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# Exchange Rate and Inflation Dynamics in Zambia

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## Abstract

This paper investigates the dynamics between the exchange rate and consumer price inflation in Zambia. The analysis uses a structural vector autoregression, with quarterly data for 1995–2014 and a combination of short-run sign- and zero-restrictions to identify relevant global and domestic shocks. The findings suggest that the pass-through of exchange rates to consumer prices depends greatly on the shock that originally caused the exchange rate to fluctuate. Although the price of copper is the most important driver of the exchange rate, the fluctuations it caused are associated with a low pass-through of only about 7 percent. Exchange rate fluctuations caused by monetary shocks come with a pass-through of up to 25 percent. Food inflation is equally affected by genuine exchange rate shocks, but appears more reactive to changes in copper prices or the money supply. Historical variance decomposition shows that, across periods, the main drivers of exchange rate fluctuations varied substantially.

# Exchange Rate and Inflation Dynamics in Zambia

*By* LIONEL ROGER, GREGORY SMITH AND OLIVER MORRISSEY *

## 1. Introduction

When Zambia introduced a floating exchange rate regime in 1994, it was one of first countries in Sub-Saharan Africa to do so. While this has been welcomed as a critical step towards economic modernization and sound macroeconomic management, it has also created new challenges. Being a small, open, and rather undiversified economy (copper alone accounts for more than 70% of exports), the country is highly exposed to global shocks, potentially inducing large and unexpected fluctuations in the value of its currency.

Recently, this potential issue surfaced with great force: Between January and August 2015, the Zambian kwacha gradually lost about 21% of its value against the US dollar. In the ten weeks between September and mid-November, its value plummeted by another 60%, before partially recovering with an appreciation of 27% until the end of the year. Overall, the currency depreciated by more than 40% in 2015. The impact on the economy was severe, especially for consumers: the weakness of the currency abruptly fed through to consumer prices, and monthly inflation jumped from an average of 0.7% to 6.2% in October and another 5% in November. Overall, consumer prices had risen by 21% in 2015.

The aim of this study is to gain an understanding of the dynamics and relative importance of the multiple factors that affect the value of the kwacha and, in turn, consumer price inflation in Zambia. This study relates to three interrelated strands of the growing literature on macroeconomic dynamics in Zambia: first, the determinants and dynamics of the exchange rate; second, inflation dynamics in Zambia; and third, the interaction between the two, the exchange rate pass-through.

From the first category of studies, a wide consensus emerges that the value of the kwacha is exceptionally susceptible to global commodity prices, especially that of copper. This is supported by case studies such as Muhanga, Zyuulu and Adam (2014), who focus on the short run in an SVAR, or Bova (2009) and Chipili (2015a), who both focus on long-run cointegrating relationships and infer an equilibrium relationship between the price of copper and the exchange rate. Similarly, Cashin, Céspedes and Sahay (2002) test for a long-run relationship between main export commodities and the exchange rate in a sample of 58 countries, and conclude that the Zambian kwacha is a 'commodity currency'. Pamu (2011), however, rejects this classification on the basis of being unable to discern a relationship between the price of copper and the exchange rate.

While the literature on inflation in Zambia is relatively extensive, the focus of most studies is on forecasting rather than on the identification of the underlying mechanics and main drivers (e.g., Chipili, 2015b; Mbao, 2015). Notable exceptions include Mutoti et al. (2011), who establish the importance of the oil price and money supply as determinants of inflation, and Chileshe (2015), who shows that fiscal shocks can have a great impact on consumer prices.

Lastly, studies that explicitly address the link between the exchange rate and consumer prices, and therefore investigate the exchange rate pass through (ERPT), are scarce. To the best of our knowledge, the only study explicitly aimed at investigating this question for Zambia is Zgambo (2015). In the framework of a structural VAR (SVAR), similar in many respects to the one we will present, he estimates the ERPT to be between 41% and 49%. Beyond the country-specific literature, in a seminal study concerned with estimating the determinants of ERPT in a global sample, Choudhri and Hakura (2006) report a similar value for Zambia (an ERPT of 41% after 4 quarters).

The main novelty of this study concerns this last strand of the literature. While there is a general consensus that a depreciation in the exchange rate should translate into increases in

consumer prices as imported goods become more expensive, the extent of this effect – the ERPT – can be difficult to quantify.[1] Moreover, as some recent contributions point out, the ERPT need not be the same for all the shocks that drive the exchange rate (Shambaugh, 2008; Forbes et al., 2015): A depreciation caused by global market conditions may be associated with very different price dynamics than the same depreciation caused by, for instance, expansionary monetary policy by the domestic central bank. The focus of our paper is then to disentangle the dynamics between the exchange rate and consumer price inflation, and to explore the possibility of a differential ERPT depending on the shock that originally caused the exchange rate to move.

To this end, we identify six shocks to key variables of the Zambian economy (namely shocks to the copper price, external interest rate, output, domestic money supply, exchange rate and inflation) using sign- and zero-restrictions in the framework of an SVAR. Since its introduction by Sims (1980), Blanchard and Watson (1986) and Bernanke (1986), this method has found thousands of applications in empirical macroeconomics. The most common identification scheme remains a triangular Cholesky decomposition, which reduces the number of free parameters exactly to the point where the system is just-identified. This approach, however, often implies assumptions that are hard to justify, and the results may be susceptible to the ordering of the variables. Uhlig (2005) suggests to address this using economically plausible but less restrictive sign restrictions on the impulse response functions, which can be estimated in a Bayesian VAR. His 'agnostic' approach has since inspired hundreds of papers to adopt similar methodologies. However, Baumeister and Hamilton (2015, henceforth BH) show that statistical models that appear to be 'agnostic' at first can in fact be heavily influenced by the priors imposed by the researcher, even if they were originally designed to be *uninformative*, that is, designed to have little impact on the results. Indeed, they show that there can be situations where results may be driven solely by the priors unintentionally imposed by the researcher. BH suggest to impose *informative priors* on economically interpretable parameters instead, where the prior values can, for instance, be derived from earlier empirical literature or from theory. We acknowledge their argument but note that, especially in larger VARs and for less studied economies and questions, there may simply not exist conceptually similar estimates for the relevant parameters, and that the parameters of theoretical models can rarely be directly mapped to the empirical model. In order to obtain sensible priors nonetheless, we therefore first estimate short-run elasticites using a conventional Cholesky decomposition, and then feed these into our Bayesian VAR as priors.

The remainder of this paper proceeds as follows: Section 2 discusses relevant aspects of the institutional and historical background in Zambia. Section 3 lays out our methodology and discusses the underlying assumptions. Section 4 describes the data, its basic time series properties, and any transformations. Section 5 presents the results, and Section 6 discusses the turbulence of late 2015 with respect to the results. Section 7 concludes.

## 2. Background

Zambia is a small, open commodity-dependent economy and regularly faces challenges from supply shocks. These include shifts in the global copper price, rain-fed agricultural outputs, hydro-electric generation output, and the global price of fuel. It has been a copper producer since prior to its independence in 1964, but from the early 1970s production fell

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[1] For an excellent and comprehensive overview of the theoretical and empirical literature on the exchange rate pass-through in developing and emerging markets see Aron et al. (2014).

considerably. Nationalization in 1973 and low prices hampered investment in the sector until the 2000s. Fresh investment followed privatization and higher copper prices in the mid-2000s supported a doubling of copper production between 2004 and 2014. The boost to the economy from the copper industry was also complemented by better macroeconomic fundamentals in the 2000s. For example, Zambia maintained a fairly low level of inflation, judged by its historical standards, and substantial debt relief improved investors' perception of the country after it qualified for the Heavily Indebted Poor Countries (HIPC) initiative in 2005. These factors supported the expansion of the economy and annual GDP growth, which averaged 7.4% between 2004 and 2014. As the production of copper increased and the economy prospered, much larger foreign exchange inflows followed from the mining sector. Added to this in the late 2000s were inflows from large Chinese infrastructure lending and from 2012 in the form of large commercial Eurobonds placements (2012, 2014 and 2015).

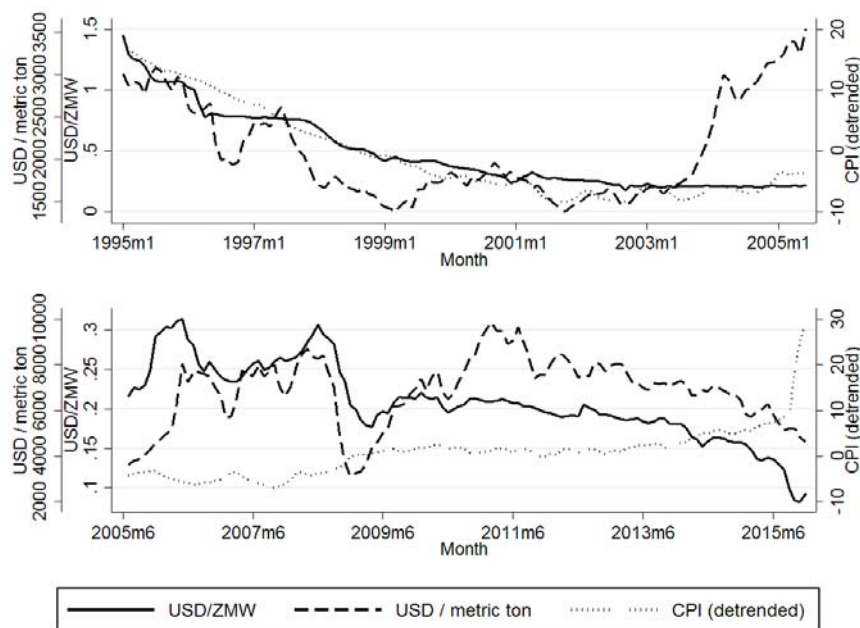Since the introduction of a floating exchange rate in 1994, the primary objective of the



*Figure 1: Key variables from 1995 to 2015 (monthly data)*

central bank has been to maintain price stability. In the foreign exchange market, its only role has been to intervene in order to reduce volatility and manage exchange rate stability. Key characteristics of Zambia's foreign exchange markets are that they are 'thin', in the sense that there is not much trading, and that markets are dominated by few players (notably the large mining firms, the commercial banks, and the Bank of Zambia). There are often times of low trading volume, when large players are not trading and the exchange rate is fairly stable. The participants that are large relative to the level of transactions can exert influence over the exchange rate, sometimes by the timing of their transactions, even if they do not intend to.

In 2014 and 2015 the economy experienced several shocks including a further decline in copper prices and after nearly a decade of running a trade surplus, the external account fell into deficit in December 2014. The initial consequence was a steady depreciation of the kwacha during the first half of 2015. In August of that same year the confidence of the economy was

eroded further as a power crisis began to impact all sectors of the economy, and the trade deficit accelerated. Between August and November, the currency depreciated by 60% in what appears to have been an instance of market panic. Some gains were recovered in 2016 following much tighter monetary policy, but at the end of 2016 the kwacha remained substantially weaker than prior to the shock. The depreciation of the currency abruptly fed through to consumer prices between September and November 2015, lifting annual inflation from less than 8% in the preceding years to more than 20% in 2015. Section 6 will discuss this episode with what can be inferred from our results.

Figure 1 traces some key macroeconomic variables relevant to our narrative (the exchange rate, the copper price and consumer prices) since 1995, after the introduction of the floating exchange rate regime in 1994 and at the start of our sample period (see Section 4). Before proceeding to the econometric analysis, it is worth relating some of the key changes in the data to the institutional context outlined above. First, notice the changing patterns in the development of the exchange rate (expressed throughout this article in USD/ZMW, such that a decrease corresponds to a depreciation).[2] In the earlier periods (top panel) it seems to be moving rather independently of the copper price (expressed in USD per metric ton). It is only after 2005, when investment and copper production increased, that the two variables began to noticeably move together. Second, this coupling coincides with a strong appreciation following scaled-up debt relief under the HIPC initiative in 2005. To be sure, this appreciation precedes the increase in the copper price around the same time; later it appears the sequence is reversed (changes in the copper price precede those in the exchange rate), consistent with the interpretation that copper became a stronger determinant of the exchange rate after the sector had attracted investment and gained importance. Lastly, while consumer prices (CPI) and the exchange rate do generally appear to be trending in the same direction in most periods, prices do not react to exchange rate fluctuations in any obvious manner. This does not apply to the end of 2015, when a sharp depreciation comes with an equally sharp increase in inflation, an observation that will be further discussed in Section 6.

### 3. Methodology

Subsection 3.1 outlines the general form of the structural VAR employed and discusses the central problem of identifying the relevant shocks. Drawing from recent methodological advancements, especially Baumeister and Hamilton (2015) and building on Uhlig (2005), we avoid enforcing a fully identified structure on our system, and instead rely on a combination of sign- and zero-restrictions to achieve set identification in an under-identified system. This allows us to relax a common, but in our view overly strong (and as our results will show, influential), assumption about the contemporaneous interaction of the exchange rate and inflation, which our specification will allow to take place in either direction.

As our system is under-identified, estimation will be carried out in a Bayesian framework. This raises the critical issue of selecting sensible priors. As Baumeister and Hamilton (2015) point out, these can be highly influential even where they are designed for opposite (supposedly flat priors). Priors therefore need to be chosen with corresponding care, and reported in a transparent manner. Subsection 3.2 will discuss and make explicit our choices in this respect.

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[2] We apply the 2013 redenomination of the kwacha retroactively throughout the series for consistency, that is, we divide older values by 10,000 to have a consistent series.

### 3.1. Identification

We estimate the macroeconomic dynamics of interest in the framework a vector autoregression of the following form (using the notation of Ramey (2016) and Stock and Watson (2016)):

$$A(L)Y_t = \eta_t, \tag{1}$$

Where $\eta_t$ is a vector of reduced form VAR innovations, that is, the observed residuals as obtained when forecasting $Y_t$ based on its lagged values. We make the usual assumptions that these innovations have a zero mean, constant variance, and are uncorrelated with each other. Furthermore, $A(L)$ is a lag polynomial of the form $A(L) = I - \sum_{k=1}^{p} A_k L^k$, where $L^k$ is the lag operator, shifting values by $k$ lags. It effectively applies weights to each lag and element of $Y_t$ in order to explain its current values, short of the innovations $\eta_t$.

However, the idea of a structural VAR is specifically to represent $Y_t$ in terms of structural shocks $\varepsilon$ that are *unexpected, exogenous* disturbances to the system, in order to identify the effect of unexpected changes in each of the variables, and to subsequently compute parameters of interest such as impulse response functions and variance decompositions. The SVAR assumes that these structural shocks $\varepsilon$ are related to the VAR innovations $\eta$ in the following way:

$$\eta_t = H\varepsilon_t, \tag{2}$$

Where the matrix $H$ describes the contemporaneous relationships between the structural shocks $\varepsilon_t$ and the reduced form VAR residuals $\eta_t$, or how an exogenous shock to any variable will affect each of the variables in $Y$ *within* the period.[3] We will normalize it such that the structural shocks have unit effect, that is, its diagonal elements are unity (an exogenous shock to a given variable will translate one to one into a change of that variable). Without any further restrictions however, the system is unidentified and there exists an infinite number of parameter combinations in $H$ that are equally consistent with the observed data. The challenge is then to impose some structure that will allow us to uncover the parameters of $H$, and therefore the impact of each of the individual shocks onto the system.

This leads us to the critical issue of identification, which sets our study apart from most of the previous literature (that on Zambia in particular), much of which relies on a Cholesky decomposition first suggested by Sims (1980) and still common in the exchange rate and monetary literature (with respect to Zambia, recent examples include Muhanga et al. (2014) and Zgambo (2015)). For all its benefits (most importantly, pinpointing parameters by just-identifying the system), this comes at the cost of substantial rigidity and requires the researcher to impose strong assumptions on the economic mechanisms that are being investigated. Our approach will therefore build on more recent developments in the literature, which has increasingly moved away from strict just-identified systems towards more flexible specifications; specifically, we will rely on a combination of sign- and zero-restrictions in a fashion similar to Uhlig (2005). The general idea here is to restrict parameter combinations to the set of those that are consistent with fundamental macroeconomic principles, instead of

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[3] In the literature using a Cholesky decomposition, matrix $H$ is commonly referred to as $A$. We stick to the Ramey (2016) and Stock and Watson (2016) notation to facilitate reference to their excellent discussion of the matter.

imposing so many (but potentially unwarranted) restrictions that only one combination remains possible. We also acknowledge recent improvements on the Uhlig (2005) approach, and in particular we use the Baumeister and Hamilton (2015) methodology in order to avoid the undue impact of supposedly uninformative priors (see Section 3.2).

Consider now the following general set of equations that describe the relationship between the variables in our system, which are chosen in line with the literature on exchange rates and inflation. The model is limited to six variables: the *US Federal Funds rate* (to represent the external interest rate), the international *price of copper*, domestic *money supply*, the domestic *output gap*, the *exchange rate* and *consumer price* inflation (the choice and details of the variables will be discussed in more detail in section 4, and the assumptions underlying this structure below):

$$
\begin{aligned}
Fed_t &= \varepsilon_{F,t} \\
Copper_t &= \Phi_C Fed_t + \varepsilon_{C,t} \\
Money_t &= \phi_M Fed_t + \kappa_M Copper_t + \varepsilon_{M,t} \\
Output_t &= \phi_Y Fed_t + \kappa_Y Copper_t + \mu_Y Money_t + \varepsilon_{Y,t} \\
ER_t &= \phi_E Fed_t + \kappa_E Copper_t + \mu_E Money_t + \upsilon_E Output_t + \pi_E Infl_t + \varepsilon_{E,t} \\
Infl_t &= \phi_P Fed_t + \kappa_P Copper_t + \mu_P Money_t + \upsilon_P Output_t + \xi_P ER_t + \varepsilon_{P,t}.
\end{aligned}
\tag{3}
$$

More concisely, we can represent the dynamic behavior of this system in matrix notation as:

$$
Y_t = \Phi(L)Y_t + \Omega\varepsilon_t \tag{4}
$$

where $\Phi(L) = \Phi_0 + \sum_{k=1}^{p} \Phi_k L^k$: The structural coefficients in system (3) are captured in the contemporaneous matrix $\Phi_0$, while the dynamics of additional lags are captured in the matrices $\Phi_k$. The $\varepsilon$'s are now the structural shocks we will aim to identify, entering the system as determined by matrix $\Omega$. We follow common practice in assuming that each *structural* shock only enters one equation, or $\Omega = I$.

As outlined above, our identification strategy will rely on imposing structure on $H$ in order to identify the contemporaneous relationship defined in (2). The combination of sign- and zero-restrictions we employ takes the form:

$$
H = \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 \\
\phi_F & 1 & 0 & 0 & 0 & 0 \\
\phi_M & \kappa_M & 1 & 0 & 0 & 0 \\
\phi_Y^+ & \kappa_Y & \mu_Y & 1 & 0 & 0 \\
\phi_E & \kappa_E^- & \mu_E^- & \upsilon_E & 1 & \pi_E^- \\
\phi_P & \kappa_P & \mu_P^+ & \upsilon_P & \xi_P^- & 1
\end{pmatrix}
\tag{5}
$$

This specification is similar to a Cholesky decomposition, but it relaxes the restrictions on the contemporaneous interactions on our main variables of interest, inflation and the exchange rate. Instead, we impose a number of sign restrictions on the parameters, indicated by the superscripts '−' and '+'. More specifically, this specification reflects three types of assumptions:

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1. *Small economy*: The domestic macroeconomic variables in Zambia are assumed to have no contemporaneous impact on the two global variables in the system, the US Federal Funds rate and copper prices. Given the importance of copper as an export in Zambia, the latter may seem restrictive; however, Zambia only accounts for about 2% of the global copper production.
2. *Delayed responses*: Monetary policy is assumed to react only with a delay to developments in the economy. This assumption is commonly made and rooted in the observation that information on macroeconomic variables typically becomes available only with a lag. Similarly, output is typically observed to react to changes in other variables only with a lag. The ordering above implies that output may respond to monetary policy contemporaneously, but not vice versa. Note that a few studies have made the opposite assumption in the past and constrained GDP to only react with a lag based on the argument that it is a notoriously slow variable; in a robustness check, we changed the order and the results were robust to this choice.
3. *Sign restrictions*: We impose sign restrictions on contemporaneous parameters where we deem this choice consistent with a broad range of macroeconomic theories. Specifically, the exchange rate is constrained to depreciate (if anything) as the fed funds rate increases, as broad money increases, and as domestic inflation increases. Similarly, we constrain the contemporaneous impact of an exchange rate appreciation on prices to be negative or zero, thus excluding parameter combinations that would imply a negative ERPT at impact. Further, the contemporaneous reaction of output to an increase in copper prices is assumed to be positive or zero, as well as that of inflation to an expansionary monetary shock.

### 3.2. Priors

As our system is not fully identified as in the pure Cholesky case, we follow the literature in taking a Bayesian approach in order to estimate the VAR. Crucially, this requires us to select priors. As shown by Baumeister and Hamilton (2015), seemingly uninformative priors (e.g., the commonly used Haar prior) can effectively be very influential, in a manner that is neither intended, understood, or related in any intuitive way to the underlying economic meaning. This can be the case when the outcome of interest (e.g., the impulse response function) is a non-linear transformation of the parameters the priors are imposed on. Instead, they suggest to formulate informative priors directly on parameters with an intuitive economic interpretation, in our case on the contemporaneous coefficients in matrix $H$. We will follow their approach, and use their numerical algorithm to obtain our results.

This poses the fundamental challenge of finding sensible prior values, that is, expectations about the values of the contemporaneous elasticities between the variables included in our system. In fact, we found it impossible in the present study to base all our priors on results of the earlier literature, which would be the obvious way to proceed. This is the case for a number of reasons: First, *reporting conventions* make it difficult to draw from earlier studies. It is not common for the empirical literature to report the contemporaneous coefficients making up the matrix $H$. For instance, Muhanga et al. (2014), even though they study the same country with a similar research question and a comparable set of variables, only report their results in the form of impulse response functions, and thus do not offer a starting point for our priors.

Second, the *size of our VAR* complicates the search for priors. With an increasing number of parameters (we estimate 16 contemporaneous parameters), it becomes increasingly difficult to

find sensible priors for each of them that would be conceptually similar and could reasonably be expected to apply to Zambia.

Third, there is *little guidance by theory* in the choice of priors. The theoretical literature is generally not parameterized in a way that suggests any particular amplitudes for the coefficients in our empirical model. To illustrate this, consider Baldini et al. (2012), who develop a DSGE model to analyze monetary policy in Zambia. While conceptually and contextually close to our study, and very transparent about the parameters applied and derived, none of the macro-parameters of interest here correspond to those employed in their model (which by construction roots the dynamics in deep parameters at the micro level).

In order to obtain sensible priors, we take the following approach. Instead of collecting or deriving coefficients from earlier literature, we generate our own priors from a more traditional approach (*as if* there was previous literature sufficiently consistent with our study). We start by estimating the model using a conventional Cholesky decomposition, thereby obtaining results based on more restrictive assumptions as typically made in the earlier literature. We then feed the resulting estimates as the prior modes into the system described earlier. Thus, we take traditional estimates with all their shortcomings as a *first guess*, and then use algorithms to improve on them.

Note that – given our structure of choice described above – it is not possible to estimate $\pi_E$ and $\xi_P$ simultaneously. In order to obtain prior modes for both, we estimate the system twice, once as described above, and then reversing the order of the last two variables (exchange rate and inflation). All other parameters are those obtained from the estimation with the order as described throughout the article (exchange rate before inflation). Beyond the mode, in order to complete the specification of our priors, we need to specify the nature of our prior distribution (as the parameters are inherently treated as random variables). In line with Baumeister and Hamilton (2015), we formulate the priors on the parameters in $H$ as student $t$ distributions with three degrees of freedom, and a scale parameter of 0.6 reflecting moderate confidence in our prior modes. Appendix A explicitly reports the prior modes.


*4. Data*


We use quarterly data from 1995:2 to 2014:4. This corresponds to a period of relative stability in the Zambian economy, and a regime of flexible exchange rates since 1994. Furthermore, we only have data on the output gap starting from 1995, the first quarter of which drops out as we take first differences. We deliberately exclude the tumultuous year 2015 from the main analysis as it exhibits extreme developments that are likely to dominate and distort our baseline estimations.

We obtain the price of copper from the IMF's Primary Commodity Price database; the Federal funds rate, the nominal USD/ZMW exchange rate (expressed such that a decrease corresponds to devaluation) and the Zambian CPI from the IMF's International Financial Database; Broad Money (M2) from the Bank of Zambia's fortnightly statistics; and an internal estimate of the output gap kindly provided to us by the Bank of Zambia. All series are originally obtained at a monthly frequency and averaged over quarters, except for the output gap which was provided to us at quarterly frequency.

Figure 2 plots all variables in levels (solid lines) and in log differences (dashed lines). All series, except for the output gap (especially in early periods) resemble non-stationary series; the differenced series however appear stationary. This is confirmed by Augmented Dickey-

Fuller tests reported in Appendix A. As our study focusses on relatively short time horizons, we will restrict our attention to the differenced series.

Specifically, we use the log-difference (multiplied by 100) of the copper price, money, the exchange rate and the consumer price index, so as to measure percentage changes between quarters. The Federal Funds rate, already expressed in percentages, will be included in first differences, therefore reflecting changes in percentage points. The output gap is expressed in percentage deviations from potential output and will be included as obtained. Furthermore, we de-trend the consumer price and money series.
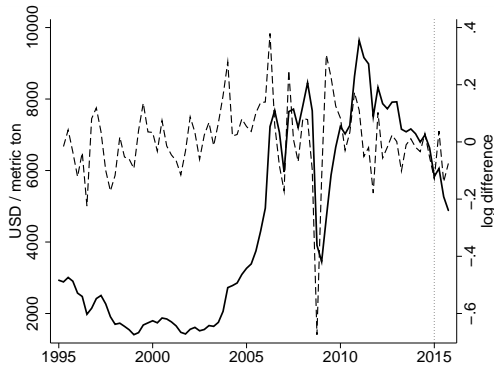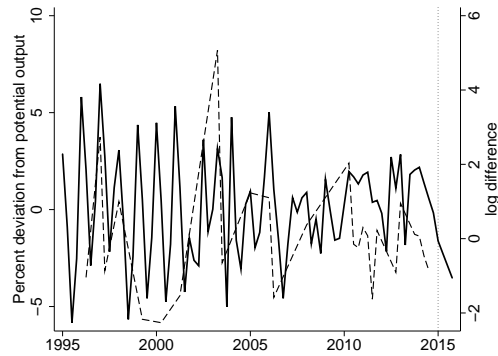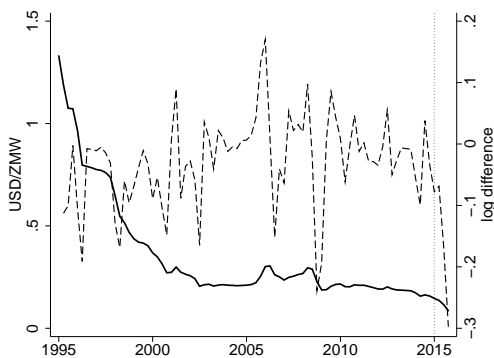
*(a) Copper price*
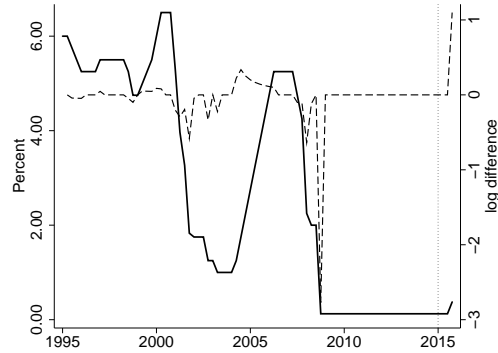
*(b) Fed funds rate*
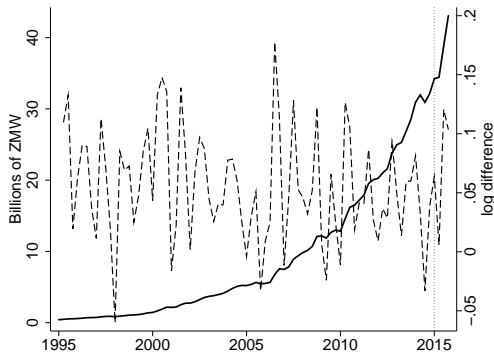
*(c) Money (M2)*

*(d) Output gap*

*(e) Exchange rate*
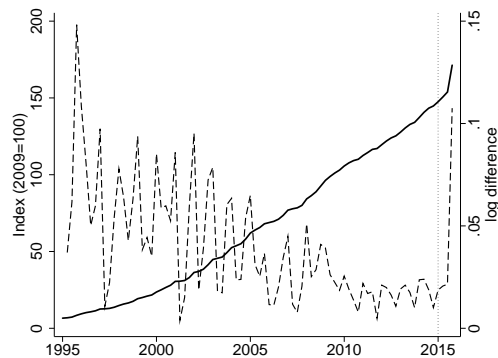
*(f) Consumer Price Index*

Notes: The solid lines describe the variables in levels and native units (see left y-axis), the dashed lines indicate are the first differences of the logarithm of these series. The dotted vertical line at the beginning of 2015 indicates the end of the sample period used for our main specification. See main text for further transformations applied to the series.

*Figure 2: Variables in levels and log differences*

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*5. Results*

We discuss our results in three steps. First, we present the basic impulse response functions of our main variables of interest, the exchange rate and inflation. These indicate a strong dependence of the exchange rate on copper, as well as a moderate effect of the exchange rate on price levels. Second, we report variance decompositions over the sample periods in order to isolate the most important contributing factors on each of the variables, and the evolution of this pattern over time. Third, we analyze whether there is a differential ERPT depending on the shock that drives the exchange rate fluctuation, following Forbes et al. (2015). We further investigate whether and to what extent food and non-food inflation are affected differently, and also report differential ERPTs obtained using the respective disaggregated CPIs.

*5.1 Impulse response functions*

Figure 3 depicts the cumulative impulse response functions (IRF) for the exchange rate as a reaction to a 1% positive shock in the other variables. The solid line reports the pointwise mean IRF, which is the recommended point estimate to be reported given a linear loss function (Baumeister and Hamilton, 2015). The dashed lines depict the 68th and 90th percentiles of the estimated IRFs (following the Bayesian convention of *credible* intervals, in lieu of frequentist confidence intervals).

Panel *(a)* summarizes one of the key results of this exercise: the exchange rate reacts strongly and quickly to an increase in copper prices. The mean response suggests that, at impact (within the quarter), an unanticipated 1% rise in copper prices leads to an exchange rate appreciation of 0.2%. The exchange rate continues to markedly appreciate for the next two quarters, up until 0.4%, and then stays at roughly that level. This is slightly lower than the 4.8% appreciation following a 10% increase in copper prices in the long run reported by Chipili (2015), although this estimate is within the bounds of the 68% interval.

An expansionary monetary shock of 1% (panel *(c)*) is estimated to induce a marked depreciation of about 0.7% within the quarter, reaching its peak in the next quarter at 0.9%. The point estimates suggest a slight overshooting here, and the persistent effect is of about 0.8%. Note that after three quarters, the estimates become less confident to the point where a zero effect cannot be excluded based on the 90% credible interval.
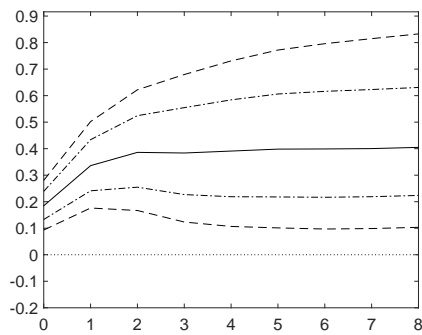
*(a) Copper prices*
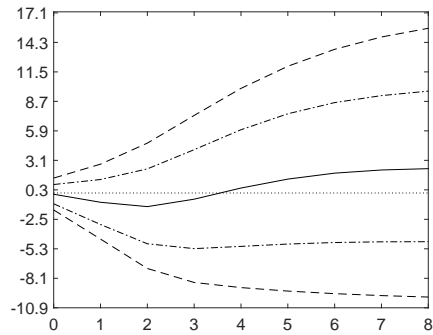
*(b) Fed funds rate*
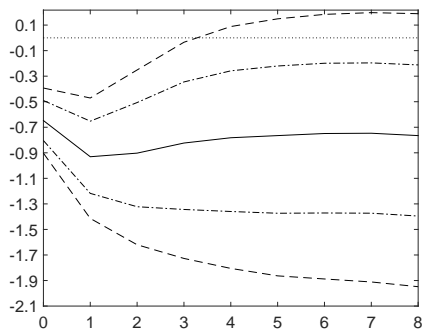
*(c) Monetary (expansionary)*
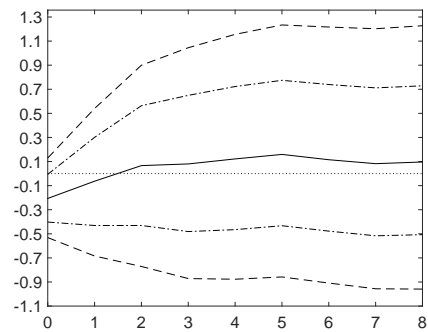
*(d) Output gap*
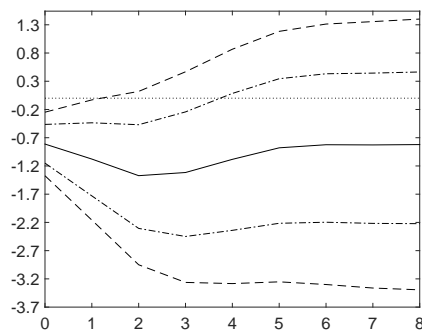
*(e) CPI*

*Figure 3: Response of the exchange rate to a 1% shock to key variables*

The third most salient driver is domestic prices, reported in panel *(e)*. Although the estimates are too imprecise for any stark conclusions, the point estimates suggest a contemporaneous depreciation of about 0.8% following a 1% inflationary shock to CPI. The median response suggests a peak depreciation at about 1.4% after one quarter, which then levels off at about 0.9% after five quarters. This is evidence that our decision to leave the contemporaneous impact

of inflation on the exchange rate unrestricted was well-warranted; restricting it to zero would have forced the intercept of this IRF to be zero, and exerted great but possibly undue effect on our estimates of the exchange rate pass-through, discussed below.

The effect of the output gap and the fed funds rate, panels (b) and (d), are ambiguous and estimated with little precision.
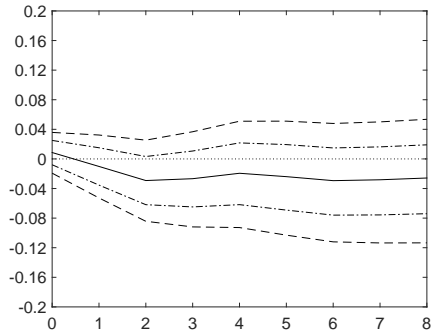
*(a) Copper prices*
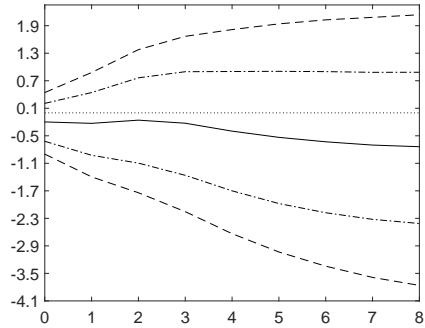
*(b) Fed funds rate*
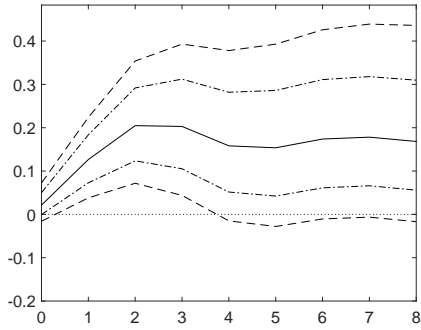
*(c) Monetary (expansionary)*
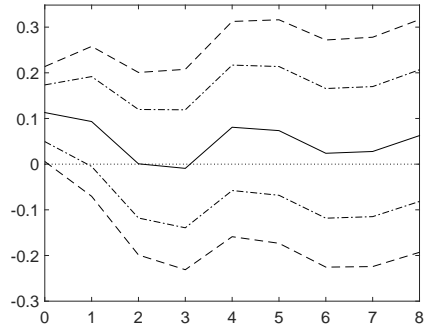
*(d) Output gap*
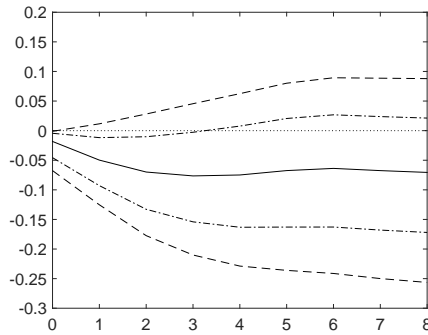
*(e) Exchange rate*

*Figure 4: Response of consumer prices to a 1% shock to key variables*

Figure 4 is identical in notation and plots the responses of consumer prices to 1% shocks to any of the other variables. The general picture here is that consumer prices do not react very

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strongly to the other macro variables, at least based on the short run dynamics analyzed in our framework.

The most pronounced effect comes from monetary shocks (panel *(c)*): While a monetary expansion does not have much of an impact contemporaneously, after two quarters, a 1% monetary shock is estimated to induce a 0.2% increase in prices.

Panel *(e)*, reporting the response of CPI to a shock in the exchange rate – the ERPT to consumer prices – reveals a very moderate response of consumer prices to changes in the exchange rate based on the short run dynamics. At impact, there is no evidence for an increase in consumer prices. While the precision of the estimate is very low given the small amplitude of the effect, the median IRF suggests a steady decrease (increase) in prices following an unanticipated appreciation (depreciation) of the exchange rate. The dynamics settle down after four quarters, after consumer prices have decreased (increased) by about 0.07%.

Our estimates therefore imply an ERPT to consumer prices of 7% after four quarters. This is very low compared to other estimates in the literature. The corresponding figures obtained by Zgambo (2015) range between 41% and 49%, although this is reduced to 20% when focusing on a more recent period (2004-2014) characterized by lower inflation. Choudhri and Hakura (2006) estimate an ERPT to domestic prices in Zambia of 15% at impact, and 41% after four quarters. The average pass-through after four quarters they obtain for developing countries is 24% (although with some notable exceptions, like 9% in Burundi, and -1% in Colombia).

It is worth emphasizing that, besides other important methodological differences in their study, Choudhri and Hakura (2006) study the period 1979-2000 which overlaps with our sample for only five years. The discrepancy is somewhat consistent with the main point of their paper: low inflation is associated with a low pass-through. In our sample period, Zambian inflation is much lower than in earlier decades, averaging 18% per annum over 1995-2014 compared to 71% per annum during 1986-2000 (World Bank, 2016). Our results may therefore reflect a genuine increase in the resilience of the Zambian economy until 2014.

A second factor is our decision to leave the initial impact of inflationary shocks on the exchange rate, $\pi_E$, unrestricted. Estimating the same set of equations with full identification through a classical Cholesky decomposition ($\pi_E = 0$, no sign restrictions) leads to a higher ERPT estimate of 9% at impact and about 15% after four quarters. This is indeed what much of the previous ERPT literature has been doing, suggesting that some of the results are inflated as causality was constrained to go from exchange rates to prices.

*5.2 Historical decomposition*

Figure 5 and Figure 7 describe the historical contributions of each of the shocks to the changes in the exchange rate and consumer prices. The red line is the observed value of the respective (de-trended) series, expressed in quarter to quarter changes. The colored bars indicate the contribution of each of the shocks to this value over the eight periods (two years) prior to the indicated date, computed from the median IRFs discussed in the previous section. These illustrate the decompositions reported in Table 1, which shows that money supply (M2) and the copper price account for most of the variation in exchange rates, and M2 is usually the more important factor (except for 1996-99 and 2008-11). The lower panel shows that the output gap, money supply and the copper price account for most of the variation in exchange rates (their relative importance varies, which M2 generally becoming more important over time). The role of domestic inflation as a driver of the exchange rate appears to have steadily declined, from 19% in 1996-99 to 6% in 2012-14.

|  |  | 1996q2-1999q4 | 2000q1-2003q4 | 2004q1-2007q4 | 2008q1-2011q4 | 2012q1-2014q4 |
|---|---|---|---|---|---|---|
| Exchange rate | Fed | 3% | 8% | 9% | 6% | 3% |
| | Copper | 22% | 13% | 16% | 29% | 15% |
| | M2 | 15% | 24% | 24% | 20% | 31% |
| | Output Gap | 9% | 10% | 9% | 4% | 6% |
| | Exchange Rate | 30% | 32% | 33% | 32% | 40% |
| | CPI | 19% | 13% | 8% | 8% | 6% |
| | | | | | | |
| CPI | Fed | 2% | 4% | 5% | 6% | 1% |
| | Copper | 10% | 6% | 13% | 23% | 14% |
| | M2 | 7% | 15% | 18% | 20% | 24% |
| | Output Gap | 21% | 21% | 15% | 10% | 21% |
| | Exchange Rate | 5% | 3% | 8% | 6% | 6% |
| | CPI | 55% | 51% | 41% | 35% | 34% |

Notes: The first panel reports the contribution of each variable to the fluctuations of the exchange rate averaged across quarters within five sub-periods. The second panel reports the same information for fluctuations in CPI.

*Table 1: Historical variance decomposition of exchange rate and price fluctuations*

Figure 5 illustrates these results for the exchange rate and depicts the year by year variation. It is apparent that the factors contributing to exchange rate fluctuations have varied quite substantially over time, but also that the amplitude of the shocks – and therefore that of the exchange rate fluctuations – has declined since about 2009. The graph also offers insights about the nature of individual fluctuations. For instance, the early 2000s saw a number of stark movements in the exchange rate, with money appearing to be the main driver. The strong appreciation in 2005, corresponding to the debt relief under the HIPC initiative, enters mainly as a genuine exchange rate shock. While the proportional contribution of the price of copper appears rather moderate over much of the sample period, the abrupt depreciation in 2009 illustrates its potential importance, as it accounts for about two-thirds of the variation. The variety of the drivers of these shocks further underlines the importance of our research question, whether the ERPT will vary with the underlying economic shock that originally caused the exchange rate to move.
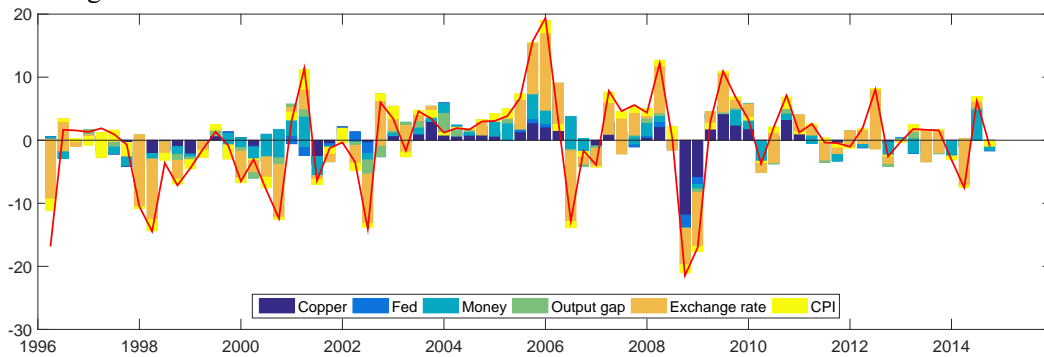


*Figure 5: Historical decomposition of changes in the exchange rate (USD/ZWA)*

Figure 6 decomposes changes in consumer prices in the same way. As expected from the low amplitude of the IRFs presented in section 5.1, the contribution of the other variables in our

system to changes in CPI appears to be relatively limited, and much of the variance is attributed to price shocks that are exogenous to our system. However, as fluctuations decline over time, it is apparent from Table 1 that the role of our macro-variables is increasing towards the end of the period: over the sample period, the role of genuine price shocks steadily decreases from 55% in 1996-99 to 34% in 2012-14. A few factors have a notable impact in certain periods. This is the case for the fluctuations in output, especially in periods before 2002. Contractionary monetary shocks contributed to slowdowns in inflation in 2001 and in 2006. While copper prices do not play a prominent role in determining inflation in the first half of the sample period, it becomes more important in the late 2000s. This is plausible, as both copper production as well as prices were significantly higher in later periods (see Section 2).
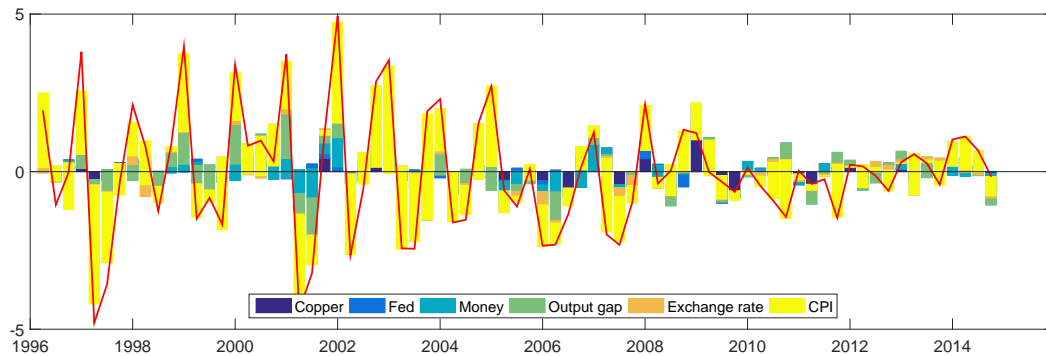


*Figure 6: Historical decomposition of changes in Zambian consumer prices*

## 5.3 Differential exchange rate pass-through

We will now examine the extent to which different shocks that affect the exchange rate entail different reactions of consumer prices. Our approach is similar to Forbes et al. (2015), in that we use the ratio of the IRF of CPI over the IRF of the exchange rate for a shock to any given variable. These estimates therefore indicate the change in *consumer prices induced by a shock that leads to a 1% appreciation in the exchange rate* in any period. The interpretation is then slightly different to the IRFs reported in section 5.1. These traced the effect of a shock that causes a 1% appreciation *at impact.* The measures reported here are computed for a shock that causes a 1% appreciation in *the period itself.* For instance, in order for a shock to the copper price to lead to an exchange rate appreciation of 1% *at impact*, it needs to have an amplitude of $1\%/0.2 = 5\%$ (see Figure 3). But the shock takes some time to fully deploy its effect on the exchange rate; a copper price shock that leads to an appreciation of 1% *after four quarters* therefore only needs to have an amplitude of $1\%/0.4 = 2.5\%$.

Note also that the direction of the original shocks we consider in this section need not be identical to that discussed in section 5.1 when describing the IRFs. Specifically, Figure 7 reports the result of a *contractionary* monetary shock (reducing inflation), while our previous discussion as well as Figure 4 were based on *expansionary* shocks (increasing inflation). This is because we consider shocks that lead to an exchange rate *appreciation*, which for money needs to be a contractionary one.

Since in section 5.1 we established that both the fed funds rate and the output gap had little discernible effect on the exchange rate, we focus on shocks to copper prices, money and the exchange rate itself.[4]
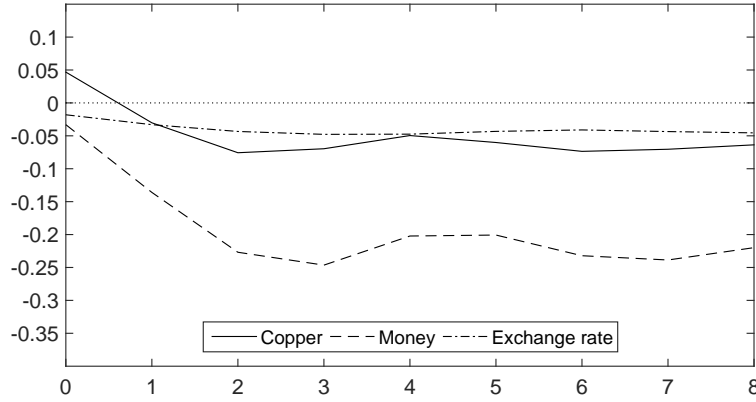


*Figure 7: Pass through to consumer prices for different shocks*

| Horizon | 0 | 1 | 4 | 8 |
|---|---|---|---|---|
| Copper | 0.06 | -0.02 | -0.03 | -0.04 |
| Money | -0.03 | -0.14 | -0.21 | -0.22 |
| Exchange rate | -0.02 | -0.03 | -0.05 | -0.05 |

*Table 2: Pass through for different shocks and time horizons*

Figure 7 plots the results. First, note that for a shock to the exchange rate, the effect is even slightly lower than that reported in section 5.1. This is because a shock that raises the exchange rate by 1% at impact still raises it in the subsequent periods; effectively, Figure 7 refers to smaller exchange rate shocks in all periods after impact.

A 1% increase in the exchange rate caused by a shock to copper prices comes with an increase in consumer prices of 0.05%, implying a negative pass-through at impact of about -5%. This may reflect aggregate demand effects related to the stimulus to the copper industry (increased employment, rents). The effect is reversed in later periods, with a pass through between 5% and 8% in the following quarters.

Finally, monetary shocks are associated with by far the strongest pass-though: exchange rate fluctuations that are caused by a monetary shock are estimated to translate into consumer prices with an ERPT of about 25% after three quarters, with a lasting effect of about 23%. This is particularly relevant in the view of the results from the historical variance decomposition in section 5.2, which indicate that, while the variation of the exchange rate has markedly declined overall, it has recently increasingly been driven by monetary shocks. The remaining exchange rate fluctuations may therefore be disproportionately associated with consumer prices. Note however that this is more than offset by the smaller amplitude of the fluctuations in general.

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[4] The latter may seem redundant, as conceptually it is very similar to the exchange rate pass-through already quantified above. Because of calculation in each period, and because an exchange rate shock that raises it by 1% in the first period may (and does) have a different effect in the second period, it is not identical.

*5.4 Food versus non-food inflation*
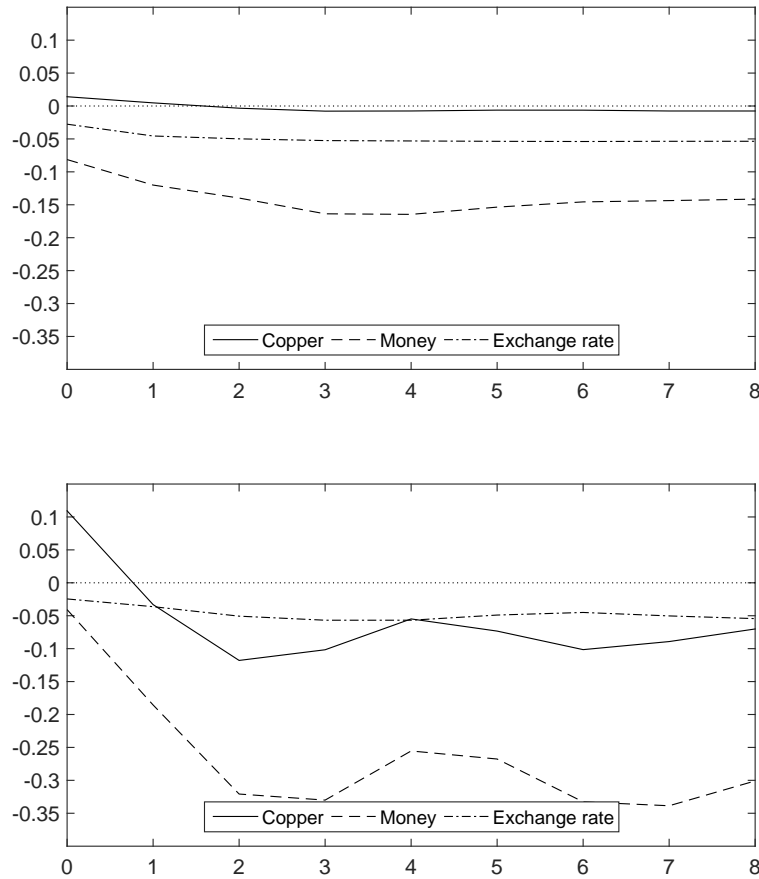


*Figure 8: Differential ERPTs for non-food (top) and food (bottom) inflation*

We further repeat the previous exercise with disaggregated measures of inflation, that is, we repeat the entire analysis as outlined previously, replacing only the overall CPI series with the food and non-food CPI respectively. Appendix A also reports the priors employed in this additional exercise, which we derived for each CPI category separately in the same manner as the one employed previously and described in section 3.1. For the sake of conciseness, we restrict our discussion to the differential exchange rate pass-through; a document containing all the graphs from the results section for the alternative CPI measures can be provided by the authors upon request.

Figure 8 then summarizes the differential pass-through, with an interpretation identical to that of Figure 7. For genuine exchange rate shocks, the difference appears to be only marginal with an ERPT of about 5%. As for monetary and copper price shocks, there seems to be a marked difference between food and non-food inflation. Non-food inflation (top panel) appears almost indifferent to the exchange rate fluctuations induced by copper price shocks, and

exhibits a pass-through of about 15% for fluctuations driven by monetary shocks, as opposed to nearly 25% in the case of overall inflation (previous section). In fact, the exercise suggests that the overall pass-through is overwhelmingly driven by food prices (bottom panel). Exchange rate fluctuations induced by copper prices come with a pass through of up to 10%, those resulting from monetary shocks with up to 33%. This corroborates the finding of a higher ERPT for food items in Zgambo (2015).

To some extent, this may appear puzzling as food items are typically sourced domestically (with most of the labor force working in agriculture), and often produced on small scale farms that do not tend to employ large amounts of imported inputs. Possible explanations could be lower menu costs in the often informal market for food items, or the fact that processed food items are almost exclusively imported. The latter would additionally increase in relevance if there existed an urban bias (or a bias towards formal food vendors such as supermarkets) in the CPI figures, as this is where imported food items prevail. We leave this as an open question for future research.

### 6. Exchange rate and price shocks 2015

In order to investigate the dynamics of the kwacha exchange rate and its interaction with consumer prices, we deliberately excluded the periods after 2015 from our estimations, as the amplitude of these events means that they would have exerted undue influence on our parameter estimates. Having established the dynamics in arguably normal times, we will conclude our analysis by quantifying the extent to which the variables deviated from their econometrically expected behavior in late 2015. To this end, we compute the predicted values for each period up until 2015, therefore extending beyond our original sample period but using the parameters derived from the original sample period.

**Error! Reference source not found.** plots the predicted series against the observed values since 2009. In the first six years, the difference between the observed exchange rate fluctuations and the predicted series is on average below 4% (top panel). However, the fundamentals included in our model fail to predict or explain the massive depreciation in late 2015. For the last quarter of 2015, it would have predicted a depreciation of 7%, while the kwacha actually depreciated by almost 30%, a discrepancy of 23 percentage points.

An even more striking discrepancy arises between the observed and predicted CPI series (Figure 9, bottom panel). Mainly due to a general economic downturn, as captured in the Output gap, that counteracts the inflationary pressures arising from the depreciation, consumer prices (adjusted for the trend) were expected to stay stable (-0.1) according to the model in the last quarter of 2015. Instead, monthly inflation shot up by an unexpected 9.6%.

These discrepancies point towards dynamics that are substantially out of the ordinary, taking the preceding two decades as a benchmark. In view of the abruptness and peculiarity of the events, it should be emphasized that a narrative case study is needed in order to understand the mechanisms that led up to the sweeping currency depreciation and price inflation. While this is not the scope of our paper, our discussions with policy makers and private stakeholders suggested the following aspects were key in understanding the abrupt currency depreciation:
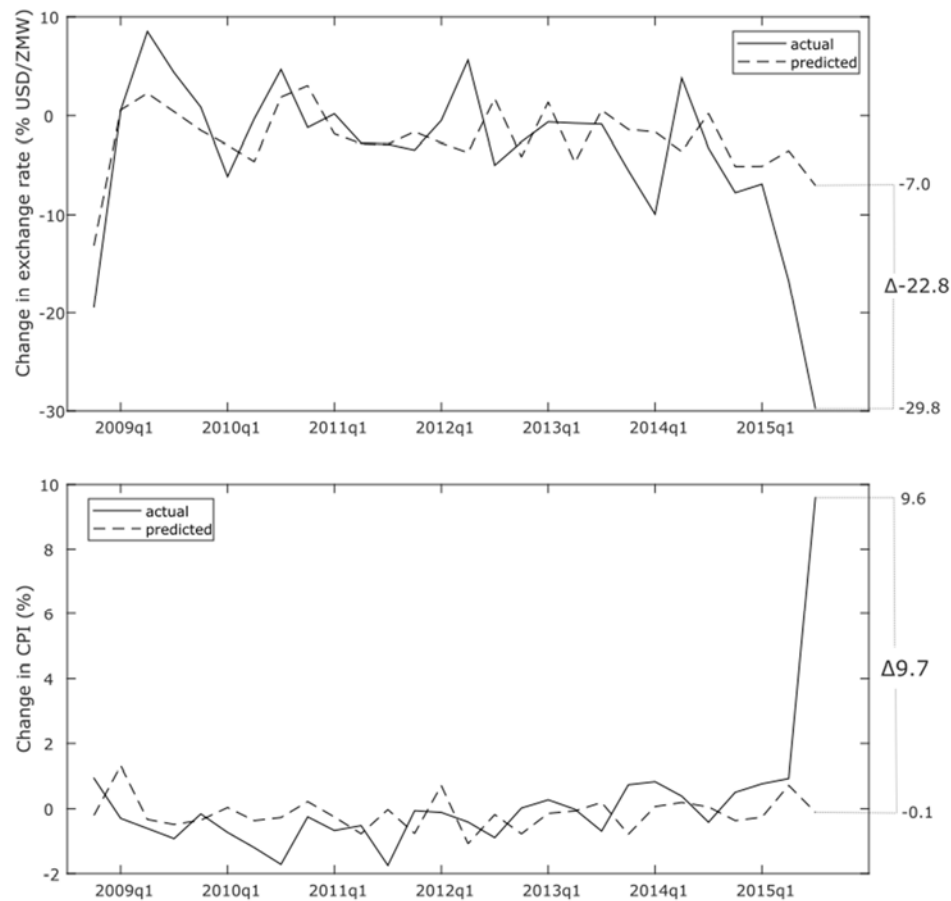
*Figure 9: Predicted and observed changes in exchange rate (top) and CPI (bottom)*

- *Thin market*: The currency market in Zambia is very thin and dominated by a few large players, most notably mining companies, the central bank, and some private banks. Individual transactions can have a great weight in the determination of the market exchange rate, something that is perpetuated as such transactions work as a signal for other market participants.
- *Trade deficit*: In December 2014, Zambia's balance of trade turned negative after nearly a decade of surpluses. In the first half of 2015, there was a widespread apprehension among currency traders that the negative trade balance would persist or worsen. This was confirmed by the government in late August, inducing a sharp and sudden depreciation.
- *Breakdown of price revealing mechanisms:* In an attempt to limit speculative and panic behavior, authorities closed the conventional foreign exchange market, where offers could openly be published and observed by participants. Contrary to the original intention, this effectively led to a breakdown of price revealing mechanisms and nurtured suspicions among market participants that authorities were artificially

keeping the exchange rate from dropping to its 'true' value. This turned into a self-fulfilling prophecy, and the actual rate consequently dropped to excessively low levels, reaching a low of 14 ZMW/USD on November 10.

- *Delayed policy response:* The central bank remained passive in terms of monetary policy at first; at least in part because of the factors described above, the developments only took up more pace instead of settling. When authorities substantially tightened monetary policy in mid-November, the exchange rate rapidly stabilized, as did inflation.

The fact that consumer price inflation so markedly increased in line with the exchange rate depreciation during this episode may seem at odds with the finding of a relatively low overall exchange rate pass-through.[5] It is also not the case that the exchange rate fluctuations were driven by monetary shocks, which, based on our results, would explain part of the higher pass-through. We conjecture that this is related to the following factors:

- *Confounding factors:* The currency crisis coincided with poor harvests in the agricultural sector, independently driving food price increases.
- *Size non-linearities:* It is often conjectured that small changes in the exchange rate may translate into prices differently than large changes in the exchange rate (e.g., Aron et al., 2014), for several reasons. First, menu costs may imply that producers and retailers absorb small changes in the exchange rate through their profit margins, and will only adjust prices once a certain threshold has been surpassed. A large depreciation such as in late 2015 would then surpass these thresholds across sectors and firms, leading to a larger ERPT. Similarly, in times of large exchange rate fluctuations, retailers pay increased attention to the exchange rate and may adjust prices at a higher frequency. Anecdotal evidence suggests that this was the case during 2015, with some retailers informally declaring prices in USD, and converting them into kwachas based on the daily exchange rate for every purchase. This practice mechanically leads to a complete ERPT for these transactions.

## *7. Conclusions*

We investigated the dynamics of the exchange rate and its interaction with consumer prices in Zambia in a structural VAR framework, identifying shocks with a combination of theoretically plausible zero-restrictions and sign-restrictions. Crucially, we imposed minimal restrictions on the interaction between these two key variables. Furthermore, we explored the possibility of differential pass-through depending on which shock originally caused the exchange rate to fluctuate, and disaggregated these results into food and non-food items. Finally, we used our results and qualitative evidence to put into context the tumultuous period of late 2015.

Our findings suggest that the pass-through from the exchange rate to consumer prices is relatively moderate for genuine exchange rate shocks; we estimate a 10% depreciation to induce

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[5] To obtain an order of magnitude, a back of the envelope calculation using monthly exchange rates and price data between August and November 2015 data would suggest that a 60% depreciation came with an approximate 20% of additional inflation (when adjusting for a baseline inflation of about 7%), implying an ERPT of more than 30% in the short run. This is in contrast to about 7% suggested by our estimates.

an increase in consumer prices of ca. 0.7% after one year, corresponding to an ERPT of 7%. This is substantially less than what other studies typically find for small, low income countries, and far below the 41% estimated for Zambia by Choudhri and Hakura (2006). This is likely due to two factors. First, unlike much of the comparable literature, we do not impose any directionality on the contemporaneous relationship between the exchange rate and inflation. When doing so, our estimates of the ERPT are more than doubled. Second, we study more recent periods where Zambia has maintained a fairly low level of inflation judged by historical standards. It is a well-established finding that countries with lower inflation typically have a smaller ERPT, and Zambia may indeed have successfully reduced its vulnerability to global shocks in this respect.

Variance decomposition suggests that the main drivers of exchange rate fluctuations are, as suggested by much of the earlier literature, copper prices and the money supply. The relative importance of these factors has varied over time; while money supply has typically accounted for the largest share of the fluctuations, copper was relatively more important in the period 2008-11. The role of inflation in the determination of the exchange rate declined throughout the sample period.

We further investigated whether the ERPT varies with the shock that initially caused the exchange rate to fluctuate. Our findings suggest that, as opposed to exchange rate fluctuations caused by copper shocks or genuine exchange rate shocks, those fluctuations going back to monetary shocks are associated with a much larger pass-through of about 25%. When considering only food inflation, this figure is even higher with up to 33%. Our findings therefore suggest that, if consumer prices – especially food prices – are the outcome of interest, monetary policy must be conducted with great care, in the sense that counteracting exchange rate fluctuations with monetary interventions may have substantial repercussions on consumer prices.

Lastly, we show that the extent of the sharp depreciation of the exchange rate, as well as the steep increase in consumer prices in late 2015 cannot be explained from the underlying fundamentals included in our system. Instead, we suggest a narrative of market panic paired with non-linearities in the ERPT, and outline the core aspects: thin markets, a deteriorated balance of trade, the breakdown of price revealing mechanisms, and a delayed policy response. We suggest that a dedicated case study is required in order to provide a satisfactory narrative of this episode, and leave this as a fruitful topic for further research.

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*Appendix A: Prior values of contemporaneous matrix H*

| | CPI type | Shock | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | | Fed | Copper | Money | Output | Exchange rate | Price |
| Fed funds rate | All | 1 | 0 | 0 | 0 | 0 | 0 |
| | Non-Food | | | | | | |
| | Food | | | | | | |
| Copper | All | 8.52 | 1 | 0 | 0 | 0 | 0 |
| | Non-Food | 9.42 | | | | | |
| | Food | 8.53 | | | | | |
| M2 | All | -2.65 | -0.04 | 1 | 0 | 0 | 0 |
| | Non-Food | -2.53 | -0.04 | | | | |
| | Food | -2.47 | -0.04 | | | | |
| Output Gap | All | -0.49 | **0.03** | -0.02 | 1 | 0 | 0 |
| | Non-Food | 0.05 | **0.03** | -0.03 | | | |
| | Food | -0.64 | **0.04** | 0.00 | | | |
| Exchange rate | All | **-1.77** | 0.21 | **-0.76** | 0.28 | 1 | **-0.85** |
| | Non-Food | **-2.98** | 0.22 | **-0.79** | 0.16 | | **-1.30** |
| | Food | **-1.67** | 0.18 | **-0.77** | 0.34 | | **-0.47** |
| Inflation | All | -0.11 | 0.02 | -0.07 | 0.04 | **-0.09** | 1 |
| | Non-Food | 0.25 | 0.02 | -0.04 | 0.05 | **-0.11** | |
| | Food | -0.55 | 0.03 | -0.11 | 0.08 | **-0.09** | |

Notes: Priors reported in **bold** are subject to a sign restriction. The respective sign can be inferred from the reported value of the prior. The priors are obtained from just-identified Cholesky decompositions as described in section 3.1.

*Appendix B: Augmented Dickey Fuller tests for a unit root*

| | | Intercept | Trend | *t*-statistic | 5% CV | *p*-value |
| --- | --- | --- | --- | --- | --- | --- |
| Copper price | Level | yes | no | -1.11 | -2.90 | 0.71 |
| | 1st Diff | no | no | -3.71 | -1.95 | 0.00 |
| Fed funds rate | Level | no | no | -1.50 | -1.95 | 0.13 |
| | 1st Diff | no | no | -2.97 | -1.95 | 0.00 |
| Money | Level | yes | yes | 3.47 | -3.47 | 1.00 |
| | 1st Diff | yes | no | -3.20 | -2.90 | 0.02 |
| Output gap | Level | no | no | -3.98 | -1.95 | 0.00 |

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
|  | 1st Diff | no | no | -6.34 | -1.95 | 0.00 |
| Exchange rate | Level | yes | yes | -1.77 | -3.47 | 0.71 |
|  | 1st Diff | yes | no | -4.37 | -2.90 | 0.00 |
| CPI | Level | yes | yes | -2.53 | -3.47 | 0.31 |
|  | 1st Diff | yes | yes | -5.29 | -3.47 | 0.00 |

Notes: All tests have been carried out with trends and intercept where the graphs in section 4 suggested their relevance, and removed when they turned out insignificant in the Dickey Fuller regression. The tests in first differences were carried out with the *log* differenced series as this corresponds to the series eventually included in out estimation for most variables. The exception is the output gap, where logs cannot be taken because of negative values. All results refer to a test with 4 lags of the variable for consistency with the main analysis.