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# TRANSMISSION MECHANISM OF EXCHANGE RATE PASS-THROUGH IN INDIA*

Rucha R. Ranadive[1]
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## Abstract

The degree of transmission of the exchange rate fluctuations to domestic prices manoeuvres the monetary policy actions to contain the inflationary pressure on the economy. The study applies unrestricted vector auto-regression (VAR) model and innovation accounting tools such as impulse response functions (IRFs) and variance decomposition to analyse the exchange rate pass-through (ERPT) to import and domestic prices in India after the global financial crisis. This empirical study has been undertaken from April 2009 to May 2013 considering eight variables VAR comprising oil prices, output gap, the exchange rate, interest rate, money supply, import prices, wholesale prices and consumer prices in India. Incomplete pass-through to import and domestic prices has been encountered and the transmission of pass-through declines along the distribution chain of pricing. The magnitude of pass-through is high for import prices and moderate for wholesale and consumer prices. The variance decomposition results reveal that industrial output, interest rate and money supply significantly impact domestic prices in India.

*Keywords:* Exchange Rate Pass-through, Prices, VAR, Impulse Response Function, Variance Decomposition

*JEL Codes:* C32, F31

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# 1 INTRODUCTION

The high level of inflation rate has always been a cause of concern for the developing countries, including India. India has been considered as one of the fastest growing economies in the world. Therefore, policy makers are vigilant regarding the economic indicators such as inflationary pressure in the economy. India being a liberalised country with the managed floating exchange rate regime, a rigorous research on the underlying relationship between the exchange rate and prices is important from the monetary policy perspective. The extent to which the exchange rate and import prices influence domestic inflation, known as the exchange rate pass-through (ERPT), is a major concern for the monetary policy. The assessment of the size and speed of ERPT is essential for understanding the pass-through mechanism as it impacts the transmission mechanism of the monetary policy on prices and inflation forecasts (Hahn, 2003; Stulz, 2007). Thus, the degree of ERPT has important implications for the design of the monetary policy to undermine the inflationary and trade implications of an exchange rate shock.

ERPT refers to the transmission of the exchange rate changes into import prices of specific goods in the destination market currency (Saha and Zhang, 2011; Ghosh and Rajan, 2006). According to Goldberg and Knetter (1997), the textbook definition of ERPT is the percentage change in local currency in import prices resulting from one percent change in the exchange rate between importing and exporting countries. Broadly, ERPT implies changes in domestic prices that can be attributed to changes in the nominal exchange rate. ERPT is complete if change in the exchange rate generates a proportional change in the domestic prices; otherwise, it is incomplete. Formally, the statistical relationship between the import prices to the exchange rate can be written as follows:

$$\Delta p_t = \gamma \Delta e_t + \varepsilon_t \qquad \text{.................................} \quad (1)$$

where,

$p_t$ = Natural log of import price
$e_t$ = Natural log of nominal exchange rate
$\varepsilon_t$ = Error term

The ERPT coefficient is $\gamma$. If $\gamma = 1$, then ERPT is complete. However, if $\gamma < 1$, then ERPT is partial or incomplete (Barhoumi, 2006). ERPT not only refers to the effect of the exchange rate changes on import and export prices but also on consumer prices, producer prices, investment and trade volumes (Tandrayan-Ragoobur and Chicooree, 2013). The transmission mechanism of ERPT has two stages. In the first-stage pass-through, a depreciation of the exchange rate increases the prices of imported goods. In the second-stage pass-through, increase in the prices of imported goods, in turn, raises the prices of domestically produced goods through supply and demand channels (Bhattacharya *et al.*, 2008). The degree of ERPT exerts the importance of the exchange rate fluctuations on the domestic price inflation as well as an extent to which the exchange rate and import price influence domestic inflation. There are two channels through which the exchange rate affects domestic prices.

**A. Direct Channel:**

A direct channel works through import prices. *Ceteris paribus*, at constant cost of production in foreign currency, the import prices denominated in local currency are affected by the exchange rate. These import prices may affect the consumer prices through two ways:

a) If the imported items constitute of finished goods used directly for consumption then the price level is directly affected.
b) If imports consist of intermediate goods used for producing the domestic output, depreciation increases the cost of production of final domestic output, thereby leading to higher output prices.

However, a complete pass-through would be realised if mark-ups of prices over cost and marginal costs are constant.

**B. Indirect Channel:**

This channel refers to the competitiveness of goods in the international market. The exchange rate fluctuations have two indirect effects on domestic prices.

a) *Competition Effect:* This effect occurs when there is a shift in demand for domestic output due to the exchange rate changes. The exchange rate appreciation would increase export prices and decrease import prices. If the domestic cost remains unchanged, then domestic producers face competition in the form of low prices of imported items. In this case, the domestic producers would have to cut down their own prices and profit margins. This would change the domestic prices.

b) *Wage Effect*: The exchange rate depreciation would make domestic products cheap for foreign consumers, and thus, exports and aggregate demand will increase, thereby increasing domestic prices. Since wages are constant in the short run, real wages will decrease and output will increase. However, eventually when the real wages return to their original level, the production cost increases, leading to an increase in the price level.

The objective of this study is to empirically examine ERPT along the distribution chain of pricing in India after the eruption of the global financial crisis, with the fallout of the Lehman Brothers Ltd. in the U.S. The rupee–US $ exchange rate has depicted highest fluctuations during this period. This would enable us to investigate whether the persistent inflation in the recent periods has been due to the high exchange rate volatility in India. The analysis would be undertaken using the unrestricted VAR model and innovation accounting tools.

This study is organised as follows. Section *Two* overviews the literature related to ERPT. The data and model adopted for the analysis are explained in Section *Three*. Section *Four* lists the empirical results which are presented in various sub-sections. Section *Five* presents the concluding remarks.

## 2 OVERVIEW OF LITERATURE

The literature pertaining to ERPT is quite extensive and most of the empirical studies have supported the existence of incomplete pass-through for developed as well as developing economies. The incomplete pass-through is generally explained by the microeconomic factors such as demand elasticities, production cost, market structure and macroeconomic factors *viz.,* trade barriers, transaction and transportation costs, market power and imperfect substitutability between domestic and foreign products. The characteristics of the traditional open-economy macroeconomic models are perfect competition, fully flexible prices and purchasing power parity (PPP). With the law of one price and PPP, ERPT to domestic prices is always immediate and complete. However, the law of one price was criticised on the basis of price stickiness. Thus, the evidence of incomplete pass-through relied on imperfect competition. While explaining the microeconomic reasoning for incomplete pass-through to import prices, Krugman (1986) introduced the concept of pricing-to-market (PTM). It denotes the exchange rate-induced price discrimination across countries. The exporting firms adjust their mark-ups in order to compensate the exchange rate changes in the international market to maintain their market share. Dornbusch (1987) pointed that the degree of market concentration, the extent of product homogeneity and substitutability, the relative market shares of domestic and foreign firms and market structure affect the adjustment of relative prices to the exchange rate movement. The market structure plays an important role in determining ERPT as the responsiveness of prices to an exchange rate movement depends upon the relative number of foreign firms and the ratio of marginal cost to the price of foreign suppliers. According to Goldberg and Knetter (1997), the magnitude of pass-through to import prices is small in more segmented markets where firms are able to engage in price discrimination. In an imperfectly competitive market, firms can charge different prices for the same product in different export markets, leading to incomplete pass-through.

The macroeconomic perspective regarding the incomplete pass-through was pioneered by Obstfeld and Rogoff (1995) and Betts and Devereux (1996). They suggested that destination prices can marginally change despite the exchange rate variation, with nominal rigidity and local currency pricing (LCP). According to the new open macroeconomic model, the pricing strategies of the firms influence ERPT. Producer currency pricing (PCP) implies that the consumer prices change one-for-one with changes in the nominal exchange rate in the short run. Thus, pass-through will be complete under PCP. If the nominal prices are set in advance in the currency of the consumer, it is known as LCP. The change in the nominal exchange rate does not change prices with LCP in the short run. Hence, ERPT will be complete in PCP and no ERPT will exist in LCP in the short run. The aggregate pass-through depends upon the combination of firms practising PCP and LCP. Engle (2002) concluded that firms prefer to invoice in the importers' currency when their optimal price is stable in the importer's currency. Regarding the determinants of ERPT, Mann (1986) discussed some macroeconomic variables that may affect the pass-through. One of them is the exchange rate volatility. Greater volatility may make importer more wary of changing prices and more willing to adjust profit margins, thereby reducing pass-through. Taylor (2000) proposed another determinant of the pass-through. He argued that the decline in pass-through to aggregate prices is the result of low inflation environment. Thus, the pass-through depends only on the monetary policy regime *i.e.,* a credible low inflation regime will automatically achieve a low pass-through (Saha and Zhang, 2011). Bailliu and Fujii (2004), Barhoumi (2006), Choudhri and Hakura (2006) and Caulibaly and Kempf (2010) employed the panel data framework for different sets of countries to test Taylor's hypothesis. They supported the hypothesis that ERPT declines with a shift to low inflationary environment.

A large pool of literature dwells on the degree of ERPT to import, producer and consumer prices by making use of variants of the Vector Auto-Regression (VAR) methodology such as recursive VAR, structural VAR and unrestricted VAR. Studies by Belaisch (2003) and Jin (2012) found that the degree of ERPT is low to the domestic and consumer prices compared to that of import prices. Gagnon and Ihrig (2004) used cross country analysis, Frenkel*et al.* (2005) employed panel data techniques and Choudhri*et al.* (2005) used VAR for G-7 countries to reveal that the pass-through is low to consumer prices and that less developed countries (LDCs) tend to have higher pass-through of the exchange rate onto prices. Another group of studies suggested that the pass-through of the exchange rate to prices is incomplete in most cases probed for the analysis (Rowland, 2003; Campa and Goldberg, 2005; Stulz, 2007; Masha and Park, 2012; Razafimahefa, 2012). Numerous studies also examined the transmission of ERPT along the distribution chain of prices. Results of these studies emphasised that the pass-through declines along the pricing chain. The impact of the exchange rate shock on the import prices is higher than that on producer prices, and the impact is moderate on the consumer prices. They emphasised that the incomplete nature of ERPT to import and producer prices almost nullifies the degree of pass-through to consumer prices. Therefore, consumer prices indicated very low level of pass-through (McCarthy, 2000; Bhundia, 2002; Leigh and Rossi, 2002; Kang and Wang, 2003; Hahn, 2003; Faruqee, 2006; Naqvi and Rizvi, 2006; Ito and Sato, 2006, 2007; Ca'Zorzi*et al.*, 2007; Ghosh and Rajan, 2009; Ocran, 2010; Przystupa and

Wróbel, 2011). On the contrary, opposite results were obtained by Tandrayen-Ragoobur and Chicooree (2013) who encountered high pass-through to consumer prices, followed by producer prices and lowest for import prices in Mauritius.

These studies have also analysed ERPT in the Indian context. Dholakia and Saradhi (2000) employed the quarterly data for the period 1980–96 to assess the impact of the exchange rate and exchange rate volatility on export and import prices and quantities. They employed a special case of auto-regressive distributed lag model, a partially adjusted model. The study revealed that ERPT to import prices was full, indicating the price taking behaviour, whereas for export prices it was incomplete before 1991 and nearly complete after 1991. The study concluded that increased exchange rate volatility adversely impacted the prices. Ghosh and Rajan (2007a) examined ERPT into India's Consumer Price Index (CPI) at aggregate level considering two models, one with the bilateral exchange rate between rupee and the U.S. $ and another with nominal effective exchange rate (NEER) for the period 1980–2006. By employing Dynamic OLS technique the study resolved that the pass-through elasticity of the rupee–USD exchange rate is approximately 50 percent over the period. They found that the exchange rate volatility exerted consistently negative effect on ERPT elasticities. In another attempt by Ghosh and Rajan (2007b), they undertook analysis of similar models from 1980 to 2005. They sub-divided the sample into two periods; pre- and post-liberalisation. They applied cointegration and vector error correction techniques and found 40 percent elasticity of ERPT over the entire sample period and only 10 percent in the short run. They encountered high pass-through for the post-liberalisation period.

Bhattacharya *et al.* (2008) examined the relationship between domestic inflation and the exchange rate in India from 1997 to 2007. Using VAR they found an incomplete pass-through for India and moderate pass-through into domestic prices. The analysis, based on vector error correction model (VECM), impulse response function (IRF) and variance decomposition, undertaken by Raj *et al.* (2008) from 1950 to 2007 revealed that the inflation in India is positively influenced by the import price, capital flows and the exchange rate. In fact, the capital flows significantly impacted the domestic inflation in India. Khundrakpam (2008) examined the behaviour of ERPT to domestic prices in India in the post-liberalisation period. The study applied rolling regression to monthly data from January 1990 to March 2005. The study also incorporated asymmetry and non-linearity dummies in the model. The analysis deduced that there has been increase in the pass-through. According to him, it has been observed due to persistent high rate of inflation experienced in India in recent years. Sohrabji (2011) inferred that there is an incomplete pass-through to consumer prices and the exchange rate is not the only important factor for the price variation in India. Considering three sub-periods (1975–1986, 1992–1998 and 1999–2010), she pointed that openness is one of the dominant factors in determining the level of ERPT. The study revealed that the exchange rate shocks have greater impact on the domestic prices in the long run than in the short run. Saha and Zhang (2011) examined the pass-through of the exchange rate and import prices to producer and consumer prices for three major economies namely, Australia, China and India using the monthly data from 1990 to 2011. Using a structural VAR model, the study pointed that the pass-through is comparatively lesser for India compared to Australia and China. Appreciation of the rupee decreased import prices but exerted inflationary impact on domestic prices in India.

Mallick and Marques (2009) undertook a micro-level study for India. The study used two-digit industry level export price data during post-1991 economic reform period. The results of cointegration for heterogeneous panels evidenced incomplete ERPT to prices in India's export market. Monthly data reflected more incomplete pass-through than annual data. Thus, they concluded that high frequency data are likely to find incomplete ERPT in the short run. Besides this, Roy and Pyne (2011) estimated ERPT to India's export prices during 1960 to 2000. They applied simultaneous equation demand and supply model and full information maximum likelihood method to estimate pass-through at aggregate and disaggregate manufacturing export prices. The study showed high but incomplete ERPT into India's export prices. However, the degree of pass-through varied across product groups. Similarly, Pyne and Roy (2011) used simultaneous equation model and panel data estimation techniques incorporating both demand and supply sides to investigate the degree of ERPT to non-oil import prices in India. The empirical results exhibited incomplete ERPT to import prices in India.

From the literature overview, it is quite evident that the studies focusing on ERPT in India are rather scarce. None of the studies have used the VAR technique to analyse the pass-through on import prices. Furthermore, the transmission mechanism which works through import, wholesale and consumer prices has not been thoroughly studied. Hence, this study analyses the pass-through mechanism to all prices *i.e.,* import prices, wholesale prices and consumer prices as well as examines the transmission of pass-through along the distribution chain of prices whereby fill the gap in the existing literature in India.

## 3 DATA AND METHODOLOGY

This study analyses the transmission of the exchange rate changes into import prices, wholesale prices and consumer prices in India. The variables considered for the analysis are oil prices, output gap, exchange rate, interest rate, money supply, import prices, wholesale prices and consumer prices. Oil prices comprise world crude oil price index (2005 = 100). The output gap is measured as the deviation of log of index of industrial production (IIP) from its HP filtered value with 2004–05 as a base year. The bilateral exchange rate between the rupee and the U.S. $ has been used as the exchange rate variable. The interest rates of 91-day treasury bills and broad money (M3) are used as proxies for interest rate and money supply respectively. Import prices are the import unit value index (2005 = 100). Wholesale price index (WPI) with 2004–05 base year and CPI (2005 = 100) are used for the analysis. The data are monthly from April 2009 to May 2013 comprising 50 observations. The data on IIP, interest rates, money supply and WPI have been obtained from RBI bulletin, Handbook of Statistics on Indian Economy, International Financial Statistics, IMF data for oil price index, bilateral exchange rate, import unit value index and CPI (RBI, 2013a, 2013b; IMF, 2013). The choice of data period has been dominated by the availability of monthly import unit value index published by IMF for India. However, the effect of subsidies granted by the Government of India on imported products such as petroleum products, chemicals, fertilizers, and so on. have not been separated from the domestic prices. All the data series, except the exchange rate and interest rates, are seasonally adjusted using Census X-12 method. Natural logs of all variables are considered for further analysis.

***Model:***

The analysis of ERPT has been performed using the unrestricted VAR analysis based on McCarthy (2000), Hahn (2003), Faruqee (2006) and Ito and Sato (2006, 2007). It is useful approach to analyse the interrelationship between the exchange rate and other macroeconomic variables. VAR model examines the pass-through effects of the exchange rate shocks along the pricing chain by treating them as endogenous variables. It enables the identification of structural shocks through a Cholesky decomposition of innovations. Using the VAR framework, effect of structural shocks of other macroeconomic variables on the domestic inflation can also be investigated.

This study forms a VAR model with a vector of eight endogenous variables, including log of oil prices (LOIL), output gap (GAP), log of the bilateral rupee–USD exchange rate (LE), log of interest rate (LI), log of money supply (LM), log of import prices (LIMP), log of wholesale prices (LWPI) and log of consumer prices (LCPI). The reduced form VAR (p) can be written as

$$Y_t = c + A(L)\, Y_{t-1} + \mu_t \qquad \text{........................ (2)}$$
$$E(\mu_t \mu_t') = \Omega$$

where,

$Y_t = [LOIL_t, GAP_t, LE_t, LI_t, LM_t, LIMP_t, LWPI_t, LCPI_t]'$

c = Vector of deterministic terms

A = Matrix of the polynomials of degree p in the lag operator

$\mu$ = Vector of reduced form residuals

$\Omega$ = Variance covariance matrix of $\mu_t$

Identification of structural shock has been achieved by appropriate order of the endogenous variables and by applying Cholesky decomposition. The Cholesky decomposition encompasses the decomposition of the variance–covariance matrix $\Omega$ of the reduced form residuals ($\mu_t$) in a lower triangular matrix S. The relationship between reduced form VAR residuals and structural disturbances can be written as follows:

$$
\begin{bmatrix} \mu_t^{LOIL} \\ \mu_t^{GAP} \\ \mu_t^{LE} \\ \mu_t^{LI} \\ \mu_t^{LM} \\ \mu_t^{LIMP} \\ \mu_t^{LWPI} \\ \mu_t^{LCPI} \end{bmatrix} = \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & 0 & 0 & 0 \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & 0 & 0 & 0 \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} & 0 & 0 \\ S_{71} & S_{72} & S_{73} & S_{74} & S_{75} & S_{76} & S_{77} & 0 \\ S_{81} & S_{82} & S_{83} & S_{84} & S_{85} & S_{86} & S_{87} & S_{88} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{LOIL} \\ \varepsilon_t^{GAP} \\ \varepsilon_t^{LE} \\ \varepsilon_t^{LI} \\ \varepsilon_t^{LM} \\ \varepsilon_t^{LIMP} \\ \varepsilon_t^{LWPI} \\ \varepsilon_t^{LCPI} \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)
$$

The structural model is identified by imposing n(n-1)/2 economic restrictions on matrix S as zero restrictions where n is the number of endogenous variables in the model. The lower triangular matrix S implies that some structural shocks have no contemporaneous effect on other endogenous variables, given the ordering of the variables (Ito and Sato, 2006).

In the Cholesky decomposition ordering of the variables is important. In the model, oil prices are included to capture supply shocks, whereas demand side shocks are measured via output gap. Interest rate and money supply are included to represent monetary policy effects in the model. WPI and CPI will capture the domestic inflation. The bilateral exchange rate of rupee *vis-à-vis* the U.S. $ has been considered as the U.S. $ is the international vehicle currency. The oil prices are ordered first in the model as it is not contemporaneously affected by any other shocks, whereas all other variables in the model are likely to be contemporaneously affected by shocks. Output gap, measuring demand side, is said to be affected only by oil prices and its own shocks in the lagged period, thus, ordered next to oil prices. The exchange rate has been ordered immediately after the output gap as it would affect other variables and that is the aim of analysing pass-through. The monetary policy shocks measured in terms of interest rate and money supply are ordered after the exchange rate as they are likely to contemporaneously affect prices. Prices are ordered as import prices, wholesale prices and consumer prices which is a logical link of the distribution chain of prices. All these prices are contemporaneously affected by all other shocks of variables in the VAR, whereas price shocks have no contemporaneous impact on other variables (Hahn, 2003).

$$LOIL \rightarrow GAP \rightarrow LE \rightarrow LI \rightarrow LM \rightarrow LIMP \rightarrow LWPI \rightarrow LCPI$$

The pass-through effects of the exchange rate changes have been analysed as stated in the VAR model, using innovation accounting tools *i.e.* IRF and forecast error variance decomposition (FEVD). IRF traces the contemporaneous responses of current and future values of prices to a shock in one of the VAR equations. It provides information on the size and speed of ERPT. However, they do not provide insights into the importance of the respective shocks for the variance of price indices. The additional information regarding the impact of external shocks on different prices can be obtained from variance decomposition. Variance decomposition examines fluctuations of each price variable that occur due to the exchange rate shock or other factors. FEVD provides the percent of variance of the error made in forecasting prices at a given horizon due to a specific shock. In other words, it indicates the percentage contribution of different shocks to the variance of the n-period ahead forecast errors of the variables (Hahn, 2003).

## 4 EMPIRICAL RESULTS

Augmented Dickey-Fuller (ADF) test has been conducted to test the time series properties of the variables in the VAR model. Table 1 summarises the test results. The ADF test statistic indicated that all variables, except LOIL contain a unit root. Variables GAP, LE, LI, LM, LIMP, LWPI, LCPI are all non-stationary, however, the first differences of variables are found to be stationary by the ADF test. Thus, LOIL is a stationary variable at level and all other remaining variables are integrated of order one, I(1), processes. Since the set of variables has one stationary variable *i.e.,* LOIL and the aim is to assess the impulse responses, the VAR model would then be estimated in the first differences of the variables except LOIL. Therefore, the set of endogenous variable in the VAR model would be;

$$Y_t = [LOIL_t, DGAP_t, DLE_t, DLI_t, DLM_t, DLIMP_t, DLWPI_t, DLCPI_t]' \quad \text{......} \quad (4)$$

**Table 1**: Unit Root test results

| Variables | | t-statistic | p-value |
|---|---|---|---|
| LOIL | Level | - 4.8007 | 0.0016 |
| -- | First Difference | N.A. | N.A. |
| GAP | Level | - 2.2476 | 0.4528 |
| DGAP | First Difference | - 6.2980 | 0.0000 |
| LE | Level | - 2.1636 | 0.4983 |
| DLE | First Difference | - 5.2565 | 0.0004 |
| LI | Level | - 1.2120 | 0.8966 |
| DLI | First Difference | - 10.9381 | 0.0000 |
| LM | Level | - 1.3176 | 0.8715 |
| DLM | First Difference | - 10.7727 | 0.0000 |
| LIMP | Level | - 2.1170 | 0.5234 |
| DLIMP | First Difference | - 10.0158 | 0.0000 |
| LWPI | Level | 0.0765 | 0.9962 |
| DLWPI | First Difference | - 6.2169 | 0.0000 |
| LCPI | Level | - 2.9911 | 0.1451 |
| DLWPI | First Difference | - 5.6848 | 0.0001 |

The lag order of the VAR model is selected on the basis of the lag selection criteria such as Akaike Information Criteria (AIC), Schwartz Bayesian Criteria (SBC), Hannan-Quinn (HQ) and Final Prediction Error (FPE). Based on AIC (-38.9676), SBC (-36.1057), HQ (-37.8957) and FPE (1.72e-27) appropriate lag length of two is chosen for the model. Thus, VAR model with two lags along with intercept is estimated based on which IRFs and FEVDs are computed.

The diagnostic tests are computed to check for the stability of the VAR model, serial correlations in residuals, normality of residuals and autoregressive conditional heteroskedasticity (ARCH) effects in the residuals. Moduli of characteristic roots of the VAR model are less than one and all eigenvalues lay inside the unit root circle. For testing the serial autocorrelation among residuals, the serial autocorrelation LM test is computed and we failed to reject the null hypothesis of no serial correlation up to 12 lags. Thus, there was no serial correlation among the residuals. Similarly, the Portmanteau tests for autocorrelations also failed to reject the null hypothesis of no residual autocorrelation. The Jarque-Bera test suggested individual residuals were multivariate normal; however, the joint hypothesis was rejected at 5 percent level of significance. To compute the IRFs and FEVDs, we assume them to be normal. Using the residual heteroskedasticity test, we failed to reject the null which then implied the absence of ARCH effects in the residuals (Appendix A).

### 4.1 Impulse Response Functions:

The impulse responses of prices to the shocks of specific variables are displayed over a 12 months' time horizon. All shocks are standardised to one percent shocks. In the resultant figures (Figures 1-5), horizontal axis measures the time period and vertical axis reports an approximate percentage change in the respective prices due to one percent shock in the concerned variables which is the percentage of pass-through. The solid line in the figures indicates estimated responses of prices to shocks over the consecutive period, whereas the dotted lines indicate a two standard error confidence band around the estimated line. In addition to the impulse responses, the dynamic ERPT elasticity or coefficient from IRF has also been analysed as it will be informative to assess the extent of ERPT by normalising the price responses to the exchange rate shock by corresponding response of the exchange rate to its own shock (Ito and Sato, 2007).

$$PT_{t,\,t+j} = \frac{\sum_{j=1}^{T} \Delta P_{t,\,t+j}}{\sum_{j=1}^{T} \Delta e_{t,\,t+j}} \qquad \text{..................} \ (5)$$

where,

$\Delta P_{t,\,t+j}$ = Impulse response of the price change to the exchange rate shock after j months.

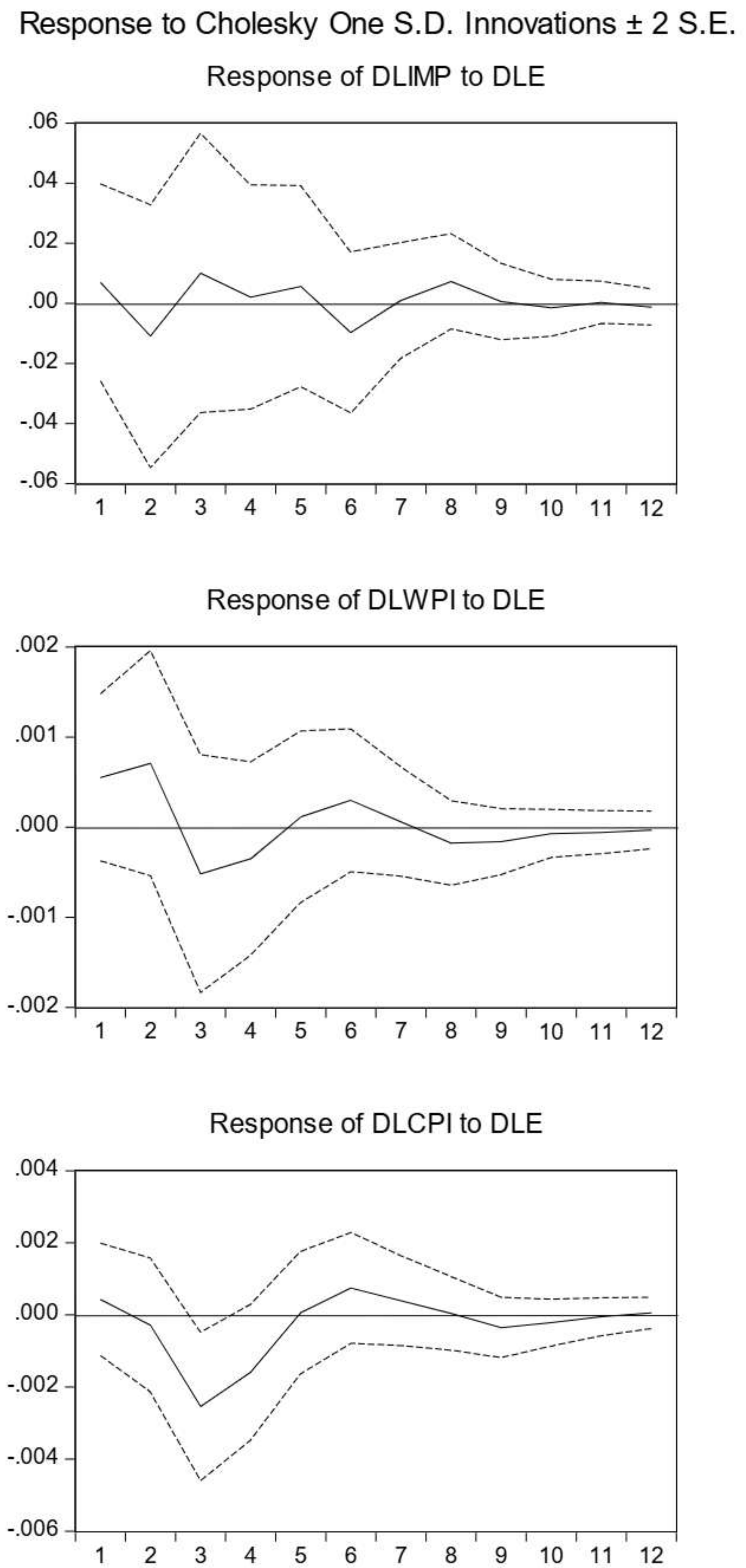
$\Delta e_{t,\,t+j}$ = Corresponding impulse response of the exchange rate change.

The dynamic ERPT elasticity $PT_{t,\,t+j}$ shows the cumulative responses of price change to the exchange rate shock after j months normalised by the corresponding responses to the exchange rate change.

#### *4.1.1 Responses of Prices to Exchange Rate Shock:*

The IRFs of DLIMP (import prices), DLWPI (wholesale prices) and DLCPI (consumer prices) are plotted in Figure 1. The responses of all prices to the one percent exchange rate shocks are statistically significant. The IRF of import price is initially negative but later it is positive and settles down after 10 months. It implies

**Figure 1:** Impulse Response of Prices to the Exchange Rate Shock



that import prices respond to the exchange rate shock from the second period onwards in India. An increase in the exchange rate indicates depreciation of the rupee against the U.S. $. Thus, as per this definition, depreciation of the exchange rate increases import prices. Similarly, IRF of the wholesale prices are positive up to second month but becomes negative at later periods and dies out after 12 months. It, therefore, shows that wholesale prices quickly respond to depreciation and adjust at later periods. The one percent exchange rate shock has a negative effect on the consumer prices but has positive effect after 5 months. Hence, the exchange rate depreciation has very little impact on the consumer prices. From the figures, it is clear that the response to the exchange rate shock is the largest in import prices followed by WPI and least on CPI. The reason is quite obvious. As the import contents are highest in import price index, it is bound to have larger response to the exchange rate changes than other prices.

Table 2 shows the ERPT elasticities for import prices (DLIMP), wholesale prices (DLWPI) and consumer prices (DLCPI). The results indicate that elasticities are higher for import prices, and thus it reiterates that the ERPT prevails in India although it is incomplete. Similarly, ERPT elasticity is positive for WPI, however, it is much smaller compared to the import prices. The elasticity of CPI is in fact negative, which means that CPI are not much affected by the exchange rate shocks in India.

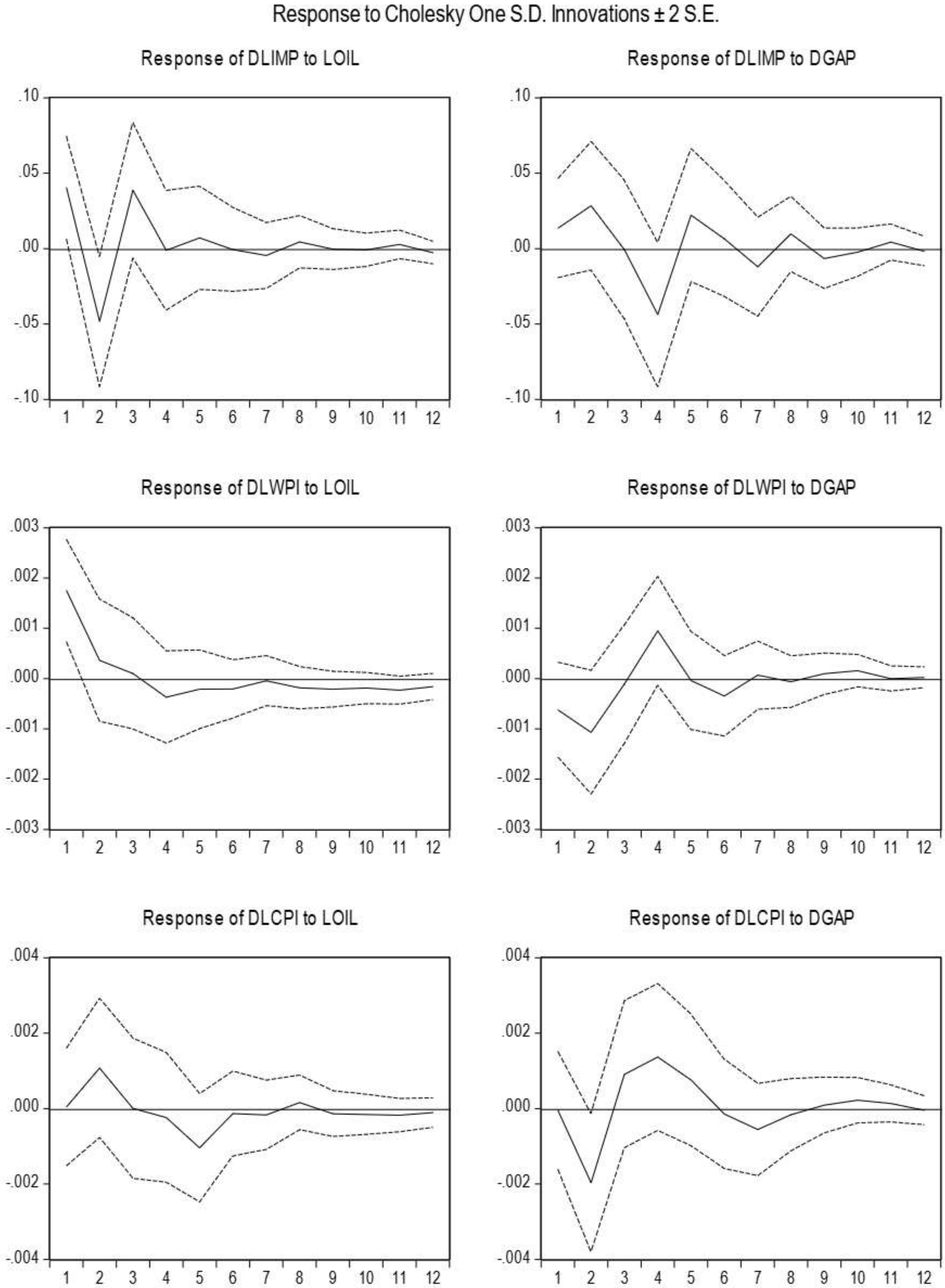
**Table 2**: ERPT Elasticity

| **Variable** | **T = 1** | **T = 3** | **T = 6** | **T = 9** | **T = 12** |
|---|---|---|---|---|---|
| DLIMP | 0.34 | 0.25 | 0.23 | 0.61 | 0.48 |
| DLWPI | 0.03 | 0.03 | 0.05 | 0.02 | 0.02 |
| DLCPI | 0.02 | - 0.10 | - 0.18 | - 0.15 | - 0.16 |

*4.1.2 Responses of Prices to Other Macroeconomic Variables:*

It is also interesting to assess the response of prices to the supply shocks (LOIL), demand shock (DGAP) and monetary policy shocks (DLI, DLM). Figure 2 comprises the responses of prices to oil price shock and output gap. One percent shock in the oil prices indicates negative response by import and wholesale

**Figure 2:** Impulse Response of Prices to the Oil Price and Output gap Shock




**Left Panel** **Right Panel**

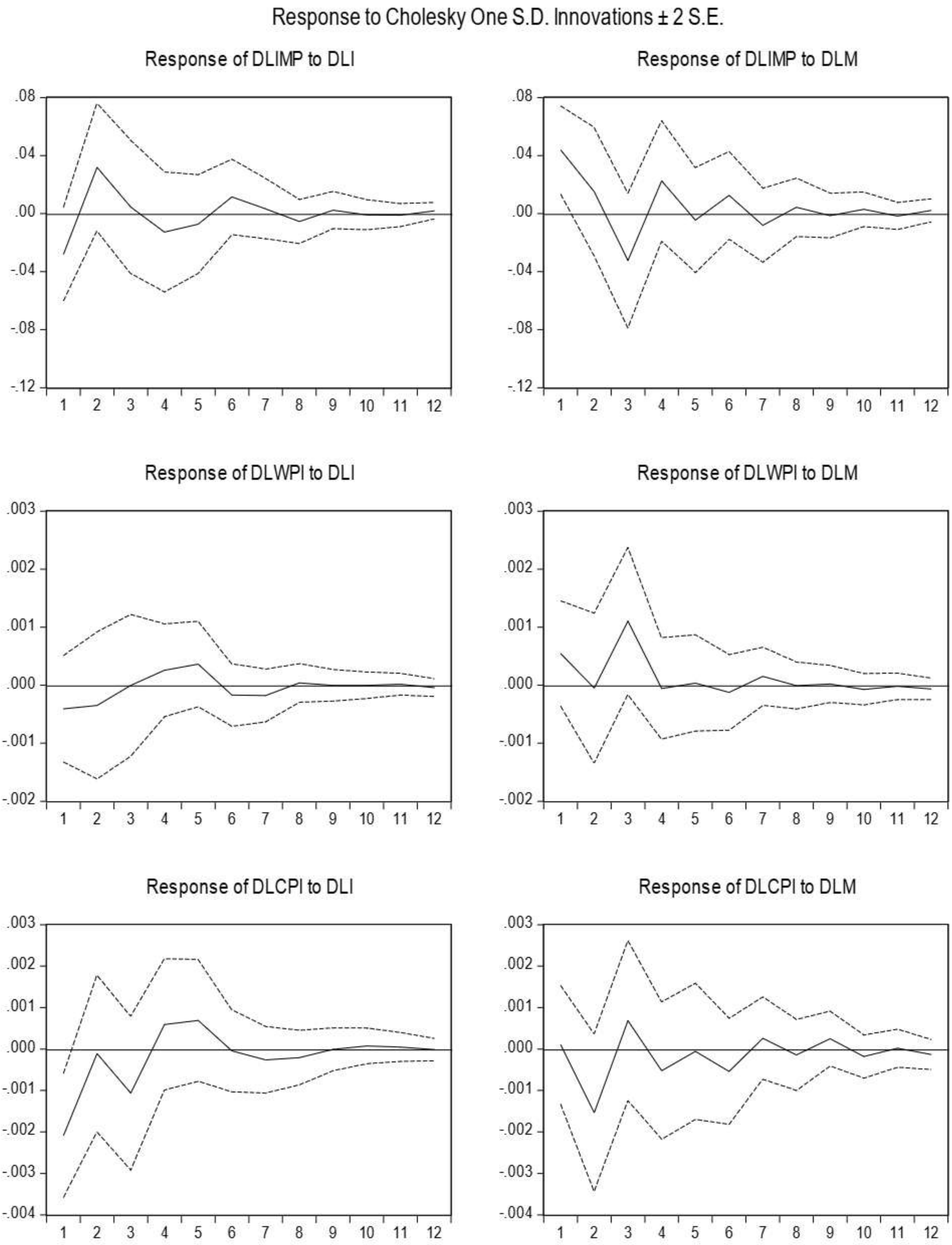
prices. However, import prices positively respond to oil price shock after second period which is approximately 0.05. In India, the largest share of import is of oil imports, and thus it affects import prices by a higher magnitude. CPI positively responds at the initial period to the oil price shock, but later it becomes negative. The output gap shock has varied effect on prices. While the import prices negatively respond to the output shock, WPI and CPI respond positively. It indicates that the IIP affects domestic inflation.

Figure 3 displays IRFs of the monetary policy shocks to all the prices. The left panel of figure indicates the response of prices to the one percent interest rate shock and right panel indicates the response of prices to the money supply shock. The response of interest rate shock to import, wholesale and consumer prices is positive and statistically significant. The money supply shock has a negative effect on import prices up to three months. However, it becomes positive at later periods and the effect nullifies after eight or nine months. The wholesale and consumer prices positively respond to money supply shock after second month, nevertheless, the impact of the shock is not observed prominently after four months in wholesale prices and after 11$^{th}$ month in consumer prices. It, thus, implies that consumer prices respond to money supply shock.

*4.1.3 Transmission along the Distribution Chain of Prices:*

Distribution costs may affect the sensitivity of domestic inflation if domestic distributors adjust the margins as per the external shocks at different stages of distribution. Such effect would be analysed by observing the impulse responses of WPI and CPI to import price shocks and response of CPI to WPI shock. Figure 4 indicates the IRFs of WPI and CPI to one percent increase in import prices. The figures reveal that both WPI and CPI positively respond to the import price shock and are also statistically significant. The response of wholesale prices is higher than consumer prices. However, the effect dies out after 6 months. Surprisingly, the response of CPI to WPI shock is negative at initial three months which later becomes positive (Figure 5). It implies that CPI does not immediately respond to WPI shocks.

**Figure 3:** Impulse Response of Prices to the Interest Rate and Money Supply Shock




**Left Panel** **Right Panel**

**Figure 4:** Impulse Response of import prices to WPI and CPI

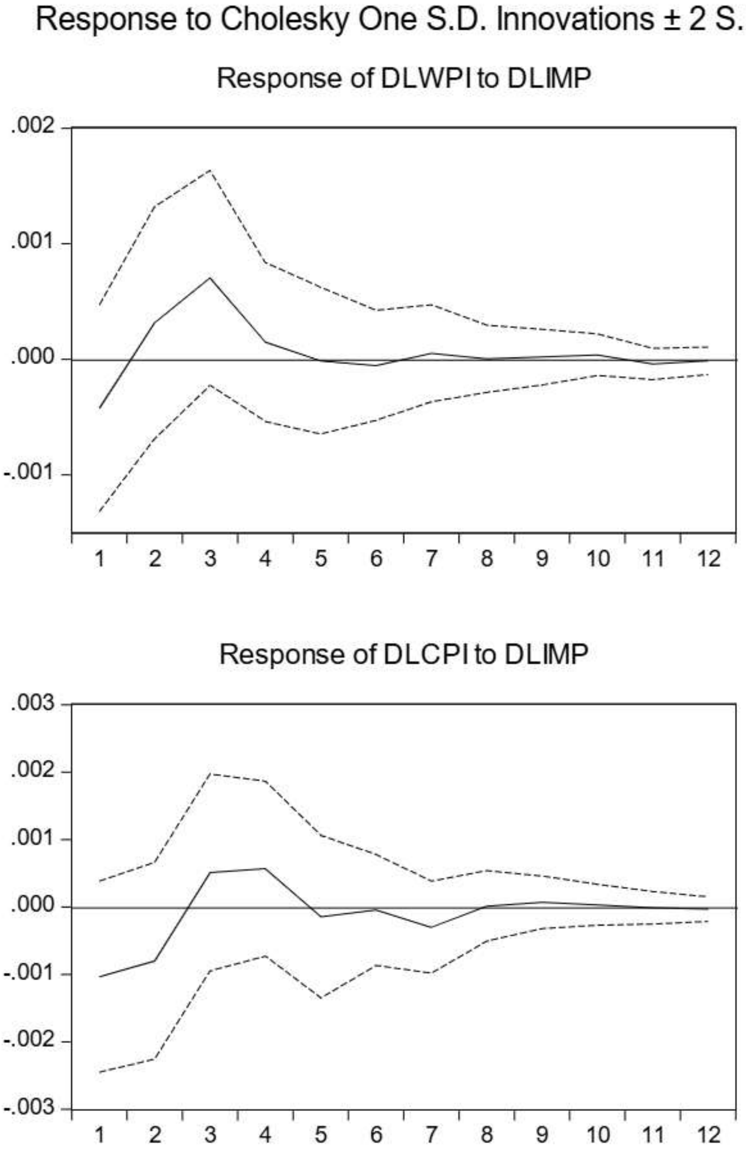
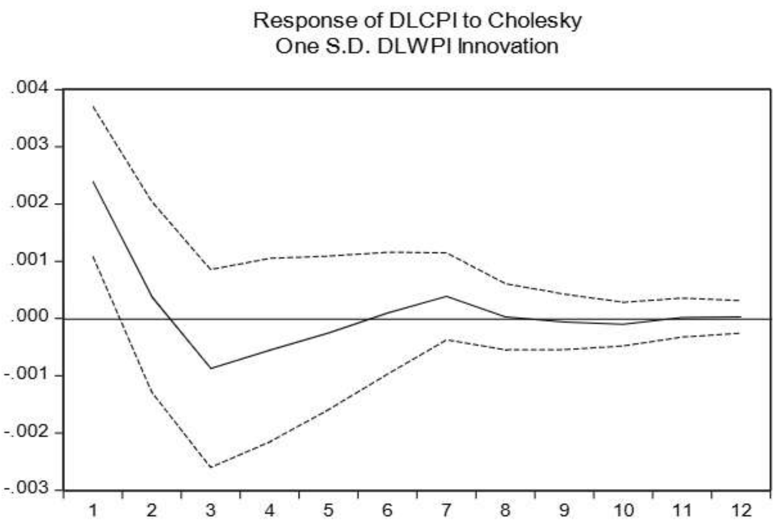



**Figure 5:** Impulse Response of WPI to CPI



## 4.2 Variance Decomposition:

Table 3 summarises the results of FEVDs of import prices, wholesale prices and consumer prices over a forecast horizon of 12 months at three month intervals. It is found that majority of the error variance of prices are explained by the composite shocks of their own. For import prices, oil prices and money supply are important factors for explaining the variance. The exchange rate shocks constitute approximately 1.58 percent for import price variation. The major chunk of wholesale price variation is explained by oil prices and output gap after its own shock. Money supply also indicates significant portion in the wholesale price variation. Evident variation is caused by the exchange rate *i.e.,* approximately 6 percent which is much higher than that of the import prices. It means that wholesale prices are affected by the exchange rate shocks. The scenario of CPI shows that larger portion of CPI variation is due to the exchange rate and wholesale prices followed by interest rate and output gap. Thus, the results suggest that internal factors account for the domestic price variations.

**Table 3**: Forecast Error Variance Decomposition of Prices

| **Variance Decomposition of DLIMP:** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | S.E. | LOIL | DGAP | DLE | DLI | DLM | DLIMP | DLWPI | DLCPI |
| 1 | 0.02 | 11.36 | 1.27 | 0.33 | 5.40 | 13.27 | 68.38 | 0.00 | 0.00 |
| 3 | 0.03 | 22.60 | 4.09 | 1.11 | 7.51 | 13.19 | 47.58 | 2.96 | 0.96 |
| 6 | 0.03 | 19.50 | 12.13 | 1.41 | 7.64 | 13.69 | 40.94 | 3.65 | 1.04 |
| 9 | 0.03 | 19.21 | 12.83 | 1.57 | 7.64 | 13.67 | 40.12 | 3.67 | 1.30 |
| 12 | 0.03 | 19.20 | 12.89 | 1.58 | 7.63 | 13.69 | 40.05 | 3.66 | 1.30 |
| **Variance Decomposition of DLWPI:** | | | | | | | | | |
| Period | S.E. | LOIL | DGAP | DLE | DLI | DLM | DLIMP | DLWPI | DLCPI |
| 1 | 0.02 | 22.42 | 2.81 | 2.21 | 1.21 | 2.16 | 1.31 | 67.88 | 0.00 |
| 3 | 0.02 | 17.72 | 8.49 | 5.90 | 1.58 | 8.36 | 4.27 | 52.22 | 1.45 |
| 6 | 0.03 | 17.05 | 12.70 | 6.42 | 2.55 | 7.62 | 3.97 | 47.73 | 1.97 |
| 9 | 0.03 | 17.20 | 12.59 | 6.63 | 2.67 | 7.63 | 3.92 | 47.32 | 2.03 |
| 12 | 0.03 | 17.62 | 12.61 | 6.62 | 2.66 | 7.61 | 3.91 | 46.95 | 2.04 |
| **Variance Decomposition of DLCPI:** | | | | | | | | | |
| Period | S.E. | LOIL | DGAP | DLE | DLI | DLM | DLIMP | DLWPI | DLCPI |
| 1 | 0.14 | 0.01 | 0.01 | 0.63 | 15.18 | 0.04 | 3.73 | 19.96 | 60.44 |
| 3 | 0.18 | 2.43 | 9.83 | 14.09 | 11.52 | 5.95 | 4.13 | 13.90 | 38.15 |
| 6 | 0.19 | 4.08 | 12.55 | 17.23 | 11.10 | 5.99 | 4.07 | 12.31 | 32.67 |
| 9 | 0.19 | 4.11 | 12.86 | 17.32 | 11.04 | 6.11 | 4.14 | 12.30 | 32.11 |
| 12 | 0.19 | 4.21 | 12.92 | 17.33 | 11.01 | 6.17 | 4.12 | 12.26 | 31.98 |
| **Cholesky Ordering: LOIL DGAP DLE DLI DLM DLIMP DLWPI DLCPI** | | | | | | | | | |

## 5 CONCLUSIONS

A better understanding of the economic behaviour underlying the degree of pass-through is very pertinent for investigating the implications of the exchange rate fluctuations and the role of monetary policy. This study assesses the degree of ERPT post-global financial crisis using the monthly data. In addition, it applied innovation accounting tools using the unrestricted VAR framework which incorporates distribution chain of prices to analyse ERPT to domestic prices. The results from IRF reveal the existence of incomplete pass-through from the exchange rate to import and domestic prices. The exchange rate shock positively impacts import and wholesale prices; however, it indicates negative response of consumer prices. The ERPT elasticity is high and positive for import prices, whereas the elasticity is quite low for wholesale prices. It is estimated to be negative for consumer prices. It, thus, implies that consumer prices are not much affected by the exchange rate fluctuations in India. The pass-through to CPI is low because it includes non-tradeables and is also impacted by other factors such as distribution channel and market structure of retail chains. Therefore, the impact of the exchange rate changes on CPI are indirect than import prices (Ghosh and Rajan, 2009). The impulse response of oil prices and output gap exhibits positive effect. Thus, it can be inferred that oil prices and IIP significantly impact prices. Similarly, interest rate also exerted positive effect on all prices whereas consumer prices have prominent effect of money supply. Along the distribution chain, wholesale prices quickly respond to import prices than consumer prices, whereas wholesale prices largely impact consumer prices. The analysis of variance decomposition exhibits that for import prices, oil prices are important while for wholesale prices, output gap and money supply along with oil prices explain the large proportion of variation. The consumer prices are affected more by the wholesale prices in India. Thus, it can be concluded that internal factors such as industrial output, interest rate and money supply largely impact domestic inflation. The massive increase in money supply also has caused high inflation in India. In India, the Government of India has allocated various subsidies on petroleum products, fertilizers, and so on which reduces the degree of ERPT in the domestic prices. This could be the reason for incomplete and low level of ERPT in India. However, off lately, the Government of India has begun to liberalise the administrative controls on prices and gradually reduced the subsidies whereby the increase in the international prices of oil could be directly percolated to the consumer, although at a lower magnitude. If such liberalisation of price controls and reduction in subsidies on various imported commodities continues in the future, it is possible to realise the high degree of ERPT into domestic prices in India.

The degree of ERPT is important while designing the monetary policy, particularly in response to the exchange rate shock. Thus, results can be used for drawing important monetary policy implications in India. The exchange rate and import prices do not significantly impact domestic inflation. The high rate of inflation must be due to internal factors. Therefore, policy makers must focus on monetary policy targets and its usage to control high inflation prevailing in India.

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# Appendix A

**Table A.1:** Test of Stability of the VAR Model

| Roots of Characteristic Polynomial | Modulus |
|---|---|
| 0.9431 | 0.9431 |
| -0.7821 | 0.7821 |
| -0.512953 - 0.487874i | 0.7079 |
| -0.512953 + 0.487874i | 0.7079 |
| 0.301978 - 0.607038i | 0.6780 |
| 0.301978 + 0.607038i | 0.6780 |
| 0.6754 | 0.6754 |
| -0.172030 - 0.596185i | 0.6205 |
| -0.172030 + 0.596185i | 0.6205 |
| -0.306005 - 0.518768i | 0.6023 |
| -0.306005 + 0.518768i | 0.6023 |
| 0.318948 - 0.429032i | 0.5346 |
| 0.318948 + 0.429032i | 0.5346 |
| -0.5006 | 0.5006 |
| -0.130648 - 0.164316i | 0.2099 |
| -0.130648 + 0.164316i | 0.2099 |

No root lies outside the unit circle.
VAR satisfies the stability condition.
Endogenous variables: LOIL DGAP DLE DLI DLM DLIMP DLWPI DLCPI

**Table A.2:** Tests of Autocorrelation among Residuals

| Lags | LM Test | | Portmanteau Test | | | |
|---|---|---|---|---|---|---|
| | LM-Stat | Prob | Q-Stat | Prob. | Adj Q-Stat | Prob. |
| 1 | 63.3402 | 0.4998 | 23.3155 | NA* | 23.8224 | NA* |
| 2 | 61.8103 | 0.5543 | 63.2541 | NA* | 65.5360 | NA* |
| 3 | 68.0694 | 0.3405 | 115.9941 | 0.6115 | 121.8719 | 0.4607 |
| 4 | 68.9051 | 0.3151 | 172.7933 | 0.7305 | 183.9547 | 0.5079 |
| 5 | 62.0383 | 0.5462 | 231.9329 | 0.7743 | 250.1348 | 0.4679 |
| 6 | 62.9027 | 0.5154 | 289.9519 | 0.8207 | 316.6444 | 0.4318 |
| 7 | 56.7048 | 0.7296 | 346.8306 | 0.8654 | 383.4768 | 0.3979 |
| 8 | 83.6682 | 0.0501 | 415.0333 | 0.8077 | 465.6699 | 0.2010 |
| 9 | 62.3225 | 0.5361 | 460.8687 | 0.9208 | 522.3610 | 0.2874 |
| 10 | 75.2899 | 0.1580 | 514.9588 | 0.9491 | 591.0701 | 0.2528 |
| 11 | 73.4420 | 0.1963 | 567.1789 | 0.9712 | 659.2462 | 0.2277 |
| 12 | 66.5825 | 0.3882 | 617.0078 | 0.9865 | 726.1594 | 0.2153 |

**Table A.3:** Test of Normality of Residuals

| Component | Skewness Test | | | Kurtosis Test | | | Jarque-Bera Test | |
|---|---|---|---|---|---|---|---|---|
| | Skewness | Chi-sq | Prob. | Kurtosis | Chi-sq | Prob. | Jarque-Bera | Prob. |
| 1 | -0.0642 | 0.0323 | 0.8573 | 2.3220 | 0.9001 | 0.3427 | 0.9325 | 0.6274 |
| 2 | 0.0279 | 0.0061 | 0.9379 | 3.7343 | 1.0560 | 0.3041 | 1.0621 | 0.5880 |
| 3 | 0.3358 | 0.8832 | 0.3473 | 3.0642 | 0.0081 | 0.9284 | 0.8913 | 0.6404 |
| 4 | -1.5133 | 17.9401 | 0.0000 | 8.4960 | 59.1541 | 0.0000 | 77.0942 | 0.0000 |
| 5 | 0.3671 | 1.0554 | 0.3043 | 5.4408 | 11.6665 | 0.0006 | 12.7219 | 0.0017 |
| 6 | 0.1585 | 0.1967 | 0.6574 | 4.1405 | 2.5471 | 0.1105 | 2.7438 | 0.2536 |
| 7 | 0.3693 | 1.0680 | 0.3014 | 3.5687 | 0.6334 | 0.4261 | 1.7015 | 0.4271 |
| 8 | 0.2538 | 0.5044 | 0.4776 | 3.9979 | 1.9500 | 0.1626 | 2.4544 | 0.2931 |
| **Joint** | -- | **21.6862** | **0.0055** | -- | **77.9153** | **0.0000** | **99.6016** | **0.0000** |

**Table A.4:** Test of Heteroskedasticity in Residuals

**Joint test:**
Null Hypothesis: No Cross Terms

| Chi-sq | df | Prob. |
|---|---|---|
| 1158.0005 | 1152 | 0.4449 |

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