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Abstract

This paper investigated whether monetary policy disturbances matter in Ghana. A previous study pursued this question but the evidence brought forth was plagued with the exchange rate and price puzzles. We argued, in this paper that these puzzles arise because of identification scheme of the kind utilized in that paper. We showed that a better approach to overcoming these puzzles is by using the agnostic identification scheme. Using a quarterly time series over the 1990Q1 – 2015Q3, and an efficient algorithm for solving sign restricted SVARs, we found that short-term interest rate responded largely and positively, real output and consumer prices reacted negatively, nominal exchange rate reacted by appreciating after just 2 quarters, and dropped gradually to its baseline, and monetary base and commodity prices reacted by dropping below zero and remained there, following a contractionary monetary policy disturbance. The reaction of nominal exchange rate is rather lethargic, taking into account the strong rise in the short-term interest rate, pointing to: some existing structural and institutional rigidities in the Ghanaian economy that inhibit the size of capital inflows expected, the country's dismal sovereign bond rating, or the increase in the short-term interest rate is not high enough to mitigate the cost of capital investment.

JEL Codes: C11; C32; E52

Keywords: Agnostic Identification; Monetary Disturbances; Structural Shocks; Ghana

1. Introduction

The role of monetary policy in the real economic activity has been of interest to macroeconomists for a very long time. In the seminal work of Friedman and Schwartz (1960), they found that the correlations of money and real output are not due to the passive response of money to the changes in economic activity. Instead, they argued, the rates of change in money are strongly linked to monetary policy disturbances. A lot of work has since been put in to debunk this conclusion. There is evidence in the literature that monetary disturbances generate responses in interest rates that are complicated to interpret – the liquidity puzzle (see Leeper and Gordon, 1992; Canova and De Nicoló, 2002). An attempt to demystify this puzzle has generated several studies. For example, Sims (1980), and Bernanke and Blinder (1992) advanced the use of short-term interest rate innovations to proxy monetary policy disturbances. This approach has led to another puzzle, the price puzzle. General prices turn to increase before falling shortly after contractionary monetary policy disturbances, which is against the conventional wisdom (see Sims, 1992; Leeper *et al.*, 1996; Bernanke and Mihov, 1998; Canova and De Nicoló, 2002; Uhlig, 2005).

Overcoming the price puzzle and the other puzzles has been the focus of several studies over the last 15 years or so. Different approaches have been advanced to this end, including the inclusion of nonborrowed reserves, total reserves as well as commodity price indexes in parsimoniously restricted time series models.[2] A unification of these studies has been kindly provided in Bernanke and Mihov (1998a, b). Leeper *et al.* (1996) have also carefully provided the summary of the state-of-the-art in the literature. Others, including Canova (1995), Christiano *et al.* (1999) and Bagliano and Favero (1998), have also added excellent surveys of their own.

One important conclusion appears to resurface in the empirical literature: monetary policy disturbances are important in the real economic activity; the transmission mechanisms of such disturbances being left for theoretical investigation. There are studies today that argue for the role of policy changes and regime shifts in altering the transmission mechanisms of monetary policy disturbances over the course of time (see among others, Uhlig, 1997; Canova and Gambetti, 2004; Cogley and Sargent, 2005; Primiceri, 2005; Rubio-Ramirez *et al.*, 2005, Boivin and Giannoni, 2006; Sims and Zha, 2006; Gambetti and Canova, 2008). Others stressed the importance of measurement errors, and the size of information available to the policymaker in the transmission mechanism of monetary policy disturbances (see Forni and Rechlin, 1998; Stock and Watson, 2002; Bernanke *et al.*, 2005; Del Negro and Otrok, 2008; Korobilis, 2009; Banbura *et al.*, 2010; Cogley and Sargent, 2014; Cogley *et al.*, 2015; Amir-Ahmadi *et al.*, forthcoming).

Whereas the literature is now unanimous on the role of monetary policy disturbances on major economies such as the U.S., U.K., countries in the G-7 in general, and most OECD countries in particular, the evidence for smaller economies is unsurprisingly very limited. The skewed nature of the literature is clearly understandable because data on small and/or developing countries for undertaking such economic exercises are very limited. On top of that, one cannot guarantee the independence of the monetary authority in these countries. A necessary condition for effective monetary policy transmission is the independence of the monetary authority. Moreover, developing economies have severe distortions and structural rigidities (such as excessive state controls, weak institutions, and limited infrastructure), which make the policy path of structural disturbances extremely blurred to examine.

We are aware of a handful of studies on monetary policy disturbances for emerging market economies and smaller economies (see, for example, Berument, 2007; Bjørnland, 2008; Ho and

[2] See, among others, Eichenbaum (1992), Christiano and Eichenbaum (1992), Leeper and Gordon (1992), Gordon and Leeper (1994), Christiano *et al.* (1999), Kim (1999).

Yeh, 2010; Bowman *et al.*, 2015; Ramos-Tallada, 2015). The aim of this paper is to add to this growing literature by assessing whether monetary disturbances matter for the Ghanaian economy. The modelling strategy for a small open economy of this kind is very crucial. We cannot treat a small open economy as it is done for, say the U.S. or the U.K. whereby recursive approaches to identifying monetary disturbances may deliver theoretically consistent responses or even build the economic setup by assuming that such disturbances are transmitted through only the interest rate but not the exchange rate channel (see Cushman and Zha, 1997). Economies such as the U.S. and the U.K. are relatively closed and therefore are less responsive to external disturbances. In contrast, small open economies such as Ghana are very responsive to external disturbances, thereby ruling out the interest rate independence assumption made using a recursive approach to identifying monetary policy disturbances. Thus, if identification is done using recursive ordering of variables, the exchange rate in small open economies will respond to monetary policy disturbances in a fashion that is not consistent with the conventional wisdom.[3] This give rises to another puzzle – the exchange rate puzzle (see Cushman and Zha, 1997).

In this paper, we attempt to overcome these puzzles by utilizing a structural vector autoregression (SVAR), which draws on the agnostic identification procedure proposed in Uhlig (2005), and generalized in Rubio-Ramirez *et al.* (2010) to identify monetary policy disturbances as contractionary monetary disturbances, for the period 1990Q1 – 2015Q3. The identification procedure is agnostic because the question we want to answer is left agnostically open, so that the data will "speak for itself". This distinctive characteristic of the agnostic procedure makes it very appealing to the policymaker. Particularly, the identification procedure allows the policymaker to focus on identifying the disturbances of interest, in the present paper, the monetary policy disturbances. Hence, the policymaker will not have to shoulder the burden of identifying other fundamental disturbances, which may not necessarily contribute to answering the question at hand.[4]

There is an existing study which is related to ours, namely Abradu-Otoo *et al.* (2003). That study examines the transmission mechanisms of monetary policy in Ghana using SVECM models. Among other shocks, the study assessed money supply shocks, interest rate shocks, and exchange rate shocks by identifying these shocks using long-run restrictions of Blanchard and Quah (1989). The identification procedure applied by that study was unable to overcome the exchange rate and price puzzles. Abradu-Otoo *et al.* (2003) argued, in support of their results, that the financial system and infrastructure in Ghana is undeveloped thereby inhibiting the true transmissions of monetary disturbances. Whereas their assertion appears true, their identification

[3] Under this circumstance, a contractionary monetary policy disturbance leads to increases in the domestic interest rate but depreciation in the local currency, which is odd. The conventional wisdom suggests that increases in the domestic interest rate will stimulate capital inflows, leading to a surge in the demand for the local currency, and hence appreciation of the nominal exchange rate.

[4] This challenge (of short- and long-run identification schemes) was recognized by studies such as Bernanke and Mihov (1998a, b), Faust (1998), Christiano *et al.* (1999), and Canova and De Nicoló (2002). These authors utilized a block-recursive ordering to concentrate the identification exercise on only a limited set of variables, which interact with the policy shock in order to circumvent this problem (see also Uhlig, 2005; Rubio-Ramirez *et al.* 2010).

procedure is well-known to have hard times overcoming these puzzles. Our study hereby resolves the shortcomings of this earlier study by utilizing an agnostic identification procedure to identify monetary policy disturbances. We are not, by this, implying that the agnostic identification procedure is flawless. Instead, this approach delivers impulse responses in the current empirical exercise that are at least consistent with the theory. Our findings can be summarized as follows:

- The short-term interest rate responded largely and positively, rising by 1.52%, and ultimately wandering around 0.5% to 1.0% within 20 quarters after the disturbance.
- Real output declined by 0.02% after 5 quarters, declined further to approximately 0.06% after 20 quarters.
- Consumer prices reacted negatively, falling by 0.025% after 10 quarters, and ultimately climbing by nearly 0.012% after 20 quarters. Clearly, the price puzzle has been avoided.
- The nominal exchange rate reacted, appreciating by 0.00525% after just 2 quarters, and then dropping gradually to the baseline after 20 quarters. Notice again that the exchange rate puzzle has been mitigated.
- Monetary base dropped in reaction to the disturbance by 0.010% after 5 quarters, then meandered around this figure after 20 quarters.
- Commodity prices reacted, dropping by 0.02% after just 4 quarters, and then wandered between -0.02% and -0.03% thereafter.

In the next section, we present the data and some stylized facts. In section 3, we lay out the empirical SVAR model and the agnostic identification procedure. Section 4 presents the results. Section 5 concludes.

2. Data and Some Stylized Facts

2.1 Data

The data utilized in this paper is quarterly and covers the period 1990Q1 – 2015Q3. The monetary variables, namely the short-term interest rate proxied by monetary policy rate (MPR) and 91-day treasury bill rate, and the monetary base proxied by M1, M2 and M2+ are taken from the Bank of Ghana's Macroeconomic Time Series database available at the bank's website. The indicators of price stability, namely overall consumer price index (CPI) and inflation are also taken from the same database of the Bank of Ghana (BoG). The measures of exchange rate [i.e. nominal exchange rate (NER) and nominal effective exchange rate (NEER)] are taken from the IMF's international financial statistics (IFS) database. Data on real output proxied by real GDP is taken from the Ghana Statistical Service's website and complemented by data from the BoG's Quarterly Bulletins and Economic Reviews. Data on primary commodity prices is taken from the World Bank's Commodity Prices database. The original data on primary commodity prices is collected on monthly basis. We converted it to quarterly frequency for our exercise. We used primary commodity prices based on energy price index, which is derived using weights of crude oil, coal, and natural gas. All the variables are in logarithms except the short-term interest rates (i.e. monetary policy and 91-day treasury bill rates). Figure 1 shows the plot of these variables for the study period, excluding MPR and M1 to save space.

2.2 Some Stylized Facts

Figure 1 shows that Ghana has experienced steady expansion in terms of real output from the first quarter of 1990 till date. This can be partly attributed to the country's transition from a military regime to multi-party democracy during this period. The air of political stability has fostered favourable investor confidence in the economy, thereby stimulating capital inflows and investment in the economy. The democratic transition has also brought some accountability and transparence in governance. This led to a near total pursuance of various State policies and initiatives. The discovery of crude oil around 2007 has also brought in huge capital investments, thus boosting infrastructure investment. The country also successfully negotiated its huge external debts to be cancelled under the heavily indebted poor countries' initiative (HIPC). These, among other factors fostered the real expansion of output in the economy.

Inflation has been pro-cyclical over the study period, reflecting the pro-cyclical nature of the treasury bill rate (TBR) and monetary base (M2). Quarterly inflation has risen during the mid-1990s. It appears the BoG responded by increasing its short-term interest rate to counter rising inflation (see Figure 1). However, money supply (M2) remained very high during this period, indicating that excess money supply has been the source of inflation during the mid-1990s. The increase in the short-term interest rate appeared to take long to be assimilated in the economy as money supply remained persistently high several quarters after the increase in short-term interest rate. Perhaps, consumers were simply unwilling to invest in treasury bills. Inflation and treasury bill rates behaved in a fashion consistent with the theory. M2+ defined as currency in circulation plus demand, saving, time, and foreign deposits have experienced rapid expansion during the first quarter of 1990 to date. This reflects the rapid expansion of the Ghanaian financial industry, where mutual funds, forex bureaus, savings and loans and related institutions have proliferated throughout these years.

The exchange rate has depreciated tremendously over the period under study. This is clearly shown by the plot for NEER and NER. The NEER has declined quarter-on-quarter basis from 1990Q1 to date. The NER has increased quarter-on-quarter basis over the study period. So whether we measure the Ghanaian cedi against the U.S. dollar or against a weighted basket of foreign currencies, the story remains the same. In essence, the Ghanaian economy has been losing its international competitiveness throughout these years, indicating a possible source of the persistent rise in the consumer price index (see Figure 1).

3. Methodology

This section discusses the econometric technique that is utilized throughout the empirical exercise, namely the sign restricted SVAR. We specify this SVAR model, and then we explain how shocks are identified in this model. In addition, we discuss the agnostic identification procedure proposed by Uhlig (2005), and the efficient algorithm developed by Rubio-Ramirez *et al.* (2010) for solving the sign restricted SVAR model.

3.1 Model Specification

Following the lead of Uhlig (2005), we specify the VAR for the Ghanaian economy as:

$$Y_t = \beta_{(1)} Y_{t-1} + \beta_{(2)} Y_{t-2} + \cdots + \beta_{(l)} Y_{t-l} + u_t, \quad t = 1, \ldots, T, \quad (1)$$

where Y_t is an $m \times 1$ vector of macroeconomic variables at $t = 1 - l, \ldots, T$. Y_t consists of real output (logGDP), consumer price index (logCPI), real commodity prices (logCOM), treasury bill rate (TBR), exchange rate (logNEER), and monetary base (logMON). $\beta_{(i)}$ are coefficient matrices of size $m \times m$, and u_t is the one-step ahead prediction error whose variance-covariance matrix is Σ.

The policymaker is interested in the behaviour of u_t, the one-step ahead prediction error. The reason is that innovations in u_t are transmitted into the economy as structural disturbances. The bulk of the VAR literature has been concentrated on decomposing u_t into forms that are economically interpretable due to this important reason. The decomposition of u_t has also been the source of debate in the literature. This is the case because the policymaker's ability to efficiently examine the transmission mechanisms of innovations in u_t to the rest of the economy relies entirely on the appropriate decomposition of u_t.

Suppose that u_t can be normalized into v_t such that $E[v_t v_t'] = I_m$ (i.e. u_t is normalized to have variance I_m, an identity element)[5], then there exist a matrix A such that $u_t = A v_t$, whose jth column represents the immediate impact on all variables of the jth fundamental innovation, one standard error in size (see Uhlig, 2005). This also implies that we have a restriction on A, which stems from the form of the variance-covariance matrix:

$$\Sigma = E[u_t u_t'] = AE[v_t v_t']A' = AA'. \quad (2)$$

Eq. (2) indicates that, in specifying A, we have $m(m-1)/2$ degrees of freedom. The current restriction on A is, therefore, not sufficient to identify shocks to u_t. As Uhlig (2005) argues, the literature has proceeded to impose the additional restrictions on A by following one of three ways: (i) by restricting A to be a Cholesky factor of Σ, thus suggesting a recursive ordering of Y_t (see, for example, Sims, 1986); (ii) by drawing information from structural relationships between

[5] Note that u_t is i.i.d.

$v_{ti}, i = 1, \ldots, m$, the fundamental innovations and $u_{ti}, i = 1, \ldots, m$, the one-step ahead prediction errors (see, for example, Bernanke, 1986; Blanchard and Watson, 1986); (iii) by decomposing shocks into permanent and transitory components (see, for example, Blanchard and Quah, 1989). In this paper, we proceed to impose additional restrictions on A in the fashion proposed in Uhlig (2005).

3.2 The Agnostic Identification Procedure

To identify the fundamental disturbances of interest, Uhlig (2005) proposed we use sign restrictions on the matrix A. This spares the policymaker the burden of identifying other shocks that may not necessarily help her in answering her policy question. In addition, the above ways of restricting A may not generate impulse responses that have the desired signs (see Rubio-Ramirez *et al.*, 2010). These points were identified by Bernanke and Mihov (1998a, b) and Christiano *et al.* (1999), who utilize a block-recursive ordering to focus their identification exercise on a few sets of covariates, which relate with the disturbance of interest. Other studies such as Faust (1998), and Canova and De Nicoló (2002) also raised these points. In spite of its strengths, the sign restriction approach has been criticized by Fry and Pagan (2011) for being unable to recover correct elasticities due to its inherent weak information.

Here, we utilize the sign restriction approach to identify the disturbances of interest, namely the monetary policy disturbance. This means that we neglect the remaining $m - 1$ fundamental innovations. Hence, our identification will be a single column $a \in \mathbb{R}^m$ of the matrix A in *Eq.* (2). We impose the identifying restrictions that monetary policy disturbances in the economy lead to increase in the short-term interest rate, and decrease in consumer prices, commodity prices, exchange rates and the monetary base within a specified period of quarters after the disturbance. Such identifying restrictions ensure that the monetary policy disturbances are appropriately identified as contractionary monetary policy disturbances. In essence, our identification scheme is constructed such that sign restrictions are imposed on the other variables for a specified period of four quarters, whereas our variables of interest, namely real output is left agnostically open.

To summarize the agnostic identification procedure, a contractionary monetary policy disturbance will be an impulse response vector, which satisfies the sign restrictions. In our case, a contractionary monetary policy disturbance is a disturbance such that the responses of short-term rate and exchange rates are non-negative, and consumer prices, commodity prices, and the monetary base are non-positive at all horizons $k = 0, \ldots, K$. Uhlig (2005) proposes two approaches to solving the sign restricted SVAR – the *pure-sign-restriction approach* and *the penalty-function approach*.[6] However, we proceed to use the generalized version of these approaches proposed in Rubio-Ramirez *et al.* (2010) to solve the sign restricted SVAR in this paper. This algorithm is discussed in the next section.

[6] The interested reader may consult Uhlig (2005) for the technical details of these approaches.

3.3 Efficient Algorithm for Solving the Sign Restricted SVAR

Sign restricted SVARs are known to be locally non-identified (see Rubio-Ramirez *et al.*, 2010; Fry and Pagan, 2011). That is, for a set of sign restrictions, if there exist a parameter point (A_0, A_+) which satisfies these restrictions, there exist an orthogonal matrix P, arbitrarily close to an identity matrix, such that a parameter point (A_0P, A_+P) also satisfies the sign restrictions (see Rubio-Ramirez *et al.*, 2010).[7] Hence, sign restricted SVARs are not identified, tasking the policymaker to search for a set of impulse responses that satisfy the same sign restrictions (see Rubio-Ramirez *et al.*, 2010; Fry and Pagan, 2011).[8]

Canova and De Nicoló (2002) developed an algorithm based on grid search to find such a P. The limitation of their algorithm is that it cannot feasibly handle a moderately large (i.e. $n > 4$) SVAR system. Uhlig (2005) developed two algorithms to find that P: the penalty-function approach and the pure-sign-restriction approach. These algorithms search for the orthogonal matrix P recursively column by column. Uhlig's (2005) algorithms are limited in that they may not find the orthogonal matrix P for some draws of (B, Σ) (see Rubio-Ramirez *et al.*, 2010).

Rubio-Ramirez *et al.* (2010) developed a new algorithm, which is based on the Householder-transformation methodology to overcome the limitations of these algorithms.[9] Their algorithm is referred popularly as the Rubio-Ramirez *et al.* (2010)' rejection method. The algorithm can be outlined as follows:

Let (A_0, A_+) be any given value of the unrestricted structural parameters.

- Step 1: Draw an independent standard normal $n \times n$ matrix $\tilde{X}$ and let $\tilde{X} = \tilde{Q}\tilde{R}$ be the QR decomposition of $\tilde{X}$ with the diagonal of $\tilde{R}$ normalized to be positive.
- Step 2: Let $P = \tilde{Q}$ and generate impulse responses from A_0P and $B = A_+A_0^{-1}$.
- Step 3: If these impulse responses do not satisfy the sign restrictions, return to Step 1.[10]

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[7] Rubio-Ramirez *et al.* (2010) formulates a compact form of the SVAR as $y_t'A_0 = x_t'A_+ + \varepsilon_t'$ and a reduced-form as $y_t' = x_t'B + u_t'$, so that $B = A_+A_0^{-1}$, $u_t' = \varepsilon_t'A_0^{-1}$, and $E[u_tu_t'] = \Sigma = (A_0A_0')^{-1}$. The reduced-form parameters are thus (B, Σ). Two parameter points are observationally equivalent if and only if they have the same reduced-form representation (B, Σ). Therefore, parameter points (A_0, A_+) and $(\tilde{A}_0, \tilde{A}_+)$ have the same reduced-form representation (B, Σ), if and only there exists an orthogonal matrix P such that $A_0 = \tilde{A}_0P$ and $A_+ = \tilde{A}_+P$ (see Rubio-Ramirez *et al.*, 2010).

[8] Numerically, the policymaker must bear the computational burden of locating a set of Ps such that the parameter point (A_0P, A_+P) satisfies the sign restrictions.

[9] See Rubio-Ramirez *et al.* (2010) for the distinction between their algorithm and the ones proposed in Uhlig (2005). In particular, this algorithm has a sizeable efficiency gain if more than one shock is to be identified.

[10] Rubio-Ramirez *et al.* (2010) set a maximum of 100,000 iterations for Steps 2 – 3 to be repeated. If the maximum is reached, the algorithm moves to Step 1 to draw another orthogonal matrix $\tilde{Q}$.

4. Results

This section presents the key empirical results. We begin by reporting the impulse responses stemming from the popular identification procedure based on Cholesky decomposition. This identification procedure is frequently used in the literature as the baseline with which to compare competing identification procedures (see for example, Canova and De Nicoló, 2002; Uhlig, 2005). We add to this by discussing the impulse responses based on the agnostic identification procedure. Then, we discuss the forecast error variance decomposition. We take the results further by reporting the results based on alternative measures of the monetary base, short-term interest rate, consumer prices, and exchange rate. This constitutes our sensitivity analysis. Throughout the empirical exercise, we used the variables in their levels. This is consistent with Uhlig (2005), who argues in favour of levels as against first differences in order that the restrictions are imposed directly on the impulse responses and not the cumulative impulse responses. It turns out that the results are invariant regardless of whether the variables are demeaned, differenced, or detrended.[11]

4.2 Impulse Responses Generated from Cholesky Decomposition

We begin our empirical analysis by reporting the results based on Cholesky decomposition. The order in which the variables enter into the model is important when identifying disturbances using the Cholesky decomposition (see Sims, 1992; Christiano *et al.*, 1996; Uhlig, 2005). In the current exercise, we are particularly concern about the positions of the real output and consumer prices in the model, and also the choice of the variable whose innovations are denominated as the monetary policy disturbances. The following equations summarize our ordering strategies:

$$Y = [logGDP, logCPI, logCOM, logNEER, TBR, logM2], \quad (3)$$

$$Y = [logCPI, logGDP, logCOM, logNEER, TBR, logM2]. \quad (4)$$

In the first model, real output enters first followed by consumer prices (see Uhlig, 2005; Berument, 2007). In the second model, consumer prices enters first, followed by real output (see Abradu-Otoo *et al.*, 2003). In both cases, monetary policy disturbances are identified as innovations in *TBR*. Monetary base enters last in each of the above models in line with the existing literature (see Uhlig, 2005; Berument, 2007). We imposed lower triangularity on A in *Eq.* (2) in line with the conventional Cholesky decomposition. In addition, we set the prior restriction on (B, Σ) as a flat Normal inverted-Wishart prior.[12] The impulse responses are generated using 1000 Markov Chain Monte Carlo (MCMC) replications, 4 lags, and a horizon of 20-quarters ahead. The size of the shock is one standard deviation, thereby constraining the impulse responses to the median, 16% and the 84% quantiles. Figures 2 and 3 report the impulse

[11] These results are withheld for the sake of concision. They are freely available upon request.
[12] Canova (2007) provides technical details on this prior restriction.

responses from the Cholesky identification scheme.

A contractionary monetary policy disturbance generates inconsistent responses for some variables (see Figures 2 and 3). Notably among them are consumer prices and nominal exchange rate. Consumer prices responded sluggishly, increasing initially before falling below the baseline after a contractionary monetary policy disturbance. This is the price puzzle noted in Sims (1992) and other studies. To avoid this puzzle, Eichenbaum (1992) has recommended the use of commodity prices. Our empirical exercise contains commodity prices but the price puzzle still shows up. An alternative approach is to reorder the variables such that the short-term interest rate enters last. We have done this (the results are not shown here), yet the price puzzle has not been eliminated.[13] The price puzzle is also visible in the study by Abradu-Otoo *et al.* (2003), whereby consumer prices increase above zero and take not less than 6 months to decline below zero following a contractionary monetary policy disturbance.

The exchange rate puzzle is evident in the impulse responses generated by the Cholesky identification scheme (see Figure 2 and 3). That is, the nominal effective exchange rate has declined below the baseline following a contractionary monetary policy disturbance, and remained so even after 20 quarters. The conventional wisdom suggests that short-term interest rates will increase to stimulate capital inflows, demand for the local currency, and appreciation of the nominal exchange rate, following a contractionary monetary policy disturbance. This is the total opposite in the current results and precisely what is reported in Abradu-Otoo *et al.* (2003). To support their findings, Abradu-Otoo *et al.* (2003) argued that the financial system and infrastructure in Ghana is undeveloped thereby inhibiting the true transmissions of monetary disturbances. Their assertion may be true but their identification procedure is to blame for unable to overcome the exchange rate and price puzzles. There is an increasing justification that identification through short- or long-run restrictions struggles to overcome these puzzles. However, agnostic identification handles these puzzles easily (see Uhlig, 2005).

The other variables, namely: short-term interest rate, real output, commodity prices, and monetary base responded in fashions consistent with textbook rendition of contractionary monetary policy disturbances (see Figures 2 and 3). The short-term interest rate increased above its baseline level and permanently so, following a contractionary monetary policy disturbance. The monetary base fell below zero but revert to zero after nearly 13 quarters, following the disturbance. Real output reacted to this contractionary monetary policy disturbance by falling below zero and remained there after 20 quarters. Similarly, commodity prices fell below zero and remained there after 20 quarters, following the monetary policy disturbance.

[13] In any case, Uhlig (2005) argues that this alternative approach is not a convincing identification approach.

4.3 Impulse Responses Generated from the Agnostic Identification Scheme

It is clear from the above discussion that identification based on Cholesky decomposition is often unable to generate theoretically consistent impulse responses. For this reason, the remaining empirical exercises will focus on a better approach, which does a great job in mitigating the failures of the Cholesky strategy. To this end, we utilized the agnostic identification as proposed in Uhlig (2005).

In the case of the agnostic identification, ordering of the variables is not important. Hence, we maintained the ordering in *Eq.* (3), so that a contractionary monetary policy disturbance is the innovations in the short-term interest rate. Figure 4 shows the impulse responses generated from this benchmark identification scheme. We iterate the impulse responses using the Rubio-Ramirez *et al.* (2010) rejection algorithm. The size of the shock is one standard deviation, thereby constraining the impulse responses to the median, 16% and the 84% quantiles. It turns out that a maximum of 1000 MCMC draws meet the imposed sign restrictions. A total of 500 MCMC replications, and 500 sub-replications over the rejection routine were more than sufficient for convergence. Recall that we restricted consumer prices, commodity prices, nominal exchange rate, short-term interest rate, and the monetary base to respond in particular fashion, following a monetary policy disturbance. Specifically, we imposed the identifying restrictions that monetary policy disturbances in the economy lead to increase in the short-term interest rate, and decrease in consumer prices, commodity prices, nominal exchange rates and the monetary base within a specified period of four quarters after the disturbance.

The impulse responses delivered by the agnostic identification scheme are generally consistent with the observed pattern brought forth in the literature. The results in Figure 4 can be summarized as follows:

- The short-term interest rate responded largely and positively, rising by 1.52%, and ultimately wandering around 0.5% to 1.0% within 20 quarters after the disturbance.
- Real output declined by 0.02% after 5 quarters, declined further to approximately 0.06% after 20 quarters.
- Consumer prices reacted negatively, falling by 0.025% after 10 quarters, and ultimately climbing by nearly 0.012% after 20 quarters. Clearly, the price puzzle has been avoided.
- The nominal exchange rate reacted, appreciating by 0.00525% after just 2 quarters, and then dropping gradually to the baseline after 20 quarters. Notice again that the exchange rate puzzle has been mitigated.
- Monetary base dropped in reaction to the disturbance by 0.010% after 5 quarters, then meandered around this figure after 20 quarters.
- Commodity prices reacted, dropping by 0.02% after just 4 quarters, and then wandered between -0.02% and -0.03% thereafter.

The responses of all the variables following a contractionary monetary policy disturbance are consistent with the conventional wisdom. Most importantly, a contractionary monetary policy disturbance results in an increase in the short-term interest rate, and a fall in real output. In addition, the two main puzzles that are evident in the existing study (see Abradu-Otoo *et al.,* 2003) have vanished. An interesting result is how the nominal exchange rate reacted, following the disturbance. The nominal exchange rate reacted rather lethargically in spite of the strong rise in the short-term interest rate. This perhaps points to some existing structural and institutional rigidities in the Ghanaian economy, which reduces the size of capital inflows that is expected, following the increased in the short-term interest rate. Until the latter part of the 2000's, the Ghanaian economy was quite restricted to the external economy. We will not be overstating by saying that these rigidities still exists, albeit not as prevalent as before. To add to this, the country's sovereign bond rating was quite dismal before the mid-2000s and even today, perhaps making capital investment unappealing to investors (local and foreign). Another plausible explanation is that the rise in short-term interest rate may not be high enough to generate returns marginally high than the costs of capital investment in order to induce foreign investment in the economy. Other good explanations may be available to justify why the nominal exchange rate reacted rather lethargically, following a contractionary monetary policy disturbance but the ones provided here are just as reasonable to us.

4.4 Forecast Error Variance Decomposition

In this section, we analyze the proportion of the variance in the variables explained by contractionary monetary policy disturbances. To put it technically, we want to know what proportion of the variance of the k-step ahead forecast revision $E_t[Y_{t+k}] - E_{t-1}[Y_{t+k}]$ in the variables is attributed to the contractionary monetary policy disturbance. Figures 5 and 6 report the proportion of the variance of the 20-step ahead forecast revision of these variables. We will concentrate on Figure 6 because it displays the forecast error variance decomposition delivered by the agnostic identification scheme. After 20 quarters the contractionary monetary policy disturbance has explained 10%-14% of the variation in real output, 9%-13% in consumer prices, 15% in the nominal exchange rate, 12%-17% in the commodity prices, and 12%-14% in the monetary base. Overall, the contractionary monetary policy disturbance has explained larger proportion (21%-23%) of the variation in the short-term interest rate than any of the remaining variables. This further confirms the swift reaction of the short-term interest rate, following the contractionary monetary policy disturbance shown in Figure 4. The monetary policy disturbance was able to explain 21% of the variation the short-term interest rate even after 20 quarters, suggesting that monetary policy disturbances are actually errors made by the Bank of Ghana. If not, we should have seen the impact wane off several quarters after the disturbances. The results suggest further that, in the long run, the monetary policy disturbances have influence on the nominal exchange rate, consumer prices, real output, and commodity prices in the Ghanaian economy. This seems quite at odd with the textbook explanation of monetary policy. According to the theory, monetary policy should have long-run impact on only consumer prices. This evidence may just be idiosyncratic to the Ghanaian economy.

4.5 Sensitivity Analysis

In this section, we want to assess the robustness of the results reported so far to alternative measures of consumer prices, nominal exchange rate, short-term interest rate, and monetary base. There exist different proxies for these variables in the literature. Without assessing the sensitivity of our results to the different proxies, we leave them widely open for the skeptic to ponder.

Until this point, a contractionary monetary disturbance is an innovation in the 91-day Treasury bill rate (TBR). We wish to see what will happen if we replace TBR with the BoG's monetary policy rate (MPR). Figure 7 shows the responses to contractionary monetary policy disturbances identified as innovations in MPR. The responses reported in this case are qualitatively similar to the previous results; the marginal difference being the quantitative response of MPR following the disturbance. The MPR seems to hover around 0.5% and 1.0% as compared to the TBR which was between 0.5% and 1.52%, following the monetary policy disturbances. In our main empirical exercise, we utilized M2 as the monetary base. Figures 8 and 9 present the impulse responses of the variables, following a contractionary monetary policy disturbance, replacing M2 with M1 and M2+, respectively. The responses are not qualitatively different from the earlier results, except that consumer prices revert to its baseline after 20 quarter, following the disturbance.

The other results namely, when inflation (INF) and bilateral nominal exchange rate (NER) replaced, respectively, consumer prices (CPI) and nominal effective exchange rate (NEER) are reported in Figures 10 and 11. Here, consumer prices and nominal exchange rate behaved quite differently from the previous results. When CPI is replaced with INF, consumer prices revert to and above its baseline 7.5 quarters after falling below. The nominal exchange rate depreciates 10 quarters after appreciating. When NER replaces NEER, the nominal exchange rate is shown to appreciate up to 11 quarters, and revert to and below its baseline after that. The remaining variables are, however, qualitatively the same as the previous results. Evidently, we are able to mitigate price and exchange rate in these cases too.

Finally, the reader is tempted to pose another question. What happens if we adjust the restriction horizon (i.e. K) on the variables? Recall that we identified a contractionary monetary policy disturbance such that the responses of short-term interest rate and exchange rates are non-negative, and consumer prices, commodity prices and the monetary base are non-positive at all horizons $k = 0, \dots, 3$. The popular view is that monetary policy action takes about 6 month or 2 quarters lags to be properly digested. Hence, our choice of 4 quarters or 12 monthly (i.e. $k = 0, \dots, 3$) could be restrictive. To this end, we experimented with K=1 and 2 (i.e. 3 months and 6 months, respectively. The results reported for these horizons are not significantly different from our main results reported earlier to suggest any biasedness on our part.[14]

5. Conclusion

This paper investigated whether monetary policy disturbances matter in Ghana. A previous study pursued this question but the evidence brought forth was plagued with the exchange rate and price puzzles. We argued, in this paper that these puzzles arise because of the identification scheme of the kind utilized in that paper. We find these puzzles to emerge using the Cholesky identification scheme. We show that a better approach to overcoming these puzzles is by using the agnostic identification scheme proposed in Uhlig (2005), which allows the policymaker to identify a contractionary monetary policy disturbance such that the responses of short-term interest rate and exchange rate are non-negative, and consumer prices, commodity prices and the monetary base are non-positive at all horizons $k = 0, \dots, 3$ and leaving the real output for the data to decide. Using a quarterly time series over the 1990Q1 – 2015Q3, and an efficient algorithm for solving sign restricted SVARs proposed in Rubio-Ramirez *et al.* (2010), we found that short-term interest rate to have responded largely and positively, real output declined and consumer prices reacted negatively, nominal exchange rate reacted by appreciating after just 2 quarters, and then dropped gradually to its baseline, monetary base dropped below its baseline in response to the disturbance, and commodity prices reacted by dropping below its baseline and remained there. These results are broadly consistent to most existing studies on the effect of monetary policy disturbances. A quite surprising result is the way in which the nominal exchange rate reacted, following the disturbance. Its reaction is rather lethargic, taking into account the strong rise in the short-term rate. This may be due to some existing structural and institutional rigidities in the Ghanaian economy that inhibit the size of capital inflows expected, following an increase in the short-term interest rate. The country's sovereign bond rating has been dismal over the years, perhaps making capital investment unappealing to investors (local and foreign). It is also conceivable that the increase in the short-term interest rate is not high enough to generate returns judicious to offset the cost of capital investment in the economy. We acknowledge that other equally appealing renditions may be available, but the ones provided here are just as satisfying.

[14] The results are withheld to preserve space. They are readily available upon request.

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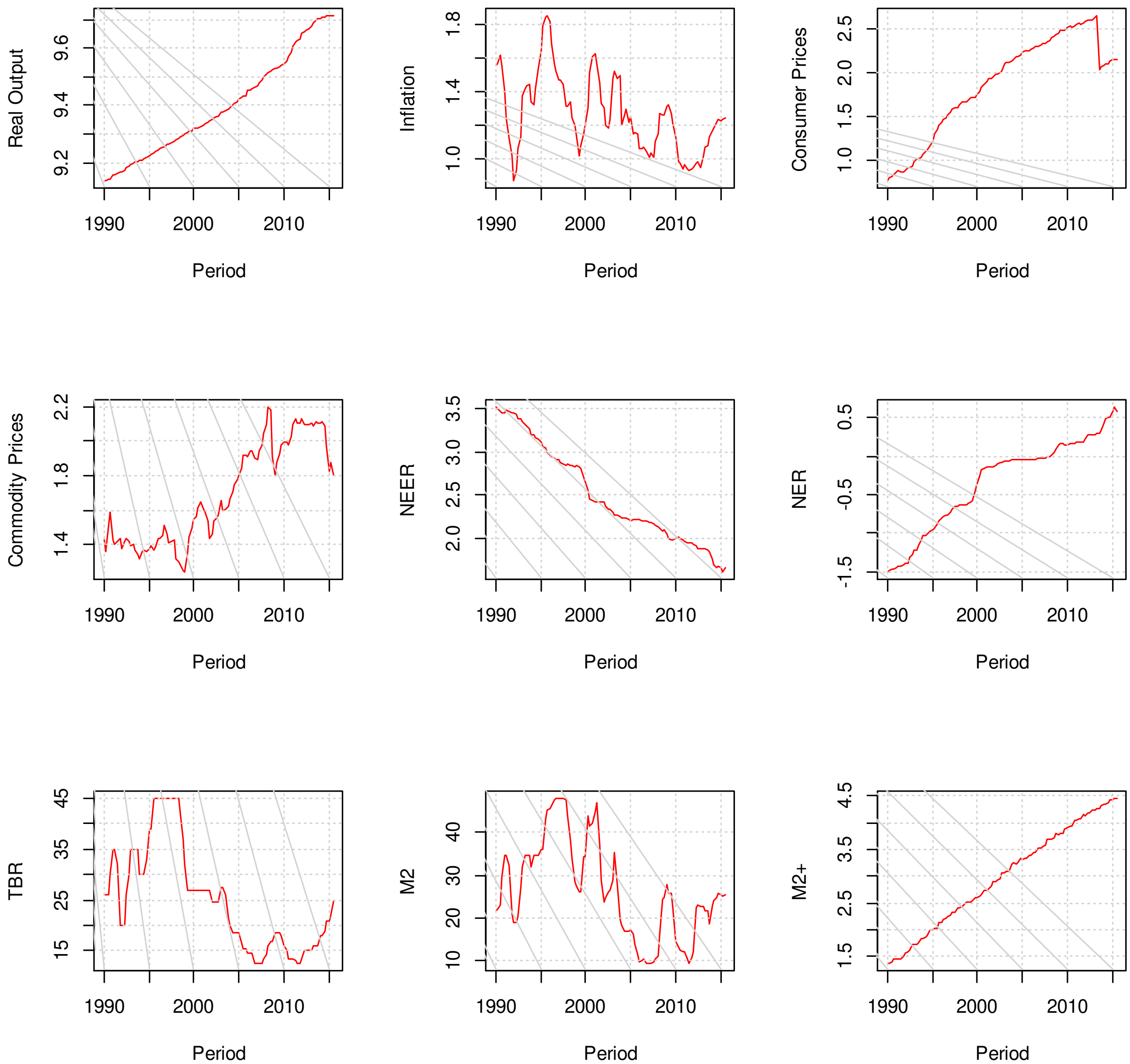

Figure 1: Plots of variables over the period 1990Q1 – 2015Q3. All the variables are in logarithms except monetary policy and 91-day treasury bill rates. Six of the variables, namely real output, CPI, commodity prices, NEER, NER, and M2+, exhibit trends. Four are pro-cyclical. These are inflation, commodity prices, TBR, and M2.

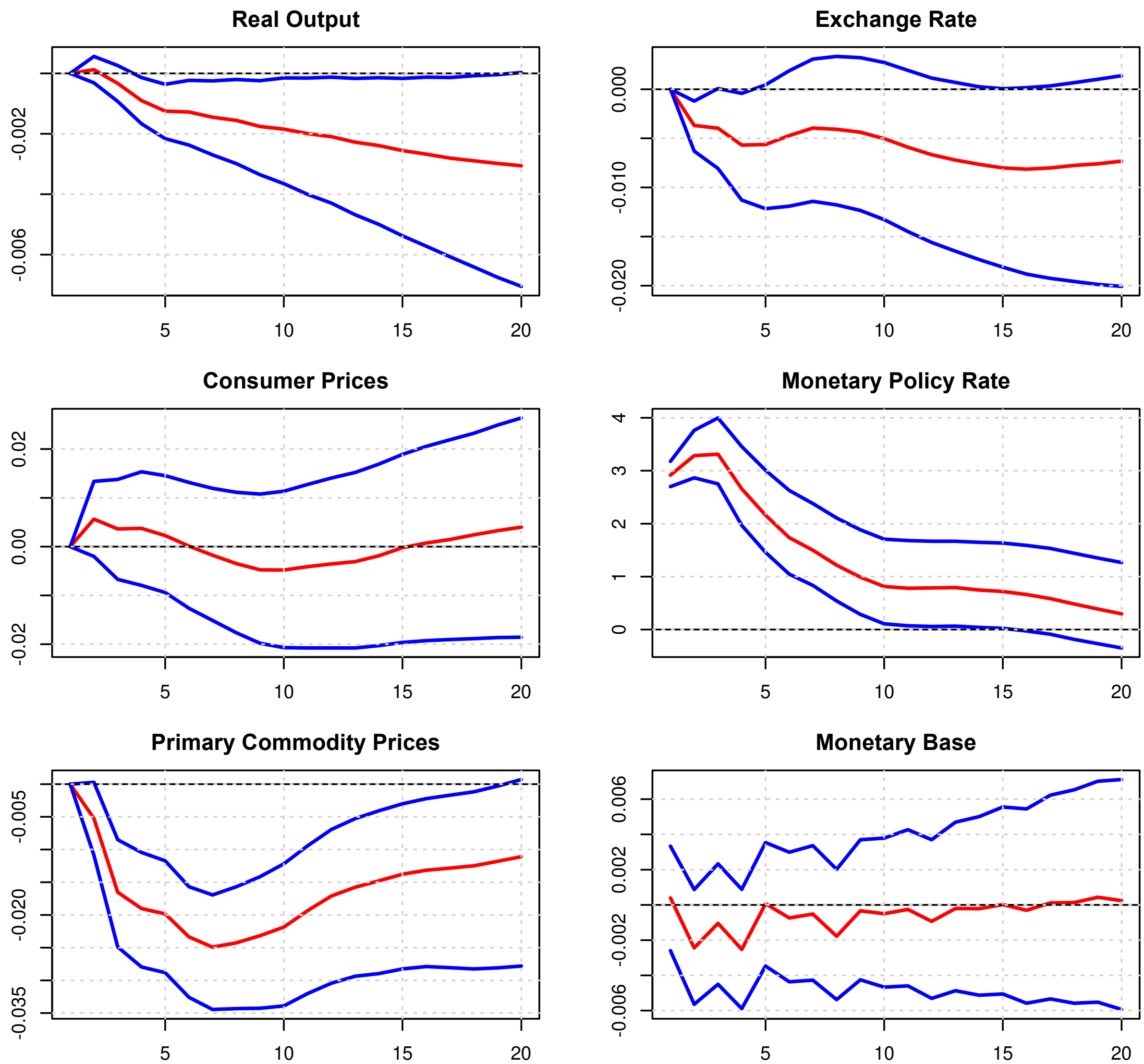

Figure 2: Impulse responses to a contractionary monetary policy disturbance one standard deviation in size, which is identified as the innovation in the short-term interest rate, ordered fifth in Cholesky decomposition before the monetary base. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution.

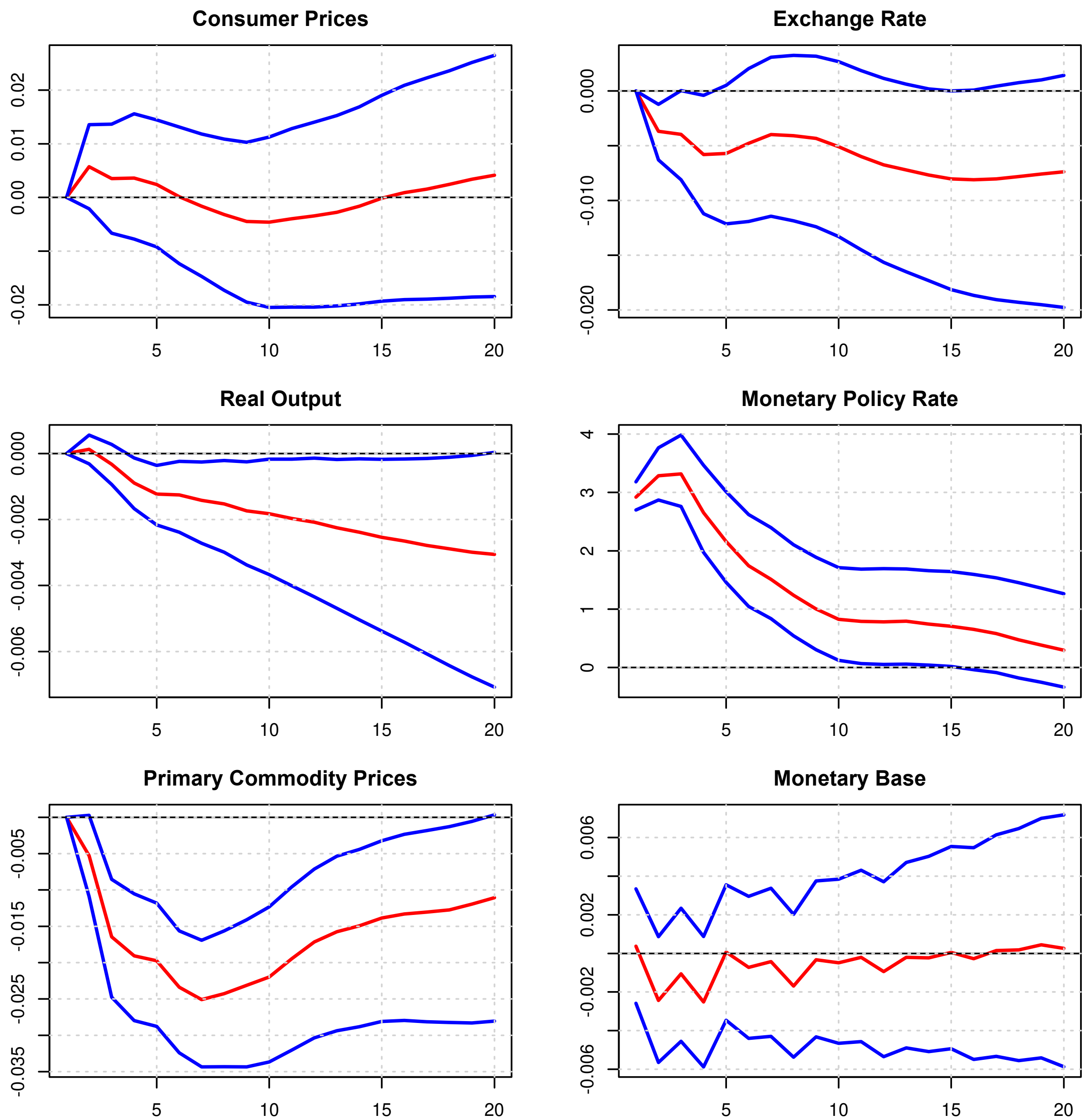

Figure 3: Impulse responses to a contractionary monetary policy disturbance one standard deviation in size, which is identified as the innovation in the short-term interest rate, ordered fifth in Cholesky decomposition before the monetary base. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution. Re-ordering the variables, by allowing consumer prices to enter first, does not change the results.

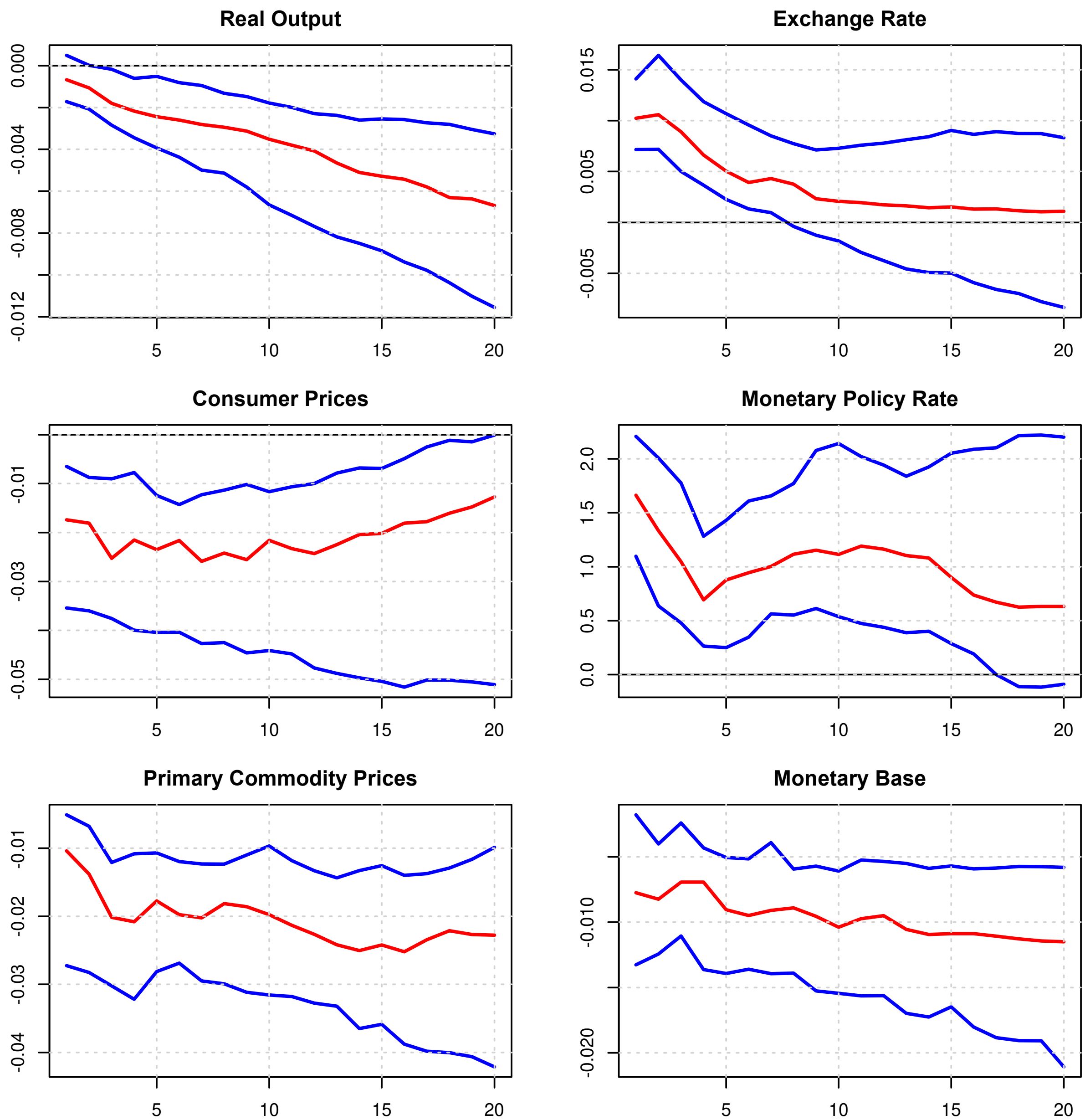

Figure 4: Impulse responses to a contractionary monetary policy disturbance one standard deviation in size, using the Rubio-Ramirez *et al.* (2010) rejection method with K=3. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution. Responses of short-term interest rate, consumer prices, commodity prices, real exchange rate, and monetary base are restricted for quarters k, $k = 0, \dots, 3$, after the contractionary monetary policy disturbance.

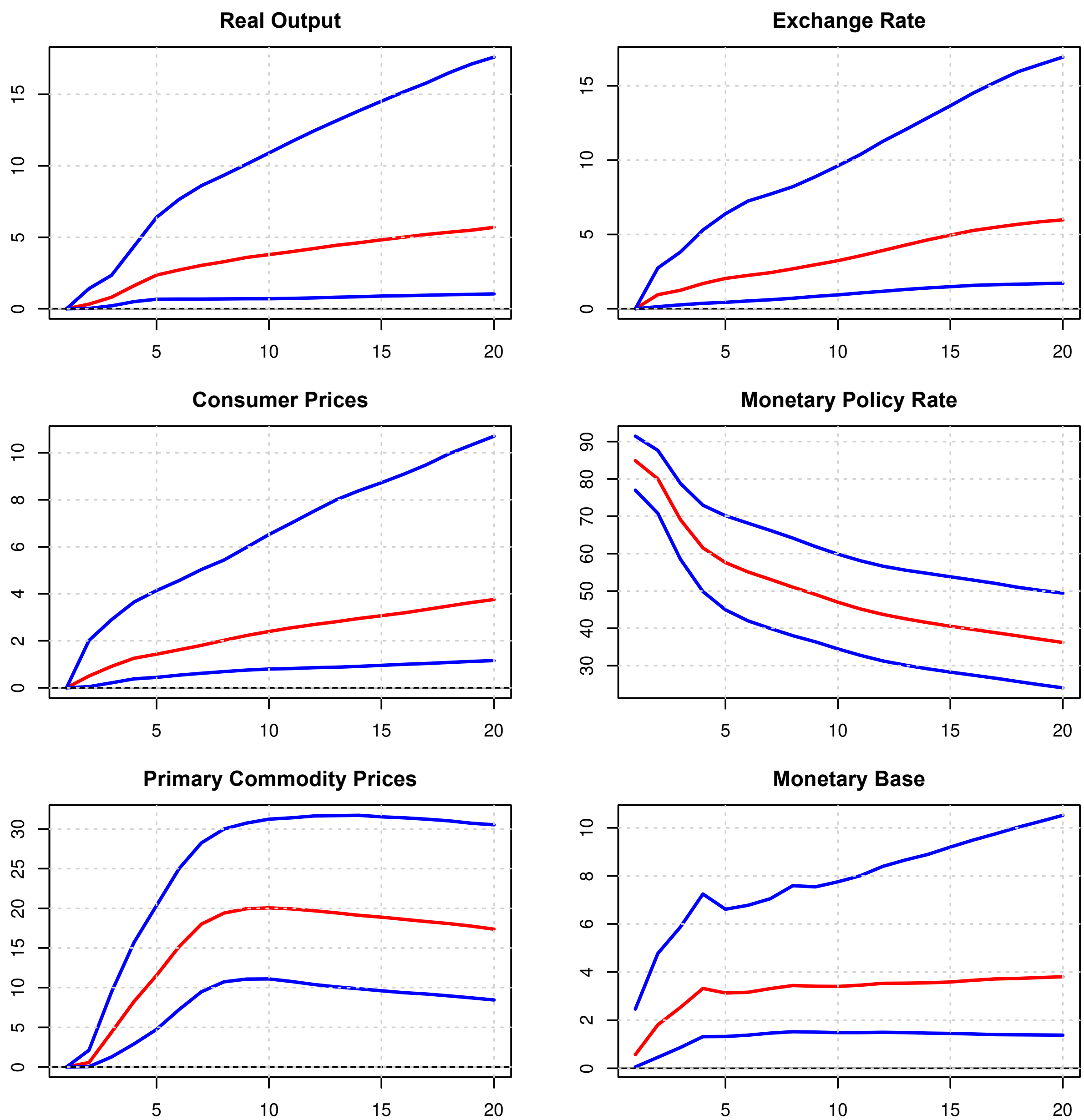

Figure 5: FEVDs due to a contractionary monetary policy disturbance one standard deviation in size, which is identified as the innovation in the short-term interest rate, ordered fifth in Cholesky decomposition before monetary base. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution.

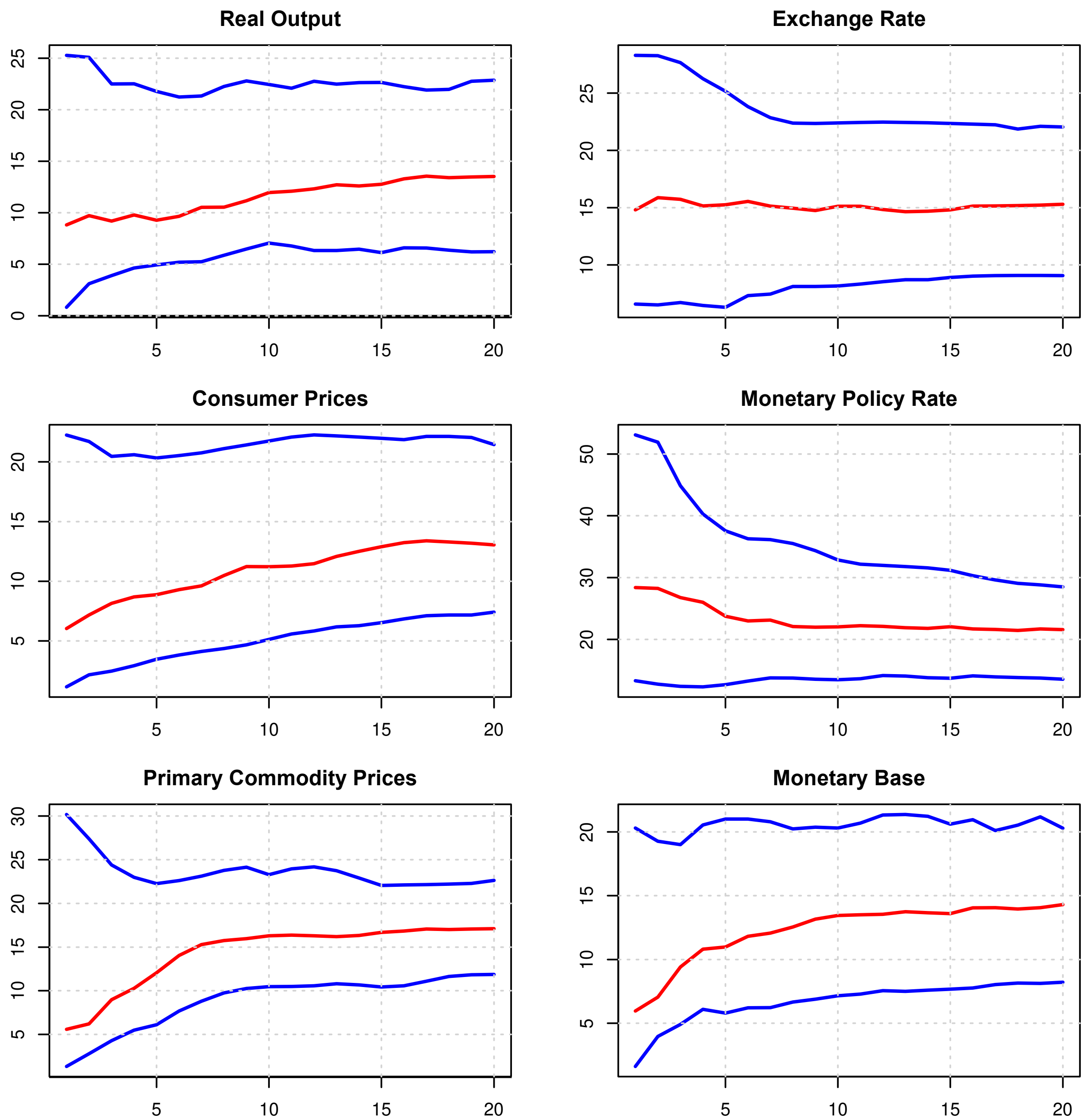

Figure 6: FEVDs due to a monetary policy disturbance one standard deviation in size, using the Rubio-Ramirez et al. (2010) rejection method with K=3. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution. Responses of short-term interest rate, consumer prices, commodity prices, real exchange rate, and monetary base are restricted for quarters k, $k = 0, \ldots, 3$, after the contractionary monetary policy disturbance.

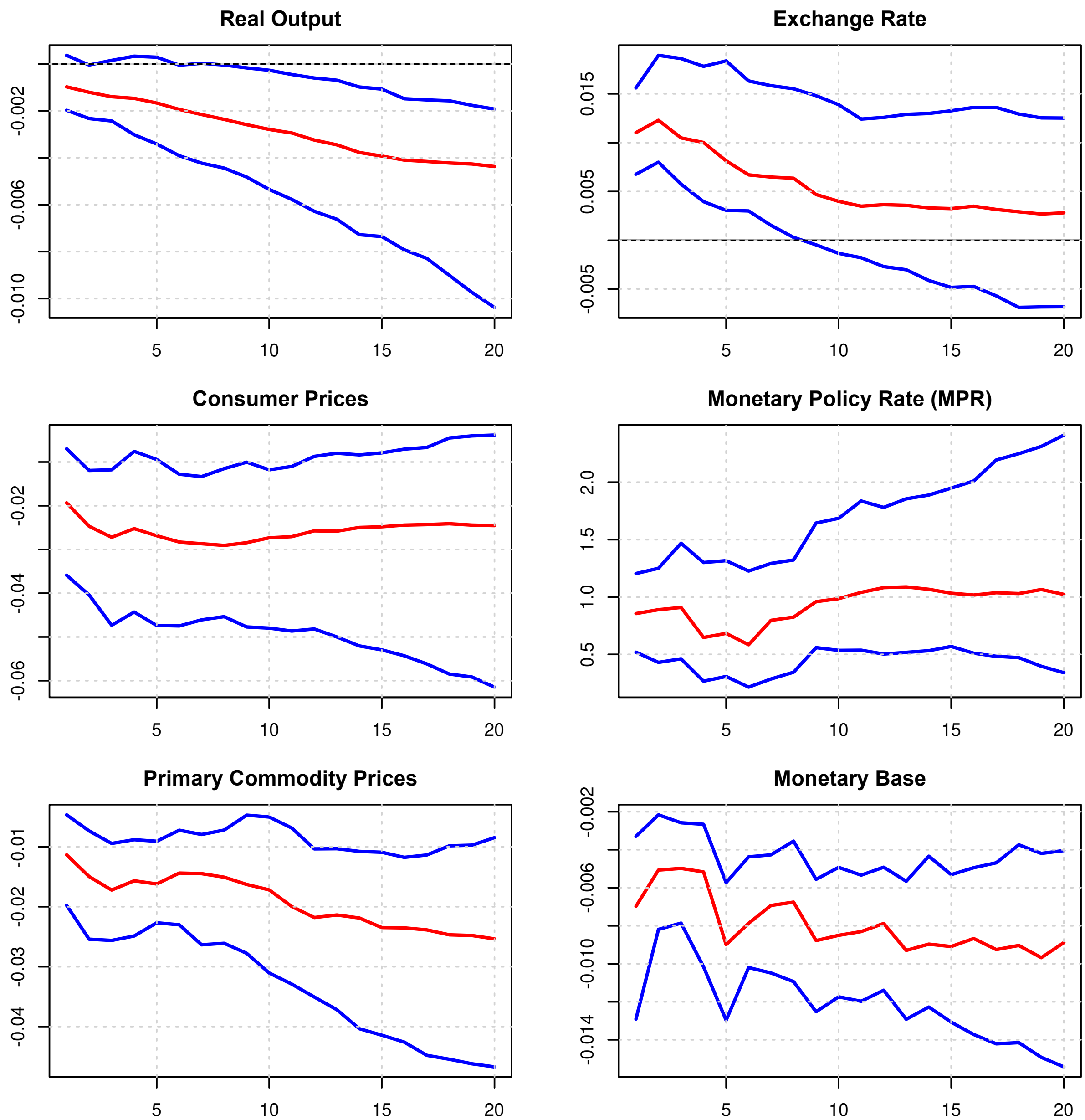

Figure 7: Impulse responses to a monetary policy disturbance one standard deviation in size, using the Rubio-Ramirez *et al.* (2010) rejection method with K=3. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution. Responses of monetary policy rate (MPR), consumer prices, commodity prices, nominal exchange rate, and monetary base are restricted for quarters k, $k = 0, \ldots, 3$, after the contractionary monetary policy disturbance.

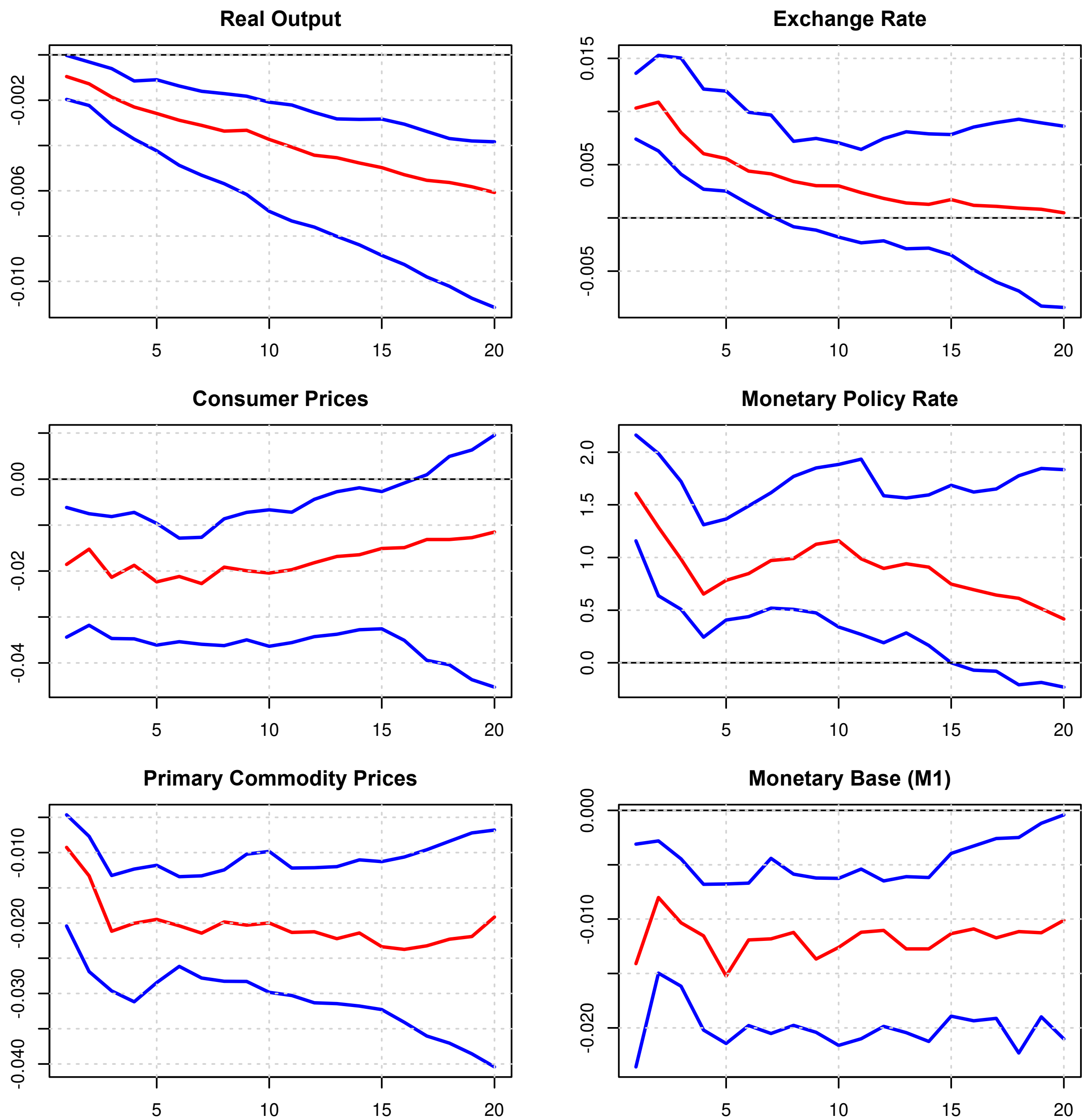

Figure 8: Impulse responses to a monetary policy disturbance one standard deviation in size, using the Rubio-Ramirez *et al.* (2010) rejection method with K=3. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution. Responses of short-term interest rate, consumer prices, commodity prices, nominal exchange rate, and monetary base (M1) are restricted for quarters k, $k = 0, \ldots, 3$, after the contractionary monetary policy disturbance.

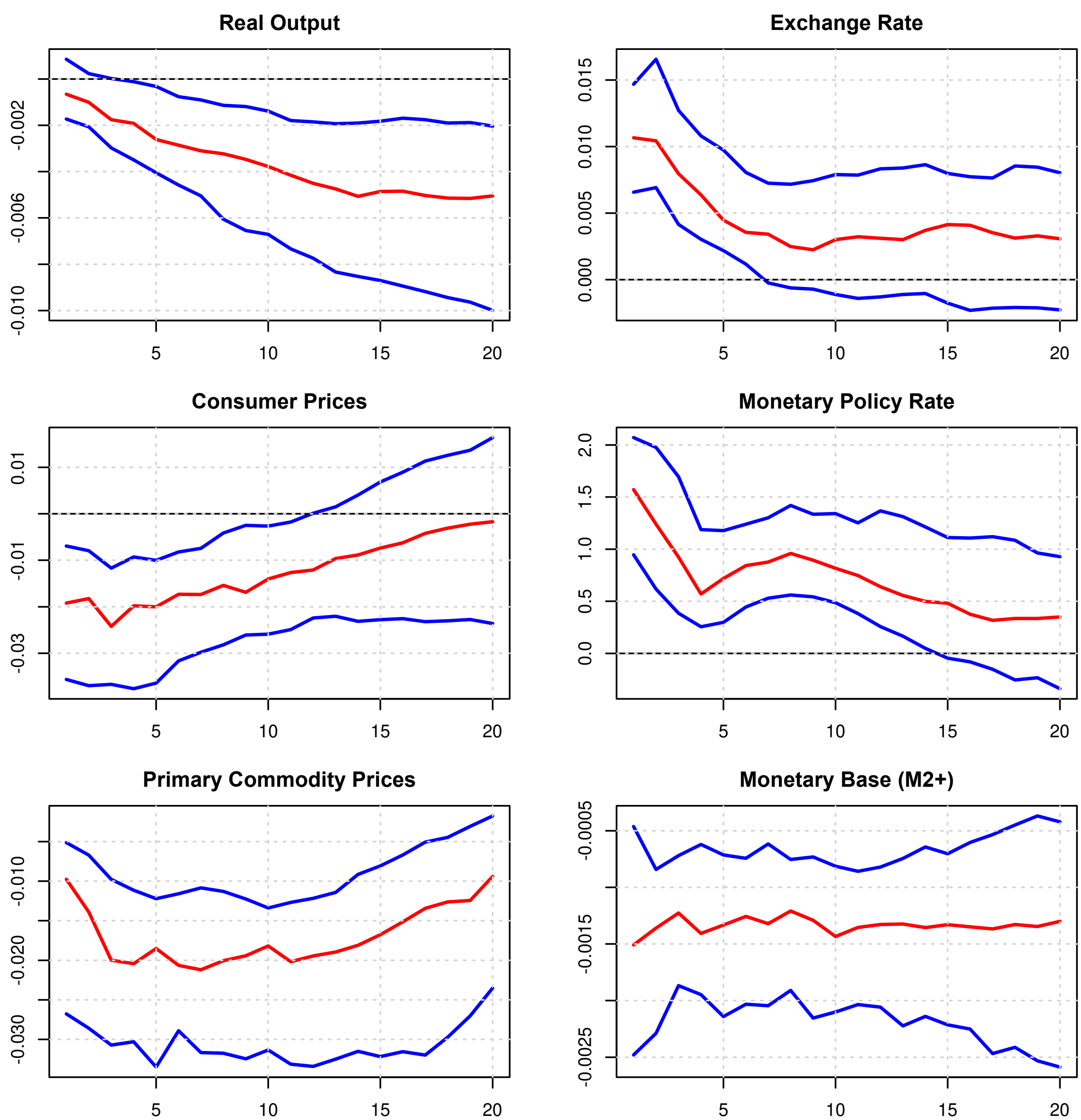

Figure 9: Impulse responses to a monetary policy disturbance one standard deviation in size, using the Rubio-Ramirez *et al.* (2010) rejection method with K=3. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution. Responses of short-term interest rate, consumer prices, commodity prices, nominal exchange rate, and monetary base (M2+) are restricted for quarters k, $k = 0, \ldots, 3$, after the contractionary monetary policy disturbance.

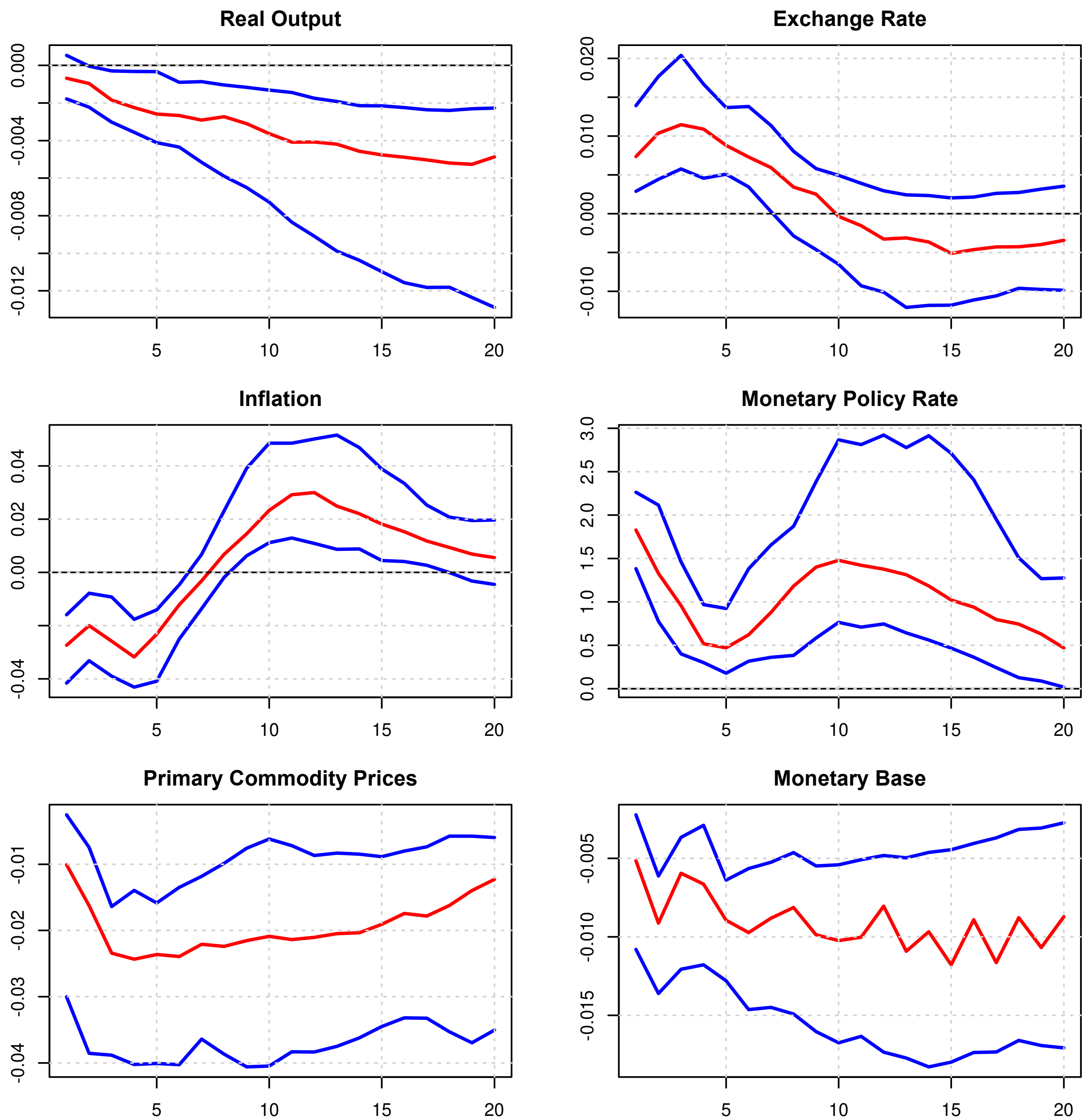

Figure 10: Impulse responses to a contractionary monetary policy disturbance one standard deviation in size, using the Rubio-Ramirez *et al.* (2010) rejection method with K=3. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution. Responses of short-term interest rate, Inflation, commodity prices, nominal exchange rate, and monetary base are restricted for quarters k, $k = 0, \dots, 3$, after the contractionary monetary policy disturbance.

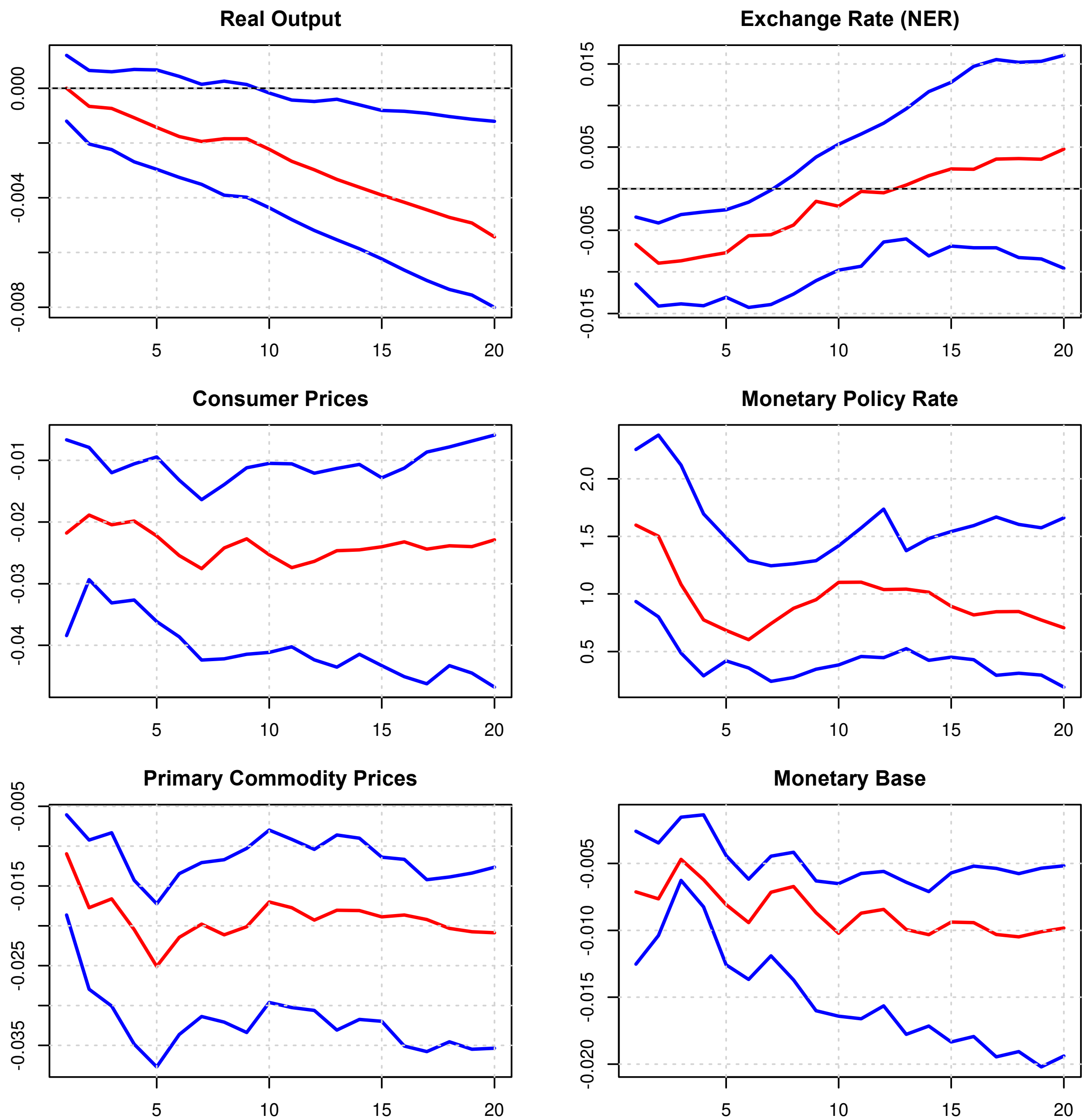

Figure 11: Impulse responses to a monetary policy disturbance one standard deviation in size, using the Rubio-Ramirez *et al.* (2010) rejection method with K=3. The three lines denote the 16% quantile, the median and the 84% quantile of the posterior distribution. Responses of short-term interest rate, consumer prices, commodity prices, nominal exchange rate (NER), and monetary base are restricted for quarters k, $k = 0, \ldots, 3$, after the contractionary monetary policy disturbance.