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## Article

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*Suggested Citation:* Sheferaw, Henok Ezezew; Sitotaw, Kalid Wendimnew (2023) : Empirical investigation of exchange rate transmission into general inflation level in Ethiopia – SVAR approach, Cogent Business & Management, ISSN 2331-1975, Taylor & Francis, Abingdon, Vol. 10, Iss. 2, pp. 1-28,  
<https://doi.org/10.1080/23311975.2023.2243662>

This Version is available at:

<https://hdl.handle.net/10419/294569>

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**To cite this article:** Henok Ezezew Sheferaw & Kalid Wendimnew Sitotaw (2023) Empirical investigation of exchange rate transmission into general inflation level in Ethiopia – SVAR approach, Cogent Business & Management, 10:2, 2243662, DOI: [10.1080/23311975.2023.2243662](https://doi.org/10.1080/23311975.2023.2243662)

**To link to this article:** <https://doi.org/10.1080/23311975.2023.2243662>



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Published online: 09 Aug 2023.



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Received: 02 June 2023  
Accepted: 26 July 2023

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## BANKING & FINANCE | REVIEW ARTICLE

# Empirical investigation of exchange rate transmission into general inflation level in Ethiopia – SVAR approach

Henok Ezezew Sheferaw<sup>1\*</sup> and Kalid Wendimnew Sitotaw<sup>2</sup>

**Abstract:** Examining the extent of exchange rate pass-through (ERPT) to domestic prices has substantial significance for policymaking given the ongoing devaluation of the Ethiopian currency. This study aimed to investigate the impact of exchange rate pass-through (ERPT) on domestic prices in Ethiopia between 1975 and 2020, using recursive structural vector autoregressive (SVAR) analysis. The results revealed that a unit change in the nominal effective exchange rate (appreciation) was associated with a reduction of 0.059 in consumer prices after 1 year, indicating that ERPT to domestic inflation in Ethiopia is significant, but incomplete and temporary. Additionally, impulse response and variance decomposition analyses revealed that government expenditure and international energy prices had an expanding effect on domestic prices. Therefore, the policy implications of the study include measures to stabilize and control the exchange rate, promote domestic production, reduce reliance on imported goods, and explore alternative energy sources and transportation methods.

**Subjects:** Development Policy; Economics and Development; Economics;

**Keywords:** ERPT; domestic price; SVAR; Ethiopia

## 1. Introduction

The rise in global economic integration has been accompanied by the idea that macroeconomic variables in a given country are expected to increasingly be affected by the events happening in



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Henok Ezezew Sheferaw (MSc) is a lecturer in the department of Economics at Woldia University, Ethiopia. I received my B.A. degree from Bahir Dar University and my MSc degree in development economics from Gondar University, Ethiopia. My major research interests include exchange rate policy, sustainable development, firm performance, inclusive growth, income inequality, international trade, aid effectiveness in developing countries, and industrialization in Africa. I am an expert in quantitative research methods. My econometric skills include applied cross-sectional, time series, panel data analysis, and so on.

the rest of the world. Indeed, the intensification of international economic and financial integration (globalization) should mean that the economic and financial disruptions that occur in one economy are more likely to be transmitted to another economy than was the case before. This helps to understand why globalization has become a primary concern for both academics and policymakers. Indeed, there has been an intensification of debate, research programmes and political agendas to understand the different influences of globalization on national economies and their management (Revelli, 2020).

Economic theory suggests that the key elements of a monetary policy framework, such as inflation and how its effects are transmitted, may be affected by the global integration of financial and goods markets through different channels (Kaneez, 2013). Globalization affects the structure and functioning of the financial and economic environments in which monetary policy operates. Thus, the conduct of monetary policy is also influenced, given that the relative importance of the channels through which monetary policy is transmitted can vary. In an integrated economic environment, shocks can be easily and quickly transmitted across borders as long as the links between the real variables have implications for the nominal ones. That is why it is important to understand the implications of globalization for monetary policy (Revelli, 2020).

One of the many influences that globalization can have on monetary policy is imported inflation. The idea that price inflation is caused by exchange rate depreciation mainly originates from “structuralist” economists who believe that export earnings in developing countries are generally not enough to finance imported capital and intermediate goods, which play an essential part in their development process. The lack of foreign exchange reserves and the high demand for imported goods inevitably lead to exchange rate depreciations and a resulting rise in the price of imported goods. The inflationary process will become self-perpetuating when the initial rise in the price of imported goods triggers a wage-price spiral (Nell, 2000).

Ethiopia’s economy is heavily reliant on imported products for domestic consumption as well as primary commodity exports and foreign aid to develop reserves (Alemu & Lee, 2015). This means that the country’s internal inflation and external sector performance are highly subject to foreign monetary developments, particularly the volatility of the local currency against the currencies of its key trading partners (Tuzcuoğlu, 2020). Furthermore, the Birr has been continuously depreciating since 2007/08, which translates into increasing import costs for goods and services, culminating in internal inflation (Zewdu, 2014).

In Ethiopia, after the fall of communist governance in 1991, the government took numerous reforms. As part of this overall reform program, on 1 October 1992, the Ethiopian Birr was devalued from its nominal position of 2.07 Birr per US Dollar to 5.00 Birr per US Dollar, i.e., depreciation by about 142%, and in 2009/10 and 2010/2011, the Ethiopian Birr was devalued by 23.7% and 16.5%, respectively, against the US Dollar (Hunegnaw, 2012). This huge devaluation was expected to “decrease overvaluation and increase competitiveness” (MOFED, 2009 cited in Alamneh & Malebo, 2021). After the massive devaluation of 1992, the Ethiopian Birr has consistently been depreciating in nominal terms from year to year, and by the year 2019/20, the average nominal exchange rate stood at 35.1571 Birr per US dollar, which shows about 603% depreciation as compared to 1992 (NBE, 2019/20).

Also, consumer prices in Ethiopia are accelerating, as indicated by the consumer price indicator. Since 2005/06, there’s been a non-stop increase in the price of goods and services. Indeed, though there’s no agreement on the causes of inflation, which reached a peak in recent years in Ethiopia, the above analyses show the trend of inflation seems to have mimicked the trend of exchange rate depreciation, suggesting that in addition to financial instability, exchange rate depreciation is potentially an important motorist of inflation in Ethiopia (Hunegnaw, 2012).

The emphasis on knowing the ERPT of Ethiopia is supported by the fact that the country exports large quantities of primary and intermediate goods, which serve as inputs to the manufacturing sector. Also, the country imports a sizeable quantity of finished consumer goods. Despite the observed high growth rate of exports, the country suffers from a ceaseless and significant trade deficit, which reached a value of 33.2 billion US dollars in the 2019/20 fiscal year (Berga, 2012).

As a result, it is critical to probe the magnitude and rate of ERPT to inflation in Ethiopia in order to understand the dynamics of ERPT and provide valuable insight into the appropriate policy responses required to dampen exchange rate volatility, thereby lowering inflation and facilitating macroeconomic stability.

The article contributes to the existing literature on ERPT, which has been widely studied in the context of developing countries. The study is particularly relevant for Ethiopia, a country that has experienced sustained inflation and depreciation of its currency for the last two decades.

Hence, the research questions of the study are to answer: to what extent and how quickly can ERPT contribute to Ethiopia's domestic inflation? What are the fundamental macroeconomic variables affecting Ethiopia's inflation rate? using sample data from 1975 to 2020 and employing the SVAR econometric model.

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

## **2. Pass-through literature**

### **2.1. Theories on causes of inflation**

The literature on the sources of inflation is different, with multitudinous difficulties. Large bodies of economic literature have a range of explanations of the determinants of inflation and its effect in different macroeconomic environments. Most agree that the sources vary across countries with varying macroeconomic surrounds. The quantity theory of money, demand-pull theory, cost-push theory, expectations hypothesis, and structural inflation theory are different perspectives that economists use to explain the causes of inflation.

The quantity theory of money holds that the amount of money in circulation determines the level of prices in an economy. This theory holds that an increase in the quantity of money will result in an increase in the general price level, and vice versa. According to Milton Friedman's modern quantity theory, "inflation is always and everywhere a monetary phenomenon that results from a more rapid expansion in the quantity of money than in total output" (Totonchi, 2011).

According to the demand-pull theory, which was pioneered by John Maynard Keynes (1883–1946), inflation results from excessive demand for goods and services. When the demand for goods and services exceeds the available supply, firms increase their prices to maximize profits. This theory suggests that economic growth may lead to inflation as consumers and businesses increase spending. The cost-push theory, on the other hand, suggests that inflation results from an increase in production costs, such as rising wages or raw material costs. This theory suggests that inflation may occur even during periods of economic stagnation or low demand.

The new development in inflation theory, the Expectations Hypothesis Theory, suggests that inflation expectations play a critical role in determining current inflation levels. According to this theory, if people expect prices to rise in the future, they will demand higher wages, and prices will rise accordingly. Finally, structural inflation, which has been put forward as an explanation of inflation in developing countries, suggests that persistent imbalances in the economy can lead to

long-term inflation. Examples include shortages in raw materials or production bottlenecks, which can increase production costs and inflation.

Overall, the various theories on the causes of inflation are not mutually exclusive, and different factors can contribute to inflation in different economic contexts.

### 2.1.1. *Imported inflation definition*

After getting acquainted with inflation in general, it is necessary to give an understanding of imported inflation that arises as a result of the evolution of economies toward each other, which makes these economies affect and are affected by global economic changes. Therefore, the levels of inflation in these economies will be affected by factors outside their geographical scope as well as by local factors that affect the market for goods and services (Beck et al., 2009). As a result, inflation might be from external sources, and it is called imported inflation (Hahn, 2003). This type of inflation may appear in small and developing countries that import most of their goods and services from abroad. Hence, imported inflation is a general and sustainable price increase due to an increase in the cost of imported products (Bada et al., 2016b). This price increase worries the price of raw materials and all imported products or services used by companies in a country. The theoretical literature on ERPT draws its ideas from the law of one price (LOOP), purchasing power parity (PPP), and monetary theory to determine exchange rates (Bada et al., 2016a)

### 2.1.2. *Law of one price and purchasing power parity*

The theoretical basis for the relationship between prices and exchange rates evolves from the doctrine of purchasing power parity (PPP), which is an outgrowth of the law of one price (LOOP), with the assumptions that there are no trade barriers and transport costs (Goldstein, 2010). However, trade frictions exist in the actual world, and they alter the basic assumptions of PPP. Withstanding these developments, the law of one price is still useful in understanding the relationship between prices and exchange rates. The LOOP indicates that in the non-appearance of trade frictions and under conditions of free competition and price flexibility, similar goods sold in different locations must sell for the same price when prices are expressed in a common currency (Bada et al., 2016b). As a result, at equilibrium, the prices of tradable products in two marketplaces should not differ when stated in the same currency, ensuring complete pass-through. Thus, even if the marketplaces are in different nations, a change in domestic currency in one market would result in an equal change in pricing in the other (Bada et al., 2016a).

Algebraically, PPP with no transport costs and tariffs can be written thus:

$$P_t^a = EXC_t P_t^* \quad (1)$$

Where  $P_t^a$  represents domestic price at time  $t$ ,  $P_t^*$  stands for the world import price, and  $EXC_t$  is the nominal exchange rate (domestic per unit of foreign). However, due to trade frictions, the LOOP may or may not hold in other cases. This is due to the fact that several factors, including production costs, producer mark-ups, and exchange rate variations, influence domestic import prices (Bada et al., 2016b).

The PPP principle is the macroeconomic counterpart to the LOOP concept. PPP states that price levels between the two countries are equal when expressed in the same currency over any period of time (Gonzalez-Anaya, 2000). As a result, assuming PPP holds, exchange rate swings translate into corresponding changes in the domestic price level, implying that pass-through is one. PPP necessitates two constraining assumptions: (i) There is instantaneous, frictionless, and costless arbitrage. (ii) The same goods enter the basket of goods with the same weight in every country (Gonzalez-Anaya, 2000). Surely, neither of the above can hold all the time, leading to a weak or relative version of PPP. It is also known as the inflation theory of exchange rates, and it proposes that changes in the exchange rate between two countries are determined by the difference in their inflation levels (Mussa, 2019). The relative version eliminates the requirement that arbitrage is

costless, but it does require that it occurs at a constant cost. This will clearly not be the case if there are quantitative restrictions in place or if there are modifications to trade policy. More importantly, the determination of domestic inflation may use different shares of goods in their respective baskets, and certainly non-traded groups are not the same and cannot be arbitrated (Oyinlola, 2008).

Campa et al. (2005) defined ERPT as the percentage change in local currency import prices resulting from a one percent change in the exchange rate between the exporting and importing economies. ERPT is generally used to refer to the effect of exchange rate changes on import and export prices, consumer prices, investments, or trade volumes.

The significance of exchange rate changes in macroeconomic adjustment is determined to a large extent by its influence on domestic prices and the speed of its transmission (Bada et al., 2016a). If the degree of pass-through is substantial, exchange rate swings will modify the relative pricing of commodities, causing trade balances to adjust quickly. For example, if ERPT is high, imported items become more expensive, import demand falls, and customers migrate to domestically produced goods. Conversely, if the degree of ERPT is low, the exchange rate has little impact on domestic pricing and trade balances (Bada et al., 2016b).

Exchange regimes play an important role in ERPT (Lopez-Villavicencio & Mignon, 2016). Economic agents adjust prices quickly in a fixed exchange rate regime because they believe any change in the exchange rate is permanent. However, because changes are perceived to be transient in a flexible exchange rate regime, economic agents do not alter their pricing quickly. In a high-income country, economic agents do not alter prices quickly in reaction to exchange rate changes because higher incomes give more opportunities for competitors in the domestic market, limiting enterprises' pricing power. In low-income countries, however, the opposite is true (Sow & Razafimahefa, 2017).

Monetary policy also has its own impact on ERPT (Lopez-Villavicencio & Mignon, 2016). Contractionary monetary policy reduces ERPT, whereas expansionary monetary policy increases ERPT because economic agents perceive the policy as unstable and tend to alter prices quickly. In the same vein, expansionary fiscal policy will lead to an increase in the degree of pass-through because economic agents fear that the government will address the accumulated fiscal deficit by increasing taxes or cutting expenditure, which will invariably reduce the profitability of firms or contract the market. Constrictive fiscal policies, on the other hand, will lower the amount of pass-through (Bada et al., 2016a).

## 2.2. Empirical review

There is extensive literature on ERPT in cross-country and specific-country studies. Most of the studies found ERPT to be asymmetric and incomplete, and its impact depends on the regime of exchange rates that countries adopted. The study by Aisen and Manguinhane (2021), Revelli (2020), Teferra (2020), and Kassi et al. (2019) examined ERPT in cross-country study.

In order to determine the magnitude of exchange rate pass-through to inflation of Mozambique, Aisen and Manguinhane (2021) utilized ARDL model by taking the sample spanning from 2001 to 2019 and the result uncovers the presence of ERPT which is asymmetric, seizable and fast, with 50% of the exchange rate variations passing through to prices in less than 6 months.

Revelli (2020) uses SVAR to examine the extent of currency rate pass-through to the Consumer Price Index in Cameroon and Kenya. The result of impulse response functions from the SVAR model indicates a more immediate impact of the dynamic elasticity of the degree of the ERPT on prices in Cameroon than Kenya.



Teferra (2020) analyses ERPT and inflation dynamics in selected 14 Eastern and Southern African countries using quarterly data. Based on the NARDL framework, the study found an asymmetrical ERPT in the entire sample of SSA. The pass-through is found to be higher in countries with fixed exchange rate regimes in a high inflationary environment than in countries with floating exchange rate regimes and low inflation levels, which supports Taylor's hypothesis.<sup>1</sup> Similarly, Kassi et al. (2019) examined ERPT to consumer prices for 40 SSA countries using NARDL framework 1990Q1 to 2017Q4. In line with Teferra (2020), he found asymmetrical, incomplete, and significant ERPT to consumer prices in the entire SSA region. Pass-through is greater in countries with fixed exchange rate regimes (the CFA franc zone) and low inflation than in countries with flexible exchange rate regimes and high inflation. Pass-through is greater after substantial changes in exchange rates than after slight ones.

By applying SVAR model to estimate the pass-through effects of exchange rate changes to consumer prices of Sierra Leone, Bangura et al. (2012) shows the presence of pass-through to consumer prices, which is incomplete and significant. In addition, using variance decomposition analyses and the dynamic elasticity concept, the researchers found that nominal exchange rate depreciation has been more important in explaining Sierra Leone's actual inflationary process. Bada et al. (2016b) investigated the aggregate ERPT effect on import and consumer prices in Nigeria from 1995 Q1 to 2015 Q1. Using VECM, the study discovered that the ERPT into Nigeria's CPI inflation was insufficient. The long-run pass-through elasticities for the baseline and alternative models were 0.24 and 0.30, respectively. In addition, the researchers discovered a higher effect of pass-through imports than consumer prices.

A study by Emeru (2020), Altasseb (2013), Berga (2012), and Geda and Tafere (2008) examined ERPT at a specific country level.

Emeru (2020) examined the major sources of inflation in Ethiopia's economy by using VECM. According to the VECM results, only the budget deficit as a proportion of GDP influences Ethiopian inflation in the short run. In the long run, the broad money supply, real GDP, interest rate, nominal exchange rate, and budget deficit were the major drivers of inflation.

Altasseb (2013) analyses annual data from 1980 to 2012 to investigate the origins and dynamics of price inflation in Ethiopia. The VECM results demonstrated that in the long run, the money market, agriculture market, and external market determine price inflation. In the short run, various other factors influence price inflation. Inflationary changes are very sensitive to changes in money growth, the cost of capital, the exchange rate, and inertia. External factors such as the price of fertilizer, intermediate goods imports, oil, and the exchange rate are found to have a significant effect on domestic price inflation. The cost of capital is the most important domestic supply-side component, explaining price increases in the short run. Apparently, the effects of supply-side, monetary, and external factors are highly significant through their long-run co-integrating relationships.

Melesse (2014) analysed the impact of exchange rate changes on consumer price inflation in Ethiopia using a structural vector autoregression (SVAR) approach. The study finds that the impact of exchange rate changes on consumer prices is short-lived and incomplete. The forecast error variance decomposition shows that inflation is mainly influenced by own shocks, followed by world oil prices and exchange rates. Besides, the researcher tried to analyse the rate of pass-through of inflation in different sectors of the economy, and sectors with higher import content have stronger pass-through effects.

Berga (2012) using the SVAR model and data between 1991/92 and 2010/11, she investigates the degree of ERPT's impact on import and consumer prices in Ethiopia. The study discovered that ERPT in Ethiopia during the study period was considerable, moderate, and durable in terms of import prices, but low and transient in terms of consumer pricing.



Haji and Gelaw (2012) identified the long-run and short-run factors causing Ethiopia's food inflation using Johansen's co-integration and VECM for the period 1997 to 2010, respectively. The study showed a significant and important effect of monetary developments in explaining the high food prices in the country. Similarly, Geda and Tafere (2008) tried to understand the forces behind the inflationary experiences in Ethiopia by applying both monetarist and structuralist models of inflation. They exploit the VAR formulation for the period 1994/95 to 2007/08 using quarterly data. The result revealed that the most important forces behind food inflation in the long run are a sharp rise in the money supply, credit expansion, inflation expectations, and an international food price hike. Money supply, interest rates, and inflation expectations, on the other hand, are long-run determinants of non-food inflation. Wages, foreign pricing, exchange rates, and food supply constraints are identified as the primary sources of inflation in the short-run model.

### 3. Methodology

Research on the transfer effect of exchange rates on domestic price levels should be studied in conjunction with macroeconomic background. In consideration of the macroeconomic background, single-equation regression has been unable to deal with multivariate problems. Therefore, empirical studies have begun to adopt the vector autoregressive (VAR) method, which takes into account the characteristics of the time series of variables and the inter-variable endogeneity. The VAR model has significant advantages in measuring the exchange rate conduction effect (Pan, 2018), but the errors in a VAR will generally be correlated. For this reason, it is hard to know how to use an impulse response function, as these are meant to measure the change in a shock, *ceteris paribus*. If the shocks are correlated, however, one can't hold other shocks constant when a shock occurs. Provided that, different methods are proposed by the scholars that combine the VAR errors together so as to produce a set of uncorrelated shocks for which impulse responses can be computed. The other solution is to use generalized impulse responses (GIR). This method does not re-define the shocks as previously described, but instead computes impulse responses to the VAR errors while accounting for the fact that they are associated.<sup>2</sup>

In addition to the above, the more standard approach is to note that correlations between shocks arise as a result of contemporaneous correlations between variables, and thus, rather than having a variable rely solely on the past values of other variables, one should consider systems in which each variable can also rely on the contemporaneous values of other variables. The mistakes in the structural equations can now be assumed to be uncorrelated because one has (hopefully) captured the contemporaneous effects (Ouliaris et al., 2016).

This new system will have a different purpose as a result of its creation. It is now performing an interpretive function. It is composed of structural (simultaneous) equations rather than a reduced form like the VAR. Because structural equations were developed with the intention of reflecting agent decisions, this technique can be said to contain economic content (Ouliaris et al., 2016).

To be more specific, the resulting structural VAR (SVAR) system of order  $p$  will be:

$$A_0 Z_t = A_1 Z_{t-1} + \dots + A_p Z_{t-p} + \varepsilon_t \quad (2)$$

Where the shocks  $\varepsilon_t$  are taken to be uncorrelated, i.e.,  $E(\varepsilon_t) = 0$ ,  $\text{cov}(\varepsilon_t) = \Omega S$  and  $\Omega S$  are a diagonal matrix,  $z_t$  and  $\varepsilon_t$  are  $n \times 1$  vectors which are a set of model variable and error, respectively.  $A_1$ - $A_p$  are  $n \times n$  matrices of parameters. It is necessary to look more carefully at  $A_0$ . It will be defined as

$$A_0 = \begin{bmatrix} a_{11}^0 & -a_{12}^0 & \cdot \\ -a_{21}^0 & a_{22}^0 & -a_{23}^0 \\ \cdot & \cdot & \cdot \end{bmatrix}$$

where the signs on  $a_{ij}^0$  are chosen so as to enable each of the equations to be written in regression form. That is:

$$Z_{1t} - \alpha_{12}^0 Z_{2t} = \alpha_{11}^1 Z_{1t-1} + \alpha_{12}^1 Z_{2t-1} + e_{1t} \quad (3)$$

$$Z_{2t} - \alpha_{21}^0 Z_{1t} = \alpha_{21}^1 Z_{1t-1} + \alpha_{22}^1 Z_{2t-1} + e_{2t} \quad (4)$$

Now the model (3.3) -(3.4) implies that  $A_0 = \begin{bmatrix} 1 & -\alpha_{12}^0 \\ -\alpha_{21}^0 & 1 \end{bmatrix}$ , and it is said to be in normalized form, i.e., every equation has a “dependent variable”, and every shock  $e_{it}$  has a variance of  $\sigma_i^2$ . In contrast, the un normalized form would be

$$\alpha_{11}^0 Z_{1t} - \alpha_{12}^0 Z_{2t} = \alpha_{11}^1 Z_{1t-1} + \alpha_{12}^1 Z_{2t-1} + e_{1t} \quad (5)$$

$$\alpha_{22}^0 Z_{2t} - \alpha_{21}^0 Z_{1t} = \alpha_{21}^1 Z_{1t-1} + \alpha_{22}^1 Z_{2t-1} + e_{2t} \quad (6)$$

$$\text{var}(e_{1t}) = 1, \text{var}(e_{2t}) = 1, \text{cov}(e_{1t}e_{2t}) = 0.$$

In this latter form,  $A_0$  is left free and it can be assumed that the variances of the  $\eta_{it}$  are unity, since  $\alpha_{ii}^0$  is effectively accounting for them. By our definitions, we would have  $e_{jt} = \sigma_j \varepsilon_{jt}$ , where  $\sigma_j$  is the standard deviation of  $\varepsilon_{jt}$ . More generally, a SVAR could be written as:

$$A_0 Z_t = \alpha + A_1 Z_{t-1} + \dots + A_p Z_{t-p} + \beta e_t \quad (7)$$

with  $\text{var}(\varepsilon_{it})$  set to unity and with  $A_0$  and  $B$  being chosen to capture the contemporaneous interactions among the  $z_t$ , along with the standard deviations of the shocks. The representation makes it possible to shift between whether the system is normalized or unnormalized depending on how one specifies  $A = A_0$  and  $B$  (Ouliaris et al., 2016).

Because of the complicated dynamics of the VAR and SVAR models, it is rarely the case that one is interested in the  $A_j$ 's of the models. For this reason, Sims (1980) suggested that one change the focus on how the shock  $e_{kt}$  would impact upon  $z_{jt}$ , i.e. to ask what is the response of  $z_{j,t+M}$  to a shock  $e_{kt}$ ? Accordingly, it is the partial derivative  $\partial z_{j,t+M} / \partial e_{kt}$  that is of interest. These partial derivatives were called impulse responses since they 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 (Ouliaris et al., 2016).

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.<sup>3</sup> The sum of these MA coefficient matrices is known as long-run effects or total multipliers (Melesse, 2014).

### 3.1. SVAR identification

To impart economic content<sup>4</sup> 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<sup>5</sup> 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 (Melesse, 2014).

We can define an SVAR model by modifying the expression given in equation (6):

$$Z_t = A\alpha^{-1} + \sum_{i=1}^p A\alpha^{-1}A_iX_{t-i} + e_t \quad (8)$$

where  $\alpha$  is vector of estimated constants, it is the vector of estimated residuals in the reduced form and can be expressed as:

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

Following Melesse (2014), this study uses five main variables (WOP, NEER, BMS, GE, and CPI) by considering monetarist and structuralist models of inflation. In line with this, 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 restrictions 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:

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

$$e_t = \begin{bmatrix} e_{wop,t} \\ e_{neer,t} \\ e_{ge,t} \\ e_{ms,t} \\ e_{cpi,t} \end{bmatrix}, \varepsilon_t = \begin{bmatrix} \varepsilon_{wop,t} \\ \varepsilon_{neer,t} \\ \varepsilon_{ge,t} \\ \varepsilon_{ms,t} \\ \varepsilon_{cpi,t} \end{bmatrix}, A\alpha^{-1} = \begin{bmatrix} \psi_{1,1} & \psi_{1,2} & \psi_{1,3} & \psi_{1,4} & \psi_{1,5} \\ \psi_{2,1} & \psi_{2,2} & \psi_{2,3} & \psi_{2,4} & \psi_{2,5} \\ \psi_{3,1} & \psi_{3,2} & \psi_{3,3} & \psi_{3,4} & \psi_{3,5} \\ \psi_{4,1} & \psi_{4,2} & \psi_{4,3} & \psi_{4,4} & \psi_{4,5} \\ \psi_{5,1} & \psi_{5,2} & \psi_{5,3} & \psi_{5,4} & \psi_{5,5} \end{bmatrix} \text{ and}$$

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

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

In the Cholesky decomposition employed below, supply factors are most exogenous, as a small open economy like Ethiopia has little or no leverage over international commodity (including petroleum) price movements. Thus, the 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 $\alpha$ . The data generating process is described as:

$$e_{wop,t} = \varepsilon_{wop,t} \quad (9)$$

The behavior of the exchange rate is assumed to respond to multiple factors that cannot be more directly influenced by the decisions of monetary authorities in Ethiopia. As a result, the currency rate should rise in response to significant inflows of foreign aid and remittances (which are dependent on economic conditions in the West) or a rise in foreign exchange reserves due to improvements in the country's terms of trade. Conversely, we should expect significant depreciation over time when foreign capital inflow is declining, say, because of catastrophic global financial and economic crises that disrupt capital mobility in the developing world. Equation (10) summarizes the behavior of the exchange rate shock, which responds simultaneously to the energy price shock but is not affected by the shocks originating from other variables:

$$e_{neer,t} = \psi_{2,1}\varepsilon_{wop,t} + \varepsilon_{neer,t} \quad (10)$$

As Melesse (2014) and Ito and Sato (2007), demand factors precede the monetary measure. The consumer price is the most endogenous variable and appears last in the recursive representation. Equations (11) to (13) define the structural dynamic relationships for public spending, money growth, and domestic price shocks, respectively.

$$e_{ge,t} = \psi_{3,1}e_{wop,t} + \psi_{3,2}e_{Neer,t} + e_{ge,t} \quad (11)$$

$$e_{ms,t} = \psi_{4,1}e_{wop,t} + \psi_{4,2}e_{Neer,t} + \psi_{4,3}e_{ge,t} + e_{ms,t} \quad (12)$$

$$e_{cpi,t} = \psi_{5,1}e_{wop,t} + \psi_{5,2}e_{Neer,t} + \psi_{5,3}e_{ge,t} + \psi_{5,4}e_{ms,t} + e_{cpi,t} \quad (13)$$

As a result, the exactly identified model to be estimated takes the form defined by equation (13):

$$e_t = \begin{bmatrix} e_{wop,t} \\ e_{Neer,t} \\ e_{ge,t} \\ e_{ms,t} \\ e_{cpi,t} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \psi_{2,1} & 1 & 0 & 0 & 0 \\ \psi_{3,1} & \psi_{3,2} & 1 & 0 & 0 \\ \psi_{4,1} & \psi_{4,2} & \psi_{4,3} & 1 & 0 \\ \psi_{5,1} & \psi_{5,2} & \psi_{5,3} & \psi_{5,4} & 1 \end{bmatrix} \begin{bmatrix} e_{wop,t} \\ e_{Neer,t} \\ e_{ge,t} \\ e_{ms,t} \\ e_{cpi,t} \end{bmatrix} \quad (14)$$

## 4. Data and empirical results

### 4.1. Data

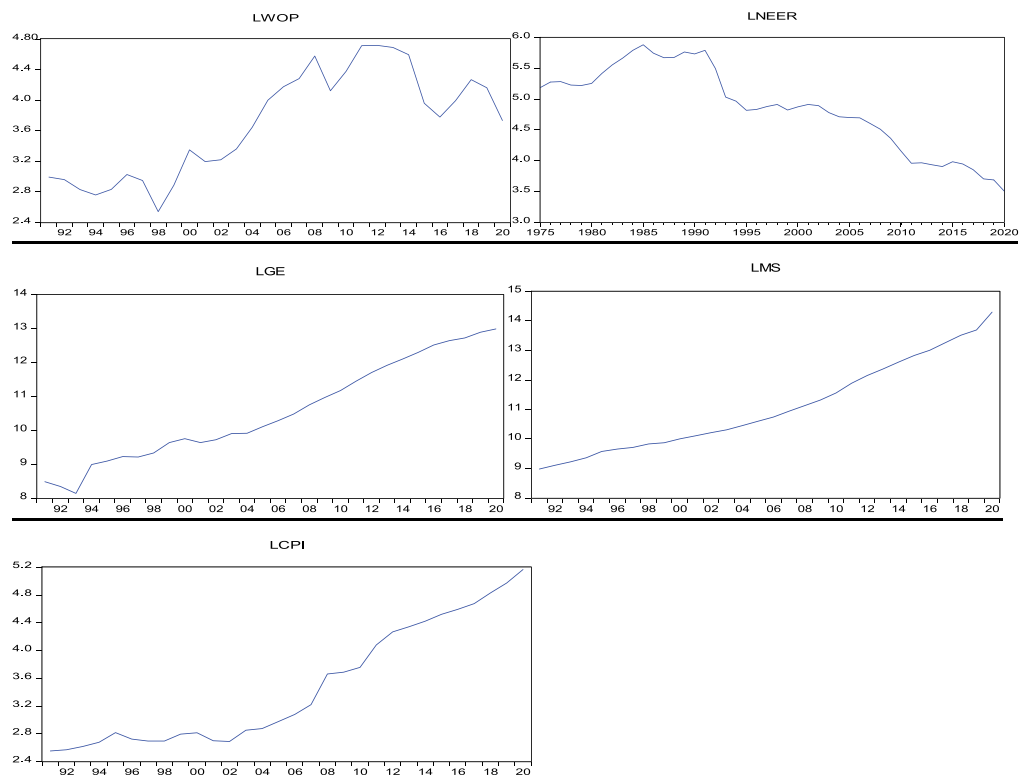
Annual data for the period from 1975 to 2020 from a variety of sources is used. The oil price in terms of the US dollar is collected from our world in database. Data for government expenditure, money stock, and CPI is collected from the National Bank of Ethiopia. Finally, the data for the nominal effective exchange rate collected from the Bruegel database.<sup>6</sup>

### 4.2. Discussion of results

The first step in dealing with time-series data is examining the behaviour of the variable through time. The following figure presents how variables behave across time.

As can be seen from the plots of the natural log-transformed series in Figure 1, most of the series appear to be non-stationary. The consumer price index, government expenditure, and broad

**Figure 1. Time series plot of each variables.**



**Table 1. Basic summary statistics**

Variable	Mean	SD	Min	Max
LWOP	3.360561	0.675132	2.444952	4.715545
LNEER	4.885267	0.67967	3.505729	5.879015
LGE	9.244333	1.778353	6.907675	12.99253
LMS	9.771282	1.975979	7.0483	14.30245
LCPI	2.699259	1.090945	1.012295	5.167371

money supply exhibit a clear, persistent, and increasing trend, while the trade weighted nominal exchange rate is declining over time, which is quite consistent with the country's depreciation policy on the exchange rate. The international oil price exhibits an unclear path that declines at the initial period of the sample and continues with the wave shape.

The basic summary statistics computed based on the natural log-transformed data are given in Table 1. The log of the nominal effective exchange rate of Birr declines and reaches its minimum value of about 3.51 in the late period of the sample. The highest variability as proxied by the respective standard deviation for each log series was observed in broad money supply (1.97), which was more than twice as volatile compared with the trade weighted exchange rate (0.67). The world oil price showed the same degree of volatility as the inflation rate, while government expenditure exhibited closely similar fluctuations with broad money supply stocks. Beside this, as can be seen from the statistics, the change in inflation rate in Ethiopia almost doubles itself from year to year, which needs special attention by the government.

The variable name is abbreviated as follows: LWOP (log of the world oil price), LNEER (log of the nominal effective exchange rate), LGE (log of government expenditure), LMS (log of the broad money supply), and LCPI (log of the consumer price index). As for the PP test by Phillips and Perron (1988), the 95% critical values are -2.9298 and -3.515 for the constant and constant and trend equations, respectively. The 95% critical values of the ADF test are -2.928 and -3.513 for the constant and constant and trend equations, respectively.

**Table 2. Results of unit root test**

ADF			PP	
Variable	Constant	Constant and Trend	Constant	Constant and Trend
<b>Level</b>				
LWOP	-1.800	-1.871	-1.839	-1.871
LNEER	0.160	-1.871	0.560	-2.143
LGE	1.112	-0.912	1.182	-0.893
LMS	5.362	3.090	4.815	3.131
LCPI	0.722	-0.713	0.600	-0.977
<b>First difference</b>				
LWOP	-5.933**	-5.913**	-5.869**	-5.861**
LNEER	-3.904**	-4.162**	-3.904**	-4.209**
LGE	-6.664**	-6.921**	-6.675**	-6.921**
LMS	-0.240	-3.766**	-1.535	-4.276**
LCPI	-5.862**	-6.021**	-5.867**	-6.010**

Note \*\* indicate that the variable is statistically significant at 5%.

**Table 3. Johansen cointegration test result**

H <sub>0</sub>	H <sub>1</sub>	Statistics					
		Trace			Maximum eigenvalue		
		Trace statistics	Critical value	Prob.**	maximum eigenvalue	Critical value	Prob.**
r=0 r=1		78.09391	79.34145	0.0618	32.26517	37.16359	0.1645
r=1 r=2		45.82874	55.24578	0.2576	20.79819	30.81507	0.4876
r=2 r=3		25.03055	35.01090	0.3819	19.00484	24.25202	0.2126
r=3 r=4		6.025719	18.39771	0.8669	5.144782	17.14769	0.8916
r=4 r=5		0.880937	3.841466	0.3479	0.880937	3.841466	0.3479

#### 4.3. Estimation of standard VAR

An initial step towards the SVAR model is to check the stationary properties of all relevant time series. Two powerful unit-root tests, ADF and Phillips–Perron (PP) by Phillips and Perron (1988), as presented in Table 2, confirmed that public spending, CPI, broad money supply, and NEER are I(1). Further, the Johansen test of cointegration has confirmed the absence of a long-term relationship among the variables (see Table 3). As a result, the SVAR model can be deemed suitable for analysing their dynamic interactions. Using the SVAR model allows us to place the concentration on the ERPT dynamics into consumer prices in Ethiopia in a distribution chain. The empirical VAR is estimated with one (1) lag as suggested by the AIC (see Appendices 4A and 4C), which minimizes the prediction mean square errors.

#### 4.4. Estimation of SVAR

The estimated system of shocks from the SVAR is given by equations 15 through 16 below. They are derived from the estimated residuals of the standard VAR using structural factorisation. The figures in parenthesis are the p-values. The coefficients of the structural shocks,  $\varepsilon_p$ , are their respective standard deviations.

$$e_{wop} = 0.289\varepsilon_{wop} \quad (15)$$

$$e_{Neer} = -0.004\varepsilon_{wop} + 0.098\varepsilon_{Neer} \quad (16)$$

$$e_{ge} = 0.062\varepsilon_{wop} + 0.094\varepsilon_{Neer} + 0.129\varepsilon_{ge} \quad (17)$$

$$e_{ms} = -0.078\varepsilon_{wop} - 0.299\varepsilon_{Neer} - 0.083\varepsilon_{ge} + 0.079\varepsilon_{ms} \quad (18)$$

$$e_{cpi} = 0.128\varepsilon_{wop} + 0.076\varepsilon_{Neer} + 0.121\varepsilon_{ge} + 0.503\varepsilon_{ms} + 0.969\varepsilon_{cpi} \quad (19)$$

Where

$$@e1 = C(11)*@u1$$

$$@e2 = C(1)*@e1 + C(12)*@u2$$

$$@e3 = C(2)*@e1 + C(5)*@e2 + C(13)*@u3$$

$$@e4 = C(3)*@e1 + C(6)*@e2 + C(8)*@e3 + C(14)*@u4$$

$$@e5 = C(4)*@e1 + C(7)*@e2 + C(9)*@e3 + C(10)*@e3 + C(15)*@u5$$

and

@e1 represents DLWOP residuals

@e2 represents DLNEER residuals

@e3 represents DLGE residuals

@e4 represents DLMS residuals

@e5 represents DLCPI residuals

#### 4.4.1. SVAR is just identified

The SVAR result indicates that the system has been identified, implying that the empirical data meets the identification scheme. Furthermore, the system's contemporaneous relationship between variables appears to be rather well recorded, as all coefficients are correctly signed. Notes: The estimate of one SDA shock to the variables is obtained from the SVAR coefficients (i.e.  $\epsilon_i$ 's) as shown in equations 15 through 19. The numerical values of the impulse of inflation are divided by these SDA shocks to derive at the respective dynamic pass-through elasticities as shown in the table 4.

$$\text{Dynamic pass through elasticities} = \frac{\text{Percentage change in price(Inflation) at time } t}{\text{Percentage change in the the respective variables at time } 0 \text{ (One SDA shocks to the respective variable)}} \quad (20)$$

The generated SVAR was used to do innovation accounting to determine the influence 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 of NEER exerts downward pressure on domestic price changes in the medium term. As shown in Figure 2, a one SD shock to the exchange rate (9.8%) causes the overall cumulative consumer price inflation to fall by 0.58%. This implies an impact elasticity of 0.059 (5.9%), which is significant but incomplete. The maximum impact of one SD shock to the exchange rate on inflation is realized after 2 years, which is about a 0.0222 decrease in price, implying a dynamic pass-through elasticity of 0.227 (22.7%).

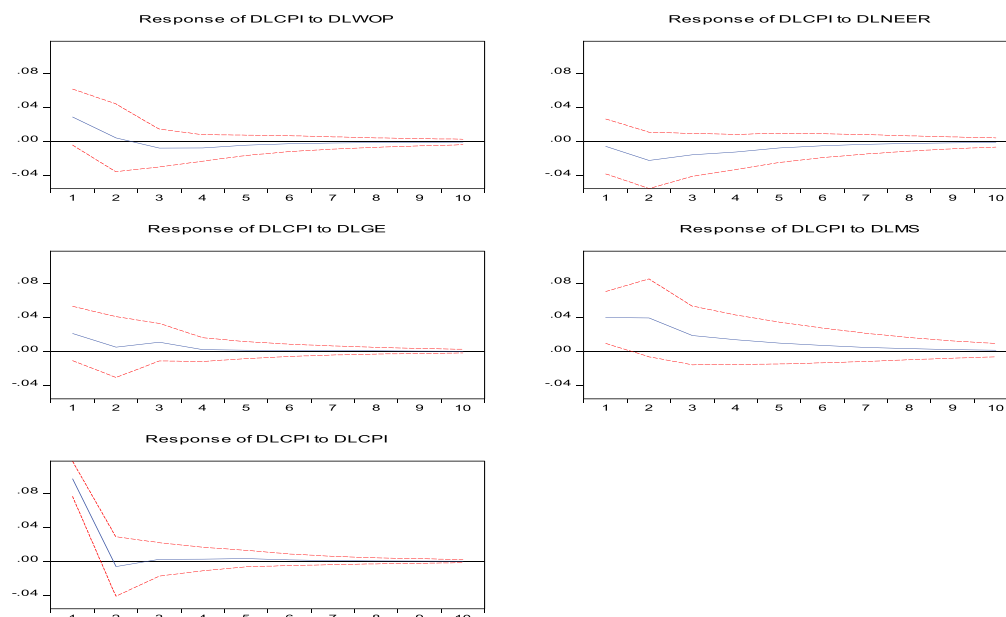
In other words, this means that inflation will increase by about 23% of the margin of decrease in the exchange rate after 2 years. As illustrated in figure 2, the effect of an exchange rate shock on domestic prices is immediate (just after the first year), reaching its peak of 0.227 in the second year and persistent throughout the 10 years.

Below, Figure 3 shows the effect of depreciation of the exchange rate on inflation, which can be traced by changing the sign of the impulse response function table to a positive number. These results are evidence of the presence of ERPT in Ethiopia and are broadly in line with those of other empirical studies by Melesse (2014). The presence of ERPT in Ethiopia could be attributed to the continuous depreciation of the Birr over the whole sample period.

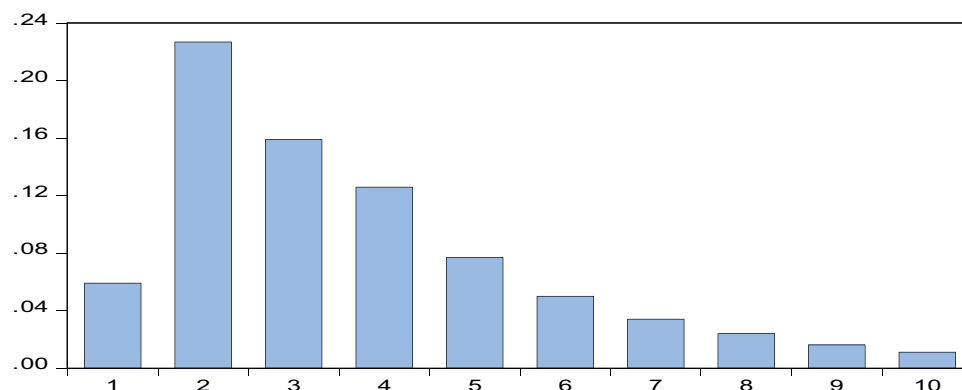
Consistent with the research, a country's currency rate depreciation raises agents' expectations of more depreciation and inflation (Bangura et al., 2012). Firms and importers are therefore likely to perceive any increase in costs due to exchange rate depreciation as persisting and, therefore, pass on some of the resultant increases in costs to consumers. This assertion seems plausible for a country like Ethiopia that is vulnerable to imported inflation due to its high dependence on imported goods for local consumption and investment activities. Beside this, as noted by profit-push inflation theory, if the market structure of most industries is imperfect (oligopolist and monopolist), firms raise the price of their products to offset the rise in labor and cost of production



**Figure 2. Impulse response function for general consumer price inflation.**



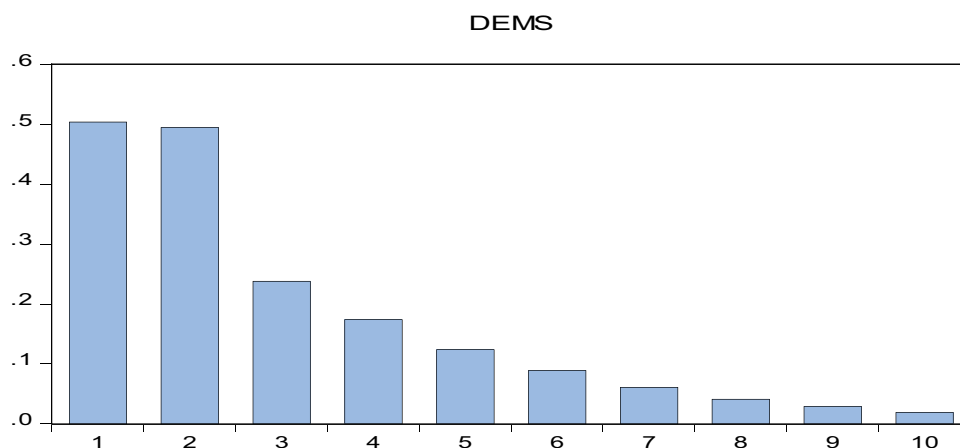
**Figure 3. Dynamic elasticity of exchange rate pass-through to inflation.**



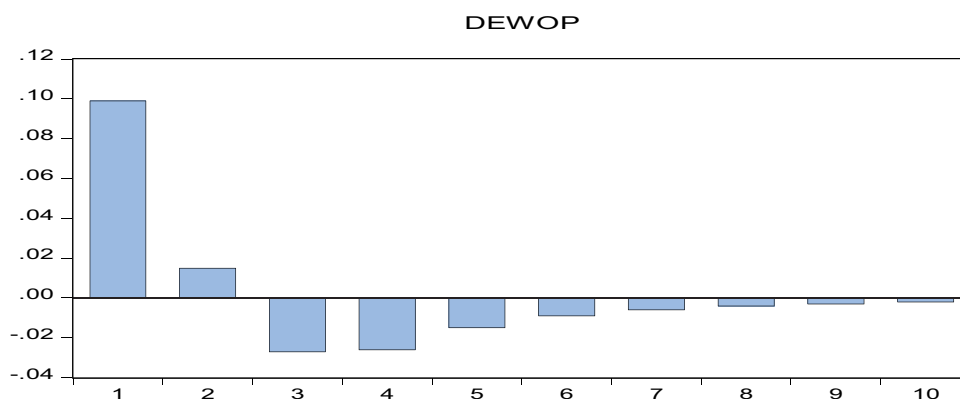
to earn higher profits. As imperfect competition exists, firms are able to administer the price of their products (Bangura et al., 2012).

According to the monetarist viewpoint, which has its roots in neoclassical economic theories, inflation is exclusively a monetary phenomenon arising from excessive demand, in particular, when there is “too much money for few goods.” Providing that, the study confirms the positive and significant impact of money supply shocks on domestic prices. As illustrated by columns 11, 12, and 13 of Table 4, a structural shock of 0.079 to the money supply leads to a 0.0398 increase in price for the first 2 years. This implies a dynamic pass-through elasticity of 0.50 (50%) after the first 2 years. The maximum impact of monetary shocks on inflation is realized after the first year. Intuitively, this implies that inflation will increase by 50% of the margin of change or increase in M2 after the first year. The ground for this result can be related to the monetarist argument, which says that to the extent that monetary expansion is not accompanied by expansion from the production sector of the economy, the supply of money will have a direct effect on inflation. Beside this it is important to note the idea of Kalecki (1962) on the effect of money supply on inflation: “In normal conditions, increases in the quantity of money in circulation result directly in greater liquidity and a lower velocity of circulation rather than an increase in prices, but this is not the case in the state of hyperinflation<sup>7</sup> here any additional money is converted into goods within

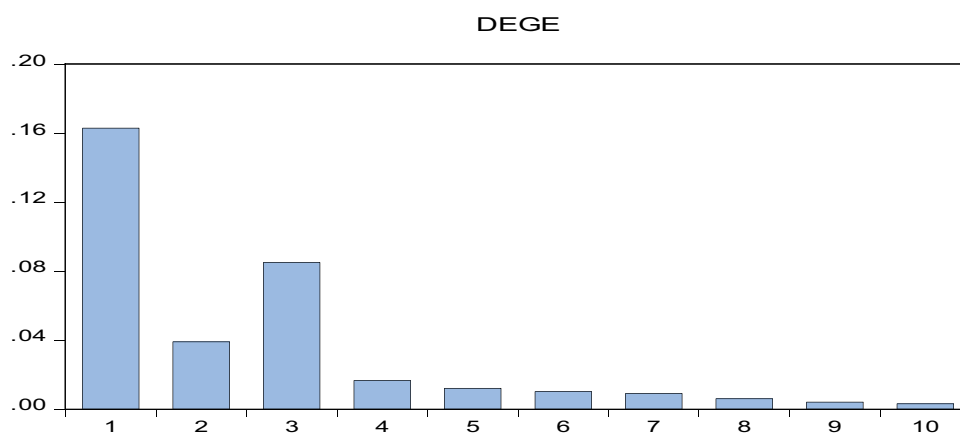
**Figure 4. Dynamic elasticity of money supply pass-through to inflation.**



**Figure 5. Dynamic elasticity of world oil price pass-through to inflation.**



**Figure 6. Dynamic elasticity of government expenditure pass-through to inflation.**



a certain spending period, which itself is dependent on the rapidity of the increase in prices. Thus, in this case, the expansion in the quantity of money does lead directly to the increase in prices”.

The dynamic pass-through elasticity of monetary aggregates subsequently declines consistently until the tenth year to the tune of only 0.01 (1%). Thus, monetary shocks to inflation appear to be transient, implying that the monetary authorities are reactive in controlling monetary shocks in order to minimize inflation. It is evidenced from 3 [Figure 4](#) that the effect of monetary shocks on inflation is immediate (just after the first year) but short lived as it dies out consistently throughout the tenth year. This finding is consistent with (Geda and Tafere (2008), Bane (2018) (Bane, 2018), and Denbel et al. (2016)) findings.

Ethiopia is well known for its reliance on imported crude oil and gas for energy usage. Hence, the world oil price shock directly affects the domestic price through its impact on transportation costs and the high cost of production. The same to the Ambachew et al. (2012) finding, our result confirms that in the short run, world energy price increases have an expansionary effect initially, causing consumer price inflation to increase by a significant amount, but after the 3rd year, world oil price shocks will have a contractionary impact on prices (See Figure 5). This can be attributed to the substantial oil price subsidies of the government, which 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 (such as using charcoal rather than gas or choosing public transportation over driving their own cars) that could potentially reduce their heavy reliance on imported oil. This result is in contrast with the finding of Melesse (2014) who get negative result in the short run and the positive impact of oil price shock on the general price of commodities in Ethiopia.

In contrast to Melesse (2014) findings, increased government consumption and investment spending have a significant impact on general consumer price inflation in the first 3 years (see Figure 6), and it will die off after 10 years. This is because massive development projects and programs sponsored by the government may have a problem of corruption, and most of the government expenditure is focused on subsidizing the economies of different sectors, but this public expenditure may not have an expansionary effect on the general price if it is spent on increasing the supply of commodities (especially in the agriculture sector). This is in line with the idea of Kalecki (1962) which states that in situations of budget deficit (which is true for our country), increasing public expenditure on industries whose supply cannot readily respond, with the consequent creation of bottlenecks.

#### **4.5. Estimation of variance decomposition**

As indicated below, the researcher employed variance decompositions to explore the relative contribution of the structural shocks in explaining changes in inflation. Provided that, as the result reveals, the money supply shock contributes more to inflation than the exchange rate shock, followed by the world oil price shock. Specifically, money supply shocks account for about 12–24 percent of variations in the price level between 1 and 10 years, while exchange rate shocks account for about 3–6 percent over the same time horizon. After the first year, the contribution of the own shock to consumer price inflation forecast variability drops to 65%, while that of the trade-weighted nominal exchange rate, world oil price, government expenditure, and money supply shock shows a significant increase after the passage of 1 year.

More over, the last column of Table 5 suggests high inflation persistence, as up to 59 to 76% of the price-level changes are explained by its own shocks during the 10 quarters. This underscores the important role other factors play in the inflationary process in Ethiopia that are not explicitly accounted for in the current paper.

#### **4.6. 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 using the Cholesky decomposition of the covariance matrix  $\Sigma$  is only unique up to the ordering of the variables in the system. Consequently, the same is true for the orthogonalized impulse responses (Stulz, 2007, cited in Berga (2012)). In this section, two alternative identification strategies are applied to check the robustness of the baseline model. The first alternative is to rank some variables in the VAR differently, while the second option is to estimate the impulse responses using a different methodology. Concerning the first option, we check whether the base-line model is sensitive to the order of one variable. In the first alternative model, we ordered the monetary variable (M2) differently, accounting for the fact that the appropriate position of the money supply is somewhat debatable.

**Table 4. Accumulated impulse responses (AIR) of domestics price levels to structural one sd shocks and dynamic pass-through elasticity (DP)**

Period	Estimated impulse of Inflation to one SDA Shock to WOP	Estimates of one SDA Shock to WOP	Dynamic pass-through Elasticity Of WOP	Estimated impulse of Inflation to one SDA Shock to NEER	Estimates of one SDA Shock to NEER	Dynamic pass-through Elasticity Of NEER	Estimated impulse of Inflation to one SDA Shock to GE	Estimates of one SDA Shock to GE	Dynamic pass-through Elasticity Of GE	Estimated impulse of Inflation to one SDA Shock to MS	Estimates of one SDA Shock to MS	Dynamic pass-through Elasticity Of MS
1	0.0287	0.289	0.099	-0.0058	0.098	-0.059	0.021079	0.129	0.163	0.0398	0.079	0.504
2	0.0043	0.289	0.015	-0.0222	0.098	-0.227	0.005089	0.129	0.039	0.0393	0.079	0.495
3	-0.0077	0.289	-0.027	-0.0156	0.098	-0.159	0.010937	0.129	0.085	0.0188	0.079	0.238
4	-0.0076	0.289	-0.026	-0.0123	0.098	-0.126	0.002134	0.129	0.0165	0.0137	0.079	0.174
5	-0.0044	0.289	-0.015	-0.0075	0.098	-0.077	0.001521	0.129	0.012	0.0098	0.079	0.124
6	-0.0025	0.289	-0.009	-0.0049	0.098	-0.050	0.001295	0.129	0.01	0.0070	0.079	0.089
7	-0.0017	0.289	-0.006	-0.0033	0.098	-0.034	0.001124	0.129	0.009	0.0048	0.079	0.061
8	-0.0012	0.289	-0.004	-0.0023	0.098	-0.024	0.000772	0.129	0.006	0.0032	0.079	0.041
9	-0.0008	0.289	-0.003	-0.0016	0.098	-0.016	0.000508	0.129	0.004	0.0022	0.079	0.029
10	-0.0006	0.289	-0.002	-0.0011	0.098	-0.011	0.00034	0.129	0.003	0.0015	0.079	0.019

**Table 5. Variance decomposition of inflation**

Period	S.E.	DLWOP	DLNEER	DLGE	DLMS	DLCPI
1	0.289639	6.724635	0.274115	3.616855	12.90023	76.48416
2	0.29885	5.863134	3.661018	3.263298	21.75943	65.45312
3	0.30215	5.950953	5.089654	3.882088	22.96345	62.11385
4	0.303076	6.167311	5.934819	3.808451	23.57099	60.51843
5	0.303215	6.21827	6.2254	3.777936	23.90399	59.87441
6	0.303254	6.226429	6.344176	3.768079	24.08783	59.57349
7	0.303269	6.230217	6.398612	3.76659	24.17274	59.43184
8	0.303275	6.233054	6.425315	3.76588	24.21112	59.36463
9	0.303277	6.234625	6.438055	3.765394	24.22885	59.33307
10	0.303279	6.235341	6.444013	3.765129	24.23725	59.31827

Cholesky Ordering: DLWOP DLNEER DLGE DLMS DLCPI

Table 4 presents the results from the forecast error variance decomposition exercise.

In the base-line model, M2 was placed after exchange rate as Melesse (2014) did by 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, Berga (2012) and Ito and Sato (2007) did, assuming forward looking nature of monetary policy.

$$\Delta WOP \rightarrow \Delta MS \rightarrow \Delta NEER \rightarrow \Delta GE \rightarrow \Delta CPI$$

As a second alternative, generalized impulse responses are calculated instead of Cholesky orthogonalized impulse responses. As Stulz (2007) discusses, the notion of generalized impulse response was developed by Koop et al. (1996) and extended to VAR models by Pesaran and Shin (1998). Unlike standard impulse responses, this method does not require shock orthogonalization and is independent of variable ordering. Thus, generalized impulse responses are estimated, and the results are reported in Appendix 9. The results obtained from this method are also virtually similar to those of the other models. The generalized responses of import prices to exchange rate shocks are similar to the baseline (orthogonalized) responses.

## 5. Conclusion and policy implications

Recursive structural vector auto-regression (SVAR) is used in this study to investigate ERPT into domestic consumer price inflation in Ethiopia. The study utilizes annual data spanning the period from 1975 to 2020. 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. Evidence from the analysis, reveals that ERPT on consumer prices in Ethiopia is significant but short lived. Specifically, one unit change in the nominal effective exchange rate (appreciation) caused consumer price inflation to fall by 0.059 after 1 year. As a result, ERPT for domestic prices in Ethiopia is incomplete. The variance decomposition analysis indicates that shocks to monetary variables significantly account for variation in inflation, followed by the world gas price, which partly lends support to the literature that inflation is a monetary phenomenon.

An important policy implication of this finding is that, given the presence of exchange rate pass-through to inflation in Ethiopia, monetary authorities need to be vigilant vis-à-vis exchange rate fluctuations to take rapid monetary policy measures and to place emphasis on foreign exchange interventions capable of curbing the inflationary pressure coming from outside. Provided that, the monetary authorities in Ethiopia would rather not put much weight on the exchange rate as an instrument to control inflation or improve the country's current account positions. All available evidence shows that the external sector has exhibited a persistent deficit since greater flexibility of the exchange rate was introduced in the early 1990s, and domestic inflation has been steadily on the rise. Periodic devaluation is not the ideal remedy for an economy with a heavy reliance on

imports and a limited export base. Beside this, the monetary authority should reduce the supply of money by issuing compulsory bonds that have to be purchased by private sectors on their profit, this in turn reduces the people's spending on consumption, and it also reduces the probability of converting Birr into dollars in parallel markets.

In addition, it is important that policymakers accelerate the pace of structural reforms aimed at economic diversification. The degree of ERPT to inflation, which is still high in Ethiopia's economy, appears to stem from a less diversified economic structure and, therefore, from increased dependence on imports. Policymakers in Ethiopia therefore need to create an environment conducive to economic diversification and the promotion of domestic industries.

Moreover, as both the impulse response function and variance decomposition result indicate that a unit shock in government expenditure has an effect on the general price of commodities in Ethiopia. This result may be due to the large number of subsidies provided by the government to different sectors of the economy, which eventually have an inflationary effect. Therefore, policymakers should focus on increasing the supply of commodities rather than subsidizing the economy.

Finally, as the result of the impulse response function shows, the shock on the international energy price has an expanding effect on the general price of Ethiopia for the next two consecutive years, provided that the government has to launch different huge projects like trains, which can save energy relative to vehicles, and the location of the industries should be nearer to the place, which can reduce transportation costs, and finally, the government should control illegal retailers from selling oil in parallel markets.

#### Funding

No funding for this research

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#### Disclosure statement

No potential conflict of interest was reported by the author(s).

#### Authors' contributions

Henok Ezezew Sheferaw (First Author) and Kalid Wendimnew Sitotaw (Second Author)

#### Availability of data and materials

Data are available upon request to the corresponding author

#### Citation information

Cite this article as: Empirical investigation of exchange rate transmission into general inflation level in Ethiopia – SVAR approach, Henok Ezezew Sheferaw & Kalid Wendimnew Sitotaw, *Cogent Business & Management* (2023), 10: 2243662.

#### Notes

1. The Taylor Rule is an interest rate forecasting model invented by famed economist John Taylor in 1992 and outlined in his 1993 study, "Discretion Versus Policy Rules in Practice." It suggests how central banks should change interest rates to account for inflation and other economic conditions. Taylor's rule makes the recommendation that the Federal Reserve should raise interest rates when inflation is high or when employment exceeds full employment levels. Conversely, when inflation and employment levels are

low, the Taylor rule implies that interest rates should be decreased.

2. For more information see the book by S. Ouliaris, A.R. Pagan and J. Restrepo, (2018).
3. To get more information about the computation of impulse response from moving average function see a book by S. Ouliaris, A.R. Pagan and J. Restrepo, (2018).
4. 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.
5. The Bivariate VAR (1) system has the following form.

$$\begin{bmatrix} 1 & a_{12}^0 \\ a_{21}^0 & 1 \end{bmatrix} \begin{bmatrix} Z_{1t} \\ Z_{2t} \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11}^1 & a_{12}^1 \\ a_{21}^1 & a_{22}^1 \end{bmatrix} \begin{bmatrix} Z_{1t-1} \\ Z_{2t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$$

and it has 10 unknown parameters (two constants, four auto-regressive coefficients, three elements in the symmetric 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.

6. <https://www.bruegel.org/publications/datasets/real-effective-exchange-rates-for-178-countries-a-new-database/>
7. The two characteristic features of hyperinflation are: a very rapid rise in prices and a general tendency to convert money into goods.

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## Appendix

### 1. Model selection

	VAR(1)	VAR(2)	VAR(3)	VAR(4)
LR	42.81413*	33.57576	22.31245	26.92423
FPE	1.47E-09	1.72E-09	2.77E-09	3.35E-09
AIC	-6.160337*	-6.060017	-5.733003	-5.859702
SC	-4.906504	-3.761323	-2.389448	-1.471286
HQ	-5.703761	-5.22296	-4.515465	-4.261683

### 2. Diagnostic Test

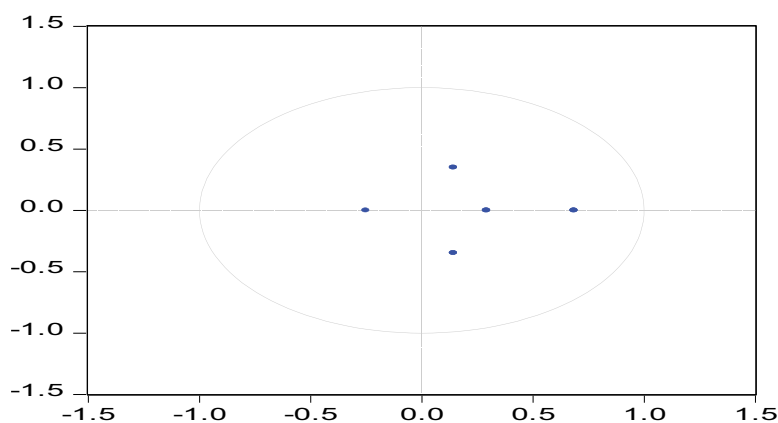
Tests	VAR(1)	VAR(2)	VAR(3)	VAR(4)
Serial correlation	0.1167	0.3326	0.3198	0.7737
Heteroskedasticity	1.47E-09	1.72E-09	2.77E-09	3.35E-09
Normality				
Skewness	0.5173	0.3551	0.3053	0
Kurtosis	0.4022	0.9327	0.6749	0
Jarque-Bera	0.571	0.6497	0.5415	0

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.

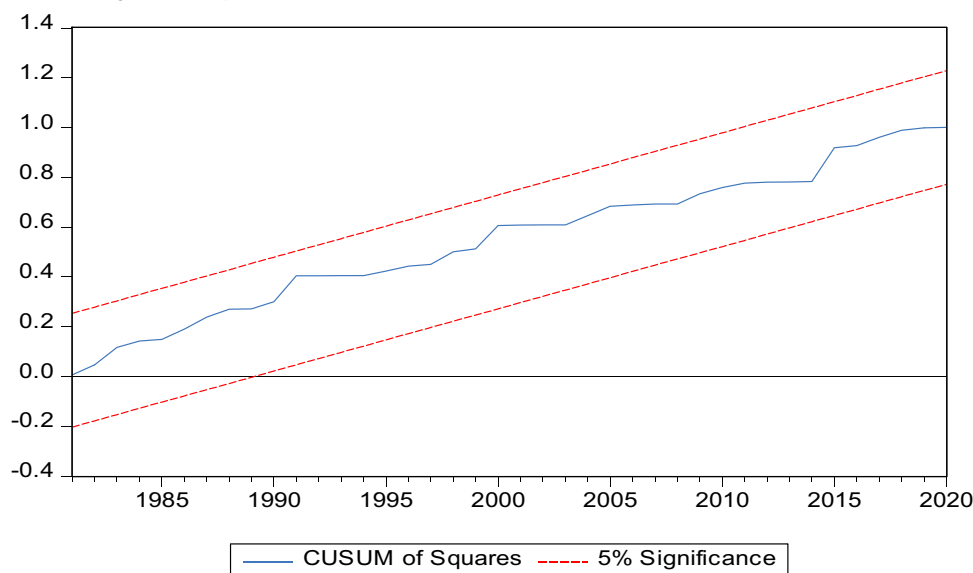
### 3. Stability Test

Stability test result of the VAR (1) model

**Inverse Roots of AR Characteristic Polynomial**



#### 4. Ordinary Least Square Cumulative Sum Plots of Model Residuals



#### 5. Co integration result

##### Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.527800	78.09391	79.34145	0.0618
At most 1	0.383489	45.82874	55.24578	0.2576
At most 2	0.357233	25.03055	35.01090	0.3819
At most 3	0.112766	6.025719	18.39771	0.8669
At most 4	0.020278	0.880937	3.841466	0.3479

Trace test indicates no cointegration at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

##### Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

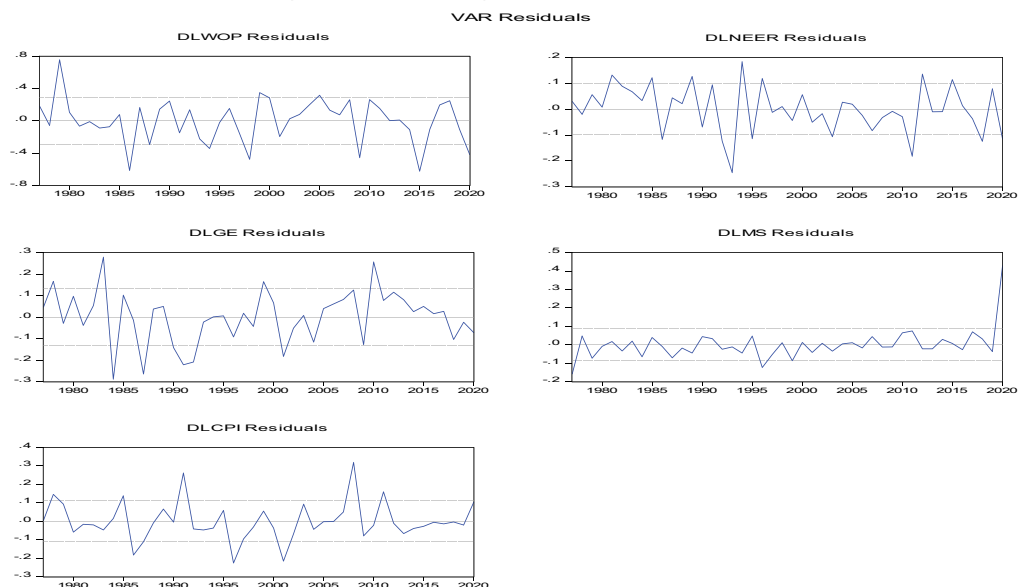
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.527800	32.26517	37.16359	0.1645
At most 1	0.383489	20.79819	30.81507	0.4876
At most 2	0.357233	19.00484	24.25202	0.2126
At most 3	0.112766	5.144782	17.14769	0.8916
At most 4	0.020278	0.880937	3.841466	0.3479

Max-eigenvalue test indicates no cointegration at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

## 6. Residuals of the VAR Equations (Full Sample)



## 7. Vector Autoregression Estimation

Vector Autoregression Estimates

Date: 03/15/22 Time: 14:02

Sample (adjusted): 1977 2020

Included observations: 44 after adjustments

Standard errors in ( ) & t-statistics in [ ]

	DLWOP	DLNEER	DLGE	DLMS	DLCPI
DLWOP(-1)	0.047732 (0.17328) [ 0.27546]	0.131035 (0.05866) [ 2.23398]	-0.051018 (0.07837) [-0.65100]	-0.011298 (0.05223) [-0.21632]	0.058434 (0.06631) [ 0.88122]
DLNEER(-1)	-0.469051 (0.38993) [-1.20290]	0.509113 (0.13199) [ 3.85717]	-0.302002 (0.17635) [-1.71249]	-0.066518 (0.11752) [-0.56600]	-0.076586 (0.14922) [-0.51325]
DLGE(-1)	0.298245 (0.35226) [ 0.84666]	0.205073 (0.11924) [ 1.71985]	-0.032366 (0.15932) [-0.20316]	0.114567 (0.10617) [ 1.07910]	0.005621 (0.13480) [ 0.04170]
DLMS(-1)	-0.543351 (0.81732) [-0.66480]	0.084885 (0.27666) [ 0.30682]	0.329193 (0.36964) [ 0.89058]	0.555773 (0.24633) [ 2.25621]	0.528822 (0.31276) [ 1.69081]
DLCPI(-1)	-0.253256 (0.46936) [-0.53958]	-0.378703 (0.15887) [-2.38366]	-0.243650 (0.21227) [-1.14782]	0.016428 (0.14146) [ 0.11613]	-0.061380 (0.17961) [-0.34174]
C	0.073111 (0.11601) [ 0.63022]	-0.034806 (0.03927) [-0.88637]	0.103033 (0.05247) [ 1.96381]	0.057114 (0.03496) [ 1.63352]	0.008516 (0.04439) [ 0.19184]
R-squared	0.073504	0.394764	0.149432	0.239043	0.116785
Adj. R-squared	-0.048404	0.315128	0.037515	0.138917	0.000573
Sum sq. resids	3.187852	0.365261	0.652047	0.289571	0.466819
S.E. equation	0.289639	0.098042	0.130993	0.087294	0.110836
F-statistic	0.602948	4.957089	1.335202	2.387423	1.004927
Log likelihood	-4.686768	42.97600	30.22694	48.08468	37.57880
Akaike AIC	0.485762	-1.680727	-1.101225	-1.912940	-1.435400
Schwarz SC	0.729061	-1.437429	-0.857926	-1.669641	-1.192101
Mean dependent	0.026917	-0.040226	0.134709	0.160063	0.088542
S.D. dependent	0.282874	0.118469	0.133521	0.094073	0.110868
Determinant resid covariance (dof adj.)	7.94E-10				
Determinant resid covariance	3.81E-10				
Log likelihood	164.9500				
Akaike information criterion	-6.134092				
Schwarz criterion	-4.917599				
Number of coefficients	30				

## 8. Structural VAR Estimation

Structural VAR Estimates

Date: 03/15/22 Time: 14:00

Sample (adjusted): 1977 2020

Included observations: 44 after adjustments

Estimation method: Maximum likelihood via Newton-Raphson (analytic derivatives)

Convergence achieved after 9 iterations

Structural VAR is just-identified

Model:  $Ae = Bu$  where  $E[uu'] = I$

A =

1	0	0	0	0
C(1)	1	0	0	0
C(2)	C(5)	1	0	0
C(3)	C(6)	C(8)	1	0
C(4)	C(7)	C(9)	C(10)	1

B =

C(11)	0	0	0	0
0	C(12)	0	0	0
0	0	C(13)	0	0
0	0	0	C(14)	0
0	0	0	0	C(15)

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.003748	0.051027	0.073451	0.9414
C(2)	-0.061988	0.067379	-0.919995	0.3576
C(3)	0.078139	0.041559	1.880185	0.0601
C(4)	-0.128251	0.052946	-2.422320	0.0154
C(5)	-0.093892	0.199054	-0.471693	0.6371
C(6)	0.299452	0.121919	2.456156	0.0140
C(7)	-0.076256	0.159351	-0.478542	0.6323
C(8)	-0.082610	0.092104	-0.896922	0.3698
C(9)	-0.121258	0.113919	-1.064425	0.2871
C(10)	-0.503379	0.184780	-2.724202	0.0064
C(11)	0.289639	0.030876	9.380830	0.0000
C(12)	0.098036	0.010451	9.380830	0.0000
C(13)	0.129444	0.013799	9.380830	0.0000
C(14)	0.079083	0.008430	9.380830	0.0000
C(15)	0.096932	0.010333	9.380830	0.0000

Log likelihood 148.8236

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.003748	1.000000	0.000000	0.000000	0.000000
-0.061988	-0.093892	1.000000	0.000000	0.000000
0.078139	0.299452	-0.082610	1.000000	0.000000
-0.128251	-0.076256	-0.121258	-0.503379	1.000000

Estimated B matrix:

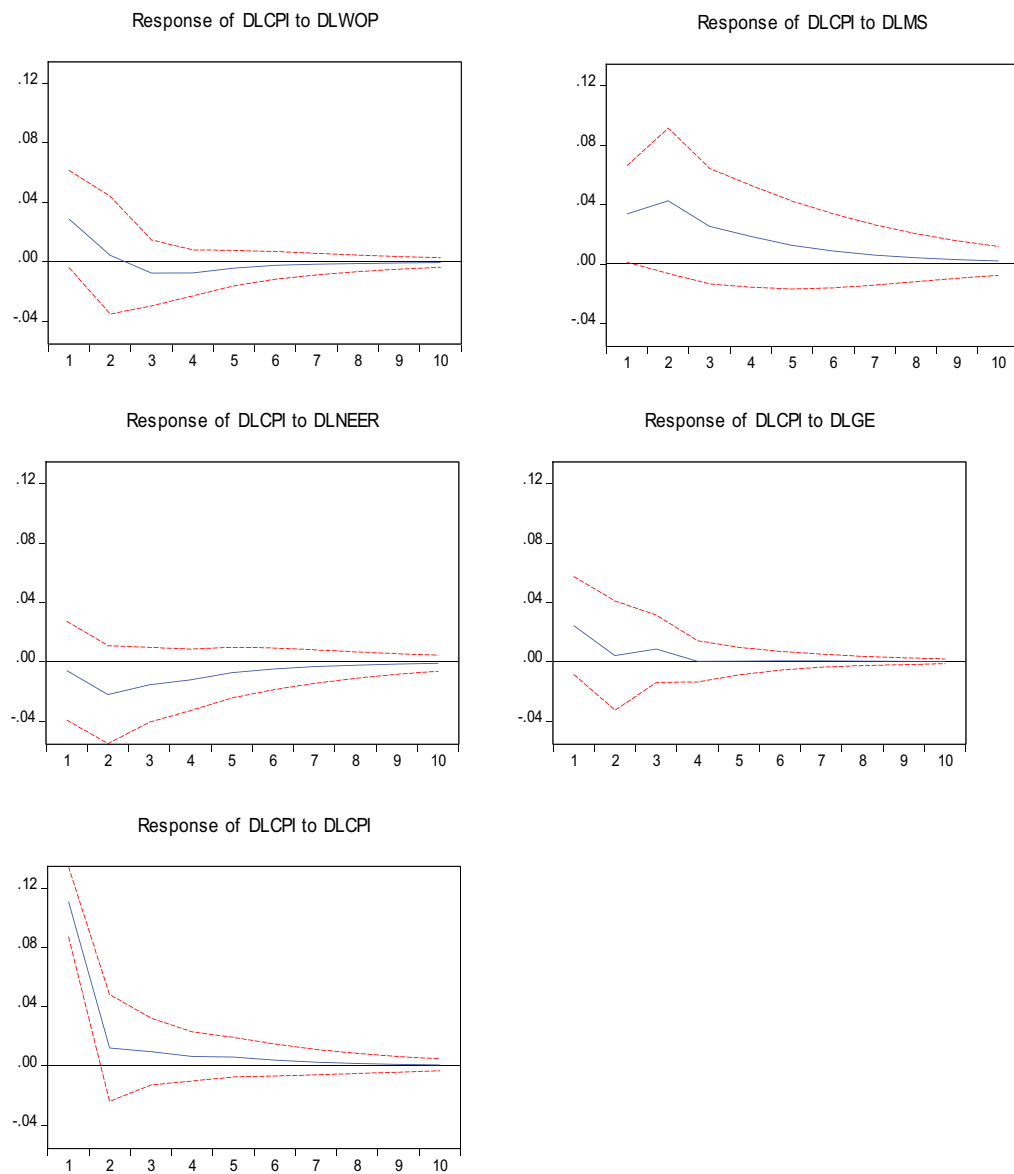
0.289639	0.000000	0.000000	0.000000	0.000000
0.000000	0.098036	0.000000	0.000000	0.000000
0.000000	0.000000	0.129444	0.000000	0.000000
0.000000	0.000000	0.000000	0.079083	0.000000
0.000000	0.000000	0.000000	0.000000	0.096932

Estimated S matrix:

0.289639	0.000000	0.000000	0.000000	0.000000
-0.001086	0.098036	0.000000	0.000000	0.000000
0.017852	0.009205	0.129444	0.000000	0.000000
-0.020832	-0.028597	0.010693	0.079083	0.000000
0.028742	-0.005803	0.021079	0.039809	0.096932

Estimated F matrix:

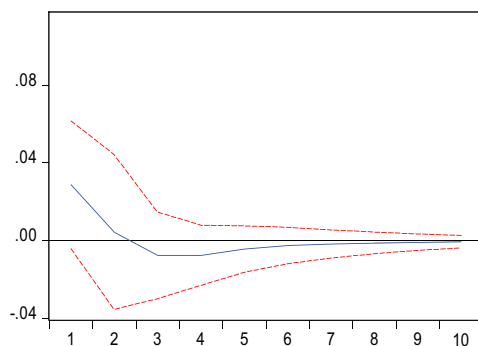
0.308092	-0.035109	-0.015450	-0.103226	0.001552
0.048899	0.203953	0.023046	-0.076029	-0.076648
-0.036081	-0.066686	0.126280	0.061370	0.002685
-0.071179	-0.114153	0.055266	0.213182	0.016011
0.004858	-0.079346	0.045551	0.143850	0.104934



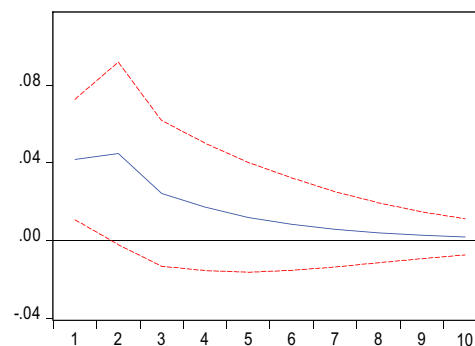


## 9. Generalized Impulse response function

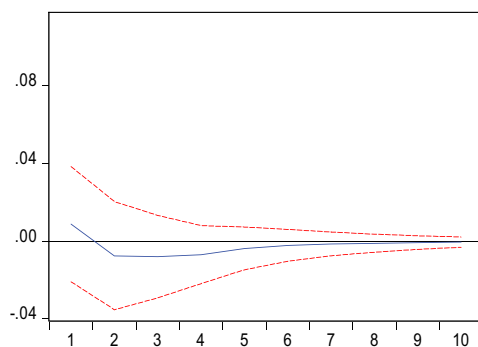
Response of DLCPI to DLWOP



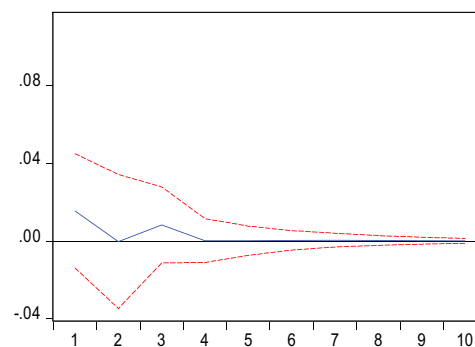
Response of DLCPI to DLMS



Response of DLCPI to DLNEER



Response of DLCPI to DLGE



Response of DLCPI to DLCPI

