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Abstract

This study investigates the asymmetric effect of appreciation and depreciation of the Kwacha/US dollar exchange rate on the domestic price formation in Zambia. It also estimates the size of the exchange rate pass-through (ERPT) to domestic food and non-food inflation in the short and long run using a sign restricted structural vector autoregressive (SVAR) and the nonlinear autoregressive distributed lag (NARDL) models. We find evidence of asymmetric ERPT in both short and long-run for food and non-food inflation: the impact from exchange rate depreciation is greater than that from exchange rate appreciation. These findings suggest moderation of exchange rate depreciation cycles.

Keywords: Exchange rate; inflation; non-linear autoregressive distributed lag (NARDL); structural vector autoregression

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1.0 Introduction

The ever-growing literature on the exchange rate pass-through (ERPT) to inflation has continued to provide valuable insights and evidence on the relationship between the exchange rate and price formation in the economy. In general, extensive research converges on the factors that influence the ERPT such as the degree of economic integration, the currency in which prices are set, and monetary policy.

In Zambia, stability of the exchange rate market remains key to maintaining low and stable inflation with extra benefits of supporting sustainable economic growth and a stable financial system. It is for this reason that an interrogation into the intrinsic nature of the ERPT to inflation is warranted. Given that monetary policy is aimed at managing demand pressures, this inquiry provides an opportunity to provide information useful in formulating responsive and well guided monetary policy when reacting or managing future price pressures and expectations arising from exchange rate movements.

There exists ample research on the drivers of inflation both overall and its components (Mwansa, 1998; Pamu and Simuchile, 2004; Mutoti, 2006; Musongole, 2011; Chipili, 2015; Chipili, 2021). Another strand of research on developing economies has concerned itself with understanding ERPT to overall inflation. However, most of this research, especially on developing economies and Zambia in particular, has either assumed a linear ERPT to inflation or assumed that the ERPT to food and non-food inflation is the same (Zgambo, 2015; Roger et al, 2017; Mwila et al, 2018; Fandamu et al, 2023). For instance, Zgambo (2015), and to some extent Mwila et al, (2018), estimate the ERPT separately for food and non-food inflation, but do not allow for asymmetry of ERPT of depreciation and appreciation to the inflation components. Fandamu et al (2023) consider asymmetric ERPT, but only analyse overall inflation and not its components, implicitly assuming that ERPT of depreciation and appreciation to food and non-food inflation is the same. In addition, the other common challenge of the studies by Fandamu et al (2023), Mwila et al (2018) and Zgambo (2015) are with respect to the use of a simple Cholesky scheme to identify exchange rate shocks. The use of a Cholesky scheme places a rigid structure on the relationship between the variables by forcing a recursive relationship to exist, which would be problematic when this is not the case and recursive relationships are generally difficult to justify from an economic perspective (Kilian and Lutkepohl, 2017). For instance, by ordering the exchange rate before inflation, all three studies implicitly assume that the causal chain is strictly from exchange rate to inflation, but this is at odds with the purchasing power parity theory.

To obviate this limitation imposed by using simple Cholesky identification schemes, Roger et al (2017) employ zero and sign restrictions to uncover the ERPT for Zambia. However, the study only focuses on overall CPI ignoring the benefits of disaggregation. In addition, the study did not account for the asymmetry or nonlinearities in the differential impact of exchange rate appreciation or depreciation on prices. This study, therefore, fills this gap by analysing the ERPT to disaggregated components of inflation i.e. food and non-food inflation and accounting for asymmetry by investigating the role of appreciation and depreciation on inflation. This is done in two ways: the use of sign restrictions in a SVAR framework as well as estimation of a nonlinear ARDL model. Accounting for the non-linearities of the ERPT in the distinctive components of inflation means that exchange rate appreciation and depreciation have different strength on the specific components of inflation. This impact may also varydepending on whether considerations are for the long-run or short-run.

Correct attribution of the ERPT applied on a timeline is of prime importance for responsive monetary policy. Therefore, it is sensible to assume that the food sector and the non-food sector are differently exposed to both external supply and exchange rate shocks. For example, availability of substitutes for imported inputs domestically can affect the symmetric nature of the ERPT for individual components of inflation. Our approach does not detract from the existing knowledge, but adds the benefit of offering an extended insight beneficial to the monetary policymaker, more specifically, a time conscious analysis of how depreciation and appreciation transmit into the domestic price formation process through individual components.

Our results show that the ERPT to inflation is strongly asymmetric. Using a sign restricted structural autoregressive (SVAR) model, we estimate the ERPT for food inflation to be 0.53 percent and 0.25 percent for non-food inflation. These results are similar in magnitude to those obtained by Choudhri and Hakura (2001), Akram et al (2012) and Zgambo (2015). We also establish that the ERPT is incomplete, consistent with what others have found in previous studies (Zgambo, 2015; Rogers et al, 2017; Mwila et al, 2018 and Fandamu et al, 2023). We find and show that depreciation shocks are followed by statistically significant rise in both food and non-food inflation, but there is no evidence suggesting the same when the Kwacha appreciates. We, however, find that the peak impact of the ERPT is much shorter at six months for food inflation and four months for non-food inflation while the previous studies reported peak impacts ranging from 10-20 quarters. Further, using the nonlinear autoregressive distributed lag (NARDL) model, we show that in both the long-run and short-run, the depreciation of the Kwacha has a positive effect on domestic food prices while we fail to find evidence of exchange rate appreciation significantly affecting food prices.

The remainder of this paper is structured as follows: The second section reviews theoretical and empirical literature. Section 3 presents the methodology, specifies the sign restricted SVAR and NARDL econometric models. Section 4 presents data. Section 5discusses the key findings. Section 5 concludes and provides policy recommendations.

2.0 Literature Review

2.1 Theoretical Models

Two theoretical models are presented because they encompass the two possible outcomes of ERPT i.e. incomplete and complete pass-through. The first theoretical model that explains the ERPT to inflation is the traditional pricing-to-market (PTM). According to this model, firms engage in strategic pricing by setting different prices in different markets to maintain market share. Thus, changes in exchange rates affect prices of imported goods, but prices of domestically produced goods remain unaffected. Therefore, the ERPT to inflation is incomplete as only a fraction of the exchange rate change is passed through to domestic prices (Marazzi and Sheets, 2007). The PTM model can be expressed as

$$P \;=\; (1-\beta)\, P* \; + \beta\, Pd$$

where P is the domestic price, P^* is the foreign price, Pd is the marginal cost of production, and β is the market share parameter. This equation suggests that the degree of ERPT to inflation depends on the value of β. If β is small, then the ERPT to inflation is incomplete as changes in exchange rates affect only a fraction of domestic prices.

The second theoretical model that explains the ERPT to inflation is the sticky-price. This model states that prices are fixed and take time to respond to changes in exchange rates. Thus, firms absorb exchange rate fluctuations in their profit margins, and the ERPT to inflation is incomplete in the short-run. The sticky-price model is written as

$$P = \alpha + \beta E + \varepsilon$$

where P is the domestic price, E is the exchange rate and ε is the error term. This equation suggests that the degree of ERPT to inflation depends on the adjustment speed of prices, which is captured by the parameter β. If β is small, then the ERPT to inflation is incomplete in the short-run as prices do not adjust immediately to changes in the exchange rate. However, in the long-run, prices adjust to changes in the exchange rate, and the ERPT to inflation is complete (Gagnon and Ihrig, 2004).

2.2 Related Empirical Literature

Exchange rate dynamics and their far-reaching impact on domestic prices of goods and services and ultimately on domestic macroeconomic management make the ERPT subject matter an ever-interesting area of research. Bahmani-Oskooee and Fariditavana (2020) regurgitate this position with many researchers and policymakers working towards better understanding of the intrinsic nature of the relationship between the exchange rate and inflation. In general, literature has shown that the degree of ERPT varies across countries and time periods.

Early work on ERPT by Dornbusch (1987) showed that changes in the exchange rate had a significant effect on import prices, which in turn affected consumer prices. Various studies that followed, for instance Goldberg and Knetter (1997), validated this finding and pointed out that the degree of ERPT tended to vary from one country to another depending on the extent of import competition and how firms price goods in local currency. Others showing variations in the size of the ERPT include Forbes and Chinn (2004), Ca' Zorzi et al. (2007) and Baumeister and Kilian (2016). Ribeiro and Carneiro (2021) for Brazil added another dimension to the conversation by showing that the ERPT was time-varying.

The implications of the ERPT for macroeconomic policy have also been studied extensively. For instance, Campa and Goldberg (2002) and Gagnon (2007) found evidence suggesting that the degree of the ERPT is affected by monetary policy actions. Ebo and Danquah (2019) and Rajan and Sen Gupta (2020) studied factors that affect the ERPT and showed that the ERPT can vary depending on several factors, including the extent of openness of the economy and the level of exchange rate flexibility.

In Sub-Saharan Africa, various researchers have estimated the size of the ERPT and investigated whether or not it is complete. Examples of such studies include Ocran and Ackah (2021) for Ghana who found that that the ERPT was incomplete in the short-run, but complete in the long-run. On impact, a one percentage point increase in the exchange rate was found to lead to a 0.39% increase in inflation. These results are similar to those in a previous study by Bokpin and Sowa (2020). For South Africa, Cattaneo and Malacrino (2020), using a time-varying parameter vector autoregressive model, estimated the ERPT to inflation to be 0.5%.

In Zambia, Zgambo (2015) estimated the ERPT to range between 0.41% and 0.49% broadly in line with Choudhri and Hakura (2001), Akram et al (2015) who estimated it to be around 0.16% in the short-run and 0.48% in the long-run. Banda et al. (2019) found the ERPT impact ofabout 0.30% in the long-run. Others, however, find the ERPT to be high in Zambia, for example, Chileshe et al. (2019) and Kabwe et al. (2020) who estimated the long-run pass-through of 0.8% and 0.9%, respectively.

Our review of related literature on Zambia so far identifies our current research as being closely related to studies by Zgambo (2015), Rogers et al (2017), Mwila et al (2018) and Fandamu et al (2023). Fandamu et al (2023), like Mwila et al (2018) and Zgambo (2015), carry out the ERPT analysis using the SVAR with short-run exclusion restrictions. Zgambo (2015) finds that the impact of shocks to the exchange rate exerts more influence on food prices than on non-food and overall prices and with the estimated dynamic pass-through elasticities ranging between 0.41% and 0.49%. Similarly, Mwila et al (2018), using monthly data, also showed that depreciation causes consumer prices to increase over time with food prices responding faster to depreciation than does the overall price level. In a more recent study, Fandamu et al (2023) finds that the ERPT to consumer price inflation is incomplete and asymmetric as inflation is more responsive to the kwacha depreciation than appreciation. Rogers et al (2017) approach this matter differently and combined short-run sign- and zero-restrictions to identify relevant global and domestic shocks and found that the ERPT to consumer prices depends so much on the shock that originally caused the exchange rate to fluctuate with the monetary shock causing the largest ERPT to prices.

Although Zgambo (2015) takes a disaggregated approach to estimating the ERPT, the study does not fully account for the asymmetries in the impact of depreciation and appreciation thus implying symmetric impacts. While Fandamu et al (2023) explicitly studies asymmetries of depreciation and appreciation, the study analyses overall CPI and like Zgambo (2015) using quarterly data. Mwila et al (2018) also concentrates the pass-through analysis on food inflation and overall inflation and obtain broadly similar results to Zgambo (2015). All three studies use Cholesky identification strategies, which has been critiqued for being inflexible as the recursive assumption is hardly justifiable in economic theory and in practice (Killian & Lutkepohl, 2017). While Rogers et al (2017) resolve this by using a combination of sign and zero restrictions in the SVAR, but do not consider the impact of asymmetry of exchange rate changes.

Given this assessment of the literature, our study builds on by firstly using a high frequency relatively stable dataset (between 2010 and 2019) that is over 86% collected during the same monetary regime. Secondly, by avoiding the shock periods such as the Global Financial Crisis and COVID-19 crisis, our analysis captures the underlying economic relationships free of extreme biases that are difficult to predict with statistical models. Finally, we improve on the qualitative conclusions made by similar studies by providing evidence from non-linear econometric models estimating asymmetries with a disaggregated approach and using a more robust theoretical identification strategy.

3.0 Model Specification and Estimation Strategy

3.1 Econometric Model Specification

In the SVAR framework, let Y_t be a vector of stationary economic variables whose structural representation is given by

$$Y_t = B(L)u_t\ , u_t \sim WN(0, I) \tag{1}$$

u_t is the vector of structural shocks and the impulse response function (IRF) is given by

$$B(L) = B_0 + B_1L + B_2L^2 + \cdots \tag{2}$$

In which B_j are the matrices of coefficients and L is the lag operator.

The goal is to estimate structural shocks u_t and $B(L)$. By stationarity, Y_t has a Wold representation in its reduced form as shown in equation (3)

$$Y_t = C(L)\varepsilon_t,\ \ \varepsilon_t \sim WN(0, \Sigma) \tag{3}$$

where

$$C(L) = C_0 + C_1L + C_2L^2 + \cdots \tag{4}$$

Equation (4) are the Wold IRFs and the key assumption in that the Wold shocks are a linear combination of the structural shocks i.e. $\varepsilon_t = B_0u_t$

This implies that

$$Y_t = C(L)B_0u_t \tag{5}$$

and that the structural IRFs are given by $B(L) = C(L)B_0$

$C(L)$ and ε_t are estimated using OLS while B_0 can be pinned down through identification.

In the case of the Cholesky identification scheme, $B_0 = S$ where S is the Cholesky factor of Σ and $SS' = \Sigma$. Therefore, equation (5) can be rewritten as

$$Y_t = C(L)S^{-1}\varepsilon_t \tag{6}$$

$$Y_t = D(L)\eta_t \tag{7}$$

Let H be an orthogonal matrix such that $HH' = I$ then

$$Y_t = D(L)HH'\eta_t \tag{8}$$

$$Y_t = B(L)u_t \tag{9}$$

with $\mathrm{B}(L) = D(L)H$ and $u_t = H'\eta_t$ is also orthogonal.

We can now set H so that our theoretical restrictions are satisfied and compute

$$B_0 = SH \tag{10}$$

In equation (10), it can be seen the Cholesky identification is but a special case when $H = I$.

Following the approach by Rubio-Ramirez et al (2010), H is obtained by QR decomposition of another matrix $M = QR$. M is a random matrix drawn from a multivariate normal distribution with zero mean and constant variance equal to the Identity matrix.

$H = Q$ when the restrictions placed on parameters are satisfied.

If the IRFs satisfy the restrictions, we keep the H and draw another random matrix. We iterate this over 10,000 random draws and therefore end up with several H matrices, any by extension several IRFs that meet our restrictions. We then choose the IRF that is closest to the median of all the set of IRFs identified by finding the draw that minimizes the sum of squared errors between the median and the draws of Q.

Our model has five variables and follows closely the model specification[2] by Kassi et al (2019) and Fandamu et al, (2023) i.e. growth in oil prices (a proxy for foreign price), growth in real money supply, positive exchange rate change,[3] negative exchange rate changes and inflation (food or non-food inflation). The restrictions we place on the H matrix to identify the respective shocks is given in equation 11.

$$\text{H}=\begin{bmatrix} (+) & ? & ? & ? & (+) \\ ? & (+) & ? & ? & (+) \\ ? & (+) & (+) & ? & (+) \\ ? & (-) & ? & (-) & (-) \\ ? & ? & ? & ? & (+) \end{bmatrix} \begin{bmatrix} Oil\ Shock \\ Money\ Shock \\ Depreciation\ \ Shock \\ Appreciation\ Shock \\ inflation\ Shock \end{bmatrix} \tag{11}$$

The (?) implies that the respective parameter is free of any imposed restrictions while the other restrictions (+) or (-) are based on theoretical underpinnings. We restrict a positive shock to oil prices and money to impact inflation only while the appreciation (depreciation) shock will decrease (increase) money supply and inflation. Inflation shock is also not constrained to have a particular relationship with the rest of the variables and is left to the data to decide. Therefore, in essence this is an overidentified system, but the results we obtain are not significantly different from a partial identification scheme[4] (results can be provided on request).

To study the possible asymmetries in the ERPT, we borrow the econometric approach, with the empirical specification, from Delatte and Lopez-Villavicencio (2012), Brun-Aguerre et al. (2016) and Kassi et al (2019) who specify some restrictions to examine the asymmetrical ERPT to CPI. However, because our interest is to examine the asymmetric ERPT to individual CPIs, we start with two basic empirical models, namely,(1) food and (2) non-food as follows

[2] Exception is that we leave out GDP in the specification because we use real money growth, is used which is expected to reflect real sector dynamics
[3] The amount of local currency needed for 1 US dollar
[4] Results can be provided upon request to the authors

$$l\_fcpi_t = \alpha_i + \varphi_i l\_ex_t + \beta_i l\_oil_t + \varepsilon_{i,t} \ldots \quad (12)$$
$$l\_nfcpi_t = \alpha_i + \varphi_i l\_ex_t + \beta_i l\_oil_t + \varepsilon_{i,t} \ldots \quad (13)$$

where l_fcpi is the food CPI and l_nfcpi is the non-food CPI. lex is nominal exchange rate variable denoting the amount of Kwacha needed for 1 US dollar, l_oil denotes the price of crude oil (Brent) used as a proxy for the foreign price, and ε is the error term. The subscripts $i = [1,2]$ and t denote individual inflation components and time specification, respectively.

A NARDL specification for individual components of inflation that allow for asymmetries is formulated as:

$$\Delta l\_fcpi_t = \alpha + \psi_i l\_fcpi_{t-1} + \varphi_i^+ l\_ex_{t-1}^+ + \varphi_i^- l\_ex_{t-1}^- + \beta_i l\_oil_{t-1} + \sum_{k=1}^{m} \gamma_{i,k} \Delta l\_fcpi_{t-k} + \sum_{k=0}^{n} w_{i,k}^+ \Delta l\_ex_{t-k}^+ + \sum_{k=0}^{\theta} w_{i,k}^- \Delta l\_ex_{t-k}^- + \sum_{k=0}^{p} \vartheta_{i,k} \Delta l\_oil_{t-k} + \sum_{k=0}^{q} \lambda_{i,k} \Delta l\_y_{t-k} + \mu_{i,t} \ \ldots \quad (14)$$

$$\Delta l\_nfcpi_t = \alpha + \psi_i l\_nfcpi_{t-1} + \varphi_i^+ l\_ex_{t-1}^+ + \varphi_i^- l\_ex_{t-1}^- + \beta_i l\_oil_{t-1} + \sum_{k=1}^{m} \gamma_{i,k} \Delta l\_nfcpi_{t-k} + \sum_{k=0}^{n} w_{i,k}^+ \Delta l\_ex_{t-k}^+ + \sum_{k=0}^{\theta} w_{i,k}^- \Delta l\_ex_{t-k}^- + \sum_{k=0}^{p} \vartheta_{i,k} \Delta l\_oil_{t-k} + \sum_{k=0}^{q} \lambda_{i,k} \Delta l\_y_{t-k} + \mu_{i,t} \ \ldots \quad (15)$$

Like the equation notations in Kassi et al (2019), Δ is the difference operator; $l_ex^+$and l_ex^- represent the positive and negative changes in the exchange rate respectively α refers to the intercept term and $\mu_{i,t} \sim IID\ (0, \sigma^2)$. The l in the variable names means that the variable is transformed into its logarithmic form; φ_i^+ and φ_i^- are coefficients for the long-term asymmetrical effects of exchange rate changes on the individual components of the CPI accounted for by its depreciation (l_ex^+) and appreciation (l_ex^-), respectively; and $\omega_{i,k}^+$ and $\omega_{i,k}^-$ are coefficients for the short-term effects of depreciation and appreciation on the domestic components of CPI.

Equations 14 and 15 represent the unrestricted NARDL models for the CPI component., However, to allow for long-term symmetry, short-term symmetry or both symmetries, based on the results of the Wald tests[5], we must reformulate the equations to the following:

1. When the results of the Wald tests cannot reject the hypothesis of long-term symmetry, the NARDL models (14 -15) are formulated as follows:

$$\Delta l\_\boldsymbol{i}cpi_t = \alpha + \psi_i l\_\boldsymbol{i}cpi_{t-1} + \varphi_i l\_ex_{t-1} + \beta_i l\_oil_{t-1} + \sum_{k=1}^{m-1} \gamma_{i,k} \Delta l\_\boldsymbol{i}cpi_{t-k} + \sum_{k=0}^{n-1} \omega_{i,k}^+ \Delta l\_ex_{t-k}^+ + \sum_{k=0}^{\theta-1} \omega_{i,k}^- \Delta l\_ex_{t-k}^- + \sum_{k=0}^{p-1} \vartheta_{i,k} \Delta l\_oil_{t-k} + \sum_{k=0}^{q-1} \lambda_{i,k} \Delta l\_y_{t-k} + \nu_{i,t} \quad (16)$$

where ***i***, in $\Delta l\_\boldsymbol{i}cpi_{,t}$ denote the individual components of CPI.

[5] Here we test for the equality of two regression coefficients one on depreciation covariate and another on the appreciation covariate.

2. When there is long-term asymmetry between the exchange rate and domestic price changes and secondly, with the short-term symmetry:

$$\Delta l\_icpi_t = \alpha + \psi_i l\_icpi_{t-1} + \varphi_i^{+} l\_ex_{t-1}^{+} + \varphi_i^{-} l\_ex_{t-1}^{-} + \beta_i l\_oil_{t-1} + \sum_{k=1}^{m} \gamma_{i,k} \Delta l\_icpi_{t-k} + \sum_{k=0}^{n-1} \omega_{i,k} \Delta l\_ex_{t-k} + \sum_{k=0}^{p-1} \vartheta_{i,k} \Delta l\_oil_{t-k} + \sum_{k=0}^{q-1} \lambda_{i,k} \Delta l\_y_{t-k} + \nu_{i,t} \quad \ldots \qquad (17)$$

3. Model with long-run and short-run asymmetries:

$$\Delta l\_icpi_t = \alpha + \psi_i l\_icpi_{t-1} + \varphi_i l\_ex_{t-1} + \beta_i l\_oil_{t-1} + \sum_{k=1}^{m} \gamma_{i,k} \Delta l\_icpi_{t-k} + \sum_{k=0}^{n-1} \omega_{i,k} \Delta l\_ex_{t-k} + \sum_{k=0}^{p-1} \vartheta_{i,k} \Delta l\_oil_{t-k} + \sum_{k=0}^{q-1} \lambda_{i,k} \Delta l\_y_{t-k} + \nu_{i,t} \quad \ldots \qquad (18)$$

Kassi et al (2019) notes that this modelling approach, according to Shin et al. (2014) with optimised lags, NARDL (m, n, θ, p, q) based on the general-to-specific approach and the Akaike information criterion, involves the decomposition of the partial sum of the exchange rate variable (l_ex) into positive $(l\_ex_t^{+})$ and negative changes $(l\_ex_t^{-})$ and is computed as follows:

$$l\_ex_t^{+} = \sum_{j=1}^{t} \Delta l\_ex_j^{+} = \sum_{j=1}^{t} \max(\Delta l\_ex_j, 0) \text{ and } l\_ex_t^{-} = \sum_{j=1}^{t} \Delta l\_ex_j^{-} = \sum_{j=1}^{t} \min(\Delta l\_ex_j, 0)$$

$l\_ex_{i,t} \equiv l\_ex_{i,0} + l\_ex_{i,t}^{+} + l\_ex_{i,t}^{-}$ and the long-term ERPT elasticities is given by $\tau^{+} = -(\varphi_i^{+}/\varphi_i)$ and $\tau^{-} = -(\varphi_i^{-}/\varphi_i)$.

Based on the general restricted models 16 -18, like Kassi et al (2019), and following Brun-Aguerre et al. (2016), for each component, we outline six hypotheses:

a. *Hypotheses 1* assumes zero ERPT in the long run: $H_0^1\colon \tau_i^{+} = 0$ $(\tau_i^{-} = 0)$ against $H_A^1\colon \tau_i^{+} \neq 0$ $(\tau_i^{-} \neq 0)$

b. *Hypothesis 2* assumes a complete long-term ERPT
$H_0^2\colon \tau_i^{+} \geq 1$ $(\tau_i^{-} \geq 1)$ against $H_A^2\colon \tau_i^{+} < 1$ $(\tau_i^{-} < 1)$

c. *Hypothesis 3* assumes a symmetrical long-term ERPT
$H_0^3\colon \tau_i^{+} = \tau_i^{-}$ against $H_A^3\colon \tau_i^{+} \neq \tau_i^{-}$

d. Hypothesis 4 assumes zero ERPT in the short run
$H_0^4\colon \sum_{k=0}^{n-1} \omega_{i,k}^{+} = 0, (\sum_{k=0}^{\theta-1} \omega_{i,k}^{-} = 0)$ against $H_0^4\colon \sum_{k=0}^{n-1} \omega_{i,k}^{+} \neq 0, (\sum_{k=0}^{\theta-1} \omega_{i,k}^{-} \neq 0)$

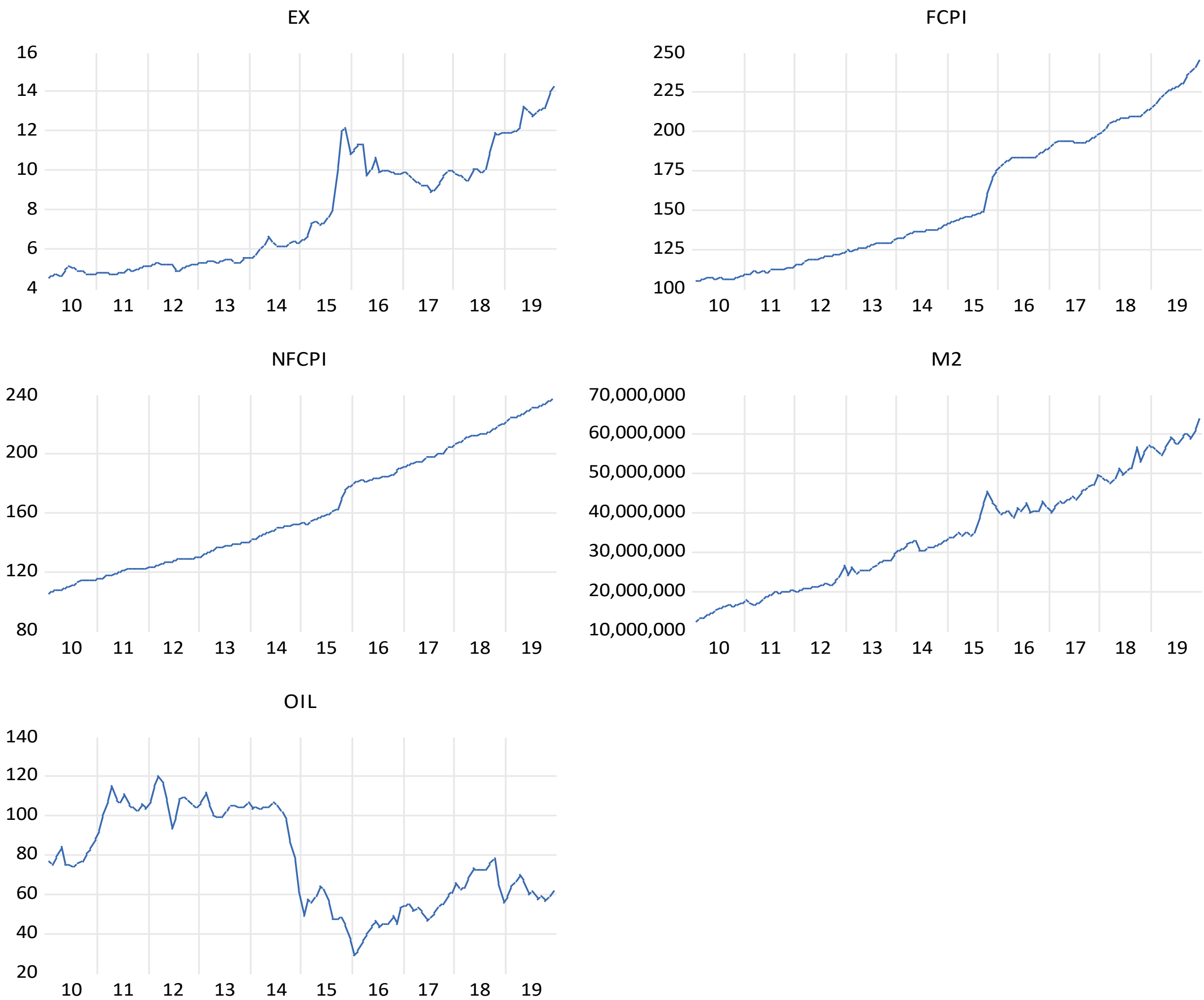
e. Hypothesis 5 assumes a complete short-term ERPT
$H_0^5\colon \sum_{k=0}^{n-1} \omega_{i,k}^{+} \geq 1, (\sum_{k=0}^{\theta-1} \omega_{i,k}^{-} \geq 1)$ against $H_0^5\colon \sum_{k=0}^{n-1} \omega_{i,k}^{+} < 1, (\sum_{k=0}^{\theta-1} \omega_{i,k}^{-} < u1)$

f. Hypothesis 6 assumes a symmetrical short-term ERPT
$H_0^6\colon \sum_{k=0}^{n-1} \omega_{i,k}^{+} = \sum_{k=0}^{\theta-1} \omega_{i,k}^{-})$ against $H_0^6\colon \sum_{k=0}^{n-1} \omega_{i,k}^{+} \neq \sum_{k=0}^{\theta-1} \omega_{i,k}^{-}$

4.0 Data Description and Sources

In this study, we analyse the exchange rate pass-through to inflation using monthly time series of food CPI (fcpi), non-food CPI (nfcpi), exchange rate (ex), Brent oil price (oil) and money supply (M2) for the period January 2010 to December 2019. The study period considered is carefully selected to avoid potential analytical biases that may be introduced by extreme economic periods such as the Global Financial Crisis and the recent Covid-19 crisis. Our CPI data is collected from the Zambia Statistics Agency while the rest of the data are from the Bank of Zambia database. The data is comprehensive, validated and reported as final by the respective collecting agencies. We use oil price to control for foreign prices in line with the literature for example Kassi et al (2019) and Fandamu et al (2023) as alluded to earlier. Figure 1 below plots the series and the trends of these variables.

Figure 1: Evolution of Exchange Rate, Food CPI, Non-Food CPI, Money Supply and Oil Price



Source: Authors' own computations

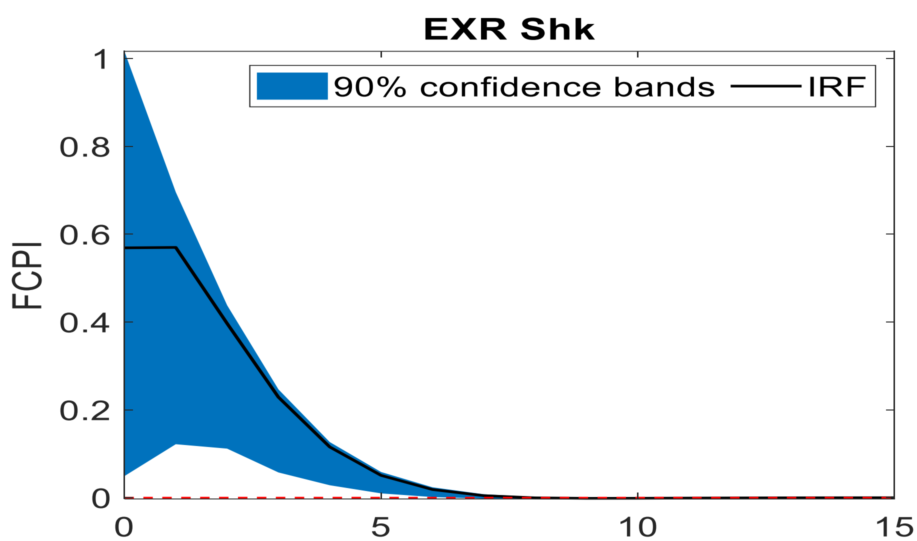
The evolution of the domestic variables is upward trending, but all tend to show some structural break in 2015. In this year, there was excessive exchange rate depreciation coupled with the onset of electricity rationing, hence the level shift in the exchange rate, food inflation, non-food inflation and money supply. The foreign variable of oil price is volatile but also shows some structural break in 2014 largely due to oversupply[6].However, as all these variables are used in first difference in the models, structural breaks in the series are controlled for.

5.0 Empirical Results and Discussion

We present three sets of results from three different models. First, we begin with a fully identified SVAR model of four variables oil prices, money supply, exchange rate and inflation (food and non-food) in order to obtain the magnitude of ERPT for comparison with previous studies. We then extend the model to test for asymmetric impacts of exchange rate depreciation and appreciation in a fully identified model. The magnitude of the shocks from the five-variable model which has positive and negative exchange rate changes as separate variables cannot be used to extract the magnitude of ERPT because the exchange rate variable has been decomposed into its partial sum of positive and negative changes. Therefore, all magnitudes for ERPT are interpreted based on the 4-variable model which includes the exchange rate as a complete variable while the IRFs from the 5-variable model with the partial sum of positive and negative changes are used to infer the presence of asymmetry. Thirdly, we present the results from the NARDL to complete the discussion of results with long and short-run implications as well as formal tests of asymmetry. In essence, the SVAR model results and the NARDL are robustness checks of each other.

The four variable model is fully identified as in equation (11) except the fourth row and column of H are omitted since we only have one exchange rate variable which is defined in terms of a depreciation. The IRF of interest is the shock to the exchange rate and the variable of interest is food inflation. Therefore, we only show the results of the relevant impulse responses of food to an exchange rate shock.

Figure 2: Impulse Response Function for Fully Identified 4-Variable Model for Food Inflation

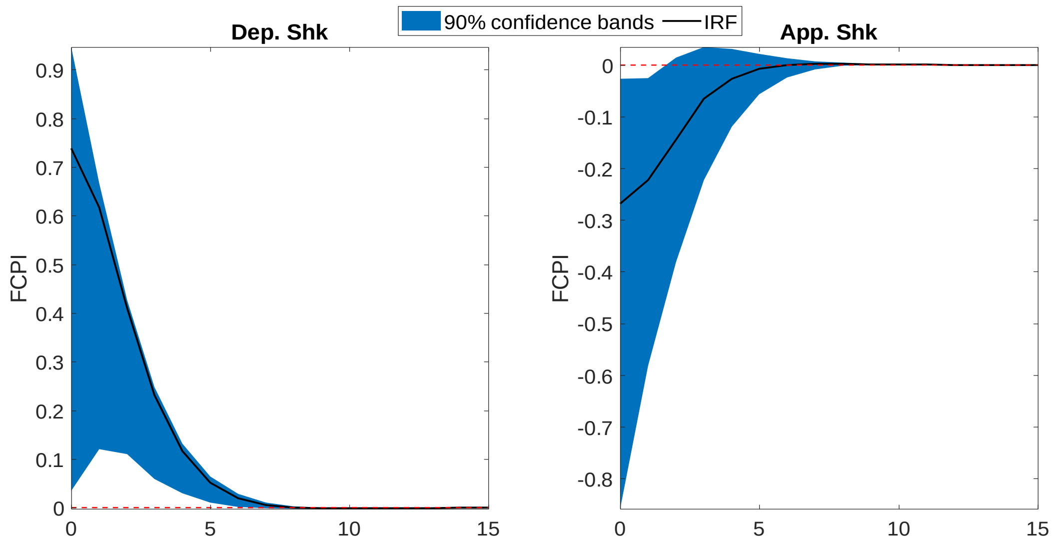


Source: Authors' computation

[6] https://www.bls.gov/opub/btn/volume-4/pdf/the-2014-plunge-in-import-petroleum-prices-what-happened.pdf

From the above, an exchange rate depreciation shock of about 1 percent will cause food inflation to increase by 0.53 percent after six months (Figure 2). To check for asymmetry, we analyse the IRFs from the five-variable model in which exchange rate depreciation and exchange rate appreciation are included as separate variables in a fully identified model (Figure 3).

Figure 3: Impulse Response Functions for Fully Identified 5-Variable Model for Food Inflation



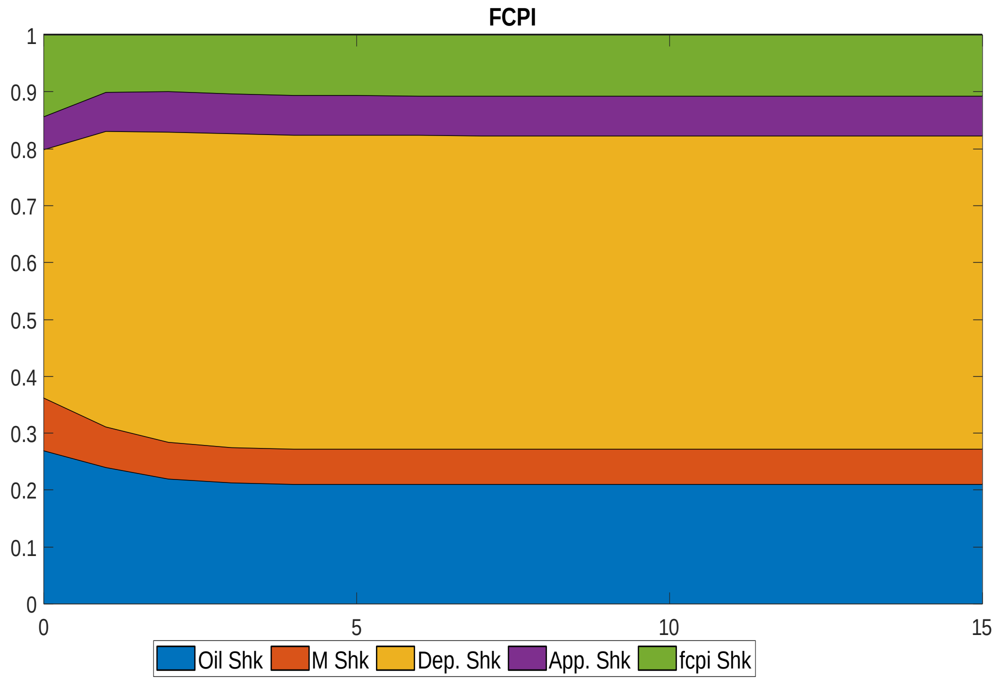
Source: Authors' computation

Note: *App shk and Dep. Shk represent the appreciation and depreciation shocks from the positive and negative changes of the exchange rate. respectively.

With regards to asymmetry, a depreciation shock increases food inflation much more than does an exchange rate appreciation shock in decreasing it (Figure 3). An exchange rate appreciation shock in the IRF is significant only at the one-month lag while the exchange rate depreciation shock dies down after six months.

Therefore, we find evidence of asymmetric ERPT to food prices. The asymmetry is also supported by results from the forecast error variance decomposition chart in which exchange rate depreciation accounts for 55.1 percent of variation in food inflation after 15 months while the appreciation only accounts for 7.0 percent over the same horizon (Figure 4).

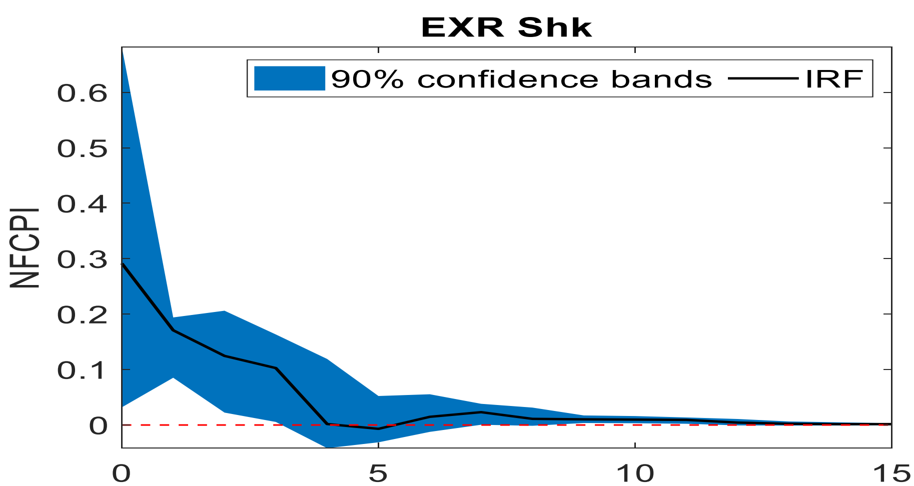
Figure 4: Forecast Error Variance Decomposition of Five-Variable Model of Food Inflation



Source: Authors' own computations
App shk and Dep. shk represent the appreciation and depreciation shocks, respectively.

Next, we present the results for non-food inflation. As before, Figure 5 shows the four-variable model used to obtain ERPT magnitudes. A 1 percent exchange rate depreciation shock increases non-food inflation by 0.25 percent and the peak is reached after four months (Figure 5) after which the IRF becomes statistically insignificant.

Figure 5: Impulse Response Functions for Fully Identified Four-Variable Model for Non-Food Inflation

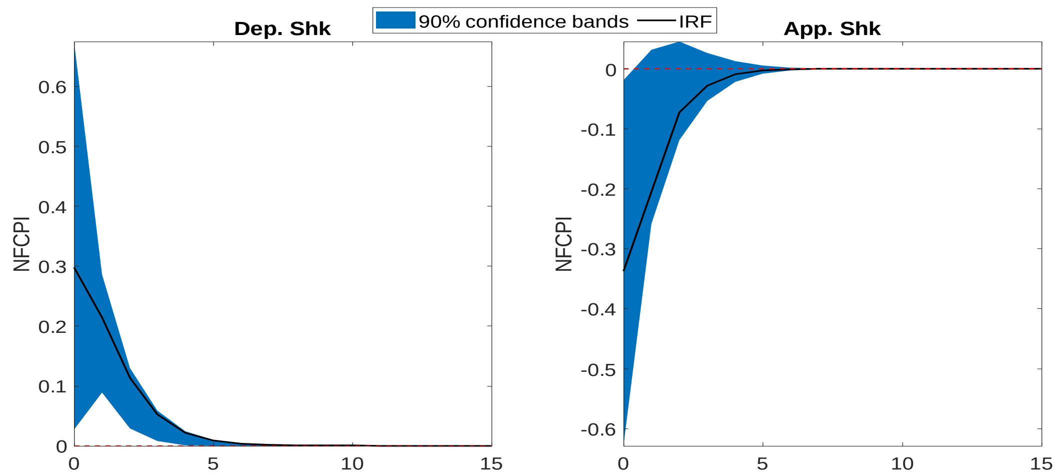


Source: Authors' own computations

To analyse the presence of asymmetry from the exchange rate changes, Figures 6 shows the IRFs for the five-variable fully identified model. These results show an asymmetric impact of

ERPT to non-food prices with the depreciation being more statistically significant over a relatively longer horizon than an appreciation. The appreciation of the exchange rate only has a contemporaneous effect in the non-food inflation case.

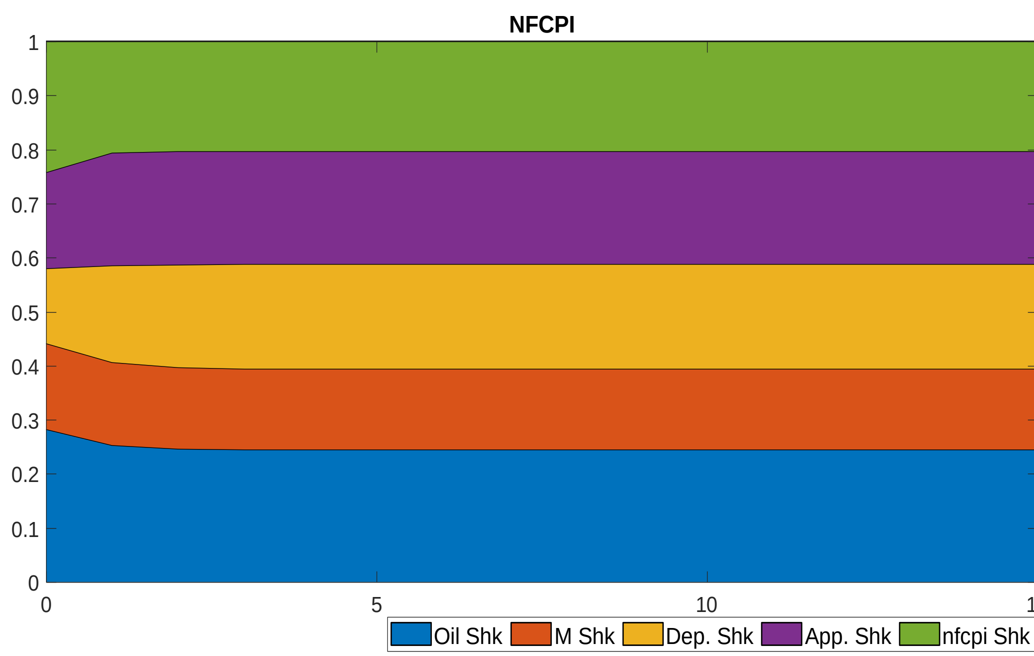
Figure 6: Impulse Response Functions for Fully Identified Five-Variable Model for Non-Food Inflation



Source: Authors' own computations

Unlike the results presented for food inflation, which show a clear dominance of exchange rate depreciation, the exchange rate depreciation and appreciation explain the variation of non-food inflation in almost equal magnitudes of 19.4 percent and 20.1 percent, respectively, after 15 months in the non-food inflation case (Figure 7).

Figure 7: Forecast Error Variance Decomposition of Five-Variable Model of Food Inflation



Source: Authors' own computations

To further investigate the asymmetric nature of the ERPT, we employ the NARDL model where we begin by testing for stationarity of the interest variables. The Augmented Dickey Fuller (ADF) stationarity tests conducted under a null hypothesis of the non-stationary fail to reject for all our variables in levels. Our test results indicate that all the series are non-stationary in levels and only become stationary after the first difference. This step is important as we intend to analyse the long-run relationship among the variables in the NARDL model. Moreover, cointegration tests under the null hypothesis of no cointegration show that there are long-run co-integration relationships between our two target variables and other variables.

We begin our analysis with the food inflation component. As reported in Table 1, in this model, it can be observed that the depreciation of the Kwacha has a statistically significant and positive effect in both the long-run and short-run (with a one-month lag). In this model set up, we fail to find evidence that the appreciation of the domestic currency has an impact on food inflation both in the long-run and short-run. This observation, therefore, suggests strong asymmetric effects of exchange rate changes on domestic food inflation (Table 1).

Table 1: NARDL Estimation Results of the Food Inflation Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.225209	0.103141	2.183502	0.0311
*log*FCPI(-1)	-0.109137	0.040798	-2.675067	0.0086
*log*EX_POS(-1)	0.048830	0.013299	3.671727	0.0004
*log*EX_NEG	0.020459	0.015446	1.324571	0.1881
*log*OIL	0.005179	0.002875	1.801181	0.0744
*log*M2	0.011386	0.006170	1.845281	0.0677
Δ*log*FCPI(-1)	0.335658	0.092437	3.631215	0.0004
Δ*log*EX_POS	0.009255	0.019413	0.476726	0.6345
Δ*log*EX_POS(-1)	0.109721	0.023860	4.598494	0.0000
Δ*log*EX_POS(-2)	-0.041435	0.026241	-1.579039	0.1172

Source: Authors' own computations

The estimation results for the non-food component are somewhat different (Table 2). However, like food inflation, we observe that depreciation has statistically significant and positive effect in both the long-run and short-run (with a month lag). We also find that appreciation has statistically significant and negative effect in the long-run. Based on the hypothesis that $H_0^{3\&6}: \tau_i^+ = \tau_i^-$ against $H_A^{3\&6}: \tau_i^+ \neq \tau_i^-$ for both the long-run and short-run, and in order to test for the presence of an asymmetric effect of depreciation and appreciation on non-food inflation in both the long-run and short-run, we follow the "additive symmetry condition" proposed by Shin et al. (2009). In the context of our study, this proposition means that the symmetry condition can only be rejected if the sum of positive changes (depreciation) is significantly different from the sum of negative changes (appreciation). Based on the Wald-test[7], the results reject the null hypothesis at 5% and conclude that the

[7] We test $H_0^3: \tau_i^+ = \tau_i^-$ against $H_A^3: \tau_i^+ \neq \tau_i^-$ i.e. H_0^3: 0.029819 = 0.024540 and obtain a small p-value i.e. p-value = 0.0031

impact of a depreciation on non-food inflation is greater than the impact of an appreciation in the long-run. This means that non-food inflation is more sensitive to depreciation than to appreciation. For the case of the short-run, we observe similar asymmetries in the non-food inflation. The coefficient on appreciation is negative, but its impact is again less than that of a depreciation. On the basis of our results, we contend that depreciation effects dominate appreciation effects, thus, suggesting strong asymmetries in both components of inflation. These results are consistent with visual results presented in SVAR IRFs above. Finally, based on the hypothesis $H_0^{2\&5}: \tau_i^+ \geq 1$ $(\tau_i^- \geq 1)$ against $H_A^{2\&5}: \tau_i^+ < 1$ $(\tau_i^- < 1)$ for both the long-run and short-run, we observe that the ERPT is incomplete in both inflation components.

Table 2: NARDL Estimation Results of The Non-Food Inflation Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.059328	0.045557	1.302259	0.1957
*log*NFCPI(-1)	-0.185088	0.036039	-5.135825	0.0000
*log*EX_POS(-1)	0.029819	0.007622	3.912149	0.0002
*log*EX_NEG(-1)	-0.024540	0.011529	-2.128605	0.0356
*log*OIL	0.001187	0.002225	0.533548	0.5948
*log*M2	0.042626	0.008879	4.800569	0.0000
Δ*log*NFCPI(-2)	0.244655	0.077703	3.148579	0.0021
Δ*log*EX_POS(-1)	0.058098	0.017776	3.268296	0.0015
Δ*log*EX_NEG(-3)	-0.001610	0.018014	3.975235	0.0756

Source: Authors' own computations

In terms of how the current study compares with similar inquiries, our SVAR asymmetry results coincide with Fandamu et al (2023) who also found asymmetry in the ERPT to inflation, in particular, that depreciation matters more for inflation than does exchange rate appreciation. Our findings that the ERPT to food inflation is higher than that of non-food inflation is similar to Chipili (2021) and Zgambo (2015). The magnitude of the ERPT for food inflation is broadly the same as reported by Zgambo (2015) although the ERPT magnitude for non-food inflation is lower. The pass-through to non-food inflation is, however, closer to the estimates obtained by Rogers et al (2017) who posit that the ERPT may have lowered due to the resilience of the Zambian economy as it enjoyed a considerable time span of low inflation rates. Mwila et al (2018) use monthly series and report a lower ERPT of 0.18 percent for food inflation which culminates after 6 months. There is an obvious difference in the time it takes for exchange rate shocks to transmit to inflation. Our results generally show that shocks to food inflation are more persistent (peaking after six months) than those to non-food inflation (peaking after four months). The persistence of food inflation may stem from the fact that the bulk of the exchange rate shock is indirectly impounded into domestic prices through imported inputs and final consumer goods (Chipili, 2021). Food inflation accounts for 52.6 percent of weight in consumer basket. A qualitative assessment of the role of imported products in the food sub-group (at the product level) from informal anecdotal conversations with industry experts shows that the exchange rate does feature prominently both directly through imported final goods (at least 37 per cent food items in the consumer basket) and indirectly through imported inputs (Table 3).

Table 3: Exchange rate impact on food products in CPI

Food Sub-groups	Weight (out of 1000)	Impact from exchange rate
Bread and cereals	146.03	About 11% of products in this group are imported final goods.
Fish	89.22	In Zambia, about 25-35% of fish consumed is imported.
Food products n.e.c	17.46	At least 97% of products in this sub-group are imported.
Fruit	17.90	At least 21% of fruits are imported.
Meat	82.70	Production of stock feed for livestock uses imported inputs and most livestock medicine is imported.
Milk, Cheese & Eggs	23.64	In this sub-group14% are imported final goods and there is also and indirect impact from imported inputs used in the production of stock feed and livestock medicines.
Oils and Fats	40.06	In this sub-group, 50.5% are imported final products but there is also indirect effect is through imported edible oils/ Crude palm oil used to produce local cooking oil.
Sugar, Jam, honey, chocolate and confectionery	34.91	Sugar which accounts for 94.9% uses imported especially fortifiers.
Vegetables	74.37	In this sub-group 10% are imported final products.
Total Weight	**526.29**	

Source: Authors' own compilation

This contrasts with non-food inflation which has most products imported as final goods. Therefore, it is reasonable to expect the exchange rate shock to impound quickly to non-food items as opposed to food items which show stronger inertia and perhaps a slower adjustment process.

Other studies such as Zgambo (2015) and Fandamu et al (2023) have estimated the peak period of ERPT to be between 10 - 20 quarters. There is a high chance of overestimation as they consider all exchange rate shocks and inflation responses whether significant or not. This is somewhat evident in the IRFs they report. For instance, a visual inspection of the IRFs in Zgambo (2015) and Fandamu et al (2023) may be consistent with a peak ERPT impact occurring at no later than four-quarters and because all the IRF values regardless of whether significant or not are considered, they end up with a much longer peak impact. Of course, there is also the difference in data frequency in estimation which cannot be ignored because quarterly data, especially for the exchange rate and inflation, exhibit more inertia compared to the monthly frequency but a peak ERPT of over 10 quarters is rather difficult to justify. This is reinforced by the fact that what is being modelled is month-on-month (quarter-on-quarter) inflation as opposed to year-on-year. Since month-on-month (quarter-on-quarter) is a quasi-measures of inflation momentum, our results seem more plausible that the inflation momentum would increase and die off by the fifth month. However, in year-on-year computations, this shock would persist for a full12-month period through the so-called base-effects.

Although many aspects of the ERPT in Zambia have been researched as shown above, to the best of our knowledge, this study remains among the few studies to provide statistical evidence on the long-run and short-run asymmetric impact of depreciation and appreciation of the Kwacha/US dollar exchange rate on domestic prices. However, we note that our results are similar to those reported elsewhere, for example, Obeng et al (2022) for Ghana who found that the pass-through of depreciation in the long-run is statistically significant and incomplete, but fails to find statistical evidence for appreciation. Others are Kassi et al (2019), Hong et al (2022), Aisen et al (2021) who found asymmetrical ERPT in both the short-run and long-run for emerging Asian sub-region, Vietnam, and Mozambique, respectively.

6.0 Conclusion

This study aimed at examining the nature of the ERPT to inflation in Zambia. We conducted our analysis for a period between 2010M1 and 2019M12. We carefully selected this period as it does not include periods of extreme economic instability, such as, the Global Financial Crisis and the recent COVID-19 crisis. Inclusion of these periods in our analysis would bias our estimations of the magnitude of the ERPT and our qualitative results since periods like these often are characterised by breakdowns in traditional economic relationships. We estimate the ERPT to inflation and examine the asymmetric effect of appreciation and depreciation of the Kwacha exchange rate on the domestic price formation in Zambia.

Using sign restricted structural vector autoregressive (SVAR) models, we estimate the ERPT to food inflation to be 0.53 percent, 0.25 percent for non-food inflation and show that depreciation shocks are followed by a statistically significant rise in inflation. Nonetheless, we find no evidence suggesting the same when the Kwacha appreciates. We also establish that the ERPT is incomplete and both results are consistent with what others have found in previous studies.

Using the nonlinear autoregressive distributed lag (NARDL) model, the study proceeds to examine asymmetries of appreciation and depreciation and show that in both the long-run and short-run, the depreciation of the Kwacha has a positive effect on domestic food prices while we fail to find evidence of appreciation significantly affecting food prices. Further, the results suggest that both depreciation and appreciation affect non-food prices in the long-run: a depreciation leads to higher prices and the converse is true.

The Wald test of equality to establish asymmetries in both the long-run and short-run indicate asymmetry by rejecting a null hypothesis of equality indicating that the impact of depreciation is greater than that of appreciation. Depreciation is also found to be statistically significant at 5% for non-food inflation in the short-run and appreciation has a small impact which is only significant at 10%. Overall, our findings from our SVAR and NARDL suggest strong asymmetric impacts of exchange rate changes in both food and non-food inflation. In broad terms, since we do not find strong evidence of exchange rate appreciation leading to significant decreases in domestic food and non-food prices, particularly in the short-run, future research may focus on investigating if exchange rate stability rather than one-off appreciation shocks is what matters for negative price changes. Exchange rate stability may be defined as small enough changes sustained over a period so that sensible thresholds in both exchange rate changes and time periods serve as triggers for inflation changes. Therefore, such a study would hinge so much on a careful construction of the exchange rate stability variable. Another dimension that can be exploited in future research is a threshold analysis to establish the extent and persistence of exchange rate appreciation that would matter for price movements both in the long-run and short-run[8].

This study has reinforced previous research findings but also added a unique dimension to policy conversations around exchange rate management strategy in Zambia. In a true fashion of the famous economic remark that "prices are sticky downwards", our findings suggest that the monetary authority need to moderate the Kwacha depreciation cycles as they adversely impact both food and non-food inflation in the near-term. Given that inflation is persistent, depreciation is thus expected to have a direct influence in determining whether the central bank's medium-term inflation target is achieved or not.

[8] Chipili (2014) finds that exchange rate depreciation more than 4 percent within a month will increase inflation, there should be a study to investigate the appreciation extent and how persistent it should be for inflation to reduce.

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