Exchange rate pass-through to consumer prices in Ghana: Evidence from structural vector auto-regression

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Exchange Rate Pass-Through to Consumer Prices in Ghana: Evidence from Structural Vector Auto-Regression[1]

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ABSTRACT

This paper develops a Structural Vector Autoregression (SVAR) model for the Ghanaian economy to estimate the pass-through effects of exchange rate changes to consumer prices. The model incorporates the special features of the Ghanaian economy, especially its dependence on foreign aid and primary commodity exports for foreign exchange earnings. The findings show that the pass-through to consumer prices, although incomplete, is substantially large. This suggests that exchange rate depreciation is a potentially important source of inflation in Ghana. Using variance decomposition analyses, it is found that monetary expansion has been more important in explaining Ghana's actual inflationary process than the exchange rate depreciation. One policy implication of these findings is that policies that aim at lowering inflation must focus on monetary and exchange rate stability.

JEL Classification Codes: *F41, F31, E31, E41*
Keywords: *Exchange Rate Pass-Through, Inflation, Structural Vector-Autoregression, Foreign Aid, Ghana*

1.0 Introduction

One of the central issues in the Ghanaian economic reforms that started in 1983 was the correction of the real exchange rate overvaluation that resulted from the pre-1983 trade and exchange regime. One approach to this disequilibrium correction was to induce nominal depreciation, along with trade policy reforms, in order to achieve the needed real depreciation of the cedi. The result was a sustained and massive nominal depreciation of the cedi following the Economic Recovery Programme (ERP) in 1983. For instance, over the period 1983-2005, the exchange rate depreciated against the US dollar by around 35 percent per annum, while the real (effective) exchange rate depreciated by about 13 percent per annum. The rate of depreciation was even higher during the ERP period covering 1983-1992 when, on average, the nominal exchange rate depreciated by about 52 percent per annum while the real effective exchange rate depreciated by around 27 percent per annum (See Table 1)

Even after the reforms, between 1992 and 2006, the nominal and real exchange rates continued to depreciate by an average of around 22 and 3 percent per annum respectively,

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roughly in line with the inflation differentials. Although inflation, which has proven to be the single most important problem during the pre-reform period, has significantly been reduced relative to its pre-reform levels, it continues to be high and variable (see Government of Ghana, 1998). For instance, the annual average rate of inflation during the ERP period was about 35 percent, declining to about 26 percent in 1993-2005. Over the reform period (1983-2005), inflation averaged around 30 percent annually with a standard deviation of 23.7 percentage points. Even in the post-reform period (2006-2009) when inflation targeting is adopted, the nominal and real exchange rates depreciated 10.11 and 1.43 percent respectively, while inflation remains relatively high at 14 percent on the average (Table 1).

There is an ongoing debate about the major sources of inflation in Ghana. On the one side of this debate, exchange rate depreciation is regarded as a major source of the inflationary trend. Some empirical studies, therefore, have related the inability of Ghana to achieve low inflation rates with the continuous depreciation of the national currency following the adoption of flexible exchange rate regime (see, for instance, Bawumia and Abradu-Otoo, 2003; Atta-Mensah and Abrodu-Otoo, 2000; Sowa and Kwakye, 1993). These studies, therefore, imply that the exchange rate pass-through in Ghana is substantially high.

A number of empirical studies, however, suggest that the response of consumer prices to exchange rate changes in the Sub-Saharan African (SSA) is low, and in some cases even zero. For instance, Frimpong and Adam (2010) found that the exchange rate pass-through to inflation low in Ghana, a finding that is consistent with a number of other studies. For example, using a single equation, direct approach, Devereux and Yetman (2003) found a statistically insignificant exchange rate pass-through elasticity of 0.05% for Ghana. They also reported very low and zero pass-through for a number of SSA countries. Similar results were obtained for Tanzania by Mwase (2006). According to this side of the debate, therefore, exchange rate depreciation could not have been a major source of the high inflation that Ghana has experienced since 1983. These evidences of low pass-through leaves open the question of the extent to which the exchange rate depreciation has contributed to the high and variable inflation in Ghana. This paper contributes to this debate by estimating the magnitude and speed of the exchange rate pass-through to consumer prices in Ghana, using the Structural Vector Autoregressive (SVAR) approach[2]. One advantage of this approach over others' (such as Frimpong and Adam's, VEC, and Devereux and Yetman's single-equation) is that it allows us to include specific features of the Ghanaian economy, in particular its dependence on foreign aid and primary commodity exports. These are important in monetary management in Ghana, and are therefore crucial in the inflationary process and exchange rate determination. In addition, the use of SVAR model would allow the estimation of the dynamic elasticity of the pass-through.

The knowledge of the empirical estimate of the degree and speed of the exchange rate pass-though, is important for the Ghanaian monetary authorities for several reasons. First, exchange rate pass-through, defined as the sensitivity of domestic-currency prices to exchange rate changes, has important implications for monetary policy. For instance, in addition to its effect on the transmission mechanism of monetary policy, exchange rate pass-

[2] To the best of our knowledge, this approach has not been used to study the exchange rate pass-through for Ghana.

through also has implications for external adjustment. Large exchange rate pass-through implies that the response of trade balance to nominal exchange rate changes will be large (IMF, 2006). The empirical knowledge of the exchange rate pass-through would also provide additional support to the argument that the depreciation of the exchange rate since the inception of the ERP is contributory to the difficulty of the Ghanaian authorities to achieve low (single digit) and stable inflation.

Table 1 Some Macroeconomic Indicators

	1983-92	1993-05	1983-05	2006-09
Exchange Rate Appreciation ($/C, annual %)	-52.44	-22.03	-35.25	-10.11
	(67.4)	(20.08)	(48.5)	(8.69)
NEER Appreciation (annual %)	-44.69	-21.11	-31.36	-11.14
	(43.17)	(15.34)	(32.15)	(8.42)
REER Appreciation (annual %)	-26.88	-2.63	-13.18	-1.43
	(62.4)	(15.92)	(43.28)	(5.67)
Inflation [a] (annual %)	35.92[a]	26.01	30.32[a]	14.36
	(32.49)	(13.95)	(23.73)	(4.23)

Notes: a. these figures include that of 1983 which was 122%: the figures are 26.25 and 26.11 when 1982 figure is excluded. The rates of change for all exchange rate measures are log difference of the reported measures. Figures in brackets are the standard deviation of the rates in percent.

Source: WDI and IFS online

The empirical results show that exchange rate pass-through, measured by the impulse response functions, is substantially larger than those found in a number of SSA countries but broadly in line with findings for other developing countries. We argue that the large pass-through in Ghana is plausible given that the exchange rate has predominantly been depreciating throughout the period under review.

The rest of the paper is organised as follows: section two reviews the theoretical and empirical literature on exchange rate pass-through. A common finding in the empirical literature is that the exchange rate pass-through to domestic prices is generally incomplete and has declined in the 1990s. Section 3 presents the empirical framework, develops the SVAR model and discusses the identification procedure. In section 4 we present and discuss the empirical results. Section 5 concludes the paper.

2.0 Literature Review

2.1 Theoretical Literature

Exchange rate pass-through is generally regarded as the extent to which changes in the exchange rate are reflected in prices of goods and services. It is generally distinguished into two stages: the *first-stage* (i.e., from exchange rate to import prices) and *second-stage* (i.e., from import prices to consumer prices). However, it is also common in the literature to estimate the *direct* pass-through of exchange rate changes to consumer prices. This direct approach is popular chiefly because the disaggregated data on import prices and composition is generally unavailable especially in the SSA countries.

The effects of exchange rate movements are transmitted to consumer prices via three major channels: (i) prices of imported consumption goods, (ii) domestically produced goods priced in foreign currency, and (iii) prices of imported intermediate goods. While the effect of exchange rate movements is direct in the first two channels, in the last channel exchange rate movements affect domestic prices less directly by changing the costs of production (see Sahminan, 2002). Many monetary models of the exchange rate and balance of payments assume a one-to-one relationship between the exchange rate and domestic prices, based on the law of one price (or purchasing power parity, PPP). However, empirical evidence almost unanimously concludes that the exchange rate pass-through is incomplete. The literature suggests that pass-through to import prices (the first-stage) tends to be greater, albeit incomplete, than the pass-through to consumer prices[3]. These findings have motivated numerous theoretical models aimed at explaining the incompleteness of the exchange rate pass-through.

One of such models is based on the pricing behaviour of exporting firms. It argues that because of market and product segmentations, exporting firms discriminate prices across destination market. It is assumed that exporting firms set their prices as the sum of marginal cost and destination specific mark-up. These destination specific mark-up are adjusted in response to exchange rate changes, thereby absorbing part, or all, of the exchange rate change. This pricing behaviour is referred to as pricing-to-market (PTM) by Krugman (1986), and provides the microeconomic explanation of the empirical findings of incomplete pass-through.

If, however, exporting firms set prices in the currency of their production location (producer currency pricing, PCP), exchange rate pass-through *to import prices* will be complete. Pass-through to domestic prices will be equal to the share of imported goods in the total consumption basket. In Betts and Devereux's (1996) model, aggregate pass-through depends on the combination of firms practicing PCP and local currency pricing (LCP). The greater the number of firms that set their prices in destination countries' currency, the smaller will be the pass-through to domestic prices. In the extreme, if all firms discriminate prices across countries, pass-through to domestic prices will be zero. In this model (as demonstrated in Devereux and Engel, 2003 and Engel, 2002), a flexible exchange rate regime cannot deliver the optimal relative price changes[4].

2.2 Empirical Literature

Empirical studies of exchange rate pass-through concentrate on industrialised countries and the result can be summarised as follows: first, exchange rate pass-through is generally incomplete, and the pass-through to import prices tends to be higher in both magnitude and speed than that to consumer prices. Secondly, there is a general decline in the degree of pass-through in the late 1980s and 1990s, mostly attributed to the low inflation environment achieved in most industrialised countries (see, for example, Campa and Goldberg, 2005; Gagnon and Ihrig, 2001; McCarthy, 1999; and see also Menon, 1995 for a review of empirical literature). The majority of empirical studies on exchange rate pass-through are industry and product specific[5]. In the aggregate studies, the empirical literature suggests that

[3] This is because of several factors. First, the CPI includes components of domestic value added in addition to imported inputs and final goods. Secondly, retail goods and services face more competition from substitutable goods and services than imported goods.
[4] Hence, the expenditure switching effects of the exchange rate changes are zero.
[5] The recent studies include Bernhofen and Xu (2000) and Takagi and Yoshida (2001).

exchange rate pass-through is far from complete and varies across countries depending on their size and openness.

In terms of the estimation approach, both single equation and systems based approaches are used. McCarthy (1999) presents a comprehensive study of the exchange rate pass-through for a number of industrial countries at the aggregate level, using a VAR model. In most of the countries he studied, pass-through to consumer prices is found to be modest. He found that pass-through is positively correlated to the level of openness and persistence of exchange rate changes, but negatively correlated with its volatility.

As regards to the developing countries, the literature is limited for SSA. However, the few existing works tend to show similar results to those of developed countries (see Mwase, 2006 for Tanzania; Kiptui, *et al*., 2005 for Kenya and Bhundia, 2002 for South Africa). Chaoudhri and Hakura (2001) found zero elasticity of pass-through to inflation in Bahrain, Canada, Finland, Singapore, Ethiopia and Tunisia, 0.09 for Kenya, 0.02 for South Africa, 0.06 for Zimbabwe, 0.22 for Cameroon, 0.14 for Ghana, and 0.16 for Burkina Faso. They also found that the *level* of inflation explains the cross-country differences more than exchange rate or inflation volatility. Kiptui *et al.* (2005) finds that pass-throug in Kenya was incomplete during the period 1972-2002, using a cointegration and error-correction approach. They found that an exchange rate shock leads to a sharp increase in inflation that dies out after four quarters, with the exchange rate explaining 46 percent of inflation variability. Mwase (2006) used an SVAR model to quantify the exchange rate pass-through for Tanzania using quarterly data for the period 1990-2006. He found that exchange rate pass-through has declined despite the depreciation of the currency. He divided the sample into a period prior to 1995 and one after 1995. In the full sample, pass-through elasticity is found to be 0.028. In the period before 1995, pass-through elasticity is 0.087, but declined to 0.023 after 1995. A recent study, Frimpong and Adam (2010), uses vector error-correction (VEC) 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. This finding of low pass-through in Ghana is somewhat puzzling, which is evident in the authors' submission that in spite their results "...the influence of exchange rate movements is still significant for domestic prices" (Frimpong and Adam, 2010:149)[6]. Low exchange rate pass-through is a common finding for countries that have low inflation environment, stable exchange rate, small share of imports in their consumption basket (see for example, Chaoudhri and Hakura, 2001; Stulz, 2006; Gagnon and Ihrig, 2001; Devereux and Engel, 2001 and Taylor, 2000). Ghana, however, could not be characterised as having any of these conditions. This study is therefore re-examines this issue by estimating the exchange rate pass-through using a SVAR approach, which has so far not been applied to the Ghanaian data.

3.0 Methodology

3.1 Econometric Issues

One common approach in the pass-through literature is to use a recursive VAR (for instance, McCarthy, 1999). Under this approach, the effect of exchange rate shocks is examined by

[6] Indeed, given the massive currency depreciation and inflation persistence in Ghana, especially during the reform period, a low exchange rate pass-through to domestic prices, is puzzle. Fresh studies are therefore needed to resolve this puzzle.

means of Cholesky decomposition. However, one likely drawback of this approach is that the Cholesky decomposition imposes restrictions on the residual variance-covariance matrix, and assumes that the errors are orthogonal. In cases where the covariance between innovations is empirically non-zero, the common component of the disturbances will be wrongly attributed to the first variable in the recursive VAR. This renders the obtained impulse response functions (IRFs) and variance decompositions (VD) highly sensitive to the ordering of the variables in the VAR (Enders, 2004). For these reasons, we shall follow the recent empirical literature in using the SVAR approach (see, for instance, Gagnon and Ihrig, 2001, Mwase, 2006; and Stulz 2006). Here, the Sims (1986) and Bernanke (1986) structural decomposition is used instead of Cholesky's to identify the structural shocks. The advantage of structural decomposition is that the identifying restrictions have some economic foundations. As will be seen below, our restrictions follow from assumptions relating to the delays in the reactions of particular variables to disturbances originating elsewhere within the Ghanaian economy.

In this section, therefore, we shall first present the SVAR framework and the identification strategy used to recover the structural shocks from the forecast errors of the estimated VAR.

3.2 The Structural VAR Framework

The aim of a structural VAR is to use economic theory rather than the Cholesky decomposition to recover structural innovations from residuals of a reduced-form VAR. Consider the following *bi*variate VAR model in which each variable has contemporaneous effect on the other (see Enders, 2004):

$$\begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}\begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix} \qquad 1$$

which can be written in compressed form as:

$$Bx_t = \Gamma_0 + \Gamma_1 x_{t-1} + \varepsilon_t \qquad 2$$

where

$$B = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}, \quad x_t = \begin{bmatrix} y_t \\ z_t \end{bmatrix}, \quad \Gamma_0 = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix}, \quad \Gamma_1 = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}, \quad \varepsilon_t = \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$$

The reduced-form of the structural or primitive form 1 can be written as:

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}\begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} e_{yt} \\ e_{zt} \end{bmatrix} \qquad 3$$

or

$$x_t = A_0 + A_1 x_{t-1} + e_t \qquad 4$$

where:

$$A_0 = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} \qquad A_1 = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \qquad e_t = \begin{bmatrix} e_{yt} \\ e_{zt} \end{bmatrix}$$

Comparison of 2 and 4 above suggests that the errors in the reduced-form VAR e_{yt} and e_{zt} are indeed composites of the underlying structural shocks ε_{yt} and ε_{zt} since:

$$A_0 = B^{-1}\Gamma_0; \quad A_1 = B^{-1}\Gamma_1; \qquad e_t = B^{-1}\varepsilon_t \qquad 4a$$

so that:

$$\begin{bmatrix} e_{yt} \\ e_{zt} \end{bmatrix} = \begin{bmatrix} \dfrac{1}{1-b_{12}b_{21}} \end{bmatrix} \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix} \qquad 5$$

e_t is the one-step ahead forecast errors[7] in x_t but does not have any structural interpretation, and ε_t is the autonomous changes in x_t in model 2. To obtain the impulse response functions (IRF) or variance decompositions (VD), it is necessary to use the structural shocks ε_t and not the forecast errors e_t.

The idea of structural decomposition is to take the observed values of e_t from an empirical VAR and to restrict the system so as to recover ε_t as $\varepsilon_t = Be_t$. The restriction has to be such that the various ε_{ij} are recovered and the assumed independence of the various ε_{ij} are preserved.

To solve this identification problem, we count the number of equations and unknowns: The OLS can obtain the variance-covariance matrix Σ

$$\sum = \begin{vmatrix} \sigma_1^2 & \sigma_{12} & .. & \sigma_{14} \\ \sigma_{21} & \sigma_{22}^2 & .. & \sigma_1 \\ . & . & . & . \\ \sigma_{n1} & \sigma_{n2} & .. & \sigma_n^2 \end{vmatrix}$$

where each element of Σ is constrained as the sum: $\sigma_{ij} = \left(1/T\right)\sum_{t=1} e_{it}e_{jt}$.

Since Σ is symmetric, it contains only $(n^2+n)/2$ distinct elements. But the SVAR has a total of n^2 unknowns [n^2-n in **B** since the diagonal elements are all unity**,** plus n in var(ε_{it})] to be identified from the known $(n^2+n)/2$ from the empirical VAR. It is therefore necessary to impose at least n^2-$[(n^2-n)/2] = (n^2-n)/2$ restrictions on the structural model.

3.3 The Empirical Model of Exchange Rate Pass-Through

To capture the monetary policy framework used in Ghana, i.e., net international reserves (NIR) and net domestic assets (NDA) targeting under the financial programming, we modified the model to include foreign exchange inflows, and the money supply as a policy variable. Hence, the model is a multivariate system of the economy, consisting of the foreign exchange stock (f_t), money supply (m_t), nominal exchange rate (s_t), and domestic prices (p_t). The money supply is included to capture monetary policy effects on the price level. Foreign exchange is included to capture the impact of aid and other capital inflows as well as export earnings on inflation and the exchange rate[8].

Following Mwase (2006), we assume that agents' expectations tend to rely on past developments - expectation formation is mainly adaptive[9]. Furthermore, it is assumed that the

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[7] From 4, the coefficients A_0 and A_1 can be used to obtain the various values of x_{t+1} conditional on the observed values of x_t. Thus, updating 4 one period ahead, $x_{t+1} = A_0+A_1x_t+e_{t+1}$, and taking the conditional expectation of x_{t+1} yields $E_tx_{t+1} = A_0 + A_1x_t$. The one-step forecast error is $x_{t+1}-E_tx_{t+1} = e_{t+1}$. In general, the forecast error is $e_{t+n}+A_1e_{t+n-1}+A_1^2e_{t+n-1} \ldots A_1^ne_{t+1}$.

[8] We use foreign exchange because aid and other private capital inflows data are not available on quarterly basis.

[9] The assumption of adaptive expectation is a little restrictive. However, there are arguments in support of validity of this assumption in less developed countries. For instance, it is argued that because of lack of data on output at the time of forecasting, agents therefore rely only on the available past information in expectation formation. Although studies such as Froot and Klemperer (1989) use survey data on rational used survey data on

conditional expectations are equivalent to a linear projection based on lags of the endogenous variables in the VAR.

$$A(L)x_t = e_t \qquad where\ A(L) = \Sigma^p{}_{j=0}A_jL^j \qquad 6$$

x_t is a column vector of the endogenous variables, i.e. $x_t = [\Delta f_t\ \Delta m_t\ \Delta s_t\ \pi_t]'$, $A(L)$ is a 4 ×4 matrix polynomial in the lag operator L and e_t is a column vector of serially independent errors: $e_t = [e^f{}_t\ e^m{}_t\ e^s{}_t\ e^\pi{}_t\ ]'$. As shown in 5 above, these innovations are a linear combination of serially independent structural shocks (ε_t).

The structural shocks (ε_t) in each period t are determined by expectations conditional on available information at the end of period t-1, ($E_{t-1}(.)$), and an error term (e_t). Note that the one period ahead forecasting error of s_t is equal to e_{st} since $e_t = B^{-1}\varepsilon_t$ from 4a above, so that for inflation the forecast error is:

$$e_{\pi t} = \delta\varepsilon_{ft} + \chi\varepsilon_{mt}+\varphi\varepsilon_{st} +\varepsilon_{\pi t} \qquad 7$$

These inflation forecast errors are caused by exchange rate shocks and other shocks in the system. In terms of 4a, therefore, the complete system, with no particular ordering assumed, can be written as:

$$\begin{bmatrix} e_{ft} \\ e_{mt} \\ e_{st} \\ e_{\pi t} \end{bmatrix} = \begin{bmatrix} 1 & \theta_1 & \theta_2 & \theta_3 \\ \alpha & 1 & \theta_4 & \theta_5 \\ \beta & \gamma & 1 & \theta_6 \\ \delta & \chi & \varphi & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{ft} \\ \varepsilon_{mt} \\ \varepsilon_{st} \\ \varepsilon_{\pi t} \end{bmatrix} \qquad 8$$

$$\text{where the matrix } \boldsymbol{B^{-1}} = \begin{bmatrix} 1 & \theta_1 & \theta_2 & \theta_3 \\ \alpha & 1 & \theta_4 & \theta_5 \\ \beta & \gamma & 1 & \theta_6 \\ \delta & \chi & \varphi & 1 \end{bmatrix} \qquad 9$$

To determine the role of exchange rate changes in causing movements in consumer prices, we need to estimate the effect of exogenous shock to the exchange rate, e_{st}, on the shocks $e_{\pi t}$, by estimating 8. However 8 is not identified in the sense that as long as β, γ, and θ_6 are not each equal to zero, the observed innovation in the variable s_t will depend on both the shock to the exchange rate and on the shocks e_{ft}, $e_{\pi t}$, e_{mt}. At least six additional restrictions need to be imposed on the matrix B^{-1} to extract ε_{st} from other innovations. Drawing on Sims (1986) and Bernanke (1986), we use the SVAR approach to impose contemporaneous structural restrictions that are consistent with *a priori* theoretical expectations as well as our prior knowledge of the Ghanaian economy in order to identify the impacts of the various shocks. This way, the theory-consistent restrictions on matrix B^{-1} gives economic meaning to the derived shocks. The identification procedure is described in the next section.

3.4 Identification procedure

As noted above, six additional restrictions need to be imposed on matrix B in order to identify the structural shocks. The first restriction is that we assume that foreign exchange inflows

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expectation, such data is non-existent for Ghana. Liu and Tsang (2008) have incorporated hybrid specification of the Phillips curve with both forward and backward-looking components in their theoretical model for Hong Kong. Taylor (2000) also assumes rational expectations.

(forex) are exogenous. This is plausible as it is influenced mostly by exogenous factors such as changes in foreign aid inflows, commodity prices as well as adverse weather condition leading to poor cocoa harvest, international commodity price shock. Forex is therefore modelled as independent of shocks to other variables. This assumption is equivalent to three restrictions on the B matrix, since it imposes zero on the 2nd, 3rd and 4th elements of its first row. Thus:

$$e_{ft} = \varepsilon_{ft} \qquad 10$$

The second set of restrictions is based on the assumption that shocks to the money supply are influenced by shocks to foreign exchange and are independent of shocks to all other variables in the system. This is plausible under the Ghana's monetary policy practice (NIR and NDA targeting under the financial programming) in which the BoG changes the money supply mainly in response to changes in the levels of net international reserves. For instance, foreign exchange inflows are monetised to the extent that the NIR is above the programme target and NDA is below its ceiling. Shortfalls in foreign exchange inflows that lead to decline in NIR towards its target are responded to by restricting monetary policy. The exchange rate and inflation are assumed to have no contemporaneous effects on money supply[10]. This assumption is equivalent to two additional restrictions on the B matrix as it imposes zeros on the 3rd and fourth elements of its second row. The money supply shock is therefore modelled as:

$$e_{mt} = \alpha\varepsilon_{ft}+\varepsilon_{mt} \qquad 11$$

Given 10 above, 11 can be written in terms of 4a as:

$$e_{mt} - \alpha e_{ft} = \varepsilon_{mt} \qquad 12$$

Shocks to the exchange rate are assumed to be influenced by shocks to foreign exchange and shocks to money supply. Inflation is assumed to have no contemporaneous effect on money supply[11]. This assumption forms the 6th restriction, and therefore meets the minimum requirement for the identification of the structural model from the empirical VAR.
Thus:

$$e_{st} = \beta\varepsilon_{ft} + \gamma\varepsilon_{mt} + \varepsilon_{t} \qquad 13$$

or

$$e_{st} - \beta e_{ft} - \gamma(e_{mt}-\alpha e_{ft}) = \varepsilon_{t} \qquad 14$$

Shocks to domestic prices are assumed to be influenced by shocks to all the variables in the system. Inflation shock is therefore modelled as:

$$e_{\pi t} = \delta\varepsilon_{ft}+\chi\varepsilon_{mt} +\varphi\varepsilon_{st}+\varepsilon_{\pi t} \qquad 15$$

or

$$e_{\pi t} - \delta e_{ft} -\chi(e_{mt}-\alpha e_{ft}) - \varphi\ [e_{st} - \beta e_{ft}-\gamma(e_{mt}-\alpha e_{ft})] = \varepsilon_{\pi t} \qquad 16$$

The following system of shocks can now be estimated:

[10] Although the BoG had also recently added inflation as a target, it could be argued that its response to inflation deviations from the target is likely to be with delay, due to the delays in data collection.
[11] See footnote 10 above.

$$\begin{bmatrix} e_{ft} \\ e_{mt} \\ e_{st} \\ e_{\pi t} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha & 1 & 0 & 0 \\ \beta & \gamma & 1 & 0 \\ \delta & \chi & \phi & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{ft} \\ \varepsilon_{mt} \\ \varepsilon_{st} \\ \varepsilon_{\pi t} \end{bmatrix} \qquad 17$$

3.5 The Data and Data Sources

The data consists of quarterly observations, covering the period from 1983Q3 to 2006Q3. The sample span is chosen so as to exclude the period of rigidly fixed exchange rate regime. Hence, the beginning of the sample corresponds with the launch of the ERP. Although between 1983Q3 and 1986Q3 a crawling peg was adopted, the nominal devaluations were substantial and regular such that the exchange rate was never fixed between any two quarters. The end of the sample corresponds to the period when inflation targeting was formally adopted, i.e., December, 2006.

All the data are obtained from the IMF's IFS online database; the precise definitions of the variables are as follows. The exchange rate measure is the nominal effective exchange rate (increase indicates cedi appreciation, $/¢)[12]. Foreign exchange[13] data obtained from IFS is used as proxy for foreign exchange availability from foreign aid, export receipts, remittances and foreign direct investment. The money supply is measured by M_2[14], which is the M_1 plus quasi money. The price level is measured by the consumer price index, CPI. All the data are seasonally unadjusted[15].

4.0 Empirical Results

4.1. Unit Root Tests

The integration order of the variables is investigated using both the Augmented Dickey Fuller (ADF) and Phillip-Perron (PP) tests for unit roots. With the exception of the money supply, both tests indicate that all the variables are ***I(1)***. For M_2, while ADF suggests that the first difference has a unit root, PP strongly suggests otherwise (see Table 2). Given the low power of the ADF, we assume that M_2 is ***I***(***1***) as suggested by the PP test[16]. The finding that the levels of all the variables have a unit root implies that, unless they are cointegrated, it is appropriate to estimate the unrestricted VAR in first difference. The test for cointegration is conducted in the next section.

Table 2. Unit Root Test Results

	Level		*First Difference*		*Comment*
Variable	ADF	PP	ADF	PP	
Forex	-2.1336	-2.1375	-9.9469*	-9.9480*	***I(I)***
NEER	-2.8820	-2.1157	-6.7709*	-7.1292*	***I(1)***

[12] We have tried the bilateral cedi per dollar exchange rate but the results are not significantly different from those reported.

[13] Foreign exchange (IFS line .1D.DZF) includes government's and monetary authorities' claims on non residents in the form of foreign banknotes, bank deposits, treasury bills, short- and long-term governments securities, ECUs, and other claims usable in the event of balance of payments need.

[14] Monetary base and M_1 were also tried, but M_2 appears to reflect the overall monetary condition. The results were very similar with those reported.

[15] Seasonal dummies are included in the unrestricted VAR to deal with seasonality in data (see Table A3 in the Appendix)

[16] In Addition, an examination of the correlogram of the first difference suggest that it is stationary.

CPI	-1.9608	-1.1922	-4.5624*	-6.4004*	***I(1)***
M_2	-1.3583	-1.8007	-2.5643	-12.9148*	***I(1)***

Note: For the levels, we included trend and intercept, as the line plots of the series indicate; the 5% critical value is -3.4648. For their first differences, line graphs indicate that only intercepts can be included; the 5% critical value is -2.8968. (*) indicates rejection of unit root at 5%.

4.2. Cointegration Test

Because cointegration results can be very sensitive to the lag length selected, we use the three approaches available for testing the optimal lag length. These are, first, the traditional criteria (AIC, SIC, HQ, LR, FPE) obtained from the empirical VAR in *first-difference*; second, the multivariate generalisation of AIC form the empirical VAR *in level*, and finally, the Sim's LR statistic. All the traditional information criteria in the differenced VAR suggest an optimal lag of 4, except the SC, which suggests 2[17]. However, lag 4 is the smallest lag that frees the residuals from serial correlation. Also, the multivariate generalization of AIC (reported in Eviews) for the VAR *in level* suggests that the optimal lag is 4. We also computed Sim's LR statistic which is found to be 94.68. At 27 d.f., the critical value of the χ^2 is 40.11, suggesting that we can reject the null hypothesis and conclude that the optimal lag length is 4. We tested for the inclusion of an intercept in the test VAR (hence a drift in the cointegrating equation, CE) and it was found to be significant[18].

The test for cointegration among price level, exchange rate, money supply and foreign exchange, using the Johansen Maximum likelihood approach suggests that there is no evidence of cointegration (As shown in Tables 4 and 5). This is true from both the maximum eigenvalue and trace statistics, and whether or not trend is included in the cointegrating equation. Although the absence of cointegration between the exchange rate and the price level is implausible under the PPP theory, this puzzle is well documented in the literature. The absence of cointegration is often explained by the limited sample size, possible fractional cointegration, as well as possible non-linearity of the relationship[19]. However, the cointegration test here is not aimed at providing evidence on PPP, but rather at deciding whether a cointegrating VAR (or VECM) will provide a better alternative to the SVAR in estimating the exchange rate pass-through. Given absence of cointegration here, it is appropriate to proceed with estimating the SVAR in first difference, since no information about the long-run behaviour among the variables will be lost in the process. In the next section, therefore, we provide the SVAR estimation results.

Table 3. Johansen Cointegration Test (with intercept in the CE)

Maximum Eigenvalue (λ_{max})				
No. of CE(s)	None	At most 1	At most 2	A most 3

[17] In most cases the Schwarz criterion (SC) tends to suggest fewer lags than the rest, because it places a higher penalty on larger lags. This criterion is therefore often considered to be better suited for analysis of small samples, where the degrees of freedom are an issue.

[18] The LR test statistic is $-T\sum_{i+=r+1}^{n}[\ln(1-\lambda_i^*)-(\ln(1-\lambda_i)]$ and is χ^2 distributed with *n-r* degrees of freedom. λ_i^* and λ_i are the ordered matrices of the characteristic roots of the restricted and unrestricted VARs (Enders, 2004 p355).

[19] See Engel (1996) and the references therein for a review of the controversy over the ability of the standard unit root and cointegration tests to detect the long-run PPP. Recent studies use non-linear models such as the threshold autoregressive models (TAR and ESTAR) to fit the PPP data (for example, Paya and Peel, 2005).

Eigenvalue	0.216	0.144	0.079	0.019
λ_{max} *Statistic*	21.203	13.56	7.227	1.679
Critical Value	27.584	21.132	14.265	3.841
		Trace (λ_{Trace})		
No. of CE(s)	None	At most 1	At most 2	At most 3
Eigenvalue	0.2163	0.144	0.079	0.019
λ_{trace} *Statistic*	43.668	22.465	8.906	1.679
Critical Value	47.856	29.797	15.495	3.841

Table 4. Johansen Cointegration Test (with intercept and trend in the CE)

		Maximum Eigenvalue (λ_{max})		
No. of CE(s)	None	At most 1	At most 2	
Eigenvalue	0.218	0.211	0.092	0.042
λ_{max} *Statistic*	21.470	20.596	8.359	3.734
Critical Value	32.118	25.823	19.387	12.518
		Trace (λ_{Trace})		
No. of CE(s)	None	At most 1	At most 2	At most 3
Eigenvalue	0.218	0.211	0.092	0.042
λ_{Trace} *Statistic*	54.158	32.688	12.092	3.734
Critical Value	63.876	42.915	25.872	12.518

4.3. SVAR Estimation

We started with the estimation of the SVAR by transforming all the series to stationary series by differencing their natural logarithm once. A four variable VAR is estimated with foreign exchange inflows (Δf), rate of growth of the money supply (ΔM_2), rate of appreciation of the nominal effective exchange rate (Δs) and inflation ($\pi = \Delta \log of CPI$). Seasonal dummies are included in the VAR to capture the seasonality in the data (full estimation results are reported in Table A3 of the Appendix).

The statistical properties of the VAR are reported in Tables 5 and 6. The VAR is estimated with four lags, as suggested by the selection criteria tests. All the roots of the characteristic polynomial lie within the unit circle, suggesting that the VAR satisfies the stability condition and is, hence, stationary.

The multivariate test for residuals serial correlation (LM test) could not reject the hypothesis of no autocorrelation at lags between 1 and 12. The Jarque-Bera test for normality rejects the hypothesis that the residuals are normal due to excess kurtosis in the residuals of the exchange rate equation. A careful inspection reveals that the residuals display a number of outliers (see Figure A1 of the Appendix). It should be noted that even when residuals are non-normal, the Monte Carlo test for serial correlation is still very accurate, though not exact (Lutkepohl, 1991).

The calculated variance and correlation matrices of the residuals are shown in Tables A1 and A2 of the Appendix. We conducted the LR test for the joint significance of off-diagonal elements of the covariance matrix of the residuals (see Appendix A2). The null hypothesis that the covariances are jointly zero is rejected at 5 percent level. This implies there are contemporaneous correlations among the variables ignored by the unrestricted VAR[20]. This

[20] Note also that the off-diagonal elements of the correlation matrix of the residual (Table A2) are clearly non-zero.

further justifies the need for SVAR, which takes into account these contemporaneous effects among those variables. The full estimation results of the unrestricted VAR are shown in Table A3 in the Appendix.

Table 5. VAR(4) Diagnostic Tests

	1	2	3	4	5	6	7	8	9	10	11	12
LM Stat.	16.29	14.16	12.83	22.96	9.56	8.18	15.62	9.86	17.16	7.09	11.30	21.46
Prob.	0.43	0.59	0.69	0.11	0.89	0.94	0.48	0.87	0.38	0.97	0.79	0.16
Skewness				13.90 (0.01)								
Kurtosis				18.20 (0.00)								
Normality JB				32.10 (0.00)								

Table 6. Diagnostic Test of the individual equations of the VAR

	ΔFOREX	ΔM_2	S	π
Normality JB	2.53	1.04	23.72	4.80
Prob.	0.31	0.83	0.00	0.45
Skewness	-0.26	0.06	-0.92	0.20
Prob.	0.31	0.83	0.00	0.45
Kurtosis	2.35	2.48	4.78	1.92
Prob.	0.22	0.32	0.00	0.04

The estimated system of shocks from the SVAR is given by equations 18 through to 21 below. They are derived from the estimated residuals from the unrestricted VAR using the structural factorisation described in section 3.4 above using Eviews®. Figures in parenthesis are the *p*-values. The coefficients of the structural shocks, ε_i, are their respective standard deviations. The contemporaneous relationship among the variables in the system seems to be captured fairly well; all the coefficients are correctly signed. Of special interest is the coefficient of the exchange rate shock in equation 21. It is significant and correctly signed. It suggests that an appreciation of cedi is associated with an immediate decrease in inflation. The full impact of exchange rate changes on the price level, given by the accumulated IRFs, is discussed in the next section.

$$\mathbf{e}_{ft} = 0.235\boldsymbol{\varepsilon}_{ft} \qquad (18)$$
$$\phantom{\mathbf{e}_{ft} = }\ \mathbf{(0.00)}$$

$$\mathbf{e}_{mt} = 0.02\mathbf{e}_{ft} + 0.049\boldsymbol{\varepsilon}_{mt} \qquad (19)$$
$$(0.31) \quad \mathbf{(0.00)}$$

$$\mathbf{e}_{st} = -0.034\mathbf{e}_{ft} - 0.269\mathbf{e}_{mt} + 0.061\boldsymbol{\varepsilon}_{st} \qquad (20)$$
$$(0.23) \quad \mathbf{(0.04)} \quad \mathbf{(0.00)}$$

$$\mathbf{e}_{\pi t} = 0.022\mathbf{e}_{ft} + 0.061\mathbf{e}_{mt} - 0.120\mathbf{e}_{st} + 0.023\boldsymbol{\varepsilon}_{\pi t} \qquad (21)$$
$$\mathbf{(0.03)} \quad (0.23) \quad \mathbf{(0.00)} \quad \mathbf{(0.00)}$$

4.4. Exchange Rate Pass-Through

Impulse response functions (IRF) and variance decompositions (VD) from a SVAR are used to assess the pass-through from exchange rate to domestic prices. The IRF traces out the effect over time on prices of a *structural* one standard deviation shock to the exchange rate equation. The variance decompositions break down the forecast variance of domestic price inflation into components that can be attributed to each of the various shocks to the system. It allows us, therefore, to examine the relative importance of the various shocks for fluctuations in domestic prices.

The pass-through to domestic prices over *T* periods is defined as the accumulated effect of a *structural* one standard deviation shock to the nominal exchange rate in period *t* on domestic prices in period *T*. The accumulated response measures the effects of exchange rate changes on the consumer price *level*. For ease of interpretation, the dynamic pass-through elasticity can be calculated using the following ratio:

$$PT_t = \frac{\%\Delta P_t}{\%\Delta s_0}$$

where the numerator, $\%\Delta P_t$, is the percentage change in the price level between period 0, when the initial exchange rate shock hits, and time t; and the denominator, $\%\Delta s_0$, is the percentage change in the exchange rate at time 0.

4.5. Estimation Results

Table 7 shows the accumulated response of price to a *structural* one standard deviation shock to each of the variables. Because the data are entered as first differences of logarithms, the IRFs may be regarded as measuring a proportional change in price level in each case. The penultimate column of Table 7, which shows the response of the price level to a one standard deviation shock to the exchange rate, is plotted in Figure 1[21]. It is clear from the plot that the effect of an exchange rate shock on domestic prices is fairly gradual, taking about 24 quarters to reach the full impact. According to the table, the immediate effect of a structural one standard deviation shock to the exchange rate (which is 0.061 increase, or 6.1 percent appreciation) is about 0.007 (or 0.7 percent) decrease in the price level. This implies an impact elasticity of 0.11. The full effect of this shock, which is realised after about 24 quarters, is about 0.048 (or 4.8 percent) decrease in the price level, implying a dynamic pass-through elasticity of 0.79 (see Figure 1B).

Table 7. Accumulated Impulse Response of Domestic Price Level to Structural One SD Shocks

	Structural One Standard Deviation Shock to:			
Quarters After Shock	Forex	Money Supply	Exchange Rate	Domestic Prices
T=1	0.007	0.005	-0.007	0.023
T=4	0.018	0.023	-0.021	0.034
Full Impact: T=24	0.037	0.043	-0.048	0.026
Structural SD	*0.235*	*0.049*	*0.061*	*0.023*

[21] The IRF plots of the entire system to a one standard deviation shock are shown in Figure A.2 in the Appendix.

Figure 1. Accumulated Impulse Response of Domestic Prices to a Structural SD Shock to Exchange Rate (With Two Standard Error Band)

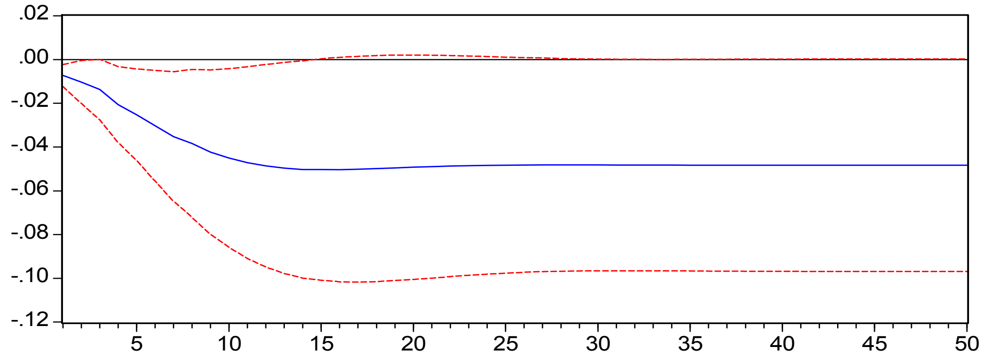
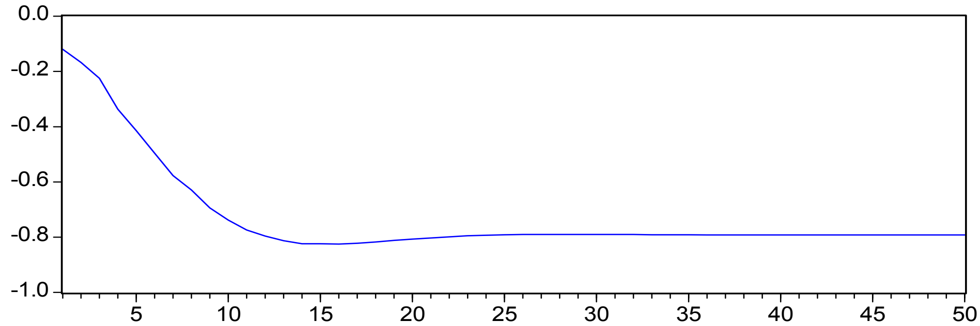


Figure 1B: Dynamic Elasticity of Exchange Rate Pass-Through



These results suggest that exchange rate pass-through in Ghana is fairly large but incomplete and slow. This finding is broadly in line with that of other empirical studies. Though relatively higher in magnitude than those found in most other SSA countries[22], the exchange rate pass-through in Ghana is of similar magnitude to those found in other developing countries. For instance, McFarlane (2002) found a pass-through of about 80 percent for Jamaica; Ito *et al.* (2005) found the pass-through to CPI be completed in four months for Indonesia and an elasticity of 1.4 after one year; Zorzi *et al.* (2007) also found substantially large pass-through elasticities for several countries. They found the pass-through elasticity of 0.77 for China and Czech Republic, 0.91 for Hungary, 0.56 for Poland and 1.39 for Mexico.

Money supply shocks also have a significant effect on domestic prices. As Table 7 indicates, the immediate effect is small; a structural one standard deviation or 4.9 percent stock to money supply leads to 0.5 percent increase in price level. However, after 24 quarters, the accumulated effect of an unanticipated structural one standard deviation or 4.9 percent increase in money supply is 4.3 percent increase in prices. This implies an elasticity of 0.88 in the long-run, suggesting that the effect of money supply shocks is less than fully transmitted to prices even in the long-run. The less than one-to-one response of prices to money supply shocks suggest that inverse-velocity and/or real output are rising. This is therefore in line with the finding in Sanusi (2006) that inverse-velocity has been rising since the adoption of the ERP.

[22] For instance, Chaoudhri and Hakura (2001) found the pass-through elasticity of 0.39 for Kenya and Cameroon, and 0.46 for Zambia, while Mwase (2006) found the pass-through for Tanzania to be 0.028.

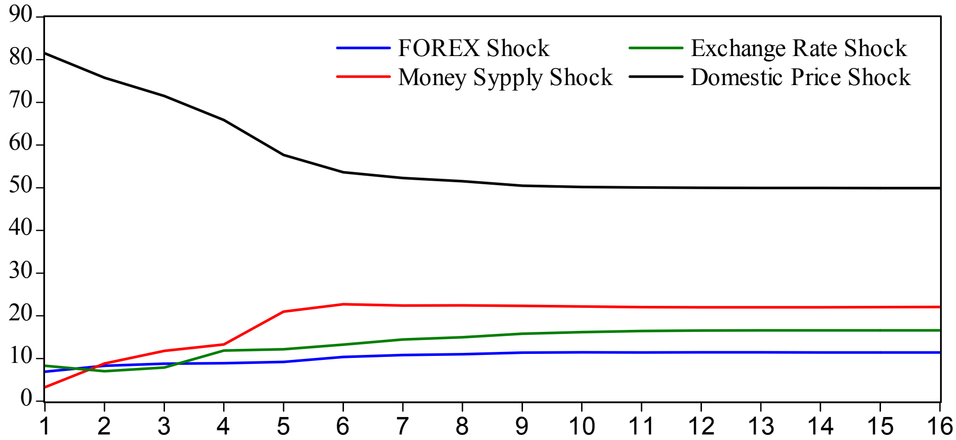
As indicated earlier, we can use the variance decompositions to explore the relative contribution of the structural shocks in explaining changes in inflation. Consistent with the IRFs discussed above, the variance decomposition, shown in Table 8 and Figure 3, reveal that money supply shocks contribute relatively more to inflation than exchange rate shocks. Specifically, while exchange rate changes account for only 8 to 17 percent of the variations of the price level (at 1-16 quarters horizon respectively), money supply shocks account for about 3.3 to 22 percent at the same horizon respectively. This seems to support the general conclusion in the literature that Ghana's inflation process has been a monetary phenomenon.

The last column of Table 8 suggests high inflation persistence, as up to 50 percent of the price level changes are explained by its own shocks in the long-run. This underscores the importance of other factors that play role in the Ghanaian inflationary process that are not explicitly accounted for. For instance, supply shocks, especially food and (domestic) oil price shocks tend to play increasingly important role in the Ghanaian inflation, particularly in the later years of the sample[23].

Table 8. Variance Decomposition of Inflation

		Shocks:			
Period	S.E.	Forex	Money Supply	Exchange Rate	Domestic Prices
T=1	0.23	6.92	3.27	8.30	81.50
T=2	0.24	8.30	8.85	7.04	75.81
T=4	0.26	8.94	13.29	11.89	65.87
T=8	0.26	11.03	22.44	15.00	51.53
T=16	0.27	11.43	22.08	16.59	49.89

Figure 2 Variance Decomposition of Inflation



5.0. Conclusions

In this paper, we estimated the exchange rate pass-through to consumer prices for Ghana using the SVAR approach. The SVAR specification incorporated specific features of the Ghanaian economy, especially the central role of foreign exchange inflows in the conduct of

[23] Lack of complete and consistent quarterly data on these variables preclude their use in our model. We attempted including output gap, as traditionally used in the literature to capture demand/supply shocks, but the signs and magnitudes with respect to output gap are theoretically inconsistent. This may be because the real GDP had to go through a series of interpolations in deriving the quarterly output gap.

monetary policy. The degree of exchange rate pass-through was estimated by means of IRFs from the SVAR.

Evidence from the analysis, covering the period 1983Q3 through to 2006Q3, reveals that exchange rate pass-through to consumer prices in Ghana is substantial but incomplete. This contrasts the findings of Frimpong and Adam (2010) who found a low pass-through for Ghana. As we argued above, such findings are indeed puzzling given Ghana's history of massive exchange rate depreciation that coexisted with high inflation.

We argued that the large pass-through found here can be attributed to the continuous depreciation of the cedi over the whole sample period. Firms and importers are therefore likely to perceive any increase in costs due to exchange rate depreciation as persisting and, therefore, pass on to consumers most of the resultant increases in costs. Other theoretical reasons for high exchange rate pass-through include the high and persistent inflation during the period under review as well as the high share of imports in the Ghanaian consumption basket.

Variance decomposition analysis indicates that money supply shocks generally dominate exchange rate shocks in explaining Ghanaian inflation. This provides some support to the claim in the literature that money supply has been the major cause of inflation in Ghana.

An important policy implication of this finding is that, although the flexible exchange rate regime would help Ghana achieve the required external adjustment, it may endanger the goal of achieving price stability, if the necessary exchange rate movements are large. In addition, the attainment of the low inflation targets in Ghana would require policy makers to aim at stable exchange rates in addition to monetary stability. Occasional foreign exchange interventions that aim at smoothing out short-term fluctuations in the exchange rate are therefore justified since they would as well enhance price stability

The large exchange rate pass-through to domestic inflation implies that the response of Ghanaian trade balance to exchange rate changes would be large and significant. This suggests that Ghanaian authorities must remain vigilant in managing aid and other private inflows because real appreciation of the cedi would endanger its external balance.

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APPENDIX A1

Table A 1 Variance-Covariance Matrix of the Residuals (Full Sample)

	ΔFOREX	ΔM_2	*s*	*π*
ΔFOREX	0.0550	0.0013	-0.0022	0.0016
ΔM_2	0.0013	0.0025	-0.0007	0.0003
s	-0.0022	-0.0007	0.0040	-0.0006
π	0.0016	0.0003	-0.0006	0.0006

Table A 2. Correlation Matrix of the Residuals (Full Sample)

	ΔFOREX	ΔM_2	*s*	*π*
ΔFOREX	1.0000	0.1081	-0.1492	0.2631
ΔM_2	0.1081	1.0000	-0.2248	0.2083
s	-0.1492	-0.2248	1.0000	-0.3556
π	0.2631	0.2083	-0.3556	1.0000

A2: Testing for Contemporaneous Correlation of Shocks

Given the seemingly low values of some the covariances of the residuals (Table A1), we test the hypothesis that the off-diagonal elements of the covariance matrix of the unrestricted VAR are zero using the Sims' log-likelihood ratio (Enders, 2004). This is important because if the covariances of the residuals are zero, there is no point proceeding with the SVAR.

The hypothesis is:

H_0: $\sigma_{12} = \sigma_{13} = \sigma_{14} = \sigma_{23} = \sigma_{24} = \sigma_{34} = 0$

H_1: $\sigma_{12} \neq \sigma_{13} \neq \sigma_{14} \neq \sigma_{23} \neq \sigma_{24} \neq \sigma_{34} \neq 0$

and the LR statistic is given by:

$LR\ (H_0/H_1) = 2(LL_U - LL_R)$ *which is* χ^2 *distributed with 4 d.f.*

where LL_U and LL_R are the maximised values of the log-likelihood function under H_0 (unrestricted model) and under H_1 (the restricted model) respectively. The restricted model's LL is the sum of the LL from the single equation estimates of the equations in the VAR.

$LL_R = LL_{\Delta forex} + LL_{\Delta M2} + LL_s + LL_{\pi}$

LR = 2(511.5370-467.8663) = 43.6374

The 95 percent critical value with 4 *d.f.* is 9.48 suggesting that the shocks in different equations are contemporaneously correlated.

Table A 3 Full Sample Estimate of the Unrestricted VAR

Unrestricted Vector Autoregression Estimates
Sample (adjusted): 1984Q4 2006Q2
Included observations: 87 after adjustments
Significant coefficients at 5% are bold, at 10%, in italics

	ΔFOREX	***ΔM_2***	***Δs***	***Δπ***
ΔFOREX(-1)	0.033	0.021	0.006	0.006
ΔFOREX(-2)	0.078	**0.040**	***-0.046***	0.004
ΔFOREX(-3)	0.057	-0.010	-0.024	-0.002
ΔFOREX(-4)	-0.046	0.005	0.014	0.001
ΔM_2(-1)	-0.642	-0.010	**-0.289**	**0.108**
ΔM_2 (-2)	-0.109	**0.216**	0.105	0.055
ΔM_2 (-3)	-0.141	0.090	0.030	0.011
ΔM_2 (-4)	0.23	0.049	0.006	**0.130**
s(-1)	0.385	*-0.133*	**0.283**	0.014
Δs(-2)	***-0.724***	-0.034	0.092	***-0.061***
Δs(-3)	**1.496**	*0.133*	**0.316**	-0.045
Δs(-4))	-0.664	**-0.245**	-0.067	-0.014
π (-1)	-0.113	-0.175	0.138	**0.525**
π (-2)	-1.480	**-0.504**	-0.053	**-0.297**
π(-3)	0.577	**0.712**	0.336	**0.275**
π (-4)	0.698	-0.252	-0.072	-0.034
C	**0.246**	**0.155**	**-0.061**	**-0.031**
Q1	*-0.214*	**-0.189**	*0.058*	**0.055**
Q2	***-0.284***	**-0.149**	0.034	**0.045**
Q3	-0.013	**-0.099**	0.045	0.016
R-squared	0.325	0.766	0.342	0.737
Adj. R-squared	0.134	0.699	0.155	0.662
Sum sq. resids	3.687	0.164	0.268	0.043
S.E. equation	0.235	0.050	0.063	0.025
F-statistic	1.698	11.526	1.833	9.872
Log likelihood	14.066	149.355	128.162	207.527
Akaike AIC	0.136	-2.974	-2.486	-4.311
Schwarz SC	0.703	-2.407	-1.920	-3.744
Mean dependent	0.026	0.081	-0.057	0.055
S.D. dependent	0.252	0.090	0.069	0.044
Det. resid covariance (d.o.f adj.)		2.61E-10		
Det. resid covariance		9.19E-11		
Log likelihood		511.5037		
Akaike information criterion		-9.919625		
Schwarz criterion		-7.652123		

Figure A 1. Residuals of the VAR Equations (Full Sample)

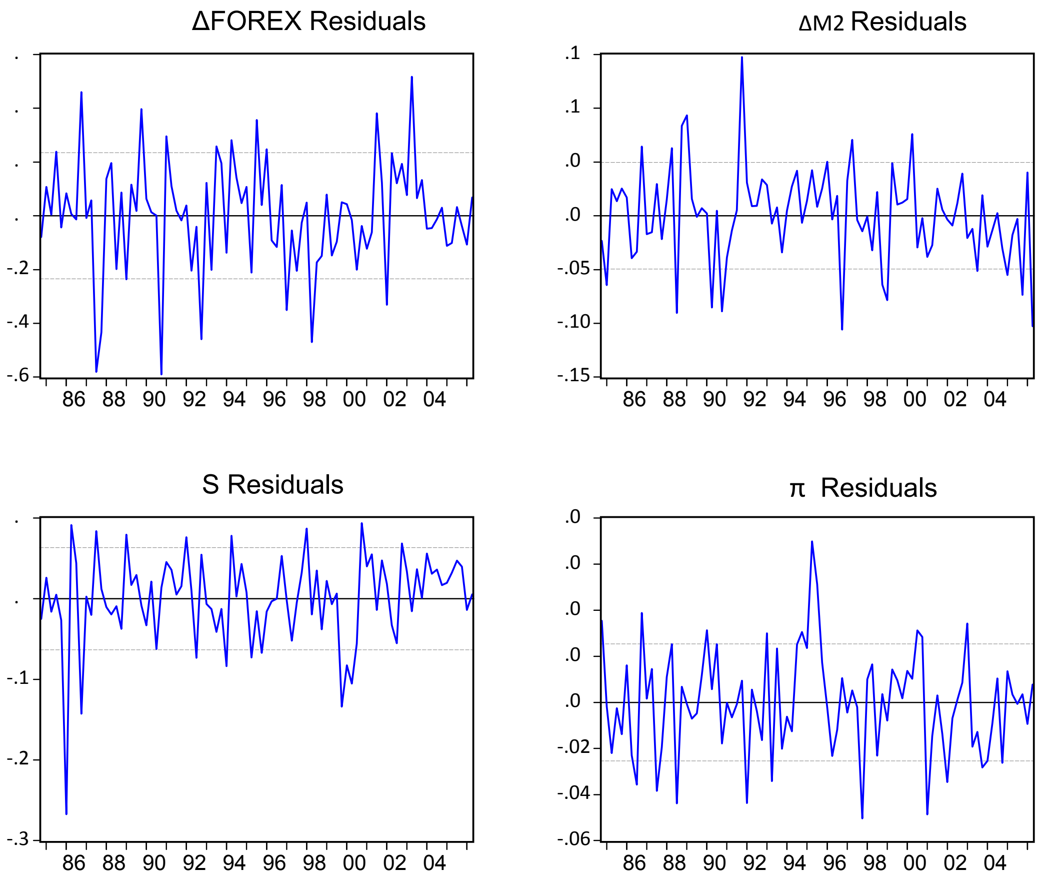

Figure A 2. Impulse Response to Forex, Money Supply, Exchange Rate and Inflation to one SD Structural Shocks 1983-2006