Exchange Rate Pass-through to Prices : Bayesian VAR Evidence for Ghana

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Abstract
Using quarterly data from 2006q3 to 2017q4, this paper employed *sign restrictions* with rejection method in a Vector Autoregression to estimate the pass-through of exchange rate dynamics to domestic prices in Ghana. The priors of the model belongs to the flat Normal inverted-Wishart family. Markov Chain Monte Carlo (MCMC) is used to collect 1000 draws from the posterior distribution of the SVAR parameters that satisfy the sign restrictions.
The model specification included some idiosyncratic features of the Ghanaian economy such as the dependence on primary export commodities for foreign exchange revenue and the dependence on foreign aid. Impulse response functions was used to analyze exchange rate pass-through whilst variance decomposition was used to explain the most dominant source of inflation in the study sample.
The impulse response showed a fairly large but not unitary pass-through of exchange rate dynamics to domestic prices. The implication herein is that exchange rate depreciation led to upsurge in prices in Ghana albeit, the impact is incomplete. Results from the variance decomposition indicated a monetary expansion was most dominant in explaining inflationary pressures in Ghana.
For inflation to be lowered, policy directives should be geared towards exchange rate stability as well as ensuring a stable interest rate environment.

Keywords: Exchange Rate Pass-through, Monetary policy, Inflation, Structural Vector Autoregressive, Bayesian Analysis

**JEL Classification Codes** : F41, F31, E31, E5, C32, F35

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1. Introduction

Does exchange rate dynamics induce inflationary pressures in Ghana? If yes, is it the most dominant source of inflationary pressure in Ghana? The above research questions sets the tone for this paper.

The overvaluation of the foreign exchange rate prior to 1983 has necessitated reforms such as the broad Structural Adjustment Programmes (SAP) and Economic Recovery Programmes (ERP) which were undertaken to liberalize the foreign exchange market. These reforms led to nominal depreciation of the cedi. The consensus in the literature is that since the adoption of the managed floating exchange rate in 1986, the cedi[2] has depreciated against the USD[3] at varying magnitudes over the vicissitude of time. For instance, in quarter 1 of 1986, the price of the cedi relative to a dollar was about 0.01. Fast forward, by the end of April 2015, the price stood at 3.84. The study of exchange rate dynamics on the macro-economy of any country is vital because, apart from its transmission mechanism, its impacts on assets and liabilities denominated in foreign currency cannot be taken lightly. In addition, it also has serious consequences for ensuring financial and macro-economic stability for any economy. The objective of this paper is in two folds; firstly, the paper examines the impact of exchange dynamics on domestic prices in Ghana. Secondly, the paper also examines whether exchange rate variations is most dominant in explaining inflationary pressures in Ghana. (**Fig 1**) below provides some graphical evidence to show that a depreciating exchange rate environment breeds inflation whilst a stable exchange rate environment is disinflationary. The red bars indicates the trend of CPI-inflation which is on an upward trajectory whilst the blue line shows the exchange rate is falling which indicates a depreciation.

Figure 1: Exchange Rate Movement and Prices in Ghana, 2006q3-2017q3
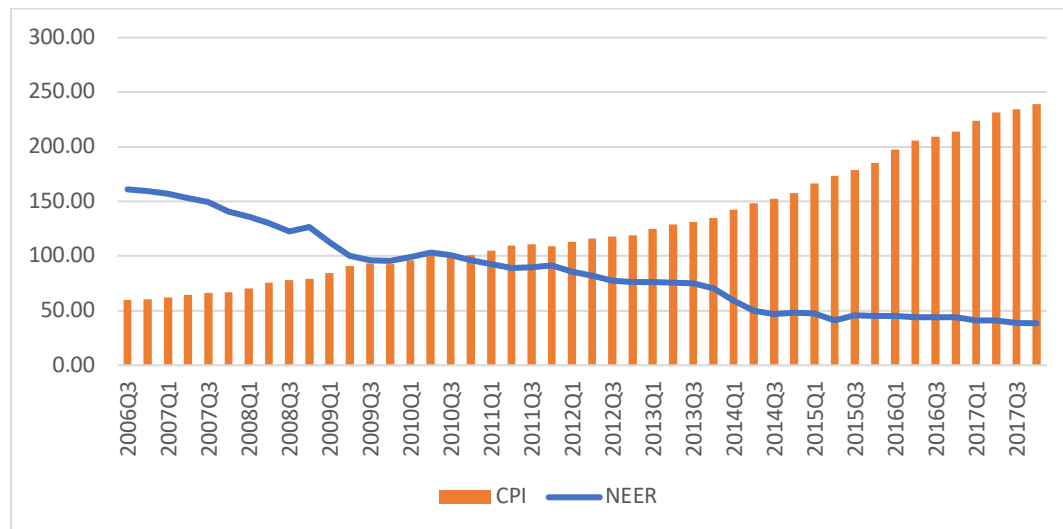
Source: International Finance Statistics, 2019

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[2] The currency of the republic of Ghana.
[3] United States dollars

Research on exchange rate pass-through to prices has provided some diverse findings with regards to whether the pass-through is high or low. Notable amongst them are; Bawumia and P. , (2003); Atta-Mensah and Bawumia (2003) ; Sowa and Kwakye (1993) who argue that the high pass-through of exchange rate dynamics to prices is attributable to the depreciation of the cedi following the adoption of the flexible exchange rate regime. Bhundia (2002) also posits that the extent of pass through depends on the weight of the goods and service that are imported and other factors such as degree of pricing. Pass-through may also be endogenous to the monetary policy regime because policy credibility underpins agents' expectations about the willingness of the authorities to counteract the second-round effects of currency depreciation on inflation. Frimpong and Anokye (2010) found low pass-through to prices in Ghana. Devereux and Yetman (2003) apart from finding very low and zero pass-through for some SSA countries, they also found a statistically insignificant pass-through elasticity of 0.05% for Ghana. Whether pass-through is low, high or/and incomplete provides the avenue for further interrogation with the hope to fill the gaps and provide some new findings.

The contribution of this paper will be to employ *sign restriction with rejection method in* Vector Autoregression (VAR) to estimate exchange rate pass-through in Ghana. To the best of my knowledge this is the first paper to employ a sign restricted VAR with rejection method to estimate exchange rate pass-through for Ghana. Albeit the VAR specification follows Sanusi (2010), this paper diverge on account of estimating the reduced form parameters using Bayesian technique.

Results from the impulse response indicates a significant but not a unitary response of domestic prices to structural standard deviation decrease in the exchange rate. The implication is that exchange rate depreciation leads to an upsurge in domestic prices in Ghana however, the impact is incomplete. This confirms Sanusi (2010) ; Acheampong (2004); Adu et al., (2015) ; Frimpong and Adam (2010); Loloh (2014) for Ghana. Furthermore, there is also a significant response of domestic prices to monetary expansion. The narrative is that monetary expansion in the form of a decrease in the policy rate has inflationary tendencies for the Ghanaian economy.   This corroborates Sanusi (2010) for Ghana.

In reference to variance decomposition, an expansive monetary policy rate shock is dominant in explaining inflation dynamics in Ghana accounting for about 12% to 18% in a 1 to 10 quarter horizon. Exchange rate shocks on the other hand accounts for about 9% to 14% of price fluctuations in Ghana within the same quarter period. This also confirms the literature that inflationary pressures in Ghana often times come from monetary sources.

The paper further performed robustness analysis using yield on government bonds in place of the monetary policy rate. Findings do not differ from the initial results. A decrease in the long term yield on government bonds signifies an easing of monetary conditions over long term which is expected to lead to a pick in economic activity and induce inflationary pressures.

The rest of the paper is structured as ; *Section 2* explains the literature review; *section 3* talks about the SVAR methodology; *section 4* presents data description and sources; Estimation is presented in *section 5; section 6* performs some robustness check; *section 7* gives the concluding remarks.

2. Literature Review

2.1 Theoretical Literature

According to Goldberg and Knetter (1997) exchange rate pass-through (ERPT) is the percentage change in local currency import prices resulting from a percentage change in the exchange rate between the exporting and importing countries. The literature categorizes ERPT into two folds

namely; exchange rate movement which affects import prices and exchange rate changes which affect import prices. This notwithstanding, it is rife in the literature to estimate the ERPT directly to domestic prices. The understanding in the empirical literature is that the effect of exchange rate movements on prices is incomplete. Krugman (1986) points to "pricing to market" by foreign suppliers as the reason why US import prices do not fully mirror exchange rate movements. Dornbusch (1987) rationalizes incomplete pass- through as coming from firms operating in markets characterized by imperfect competition and therefore adjust their mark-up in response to exchange rate innovations. Gagnon and Ihrig (2004) points to the role of fiscal and monetary authorities, which partially offset the effect of changes in the exchange rate on domestic prices. Burstein et al. (2003) emphasizes the role played by non-traded (domestic) inputs in the chain of distribution of tradable goods. Burstein et al. (2005) identifies measurement problems embedded in consumer price index, which does not account for quality adjustment of tradable goods with significant adjustment in the exchange rate. In addition, a notable reason for incomplete pass-through is the practice of pricing in the local currency Devereux and Engel (2001) and Bacchetta and van Wincoop (2003).

2.2 Empirical Literature

The empirical literature on ERPT seems to point to the fact that exchange rate pass-through is generally incomplete, sometimes the pass-through elasticity is low, high or modest.

Adu et al. (2015) used quarterly data for Ghana from 1980q1-2012q4 to analyze real exchange rate dynamics and its response to supply, demand and nominal shocks based on both a constant coefficient and a time varying SVAR models. Their findings show significant effects of supply, demand and nominal shocks on real exchange rate dynamics in Ghana; however the effects vary in terms of direction and magnitude. In addition, they also found high pass-through of exchange changes to domestic prices in Ghana.

Loloh (2014) estimate exchange rate movements on domestic prices in Ghana from 1994m1 to 2012m12 using recursive Vector Autorgressive Model (VAR). The results reveal that the effects are mainly in the first 12 months, while it decreases after 18-24 month. The impact of the shock of exchange rate on CPI inflation is more benign than non-food inflation.

Frimpong and Adam (2010) uses vector error-correction (VECM) approach to estimate the exchange rate pass-through to inflation for Ghana. They use monthly data for the period 1990-2009 to find that the exchange rate pass-through is incomplete and low.

Acheampong (2004) employed a recursive VAR to estimate the cumulative pass-through for Ghana and concludes that the pass-through is incomplete, modest and slow. He also finds that the pass-through to non-food prices is more pronounced compared to the pass- through to consumer prices and that the pass-through to consumer prices has not changed over time but the pass-through to non-food prices has gone up.

McCarthy (1999) investigates the effect of exchange rate changes and import prices on producer and consumer prices in a recursive vector autoregressive (VAR) model. Relying on data from 6

industrialized OECD nations, he discovers that exchange rate movements have modest impact on domestic consumer prices.

Chaoudhri and Hakura (2001) find that the level of inflation dominates the volatility of inflation and the exchange rate as an explanation of cross-country differences in the pass-through. They find zero pass-through to inflation in Ethiopia and incomplete pass-through in other African countries during the period 1997–2000.

Canetti and Greene (1992) also found that exchange rate movements and monetary expansion affect consumer price inflation in sub-Saharan Africa (SSA). In particular, they find that exchange rates have a significant "Granger causal" impact on prices in Tanzania, Sierra Leone, and Democratic Republic of Congo. This is linked to the high inflation episodes in these economies. They find that monetary expansion "Granger causes" inflation in the Gambia and Uganda.

Zorzi et al., (2007) used a vector autoregressive models to examine the degree of exchange rate pass-through to prices in 12 emerging markets in Asia, Latin America, and Central and Eastern Europe. Their findings were partially inconsistent with conventional wisdom that exchange rate pass-through to domestic prices are always higher in emerging than developed countries. They also discover that for emerging markets with single digit inflation, pass-through to import and consumer prices is low and not different from the levels of developed economies. The paper also finds robust evidence for a positive relationship between the degree of the exchange rate pass-through and inflation, consistent with Taylor's hypothesis.

Goldfajn and Werlang (2000) studied a panel of 71 countries and find that the exchange rate pass-through is correlated with the business cycle, the size of the initial real exchange rate misalignment, the initial rate of inflation and the degree of openness of the economy. They also ascertain that the exchange rate pass-through coefficient is positively time-varying after devaluation, and is maximized after one year (12 months).

Burstein et al (2002) investigated the behavior of consumer prices following large devaluations in nine countries and ascertain a low pass-through from the exchange rate to consumer prices. Following the floating of the exchange rate in Brazil in 1999.

Rabanal and Schwartz (2001) investigate the behavior of inflation in that country and find that the initial shock has worked through the system after 20 months.

Leigh and Rossi (2002) employ a recursive vector autoregressive model to investigate the impact of exchange rate movements on prices in Turkey. They find that firstly, the impact of the exchange rate on prices is over after about a year, but is mostly felt in the first four months. Secondly the pass-through to wholesale prices is more pronounced compared to the pass-through to consumer prices. Thirdly, the estimated pass-through is complete in a shorter time and is larger than that estimated for other key emerging countries.

3. SVAR Methodology

The Structural VAR model aims at using economic theory to generate the structural shocks. The general SVAR specification follows from a reduced form as follows:

$$y_t = q + A_1 \, y_{t-1} + A_2 \, y_{t-2} + \ldots + A_p \, y_{t-p} + u_t \tag{1}$$

Where y_t is a vector of endogenous variables: *log of seasonally adjusted foreign exchange inflows, log of nominal effective exchange rate, log of seasonally adjusted consumer price index, yield on government bonds and the monetary policy rate*, q is a vector of intercepts, $A_1, A_{2,}, A_p$ refers to matrix of parameters, u_t is the one-step ahead forecast errors with a zero mean, zero autocorrelation, and variance covariance matrix.

$$E(u_t \, u'_t) = \Sigma \tag{2}$$

The one step forecast errors u_t are assumed to be correlated across equations, hence an interpretation of the equations structurally is impossible. The paper therefore relies on a structural model where the errors are assumed to be mutually uncorrelated across equations. A structural VAR is specified as follows:

$$B_0 \, y_t = B_1 \, y_{t-1} + B_2 \, y_{t-2} + \ldots + B_p \, y_{t-p} + \varepsilon_t \tag{3}$$

Where:

B_0 refers to nxn matrix containing contemporaneous reaction of variables to structural shocks B_1, B_2, B_p refers to matrix of structural parameters, ε_t denotes mutually uncorrelated structural shocks whose covariance matrix is an identity matrix I. The idea is that the shocks are uniquely identified based on economic theory that is, the reduced form shocks, u_t are linear combinations of the structural shocks, ε_t.

$$B_0{}^{-1}B_1 = A_1 \, , \quad B_0{}^{-1}B_2 = A_2, \quad B_0{}^{-1}B_p = A_p \, , \quad B_0{}^{-1}\varepsilon_t = u_t$$

Where ε_t refers to structural shocks which are orthonormal (its covariance matrix is an identity matrix).

$$E(\varepsilon_t \, \varepsilon'_t) = I \tag{4}$$

The reduced form coefficients are estimated using Bayesian methods following Uhlig (2005) rejection method with priors belonging to the flat Normal inverted-Wishart family. Markov Chain Monte Carlo (MCMC) is used to collect 1000 draws from the posterior distribution of the SVAR parameters that satisfy the sign restrictions. The MCMC routine stops when draws have been found that satisfy the sign restrictions. The paper estimates *equation 3* with the 2 lags of the endogenous variables.

3.1 Identification

Sign restrictions are seen as superior to zero restrictions as they do not impose hard constraints on the underlying economic theory. This makes it possible to reflect the feedback effects more rigorously when compared with the recursive ordering of the endogenous variables. To this end, this paper uses sign restrictions to estimate how exogenous dynamics to exchange rate affects domestic prices in Ghana. This procedure is a partial identification scheme where only one shock

is identified one at a time. In (**Tab 1**) below the only identified shock is the nominal effective exchange rate (NEER) whilst the remaining variables are left unrestricted.

Table 1: Identification Scheme for Exchange Rate Shocks

Forex	NEER	CPI	M2	MPR
?	-	?	?	?

*Note: exchange rate appreciation/depreciation(+/-), unrestricted (?)

4. Data and sources.

The paper uses quarterly series covering the period 2006q3 to 2017q4. The starting date is chosen to reflect when Ghana has adopted inflation targeting. The description of the datasets are: *log of foreign exchange inflows (forex), log of nominal effective exchange rate (NEER), log of consumer price index all items (CPI), government bond yield (LGBY) and monetary policy rate (MPR)*. The source of the data is International Finance Statistics, 2019.

5. Estimation

5.1 Unit Root Test

It is known in the literature that time series variables exhibit non-stationary behaviors hence, this paper uses Augmented Dicker Fuller Test to check for unit root in the variables. The null hypothesis is *the series has unit root*. Estimates shown in (**Tab 2**) below indicates that all variables are *I(1)* except the nominal effective exchange rate (NEER) which is *I(0)*. However, since taking first difference of *NEER* equally makes it stationary, this paper treats it as an *I(1)* series to satisfy the research question of estimating a SVAR. The inference here is that since the variables are non-stationary at levels, it implies that unless there is a long-run convergence (cointegration) it is correct to estimate the unrestricted VAR in first differences. (**Fig 5**)
 and (**Fig 6**) in appendix provides a graphical view of the time series both in levels and first differences.

Table 2: Augmented Dicker Fuller Test

| Variables	Deterministic term	Lags	T-statistic	P-value
FOREX	none	1	1.078	0.287
ΔFOREX	drift	2	-5.656	0.000***
NEER	trend	0	-2.137	0.038**
ΔNEER	drift	2	-4.092	0.000***
CPI	trend	2	-0.959	0.343
ΔCPI	trend	2	-3.026	0.004***
MPR	trend	1	-1.710	0.095
ΔMPR	trend	1	-2.696	0.010***
BONG YIELD	none	2	-1.215	0.232
Δ BONG YIELD	none	2	-4.901	0.000***

Note: Δ *denotes first difference operator, *,**,*** denotes 10%,5% and 1% levels of significance*

5.2 Impulse Response to Exchange Rate Shocks

The sign restriction employed in this paper is a form of partial identification which meant that shocks are identified one at a time. The shock identified here is a structural standard deviation

decrease in the exchange rate (*depreciation*). Findings presented in (**Fig 2**) below generally corroborates the literature. The impulse response for exchange rate is negative which signifies a depreciation until after 10 quarters where it reaches the baseline. Secondly, the impulse response of domestic prices is significant however, it is not unitary. This meant that the pass-through of exchange rate innovations to domestic prices in Ghana is incomplete. This corroborates findings of Sanusi (2010);Acheampong (2004); Adu et al., (2015) ; Frimpong and Adam (2010); Loloh (2014) for Ghana.

Figure 2: Impulse Response of Domestic Prices to a Structural Standard Deviation Exchange Rate Shock
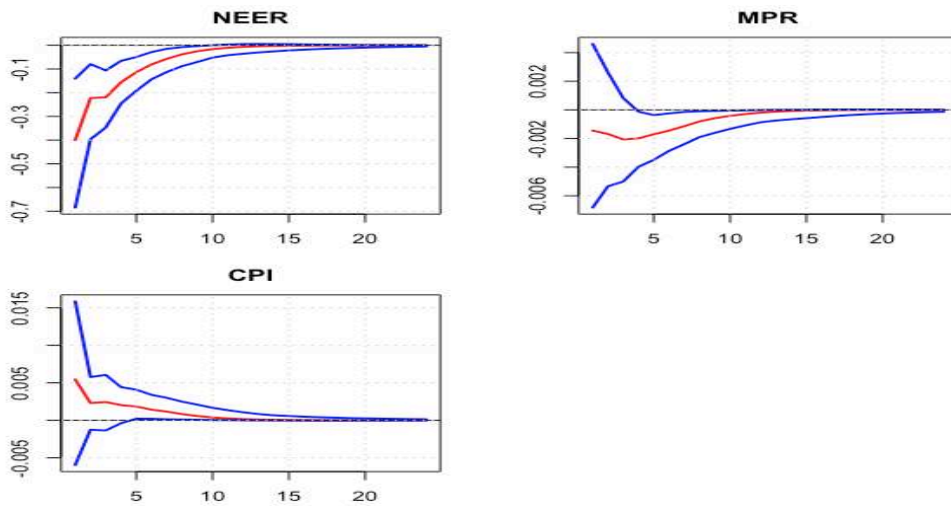
**Note: The red line depicts the median response at each horizon, while the blue lines represent the middle 68% error band.

5.3. Impulse Responses to Monetary Policy Rate Shock

Alternatively, the paper also examines the impact of monetary expansion (*decrease in the monetary policy rate*) on domestic prices in Ghana. Evidence shown in (**Fig 3**) below shows a significant response of domestic prices to a 100bp[4] decrease in the monetary policy rate.

Table 3: Identification Scheme For Monetary Policy Rate Shock

Forex	NEER	CPI	M2	MPR
?	?	?	?	-

**Note: (+/-) indicates an increase/decrease in the policy rate, unrestricted (?)

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[4] Basis point refers to a common unit of measure for interest rates and other percentages in finance. One basis point is equal to 1/100th of 1%, or 0.01%, or 0.0001, and is used to denote the percentage change in a financial instrument.

Figure 3: Impulse Response Of Prices to a Structural Standard Deviation Monetary Policy Rate Shock
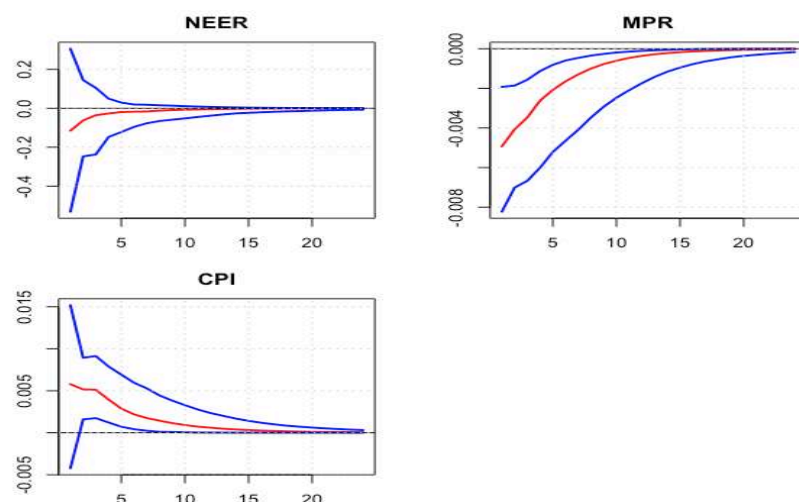
**Note: The red line depicts the median response at each horizon, while the blue lines represent the middle 68% error band.

5.3. Variance Decomposition

In relation to variance decomposition, a variable is said to explain fluctuations in another variable if it accounts for a large proportion of that variable's forecast error variance. Evidence presented in (**Tab 4)** shows percentage of forecast error variance. Findings are that, from a 1-10 quarters horizon, innovations to exchange rate explain about 9% to 14% of fluctuations in domestic prices in whereas shocks to monetary policy rate accounts for about 12% to 18% of domestic price fluctuations within the same quarter horizon. This finding confirms the literature that Ghana's inflationary is indeed a monetary phenomenon.

Table 4: Variance Decomposition of Consumer Price Index

|	Shocks:	Shocks:	Shocks:	Shocks:
Forecast horizon	Forex	NEER	CPI	MPR
1	8.49	9.29	8.09	12.23
2	10.56	11.04	10.49	13.89
3	11.93	12.04	11.58	15.48
4	11.97	12.97	11.91	16.57
5	12.17	13.41	12.04	17.00
6	12.53	13.58	12.24	17.21
7	12.57	13.75	12.53	17.19
8	12.62	13.83	12.72	17.30
9	12.65	13.85	12.82	17.49
10	12.66	13.89	12.91	17.55

Source: Author's calculation

6. Robustness Check

In order to validate the findings of paper, a different specification of the SVAR[5] model was estimated using yield on government bonds as a policy instrument. The impulse response provided

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[5] Bayesian Structural Autoregression

in (**Fig 4)** in below shows some significant but temporal response of domestic prices to a 100bp decrease in yield on government bonds.

Figure 4: Impulse Response of Prices to a Structural Standard Deviation Shock to Government Bond Yield.
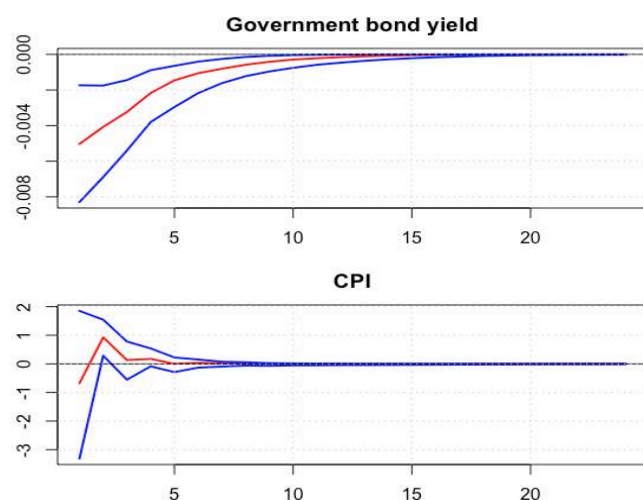
**Note: The red line depicts the median response at each horizon, while the blue lines represent the middle 68% error band.

7. Concluding Remarks.

This paper estimated the pass-through of exchange rate to domestic prices in Ghana using sign restricted VAR with rejection approach. The starting time dimension for the study was from 2006q3 to 2017q4 which captures the time the Bank of Ghana started inflation targeting. Findings presented by the impulse response indicates that exchange rate depreciation actually led to domestic price hikes in Ghana however, the pass-through is incomplete. In addition, there is also evidence of a significant response of domestic prices to a decrease in the monetary policy rate. The variance decomposition confirms that Ghana's inflationary pressures is a monetary phenomenon. This was evidenced by the monetary policy rate shocks accounting for about 12% to 18% of domestic price fluctuations in Ghana as compared to exchange rate shocks which explains about 9% to 14% domestic price fluctuation within same time horizon.

To achieve a low inflationary environment, policies should be geared towards curtailing the perennial depreciation of the cedi coupled with stable interest rate environment.

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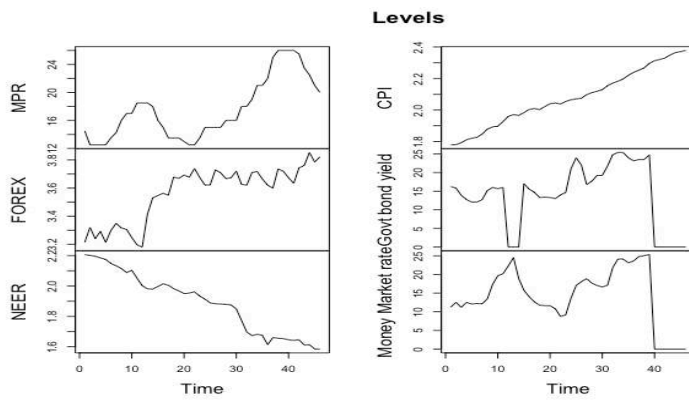
Appendix

Figure 5: Variables at Levels

Figure 6: Variables at First Differences