of relative price level' (P_t) from exchange rate across almost all the frequency levels and periods.*

ii. *the 'Gain of E_t from P_t attains the highest value (3.25) at the frequency level 0.22 i.e. at period 4 (approx).*

iii. *the ' Gains of P_t from E_t' hardly exceeded 0.25 beyond period 2 i.e. within the frequency range [0,0.3].*

iv. *the 'Gain of P_t from E_t' was close to unity at period 2 i.e. at frequency 0.325.*

All these observations indicate that

i. *the regression coefficients, in case of regressions of exchange rate on relative price level, on the basis of period or frequencies, exceeded those when relative price level series was regressed on exchange rate series across different periods or frequencies.*

This testifies for the fact that exchange rate variations were 'Granger Caused' by those in relative price level, On the contrary, variations in relative price level displayed no significant relation with those in exchange rate.

ii. *the coefficient of regression of exchange rate on relative price level appeared to be singularly significant at period 4 or at frequency level 0.22.*

This observation again supplants and confirms the predominant significance of P_{t-4} in the vector of regressors for E_t in the '*Unrestricted*' and '*Restricted*' VAR systems.

12.5 Study with the 'Coherency Spectrum' of Exchange Rate (E_t) and Relative Price Level(P_t) by Frequency and by Period.

The '*Coherency Spectrum*' for E_t and P_t by frequency is being presented by the Figure 12.5 while the Figure 12.6 presents the corresponding '*Coherency Spectrum*' by period.

Figure 12.5

'Coherency Spectrum' By Frequency for Exchange Rate (E_t) and Relative Price Level (P_t)

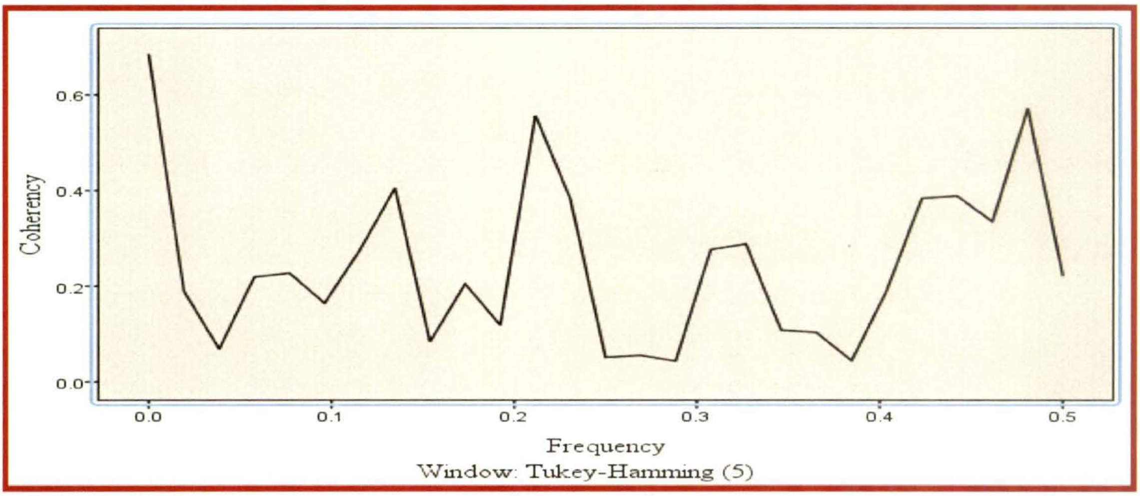
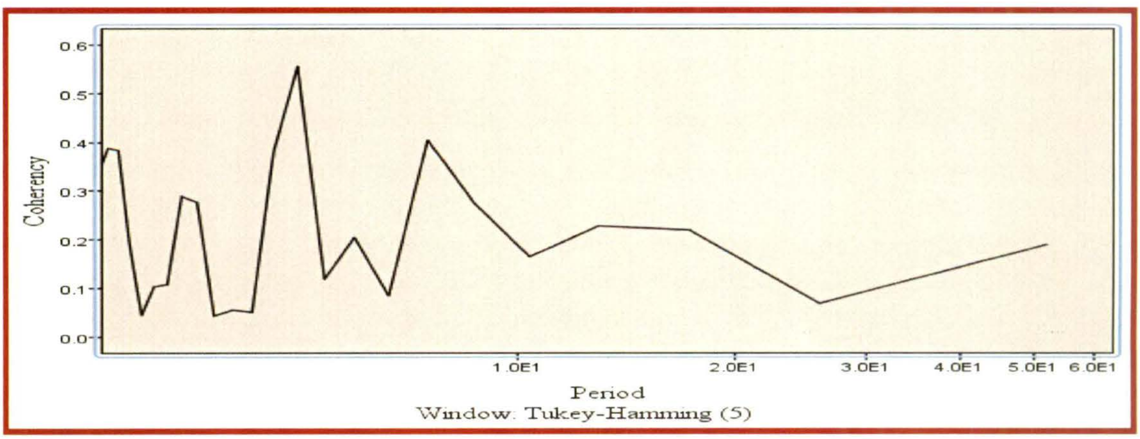


Figure 12.6

'Coherency Spectrum' By Period for Exchange Rate (E_t) and Relative Price Level (P_t)



The '*Coherency Spectrum*' in the Figure 12.5 shows that

i. the '*coherency*' for the variables E_t and P_t was as high as 0.6 (approx) at frequency 0.46 (approx).
ii. the '*coherency*' in 0.5 (approx) at frequency 0.22 (approx).

The '*Coherency Spectrum*' in the Figure 12.6 correspondingly shows that

i. the '*coherency*' was as high as 0.6 (approx) at period 4 while.
ii. the '*coherency*' was 0.5 (approx) at period 8.

These observations confirm that

i. there did exist high degree of co-movements (association) between the variables E_t and P_t over the period of study.
ii. there did exist a 'stable' relationship between the variable concerned.
iii. there did exist significant periodicity at frequency 0.46 or at period 4.

12.6 The 'Phase Spectrum' for Exchange Rate (E_t) and Relative Price Level (P_t)

The '*Phase Spectrum*' for E_t and P_t by frequency is shown by the Figure 12.7 and the Figure 12.8 shows the corresponding '*Phase Spectrum*' of the variables concerned by period.

Figure 12.7

Phase Spectrum By Frequency For Exchange Rate (E_t) and Relative Price Level (P_t)

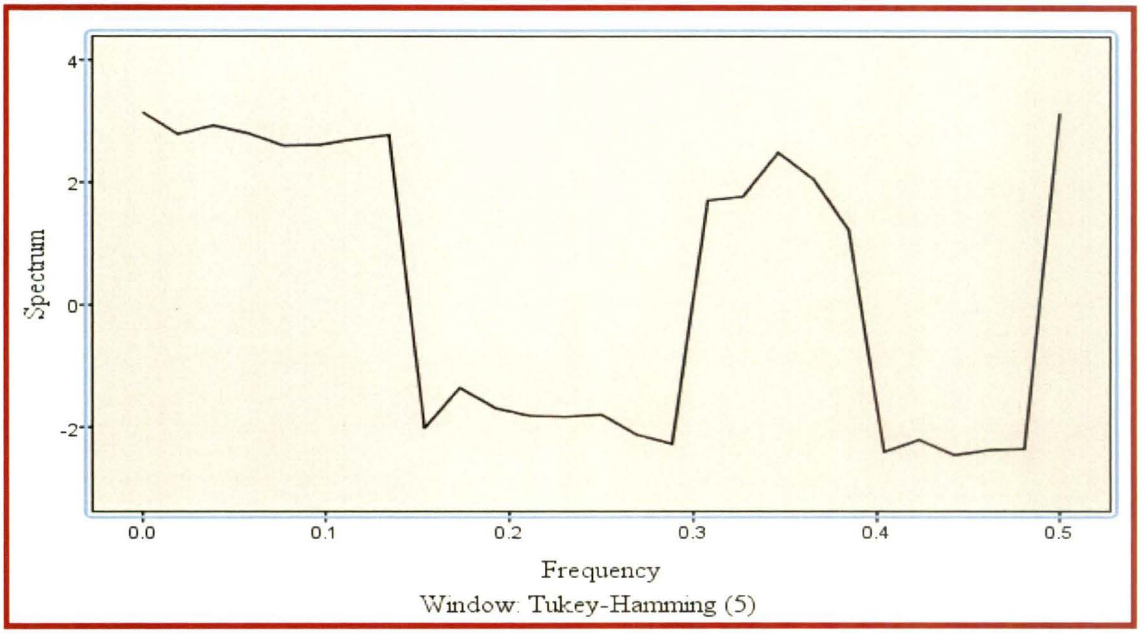
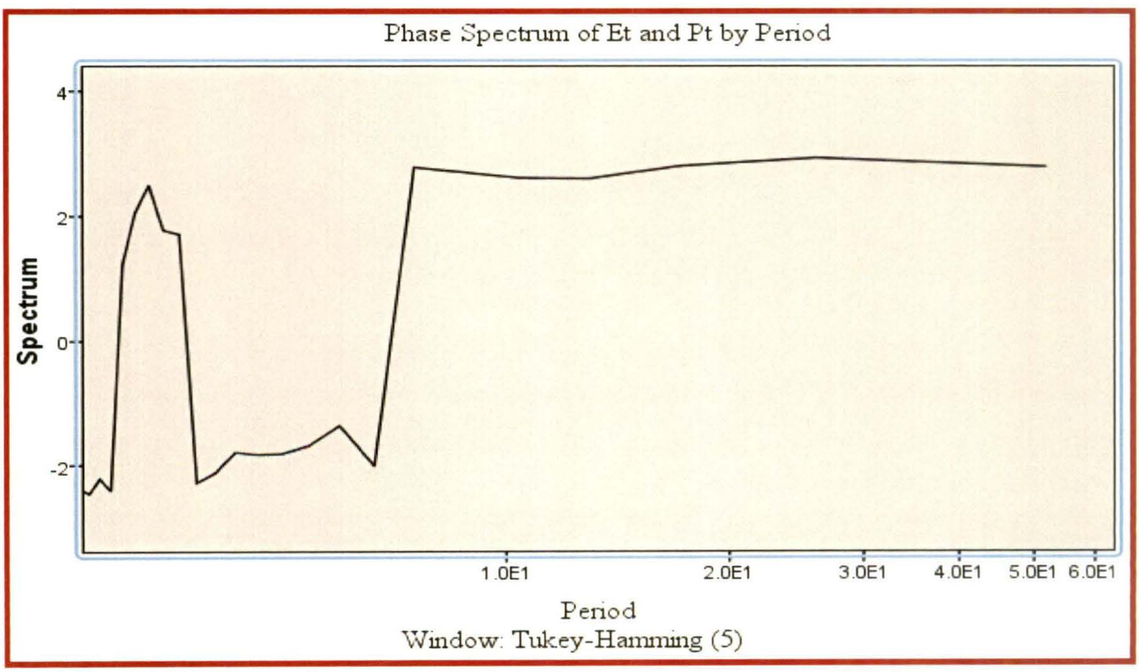


Figure 12.8

Phase Spectrum By Period For Exchange Rate (E_t) and Relative Price Level (P_t)



The *'Phase Spectrum'* in the Figures (12.7) - (12.8) show that the phase difference is negative over almost all the frequency levels barring frequency ranges (0.08 - 0.16) and (0.3 - 0.38) or corresponding period ranges (1.5-3) and (6-16) respectively. *Relative Price level* (P_t), therefore, was in '*Lead*' position and *Exchange Rate* (E_t) was in '*Lag*' position across almost all frequency levels. However, the 'lag position' of '*Exchange Rate'* implies that variation in '*Relative Price Level'* was an important source of variation in '*Exchange Rate'*.

These futures of the '*Phase Spectrum'* indicate that variations in *Relative Price Level* (P_t) occurred first and these variations then led to variations in *Exchange Rate* (E_t). *Consequently, the Spectral analysis confirms the Time Domain findings of 'Uni-directional Causality' from Relative Price Level (P_t) to Exchange Rate (E_t) over the Sub-period 1993:2 - 2006:1.*

12.7 Overview of Findings From the Spectral Analysis:

In the '*Spectral Analysis'* of time series dataset for Exchange Rate (E_t) and Relative Price level (P_t) over the sub - period 1993:2 - 2006:1.

i. *the Cospectrum for E_t and P_t exhibits dominant periodicities at 2, 3, 4 periods (or 0.25, 0.35 and 0.4 frequencies). This confirms the Time Domain finding that E_t and P_t were 'Cointegrated' and the long-run relationship between these variables was 'stable'.*

ii. *the 'Gain Spectrum' for E_t ant P_t confirms the Time Domain finding of the existence of 'Uni-directional Causality' running from Relative Price Level (P_t) to Exchange Rate (E_t) and the 'Gain' was more pronounced at the frequency level 0.22 (or at period 4).*

iii. *the 'Coherency Spectrum' for E_t and P_t confirms the presence of strong 'Coherence' in the joint variation of these variables. The maximum 'Coherence' was observed at period 4 (or at frequency level 0.44).*

iv. *the 'Phase Spectrum' for the variables further confirmed the Time Domain finding that Relative Price Level (P_t). 'Granger Caused' Exchange rate.*

CHAPTER - 13
SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

13.1 Introduction:

The relationship between Rupee/Nepalese Rupee exchange rate (e_t) and relative price level (p_t) has initially been studied in Chapters 4 and 5. The summary of the main findings on different aspects of such relationship is being presented below.

13.2 Stationarity of Exchange Rate (e_t) and Relative Price Level (p_t) Series (in Chapter 4) in the Historical Dataset for the Period 1976:1-2006:1

The study in Chapter 4 testified that both Exchange Rate (e_t) and Relative Price Level (p_t) series in the Historical Dataset for the Period 1976:1-2006:1.

i. *had 'unit roots' in them at level and these were 'non-stationary' by nature.*
ii. *did not entail any 'deterministic trend'.*
iii. *were stationary upon first differencing.*
iv. *were, therefore, integrated of order one such that $e_t \sim I(1)$ and $p_t \sim I(1)$.*

13.3 Cointegration Between Exchange Rate (e_t) and Relative Price Level (p_t) (Period 1976:1-2006:1)

Study in the Chapter 5 has been devoted to examining the existence of *cointegration* between two non-stationary variables, viz. exchange rate (e_t) and relative price level (p_t) at level. The study is carried through the *Johansen Tests of Cointegration*. The findings in Section 5.3 and 5.4 are as follows.

i. *Rupee/Nepalese Rupee Exchange rate (e_t) was not cointegrated with the relative price (p_t) at level, and therefore.*

ii. *Exchange rate and relative price level series were not CI(1,0).*

iii. *The absence of 'cointegration' between e_t and p_t at level testified for the absence of long-run relationship between Rupee/Nepalese Rupee Exchange rate (e_t) and relative price level (p_t) over the period 1976:1 - 2006:1.*

iv. *Rupee/ Nepalese Rupee exchange rate (e_t), therefore, was not in parity with the relative purchasing power of currencies of the trading countries concerned.*

v. *The 'Purchasing Parity Doctrine' of Exchange rate did not hold good in case of the quoted rates of exchange between Indian Currency (Rupee) and Nepalese Currency (Nepalese Rupee) over the period of study (1976 :1 - 2006 :1).*

13.4 Stationarity and Cointegration of Exchange Rate(e_t) and Relative Price Level (p_t) Under Two Different Sub-Periods [1976:1 - 1993:1 and 1993:2-2006 :1]

Two different sub-periods have been identified in the Historical Dataset ranging over 1976:1 - 2006:1. These sub-periods encompass two different structural relations between e_t ant p_t at level. The statonarity of e_t ant p_t in these two sub-periods [1976:1-1993:1 and 1993:2-2006:1] has also been examined in Chapter 5. The major findings are as follows.

In both the sub- periods 1976:1 - 1993:1 and 1993:2 - 2006:1

i. *both e_t and p_t at level were non-stationary.*

ii. *both e_t and p_t attained stationarity upon first differencing.*

iii. *both e_t ant p_t were, therefore, integrated of order one. Consequently,*

iv. *$e_t \sim I(1)$ and $p_t \sim I(I)$.*

13.5 Cointegration Between Exchange Rate (e_t) and Relative Price Level (p_t) in Two Different Sub-periods [1976:1-1993:1 and 1993:2-2006:1] [Chapter 6]

The cointegration between exchange rate (e_t) and relative price level (p_t) has been examined in Chapter 6 under two different sub-periods, viz, 1976:1-1993:1 and 1993:2-2006:1. The summary of the findings is being presented in Sections 13.5.1 and 13.5.2.

13.5.1 Cointegration Between e_t and p_t at level in the Sub-period 1976:1 - 1993:1

The findings on the *Cointegration* between e_t ant p_t in the sub-period 1976:1 - 1993:1 are as follows.

i. *e_t and p_t were not cointegrated at level,*
ii. *e_t and p_t were not CI(1,0).*
iii. *e_t and p_t were CI(1,1)*
iv. *There did not exist, therefore, any long-run relationship between Rupee/Nepalese Rupee exchange rate (e_t) and the relative price (p_t) at level in this sub - period.*
v. *There did exist, therefore, no evidence in favour of parity of Rupee/Nepalese Rupee exchange rate with the purchasing power of currencies concerned i.e, the relative price level prevailing in the two countries concerned during the period 1976:1-1993:1.*

13.5.2 Cointegration Between e_t ant p_t at Level in the Sub-Period 1993:2 - 2006:1

Findings from the study of *cointegration* between e_t and p_t at level in the sub-period 1993:2 -2006:1 are summarized below:

i. *e_t and p_t were cointegrated.*
ii. *e_t and p_t were CI(1,0).*
iii. *There did exist, therefore, a long-run equilibrium relationship between Rupee/Nepalese Rupee exchange rate and relative price at level in the period 1993:2 - 2006:1.*
iv. *The Rupee / Nepalese Rupee exchange rates were found to be in parity with the relative purchasing power of the currencies concerned. Thus the doctrine of 'Purchasing Power Parity' seemed to hold good in the matter of determination of Rupee / Nepalese Rupee exchange rate in the sub-period 1993:2 - 2006:1.*

13.6 Dynamics of Short-Run Shocks and the Stability of Long-run Relationship Between Exchange Rate(e_t) and Relative Price Level (p_t) [Chapter 7]

Cointegration study in Chapter 6 confirms the existence of long-run relationship between Rupee/Nepalese Rupee exchange rate (e_t) and relative price level (p_t) in the sub-period 1993:2 - 2006:1. The stability of the long-run relationship between e_t and p_t has been examined in Chapter 7 through the estimation of an appropriate *Vector Error Correction Model* (VECM) for e_t and p_t. If the short-run shocks, transmitted through the e_t and p_t channels, converge before long, the long-run relationships would be considered **'Stable'**. The study with the **VEC Model** in Chapter 7 establishes that in the sub-period 1993:2-2006:1

i. *the long-run relationship that exchange rate (e_t) maintained with the relative price level (p_t) was '**stable**'. The shocks, transmitted through the exchange rate channel, failed to exert any significant impact on the long-run relationship. Consequently, exchange rate, in response to an unanticipated shocks transmitted through the exchange rate channel, failed to display any significant adjustment in its values in order to bridge the short-run deviation from its 'target' level.*

ii. *the shocks, transmitted through relative price level channel, had significant impact on the long-run relationship and these provided damped oscillations. Consequently, the short-run dynamics of relative price level defined a '**stable equilibrium process**'.*

iii. *these did exist '**Uni-directional short-run Granger Causality**' running from relative price level (p_t) to exchange rate (e_t).*

iv. *exchange rate, on the other hand, **failed to Granger Cause** relative price level in the short-run.*

13.7 Causal Relationship Between Rupee / Nepalese Rupee Exchange Rate and Relative Price Level in the Long-run [Chapter 8]

The long-run causal relationship between Rupee/Nepalese Rupee Exchange rate [$E_t = \Delta e_t$] and relative price level [$P_t = \Delta p_t$] has been studied with the estimation of an appropriate *Unrestricted Vector Autoregressive (UVAR) Model* in Chapter 8 for the period 1993:2-2006:1. Main findings of the study in Chapter 8 are as follows :

i. *Four Period (quarter) back rise in relative price level led to appreciation of exchange rate (i.e. fall in Rupee / Nepalese Rupee Exchange Rate).*
ii. *Relative price level, thus,* **'Granger Caused'** *exchange rate over the period of study (1993: 2 - 20006:1).*
iii. *Exchange rate (E_t) was found to be negatively and non- proportionately related to previous two period (quarter) exchange rates.*
iv. *Relative price level (P_t) was positively and non-proportionately related to four period (quarter) back relative price level.*
v. *Relative price level (P_t) variations were not related to variations in any earlier period (quarter) exchange rate(E_t). Thus exchange rate(E_t) failed to* ***'Granger Cause'*** *relative price level (P_t) during this period (1993:2 - 2006:1).*
vi. *Relative price level (P_t), therefore, appeared to be* ***exogenous*** *in the* ***VAR*** *system.*

It is, therefore, observed in Chapter 8 that over the period of study (1993:2 - 2006:1)

i. *relative price level (P_t)* ***Granger Caused*** *exchange rate (E_t).*
ii. *exchange rate (E_t)* ***'failed to Granger Cause'*** *relative price level (P_t).*
iii. *there did exist, therefore,* ***Uni-directional Granger Causality'*** *running from relative price level (P_t) to exchange rate.*
iv. *relative price level (P_t) virtually emerged as an* ***'exogenous'*** *variable in the* ***VAR*** *system.*

13.8 Intervention Analysis Through the Study of Impulse Response Function in Chapter 9

In Chapter 9 we have sought to examine the responses of both exchange rate (E_t) and relative price level (P_t) to shocks transmitted through the channels of exchange rate and relative price level. The '*Intervention Analysis*' in this Chapter involves the study of the *Impulse Response Functions* of both the endogenous variables, namely, E_t and P_t. The study reveals that

i. *E_t exhibited an immediate response by rising above the long-run equilibrium base in response to shocks transmitted through the exchange rate channel.*
ii. *E_t, henceforth displayed a downward trend and attains the long-run equilibrium base quickly. This feature testifies for the 'Stability' of the long-run base and it lends a support to the '**Overshooting Phenomenon**', proposed by Dornbusch.*
iii. *E_t, in response to relative price level impulses, attained the long-run equilibrium level after significant variations in several successive periods. This testifies for the fact that relative price level impulses played a significant role in generating short- run variations in exchange rate around its long-run equilibrium base. Thus 'Granger Causality' running from relative price level to exchange rate got confirmed by the Intervention Analysis through the study of Impulse Response Functions'.*
iv. *short-run variations in relative price level were mainly due to impulses, transmitted through the channel of relative price level.*
v. *exchange rate shocks failed to generate significant variations in relative price level.*

These findings essentially give forth two important features of responses of exchange rate and relative price level to different types of shocks. These are as follows:

i. *Each endogenous variable exhibited significant responses to shocks transmitted through its own channel.*

ii. *Only relative Price level shocks evoked significant short-run variations in exchange rate while relative price level remained insoluted to exchange rate shocks.*

13.9 Intervention Analysis Through The Study of Variance Decomposition [in Chapter 10]

Chapter 10 has been devoted to the *Intervention Analysis* through variance decompositions of 20-period-ahead forecast errors for exchange rate and relative price level in the sub-period 1993:2-2006:1. The main findings are as follows:

i. *Exchange rate shocks predominantly accounted for the forecast error variances of exchange rate.*
ii. *Relative price level shocks also accounted for a significant part of the forecast error variances of exchange rate.*
iii. *Forecast error variances for relative price level were mainly due to shocks transmitted through relative price level channel.*
iv. *Exchange rate shocks failed to explain any significant part of 20-period-ahead forecasts of exchange rate.*

All these findings of the *Variance Decomposition Study* in the sub-period 1993:2-2006:1 testify for

i. *the existence of **'Predictive Causality'** (i.e 'Granger Causality') running from relative price level to exchange rate.*
ii. *the absence of **'Predictive Causality'** running form exchange rate to relative price level.*
iii. *the **exogeniety** of relative price level in the **VAR** system.*

13.10 Study of Granger Causality Between Exchange Rate and Relative Price Level Through the Estimation of a Restricted VAR Model [in Chapter 11]

The ***'Unrestricted VAR (2.4) Model'*** estimated in Chapter 8 is 'over parameterized' because of the specification of uniformity in the *auto-regressive* and *distributed lag structures* for the equation of each endogenous variables. As a result, such an ***'Unrestricted VAR Model'*** becomes less informative about the precise nature and direction of ***Granger Causality*** between the variables concerned. In order to ensure precision in the analysis a ***'Restrictive VAR Model'*** has been estimated in Chapter 11 to reconsider the nature and direction of *'Granger Causality'* between the variables concerned for the period of study (1993:2 - 2006:1).

It has been observed in Sections 11.6-11.10 that over the period of study 1993:2-2006:1

i. *exchange rate was **'Granger Caused'** by relative price level.*
ii. *exchange rate failed to **'Granger Cause'** relative price level.*
iii. *their did exist, therefore, the **'Uni-directional Granger Causality'** running from relative price level to exchange rate.*
iv. *relative price level emerged as **'exogenous'** variable in the system.*

These findings are in conformity with those obtained in the study with the estimated ***'Unrestricted VAR Model'*** in Chapter 8.

13.11 Spectral Analysis of the Relationship Between Rupee/Nepalese Rupee Exchange Rate (E_t) and Relative Price Level (P_t) in the Sub - Period 1993:2 - 2006:1 [Chapter 12]

The relationship between Rupee / Nepalese Rupee exchange rate (E_t) and relative price level (P_t) has been examined in Chapter 12 through the ***'Spectral Analysis'***. The ***'Frequency Domain'*** study is expected to supplant and supplement the ***'Time Domain'*** study carried in Chapters 5 through 11.

In the '**Spectral Analysis**'

i. *the 'Cospectrum' for E_t and P_t exhibited dominant periodicities at periods 2,3 and 4. This testifies for the existence of 'Cointegration' and the 'stable' long-run relationship between E_t and P_t.*

ii. *the 'Gain Spectrum' for E_t and P_t testified for the existence of 'Uni-directional Causality' from relative price level (P_t) to Exchange rate (E_t) over the period 1993:2 - 2006:1.*

iii. *the 'Coherence Spectrum' for E_t and P_t confirmed that the long-run relationship between these variables was 'strong' and 'stable'.*

iv. *the 'Phase Spectrum' for these variable confirmed that relative price level 'Granger Caused' exchange rate over the period of study (1993:2 - 2006:1).*

13.12 Conclusions:

All these findings give forth some basic fundamental features of the relations between Rupee / Nepalese Rupee exchange rate anal relative price level over the period of study 1976:1 - 2006:1. These features are as follows:

I. Absence of long-run relationship between Exchange Rate (e_t) and Relative Price Level (p_t) in the Historical Dataset.

There did exist no 'cointegration' between Rupee / Nepalese Rupee exchange rate and relative price level in the historical dataset (1976:1 - 2006:1). Consequently, exchange rate failed to maintain any long-run relationship with relative price level over the period of study.

II. No Evidence in Favour of Purchasing Power Parity Doctrine in The Matter of Determination of Rupee / Nepalese Rupee Exchange Rate in the Historical Dataset (1976:1 - 2006:1).

Absence of 'Cointegration' between exchange rate and relative price level testifies that Rupee / Nepalese Rupee exchange rate was not in parity with the relative purchasing power of the currencies concerned over the period of the study (1976:1-2006:1). As a *result, '**Purchasing Power Parity Doctrine**', remained invalidated by the determination of exchange rate between the currencies concerned over the period of study. Thus the Rupee / Nepalese Rupee exchange rate failed to establish the 'Law of One price' (LOOP) for the goods in international trade between India and Nepal during this period (1976:1-2006:1).*

III. 'Structural Shift' in Historical Datasets

The historical dataset (1976:1 -2006:1) is marked by the presence of two sub-periods corresponding to the 'structural shifts' in the process of exchange rate determination. These sub - periods in the historical dataset (1976:1 - 2006:1) comprise of

i. the period 1976:1 - 1993:1

ii. the period 1993:2 - 2006:1

These sub-periods essentially corresponded to the '*Paradigm shift*' with respect to the determination of exchange rate. The first sub-period (1976:1 - 1993:1) represented the period of the '*Crawling Peg*' System followed in India and Nepal. The second sub-period (1993:2 - 2006:1) represented the period of '*Market Determinations*' system which was marked by the '*Floating*' of exchange rate in the market.

IV. No Evidence in Favour of the 'Purchasing Power Party Doctrine' in the first Sub-period (1976:1 -1993:1)

There was no 'Cointegration' between Rupee / Nepalese Rupee Exchange rate and relative price level in the sub-period 1976:1 -1993:1. Thus exchange rate, over this period, did not maintain any long-run relationship with relative price level. Exchange rates between Rupee and Nepalese Rupee, therefore, were not in parity with the relative purchasing power of the currencies over this sub-period. Consequently, the determinations of Exchange rate between the currencies (viz. Rupee and Nepalese Rupee) over this sub-period did not conform to the 'Purchasing Power Parity Doctrine'.

V. Evidence in Favour of 'Purchasing Power Parity Doctrine' in the Second Sub - Period (1993:2 -2006:1)

There did exist 'Cointegration' between Rupee / Nepalese Rupee exchange rate and relative price level in the sub - period (1993 :2 -2006 :1). Thus exchange rate in this sub - period maintained a long-run relationship with relative price level. Exchange rates between the currencies (Rupee and Nepalese Rupee) were in parity with the relative purchasing power of the currencies concerned during this period. Consequently, exchange rates between the currencies established the 'Law of One Price' (LOOP) for goods in international trade between India and Nepal during the period 1993:2 -2006:1 when market forces were allowed by both the countries to determine exchange rates of the currencies concerned.

VI. Unfailing Maintenance of Purchasing Power Purity Doctrine Over the Sub-period 1993:2-2006:1.

Both the 'Time Domain' and 'Frequency Domain' studies establish that Rupee / Nepalese Rupee exchange rate maintained a stable long-run relationship with relative price level over the second sub-period (1993:2-2006:1) under 'Currency Float System'. Consequently, the 'Purchasing Power Parity Doctrine' had been consistently valid over the second sub - period (1993 :2 -2006 :1).

VII. Uni-directonal Granger Causality From Relative Price Level to Exchange rate.

Exchange rate variations were found to be '*Granger Caused*' by those in relative price level during 1993:2 -2006:1. Thus the equation of long-run relation between exchange rate and relative price level could as well be effectively used for the prediction of exchange rate with relative price level in the vector of regressors for exchange rate.

Thus the incidence of '*Unidirectional Granger Causality*' from relative price level to exchange rate further confirmed the consistent validity of the '*Purchasing Power Parity Doctrine*' in the determination of 'Rupee / Nepalese Rupee Exchange rate' during (1993:2 -2006:1).

Its may, therefore, be concluded in a nut-shell that, in case of determination of Rupee / Nepalese Rupee exchange rate over the period of study (1976:1-2006:1),

i. *the 'Purchasing Power Parity Doctrine' was not valid during (1976:1 -1993:1) when 'Crawling Peg System' was operative in both India and Nepal.*

ii. *the 'Purchasing Power Parity, Doctrine' was valid during (1993:2 -2006:1) when 'Market Determination Systems' was operative in both the countries concerned.*

iii. *exchange rate was "Granger Caused' by relative price level during the period (1932:2 -2006:1). Consequently, efficient prediction of future exchange rate could be done on the basis of relative price level existing in countries concerned.*

13.13 Public Policy Implications:

The study centres around the issue – how far Rupee/Nepalese Rupee exchange rates did conform to the 'Purchasing Power Parity Doctrine' over the period 1976:1 - 2006:1. The findings of the study indicate that Rupee/Nepalese Rupee exchange rates

i. were not in parity with the relative purchasing power of currencies concerned during 1976:1 - 1993:1.

ii. conformed to the 'Purchasing Power Policy Doctrine' during 1993:2 - 2006:1 only.

These findings bear immense economic implications along with profound public policy relevance as stated below.

a. Terms of Trade became '*neutral*' and fevourable for the expansion of trade during 1993:2 - 2006:1.

Expansion of bilateral trade between two countries becomes possible when '*trade creation*' materializes but '*trade diversion*' does not take place. It happens when '*terms of trade*' become 'neutral' in the sense that these do not unduly favour any trade partner at the cost of another. But *'terms of trade'* become '*neutral*' when real exchange rates remain constant over time. Such *time-invariance* of real exchange rates takes place when nominal exchange rates conform to the relative purchasing power of currencies concerned. In such case, as inflation rates vary in trading countries over time, relative purchasing power of currencies concerned also vary inversely over time in the same proportion. If '*Purchasing Power Parity Doctrine*' holds, then nominal exchange rates vary accordingly. Consequently, real exchange rate remains invariant over time and '*terms of trade*' become '*neutral*'. Now that Rupee/Nepalese Rupee exchange rates conformed to the '*Purchasing Power Party Doctrine*' during 1993:2-2006:1, terms of trade remained '*neutral*' for both India and Nepal ever this period. Such exchange rates were condusive for expansion of trade between these two countries. If exchange rates continue to be so in years to come, then Indo - Nepalese trade relations are expected to be stronger over time.

b. A Snag in Indo – Nepalese Trade Relation in 1989 – 1991: An Explanation

Rupee/Nepalese Rupee exchange rates were not in party with relative purchasing power of currencies concerned during 1976:1-1993:1. Terms of trade, therefore, were not *neutral* during this period. It favoured either of the partners against another. Such exchange rates were not condusive for trade expansion between the countries concerned.

As a matter of fact, in 1989 - 92 a snag in Indo - Nepalese trade relation took place when Nepal sought to proactive diversion of trade from India to China. Adverse terms of trade were quoted by Nepal as one of the reasons triggering such trade diversion. Indo - Nepalese trade suffered a lot during this period.

However, as soon as exchange rates, since 1993:1 reached parity with relative purchasing power of currencies concerned, terms of trade become *neutral*. Consequently, Indo-Nepalese trade relations also become normal.

Thus the findings of diversion of Rupee/Nepalese Rupee exchange rates from the purchasing power parity level during 1976:1-1993:1 in our study helps explain the occurrence of snag in Indo-Nepalese trade relation in 1989-92.

c. Importance of Market Determination System Established

Rupee/Nepalese Rupee exchange rates failed to be in parity with the relative purchasing power of currencies concerned during 1976:1-1993:1 when '*Crawling Peg System*' of exchange rate determination which prevailed in both India and Nepal. Under this system, market forces were not allowed to determine the equilibrium exchange rate. On the contrary, exchange rates were determined through interventions from the respective monetary authorities concerned.

Under the '*Crawling Peg system*' exchange rates deviated from the equilibrium level and terms of trade failed to be '*neutral*'. This hindered the expansion of bilateral trade. However, as soon as market forces were allowed to determine the equilibrium exchange rates, terms of trade become '*neutral*' which paved the way for the expansion of bilateral trade between India and Nepal.

It, therefore, follows that institutional intervention in the matter of determination of exchange rate may not be condusive for trade-expansion. On the contrary, floating exchange rate system where market forces freely determine exchange rates would always promote trade expansion. In such case, market forces remove all the imbalances in terms of trade so that trade could expand.

The findings from the present study, therefore, implicitly establish the lesson that market determination system is '*trade-favouring*' by nature and therefore, all inhibitions to free play of market forces be removed for the sake of expansion of trade.

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