Empirical evidence of exchange rate pass-through to prices and inflation in Ghana[1]

Abstract

The study employs autoregressive distributed lag model to establish the relationships among changes in exchange rate, prices, petroleum prices, interest rates, cocoa prices, among others, after using 1988 to account for an exogenous structural change. Two price indices are employed alternatively to capture prices in the study, because of the introduction of new cedi in 2007 to facilitate the role of money as a medium of exchange to enhance transactions in the country. Results of empirical analysis show that the extent of exchange rate pass-through to inflation in the country is incomplete but fairly larger than those observed on the average in other studies for advanced developed countries (ADCs). Additionally, the size of the exchange-rate pass-through to inflation is slightly larger in the short-run than in the long-run. The estimated impulse response functions show that inflation reinforces itself, increases Treasury Bills rates, and contributes more to depreciation than the latter's effect on inflation. Improvements in cocoa prices strengthen the cedi's value, and dampen Treasury Bills rates, although they slightly bump up inflation. However, increase in petroleum prices also depreciates the cedi, although it is not very inflationary. Monetary authorities are cautioned that although monetary policy is effective and can be used to curb inflation its excessive expansionary use is inflationary, and is the chief source of depreciation of the cedi.

Keywords: Bounds tests, autoregressive distributed lag model, structural change, exchange rate pass-through, inflation, prices, cocoa prices, petroleum prices, Treasury Bills rates

JEL: F3, F4, O1, O4, C3, C4

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1. Introduction

The Bank of Ghana (BOG), which was established in 1957, emerged from the then Bank of Gold Coast with a dual mandate to (i) maintain price stability and (ii) foster a conducive environment to sustain and maintain economic growth. Consequently, in 2002 it launched a Monetary Policy Committee which was armed through the Bank of Ghana (Act 612) section 27 to adopt a hierarchical mandate to maintain price stability as its overriding goal, along the lines of the European Central Bank's hierarchical mandate of inflation targeting.

The objective of stable prices in the BOG's mandate satisfies what has now become the overarching goal of most central banks world-wide. This is because price stability creates a stable environment consistent with low inflation; and the resulting low inflation expectation reduces nominal interest rates, the primary determinant of the cost of borrowing faced by most businesses and other market participants. The low interest rates encourage and promote high investment in capital stocks and spending on consumer durables to drive economic growth. Thus, stable prices and attending low interest rates reduce uncertainties in the financial market. Additionally, stable financial markets promote business and consumer confidences which are important spokes in the wheels of business finance and lending that drive investment, production and economic growth.

Price stability also ensures that the government eschews deficit financing. It is consistent with fiscal discipline which emanates from dissociating the BOG's authority to print money from the authority of the ruling political party forming the government. This independence of the BOG can be achieved by adhering to price stability as a long-run (but not as a short-term) monetary policy goal. Furthermore, maintaining a long-run price stability goal frees monetary policy to be implemented over the short-term to even out business fluctuations, and ensures that the BOG's monetary policy is not subject to a time inconsistency problem. The long-run price stability goal also infuses fiscal discipline which restrains unwarranted fiscal spending and its concomitant burgeoning national debt. It also relieves the BOG from employing monetary policy to accommodate fiscal policy. As a result, it is not subject to a time inconsistency problem. Instead, it enables the BOG to effectively maintain the long-run goal of stable prices by aligning fiscal policy to the national budget constraint to accommodate its monetary policy.

In fact, monetary authorities (MAs) now have complete control over their monetary policy, as the collapse of the fixed exchange rate regimes in 1973 led most developing countries (DCs) to adopt flexible exchange rate or a version of managed float regimes to end the Bretton Woods system's fixed exchange rate. But the fact that changes in money supply cause exchange rate overshooting (Dornbusch, 1976) renders the policy questionable in DCs. Additionally, the J-curve effect which emanates from the use of monetary policy amplifies exchange rate volatility. As a result, using monetary policy to change exchange rate to improve trade balance in most developing countries are unpopular. It is further complicated by the degree by which changes in exchange rate affect increase in prices (including both imports and exports) and inflation in developing countries.

In light of the above, our study will inquire into the role of monetary policy in the creation of inflation in Ghana where depreciation has been prolonged and persistent. It is believed that the instability in the national currency engineered by MAs is the root cause of increases in prices and inflation in the country. It is also the bane of monetization of deficit and a chief source of the growing national debt, as it is believed that the exchange rate pass-through in the country is incomplete. This raises the question, what is the degree of exchange rate pass-through to import (and export) prices in the country? Unfortunately, the absence of adequate reliable data on import and export prices prevents us from answering this question.

We have therefore following (Krugman, 1986; Dornbusch, 1987; Magee, 1973; Branson, 1972), attempted to find the extent by which exchange rate pass-through and pricing to market influence prices and hence inflation in the country, by estimating rather the size or degree of exchange rate pass-through to prices and inflation in the country. This finding will inform policymakers on the BOG's monetary policy role in the creation of price increases and inflation in the country. Considering that most studies in advanced developed countries (ADCs) indicate that although the size of the exchange rate pass-through to prices and inflation hovers around 20 percent, it has fallen even further to about 5 percent after the early 1980s (Gagnon and Ihrig, 2004), and remains generally low for countries with stable monetary policy environment (Taylor, 2000; Mishkin, 2008)[2], finding the size of the pass-through to prices and inflation will inform policymakers and the general public as to whether or not monetary policy is stabilizing and effective in the country. It will also absolve the BOG from any accusation that it is monetizing the fiscal spending of the government.

In view of the above, we have employed a vector error-correction model (VECM) where cointegration is used as the identifying restriction of the model. The size of the long-run exchange rate pass-through to domestic prices is obtained from the estimated cointegrated equation; and impulse response functions and variance decomposition are used to infer the short-term exchange rate pass-through to prices and inflation dynamics of the model. We have also employed Pesaran, Shin and Smith's (PSS, 2001) tests to identify the level of integration of the relationship among our variables of interest in the autoregressive distributed lag (ADL) model. The ADL model is then used to estimate the impact multipliers and long-run elasticities of the exchange rate pass-through to prices and inflation to inform policy in Ghana. We have also, for the first time in such studies, accounted for structural changes, because of myriads of monetary policy changes that have occurred in the Ghanaian economy over the period of study. See also Ghartey (1998, 481-485) and Sowah (1993).

Following the introduction, the characteristics of the Ghanaian economy and exchange rate pass-through are discussed in Section 2. The model is developed in Section 3. It is followed by a

[2] See also Ihrig et al. (2006), Bailliu and Fujii (2004), Sekine (2006), and McCarthy (1999).

discussion of the empirical results in Section 4. The paper is concluded with a summary of the findings and policy recommendation in Section 5.

2. The economy of Ghana and exchange rate pass-through

Ghana is a small open economy judging by its degree of openness (DOP) or market penetration as measured by its imports of goods and services as a ratio of the gross domestic product (GDP). Its DOP has fluctuated between a maximum of 67.2 percent in 2000 from a minimum of 14.2 percent in 1972, while the DOP of the US, the reserve country of our study, rose from a minimum of 4.2 percent in 1961 to reach its maximum of 17.6 percent in 2008. The annual average of Ghana's DOP from 1960 to 2010 was 32.5 percent compared to the annual average of 9.8 percent for the US from 1960 to 2008. Thus, Ghana is a more open economy than the US and therefore vulnerable to external influences.

Greater openness of the Ghanaian economy means that firms in the country face more competition from counterpart foreign companies which export their goods and services to the country. This intense competition from foreign firms dampens domestic prices, *all other things being equal*. However, as a smaller economy, Ghana is a price taker in the world market. It exports mostly agricultural products like timber and cocoa, and minerals like gold, bauxite, manganese, and in recent time crude oil and gas, which are priced in foreign currencies, largely in US dollars. Its exports earnings are, therefore, susceptible to fluctuations in demand and supply conditions in the world market which cannot be controlled by policymakers in the nation. As a result, the country is faced with perfect competition in the world market.

The country's import prices are dictated by world market prices. Thus, because the country's exports are inelastic in demand due to their nature, and its import prices are fixed because it is a price taker in the world market, both prices of imports and exports are fixed. As a result, the exchange rate pass-through to prices of imported goods and services are more likely to be complete in the country.

Additionally, most of the country's productive inputs, namely, raw materials and capital stock, and manufactured final goods are imported. As a result changes in the country's exchange rates which result in depreciation are expected to drive up domestic prices, *all other things being equal*.

Furthermore, like most small economies, Ghana is characterized by imperfect market conditions internally. The country is largely dominated by a few large firms as evidenced by the number of companies listed in the Ghana Stock Exchange which makes its market structure concentrated (see also Woo, 1984; Kim, 1990; Lee, 1997). Note that the more concentrated a market structure in a country the higher the concentration ratio and the lesser the effects of exchange rate pass-through to imports and domestic prices. This means that Ghana, although is a price taker in the world market, it will not necessarily experience a complete exchange rate pass-through to its imports and domestic prices.

Exchange rate is an important policy instrument in the tool kits of monetary authorities in especially developing countries, where it is often used as a substitute for operating target instrument such as Treasury Bills during open market operations. It also provides information on how prices are set in international trade of goods and services. The elasticity of exports prices with respect to exchange rates, which measures pricing-to-market, is complete when the said elasticity is unity and partial when it is less than unity. Additionally, the elasticity of import prices with respect to exchange rates measures the extent of exchange rate pass-through to imports prices. The pass-through is complete when the elasticity is unity and partial when it is less than unity.

The size of exchange rate pass-through to imports prices and pricing-to-market are therefore important determinants in setting an optimal monetary policy, and in choosing optimal exchange rate regime to serve as a nominal anchor to tie to the long-run goal of stable prices and low inflation. Both exchange rate pass-through and pricing-to-market information also assist monetary authorities to conduct sound monetary policy, balance the current account and deal with capital inflow. In particular, exchange rate pass-through to imports prices also informs policymakers about the extent the country is vulnerable to import inflation from foreign countries during international trade. See Kreinin (1977), Baldwin (1988), Hooper and Mann (1989), Kim (1990), Clark (1999), Yang (1991), Menon (1993), Lee (1997), and Campa and Goldberg (2005).

Unfortunately, as previously mentioned, there are no adequate and readily available time series data on export prices and import prices for us to estimate the size of pricing-to-market (Krugman, 1986; Dornbusch, 1987) and/or exchange rate pass-through to import prices (Magee, 1973; Branson, 1972). Consequently, instead of estimating the size of pricing to market to inform policymakers on market structure of the country, whether it faces perfect competition or imperfect competition in its international trade, and/or estimating the size of exchange rate pass-through to import prices to inform how vulnerable the country is in importing foreign inflation or deflation, in this study we have estimated the effect of exchange rate pass-through to domestic prices and inflation to inform policy in Ghana.

3. The model

The pure vector autoregressive model is expressed as

$$A^*(L)X_t = u_t \qquad (1)$$

where $A^*(L) = I - A_1L - A_2L^2 - A_3L^3 - \ldots$, $E(u_t) = 0$, $E(u_tu_s{}') = \Omega \; \forall \; t = s$, $E(u_tu_s{}') = 0 \; \forall \; t \neq s$, $E(y_tu_s{}') = 0 \; \forall \; t < s$, and **X** = = [p, rxr, y, tbr, m2, cp, petp, fp]' is an 8x1 vector of observable endogenous variables. The lower case letters in X denote the logarithmic form of the variables and subscript t denotes time period. Thus the logarithmic form of real output is y, the exchange rate is xr and price is p. The reduced form of equation (1) is

$$\mathbf{X_t = A(L)X_{t-1} + u_t} \qquad (2)$$

Where $\mathbf{A(L)} = \mathbf{(1 - A^*(L))L^{-1}} = \mathbf{A_1} + \mathbf{A_2L} + \mathbf{A_3L^2} + \ldots$. The VAR representation of the stochastic vector of variables exists only if the process is invertible, meaning that the elements of the coefficient matrices $\mathbf{Ai} \rightarrow \mathbf{0}$ as $\mathbf{i} \rightarrow \infty$. The reduced form equation (2) can be consistently estimated by using the ordinary least squares (OLS) method without experiencing a simultaneous equation bias problem. The Cholesky decomposition of the contemporaneous covariance positive definite matrix Ω is

$$\mathbf{\Omega} = \mathbf{P^{-1}P^{-1'}} \text{ or } \mathbf{P\Omega P'} = \mathbf{I}$$

Where $\mathbf{P}$ and P^{-1} are lower triangular matrices, and $\mathbf{E(Pu_t u'_t P')} = \mathbf{P\Omega P'} = \mathbf{I}$. The corresponding dynamic vector moving average (VMA) representation of the reduced form of $\mathbf{X}_t$ is written in the form of Wold decomposition as follows:

$$\mathbf{PX_t} = \mathbf{PA(L)X_{t-1}} + \mathbf{Pu_t} \qquad (3)$$

$$\rightarrow \quad \mathbf{P(I - A(L)L)X_t} = \mathbf{Pu_t}.$$

Thus X_t = $\mathbf{(I - A(L)L)^{-1}P^{-1}v_t}$, where $\mathbf{v_t} = \mathbf{Pu_t}$, and the Wold VMA becomes as follows:

$$\mathbf{X}_t = \mathbf{B(L)v_t} \qquad (4)$$

where $\mathbf{B(L)} = \mathbf{(I - A(L)L)^{-1}P^{-1}}$; $\mathbf{B(L)} = \mathbf{P^{-1}} + \mathbf{B_1L} + \mathbf{B_2L^2} + \ldots$; $\mathbf{L^J v_t} = \mathbf{v}_{t-j}$, $E(\mathbf{v_t}) = E(\mathbf{v_t v_s}') = \mathbf{0}$, $\forall$ $\mathbf{t \neq s}$, and $E(\mathbf{v_t v_s}') = \mathbf{I}$ $\forall$ t = s; $\mathbf{v}_t = [v_{pt}, v_{rxrt}, v_{yt}, v_{tbrt}, v_{m2t}, v_{cpt}, v_{petpt}, v_{fpt}]'$ is a column vector of unobservable exogenous orthogonal structural innovations which are serially and mutually uncorrelated at leads and lags with a dimension of 8x1, and $\mathbf{B(L)}$ is an 8x8 matrix of polynomials in the lag operator L.

The coefficient matrix of $\mathbf{B(L)}$ represents the response of the system to a one standard error innovation in $\mathbf{v_t}$. A representative element of B(L) is bij(L), and it shows the response of all future values of x_i to a one standard error's one-time current innovations in x_j. Thus, $b_{ij}(L)$ is the impulse response function of x_i with respect to a shock in x_j. From equation (4), the ith element of $\mathbf{X}$ at time t+h is $x_{it+h} = \sum_{j=1}\sum_{s-0} b_{ij,s} v_{j,t+h-s}$. Thus, the percentage of the expected h-period-ahead squared prediction error of x_{it} produced by an innovation in x_j is zero if x_i is exogenous. This is the necessary and sufficient condition for x_i to be exogenous with respect to the remaining variables in the system.

The structural vector autoregressive (VAR) model of the reduced form model of equation (4) is recovered in the form of VECM in the tradition of Johansen and Beveridge-Nelson decomposition as follows:

$$\mathbf{M(L)X_t = \Delta M^*(L)X_t + M(1)LX_t = M^*(L)\Delta X_t + M(1)X_{t-1} = v_t} \qquad (5)$$

where, $\mathbf{M(L) = B^{-1}(L)}$ and $\mathbf{\Delta M^*(L) = M(L) - M(1)}$ which implies that $\mathbf{M(1) = B^{-1}(1)}$.

Thus, equation (5) is the simultaneous-equation system which captures the VMA representation of the structural equation (4), and its corresponding reduced-form system is

$$\mathbf{N\alpha' x_{t-1} + \phi(L)\Delta x_t = v_t^*} \qquad (6)$$

The reduced rank ($0<q<3$) implies that $\mathbf{M(1)}$ can be factorized as $\mathbf{M(1) = N\alpha'}$. Thus, $\mathbf{M(1)}$ is a singular matrix and is expressed as a product of two rectangular matrices with full column rank, where $\mathbf{N}$ measures the adjustment speed to close deviations of the errors from equilibrium and $\boldsymbol{\alpha}$ captures the matrix of cointegration vectors. The common trend's representation of equation (5) was transformed by Johansen's VECM into equation (6), and its long-run cointegration of the variables were used to restrict and identify the non fundamental representations of the VAR model in the study, to give a reasonable or economically acceptable impulse-response functions and variance decomposition. See Blanchard and Quah (1989), Lippi and Reichlin (1993), Crowder (1995), and Ghartey (2001) for an application to a developing country.

In this regard, the level forms of the ordered variables included in the VECM are estimated, and the long-run estimates from the VECM are then used to identify and obtain a more robust impulse-response functions, and innovations accounts for policy implications and discussions.

3.1. Data and Sources

Cp denotes cocoa prices, fp denotes foreign prices which is captured by the US consumer price index (CPI), imp denotes import prices, petrolp denotes petroleum prices, mb denotes monetary base, tbr denotes Treasury Bills rates, p1 denotes Ghana's cpi with 1995 as the base year, p2 denotes Ghana's cpi with 2000 as the base year, rxr is real effective exchange rate, dopa denotes import to GDP ratios where the latter is quoted in terms of the old cedi, dopb denotes import to GDP ratio where the latter is adjusted to the value of the new cedi which was introduced in 1 July 2007, and was equivalent to 10,000 old cedi, and 0.92 US dollar. Sources of data are World Development Indicators, 2013; Bank of Ghana, Ghana Statistical Services, various issues of the IMF's Statistical Year Book, and Federal Reserve Economics Data online from Federal Reserve Bank of St. Louis. They span 1965 to 2010.

4. Discussion of the empirical results

Results of the stationarity properties of variables included in the model are presented in Table 1. It is clear that judging by the DF and ADF tests, the first difference forms of all of the variables including the intercept term with the exception of p1 are stationary at 0.05 significant levels. However, the p1 is stationary at the level form with an intercept term at 0.01 significant levels. Results of Kwiatkowski, Phillips, Schmidt and Shin (KPSS) tests which assume the null hypothesis of stationarity cannot be rejected, and they clearly show that the first difference forms of all of the variables are stationary at 0.05 significant levels with intercept and linear trend. However, the KPSS results of level forms of some variables are stationary for the case where an intercept is included as an exogenous determinant. Thus, we can generally conclude that because the variables are not integrated at the same degree, the ADL estimation technique which does not discriminate about the level relationship among the variables will be useful in estimating the exchange rate pass-through for the country. Additionally, diagnostics of the bounds tests are consistent with shift dummies introduced to capture structural change(s). See Pesaran and Pesaran (2009, pp.463-465).

To lend rigor to our findings, we employed the ADL model and used bound tests to determine the level relationship among the variables included in the model. Results of ADL estimates are reported in Table 2 for prices p1 and p2 regressands in second and third columns, respectively. They show that the impact multiplier of rxr in the p1 equation is 0.255 which is slightly less than the rxr impact multiplier of 0.232 in the p2 equation. Both multipliers are significant at 0.01 levels. The estimated p1 and p2 equations have coefficients of determination that indicate that more than 99 percent of variations in p1 and p2 are explained by the regressors, and the F-test are significant at 0.01 levels.

The diagnostics are all satisfied. There is no serial correlation or heteroscedasticity or functional form or normality problems, as none of their respective reported p-values in square brackets are significant. However, the PSS bounds F and W statistics are 9.445 and 56.672, respectively, in the p1 equation and 9.699 and 67.891, respectively, in the p2 equation. Thus, both F and W statistics for equations p1 and p2 lie above the stipulated bounds. This means that both equations must be specified in first difference form to properly address the level relationships among the dependent and explanatory variables included in each model (see PSS, 2001).

We have therefore estimated inflation (Δp1 and Δp2) equations to examine the effect of exchange rate pass-through to inflation. Results of ADL estimates of both inflation (Δp1 and Δp2) equations are reported in Tables 3a and 3b, respectively. The adjusted coefficients of determination ($\bar{R}^2$s) are 0.34 and 0.47 for Δp1 and Δp2 equations, respectively, and their F-tests are both significant at 0.05 levels. There are no serial correlation problems, their functional forms are correct and their normality assumption tests are satisfactory.

However, in Tables 3a and 3b both F- and Wald-statistics estimated lie within their respective

Table 1: Unit root test results based on Dickey-Fuller (DF) and augmented DF (ADF) test[3]

	Level				First Difference			
Variable	K	Without I and T	K	With I	K	Without I and T	K	With I
cp	1	-1.446[0.14]	1	-2.032[0.27]	1	-5.946[0.00]	1	-6.101[0.00]
fp	1	1.1639[0.97]	1	-1.526[0.51]	0	-1.144[0.23]	0	-3.036[0.04]
imp	1	1.121[0.93]	1	-0.995[0.74]	0	-2.283[0.02]	0	-4.175[0.00]
petrol	0	1.174[0.94]	0	1.125[0.99]	0	-0.927[0.31]	0	-6.281[0.00]
mb	0	10.501[1.00]	0	0.039[0.96]	1	-1.134[0.23]	0	-2.897[0.05]
p1	1	0.558[0.83]	1	-3.802[0.00]	0	-2.066[0.04]	1	-2.183[0.22]
p2	0	0.386[0.79]	0	-1.506[0.52]	0	-5.394[0.00]	0	-5.598[0.00]
rxr	0	-1.153[0.22]	0	-0.809[0.81]	0	-6.132[0.00]	0	-6.464[0.00]
dopa	0	0.012[0.68]	0	-1.199[0.66]	0	-5.287[0.00]	0	-5.231[0.00]
dopb	0	0.067[0.70]	0	-0.943[0.76]	0	-4.876[0.00]	0	-4.864[0.00]
tbr	0	-0.459[0.51]	0	-1.954[0.30]	0	-6.336[0.00]	0	-6.244[0.00]

Kwiatkowski, Phillips, Schmidt and Shin (KPSS) LM Tests

	Level		First Difference	
	With I and T	With I	With I and T	With I
cp	0.152	0.440	0.094	0.092
fp	0.205	0.941	0.151	0.257
imp	0.165	0.714	0.111	0.139
petrol	0.135	0.750	0.088	0.088
mb	0.079	0.885	0.124	0.220
p1	0.100	0.742	0.136	0.135
p2	0.194	0.690	0.097	0.580
rxr	0.154	0.535	0.133	0.138
dopa	0.107	0.470	0.094	0.107
dopb	0.102	0.566	0.136	0.138
tbr	0.154	0.240	0.087	0.122

Notes: T denotes trend, I denotes intercept, k denotes lag-lengths, cp denotes cocoa prices, fp denotes foreign prices which is based on US consumer price index (CPI), imp denotes import prices, petrolp denotes petroleum prices, mb denotes monetary base, tbr denotes Treasury Bill rates, p1 denotes Ghana's cpi with 1995 as the base year, p2 denotes Ghana's cpi with 2000 as the base year, rxr is real effective exchange rate, dopa denotes imports to GDP ratio, where the latter is quoted in terms of the old cedi, dopb denotes imports to GDP ratio, where the latter is adjusted to the value of the new cedi which was introduced in 1 July 2007, and was equivalent to 10,000 old cedi and 0.92 US dollars. Lower case notations of variables denote their logarithmic forms. Probability (p) – values are

[3] These results are obtained after accounting for an exogenous structural change by using 1988 as a structural break-point.

reported in square brackets. DF is Dickey-Fuller and ADF is augmented DF, and KPSS is Kwiatkowski, Phillips, Schmidt and Shin. *, ** and *** denote significance at 0.01, 0.05, and 0.10 levels, respectively. Asymptotic critical values of the LM statistics from the KPSS test are 0.739, 0.463 and 0.347 at 0.01, 0.05 and 0.10 levels, respectively for the case with I; 0.216, 0.146 and 0.119 at 0.01, 0.05 and 0.10 levels, respectively for the case with I and T. Similar results are obtained when exogenous structural change dummies are included in the unit roots tests.

Table 2: ADL estimates of exchange rate pass-through to prices (p1 and p2) with an exogenous structural change dummy

Dependent Variables:	Price(p1)	Price (p2)
Regressors	ADL(1, 1,1, 1, 0, 0) Estimates	ADL(1, 1, 1, 1, 0, 0, 0) Estimates
rxr	0.255[0.00]	0.232[0.00]
rxr(-1)	-0.228[0.00]	-0.187[0.00]
cp	0.273[0.04]	0.231[0.06]
cp(-1)	-0.305[0.03]	-0.255[0.05]
fp	1.668[0.01]	1.427[0.00]
fp(-1)	-1.725[0.00]	-1.509[0.00]
petrol	0.141[0.08]	0.124[0.10]
tbr	0.008[0.02]	0.008[0.01]
dumm88	0.000[0.10]	0.019[0.85]
p1(-1)	0.942[0.00]	0.956[0.00]
$\bar{R}^2$	0.997	0.998
F	1209.91[0.00]	1418.2[0.00]
DW	2.466	2.218
Dh	-1.259[0.21]	-0.586[0.56]
Bounds F-Stat	9.445; Critical Bounds = (3.018, 4.472)	9.699; Critical Bounds = (2.543, 4.041)
Bounds W-Stat	56.672; Critical Bounds = (18.111, 26.832)	67.891; Critical Bounds = (17.800, 8.287)
$\chi^2_{SC}((1))$	2.339[0.13]	0.478[0.49]
$\chi^2_{FF}((2))$	1.077[0.30]	1.499[0.22]
$\chi^2_{N}((1))$	0.335[0.85]	0.036[0.98]
$\chi^2_{H}((1))$	0.161[0.69]	0.310[0.58]

Notes: If F-statistics or W-statistics lie within the bounds, the test is inconclusive, so the model should be expressed in error-correction form to infer the Granger causal relationship from the significance of the error-correction term. If both statistics lie below the lower bound the statistics cannot be rejected so the test on the relationship should be conducted in level form, and if both statistics lie above the bounds, then the test must be conducted in first difference form. P-values are reported in square brackets. Autoregressive distributed lag (ADL) order with the number of lagged regressand followed by regressors are presented in parentheses. $\bar{R}^2$ is adjusted coefficient of determination, Dh is Durbin h statistics, χ^2_{SC} is Lagrange multiplier test of residual serial correlation, χ^2_{FF} is Ramsey's RESET test using the square of fitted values, χ^2_{N} is Jarque and Bera (1980) normality assumption test based on a test of skewness and kurtosis of residuals, and χ^2_{H} is a heteroscedasticity test (of homoscedasticity assumption) based on the regression of squared residuals on squared fitted values, with their respective degrees of freedom reported in double parentheses. EC_{t-1} is the error-correction term.

Table 3a: ADL estimates of exchange rate pass-through to inflation using p1 as the price with an exogenous structural change dummy

Regressors	ADL (1, 0, 0, 0, 1) estimates	Long-run estimates	Error-correction model estimates	FMPH long-run estimates
Δrxr	0.310[0.00]	0.520[0.02]	0.310[0.00]	0.238[0.00]
Δcp	0.266[0.04]	0.447[0.07]	0.266[0.04]	0.133[0.01]
Δfp	2.019[0.00]	3.389[0.01]	2.019[0.00]	0.351[0.06]
Δtbr	0.012[0.00]	0.007[0.06]	0.012[0.00]	0.005[0.00]
Δtbr(-1)	-0.008[0.06]			
Δp1(-1)	0.404[0.00]			
Dumm88	-0.136[0.05]	-0.229[0.06]	-0.136[0.05]	-0.245[0.00]
EC_{t-1}			-0.596[0.00]	
Intercept				0.290[0.00]
$\overline{R}^2$	0.341		0.703	
F-stat	3.248[0.02]		13.508[0.00]	
DW			1.830	
Dh	0.586[0.56]			
Bounds F-Stat	4.080; Critical Bounds = (3.18, 4.57)			
Bounds W-Stat	20.403; Critical Bounds = (15.899, 22.866)			
$\chi^2_{SC}((1))$	0.181[0.67]			
$\chi^2_{FF}((1))$	0.668[0.41]			
$\chi^2_{N}((2))$	1.582[0.45]			
$\chi^2_{H}((1))$	8.906*[0.00]			

Notes: FMPH denotes fully modified Phillip-Hansen (1990). See also the notes in Tables 1 and 2.

Table 3b: ADL estimates of exchange rate pass-through to inflation using p2 as the price with an exogenous structural change dummy

Regressors	ADL (1, 0, 0, 0, 1) estimates	Long-run estimates	Error-correction model estimates	FMPH long-run estimates
Δrxr	0.286[0.00]	0.577[0.02]	0.286[0.00]	0.176[0.00]
Δcp	0.213[0.07]	0.429[0.10]	0.213[0.07]	0.044[0.35]
Δfp	1.728[0.00]	3.489[0.01]	1.728[0.00]	0.052[0.78]
Δtbr	0.12[0.00]	0.008[0.057]	0.012[0.00]	0.006[0.00]
Δtbr(-1)	-0.008[0.03]			
Δp2(-1)	0.504[0.00]			
Dum88	-0.130[0.04]	-0.263[0.04]	-0.131[0.04]	-0.258[0.00]
EC_{t-1}			-0.496[0.00]	
Intercept				0.285[0.00]
$\overline{R}^2$	0.471		0.675	
F	4.854[0.00]		12.020[0.00]	
DW			1.839	
Dh	0.535[0.59]			
Bounds F-Stat	3.580; Bounds = (3.180, 4.573)			
Bounds W-Stat	17.902; Bounds = (15.899, 22.866)			
$\chi^2_{SC}((1))$	0.188[0.665]			
$\chi^2_{FF}((1))$	0.457[0.499]			
$\chi^2_{N}((2))$	0.148[0.929]			
$\chi^2_{H}((1))$	9.257**[0.002]			

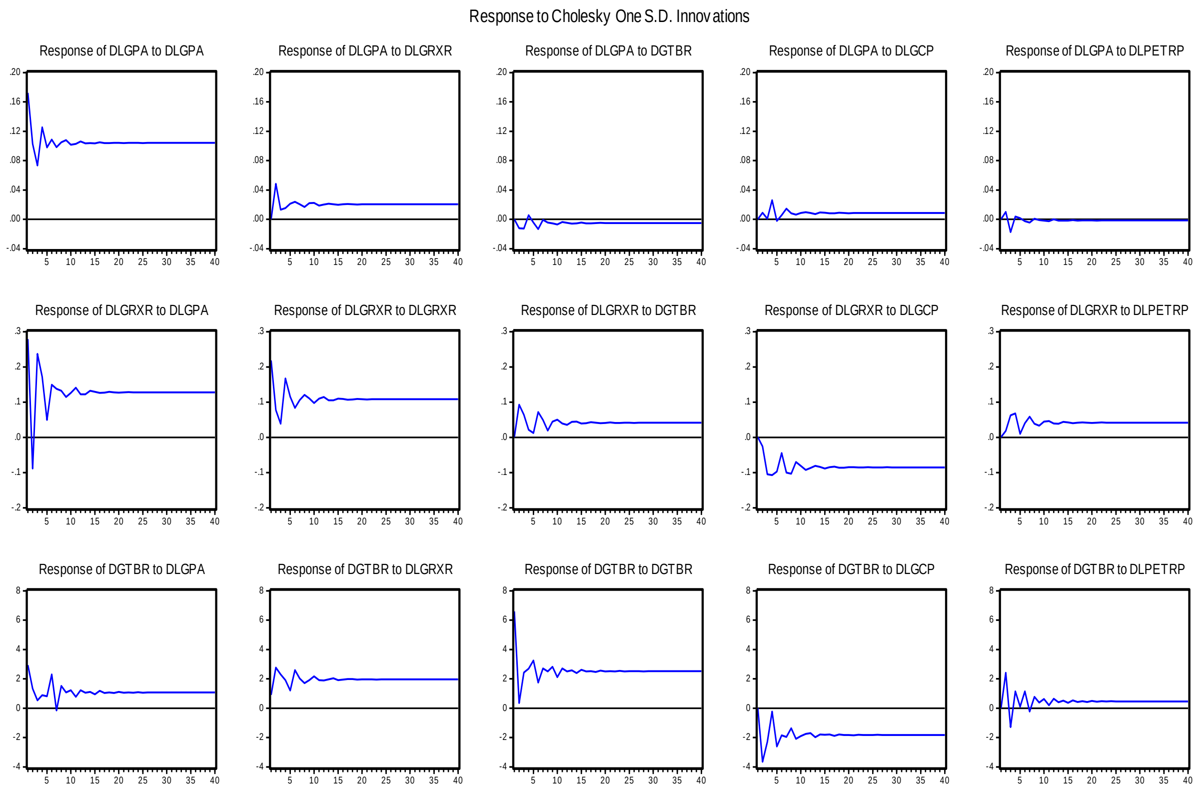
Notes: See the notes in Table 3a.

Table 4a: Forecast error variance decomposition of the effect of exchange rate pass-through after accounting for an exogenous structural change

Variance of Δp1	Innovations in:				
Period (in years)	Δp1	Δrxr	Δtbr	Δcp	Δpetrolp
1	100.000	0.000	0.000	0.000	0.000
4	93.524	4.169	0.517	1.518	0.638
8	94.056	4.057	0.512	0.966	0.408
12	94.434	3.969	0.438	0.863	0.296
16	94.653	3.909	0.396	0.807	0.235
20	94.794	3.867	0.368	0.775	0.196
30	94.997	3.803	0.327	0.731	0.141
40	95.104	3.770	0.306	0.708	0.112
Variance of Δrxr					
1	62.020	37.980	0.000	0.000	0.000
4	57.189	27.690	4.404	7.775	2.941
8	51.253	28.422	4.674	12.249	3.400
12	48.879	29.002	4.710	13.749	3.660
16	47.535	29.218	4.675	14.752	3.821
20	46.629	29.368	4.638	15.432	3.932
30	45.299	29.599	4.567	16.442	4.093
40	44.574	29.731	4.526	16.989	4.179
Variance of Δtbr					
1	16.250	1.540	82.210	0.000	0.000
4	10.124	15.348	50.223	16.557	7.747
8	10.855	17.890	46.212	19.150	5.893
12	10.056	19.785	45.256	20.091	4.812
16	9.591	20.971	44.671	20.629	4.138
20	9.263	21.778	44.314	20.958	3.686
30	8.789	22.963	43.813	21.414	3.020
40	8.532	23.611	43.538	21.661	2.656

Notes: See the notes in Table 1.

Figure 1a: Impulse response functions of the effect of exchange rate pass-through after accounting for an exogenous structural change



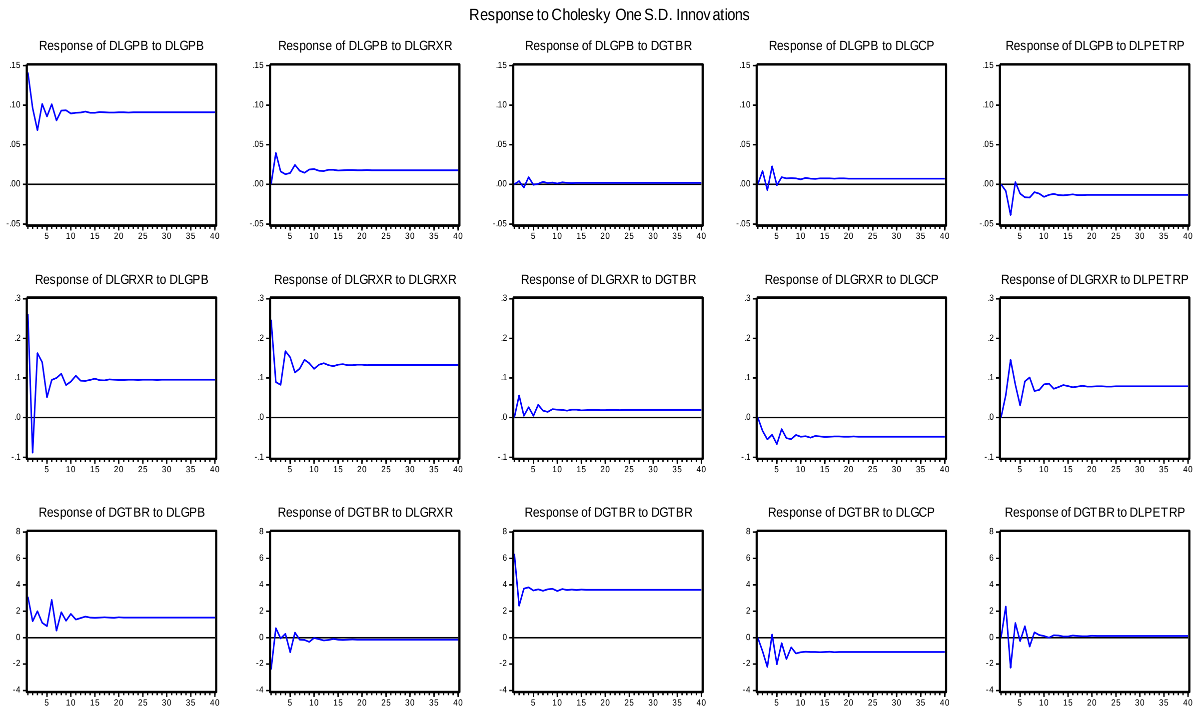
Notes: DLGPA is Δp1, DLGPB is Δp2, DLGRXR is Δrxr, DGTBR is Δtbr, DLGCP is Δcp, and DLPETRP is Δpetrolp with subscript t denoting time. See also the notes in Table 1.

Table 4b: Forecast error variance decomposition of the effect of exchange rate pass-through after accounting for an exogenous structural change

	Innovations in:				
Variance of Δp2					
Period (in years)	Δp2	Δrxr	Δtbr	Δcp	Δpetrolp
1	100.000	0.000	0.000	0.000	0.000
4	90.662	4.122	0.232	1.761	3.222
8	91.311	3.970	0.153	1.260	2.811
12	92.342	3.893	0.122	1.068	2.574
16	92.650	3.837	0.104	0.962	2.447
20	92.845	3.799	0.093	0.896	2.367
30	93.122	3.742	0.078	0.805	2.252
40	93.267	3.712	0.070	0.759	2.192
Variance of Δrxr					
1	52.991	47.009	0.000	0.000	0.000
4	45.812	38.815	1.423	2.242	11.708
8	38.121	42.947	1.314	4.113	13.504
12	34.713	44.820	1.255	4.702	15.510
16	32.826	45.794	1.212	5.049	15.119
20	31.580	46.433	1.180	5.290	15.517
30	29.775	47.367	1.134	5.639	16.085
40	28.800	47.877	1.108	5.828	16.387
Variance of Δtbr					
1	17.230	10.419	72.350	0.000	0.000
4	14.221	5.546	64.571	5.266	10.397
8	15.360	4.106	66.368	7.127	7.040
12	14.845	3.108	69.584	7.217	5.247
16	14.674	2.497	71.457	7.187	4.185
20	14.541	2.096	72.699	7.178	3.485
30	14.335	1.513	74.523	7.159	2.469
40	14.225	1.198	75.508	7.149	1.920

Notes: See the Notes in Table 1.

Figure 1b: Impulse response functions of the effect of exchange rate pass-through after accounting for an exogenous structural change



Notes: See the notes in Figure 1a.

bounds. Additionally, both results show acute heteroscedasticity problems. We therefore estimated error-correction model for both inflation (Δp1 and Δp2) equations, and corrected those heteroscedasticity problems by using the fully modified Phillips-Hansen (FMPH, 1990) estimator, which corrects both serial correlation and heteroscedasticity problems, to estimate their respective long-run inflation equations. Thus, Tables 3a and 3b contain results from ADL estimates, long-run estimates, error-correction estimates and FMPH estimates.

In both Tables 3a and 3b, the impact multipliers of exchange rate pass-through to inflation (Δp1 and Δp2) equations are 0.310 and 0.286, respectively. Furthermore, long-run estimated results reported in column 5 of Tables 3a and 3b indicate incomplete exchange rate pass-through to both inflation equations in the long-run. This means that in the long-run, a unit increase in exchange rate or depreciation will cause inflation to increase by about 52 percent in Table 3a and 58 percent in Table 3b. However, when the heteroscedasticity problem is corrected, the increase in inflation drops drastically to 23.8 percent in Table 3a and 17.6 percent in Table 3b. Thus, the exchange rate pass-through to inflation is incomplete also in the long-run, although the average size of the pass-through to inflation (Δp1 and Δp2) equations, is slightly larger than the 20 percent average generally observed for the ADCs before the 1980s, which dropped even further to 5 percent after the 1980s (see Gagnon and Ihrig, 2004).

4.1 Impulse Response Functions and Innovation Accounts

The short-term and medium-term dynamics are garnered from the estimation of Johansen's VECM. Graphs of impulse response functions of inflation equations Δp1 and Δp2 are presented in Figures 1a and 1b, respectively, and estimates of their corresponding innovation accounts are reported in Tables 4a and 4b, respectively.

In Figure 1a, a positive standard deviation (s.d.) shock in the real exchange rate results in inflation increasing by 0.05 in the first year, dropping to about 0.02 in the second year, and remaining there for the next forty years. The same own shock after fluctuating in the first ten years between 0.02 and 0.20, depreciates to about 0.10 in the 15^{th} year, and remains there till the terminal 40^{th} year. It also results in changes in interest rates fluctuating in the first eight years around 2.0 and remaining there till the 40^{th} year.

An own unit shock in Δp1 results in its prices dropping from 0.18 in the first year to 0.07 in the second year, although it climbs to 0.10 on the 10^{th} period and remains there till the terminal year. The same one s.d. shock in inflation results in the exchange rate depreciating from 0.2 in the first year and appreciating to -0.08 in the second period. It then fluctuated at a depreciating rate thereafter till the 10^{th} year when it reaches about 0.12 and remains there till the terminal period. The same unit shock in the real exchange rate or depreciation results in the T-Bill rates fluctuating between 1 and 2.8 in the first eight years till it reaches about 2.0 in the 10^{th} year, and remains there till the 40^{th} year.

In Figure 1b, one s.d. of shock in inflation, real exchange rate, T-Bill rates, and petroleum prices results in different depreciation levels, with only one s.d. shock in cocoa prices causing appreciation over the entire forty years. Thus, the impulse response functions we discussed in Figure 1a are very similar to those in Figure 1b, with one exception, which is the effect of one s.d. shock in the real exchange rates on changes in T-Bill rates. The results in Figure 1a indicate that one s.d. shock in the real exchange rates causes an increase in T-Bill rates over the entire forty periods, whereas the same shock results in T-Bill rates mildly fluctuating between negative and positive margins in the first ten years, and diminish thereafter till the terminal year.

Estimates of innovations account or variance decomposition of selected variables are reported in Tables 4a and 4b. In Table 4a the estimates show that 100 percent of the variance in Δp1 is explained by its own innovations in the first year. However, by the fourth year the explanation of the variance of

Δp1 due to its own shock drops to 93.5 percent, while about 4.2 percent of the variance in Δp1 is explained by innovation in Δrxr. The explanation of the variance in Δp1 by its own shocks rises from 94 percent in the 8^{th}-year to 95.1 percent, while the explanation of shocks in Δrxr drops to 3.8 percent in the 40^{th}-year. Innovations in the rest of the variables explain more than 1 percent of the variance in Δp1.This means that there is exchange rate pass-through to inflation Δp1 but the effect is less than 5 percent.

On the other hand, in the first year, innovations in Δp1 dominate the explanation of the variance in Δrxr. In fact, 62 percent of the variance in Δrxr is explained by shock in Δp1, while own shock explains just under 38 percent of that variance, although none of the remaining variables explain any of the variance in Δrxr that year. More than 50 percent of the variance in Δrxr is explained by innovations in Δp1 up to the 8^{th}-year, while own innovations explanation continue to drop to the 8^{th}-year and rise gradually to reach 29.7 percent in the 40^{th}-year. The explanations of the variance in Δrxr from the rest of variables also increase from the 4^{th}-year to the terminal year, with the explanation from innovations in Δcp rising from just under 8 percent in the 4^{th}-year to just under 17 percent in the 40^{th}-year.

Innovations in both Δtbr and Δpetrolp explain just above 4 percent of the variance in Δrxr throughout the period mentioned. Own innovations explain about 82 percent of the variance in Δtbr while shocks in Δp1 explain about 16 percent, with innovations in Δrxr explaining about 1.5 percent in the first year. The composition of the explanations of the variance in Δtbr by shocks from Δtbr, Δp1 and Δpetrolp drop from 50.2 percent, 10.1 percent and 7.7 percent, respectively, in the 4^{th}-year to 43.5 percent, 8.5 percent, and 2.6 percent, respectively, at the terminal 40^{th}-year. During the same period, the variance of Δtbr is explained by innovations in Δrxr and Δcp which rise from 15.3 percent and 16.5 percent, respectively, in the 4^{th}-year to 23.6 percent and 21.7 percent, respectively, in the 40^{th}-year.

In Table 4b where a different time series is used to construct the inflation rate (Δp2) by using 2000 as the base year, we observe that 100 percent of the variance in Δp2 is explained by own innovations in the first year. The composition of the variance in Δp2 explained by shocks in Δrxr, Δtbr, Δcp and Δpetrolp drop continuously from 4.1, 0.2, 1.8 and 3.2 percent, respectively, in the 4th-year to 3.7, 0.1, 0.7 and 2.2 percent, respectively, in the 40th-year. Although the variance in Δp2 explained by own innovations drop to 90.7 percent in the 4th-year, it reverses its course by rising continuously to 93.3 percent in the 40th-year. Thus, measuring inflation by Δp2 also indicates that there is exchange rate pass-through although the effect is not observed in the first year.

The explanation of the variance in Δrxr is dominated by shocks in Δp2 which explain 53 percent of that variance, leaving own shocks to explain the remaining 47 percent of the variance in Δrxr in the first year. Own innovations explanation of the variance in Δrxr drops to 38.8 percent and reverses its course by rising throughout the rest of the period to 47.9 percent in the 40th-year, while innovations in Δp2 explain 28.8 percent of the variance in Δrxr at the 40th-year. The explanation of the variance in Δrxr by innovations in Δpetrolp rises from 11.7 percent in the 4th-year to 16.4 percent in the terminal 40th-year. Innovations in Δcp explain a modest 2.2 percent of the variance in Δrxr in the 4th-year which then rises to 5.8 percent in the 40th-year.

Shocks in Δpetrolp explanation of the variance in Δtbr rises to 10.4 percent in the 4th-year, and drops thereafter continuously to 1.9 percent in the 40th-year. Shocks in Δp2 rise to 15.4 percent in the 8th-year while shocks in Δcp rise to 7.2 percent in 12th-year, but explanation of both Δp1 and Δp2 shocks in the variance of Δtbr drop steadily to 14.2 percent and 7.1 percent, respectively, in the 40th-year.

Shocks in Δtbr explain less than 1.5 percent of the variance in Δrxr in the first year which continues to drop throughout the period till it reaches 1.11 percent in the 40-year. Own shocks explain 72.3 percent of the variance in Δtbr while shocks in Δp2 and Δrxr explain 17.2 and 10.4 percent, respectively, of the variance in Δtbr in the first period. However, whereas the proportion of the variance in Δtbr explained by its own shocks, shocks in Δp2 and Δrxr decline in the 4^{th}-year to 64.6 percent, 14.2 percent, and 5.5 percent, respectively, only the trend of own shocks explanation reverses after the 12^{th}-year and continues to rise to 75.5 percent in the 40^{th}-year. Thus the effect of exchange rate pass-through to changes in interest rate occurs in the first year, but the effect dwindles from just less than 10.5 percent in the first year to 1.2 percent over the long-run. On the other hand, inflation has immediate and long lasting effect on changes in interest rate, while the effect of changes in interest rates reinforces itself over the long-run.

5. Conclusion

The estimated results indicate that both F- and Wald-statistics lie beyond their respective bounds. As a result, the level relationship of the ADL model is rejected and the model is re-estimated by re-specifying the variables in their first difference forms. The results indicate that in both short-run and long-run the size of the exchange rate pass-through to inflation is incomplete, although the size of the long-run estimates are much smaller than the size of the short-run estimates. Additionally, the size of the short-run estimates is slightly larger than the average size of the long-run estimates obtained for ADCs by Gagnon and Ihrig (2004). See also (Taylor, 2000; Mishkin, 2008). This suggests that the country experiences slightly less insulated foreign price variations than ADCs.

The effect of inflation on the depreciation of the cedi is much stronger than the effect of depreciation on the country's inflation. Thus, inflation is self-perpetuating and a chief source of depreciation of the cedi. Consequently, any attempt to arrest depreciation of the national currency must be first directed towards reducing inflation in the country. This will require that the monetary authorities stop engineering expansionary monetary policy shocks, which are the main driver of inflation in the country and also the main source of the depreciation of the cedi.

Furthermore, improvement in cocoa prices in the world market, which is beyond the nation's sphere of influence, is very important in reducing interest rates and strengthening the value of the cedi, whereas the price of petroleum, which is also determined mainly abroad has a significant effect in driving down (or depreciating) the cedi value. It also plays an important role in driving up interest rates in the country, although contrary to expectation, it is not a chief source of fueling inflation in the nation.

Thus, monetary policy is effective and can serve as a stabilizing policy instrument which can be employed to curb inflation and stabilize the national currency. However, we again caution that its abuse through excessive expansionary monetary policy shocks engineered by the monetary authorities result in inflation, which then serves as the primary source of depreciation of the cedi in the country.

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