

EXCHANGE RATE PASS-THROUGH TO IMPORT AND CONSUMER PRICES: EVIDENCE FROM ETHIOPIA

Helen Berga¹

Abstract

The fact that Ethiopia adopted managed floating exchange rate policy since 1992 as well as various trade reform measures taken makes the country's import and consumer prices susceptible to the effects of exchange rate movements. Thus, the study investigates the degree of ERPT to import and consumer prices in Ethiopia between 1991/92 and 2010/11 using Structural Vector Autoregressive (SVAR) model where the degree of pass-through is estimated by the means of impulse response functions. The paper found that ERPT in Ethiopia during the period under review is significant, moderate and persistent in the case of import price and low and short lived in the case of consumer prices. These results are robust to a number of alternative specifications of the model, such as the use of different ordering and identification schemes.

Keywords: exchange rate pass-through, consumer price, import price, SVAR, Ethiopia

JEL Classification: C32, E31, F31, F41

¹ Junior Research Fellow, EEA/EEPRI; E-mail: helenberga@yahoo.com

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1. Introduction

One of the most crucial issues in small open economies like Ethiopia is exchange rate pass-through (ERPT). ERPT is defined as the change in prices caused by the change in nominal exchange rate. In particular, the percentage by which import, export or domestic prices change when the home currency changes by one percent is called the degree of ERPT. A one-to-one response of prices to exchange rate changes is known as complete ERPT while a less than one-to-one response is known as incomplete ERPT (See for example, Goldberg and Knetter, 1997; Devereux and Yetman, 2002).

The degree to which exchange rate movements are passed-through to import and domestic prices holds a central place in international finance and is a much-debated question among policy makers. In fact, a large body of theoretical and empirical research shows that the degree of ERPT has important implications for the timing of current account adjustment (Krugman and Obstfeld, 2003)², the conduct of monetary policy (example, Adolfson, 2001; Smets and Wouters, 2002; Corsetti and Pesenti, 2001; Gagnon and Ihrig, 2004 and Monacelli, 2005)³, the choice of exchange rate regime and the international transmission of shocks (see, Engel, 2002; Devereux and Engel, 2003; Betts and Devereux, 2001 cited in Bouakez and Rebei, 2006).

The empirical literature revolving around ERPT is vast. In general the literature so far suggest ERPT to import and domestic prices is: (i) incomplete for most developed (Goldberg and Knetter, 1997; Yang 1997; McCarthy, 2000; Campa and Goldberg, 2002; Campa *et al.* 2005 and An, 2006), developing (Choudhri and Hakura, 2003; Rowland, 2003; Kiptui *et al.*, 2005; Mwase, 2006 and Aliyu, *et al.*, 2010) including Africa and emerging markets (Zorzi *et al.*, 2007 and Bhattacharya *et al.*, 2011) and (ii) declining overtime⁴ (Taylor, 2000; Choudhri and Hakura, 2003; Devereux and

² If the degree of pass-through is high the adjustments in trade balances will be relatively prompt whereas it would takes longer time for trade balance to adjust if the degree of pass-through is low (Krugman and Obstfeld, 2003, Ito and Sato, 2006)). Also, if domestic prices in general respond to the nominal exchange rate depreciation one-to-one (i.e. pass-through is not only to import prices but to CPI in general), then any export competitiveness from nominal depreciation would be cancelled out (Ito and Sato, 2006).

³ For instance, Adolfson (2001) showed that the optimal policy reaction and its implications are dependent on the degree of pass-through and Smets and Wouters (2002) indicated that the presence of imperfect pass-through reduces the incentive for the central bank to actively use the exchange rate channel.

⁴ Where most of these studies suggested that this decline is attributed to change in monetary policy towards stabilizing inflation in most developed countries while Campa and Goldberg (2002) implied that the industry composition of trade is more important than inflation performance in explaining the decline in the degree of pass-through in developed nations.

Yetman, 2002; Campa and Goldberg, 2002; Gagnon and Ihrig, 2004; Bailliu and Fuji, 2004 and Marazzi et al. 2005).

In Ethiopia, the emphasis on knowing the ERPT is underpinned by the fact that the country imports large amount of primary and intermediate goods which severe as inputs to the manufacturing sector. Also the country imports considerable amount of finished consumer goods.⁵ Despite the observed high growth rate of exports, the country suffers from a continuous and significant trade deficit which reached a value of 6.26 billion US dollars in 2009/10 fiscal year (NBE, 2009/10). Thus, the need to make the external sector competitive through appropriate exchange rate adjustments has made the study of ERPT to import and consumer prices in Ethiopia imperative. In addition, the fact that understanding the impact of exchange rate movements on prices would help to determine appropriate monetary policy coupled with the recent inflationary environment in Ethiopia signifies the importance of studying ERPT.

Recent developments in the external sector of the Ethiopian economy revealed that the National Bank of Ethiopia (NBE) devalued the Birr by 10% vis-à-vis the US dollar in January 2009 and by August 2010 it had depreciated the Birr by some 16% since September 2008 (NBE, 2009/10). In addition, in recent years, the Ethiopian economy is facing high inflation especially in food price. Starting from 2005/06 there is a continuous increase in the price level of goods and services. The highest increase is observed in food items where it is recorded to be 44.2 and 41.5 percent at national level and Addis Ababa respectively in year 2008/09 which is the highest ever. Starting from 2003/04 the country level general inflation rate increased at about 17 percent on average during the past six years (Own computation based on CSA data).

Concerns are what would be the implications of these developments on the extent of pass-through on import and consumer prices. Most of the empirical researches on the theme are on the developed or emerging economies. There are of course few studies which are conducted on the issue of ERPT in the African context (see for example, Mwase, 2006; Daniel, 2007, Siaw and Adam, 2010 and Aliyu, *et al.*, 2010). In Ethiopia, Choudhri and Hakura (2003) and Devereux and Yetman (2002) in their cross country study, founds ERPT to be zero between the period 1997-2000 and 1975-1999,

⁵ The share of the countries import as percentage of GDP (which can be considered as a measure of import penetration) continues to increase. For instance, the percentage of total import to GDP have been on average 14 percent between the periods 1991/92-2000/01 and increased to 26.1 percent between the periods 2001/02-2010/11 (own computation based on NBE data).

respectively. Devereux and Yetman (2008) found a higher (0.35 percent) degree of pass through for Ethiopia by extending the sample period from 1970 to 2007.

Although these studies are informative, there is a need to take further studies in the area in Ethiopian context due to the following reasons. First these studies are basically conducted to see cross country differences in pass-through and hence country specific study is required so as to obtain more evidence. Also, these studies apply single equation estimation techniques. However several recent empirical studies suggested the use of Vector Autoregressive models (VAR) in analyzing ERPT. Since the exchange rate and inflation rate are expected to be influencing each other in many theoretical models, it seems more appropriate to estimate a system that would treat both of them endogenous. Thus the use of VAR models would allow the reverse causality from price indices to the exchange rate which avoids arbitrary assignment of variables as endogenous and exogenous. In sight of this argument, this study will analyze ERPT to import and consumer prices in Ethiopia using VAR models. More specifically, the research is expected to address the following questions: (1) Do changes in the exchange rate have significant effect on import and consumer price inflation? (2) How much is the extent (degree) of ERPT to import and consumer prices?

2. Theoretical Background

The starting point to study the link between exchange rate and domestic prices is the law of one price (LOP) which states that the price of identical commodities sold in different market should be the same when it is converted into the same currency (Pilbeam, 1998).

The LOP is mathematically expressed as follows;

$$P_t = E_t P_t^* \quad (1)$$

Where P is the domestic price index, E_t is the nominal exchange rate (defined as domestic currency per unit of foreign), and P_t^* represents foreign prices. (Relative) purchasing power parity tests use price indices across countries to test whether this relationship holds.

Based on this fundamental relationship various researchers develop different more advanced models to analyze the degree of pass-through by starting from the following basic model;

$$P_t = \gamma e_t + \varepsilon_t \quad (2)$$

Where, ε_t is an error term and γ is the ERPT coefficient. The extent of pass-through coefficient is based on the value of γ . A one to one response of import prices to exchange rate is known as a complete ERPT ($\gamma=1$) while the case where pass-through coefficient is less than 1 ($\gamma<1$) is known as partial or incomplete ERPT. However according to Campa and Goldberg (2002) this reduced form equation is problematic for hypothesis testing because it represents a non-structural statistical relationship. More specifically, Campa *et al.* (2005) indicated that Eq. (2.2) is purely statistical relationship between exchange rates and prices, and does not have a meaningful economic interpretation.

The micro-foundations of pricing behavior by exporters are a better starting point for generating more meaningful specifications based on economic theory that are appropriate for hypothesis testing. Hooper and Mann (1989), Goldberg and Knetter (1997) and Barhoumi (2006) considered a representative foreign firm having some degree of control over the price of its goods in an importing country. They assume that this representative firm establishes the price of its exports to country i in its own currency (P^{*i}) at a markup (λ_{it}) over its marginal cost of production (C_{it}^*), that is:

$$P_t^{x,i} = \lambda_{it} C_{it}^* \quad (3)$$

The import price in the domestic currency $P_t^{m,i}$ is obtained by multiplying the export price $P_t^{x,i}$ by the exchange rate of the importing country i , E_{it} , that is,

$$P_t^{m,i} = E_{it} P_t^{x,i} = E_{it} \lambda_{it} C_{it}^* \quad (4)$$

The markup is assumed to respond to both demand pressure for the exporting country (Y_i^*) and competitive pressure in the importing country. Competitive pressure in the importing country is measured by the gap between the competitor prices in the importing country market (P_i) and the production cost of exporting firm. Therefore, according to Hooper and Mann (1989) the markup λ_{it} is given by;

$$\lambda_{it} = \{P_{i,t}/(E_{it}C_{it}^*)\}^\alpha Y_{i,t}^\beta \quad (5)$$

Where $0 < \alpha < 1$ and $0 < \beta < 1$

Substituting Equation (5) into (4), we have

$$P_t^{m,i} = (E_{it}C_{it}^*)^{1-\alpha} P_{it}^\alpha Y_{it}^\beta \quad (6)$$

If we take the logarithm of Equation (6), the ERPT, defined as the partial elasticity of import price with respect to exchange rate, is $(1-\alpha)$. Campa and Goldberg (2002:5-6) hypothesized a similar, yet more general, model. The pricing equation of an exporter from country x -- and its elasticity of response to an exchange rate movement -- depend on the structure of demand and costs confronting the exporter. If the import prices of country P_t^{mj} , are the dependent variables, the pricing rule of the foreign exporters x supplying j is:

$$P_t^{m,j} = E_t P_t^{x,j} = E_t \lambda_t^{x,j} \left(\frac{P_t^{m,j}}{P_t} \right) C^{x,j}(W_t^j, Y_t, E_t) \quad (7)$$

Where $\lambda_t^{x,j} = P_t^{x,j}/C_t^{x,j}$, $C_w^{x,j} > 0$, $C_E^{x,j}$, $C_Y^{x,j} > 0$

λ^{xj} represents the markup rate of prices over costs for the exporter. Markup rates are industry specific and depend on the demand curve facing exporters x in country j . This demand depends, in turn, on P_t^{mj}/P_t the prices of imports relative to prices of country j producers. $C_t^{x,j}$ is the marginal cost function of the exporter in his own currency. This exporter marginal cost function is increasing in export market wages, $W_t^{x,j}$, and increasing in country j demand conditions Y_t . The exchange rate is an argument in the exporter's cost function to the extent that the exporter relies on imported inputs or has other costs that move with the relative value of the destination market currency.

All the above models of ERPT are fundamentally grounded in partial-equilibrium setups which arise from the problem of a single exporter/importer or from the industrial organization of one industry. This approach ignores the view that exchange rates are endogenous economic variables and looks at the impact that an exogenous exchange rate movement has on the resulting equilibrium price in the industry.

However, exchange rates are by definition the relative prices of currencies and are endogenous variables in which their value gets determined within a general equilibrium context, alongside other asset prices. (Campa *et al.*, 2005:3).

The second strand of literature embeds a more general-equilibrium approach, whereby prices are sticky in one currency, i.e., set in advance of the realization of the exchange rate by exporters. In their pioneering work, Obstfeld and Rogoff (1995) introduced nominal rigidities and market imperfections into a micro-founded dynamic general equilibrium model. However, PPP was maintained at all times, and the pass-through was complete. Betts and Devereux (1996, 2000) cited in Bailliu and Fuji (2004) then developed an extended version of the Obstfeld-Rogoff model allowing for pricing to market (PTM). More precisely, whereas the two models feature the same simple form of price rigidity (prices are predetermined for one period), they differ in the assumed pricing strategy of firms. In the Obstfeld-Rogoff-model, nominal prices are set in producers' currencies (PCP) while in the Betts-Devereux model, a fraction of firms is allowed to set prices in destination countries' currencies (LCP).⁶ Also, assuming sticky prices and the exchange rate being an endogenous variable, these models demonstrate that ERPT is a function of the underlying shocks in the economy and the given competitive structures of the industries involved.

However, these early models neglected some important aspects. In particular, neither the original Obstfeld-Rogoff-model nor the Betts-Devereux-model explicitly distinguishes different stages of the distribution chain. More recently, a strand in the literature has been established that considers imports as intermediate goods that undergo non-traded production order distribution processes before being consumed. These production or distribution channels may dampen the impact of exchange rate shocks on consumer prices. Hence, imperfect pass-through into consumer prices may be observed even in the case of PCP (Stulz, 2006).

McCarthy (1999) introduced a new analytical approach to examine ERPT which seems to address these issues. He applied the model of pricing along a distribution which captures the endogenous nature of the exchange rate and permits one to track the pass-through from exchange rate fluctuations to each stage of the distribution chain in a simple integrated framework.

⁶ When prices are determined in the exporter's currency (PCP) ERPT tends to be much larger than when prices are set in the importer's currency (LCP). In the extreme case of a purely exogenous exchange rate shock, ERPT would be one under PCP and zero under LCP.

McCarthy's model basically put inflation at each stage-import, producer and consumer-in period t is assumed to be comprised of several components. The first component is the expected inflation at that stage based on the available information at the end of period $t-1$. The second and third are the effects of period t domestic "supply" and "demand" shocks on inflation at that stage. The fourth component is the effect of exchange rate shocks on inflation at a particular stage. Next are the effects of shocks at the previous stages of the chain. Finally, there is the shock that belongs to that stage. The shocks at each stage are that portion of a stage's inflation that cannot be explained using information from period $t-1$ plus contemporaneous information about domestic supply and demand variables, exchange rates, and inflation at previous stages of the distribution cycle. These shocks can be thought of as changes in the pricing power and markups of firms at these stages (McCarthy, 1999:4). Under these assumptions, the inflation rates of country i in period t at each of the three stages, import, producer and consumer, can be written as:

$$\pi_{it}^m = E_{t-1}(\pi_{it}^m) + \alpha_{1i}\varepsilon_{it}^s + \alpha_{2i}\varepsilon_{it}^d + \alpha_{3i}\varepsilon_{it}^e + \varepsilon_{it} \quad (8)$$

$$\pi_{it}^w = E_{t-1}(\pi_{it}^w) + \beta_{1i}\varepsilon_{it}^s + \beta_{2i}\varepsilon_{it}^d + \beta_{3i}\varepsilon_{it}^e + \beta_{4i}\varepsilon_{it}^m + \varepsilon_{it}^w \quad (9)$$

$$\pi_{it}^c = E_{t-1}(\pi_{it}^c) + \gamma_{1i}\varepsilon_{it}^s + \gamma_{2i}\varepsilon_{it}^d + \gamma_{3i}\varepsilon_{it}^e + \gamma_{4i}\varepsilon_{it}^m + \gamma_{5i}\varepsilon_{it}^w + \varepsilon_{it}^c \quad (10)$$

Where π_{it}^m , π_{it}^w and π_{it}^c are import price, producer and consumer inflation respectively; ε_{it}^s , ε_{it}^d and ε_{it}^e are supply, demand and exchange rate shocks respectively; ε_{it}^m , ε_{it}^w and ε_{it}^c are import, producer and consumer price inflation shocks, and $E_{t-1}(\cdot)$ is the expectation of a variable based on the information set at the end of period $t-1$. The shocks are assumed to be serially uncorrelated as well as uncorrelated with one another within a period.

To complete the model, McCarthy proceeds by specifying the supply, demand, and exchange rate shocks.⁷ In addition the model incorporates the central banks reaction function and money demand to capture the reaction of monetary policy to exchange rate fluctuations. The reaction function relates short-term interest rates (r_t) to the

⁷ To identify aggregate demand and supply shocks and exchange rate shocks, he made the following assumptions. (1) Supply shocks are identified from the dynamics of oil price inflation denominated in the local currency. (2) Demand shocks are identified from the dynamics of the output gap in the country after taking into account the contemporaneous effect of the supply shock. (3) Exchange rate shocks are identified from the dynamics of exchange rate appreciation after taking into account the contemporaneous effects of the supply and demand shocks.

previously cited variables in the model as central banks use the short-term rate as their monetary policy instrument. The money demand function relates money growth (Δm_t) to the other variables in the model.

$$r_{it} = E_{t-1}(r_{it}) + C_{1i}\varepsilon_{it}^s + C_{2i}\varepsilon_{it}^d + C_{3i}\varepsilon_{it}^e + C_{4i}\varepsilon_{it}^m + C_{5i}\varepsilon_{it}^w + C_{6i}\varepsilon_{it}^c + \varepsilon_{it}^{MP} \quad (11)$$

$$\Delta m_{it} = E_{t-1}(r_{it}) + d_{1i}\varepsilon_{it}^s + d_{2i}\varepsilon_{it}^d + d_{3i}\varepsilon_{it}^e + d_{4i}\varepsilon_{it}^m + d_{5i}\varepsilon_{it}^w + d_{6i}\varepsilon_{it}^c + d_{7i}\varepsilon_{it}^{MP} + \varepsilon_{it}^{MD} \quad (12)$$

Finally, to express the model in standard format and to make it plausible for estimation it is assumed that the conditional expectations $E_{t-1}(\cdot)$ in Equations (1)-(5) can be replaced by linear projections on lags of the variables in the system (McCarthy, 2000:8). Generally, given the theoretical underpinnings on the pass-through of shocks on prices, the model of pricing along a distribution chain which considers the effects of shocks (exchange rate and other external shocks) on prices at different stages of distribution is of great interest for our analysis.

3. Methodology

3.1 Data Set

The major objective of this paper is to shed light on the transmission of fluctuations in the exchange rate into import prices (MPI) and consumer prices (CPI). Thus, these three variables are the center of our empirical analysis. It is assumed that prices are set along the distribution chain, i.e. exchange rate shocks⁸ are initially passed along to import prices and then to producer prices⁹ and finally lead to a reaction in consumer prices. Next, the model includes a measure of the output gap (Y^{gap}) in order to control for domestic economic activity (demand shock). A broad measure of money (M2) is also included which allows to capture the effects of monetary policy. Finally, world commodity prices (WCPI)¹⁰ are considered to capture international supply shocks (imported inflation) which might affect the exchange rate and domestic prices.

⁸ The nominal effective exchange rate (NEER) is used in our model. Though, many studies have used the bilateral exchange rate vis-à-vis the US dollar, the effective exchange rate is the right concept to use when the total effect of the exchange rate changes is attempted to be measured in a country with diversified trading partners (Ito and Sato, 2006).

⁹ However our base line model did not include producer price index because data is not available prior the period 2000.

¹⁰ In our model, international supply shocks are identified by the world commodity price inflation unlike McCarthy and others that include oil price inflation as a proxy for supply shock. This is because, even

Based on this, we specify a six variable VAR model which includes exchange rate, import price, consumer price, output gap, world commodity price index and money supply following McCarthy (1999); Smets and Wouters (2002); Hahn (2003); Ito and Sato (2006), Bhattacharya *et al.* (2011) and others as shown in Equation 13.

$$y_t = [WCPI, y^{Gap}, NEER, MPI, CPI, M2] \quad (13)$$

Where, all the variables are as defined earlier.

3.2 Source of Data

The study used quarterly time series data obtained from National Bank of Ethiopia (NBE), Central Statistical Authority (CSA), Ministry of Finance and Economic Development (MoFED), International Financial Statistics (IFS). The period between 1991/92-2010/11 will be covered under this study. Quarterly NEER¹¹ and Money Supply data are obtained from NBE. Data on CPI is obtained from CSA and IFS. World commodity price index, 2005=100, which includes fuel and non fuel price indices, is taken from IFS. Since there is no ready-made import price index data for Ethiopia we are obliged to proxy it by constructing unit value import price index.¹² Output gap is obtained by taking the difference between actual and potential GDP where the latter is estimated by using the HP filter method¹³. Since quarterly GDP is not available it is constructed by using method introduced by Haile Kibret (2001) because it captures country specific issues in a better way.¹⁴

though Ethiopia is highly dependent on imported oil, and hence the change in the price of oil has significant impact on the economy, oil price has been administrated by the government for long time and hence we did not include this variable in the base line model.

¹¹ NEER measures the nominal effective depreciation or appreciation of domestic currency against weighted baskets of foreign currencies. Note that an increase in NEER indicates appreciation of Birr and vice versa.

$$NEER = \sum_{j=1}^n W_j E_j$$

¹² See appendix A.1 for detailed information on the construction of import price index.

¹³ The method decomposes a given time series in to trend and cyclical component

¹⁴ For detailed information about the method, interested readers can refer Haile Kibret (2001).

3.3 Estimation Technique

The baseline empirical model is estimated as a VAR with six endogenous variables. The SVAR form representation of the model may be written as:

$$B_0 y_t = B_1 y_{t-1} + \dots + B_p y_{t-p} + \varepsilon_t \quad (14)$$

Where $y_t = [\Delta wcp_i, y^{gap}, \Delta neer, \Delta mpi, \Delta cpi, \Delta m2]$ vector of $k = 6$ variables. B_0 is an invertible (6×6) matrix of coefficients of contemporaneous relations on the endogenous variables; B_i 's are (6×6) matrices which captures dynamic interactions between the k variables in the model, ε_t denotes a mean zero (6×1) vector of structural error terms, also referred to as a structural innovation or structural shock and p is the number of lags. Equivalently the model can be written more compactly as: $B(L)y_t = \varepsilon_t$ where $B(L) = B_0 - B_1 L - B_2 L^2 - \dots - B_p L^p$ is the autoregressive lag order polynomial of order p in the lag operator L .

The variance-covariance matrix of the structural error term is typically normalized such that:

$$E(\varepsilon_t \varepsilon_t') = \Sigma_\varepsilon = I_k$$

In order to allow estimation of the structural model we first need to derive its reduced-form representation (since the structural model is not observable). This involves expressing y_t as a function of its lags. To derive the reduced form representation, we pre-multiply both sides of the structural VAR representation by B_0^{-1} :

$$B_0^{-1} B_0 y_t = B_0^{-1} B_1 y_{t-1} + \dots + B_0^{-1} B_p y_{t-p} + B_0^{-1} \varepsilon_t \quad (15)$$

Hence, the same model can be represented as:

$$y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + u_t \quad (16)$$

Where $A_i = B_0^{-1} B_i$, $i=1, \dots, p$, and $u_t = B_0^{-1} \varepsilon_t$. Equivalently the model can be written more compactly as: $A(L)y_t = u_t$, where $A(L) = I - A_1 L - A_2 L^2 - \dots - A_p L^p$ and $E(u_t) = 0$ and $E(u_t u_t') = \Sigma_u$ denotes the autoregressive lag order polynomial. Standard estimation methods allow us to obtain consistent estimates of the reduced-form

parameters A_i , $i=1, \dots, p$, and the reduced-form errors u_t , and their covariance matrix $E(u_t u_t') = \Sigma_u$ (Kilian, 2011:2).

The structural model represented by system (3.2) must be identified for the purpose of policy analysis and must be given economic interpretation. The fundamental problem here is that ε_t is not directly observed but needs to be identified (Stulz, 2006). The next question is how to recover the elements of B_0^{-1} from consistent estimates of the reduced-form parameters, because knowledge of B_0^{-1} would enable us to reconstruct ε_t from $\varepsilon_t = B_0 u_t$ and B_i , $i = 1 \dots p$ from $B_i = B_0 A_i$. By construction, $u_t = B_0^{-1} \varepsilon_t$. Hence, the variance of u_t is:

$$\begin{aligned} E(u_t u_t') &= B_0^{-1} E(\varepsilon_t \varepsilon_t') B_0^{-1'} \\ \Sigma_u &= B_0^{-1} \Sigma_\varepsilon B_0^{-1'} \quad \text{but, } \Sigma_\varepsilon = I \\ \Sigma_u &= B_0^{-1} B_0^{-1'} \end{aligned}$$

One popular way of recovering the structural innovations ε_t from the reduced-form innovations u_t is to apply Cholesky orthogonalization to the reduced-form residuals. Mechanically, this can be accomplished as follows. Define a lower-triangular $K \times K$ matrix S with positive main diagonal such that $SS' = \Sigma_u$. It follows immediately from the condition $\Sigma_u = B_0^{-1} B_0^{-1'}$ that $B_0^{-1} = S$ is one possible solution to the problem of how to recover u_t . Thus, the Cholesky decomposition encompasses the decomposition of the variance covariance matrix Σ_u of the reduced form residuals in a lower triangular matrix S and an upper triangular matrix S' which allows as recovering the structural shocks¹⁵ (Ito and Sato, 2006:11). Accordingly, the relationship between the reduced-form VAR residuals and the structural disturbances can be written as follows:

$$\begin{bmatrix} u_t^{WCPI} \\ u_t^{yGap} \\ u_t^{Ex} \\ u_t^{MPI} \\ u_t^{CPI} \\ u_t^{M2} \end{bmatrix} = \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & 0 & 0 \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & 0 & 0 \\ S_{61} & S_{61} & S_{63} & S_{64} & S_{65} & S_{66} & 0 \end{bmatrix} \begin{bmatrix} \varepsilon_t^{WCPI} \\ \varepsilon_t^{Gap} \\ \varepsilon_t^{Ex} \\ \varepsilon_t^{MPI} \\ \varepsilon_t^{CPI} \\ \varepsilon_t^{M2} \end{bmatrix} \quad (17)$$

¹⁵ The Choleski decomposition of Σ_u implies $\Sigma_u = PP'$ where the Choleski factor, P , is a lower-triangular matrix. Since $E(u_t u_t') = SE(\varepsilon_t \varepsilon_t')S' = SS'$ (where structural disturbances are assumed to be orthonormal, i.e., $E(\varepsilon_t \varepsilon_t') = I$, the lower-triangular matrix S is equal to the Choleski factor P).

Where ε_t^{WCPI} , ε_t^{Gap} , ε_t^{Ex} , ε_t^{MPI} , ε_t^{CPI} and ε_t^{M2} are the structural disturbances, that is, world commodity price, output gap, NEER, import price, consumer price and money supply shocks respectively, while u_t^{WCPI} , u_t^{Gap} , u_t^{Ex} , u_t^{MPI} , u_t^{CPI} and u_t^{M2} are residuals in the reduced form of equations.

The structural model is identified because the $k(k-1)/2$ economic restrictions, necessary to identify the structural model, are imposed as zero restrictions on the matrix S , which links the reduced form and the structural residuals. The resulting lower-triangular matrix S implies that some structural shocks have no contemporaneous effect on some endogenous variables given the ordering of endogenous variables. Economic interpretation is attached to this model by the selected ordering of the variables, as the ordering indicates which shocks are not allowed to contemporaneously affect which variables (Hahn, 2003 and Ito and Sato, 2006).

In order to identify shocks or their respective impulse-response functions via Cholesky decomposition, the variables need to be given a plausible ordering. Following McCarthy (2000), Hahn (2003) and Ito and Sato (2006) we assume a recursive ordering. The aforementioned studies apply different ordering depending on the characteristics of the country/ region under consideration and the problem explored. McCarthy (2000) applies the following ordering: the change in oil prices is ordered first because the reduced-form residuals of oil prices are unlikely affected contemporaneously by any other shocks in the system while oil price shocks are likely affect all variables in the system contemporaneously. The output gap is ordered next as he assumes that the output gap is contemporaneously affected by only oil price shocks while output gap (demand) shocks have a contemporaneous impact on other variables except oil prices. The exchange rate is ordered third followed by domestic prices which are ordered according to the distribution chain (i.e. MPI, WPI, and CPI). Finally, the monetary variable is ordered last assuming that monetary policy may react to exchange rate fluctuation.

Hahn (2003) and Ito and Sato (2008) follow the same ordering as McCarthy but the monetary policy variable¹⁶ is ordered prior to exchange rate and prices by assuming that monetary policy reacts not to realized inflation but to expected inflation. The difference between the two authors's is that Hahn orders the monetary policy variable prior to out gap while Ito and Sato ordered it next to output gap.

¹⁶ Where the former use interest rate while the latter use money supply to proxy monetary policy

Against this background we assume the following order for Ethiopia.

$$\Delta wcpi \rightarrow y^{Gap} \rightarrow \Delta neer \rightarrow \Delta mpi \rightarrow \Delta cpi \rightarrow \Delta m2$$

For small open economies like Ethiopia, world commodity prices are assumed to be exogenous because the country has insignificant power in the world market to affect international prices. Thus, changes in world commodity price are ordered first because the reduced-form residuals of commodity prices are unlikely affected contemporaneously by any other shocks except commodity price shocks per se, while world commodity price shocks would likely affect all variables in the system contemporaneously. We therefore model the world commodity price shock as independent to the shocks to other variables.

Excess demand shocks which are proxied by output gap are assumed to be influenced by exogenous factors, such as adverse weather conditions. This is manifested by the fact that the Ethiopian economy is highly dependent on agriculture and in turn the agricultural sector is highly dependent on the prevailing weather condition (rain feed agriculture). Thus, output gap is ordered next, as we assume that the output gap is contemporaneously affected by only world commodity price shock while output gap (demand) shocks have a contemporaneous impact on other variables except world commodity prices.

Shocks to the exchange rate largely reflect exogenous factors, such as unexpected surge in aid inflows and terms of trade improvements which increase the country's foreign reserve and policy interventions which are assumed to be independent of other disturbances (money supply and domestic prices) in the model. Ethiopia has adopted a managed float exchange rate regime since 1992 and is still maintained with the NBE intervening in the foreign exchange market to smoothen excessive fluctuations. Thus NEER is ordered third, which implies that the NEER responds contemporaneously to world commodity price and output gap (demand) shocks. The exchange rate shocks are assumed to have a contemporaneous effect on money supply and domestic inflation.

Import price is ordered in the fourth place followed by consumer price index based on the pricing chain. The order of the monetary variable is somehow controversial in which different researchers give different ordering for this variable. Some (such as McCarthy) order it last assuming that central banks react to changes in the exchange rate and prices indices (i.e. assuming reactive nature of monetary policy). Others (such

as Hahn and Ito and Sato) order it prior to exchange rate and prices by assuming that monetary policy reacts not to realized inflation but to expected inflation (forward looking behavior). This one lets prices react to central bank policy, i.e. central banks set the target of M2 after observing leading indicators for inflation like oil prices, output changes etc. The current study orders M2 last in the base line model assuming monetary policy in Ethiopia is reactive (passive) rather than forward looking¹⁷.

Given these, the size and speed of pass-through will be estimated using impulse response functions and variance decompositions are computed to point out the relative importance of various shocks in explaining fluctuations in the price indices.

4. Empirical Results and Analysis

This section presents and discusses the empirical results derived from the SVAR model. In analyzing time series data testing for stationarity is the first vital condition. The results obtained by using non-stationary time series may be spurious in that they may indicate a relationship between variables which does not exist. In order to receive consistent and reliable results, the non-stationary data needs to be transformed into stationary data.

Before one pursues formal tests for stationarity, it is always advisable to plot the time series under study because visual plot of the data is usually the first step in the analysis of any time series. Such a plot gives an initial clue about the likely nature of the time series. The plots of the variables included in our model are provided in appendix A.2. The first impression that we get from these graphs is that at level most of the time series shown in the figures seem to be “trending” either upward or downward, albeit with fluctuations¹⁸. WCPI, M2 and CPI plots shows upward trend, while that of NEER show a downward trend. MPI seem to have upward trend with very significant fluctuation. This suggests that the mean of all the above variables might be changing which perhaps implies they are not stationary at level. Such an intuitive feel is important starting point for more formal tests of stationarity. Thus, as explained in the previous chapter, formal testing for stationarity and the order of integration of each variable are undertaken mainly using three standard methods, namely Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) and the

¹⁷ However in alternative models we gave different order for M2 to check the sensitivity of estimated pass-through coefficients to change in the order of this variable

¹⁸ Except output gap which is stationary by construction

results are summarized in appendix A.3. The lag length for each variable is automatically selected by Schwartz Information Criterion (SIC) and both intercept and trend are included in test equation for all variables. Each of the three tests shows that all variables except output gap (Y^{Gap}) are stationary at first difference - $I(0)$ where the latter is stationary by construction.

Accordingly, the SVAR is estimated in first difference of the variables and hence the estimated results represent short-term dynamics as opposed to long-term equilibrium relationships between variables. In this regard, impulse response functions of import price and consumer prices to each shock in the system are presented in Section 4.1. In Section 4.2, variance decomposition is utilized to assess the relative importance of the exchange rate for variation in import and consumer price indices. Section 4.3 presents an analysis on robustness of results to changes in the order of variables and use of different methodology.

Choosing appropriate lag length is vital before estimating a VAR model because the VAR results could be highly sensitive to the number of lags included for the endogenous variables in estimation. The optimal lag order is determined by using lag length selection criterions of LR, FPE, AIC, SIC and the HQ and as given in appendix B.1 two lags are selected by most of the criterions at the 5% level of significance. Even if the lag order selection criteria choose two lags to be included in the model, it may also be possible for some of the lags (of some endogenous variables) that are chosen as optimal to have insignificant contribution in the model. Therefore, it should be checked whether the two lags (chosen as optimal) of all variables are jointly important and hence should be included in the estimation of the VAR model. This was done using the Wald lag exclusion test (which is asymptotically chi-square distributed) and the results are reported in appendix B.1. Based on the joint hypothesis for lag 2, we reject the null hypothesis which states that the restricted model is viable (model without lags) and accept the model with lags because the first and the second lags of all endogenous variables are jointly significant. This suggests that the use of the two lags in the model is suitable. The VAR model therefore is estimated with a constant and two lags¹⁹.

¹⁹ We also undertake various post-estimation diagnostic tests which are of crucial importance for further analysis and the results are reported in appendix B. The test for stability suggests that the VAR is stable while the LM test indicates that the model is free from autocorrelation problem. Also White test for heteroscedasticity fails to reject the null hypothesis of homoscedastic variance. However the Jarque-Bera test rejects the null hypothesis of normality indicating residual normality problem.

4.1 ERPT to Import and Consumer Prices: Impulse Response Analysis

This subsection discusses to what extent exchange rate shocks are passed through into import and consumer prices in Ethiopia. Based on the fact that the model passed important diagnostic tests, we perform impulse response analysis with Cholesky orthogonal shock structure from the estimated baseline model including WCPI, NEER, Y^{Gap} , MPI, CPI and M2. Figures 1 and 2 shows the estimated orthogonalized impulse response functions for import and consumer price inflation to a one standard deviation innovation in NEER²⁰. The accumulated impulse responses (solid line in the Figures) are presented over a time horizon of twelve quarters. The dotted line in figures denotes a two standard error confidence band around the estimates.

The impulse response functions indicate a moderate degree of ERPT to import price inflation and a low degree of pass-through to consumer price inflation. Figure 1 shows response of import price to one standard innovation in NEER. A positive exchange rate shock (i.e. an exchange rate appreciation) results in a decrease in import price for the entire forecast horizon. Concerning the speed of pass-through, import price quickly responds to exchange rate shock. As indicated by the confidence bands, the responses are significantly different both from zero and one, over the whole time horizon considered implying ERPT to import price is incomplete. Figure 2 tracks the pass-through of a one standard deviation shock in the exchange rate into consumer price inflation. As we can see from the figure, the response of consumer prices to exchange rate shock is low which dies shortly after 5 quarters. This implies that ERPT to consumer price inflation is low and transitory.

²⁰ The response of MPI and CPI to other variables is given appendix C

Figure 1: Exchange rate pass-through to import prices

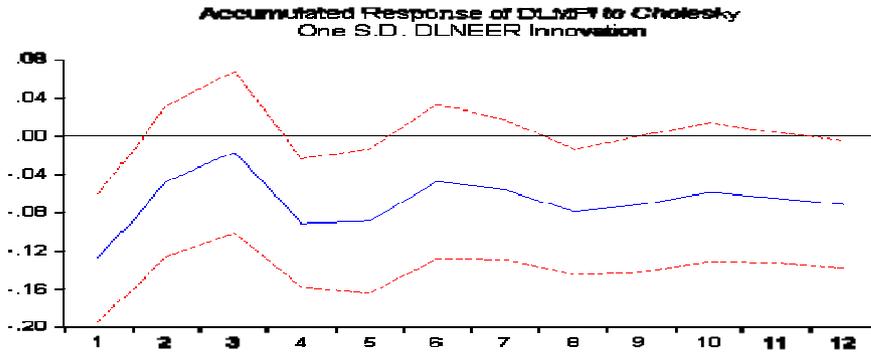
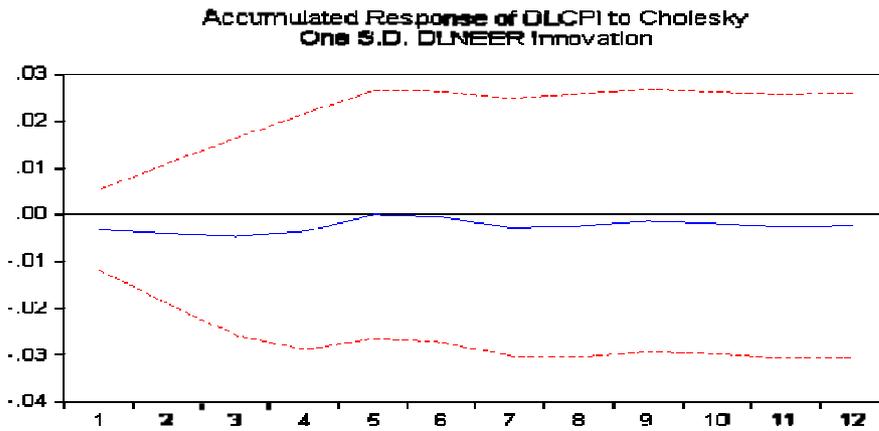


Figure 2: Exchange rate pass-through to consumer prices



The estimates of the cumulative pass-through coefficients are derived from the impulse response functions. In order to measure the pass-through coefficients, the shocks should be transformed from one standard deviation to one percent. This is done by dividing the cumulative impulse responses of each price index after j quarters by cumulative response of the exchange rate to its own shock after j quarters. The coefficients therefore show the estimated response of prices to an exchange rate shock after accounting for the disturbances of the other endogenous variables in the model²¹

²¹ The pass-through coefficient is defined as:

Table 1: The response MPI and CPI to one percent change in NEER

| Horizon | MPI | CPI |
|---------|--------|---------|
| T=1 | -0.489 | -0.013 |
| T=2 | -0.179 | -0.015 |
| T=3 | -0.065 | -0.018 |
| T=4 | -0.332 | -0.014 |
| T=5 | -0.322 | -0.0001 |
| T=6 | -0.177 | -0.002 |
| T=7 | -0.208 | -0.010 |
| T=8 | -0.29 | -0.009 |
| T=9 | -0.262 | -0.005 |
| T=10 | -0.217 | -0.007 |
| T=11 | -0.239 | -0.009 |
| T=12 | -0.263 | -0.008 |

Table 1 presents the response of import price and consumer prices to one percent change in exchange rate. Concerning ERPT to MPI, a positive exchange rate shock is passed-through to import price by about 0.49 percent after one quarter, by 0.33 after one year, and amounts to about 0.26 percent after three years (12 quarter)²². This indicates in Ethiopia, ERPT to import price is moderate²³ and declines slowly as the estimating horizon increased. For instance, a 100 percent exchange rate appreciation results in a 49 percent decrease in import price at the first quarter and about 26 percent decline after 3 years. This shows that ERPT to import price is persistent in the case of Ethiopia.

Compared with the ERPT to import prices, pass-through of exchange rate to consumer prices is low. A one percent positive shock in exchange rate leads to 0.013 percent decline in CPI inflation in the first quarter, 0.014 percent after one year (four quarters ahead) and become almost zero in the fifth quarter (and in all subsequent periods). The estimated pass-through coefficient is somehow higher compared to the finding of Choudhri and Hakura (2003) and Devereux and Yetman (2002). The aforementioned studies obtained zero ERPT to consumer prices for Ethiopia between the periods 1997-2000 and 1975-1999, respectively as it is discussed in previous chapters. In our study even if the degree of pass-through to CPI is low it is significantly different from

Where, $P_{t,t+j}$ is the cumulative change in the price level and $E_{t,t+j}$ is the cumulative change in the nominal exchange rate between quarter t and $t+j$ (see, Leigh and Rossi, 2002; Hyder and Shah, 2004; An, 2006 and Minh, 2009)

²² Note that exchange rate shocks refer to an appreciation in the exchange rate

zero up to one year. This different result could be partly caused by different estimation methodology and partly due to different sample size used.

Various reasons can be given to explain the low pass-through of exchange rate to consumer prices. First, in the model of pricing along the distribution chain the impact of exchange rate dies out along the price chain. That is the impact of the exchange rate change is primarily transmitted to import price then to producer price and finally to consumer price. Concerning this Ito and Sato (2006) argue that the impact of the exchange rate on CPI is much more indirect and remote than that of imported prices. Thus, it is reasonable that the response of CPI is smaller than that of MPI. The level of pass-through from exchange rate to CPI could also depend on monetary policy and the resulting inflation environment. As hypothesized by Taylor (2000) a lower inflationary environment generally leads to lower degree of pass-through. Therefore, the low inflation environment that Ethiopia experienced for a long time (except the recent years) can explain the lower degree of ERPT to consumer prices.

Additional reasons may also be given to explain why the rate of pass-through to consumer prices is low compared to import prices. According to Bailliu and Fujii (2004), the extent of pass-through to consumer prices will depend on the rate of pass-through to import prices and the share of imports in the consumer price index. The extent of ERPT to import prices is found to be moderate through the entire forecast horizon. This could be then another reason why pass-through to consumer price inflation is low in Ethiopia.

Moreover, the structure of domestic market and local distribution costs such as transportation costs, marketing, and services can drive a wedge between import prices as measured in the import price index and the prices of these goods as reflected in the CPI. For instance, if there is complete pass-through to import prices following appreciation (i.e. if import price decreases by one percent following one percent appreciation of exchange rate), consumer prices will decrease by less than one percent given the structure of the market. In imperfectly competitive markets domestic importers might be less responsive to exchange rate appreciation and hence the full effect of decrease in import price might not be reflected in the final price consumers pay.

Finally, the low ERPT to consumer prices suggests that inflation is most likely affected by other factors than the exchange rate in Ethiopia. Among the variables included in

our model, consumer price inflation responds significantly to shocks in world commodity price, money supply and shock to CPI itself. For instance, increase (positive shock) in WCPI results in significant increase in CPI inflation implying that the country is vulnerable to international price shocks (imported inflation). Also CPI inflation shows significant response to M2 after one year (four quarter) and in all subsequent periods. Furthermore, the significant and persistent response of inflation to its own shock shows the existence of adaptive expectation and inflation inertia.²⁴

4.2 The Relative Importance of Exchange Rate and Other Shocks for Variation in MPI and CPI

While impulse response functions provide information on the size and speed of the pass-through, they give no information on the importance of the respective shocks for the variance of the price indices. In contrast, variance decompositions (VD) indicate the percentage contribution of the different shocks to the variance of the T-step ahead forecast errors of the variables. Hence, the relative importance of different shocks for the development of the price indices may be assessed using VD analysis.

The results of the VD analysis complement the results from the impulse response analysis. Since our main objective is to analyze the degree of ERPT to import and consumer prices, Table 2 reports only the VD results for MPI and CPI.

The VD analysis for the MPI shows that in the first quarter, a shock to the exchange rate contributes 16.6 percent variation to the MPI series, while the M2 and output gap has only a zero and 0.39 percent contribution, respectively. After four quarters (one year) the contribution of exchange rate declines to 14.7 percent, while that of money supply and output gap increases to 1.3 and 7.4 percent respectively. WCPI contributes 0.16 percent of the variation in MPI in the first quarter while its contribution increases to around 5.8 percent in the remaining quarters. MPI contributes much for its own variation which amounts to be 82.9 percent in the first quarter and it becomes around 63 percent as the forecast horizon is extended.

²⁴ For impulse response of consumer prices to other variables see appendix C

Table 2: Variance decomposition analysis

| The relative importance of exchange rate and other shocks to variation in MPI and CPI | | | | | | | |
|---|--------|----------|-----------|----------|----------|----------|----------|
| | Period | WCPI | Y^{gap} | NEER | MPI | CPI | M2 |
| VD Of MPI | T = 1 | 0.162336 | 0.391894 | 16.59516 | 82.85061 | 0.00000 | 0.000000 |
| | T = 4 | 4.925207 | 7.377324 | 14.65767 | 66.86527 | 4.916063 | 1.258473 |
| | T = 8 | 5.743395 | 9.145884 | 13.90118 | 63.42031 | 6.526990 | 1.262244 |
| | T = 12 | 5.830135 | 9.400638 | 13.82277 | 62.97437 | 6.698974 | 1.270732 |
| | T = 16 | 5.841488 | 9.434606 | 13.81774 | 62.91840 | 6.715913 | 1.271861 |
| | T = 24 | 5.842803 | 9.439305 | 13.81701 | 62.91125 | 6.717674 | 1.271958 |
| VD Of CPI | T = 1 | 9.864119 | 3.993058 | 0.607052 | 0.018242 | 85.51753 | 0.000000 |
| | T = 4 | 19.47688 | 12.33309 | 0.474939 | 5.684429 | 60.72456 | 1.306105 |
| | T = 8 | 18.95365 | 12.91174 | 1.081356 | 7.737759 | 57.33358 | 1.981919 |
| | T = 12 | 18.87306 | 12.95291 | 1.144462 | 8.030774 | 57.00711 | 1.991685 |
| | T = 16 | 18.86299 | 12.95545 | 1.152082 | 8.066227 | 56.97243 | 1.991059 |
| | T = 24 | 18.86173 | 12.95571 | 1.152715 | 8.070648 | 56.96824 | 1.990952 |

The exchange rate has a contribution to the variation in CPI of 0.61 percent and 1.2 percent in one quarter and twelve quarter ahead in the forecast horizon, respectively. The contribution of exchange rate in the variation of CPI is very low compared to its contribution in the variation of MPI which is consistent with the impulse response result. Money supply contributes only 1.31 percent to the variation in CPI four quarters ahead in the forecast horizon. This slightly increases to 1.9 percent after 12 quarters. Output gap contributed 3.9 percent of the variation in CPI in the first quarter while its contribution increases to 12.9 percent after 12 quarters (3 years). The significant contribution of output gap to variation in inflation indicates that domestic structural factors have significant effect on consumer price inflation than movements in exchange rate.

We also found that WCPI have a significant contribution to the variation of CPI inflation. It explains 9.9 percent of the variation in CPI in the first quarter and increases to 19.5 percent four quarters ahead. This shows the existence of significant imported inflation to consumer prices. Lastly, inflation explains 85.52 percent of its own variation at the first quarter, 60.72 percent after one year and 56.97 percent after 3 years. This indicates the increase in consumer prices is mainly attributed to its own variations, suggesting that the inflation process in Ethiopia has significant inertia.

4.3 Robustness Analysis

Results from SVAR models may highly depend on the specification of the underlying model. Therefore, the robustness of the estimated pass-through elasticities should be examined by subjecting the baseline model to various modifications. Identification by means of the Choleski decomposition of the covariance matrix Σ is only unique up to the ordering of the variables in the system. Consequently, the same is true for the orthogonalized impulse responses (Stulz, 2006). In this section, two alternative identification strategies are applied to check the robustness of the base line model. The first option is giving different ordering to some variables included in the VAR while the second option is to apply different methodology in estimating the impulse responses. Concerning the first option we check whether the base line model is sensitive to the order of two variables. In the first alternative model we gave different ordering to the monetary variable (M2) thereby accounting for the fact that the appropriate position of the money supply is somewhat controversial in the context at issue (see the discussion in section 3.4). In the second alternative models we gave different VAR ordering to output gap.

In the base line model M2 was ordered at last assuming reactive nature of monetary policy. In the alternative model we change the order of this variable by placing it prior to exchange rate as Hanhn (2003) and Ito and Sato (2006) did, assuming forward looking nature of monetary policy.

$$\Delta wcpi \rightarrow y^{Gap} \rightarrow \Delta m2 \rightarrow \Delta neer \rightarrow \Delta mpi \rightarrow \Delta cpi \dots\dots \text{Alternative Model 1}$$

Identification is then achieved as described in section 4.3.1, i.e. by applying a Cholesky decomposition of the covariance matrix Σ . However, we do not find any significant changes in the estimated pass-through parameters due to a different ordering of M2. The results obtained from Alternative Model 1 are reported in appendix D. The estimated responses of import price to exchange rate marginally increases compared to the baseline model. In case of ERPT into consumer prices, the results are almost similar to those obtained from the baseline model. Thus, the ordering of the M2 is of little importance for the pass-through estimates.

Second, following Ito and Sato (2006) we assume the lagged availability of information on the output gap, which results in no contemporaneous effect of output gap shocks on the central bank's monetary policy. It is also assumed that the NEER responds

contemporaneously to world commodity price shocks and monetary policy shocks but not to output gap shocks. Accordingly, the “Alternative Model 2” is

$$\Delta wcpi \rightarrow \Delta m2 \rightarrow \Delta neer \rightarrow y^{Gap} \rightarrow \Delta mpi \rightarrow \Delta cpi \dots\dots \text{Alternative Model 2}$$

The estimated response of the MPI and CPI from the above alternative model is reported in appendix D. Again the result from this model shows no significant difference to those of the other models.

As a second alternative, generalized impulse responses are calculated instead of Cholesky orthogonalized impulse responses. As it is discussed in Stulz (2006) the concept of generalized impulse response was advanced in Koop et al. (1996) and applied to VAR models in Pesaran and Shin (1998). Unlike traditional impulse responses, this approach does not require orthogonalization of the shocks, and is invariant to the ordering of the variables. Thus generalized impulse response is estimated and the results are reported in appendix D. The results obtained from this method are also virtually similar to those of the other models. Generalized responses of import prices to exchange rate shocks is similar to the baseline (orthogonalized) responses while that of consumer prices are somewhat stronger than in the baseline case though the difference is not that much significant²⁵.

5. Conclusion and Policy Implications

The study examined the degree of ERPT to import and consumer prices in Ethiopia during the period 1991/92 and 2010/11. The study estimates the pass-through coefficients using SVAR model where pass-through coefficients are estimated based on impulse response function obtained from the VAR models. Based on the SVAR model, using the impulse response function, we establish that the degree of ERPT to import and consumer prices to be incomplete, persistent (in the case of import price) and significant in the short run. Pass-through to import prices was found to be significantly higher (also quick) than that of CPI and this suggests that ERPT declines along the pricing chain in Ethiopia. Accordingly, based on the fact that the concept of

²⁵ Also, given the variables in the system are I (1) we check for the existence of cointegration and re-estimate the model using structural vector error correction method (SVECM) so as to see if there is any significant difference in the result obtained. The impulse response resulted from the estimated VEC models shows nearly similar degree of pass-through to import and consumer prices compared to SVAR model. Selected results of the SVEC model are given in appendix D.

ERPT has important implication for exchange rate and monetary policy, the following policy implications are drawn based on the findings.

The finding that ERPT to import prices is incomplete in Ethiopia has important implication about the effectiveness of exchange rate measures which are intended to improve the country's trade balance. Specifically, devaluation measures which are taken to correct trade balance might not be effective to the extent they are expected due to incomplete response of import price (and the resulting change in domestic demand) to exchange rate movements.²⁶ This means if import prices are less responsive to movements in the exchange rate, the "expenditure-switching" effects might be dampened. For instance, a depreciation of the Birr would increase the price of imported goods relative to domestic goods, which should—all else being equal—reduce the domestic demand for imported goods. But, since pass-through to import prices is found to be incomplete in Ethiopia, the change in the price of imported goods will be small and hence the incentive for consumers to switch expenditures from imported to domestic goods will be reduced. Thus policy makers should take into account the incomplete response of import prices when they decide to devalue the currency so as to improve trade balance.

Our finding of incomplete ERPT also has important implication for monetary policy. As it is shown by Adolfson (2001) and Smets and Wouters (2002) incomplete pass through makes the exchange rate channel less effective. In addition, a low ERPT also implies that larger exchange rate movements are necessary for relative price adjustments.

A low degree of ERPT to consumer prices indicates that nominal exchange rate appreciations might not be an effective mechanism to lower inflationary pressures in Ethiopia. However, since the pass-through of exchange rate change to import prices is moderate, it is recommended that a more flexible exchange rate regime with a larger band of fluctuation can allow the national bank to promptly respond to both domestic shocks and foreign shocks, while bearing less risk of the impact of exchange rate change on inflation. In addition, low ERPT provides greater freedom for pursuing independent monetary policy and makes the adoption of inflation targeting regime relatively easy.

²⁶ irrespective of several other factors which might determine the effectiveness of exchange rate policy (such as supply factors, elasticity of foreign and domestic demand, availability of substitutes etc)

Lastly, even if the study addresses its objectives there are still different areas for further research concerning ERPT. To mention some, in this study the analysis is conducted based on aggregate price indices (at macro level). In order to investigate which sector or items in the consumption basket are more affected by exchange rate shock, analysis is required at a more disaggregated level (if industry or sector-specific data is available in the future). Undertaking the study at disaggregated level also allows one to study the determinants of ERPT in Ethiopia.

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Appendices

Appendix A.1: Construction of Import Price Index (Taken from Loening and Higashi, 2010)

The import unit value index of the component i is:

$$\frac{P_{mi,t}}{P_{mi,0}}$$

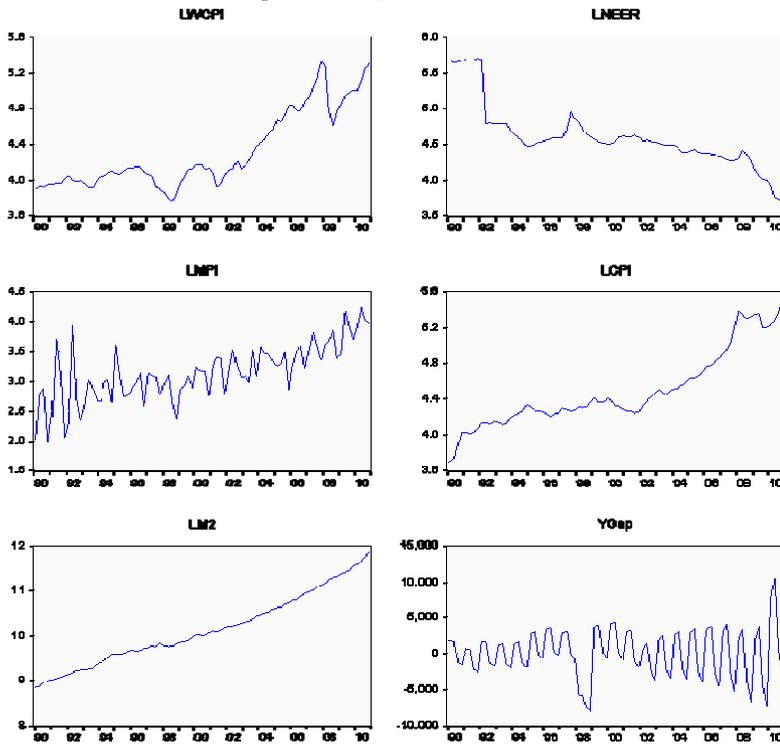
Where $P_{mi,t}$ and $q_{mi,t}$ represent the import unit value and the quantity of the component i at time t . The overall import price index (P_{mi}) is a weighted average of all components:

Where $\frac{q_{mi,t} P_{mi,t}}{P_{mi,t} q_{mi,t}}$

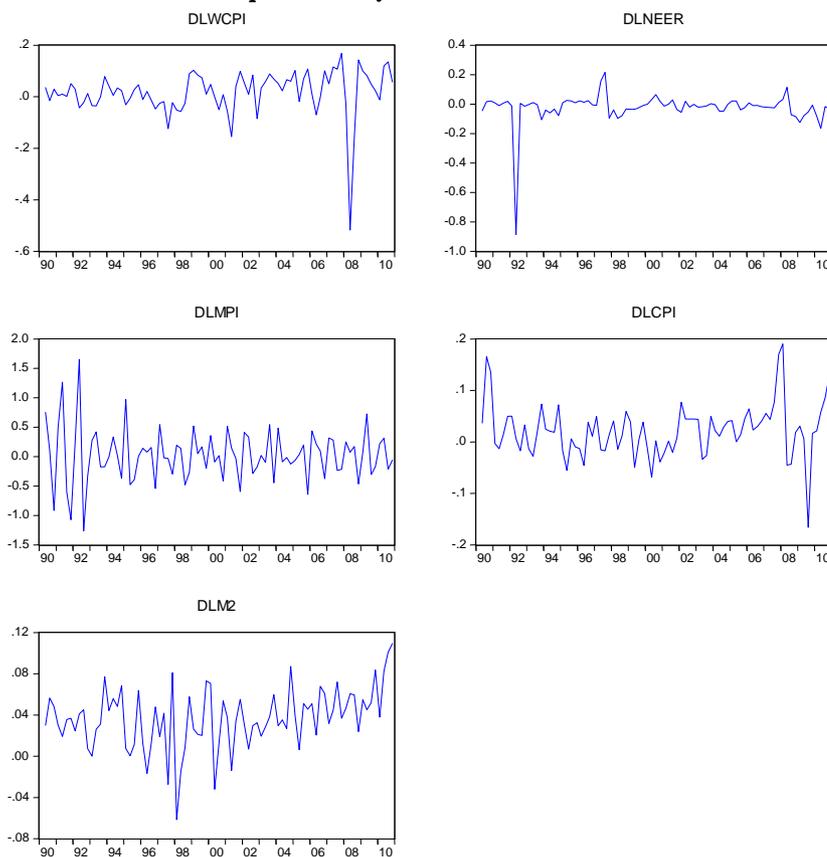
Note: To construct the index the unit value of major imports items from the class of semi-finished goods, capital goods and consumer goods including petroleum products are considered.

Appendix A.2: Time Series Plots

i) Variables Used in the Empirical Analysis at Level



ii) Variables Used in Empirical Analysis at First Differences



Appendix A.3: Unit root test results

| Variable | ADF | | Phillips-Perron | | KPSS | | I(d) |
|----------|---------|-------------|-----------------|-------------|--------|-------------|-------------|
| | Level | Differenced | Level | Differenced | Level | Differenced | |
| LWCPI | -1.6268 | -7.3302 | -1.6882 | -5.9132 | 0.2701 | 0.0486 | I(1) |
| LNEER | -2.4610 | -8.3791 | -2.3050 | -8.3742 | 0.1285 | 0.1025 | I(1) |
| LMPI | -2.4777 | -14.4483 | -3.1465 | -8.6751 | 0.1619 | 0.1338 | I(1) |
| LCPI | -1.3991 | -5.8944 | -1.1361 | -5.5529 | 0.2464 | 0.1368 | I(1) |
| LM2 | 1.9852 | -5.0509 | 2.0384 | -8.0157 | 0.2779 | 0.1086 | I(1) |
| YGap | -4.5577 | - | -5.2608 | - | 0.0329 | - | I(0) |

Note: ADF and PP critical values are -3.4566 and -3.1593 at 5% and 10% level of significance respectively. The KPSS critical values are 0.146 and 0.119 at 5% and 10% level of significance respectively.

LWCPI, LNEER, LMPI, LCPI and LM2 show the natural logarithm of world commodity price index, nominal effective exchange rate, import price index, consumer price index and broad money supply respectively.

Appendix B.1: VAR Lag order Selection Results**i) VAR Lag Order selection Criteria**

Endogenous variables: DLWCPI YGap DLNEER DLMPI DLCPI DLM2

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|----------|-----------------|------------------|------------------|-------------------|------------------|-------------------|
| 0 | 433.6927 | NA | 7.99e-13 | -10.82766 | -10.64770* | -10.75557 |
| 1 | 487.4866 | 98.05473 | 5.11e-13 | -11.27814 | -10.01843 | -10.77346 |
| 2 | 544.1673 | 94.70706* | 3.07e-13* | -11.80170* | -9.462250 | -10.86445* |
| 3 | 572.9020 | 43.64767 | 3.84e-13 | -11.61777 | -8.198570 | -10.24794 |
| 4 | 607.0141 | 46.63415 | 4.36e-13 | -11.56998 | -7.071025 | -9.767558 |

* indicates lag order selected by the criterion

ii) VAR Lag Exclusion Wald Tests

Chi-squared test statistics for lag exclusion:

Numbers in [] are p-values

| | DLWCPI | Y ^{cap} | DLNEER | DLMPI | DLCPI | DLM2 | Joint |
|-------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Lag 1 | 17.40069 [0.007918] | 47.00177 [1.87e-08] | 0.908023 [0.988860] | 42.73635 [1.32e-07] | 40.26389 [4.04e-07] | 8.183881 [0.224939] | 158.9562 [0.000000] |
| Lag 2 | 7.665978 [0.263610] | 44.09297 [7.08e-08] | 6.794962 [0.340226] | 77.42173 [1.22e-14] | 15.34229 [0.017755] | 11.19456 [0.082546] | 153.2235 [2.22e-16] |
| Df | 6 | 6 | 6 | 6 | 6 | 6 | 36 |

Appendix B.2: VAR Diagnostic Tests**i) Stability Test**

Roots of Characteristic Polynomial

Endogenous variables: DLWCPI YGap DLNEER DLMPI DLCPI DLM2

| Root | Modulus |
|-----------------------|----------|
| -0.050152 - 0.765496i | 0.767138 |
| -0.050152 + 0.765496i | 0.767138 |
| 0.127994 - 0.546686i | 0.561469 |
| 0.127994 + 0.546686i | 0.561469 |
| 0.531278 - 0.090283i | 0.538895 |
| 0.531278 + 0.090283i | 0.538895 |
| 0.012561 - 0.449274i | 0.449450 |
| 0.012561 + 0.449274i | 0.449450 |
| -0.355277 - 0.109002i | 0.371623 |
| -0.355277 + 0.109002i | 0.371623 |
| 0.277633 - 0.227543i | 0.358965 |
| 0.277633 + 0.227543i | 0.358965 |

No root lies outside the unit circle.

VAR satisfies the stability condition.

ii) Test for Residual Autocorrelation

VAR Residual Serial Correlation LM Tests

H0: no serial correlation at lag order h

| Lags | LM-Stat | Prob |
|------|----------|--------|
| 1 | 42.29716 | 0.2176 |
| 2 | 45.92372 | 0.1243 |

Probs from chi-square with 36 df.

iii) Test for Residual Normality

| Component | Jarque-Bera | Df | Prob. |
|-----------|-------------|----|--------|
| 1 | 104.6114 | 2 | 0.0000 |
| 2 | 16.88396 | 2 | 0.0002 |
| 3 | 2883.356 | 2 | 0.0000 |
| 4 | 2.144029 | 2 | 0.3423 |
| 5 | 113.9991 | 2 | 0.0000 |
| 6 | 2.896483 | 2 | 0.2350 |
| Joint | 3123.891 | 12 | 0.0000 |

iv) Test for Residual Heteroskedasticity

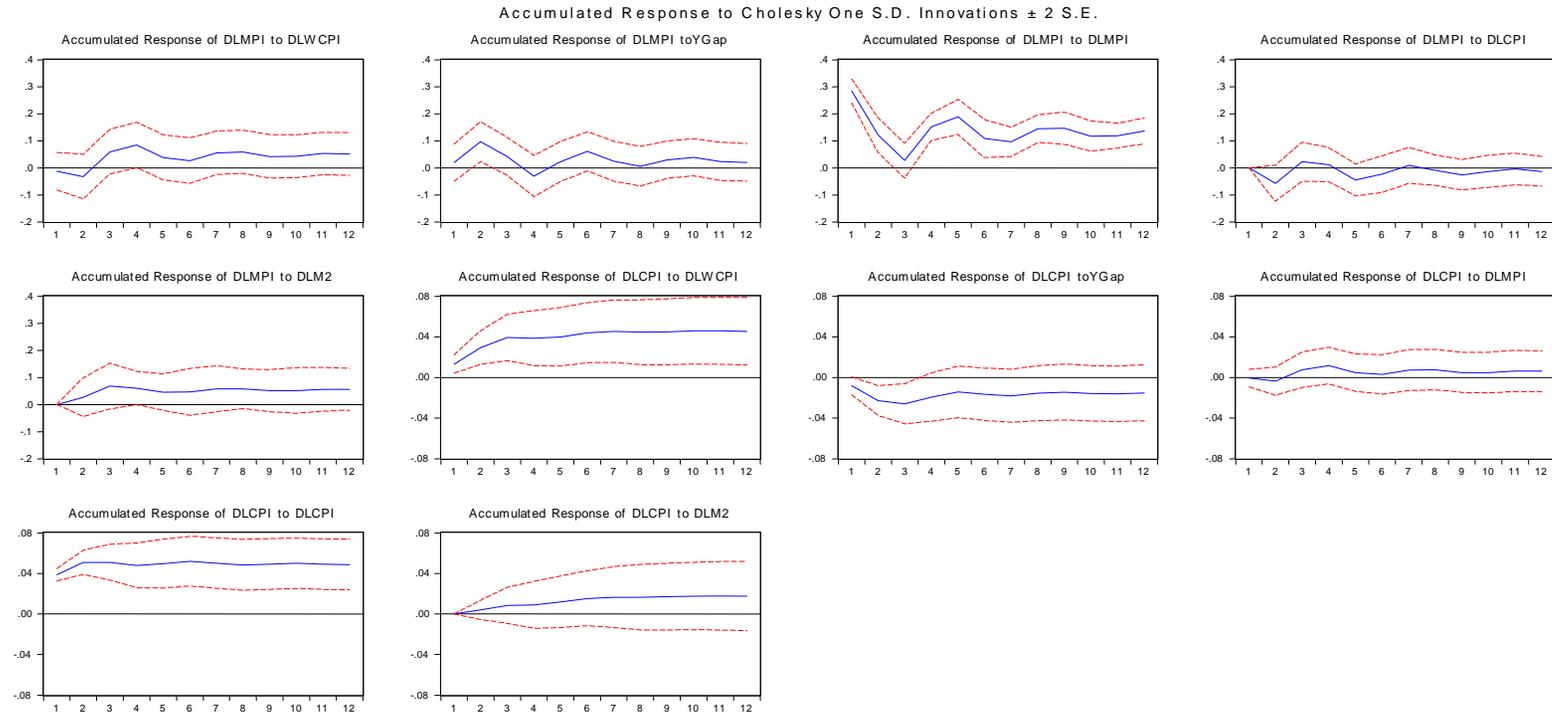
VAR Residual Heteroskedasticity Tests:

No Cross Terms (only levels and squares)

Joint test:

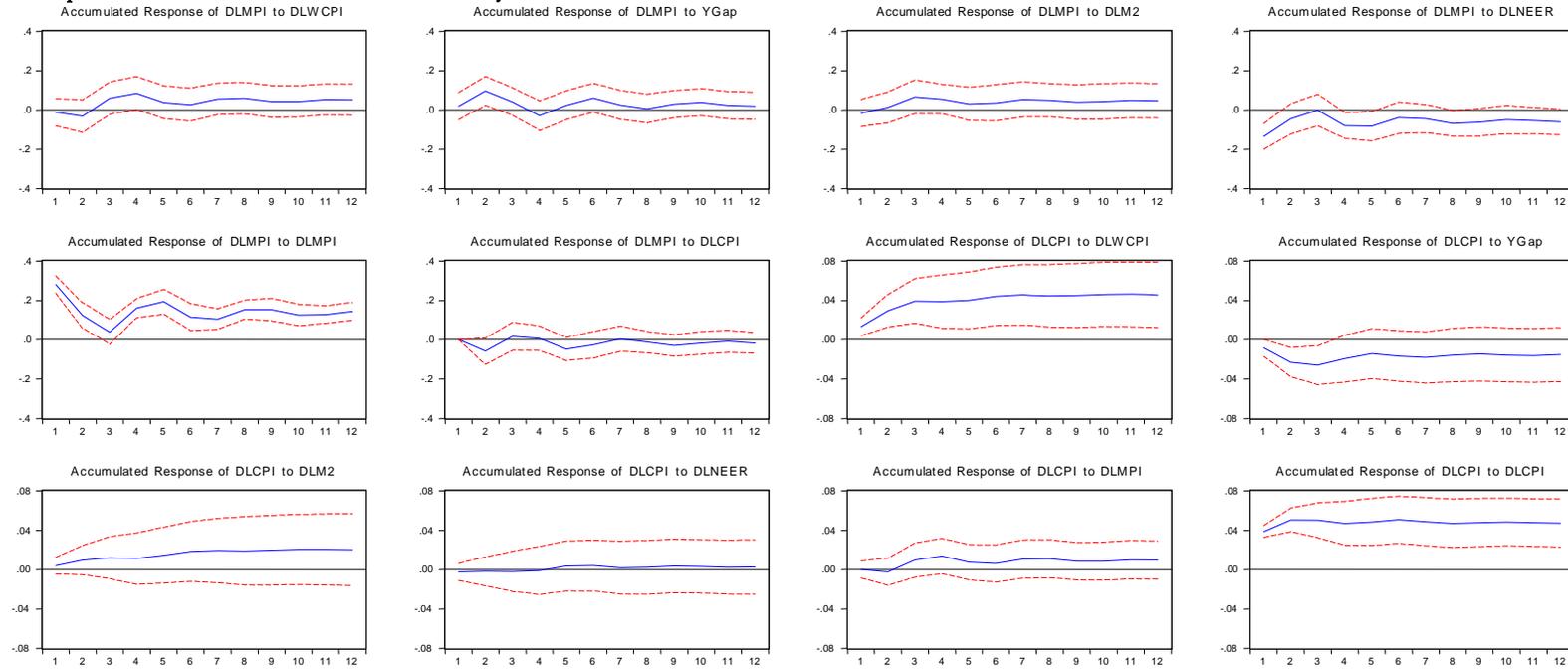
| Chi-sq | df | Prob. |
|----------|-----|--------|
| 578.9345 | 504 | 0.5432 |

Appendix C: Impulse Response Results of MPI and CPI to Shocks in Other Variables (base line model)

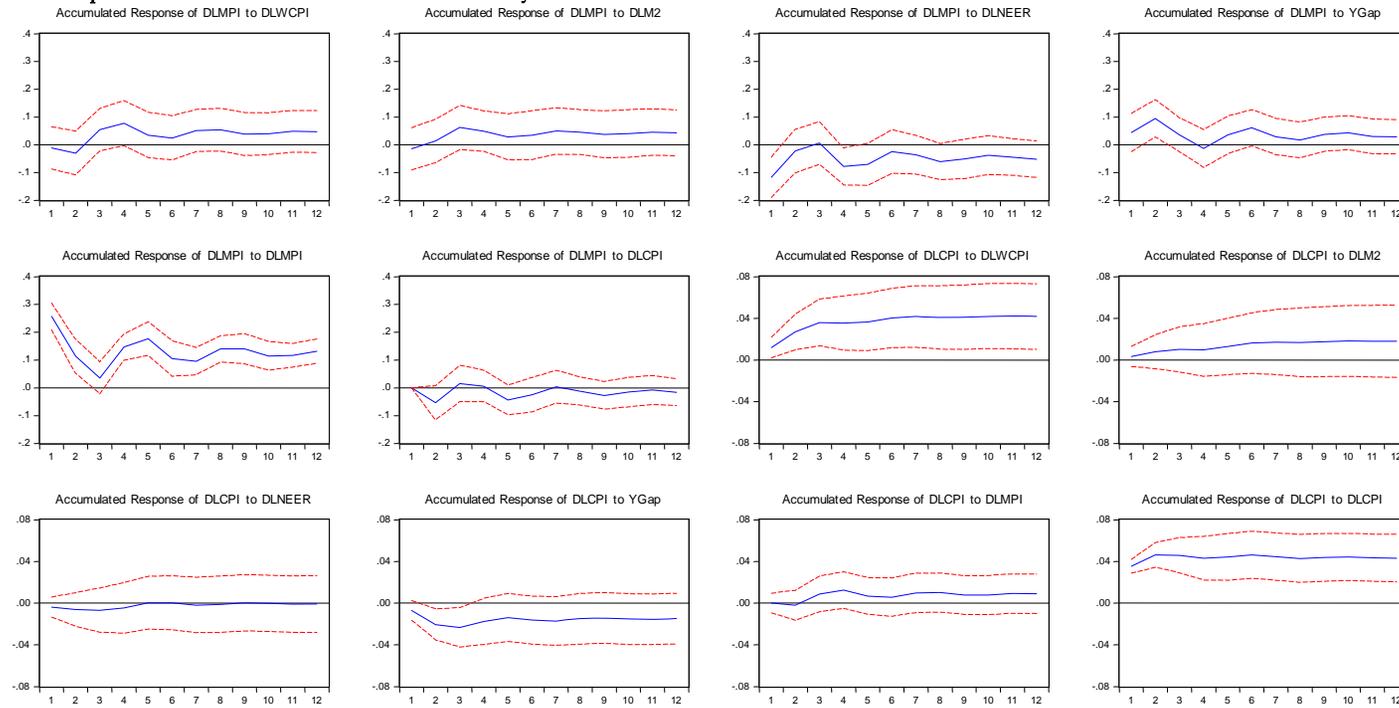


Appendix D: Results of Alternative Models

i) Alternative Model 1: $\Delta wcp_i \rightarrow y^{Gap} \rightarrow \Delta m2 \rightarrow \Delta neer \rightarrow \Delta mpi \rightarrow \Delta cpi$
 Response of MPI and CPI to various shocks in the system

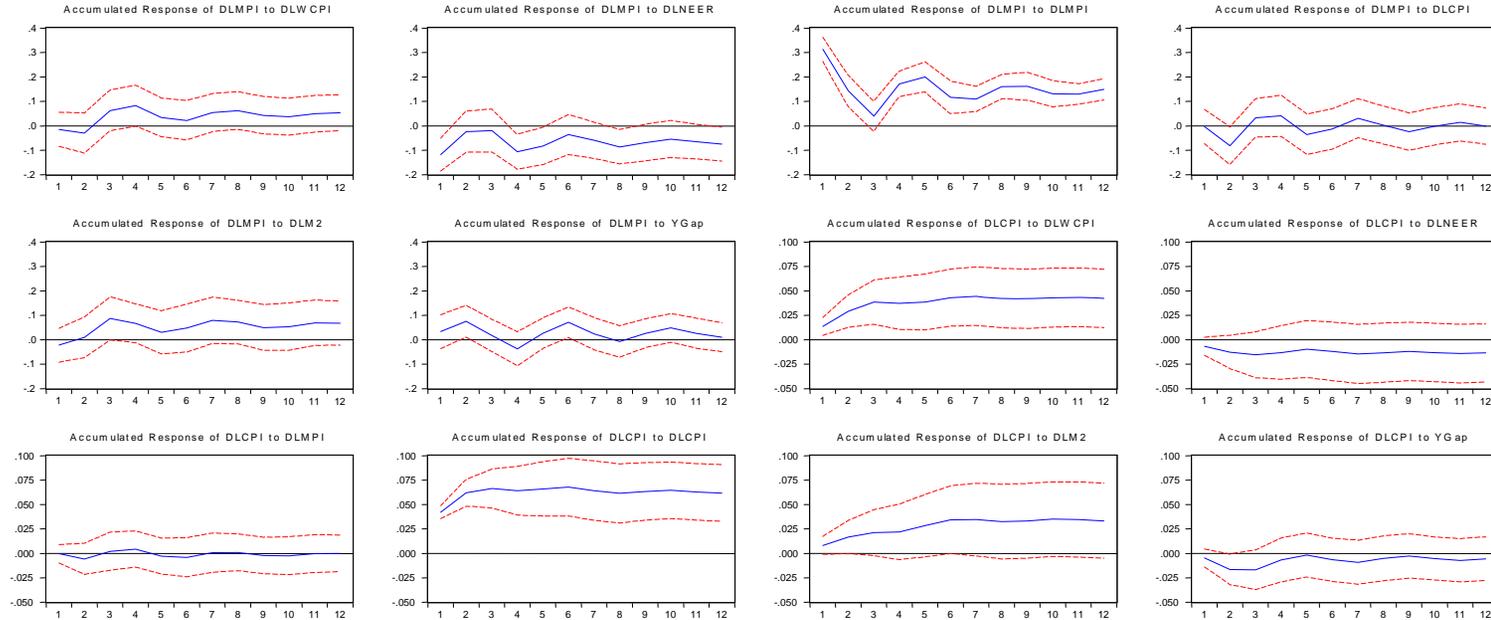


ii) **Alternative Model 2: $\Delta w_{cpi} \rightarrow \Delta m2 \rightarrow \Delta neer \rightarrow y^{Gap} \rightarrow \Delta mpi \rightarrow \Delta cpi$**
Response of MPI and CPI to various shocks in the system



iii) Generalized Impulse Response Results
 Response of MPI and CPI to various shocks in the system

Accumulated Response to Generalized One S.D. Innovations ± 2 S.E.



iv) SVECM results

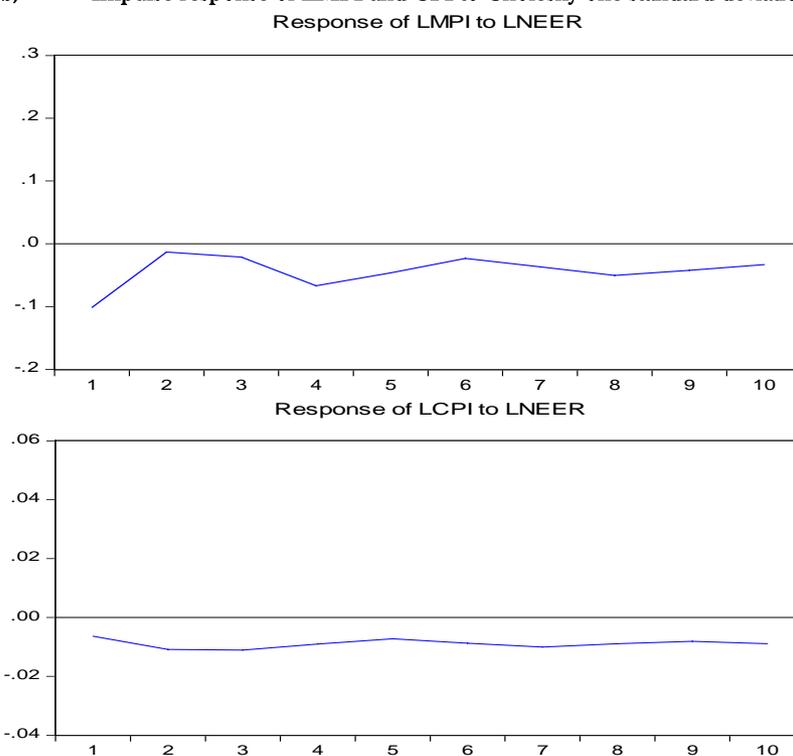
a) Johansen cointegration test results

| Hypothesized No. of CEs | Eigenvalue | Trace statistic | | Max-Eigen statistic | |
|----------------------------|------------|-----------------|----------|---------------------|----------|
| | | Statistic | C.V | Statistic | C.V |
| None | 0.600086 | 153.2232* | 69.81889 | 75.15354* | 33.87687 |
| At most 1 | 0.421080 | 78.06965* | 47.85613 | 44.82050* | 27.58434 |
| At most 2 | 0.223628 | 33.24914 | 36.79707 | 20.75612 | 21.13162 |
| At most 3 | 0.126289 | 12.49302 | 15.49471 | 11.07041 | 14.26460 |
| At most 4 | 0.017199 | 1.422603 | 3.841466 | 1.422603 | 3.841466 |

Both Trace and Max-eigenvalue test statistic indicates 2 cointegrating equation(s) at the 0.05 level of significance. *denotes rejection of the hypothesis at the 0.05 level.

C.V: Critical Value

b) Impulse response of LMPI and CPI to Cholesky one standard deviation innovation



- Note:** (1) Standard Errors are not reported for the VECM impulse response results
 (2) Identification is achieved through Cholesky orthogonalization where the ordering of the variables is as given in the base line model.
 (3) Given all the variables in the system are I (1), in the SVEC model output gap which is I (0) by construction is replaced by logarithm of real GDP because the VECM is more generally valid when each of the variables in the system is integrated of the same ^{order}.