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Exchange Rate Transmission into Sectoral Consumer Price Inflation in Ethiopia-SVAR Approach

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Abstract: This paper employs recursive structural vector auto-regression (SVAR) to study exchange rate pass-through into domestic consumer price inflation in Ethiopia. The study utilizes quarterly data spanning out the period from 1997.3 to 2011.4. Innovation accounting from the resulting SVAR was performed to trace out the impact of a one-time unit shock in one variable on the trajectory of other variables over time. The impulse response function analysis indicates that nominal effective exchange rate plays an important but short-lived role in affecting consumer price developments in Ethiopia. In particular, a unit change in the trade weigheted exchange rate (appreciation) caused the consumer price inflation to fall by about 0.01 after four quarters (or an accumulated response of about 0.11 after 14 quarters). As a result, exchange rate pass-through into domestic prices in Ethiopia is incomplete and inconsequential. The forecast error variance decomposition exercise shows own shock explains about 63 percent of the forecast error variability of inflation followed by world oil price (20 percent) and exchange rate (13 percent). Monetary aggregate has triavial effect for all horizons considered.Regarding the components of CPI, sectors which have higher import content exihibit relatively stronger pass-through effects.

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1. Introduction

Many developing countries had for a long time resisted the allure of letting the value of their currencies be determined in the market. The reason is that while fixing the exchange rate eliminates conversion costs and unnecessary volatilities, allowing it to freely float entails destabilizing macroeconomic consequences. If the government and private firms have accumulated massive amount of foreign-currency-denominated debt, a fall in the exchange rate should raise the local currency value of the debt burden because of currency mismatches. The drop in the exchange rate also makes imported goods more expensive and this in turn feeds into—passes through—overall consumer price inflation. The threat of inflationary spiral along with potentially swelling debt have made currency pegs more attractive vis-à-vis flexible exchange rates.

Yet, fixing the exchange rate requires that the central bank is willing to subjugate other policy priorities to maintaining the desired level of the currency peg. This is what is commonly known as 'the Trilemma'—the notion that a country cannot enjoy monetary independence, free capital mobility, and a fixed exchange rate all at the same time. In other words, if policy makers prefer to fix their currency and retain the ability to set interest rates autonomously, they must decide to impose tough restrictions on capital account transactions. Because the government's reserves to defend a currency peg can be exhausted—thus risking abrupt devaluation-- it is often suggested a country adopts flexible exchange rate in tandem with monetary policy independence and allow capital to get into and out of the country freely.

It was partly in line with this wisdom that the transitional government of Ethiopian decided to let the national currency float in 1992[1], ending an almost five-decade-long regime in which the national currency, birr, had been pegged to the U.S. dollar. As pointed out earlier, floating[2] a currency makes the concerned economy vulnerable to domestic price volatility arising from exchange rate pass-through which is typically the case for a small open economy like Ethiopia with a high degree of dependence on international trade, significant import content in domestic production, and sizeable share of tradable commodities.

Now that more than two decades have passed since greater exchange rate flexibility was introduced in Ethiopia, it is time that we measure the speed and size of exchange rate pass-through into domestic general and sectoral consumer prices. This is of interest to policy makers in at least two respects. First, if the degree and size of pass-through is subdued, there is no point for the central bank to vary the exchange rate in an attempt to improve the country's balance of trade. This implies that the monetary authorities should not be concerned about the potentially inflationary repercusions of finicacial developments that place downward pressure on the national currency. Second, sectoral pass-through analysis provides the degree of exchange rate transmission across each specific consumer price category. Knowing which sectors respond more strongly to exchange rate fluctuations presents valuable insights for policy action aimed at furthering the overall welfare of the society.

In this paper I endeavor to examine exchange rate pass-through into domestic consumer price changes in Ethiopia. Quarterly observations covering the period from 1997.3 to 2011.4 are used for estimation and analysis. I employ recent developments in multivariate time series tools. A modest five dimensional structural VAR is estimated to trace out the effect of shocks in one variable on the path of price and other endogenous variables included in the model. Impulse response functions and forecast error variance decomposition are used to understand consumer price behaviour to changes in fiscal policy stance, monetary policy variables, world oil price and trade weighted exchange rates.

The impulse response function analysis indicates that nominal effective exchange rate plays a short-lived role in affecting consumer price developments in Ethiopia. In particular, a unit change in the trade weigheted exchange rate (appreciation) caused the consumer price inflation to fall by about 0.01 after four quarters (or an accumulated response of about 0.11 after 14 quarters). The forecast error variance decomposition exercise shows own shock explains about 63 percent of the forecast error variability of inflation followed by world oil price (20 percent) and exchange rate (13 percent). Monetary aggregate has triavial effect for all horizons considered.

The rest of the paper follows this organization: the next section presents a brief review of the theoretical and empirical literature. Section II outlines the methodology followed by discussion of the estimation results in section IV. The last section provides the conclusion.

[1] The value of birr was fixed at 2.5 per U.S. dollar from 1945 to 1971. With the collapse of the Bretton Woods arrangement in the early 1970s it experienced a slight revaluation to 2.3. The socialist regime that took power in 1974 further revalued it to 2.07 and kept it there till its demise in 1991/1992.

[2] The dichotomy between fixed and flexible is not clear-cut and in fact many central banks adopt a middle ground. In the case of Ethiopia, for example, the monetary policy framework of the central bank states that "considering the underlying economic situation of the country, managed floating exchange rate regime is being practiced in Ethiopia since 1992. This exchange rate regime will continue to be adopted in the years to come.

2. Pass-through literature

The question of how much of the change in the exchange rate is incorporated into domestic prices, import/export prices and trade volumes has long taken up the attention of empirical economists. Exchange rate pass through (ERPT) measures the percentage change in local currency price indices for a unit change in the exchange rate. A one-for-one pass through is called complete while a less than unity pass through is considered to be partial or incomplete.

Dornbusch (1985) and Krugman (1987) were some of the early influential contributions that developed models of partial equilibrium price adjustment in response to exchange rate changes within the context of industrial organization. Dornbusch relied on a framework where time is an important element in the adjustment process evolving around market concentration and the degree of substitution between imported and home produced goods.

Import prices in destination countries can also be affected by the foreign firms' pricing strategies in light of market share and profit considerations. Krugman (1987) formally popularized this notion which is now commonly referred to in the literature as Pricing to Market (PTM). PTM predicts that contrary to conventional approach, domestic prices of imported goods may not rise following depreciation as the producers would "mark down" the export price denominated in their own currency with the objective of stabilizing price in the importing country's market. With exchange rate appreciation the foreign firm would react by raising its prices (marking up to market) in order to maintain or raise its profit margins.

All these depend on the structure of the industry, the intensity of competition, and the type of demand that the foreign producer faces. Firms operating in a highly competitive industry and, therefore, facing hugely elastic demand would not be tempted to raise markups even when importing country's currency appreciates. The rationale behind this conservative pricing decision is that the exporter firm protects its existing market share by keeping importer's local price constant. In contrast, a foreign firm operating in an oligopolistic environment with less elastic demand for its product can pass through the exchange rate changes to the price of importing country.

A mushrooming literature is also making inroads into the microeconomic approaches (like PTM) by developing alternative general equilibrium models that analyze the impact of monetary policy conduct on exchange rate transmission mechanism and on the choice of exchange rate regimes (e.g. Bacchetta and van Wincoop, 2000; Engle and Devereux, 2002; Corsetti and Pessenti, 2005; Betts and Devereux, 2001).

Over the last two decades, scores of central banks in advanced, emerging, and developing countries have explicitly targeted[3] inflation rates with the objective of anchoring public inflation expectations, maintaining sufficiently low inflation environment and achieving minimal variability in prices. People who favour inflation targeting claim that established central bank credibility and reputation for containing inflation not only create conducive environment for growth but also generate positive spillover effects from international trade and investment. It is argued that countries with bad track record of high inflation numbers will be vulnerable to import prices denominated in foreign currency and consequently the exchange rate pass-through effects into their imported prices will be direct and substantial. By contrast, countries popular for sound monetary policy practice and low volatility of inflation have higher likelihood that their import goods will be priced in their own currency, which abates exchange rate pass-through even in the event of significant depreciation. It must be noted that the structure of international financial markets has significant bearing on the effects of monetary policy in influencing the behaviour of exchange rate transmission. When access to consumption risk sharing is widely available from international capital markets, it is relative, not absolute, monetary policy soundness that matters. An economy with the most stable price will get priority in getting its imports set in its own currency even when economies in the vicinity maintain comparably stable monetary policy process[4].

The empirical test of exchange rate pass-through is diverse both in terms of methodology and scope. Ca' Zorzi et al. (2007) studied twelve emerging economies[5] using multivariate vector autoregressive methods. Six quarterly endogenous variables were considered, namely, oil price index, output, exchange rate, import price index, consumer price index, and a proxy for short term interest rate. Industrial production was chosen for some of the countries in the sample as quarterly output was not available. They identify the structural shocks through recursive variable ordering and exploiting Cholesky decomposition on the reduced VAR error covariance estimates. They repeat this exercise for each country in their sample. Some of their findings include: 1) ERPT is low for those countries (mostly Asian) with single digit inflation credentials and

[3] New Zealand was the first country to popularize inflation targeting with official adoption in 1990. It has not only avoided its highly persistent and volatile inflationary past but has also achieved a low inflation environment with high output growth rates. Other countries followed New Zealand's example over the years and as of 2013 about 28 central banks explicitly target consumer prices as their main macroeconomic policy goal. Inflation targeting is not confined to the advanced industrial world; emerging and developing countries like Ghana, Brazil and Armenia have also experimented with it though the target bands are wider for these countries (6.5-10.5 percentage points in Ghana, for instance, while it is 1-3 in New Zealand). Though inflation targeting may have achieved its main mission of containing price volatility, there are several downsides to its adoption. For one thing, it requires considerable central bank independence from public policy process and monetary planners cannot target other macroeconomic objectives like employment and the exchange rate.

[4] See Taylor (2000) for a formal discussion.

[5] Their sample comprises a list of emerging and developing countries from Asia (Hong Kong, Taiwan, China, Korea, and Singapore), Latin America (Mexico, Argentina, and Chile), and Europe (Czech Republic, Poland, Hungary, and Turkey).

that this result is not dissimilar from those documented for richer economies 2) the pass through effect is close to unity after a passage of one to two year horizons for high inflation countries like Poland, Hungary, and Turkey in Europe and for all three from Latin America (Mexico, Chile and Argentina) 3) exchange rate pass through into consumer prices is generally lower than pass through into import prices. This was consistent for all countries investigated.

E. Ihrig et al. (2006) estimated a reduced form equation derived from the low of one price. Exchange rates, commodity prices, their lags and volatilities are used as explanatory variables. Both local and foreign factors are considered. They estimate import and consumer price equations for each country using quarterly data spanning the period 1975q1-2004q4. Their estimation results suggest that import price pass through from exchange rate changes significantly dropped in the periods from 1975 to 1989 and from 1990 to 2004. Moreover, exchange rate responsiveness of consumer price declined for nearly every country.

3. Methodology

Impulse responses functions (IRFs) trace out the response of current and future values of each of the variables to a one-unit increase in the current value of one of the VAR errors, assuming that this error returns to zero in subsequent periods and that all other errors are muted. The implied thought experiment of changing one error while holding the others constant makes most sense when the errors are uncorrelated across equations, so impulse responses are typically calculated for recursive and structural VARs. Because of the complicated dynamics of the VAR models, impulse response, Granger causality and forecast error variance decomposition statistics are more informative than estimated regression coefficients or some other statistic coming from the VAR (Stock and Watson, 2005).

To see how IRFs are computed, let Yt be a k x 1 vector of endogenous variables, a reduced form vector autregression (VAR) model has the following representation,

$$AY_t = c + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \ldots + \Pi_p Y_{t-p} + B\varepsilon_t$$
$$AY_t = c + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \ldots + \Pi_p Y_{t-p} + B\varepsilon_t \qquad (1)$$

where ε_t is an (K x 1) dimensional white noise process such that $\varepsilon_t \sim WN(0,\Sigma)$

c is an (K x1) vector of constants;

Π_i is an (K x K) matrix of coefficients

In assessing innovation accounting, we need to represent the finite order VAR (p) in an infinite vector moving average (VMA) form:

$$\Pi(L)Y_t = c + \varepsilon_t \qquad (2)$$

where $\Pi(L) = I_K - \Pi_1 L - \ldots - \Pi_p L^p$ and L is the lag or backshift operator. The VAR (p) is stable if and only if the roots of the characteristic polynomial equation: $\det(I_K - \Pi_1 z - \ldots - \Pi_p z^p) = 0$ lie outside the complex unit circle.

One way to compute the impulse response function is first to get moving average coefficients from the corresponding VAR process and sum up all the MA coefficient matrices over the entire period of interest. The sum of these MA coefficient matrices is known as long-run effects or total multipliers (Lutkepohl, 2011). Let

$$\Phi(L) = \sum_{i=0}^{\infty} \Phi_i L^i$$

be an operator such that

$$\Phi(L)\Pi(L) = I_n \qquad (3)$$

Pre-multiplying equation (2) by $\Phi(L)$ gives us

$$Y_t = \Phi(L)c + \Phi(L)\varepsilon_t$$
$$= \left(\sum_{i=0}^{\infty} \Phi_i\right)c + \sum_{i=0}^{\infty} \Phi_i \varepsilon_{t-i} = \mu + \sum_{i=0}^{\infty} \Phi_i \varepsilon_{t-i} \qquad (4)$$

where the mean μ is obtained as follows:

$$\mu = \Phi(1)c = \Pi(1)^{-1}c = (I_K - \Pi_1 - \ldots - \Pi_p)^{-1}c$$

The operator $\Phi(L)$ is the inverse of $\Pi(L)$ and is therefore sometimes denoted by $\Pi(L)^{-1}$. We call the operator $\Pi(L)$ invertible if $|\Pi(z)| \neq 0$ for $|z| \leq 1$. If this condition is satisfied, the coefficient matrices of $\Phi(L) = \Pi(L)^{-1}$ are absolutely summable and, hence, the process $\Phi(L)\varepsilon_t = \Pi(L)^{-1}\varepsilon_t$ is well defined (Lutkepohl, 2011). Thus the coefficients Φ_i can be obtained from equation (3) using the relations

$$I_K = (\Phi_0 + \Phi_1 L + \Phi_2 L^2 + \ldots)(I_K - \Pi_1 L - \ldots - \Pi_p L^p)$$

$$= \Phi_0 + (\Phi_1 - \Phi_0\Pi_1)L + (\Phi_2 - \Phi_1\Pi_1 - \Phi_0\Pi_2)L^2 + \ldots + (\Phi_i - \sum_{j=1}^{i}\Phi_{i-j}\Pi_j)L^i + \ldots \tag{5}$$

Lutkepohl shows that we can recover the recursive MA coefficient matrices which are the corner stone for impulse response analysis as follows:

$$\Phi_0 = \Pi_0 \tag{6.a}$$

$$\Phi_1 = \Pi_1 \tag{6.b}$$

$$\Phi_i = \sum_{j=1}^{i}\Phi_{i-j}\Pi_j, \quad \text{i= 1, 2,...} \tag{6.c}$$

The symmetric positive definite variance covariance matrix (Σ_ε) of the innovation process in equation (4) can be decpmposed into the product $\Sigma_\varepsilon = PP'$, where P is a lower triangular non-degenerate matrix with positive elements along its diagonal. As a result, equation (4) can be re-written as:

$$Y_t = \mu + \sum_{i=0}^{\infty}\Phi_i PP^{-1}\varepsilon_{t-i} = \mu + \sum_{i=0}^{\infty}\Theta_i\omega_{t-i}, \tag{7}$$

where $\Theta_i = \Phi_i P$ and $\omega_t = P^{-1}\varepsilon_t$ are white noise processes ($\Sigma_\omega = I_K$) which have uncorrelated componets and are known as orthogonal residuals or innovations. Thus the optimal h-step ahead forecast error of the K-dimensional Y_t is:

$$Y_{t+h} - Y_t(h) = \sum_{i=0}^{h-1}\Theta_i\omega_{t+h-i} \tag{8}$$

As the orthogonal innovations ($\omega_{k,t}$'s) are uncorrelated and have unit variances, the mean square error (MSE) of the jth component, $y_{j,t}(h)$, is computed by using the formula:

$$\mathrm{E}(y_{j,t+h} - y_{j,t}(h))^2 = \sum_{k=1}^{K}(\theta_{jk,0}^2 + \ldots + \theta_{jk,\mathrm{h}-1}^2). \tag{9}$$

Equation (9) measures the contribution of the innovations originating from variable k to the overall MSE or forcaste error variability of variable j. The over all MSE in forecasting variable j is the sum of the contributions of all K endogenous variables in the system:

$$\mathrm{MSE}[\mathrm{y}_{j,t}(h)] = \sum_{i=0}^{h-1}\sum_{k=1}^{K}\theta_{\mathrm{jk},i}^2 \tag{10}$$

The ratio of (9) to (10) gives us the proportional contributions of each innovation in the h-step forecast.

3.1 SVAR Identification

To impart economic content[6] to the shocks that drive changes in endogenous variables, we should place certain restrictions on matrix A, matrix B or both. For instance, a bivariate[7] structural system of order one derived from equation (1) has 10 parameters to be estimated while its reduced form counterpart has only 9 and the SVAR is not identified. To undertake IRF and FEVD analyses, we must impose restrictions on some of the coefficients of the contemporaneous correlation matrix B. Sims (1980) suggests that the structural VAR error covariance matrix be decomposed into PP' using the so called Cholesky factorization where P is a lower triangular matrix. IRFs derived from the application of Cholesky decomposition are known as orthogonalized IRFs. A standard VAR model can be taken as the reduced form representation of a dynamic structural equation, and the lower triangular matrix P can be obtained by reorienting the structural system into a recursive representation. The orders in which the endogenous variables appear in the VAR model establish the recursive structure which in turn bears our Cholesky decomposition.

We can define an SVAR model by modifying the expression given in equation(1):

$$AY_t = c + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \ldots + \Pi_p Y_{t-p} + B\varepsilon_t \tag{11}$$

The (KxT) dimensional structural error terms, ε_t , are assumed to be white noise processes and are independent of each other. This independence assumption is critical in the identification exercise described below. The coefficient matrices Π_i for each i = 1, . . . , p, represent coefficients of the structural model which potentially differ from coefficient matrices of the corresponding reduced form model.

By left-multiplying the preceding equation by the inverse of A and replacing the resulting constant term and coefficient matrices by alpha and phi's we get:

$$Y_t = A^{-1}c + A^{-1}\Pi_1 Y_{t-1} + A^{-1}\Pi_2 Y_{t-2} + \ldots + A^{-1}\Pi_p Y_{t-p} + A^{-1}B\varepsilon_t \tag{12}$$

$$Y_t = \alpha + \Theta_1 Y_{t-1} + \Theta_2 Y_{t-2} + \ldots + \Theta_p Y_{t-p} + u_t \tag{13}$$

with $\Theta_i = A^{-1}\Pi_i$ for all i=1,...p.

We must impose restrictions on the matrices A or B or both in order to conduct impulse response and forecast error variance decomposition within the SVAR framework. In other words, the structural model differs from the reduced form model in so far as we place restricttions on the appropriate forms of residual covariance matrix coefficients A and B. As a result, the residuals of the reduced form model can be recovered from the corresponding structural VAR model using:

$$u_t = A^{-1}B\varepsilon_t \,.$$

where

$$u_t=\begin{bmatrix} u_{o,t} \\ u_{e,t} \\ u_{g,t} \\ u_{m,t} \\ u_{p,t} \end{bmatrix}, \qquad \varepsilon_t=\begin{bmatrix} \varepsilon_{o,t} \\ \varepsilon_{e,t} \\ \varepsilon_{g,t} \\ \varepsilon_{m,t} \\ \varepsilon_{p,t} \end{bmatrix}, \qquad A^{-1}=\begin{bmatrix} \psi_{1,1} & \psi_{1,2} & \psi_{1,3} & \psi_{1,4} & \psi_{1,5} \\ \psi_{2,1} & \psi_{2,2} & \psi_{2,3} & \psi_{2,4} & \psi_{2,5} \\ \psi_{3,1} & \psi_{3,2} & \psi_{3,3} & \psi_{3,4} & \psi_{3,5} \\ \psi_{4,1} & \psi_{4,2} & \psi_{4,3} & \psi_{4,4} & \psi_{4,5} \\ \psi_{5,1} & \psi_{5,2} & \psi_{5,3} & \psi_{5,4} & \psi_{5,5} \end{bmatrix} \text{ and}$$

$$B=\begin{bmatrix} \lambda_{1,1} & 0 & 0 & 0 & 0 \\ 0 & \lambda_{2,2} & 0 & 0 & 0 \\ 0 & 0 & \lambda_{3,3} & 0 & 0 \\ 0 & 0 & 0 & \lambda_{4,4} & 0 \\ 0 & 0 & 0 & 0 & \lambda_{5,5} \end{bmatrix}$$

And its variance is computed as $\Sigma_u = \text{var}(A^{-1}B\varepsilon_t) = A^{-1}B\,\text{var}(\varepsilon_t)B'A^{-1'} = A^{-1}BB'A^{-1'}$ where we have assumed that the structural error process has a k dimension identity matrix as its variance covariance matrix.

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[6] Without theoretical guidance which would help establish some kind of causal relationships within the system, the task of identification can be quite an elusive exercise. For example, if one wishes to construct a structural VAR with five variables, there will be 5! (120) possible permutations and deciding the correct ordering of the variables will become tricky.

[7] The bivariate VAR(1) system has the form $\begin{bmatrix} 1 & a_{12} \\ a_{21} & 1 \end{bmatrix}\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} c_{10} \\ c_{20} \end{bmatrix} + \begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix}\begin{bmatrix} y_{1t-1} \\ y_{2t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$, and has 10 unknown parameters (two constants, four auto-regressive coefficinets, three elements in the symetric error variance-covariance matrix, and the two contemporaneous impact parameters on the left hand side (LHS) of the system. The reduced form system has no LHS parameters and provides 9 parameters.

In the Cholesky decomposition employed below, supply factors are most exogenous as a small open economy like Ethiopia has littltle or no leverage on international commodity (including petroleum) price movementss. Thus, world energy price is independent and is not contemporaneously affected by changes in other variables. This amounts to imposing four restrictions on the last four entries of the first row in matrix A. The data generating process is described as:

$$u_{o,t} = \varepsilon_{o,t} \tag{14}$$

The behaviour of the exchange rate is assumed to respond to multiple factors which cannot be more directly influenced by the decisions of monetary authorities in Ethiopia. So the exchange rate should appreciate with substantial inflow of foreign aid and remittances (which depend on economic conditions in the West) or with rise in foreign exchange reserves from improvements in the country's terms of trade. Conversely, we should expect significant depreciation over time when foreign capital inflow is decling, say, because of catastrophic global financial and economic crises that disrupt capital mobility to the developing world. Equation (15) summarises the behavior of the exchange rate shock which responds simultaneously to energy price shock but is not affected by the shocks originating from other variables:

$$u_{\mathrm{e},t} = \psi_{2,1}\varepsilon_{o,t} + \varepsilon_{e,t} \tag{15}$$

As in Mwase[8] (2006), demand factors precede the monetary measure. The consumer price is the most endogenous variable and appears last in the recursive representation. Previous studies that have ordered price changes last in the structural equation include Ito and Sato[9] (2007), McCarthy (2006), Moshin et al. (2012) and Sanusi (2010). Equations (16) to (18) define the structural dynamic relationships for public spending, money growth and domestic price shocks, respectively.

$$u_{\mathrm{g},t} = \psi_{3,1}\varepsilon_{o,t} + \psi_{3,2}\varepsilon_{e,t} + \varepsilon_{e,t} \tag{16}$$

$$u_{\mathrm{m},t} = \psi_{4,1}\varepsilon_{o,t} + \psi_{4,2}\varepsilon_{e,t} + \psi_{4,2}\varepsilon_{\mathrm{g},t} + \varepsilon_{\mathrm{m},t} \tag{17}$$

$$u_{\pi,t} = \psi_{5,1}\varepsilon_{o,t} + \psi_{5,2}\varepsilon_{e,t} + \psi_{5,3}\varepsilon_{\mathrm{g},t} + \psi 4\varepsilon_{\mathrm{g},t} + \varepsilon_{\pi,t} \tag{18}$$

As a result, the exactly identified model to be estimated takes the form defined by equation (19).

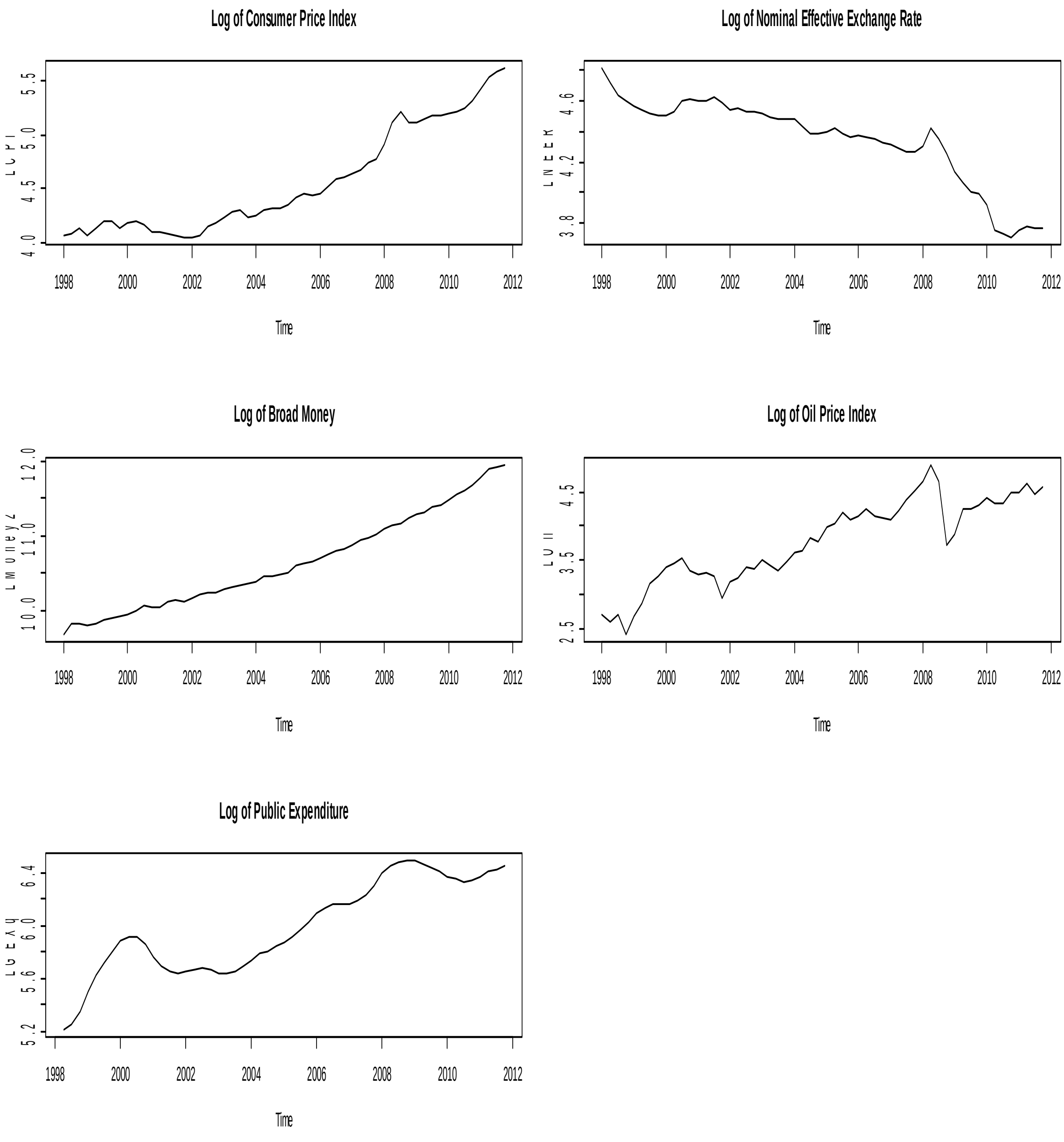
$$\begin{bmatrix} u_{o,t} \\ u_{e,t} \\ u_{g,t} \\ u_{m,t} \\ u_{p,t} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \psi_{2,1} & 1 & 0 & 0 & 0 \\ \psi_{3,1} & \psi_{3,2} & 1 & 0 & 0 \\ \psi_{4,1} & \psi_{4,2} & \psi_{4,3} & 1 & 0 \\ \psi_{5,1} & \psi_{5,2} & \psi_{5,3} & \psi_{5,4} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{o,t} \\ \varepsilon_{e,t} \\ \varepsilon_{g,t} \\ \varepsilon_{m,t} \\ \varepsilon_{p,t} \end{bmatrix} \tag{19}$$

[8] Mwase's paper on Tanzania does not consider supply side factors arguing that the most promising candidate, world oil price, is not the appropriate proxy as it is substantially subsidised by the government. But a measure of demand-side factor represented by Hodrick-Prescott-filtered output gap is ordered before the monetary aggregate. Unlike Mwase who assumes that money demand reacts to inflation, in Ethiopia it is wideley believed that the behaviour of general price level is driven by money growth which is in turn influenced by the governmet's higly interventionist spending needs.

[9] The set up implemeted in this study closely mimics the style followed by Ito and Sato (2007) where they examine pass through effects in a post-crisis environment in a host of Latin American and Asian economies. They consider oil price, trade weighted exchange rate, output gap, money supply measure, consumer price, producer price, and import price. The last two prices are not conidered here because of the lack of long, reliable data points for these indices. However, instead of a filtered output gap, I have chosen to use government expenditure to proxy demand shocks. This is quite sensible as the public sector plays a very decisive role in Ethiopia through massive spending programms with the potential to move real and nominal aggregate variables by wide margins.

4. Discussion of Results[10]

Figure 1: The Logarithm of Each Quarterly Series Plotted against Time



Visual inspection can provide rough insights into the temporal properties of the raw data.[11] The plots of the natural log-transformed series are provided in Figure 1. Most of the series appear to be non-stationary. The consumer price index, government expenditure, and broad money supply exhibit clear, persistent, and increasing trend while the

[10] Most of the time series analysis was done using R which is a freely accessible software programming language widely used for statistical computation and graphics. The latest version (R 3.0.3) can be downloaded from the project's website available at http://cran.r-project.org/.

[11] The data were collected from several sources: money stock (in millions of Birr) and price series are from the National Bank of Ethiopia (NBE). The exchange rate is from the Ethiopian Development Research Institute while quarterly world oil price was adapted from the monthly West Texas crude oil price. Government expenditure was interpolated/forecast from annual observations using the Chow-Lin generalized least square method.

trade weighted nominal exchange rate is declining over time. It is not obvious what type of path is being followed by international oil price though at first glance a fuzzy upward trend is apparent. The nominal exchange rate has been steadily and sharply depreciating, especially over the past decade.

The basic summary statistics computed based on the natural log-transformed data are given in Table A.1. The log of the nominal effective exchange rate of birr registered a minimum value of about 3.7 in the late period of the sample and was more than twice as large (4.8) early in the sample period which is quite consistent with the long-term depreciating trend of birr against the currencies of Ethiopia's key trading partners.

The highest variability as proxied by the respective standard deviation for each log series was observed in broad money supply (0.641), which was more than twice as volatile compared with the trade weighted exchange rate (0.29). World oil price showed the same degree of volatility as broad money while government expenditure and consumer price changes exhibited closely similar fluctuation.

The unit root tests based on standard ADF[12] method suggest all series contain unit roots except public spending which is trend stationary in levels. The results are shown in Table A.2. As a result the estimation of the VAR system (output included in appendix section) and the attendant innovation acccounting analysis make use of all first differenced series with the exception of government expenditure which is in levels. The automatic information criteria[13] for lag selection suggested an optimal lag length of 8. But the VAR system based on 8 lags could not pass major diagnostic checks even though the estimated model fits the data quite neatly. To overcome this problem, I implemented a specific-to-general procedure in choosing the optimal lag length by estimating systems with lag orders from one to four which are then compared with the model suggested by the information criateria.

The test scores for these models are shown in Tables A3 and A4 (see Appendix section). In Table A4 the multivariate versions of model diagnostic test results for heteroskedatsicty, serial correlation, and normality are presented. The estimated model residuals pass all diagnostic checks in VAR (1), VAR (2), and VAR (3). Clearrly model VAR (8) does not satisfy any of the diagnostic checks while model VAR (4) fails to pass the sniff test of serial correlation. Finally, I decided to proceed with VAR (1) even though VAR (2) and VAR (3) are equally qualified--for two main reasons. First, overparametrization is avoided through parsimony. Second, as shown in Table A3, VAR (1) is favoured by BIC which is robust against small sample bias.

4.1 Impulse Response and Forecast Error Variance Analyses

The CUMSUM of the residuals (provided in the appendix) confirms that structural break is not an issue as the model errors are well behaved and the SVAR is estimated based on the VAR((1). The identified structural relationships decsribed in equations (14) to (18) are shown stated in equations (20) to (22). As seen in the last expression, most of the variables have the expected sign.

$$u_{\mathrm{o},t} = 0.0238\varepsilon_{\mathrm{o},t} \tag{20}$$

$$u_{\mathrm{e},t} = 0.0166\varepsilon_{\mathrm{o},t} + 0.0464\varepsilon_{\mathrm{e},t} \tag{21}$$

$$u_{\mathrm{g},t} = 0.0203\varepsilon_{\mathrm{o},t} + 0.0020\varepsilon_{\mathrm{e},t} + 0.0356\varepsilon_{\mathrm{g},t} \tag{22}$$

$$u_{\mathrm{m},t} = 0.47e-04\varepsilon_{\mathrm{o},t} + 0.0049\varepsilon_{\mathrm{e},t} + 0.0054\varepsilon_{\mathrm{g},t} + 0.0275\varepsilon_{\mathrm{m},t} \tag{23}$$

$$u_{\pi,t} = 0.0246\varepsilon_{\mathrm{o},t} + 0.0198\varepsilon_{\mathrm{e},t} + 0.01163\varepsilon_{\mathrm{g},t} - 0.0029\varepsilon_{\mathrm{m},t} + 0.0441\varepsilon_{\pi,t} \tag{24}$$

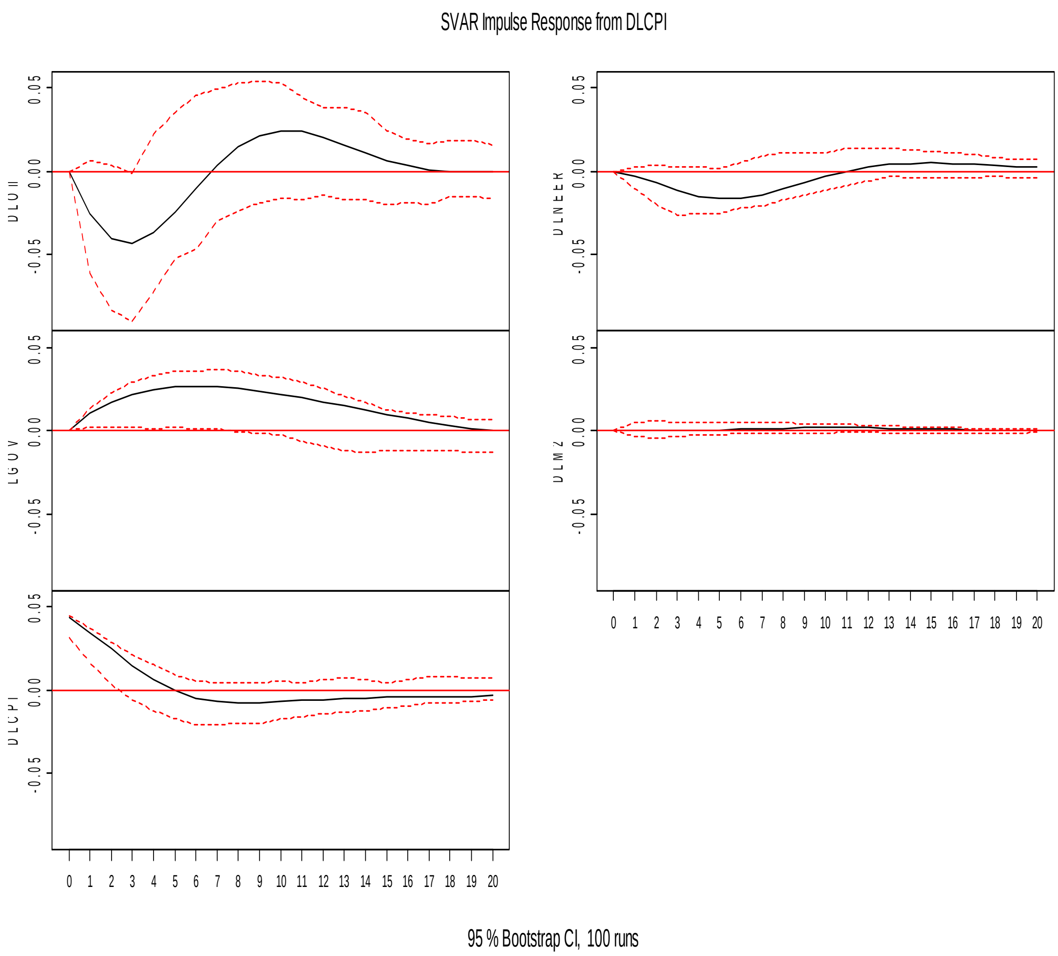
[12] Given a time series x, the ADF test for the existence of regular unit root is implemented by estimating $\Delta x_t = \alpha + \beta t + \phi x_{t-1} + \sum_{i=1}^{k-1} \gamma_i sd_i + \sum_{j=1}^{p} \delta_i \Delta x_{t-j} + \varepsilon_t$ by OLS. Depending on the data generating process under consideration, deterministic terms like drift (α), time trend (t) and/or seasonal dummies (sd) maybe included in the regression equation. The null hypothesis of unit root corresponds to testing whether the coefficient on the lagged variable (ϕ) is significantly different from zero.

[13] The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) suggested an optimal lag length of 9 each while the Forecast Prediction Error (FPE) selected a lag order of 8.

Table 1: Accumulated Impulse Response of General CPI Inflation to Exchange Rate

	DLOil	DLNEER	GOV	DLM2	DLCPI
Q [1]	0.0000	0.0000	0.0000	0.0000	0.0441
Q [2]	-0.0261	-0.0028	0.0102	0.0003	0.0791
Q [4]	-0.1096	-0.0218	0.0497	0.0006	0.1188
Q [8]	-0.1781	-0.0841	0.1536	0.0030	0.1138
Q [14]	-0.0588	-0.0997	0.2767	0.0129	0.0747
One SD Shock	0.2380	0.0464	0.0356	0.0275	0.0441

Figure 2: Impulse Response Function for General Consumer Price Inflation



Innovation accounting from the resulting SVAR was performed to trace out the impact of a one-time unit shock in one variable on the trajectory of other variables over time.

The impulse response function results are displayed in Figure 2. Consistent with theoretical prediction an appreciation[14] of the nominal effective exchange rate exterts downward preassure on domestic price changes in the medium term. But this effect is quite weak and quickly tapers off over the medium term (about four years). As shown in Table 1, a one standard deviation shock to the exchange rate (equal to 4.5 percent) causes the overall cumulative consumer price inflation to fall by 0.28 percent after two quarters or by 9.97 percent after 14 quarters, which correspond to an impact and dynamic pass-through elasticity[15] of 0.06 and 2.14, respectively. This means that exchange rate appreciation has negative but small effect on inflation through out the sample period. As a result, exchange rate pass-through into domestic prices in Ethiopia is incomplete and inconsequential.

Increased government consumption and invetsment spending has little impact on general consumer price inflation in the first few quarters. The early trivial effect on prices maybe due to the fact that initially massive development projects and programmes sponsored by the government are associated with overcoming supply side bottlenecks. This implies that productivity gains and improved trade and exchange in the private sector can greatly benefit from increased provision of power, transportation facilities, and targeted spending on education and health. However, in the long run, large and indiscriminate public spending can be hostage to a host of factors including rent seeking and embezzlement, which is particularly the case when so many projects involve so many heirarchical transactions. As a result, the government's spending programmes only end up compunding price pressures without solving business constraints.

Figure 2 also shows that in the short run, world energy price increase has a contractionary effect initially causing consumer price inflation to fall by a significant amount. This can be attributed to the substantial oil price subsidies of the government that absorb much of the oil price impact away from the shoulders of consumers. It could also be the case that households and firms resort to alternative energy sources (using charcoal rather than gas or choosing public trasnportation over driving own car) that could potentially reduce heavy reliance on imported oil. But in the long run, global energy price surge exerts strong upward pressure on inflation as oil subsidies are replaced by other spending priorities causing business establishemnets to shift the final burden onto consumers.

Table 2: Forecast Error Variance Decomposition (FEVD) for Inflation (DLCPI)

	DLOil	DLNEER	LGOV	DLM2	DLCPI
Q[1]	0.196	0.127	0.044	0.003	0.630
Q[4]	0.407	0.079	0.023	0.021	0.470
Q[8]	0.403	0.089	0.064	0.023	0.421
Q[12]	0.422	0.082	0.080	0.026	0.391
Q[16]	0.416	0.089	0.080	0.028	0.386

Table 2 presents the results from the forecast error variance decomposition exercise. In the first quarter, own shock explains about 63 percent of the forecast error variance of inflation followed by world energy price (20 percent) and the exchange rate (13 percent). A one-off disturbance to the broad money growth rate contributes about 3 percent in the same period. After 4 quarters, the contribution of own shock to consumer price inflation forecast variability drops to 47 percent while that of the trade weighted nominal exchange rate to 8 percent. The only variable that shows significant increase after the passage of one year is world oil price (which rises to 41 percentage points). As time goes by, there is a general convergence pattern in which shocks to energy prices (42 percent) and consumer price changes (38 percent) together contribute about 80 percent of the variability in inflation.

One striking result both from the impulse response and the forecast error variance analyses is that money stock growth has trivial contribution and this behaviour remained consistent througout the period. The muted impact of money

[14] Normally the value of a domestic currency is expressed per unit of its foreign counterpart. The NEER was constructed using Ethiopia's national currency as a base and the currencies of trading partners as its prices. As a result, in this specific arrangement, an increase in the exchange rate implies appreciation of the local currency.

[15] The impact/dynamic elasticity is computed using the formula $\eta_E^p = \frac{\%\Delta P_t}{\%\Delta E_t}$, where the numerator indicates the percentage change in the cosumer price index between period 0 (when the shock occurs) and the current time period t. The denominator is equal to the percentage change in the specific shock of interest (to the exchange rate in our case) in period 0.

growth on general consumer price inflation seems to validate the hypothesis that the process of monetization in Ethiopia primarily serves to cushion fiscal deficits[16].

4.2Sectoral Pass-through[17]

Table 3: Sectoral Impulse Response to Trade Weighted Exchange Rate Shock

Period	Food	Non-Food	Housing	Health	Clothing	Recreation	Personal	Furniture	Transport
Q [1]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Q [2]	-0.0034	0.0040	-0.0073	-0.0041	-0.0059	0.0106	0.0071	0.0044	0.0140
Q [4]	-0.0130	-0.0309	-0.0182	-0.0178	-0.0174	0.0047	-0.0233	0.0025	-0.0020
Q [8]	-0.0164	0.0075	0.0150	-0.0112	-0.0058	0.0140	-0.0120	-0.0075	-0.0012
Q [12]	-0.0053	0.0003	0.0006	0.0036	0.0008	0.0064	0.0087	-0.0031	0.0045

The sectoral impulse responses to the exchange rate shock are displayed in Table 3[18]. Price changes in all sectors respond after the lapse of two quarters. Sectors that tend to have substantial import contentent (clothing and medicine/health, for example,) experience a faster degree of exchange rate transmission. For instance, a year after the occurrence of the exchange rate shock, a 10 percent appreciation leads to a 1.8 percent decline in health sector inflation and a 1.7 percent decline in clothing sector inflation. By contrast sectors that are relatively insulated from imported competition, such as furniture and recreation, have slower pass-through effect. Specifically, a 10 percent appreciation in the nominal effective exchange rate causes prices to increase by less than 0.5 percent in each sector after the passage of a year (four quarters). The furniture sector shows the conventional sign following a lag of two years while the recreation sector shows persistently positive reaction to exchange rate appreciation. Similarly, the transport sector displays a weak response which might reflect the dampening effects of state subsidies on fuel prices that tend to have significant bearing on the transportation service sector mainly due to economies of scale. Regarding the major food versus non-food classification, a 10 percent appreciation resulsts in a 0.34 percent drop in food price inflation after two quarters and a 3.1drop in non-food pric inflation after four quarters. The relatively weaker response of the former could be due to Ethiopia's reduced reliance on imported food items recently--either because of increased home production or because of a shift to cash in foreign food aid delivery.

Table 4: The Contribution of Exchange Rate to Sectoral Forecast Error Variability

Period	Food	Non-Food	Housing	Health	Clothing	Recreation	Personal	Furniture	Transport
Q [1]	0.0658	0.0003	0.0031	0.0198	0.0161	0.0337	0.0186	0.0070	0.0226
Q [2]	0.0506	0.0011	0.0131	0.0133	0.0117	0.0382	0.0324	0.0341	0.0141
Q [4]	0.0309	0.0471	0.0176	0.0144	0.0076	0.0553	0.0327	0.0319	0.0696
Q [8]	0.0600	0.1726	0.0386	0.0342	0.0538	0.1271	0.0307	0.1565	0.2037
Q[12]	0.0720	0.1812	0.0611	0.0501	0.0834	0.1462	0.0252	0.1723	0.1816

Remarks: Q refers to quarterly period. Numbers have been rounded to fourth decimal precision to save space.

[16] In an African Development Bank(AfDB) brief report produced by Gurara et al. (2012), the authors attempt to disentangle the determinants of inflation in the short and long run horizons in four East African economies-Ethiopia, Kenya, Uganda ,and Tanzania. In the case of Ethiopia, they conclude that money is the most important force that drives inflation in the short run, accounting for about 40 percent of the variability in inflation followed by world oil price (27 percent) and world food price (13 percent). They allude that one key channnel through which money creation might have impacted price developments in Ethiopia is through National Bank of Ethiopia (NBE)'s purchase of government bonds and artisan gold supplies which they suggest could have played the role of quantitative easing. The idea is that increased base money finances budget deficits and thereby affect prices indirectly through the public sector. It is not obvious why the authors did not want to consider public spending as one of the major sources of price volatility in their analysis.

[17]In order to save space I have used short hand forms for sectoral categories of the CPI as follows: clothing and footwear (Clothing); house rent, construction material, water, fuel, and electricity (Housing); furniture, furnishing household equipment, and operation (Furniture); medical care and health (Health); transport and communication (Transport); recreation, entertainment, and education (Recreation); personal care and effects (Personal). Food and Non-food categories are also considered but three components, miscellaneous, drinks, and tobacco, have been excluded as they constitute insignificant fractions.

[18] The IRF and FEVD for each sector are derived from the corresponding SVAR specification in which constant is included in the reduced vector auto-regression. The housing price index was differenced twice as it was found to be integrated of order two. The optimal lag length for all sectors was two except the specification for the recreation sector which required an optimal lag length of three and the food sector for which a lag length of one was sufficient to ensure well-behaved model errors.

The forecast error variance decomposition provides alternative yet complementary framework to impulse response function analysis in tracking the dynamic behaviour of our endogenous variables. As presented in Table 4 above, consistent with the impulse response results, exchange rate has more predicive power in the forecast error variability of the non-food sector price development than that of the food sector. Aftr 12 quarters (3 years), the contribution of the exchange rate to the forecast error variance of the food sector is only about 7 percent while for the non-food sector the corresponding figure is 18 percent. For the same horizon, the contribution is the least in personal care (2.5%), health (5%), and housing (6%)—sectors which have relatively low import content or which have significant public subsidies.

5. Conclusion

This paper employs recursive structural vector auto-regression (SVAR) to study exchange rate pass-through into domestic consumer price inflation in Ethiopia. The study utilizes quarterly data spanning out the period from 1997.3 to 2011.4. Innovation accounting from the resulting SVAR was performed to trace out the impact of a one-time unit shock in one variable on the trajectory of other variables over time. The impulse response function analysis indicates that nominal effective exchange rate plays an important but short-lived role in affecting consumer price developments in Ethiopia. In particular, a unit change in the trade weigheted exchange rate (appreciation) caused the consumer price inflation to fall by about 0.01 after four quarters (or an accumulated response of about 0.11 after 14 quarters). As a result, exchange rate pass-through into domestic prices in Ethiopia is incomplete and inconsequential. The forecast error variance decomposition exercise shows own shock explains about 63 percent of the forecast error variability of inflation followed by world oil price (20 percent) and exchange rate (13 percent). Monetary aggregate has triavial effect for all horizons considered.

The potential policy recommendations that follow from this empirical exercise are twofold: 1) given the low exchange rate pass-through into general and sectoral components of CPI inflation, the monetary authorities in Ethiopia would rather not put much weight on exchnage rate as an instrument to arrest inflation or improve the country's current account positions. All available evidence shows that the external sector has exhibited peristent deficit since greater flexibility of the exchange rate was introduced in early 1990s and domestic inflation has been steadily on the upsurge. Periodic devaluation is not the ideal remedy for an economy with heavy reliance on imports and limited export base. 2) The results show that money was almost neutral throughout and public expenditure was relatively more powerful. This suggests that government spending is one major potential channel through which monetary expansion affects employment, production, and prices in the short-run. It is therefore important to sift out fiscal priorities and ensure through active monitoring that wasteful spending is minimized. The governemnt may consider tying budget deficits to capital investment needs to achive fiscal dscipline without compromising on much needed investment while at the same time restraining pressures on prices.

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Appendix

Table A1: Summary Statistics

	LOil	LM2	LCPI	LGOV	LNEER
Minimum	2.43	9.69	4.04	5.17	3.70
1st Qu.	3.34	10.12	4.17	5.67	4.27
Median	3.80	10.50	4.34	5.92	4.41
Mean	3.77	10.65	4.56	5.97	4.34
3rd Qu.	4.27	11.14	5.11	6.33	4.53
Maximum	4.90	11.96	5.62	6.52	4.81
SD	0.62	0.64	0.49	0.37	0.29

Table A2: ADF Unit Root Test Results in Levels and Differences

		Levels		Differences		
Variable	Lag	Statistic	95 Critical	Lag	Statistic	95 Critical
LGEX	1	-3.87	-3.45			
LCPI	1	-1.04	-3.45	1	-5.41	-2.89
LMoney2	1,2	1.42	3.45	0	-8.14	-2.89
LOil	0	-2.05	-3.45	0	-6.85	-1.95
LNEER	1	-1.98	-3.45	0	-4.88	-2.89

Table A3: Model Selection

	VAR(1)	VAR(2)	VAR(3)	VAR(4)	VAR(8)
LR	414.4	457.2	476.9	522.3	812.5
AIC	-758.8	-794.5	-783.8	**-824.6**	-1214.9
BIC	**-689.8**	-677.4	-619.6	-614.3	-840.1

Remarks: the Likelihood Ratio (LR) measures the likelihood (sic) that the data have been observed for a given parameter set. The largest positive number (or the smallest negative number in absolute value) suggests the best fit. Conversely, the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) minimize the prediction mean square errors. As a result, the best model is the one associated with the smallest positive number (or the largest negative number in absolute value).

Table A4: Diagnostic Test

Test	VAR (1)	VAR (2)	VAR (3)	VAR (4)	VAR (8)
Serial Correlation	0.288	0.393	0.087	0.000	0.000
Heteroskedasticity	1.000	1.000	1.000	1.000	1.000
Normality	0.313	0.987	0.993	0.964	0.000
Skewness	0.548	0.318	0.922	0.966	0.012
Kurtosis	0.181	0.878	0.972	0.757	0.000

Remarks: all numbers in the table are p values. The null hypothesis in each case is that the model errors are not serial correlated, are homoskedastic, and follow normal distribution. The methods employed are the multivariate versions of Portmanteau asymptotic, autoregressive conditional heteroskedasticity (ARCH), and Jarque Bera tests, respectively.

Figure A1: Actual, Fitted and Model Error Values of the General Inflation Equation

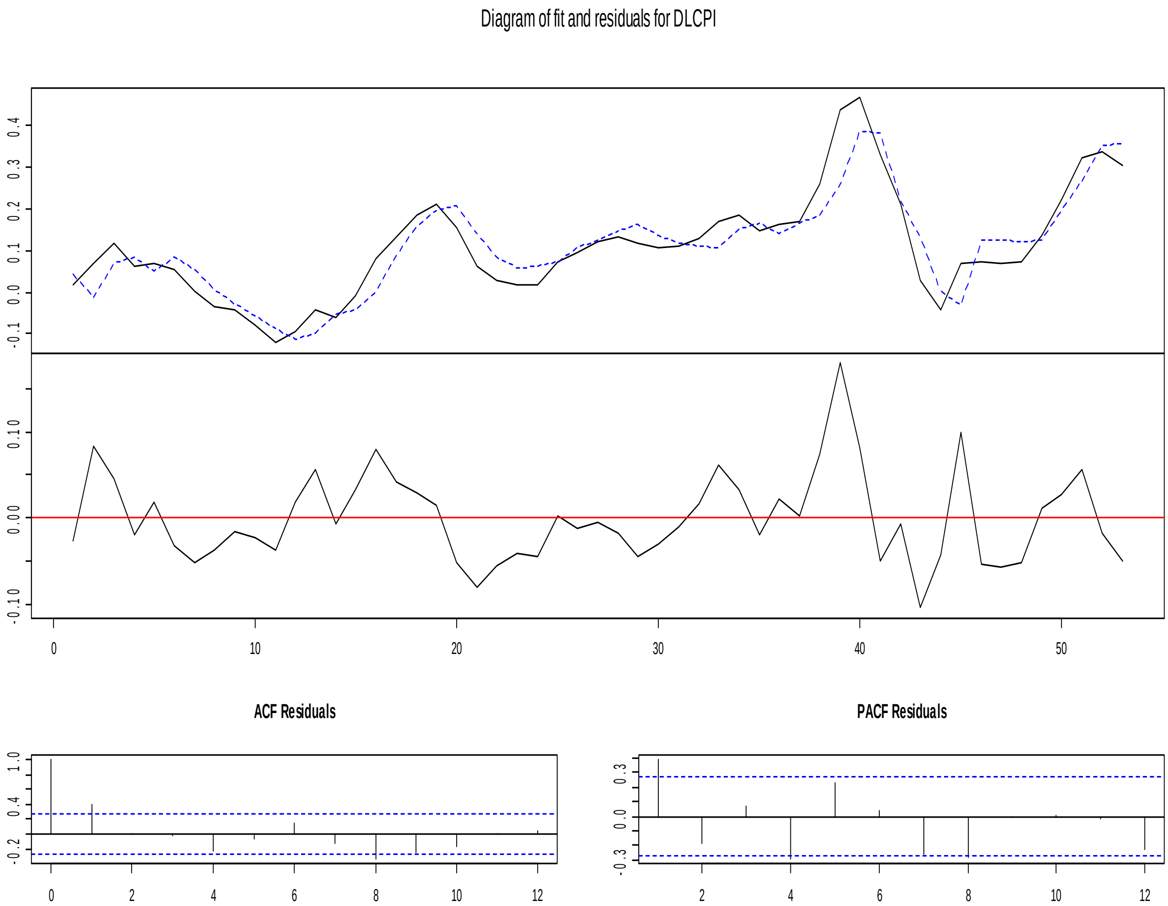

Figure A2: Ordinary Least Square Cumulative Sum Plots of Model Residuals

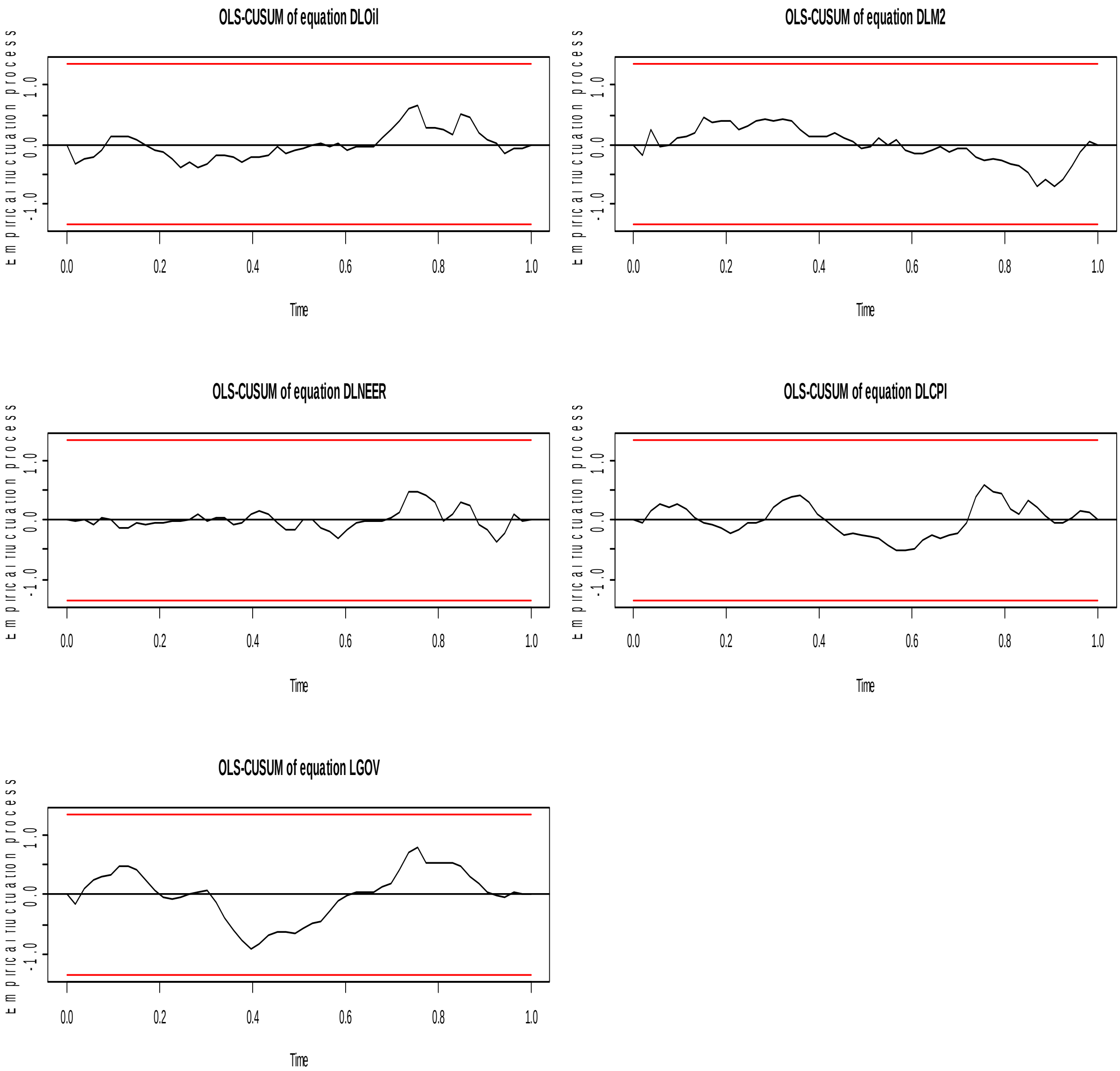

Figure A3: Diagnostic Plots of Residuals of the Inflation Equation