The Role of Energy Price Shocks in the Transmission of Monetary Policy in an Inflation Targeting Country: The Case of Ghana

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and
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List of abbreviations and acronyms

ATI	Africa Training Institute
BOG	Bank of Ghana
COICOP	Classification of Individual Consumption by Purpose
CPI	Consumer Price Index
DSGE	Dynamic Stochastic General Equilibrium
FPAS	Forecasting and Policy Analysis System
GDP	Gross Domestic Product
IMF	International Monetary Fund
MPC	Monetary Policy Committee
MPR	Monetary Policy Rate
OLS	Ordinary Least Squares
QPM	Quarterly Projections Model
RMSE	Root Mean Square Error
SVAR	Structural Vector Autoregressive
UIP	Uncovered Interest Parity
VAR	Vector Autoregression

Abstract

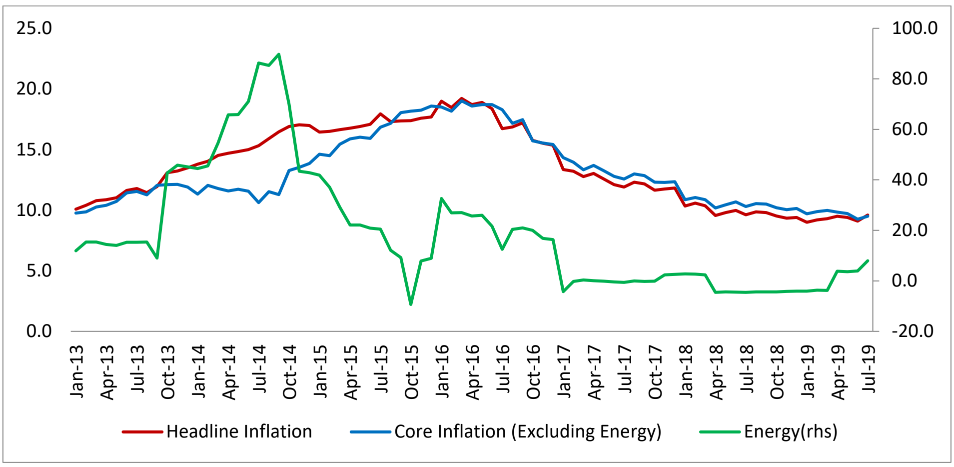
Energy inflation has become more volatile and has evolved independently of other components of headline inflation over the years. Therefore, the use of one Phillips curve to capture short-run inflation dynamics may be inadequate in terms of helping the monetary policy authorities to determine the appropriate path of the monetary policy rate. In particular, such an approach may introduce noise into the model system, making it difficult to get reliable forecasts for inflation. We extend the existing New-Keynesian model to include separate Phillips curves for energy inflation and non-energy inflation. This approach would help the monetary policy authority in Ghana to gain a deeper understanding of how shocks to energy prices affect inflation, thereby leading to informed decisions about the appropriate path of the monetary policy rate in Ghana. We also incorporate a fiscal block to capture the effects of fiscal deficits on inflation in Ghana. We use the extended model to study the transmission mechanisms of the real economy, and of the exchange rate. This analysis allows us to understand the importance of these shocks in explaining inflation developments in Ghana and their implications for monetary policy. The results are mixed, indicating that isolating energy price from the rest of prices in the CPI basket does not necessarily improve the forecasts of the key macroeconomic variables, and will therefore not necessarily lead to better policy outcomes.

Keywords: Monetary Policy, Inflation Targeting, Energy Prices
JEL classification codes: E31, E47, E52

1. Introduction

Inflation forecasts play a central role in any inflation targeting framework. Forecast deviations are normally driven by volatile components of variables. Monetary policy does not directly respond to movements in these volatile components. However, these components affect forecast performance and, therefore, influence monetary policy decisions. It is, therefore, important to isolate these volatile components to enhance forecast performance, and therefore improve monetary policy decision-making. Energy inflation in Ghana has become more volatile, and has evolved independently of other components of headline inflation over the years (see Figure 1). Therefore, the use of one Phillips curve to capture short-run inflation dynamics may be inadequate in terms of forecast performance. Such an approach may introduce noise into the model system, making it difficult to get reliable forecasts for inflation.

Figure 1: Headline, core, and energy inflation in Ghana



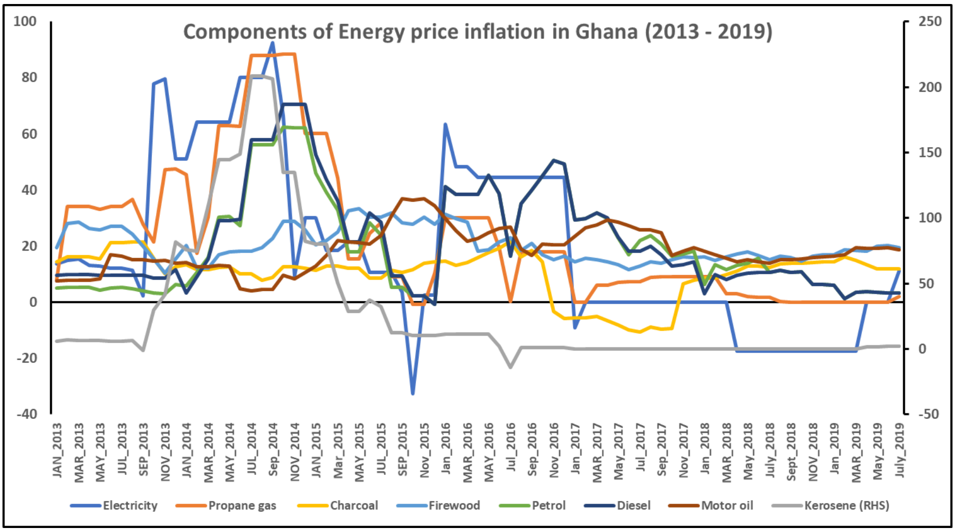
Source: Bank of Ghana.

This study makes four main contributions to the literature. First, we extend the existing New-Keynesian model to include separate Phillips curves for energy and non-energy inflation. This approach would help improve forecast performance.

As a result, the monetary policy authorities in Ghana can make informed decisions about the appropriate path of the monetary policy rate in Ghana. Second, we use the extended model to study the transmission mechanisms of shocks to energy and non-energy inflation in Ghana. We use data from the period 2013.01–2019.07. This analysis allows us to understand the importance of these shocks in explaining inflation developments in Ghana and their implications for monetary policy. Third, we also compare the forecast performance of the extended model with the existing model. Finally, we incorporate a fiscal block to capture the effects of fiscal deficits on inflation in Ghana.

One approach of addressing the volatile energy inflation in our model is to decompose energy inflation into its components and model the specific component driving the volatility. The energy market in Ghana is made up of the following sources of power: hydroelectricity, gas, kerosene, charcoal, firewood, petrol, diesel, and motor oil. The deregulation of the energy sector in 2007 removed all subsidies. Figure 2 shows the components of the energy inflation.

Figure 2: Components of energy inflation in Ghana (2013-2019)

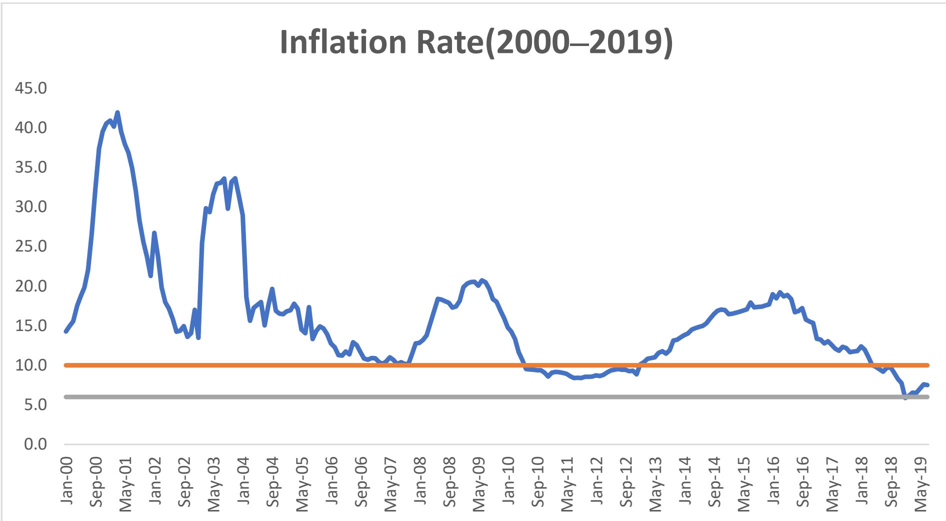


Source: Ghana Statistical Service

It is clear that no single component appears to be the main driving force behind the movements in energy price inflation. Therefore, modelling a weighted average of the components is enough for our purpose. We, therefore, proceed to disaggregate the Phillips curve into energy and non-energy inflation equations. Decision-making under the inflation targeting framework requires reasonably accurate inflation forecasts. Therefore, attempts to improve the existing model by disaggregating the Phillips curve into energy and non-energy components will enhance inflation forecast performance, and thereby improve monetary policy decision-making in Ghana.

This paper is timely as deviations from the inflation target have become more persistent, and may therefore become costly to bring down in terms of output loss. For example, inflation deviated from the band for almost five years, 2013–2018 (see Figure 3). It is, therefore, reasonable to suggest that attempts by monetary policy to contain inflation during this period may have adversely weighed on output. Although Alichi et al (2018) observed that the output loss due to the disinflation process did not appear to be that big. They also cautioned that their results were only suggestive and should not be used as evidence for policy.

Figure 3: Inflation rate in Ghana



Source: Bank of Ghana.

The results are mixed, indicating that isolating energy price from the rest of prices in the Consumer Price Index (CPI) basket does not necessarily improve the forecasts of the key macroeconomic variables, and will, therefore, not necessarily lead to better policy outcomes.

We also investigated a fiscal shock and aggregate demand shock, and the results were similar. This suggests that a fiscal policy shock is a major component of the aggregate demand shock. However, the magnitude of the response to the aggregate demand shock was bigger, implying that the other components of aggregate demand were also important. Therefore, adding the fiscal block to the model allows the monetary policy authorities to capture the separate effects of the fiscal policy shock from the overall aggregate demand shock. This suggests that policy coordination is very critical for macroeconomic stability.

The rest of this paper is structured as follows. After this introductory section, Section 2 reviews the existing literature on the Forecasting and Policy Analysis System (FPAS) and inflation in Ghana. Section 3 discusses the evolution of monetary policy in Ghana, from the controlled regime of the 1980s to the current inflation targeting monetary policy framework. The methodology and empirical results are discussed in sections 4 and 5, respectively. The paper ends with the conclusions and policy recommendations in Section 6.

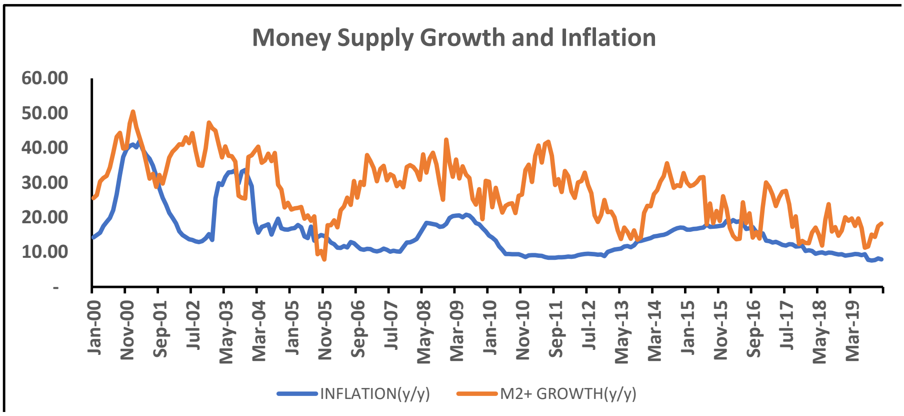
2. Monetary policy in Ghana

Ghana's monetary policy framework

The monetary policy framework in Ghana has evolved over time. Prior to the International Monetary Fund (IMF) and the World Bank sponsored economic reforms in 1983, Bank of Ghana (BOG) operated largely a direct controlled system of monetary management. Under this monetary policy regime, credit was directed to government's priority areas (Bawumia, 2010). The inefficiencies associated with this regime led to high and volatile inflation. It, therefore, became clear that the direct control regime had to be abandoned.

The performance of inflation in Ghana was to a large extent driven by direct monetization of deficits and pressures on the BOG to maintain more accommodative monetary policy stance than was desirable (IMF, 2013). Therefore, the money targeting framework was deemed appropriate to bring down inflation. However, over time, it became clear that the link between inflation and monetary aggregates had broken down (see Figure 4). In July 2002, Ghana began preparatory work to transition to an inflation targeting monetary policy framework, and formally adopted an inflation targeting monetary policy framework in 2007 as part of a broader set of reforms aimed at anchoring inflation expectations through accountable, transparent, and effective communication of monetary policy decisions to government, the investor community, and the general public. International evidence shows that countries that adopted the inflation targeting monetary policy framework experienced low inflation in the long run (Roger and Stone, 2005; Mishkin and Schmidt-Hebbel, 2007).

Figure 4: Money supply and inflation

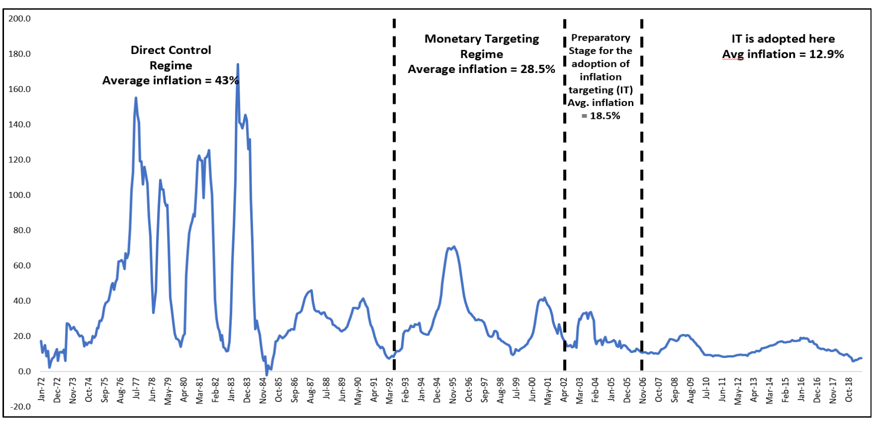


Source: Bank of Ghana

The appropriate path for monetary policy in Ghana, given the inflation target of 8 ± 2 percentage points and macroeconomic fundamentals, is based on a reduced-form New-Keynesian model that includes the open economy version of the traditional IS curve, a hybrid Phillips curve to capture the short-run dynamics of headline inflation, a version of uncovered interest parity (UIP) condition that captures the financial relationship with the rest of the world, and Bank of Ghana's policy reaction function.

Figure 4 shows that inflation targeting was initially successful in reducing inflation. The level and volatility of inflation dropped significantly after the adoption of this framework. However, as shown in Figure 5, inflation in Ghana has rarely stayed within the band. It is, therefore, important to improve the model that underpins our inflation forecast to enable Bank of Ghana to tackle the persistent inflation problem.

Figure 5: Inflation history in Ghana (1970-2014)



Source: Bank of Ghana.

Implementation of the Forecasting and Policy Analysis System (FPAS) in Ghana

The Forecasting and Policy Analysis System (FPAS) has gained popularity among central banks in emerging markets and developing economies due to its simplicity and flexibility. The FPAS process in Ghana can be summarized as follows: data collection and analysis by sector experts, setting initial conditions, forecast review, drafting monetary policy report, pre-MPC meeting (staff level meeting), monetary policy committee (MPC) meeting, press conference, and publishing monetary policy report.

Monetary policy decisions under the inflation targeting framework rely heavily on the inflation forecast that depends on a well-specified model. The process starts with data collection and analysis by sector experts. This is followed by setting initial conditions for the inflation forecast. Inflation is then forecast, based on the quarterly projection model. Ghana's quarterly projection model, like many other central banks, is a semi-structural macroeconomic model with four main blocks: aggregate demand or IS-type equation, price setting or New Phillips curve, uncovered interest rate parity equation, and monetary policy rule.

The initial forecast, along with sector reports, is presented at a staff kick-off meeting. The meeting is intended to provide comments and suggestions to improve the sector reports. The meeting is particularly important for the model team since forecast assumptions are revised based on these presentations. After this preparatory meeting, the sector experts fine-tune their reports and the model team produce their final forecast incorporating the additional information from the sector presentations.

The revised sector reports and the final inflation forecast are presented to the monetary policy committee which meets every other month. The Bank of Ghana forecasts inflation considering a broad set of indicators, including both domestic and external factors. After weighing the balance of risks to inflation, the monetary policy committee adjusts the monetary policy rate (MPR) to influence the cost of funding for banks in the interbank market, and ultimately the level of retail deposit and lending interest rates. The meeting ends with a press conference to announce the decision of the committee and factors that went into their decision. In addition to the press conference, Bank of Ghana publishes all the sector reports that formed the basis of the monetary policy committee's decision.

Various central banks (Georgia, Indonesia, Vietnam, South Africa, etc.) have tried to extend the baseline quarterly projection model to reflect current developments and trends in their economies. In Ghana's context, the inclusion of explicit roles for energy and non-energy inflation would improve the existing monetary policy framework and thereby strengthen monetary policy decision-making in the country. In addition, Andrle et al (2013) argue that an important task of monetary policy analysis is to disentangle the role of external factors versus the contribution of monetary policy decisions and other domestic factors, and the FPAS model is well-suited to accomplish that task. Apart from this study enriching the forecasting framework of central banks across the world, it demonstrates how the Phillips curve can be disaggregated to incorporate divergence in the different components of inflation in monetary policy formulation.

3. Literature review

We study the impact of energy price shocks on the transmission of monetary policy shocks in Ghana using a quarterly projection model with separate equations for energy and non-energy inflation. Our model is an extension of the semi-structured New-Keynesian model first developed by Berg et al (2006) which is based on a micro-founded model by Gali and Monacelli (2002) and further developed by Gali (2008). The model consists of an aggregate demand (or IS) curve, a price-setting (or Phillips) curve, a version of the uncovered interest parity condition, and a monetary policy reaction function.

Since its publication in 2006, the Berg, Karam Laxton model has been extended by a number of central banks across emerging and developing economies. The flexibility and simplicity of the model made it an integral part of monetary policy decision-making in many central banks operating money targeting and inflation targeting regimes. For example, Andrle et al (2013) extended the baseline model developed by Berg et al (2006) by providing explicit role for food and non-food Phillips curves in the existing framework. In particular, they develop a semi-structural New-Keynesian open-economy model with separate food and non-food inflation dynamics for forecasting and monetary policy analysis in low-income countries and apply it to Kenya.

They use the model to run several policy-relevant exercises and found that, while imported food price shocks have been an important source of inflation, both in 2008 and more recently, accommodating monetary policy has also played a role, most notably through its effect on the nominal exchange rate. Their model correctly predicted that a policy tightening was required, although the actual interest rate increase was larger than forecast. Finally, they discussed implications for the use of model-based policy analysis in low income countries.

Dizioli and Schmittmann (2015) modified the baseline model by placing a larger weight on output stabilization as the intermediate target to achieve inflation stability, while allowing greater exchange rate flexibility. They used the model to analyse domestic demand shocks, external demand shocks, food price shocks, and the effects of tighter U.S. monetary policy on the Vietnamese economy. They concluded that the optimal monetary policy rule delivered greater macroeconomic stability for Vietnam under the shock scenarios.

Some studies that investigate the role of energy price shocks rely on dynamic stochastic general equilibrium (DSGE) models. These are quantitative models that allow central banks the flexibility to investigate the impact of shocks on macroeconomic outcomes. For example, Dagher et al (2010) used a calibrated multi-sector DSGE model to analyse the likely impact of oil windfalls on the Ghanaian economy, under alternative fiscal and monetary policy responses. They distinguished between the short-run impact associated with demand-related pressures and the medium-run impact on competitiveness and growth. They concluded that the impact of oil windfall on inflation and the real exchange rate could be moderate, especially if the fiscal authorities smoothened oil-related spending or increased public spending's import content. However, a policy mix that resulted in both a fiscal expansion and the simultaneous accumulation of the foreign currency proceeds from oil as international reserves—to offset the real appreciation—would raise demand pressures and crowd-out the private sector. In the medium term, the negative impact on competitiveness—resulting from "Dutch Disease" effects—could be small, provided public spending increased the stock of productive public capital. These findings highlighted the role of different policy responses, and their interaction, for the macroeconomic impact of oil proceeds.

Morrisey and Spreng (2020) provided analysis of the macroeconomic management implications of becoming an exporter of oil, taking the case of Ghana and applying the results to Uganda as a prospective exporter. Their paper proceeded in two steps. First, they constructed a Dynamic Stochastic General Equilibrium (DSGE) model of a primary commodity exporting developing country calibrated to Ghana and Uganda and simulated the impulse response to shocks to the oil price and oil production. Second, they used parameters from the DSGE model to obtain priors for parameter values and then used a Structural Vector Autoregressive (SVAR) with monthly data from 2001 to 2019 to estimate the response to oil shocks as an importer for both countries and as an exporter for Ghana after 2010. The DSGE results suggested that, although an oil price shock generated appreciation and initial output falls, there were reductions in interest rates and inflation, and ultimately output increases. The larger the oil sector, the greater the appreciation and inflationary effects, but output rose more quickly and there are larger increases in wages and taxes. The analysis suggested that the adoption of inflation targeting, in conjunction with an improved monitoring of macroeconomic developments, mitigated the effects of oil price shocks on domestic variables in Ghana and Uganda.

Other studies that looked at the behaviour of inflation in Ghana used Vector Autoregression (VAR) models. For example, Kovanen (2011a) showed that money has only limited information value for future inflation in Ghana over a typical monetary policy implementation horizon (four to eight quarters). However, currency depreciation and demand pressures (as measured by the output gap) were shown to be important predictors of future price changes. In addition, inflation inertia was high and inflation expectations were largely based on backward-looking information, suggesting that inflation expectations were not well-anchored and hence more was needed to strengthen the credibility of Ghana's inflation targeting regime.

Bleaney et al (2019) observed that the inflation targeting regime had been in place in Ghana since 2007, but the inflation rate had remained persistently high. During the period 2007–2017, inflation exceeded the announced target by four percentage points on average, despite the target never falling below a relatively unambitious 8% per annum. They investigated whether poor conduct of monetary policy was responsible for this outcome, and found that it was not. Monetary policy reaction functions were similar to those estimated for countries with successful monetary policies, and interest rates responded in the theoretically recommended way to inflation shocks.

We differ from previous studies in several ways. First, we develop separate Phillips curves for energy and non-energy inflation in order to capture the various driving forces behind inflation dynamics in Ghana. Second, we develop a fiscal block to take care of the effects of deficits on inflation. Third, we use the disaggregated Phillips curve to study the transmission mechanism of various shocks to the Ghanaian economy. In the next section, we outline the existing model and the extensions we are proposing to enhance the existing framework.

4. Methodology

Model specification

This study is based on a semi-structured New-Keynesian model developed by Berg et al (2006). Versions of this model are used as part of the Forecast and Policy Analysis System (FPAS) that is used by many central banks worldwide. The semi-structured model has four basic equations: an aggregate demand or IS curve that relates the level of real economic activity to expected and past real economic activity, the real interest rate, and the real exchange rate; a price-setting or Phillips curve that relates inflation to past and expected inflation, the output gap, and the exchange rate; an uncovered interest parity condition for the exchange rate, with some allowance for backward-looking expectations; and a rule for setting the policy interest rate as a function of the output gap and expected inflation. Micro-foundations of these models are shown by Gali and Monacelli (2002) and Gali (2008). The equations of the model are as follows:

Aggregate demand

$$\hat{y}_t = \beta_1 E_t(\hat{y}_{t+1}) + \beta_2 \hat{y}_{t-1} - \beta_3 mci_t + \beta_4 \hat{y}_t^* + \varepsilon_t^y \qquad (1)$$

where, $\hat{y}$ is the domestic output gap, (in log terms), computed using the Kalman Filter within the model set-up, $\hat{y}^*$ is the foreign output gap, ε_t^y is an aggregate demand shock, and mci is the real monetary condition index defined as a weighted average of real interest rate and the real exchange rate gap.

That is:

$$mci_t = b_1 \hat{r}_t + (1 - b_1)(-\hat{z}_t) \qquad (2)$$

where, $\hat{z}$ is the real exchange rate gap (measured so an increase is a depreciation, in percentage points) and is adjusted for differences in price levels.

That is:

$$z_t = s_t + p_t^* - p_t \qquad (3)$$

where, s_t is nominal exchange rate, p^* is the foreign CPI in natural log, and p is domestic CPI in natural log.

Phillips curve

$$\pi_t = \alpha_1 E_t(\pi_{t+4}^4) + (1 - \alpha_1)\pi_{t-1}^4 + \alpha_2 rmc_t + \varepsilon_t^\pi \qquad (4)$$

where, π is inflation and π^4 is quarter-on-quarter annualized, real marginal costs, *rmc* is the weighted average of the real exchange rate gap and the output gap.

$$rmc_t = \alpha_3 \hat{y}_t + (1 - \alpha_3)\hat{z}_t \tag{5}$$

It is related to domestic producers (approximated by the output gap, $\hat{y}^*$) and to importers (approximated by the real effective exchange rate gap, $\ddot{Z}$). ε_t^{π} is the supply shock.

The Philips curve embodies three ideas. First, that the fundamental role of monetary policy is to provide a nominal anchor for inflation. Second, that monetary policy influences inflation through its effects on output and the exchange rate. Third, that the central bank cannot consistently fool people.

Exchange rate

$$z_t = z_{t+1}^w - [r_t - r_t^* - \rho_t^*]/4 + \varepsilon_t^z \tag{6}$$

where, z_{t+1}^w is a weighted average of the backward-looking and the forward-looking expectations, r_t^* is the real U.S. interest rate, ρ_t^* is the equilibrium risk premium, and ε_t^z is the real exchange rate shock. The interest rate term is divided by four because the interest rates and the risk premium are measured at annual rates, where z_t is quarterly.

Rational expectations were allowed for exchange rates such that:

$$z_{t+1}^w = \delta_1 E_t(z_{t+1}) + (1 - \delta_1) z_{t-1} \tag{7}$$

When δ_1=1 , Dornbusch (1976) states that overshooting dynamics are recovered.

Monetary policy rule:

$$i_t = \gamma_1 i_{t-1} + (1 - \gamma_1)(i_t^* + \gamma_2[E_t(\pi_{t+4}^4) - \pi_t^*] + \gamma_3 \hat{y}_t) + \varepsilon_t^i) \tag{8}$$

The policy rate is a function of its own lag, equilibrium nominal interest, deviation of inflation from target, and the output gap. ε_t^i is a policy shock.

Model extensions

In order to explore the role of energy price shocks in the transmission of monetary policy, we make key extensions to the Phillips curve. As indicated in the introduction, the divergence of the energy component of inflation from 2010 is an indication of changes in the fundamental determinants of the headline inflation and, therefore, the model needs to reflect these changes. This decomposition enables us to have different steady-states for the different CPI components, while the headline inflation equals inflation target. We disaggregate the CPI into two components (energy and non-energy) and specify Phillips curve for each component based on specific variables. We proceed along the IMF's specifications.

First, we specify the Phillips curve for non-energy inflation as a forward-looking open economy curve allowing for long-term changes in relative price of non-energy elements to headline inflation, $\bar{p}_t^{non-energy}$, which depends on past non-energy inflation ($\pi_{t-1}^{-Non-energy}$); headline inflation expectation $E_t(\pi_{t-1})$; and real marginal costs (rmc_t):

$$\pi_t^{non-energy} = \vartheta_1 \pi_{t-1}^{non-energy} + (1-\vartheta_1)\left(E_t(\pi_{t+4}) + \Delta\bar{p}_t^{non-energy}\right) + \vartheta_2 rmc_t + \varepsilon_t^{non-energy} \tag{9}$$

Real marginal costs (rmc) is the weighted average of the real effective exchange rate gap and the output gap. It is related to domestic producers (approximated by the output gap, $\hat{y}_t$) and to importers (approximated by the real exchange rate gap for “non-energy” items of the CPI basket, $\hat{p}_t^{non-energy}$).

$$rmc_t = \vartheta_3 \hat{y}_t + (1-\vartheta_3)\left(\hat{z}_t - \hat{p}_t^{non-energy}\right) \tag{10}$$

The real exchange rate is calculated using the headline CPI and should be used as the variable approximating real marginal costs of importers only if the Phillips curve is designed for the headline inflation. In order to properly capture the impact on non-energy inflation, the real exchange rate has to be transformed into a “non-energy inflation real exchange rate”.

That is:

$$\hat{z}_t - \hat{p}_t^{non-energy} = (s + p^* - p) - (p^{non-energy} - p) = s + p^* - p^{non-energy} \tag{11}$$

The Phillips curve for energy prices captures the evolution of domestic energy prices, assuming a pass-through of the world oil prices to domestic energy prices. Such pass-through is elaborated in a simple way, where the domestic energy inflation depends on its past value: overall inflation expectations augmented for the eventual long-term change in relative price of energy to headline inflation, $\vartheta_{31}\pi_{t-1}^{energy}$; changes in the world oil prices, Δp_t^{oil}; and changes in the nominal exchange rate against the US dollar, Δs_t^{USD}.

$$\pi_t^{energy} = \vartheta_{31}\pi_{t-1}^{energy} + (1-\vartheta_{31}-a_{32})\left(E_t(\pi_{t+4}) + \Delta\bar{p}_t^{energy}\right) + \vartheta_{32}\varphi_t + \varepsilon_t^{energy} \tag{12}$$

$$\varphi_t = \left(\Delta p_t^{oil} + \Delta s_t^{USD}\right) \tag{13}$$

Headline inflation is then recovered as a weighted sum of energy and non-energy inflation components to arrive at headline inflation based on the relevant weights in the CPI basket.

$$\pi_t = w^{energy}\pi_t^{energy} + (1-w^{energy})\pi_t^{non-energy} \tag{14}$$

Finally, we extend the aggregate demand equation by including fiscal impulse, FIMP.

$$\hat{y}_t = \beta_1 E_t(\hat{y}_{t+1}) + \beta_2 \hat{y}_{t-1} - \beta_3 mci_t + \beta_4 \hat{y}_t^* + \beta_5 FIMP_t + \varepsilon_t^y \quad (15)$$

The total deficit d_t, is disaggregated into cyclical deficit dc_t, and structural deficit ds_t, :

$$d_t = dc_t + ds_t \quad (16)$$

The cyclical deficit dc_t, is measured as a percentage Φ_1 of the output gap $\hat{y}_t$,

$$dc_t = -\mu_1 \hat{y}_t \quad (17)$$

We model the structural deficit as a structural AR (1) process, where ss_ds is steady-state deficit as defined in the fiscal rule.

$$ds_t = \mu_2 ds_{t-1} + (1 - \mu_3) ss\_ds + \varepsilon_t^{ds} \quad (18)$$

We define the fiscal impulse as a shock to the structural deficit.

$$FIMP_t = \varepsilon_t^{ds} \quad (19)$$

Testing the reliability of the model

The reliability of the model will be tested using impulse response functions of the key variables of the model. In particular, we will explore the impulse response functions using the theoretical relationships among the key variables and ensure that the model on which our findings are based produce impulse responses that are consistent with economic theory. We use the Root Mean Square Error (RMSE) assessment to evaluate the in-sample forecast performance of the two models.

Data

Data on inflation, disaggregated by Classification of Individual Consumption by Purpose (COICOP), was obtained from Ghana Statistical Service; while domestic monetary variables were compiled from Bank of Ghana. Fiscal data was obtained from Ministry of Finance. Foreign variables and their forecasts were purchased from Consensus Forecast.

5. Empirical results

In this section, we first describe how a shock to the energy components of the CPI basket affects monetary policy transmission in Ghana, and what the optimal path for monetary policy instruments and headline inflation are in the medium term. We first discuss how the model was calibrated before discussing the results.

Model calibration

The complex nature of the analytical model described above implies that there is no closed-form solution. We, therefore, evaluated the analytical model numerically. There are two sets of model parameters that are calibrated to fit the data for the Ghanaian economy. First, calibration of trend parameters such as domestic inflation target, domestic trend real interest rate, foreign trend real interest rate, equilibrium real appreciation or depreciation, and potential output was done. Second, calibration of the individual equation parameters that helps to pin down the business cycle properties of the model was done.

Following Berg et al (2006), we rely on economic theory, international experience, and domestic economy stylized facts based on previous research on the Ghanaian economy. Where data was available, we used estimation to complement our expert judgment.

Model parameters

Aggregate demand

Output gap persistence, β_1, measures backward-looking expectations formation of economic agents. For non-explosive models, this parameter should vary between 0 and 1. We calibrated this parameter based on an Ordinary Least Squares (OLS) regression of a log of output on its lagged value and a trend.

Impact of real sector expectations on output gap, β_2, measures the forward-looking expectations in the model. Together with β_1, the parameters measure the impact of expectations in the model, therefore $\beta_1 + \beta_2 = 1$ ($\beta_2 = 1 - \beta_1$).

β_3 measures the pass-through from real monetary conditions to real economy. Real monetary conditions are measured as a weighted average of the real exchange rate gap and the real interest rate gap. Tighter real monetary conditions (an increase in real monetary conditions index) play a dampening effect on real sector activity, therefore this index comes into the aggregate demand equation as a negative. Our calibration of this parameter is based on the existing practice at the Bank of Ghana, which was originally based on an impulse-response function in a structural VAR.

β_4 measures the impact of fiscal shocks on aggregate demand. We calibrated this parameter from an OLS regression of the log of GDP on the fiscal deficit. Impact of foreign demand on the output gap, β_5, is measured as the export to GDP ratio.

Phillips curve

The structure of both energy and non-energy equations is the same, and we calibrate the parameters using the same concepts. In both equations, inflation expectations are measured as an average of expectations of forward-looking and backward-looking agents in the goods markets. We, therefore, estimate from OLS regression of the rate of inflation (quarter-on-quarter) on its lagged value and complement with expert assessment based on the impulse response functions.

The impact of real marginal costs on inflation (or policy pass-through), has a value that typically varies between 0.1 (low impact and high sacrifice ratio) to 0.5 (strong impact and low sacrifice ratio). The higher the parameter, the less costly is disinflation. We complemented an OLS regression of the rate of inflation on output gap with comparing the output gap and the decline in inflation during a clear disinflationary period (Ball, 1994). The relative weight of output gap and real exchange rate gap in real marginal costs, a_3,and $(1 - a_3)$, is the share of imported goods in the consumption goods basket.

Exchange rate pass-through to domestic prices β_3, is calibrated based on an OLS regression of the rate of inflation on movements in the exchange rate.

Uncovered Interest Parity (UIP condition

Exchange rate persistence or central bank presence on the FOREX market, varies between zero (forward-looking FOREX market or no central bank interventions) and 0.9 (either heavily backward-looking FOREX agents or a central bank heavily intervening on the FOREX market). We calibrate this parameter based on the existing Bank of Ghana Quarterly Projections Model (QPM).

The policy reaction function

The policy reaction function in the model is a Taylor-rule type of policy reaction function, where the policy rate depends on a weighted average output gap and inflation gap. We use the parameters from the existing Bank of Ghana Quarterly Projections Model (QPM).

Steady state parameters

The steady state parameters of this model are set at the values of the existing Ghana model to make the model results comparable.

Table 1: Model parameters

Parameter	Value
Aggregate demand	
β_1	0.4
β_2	0.3
β_3	0.1
β_4	0.1
β_5	0.5
b_1	0.8
Non-energy equation	
ϑ_1	0.6
ϑ_2	0.4
ϑ_3	0.7
Energy equation	
ϑ_1	0.4
ϑ_1	0.2
ϑ_1	0.6
UIP	
δ_1	0.6
Monetary policy rule	
γ_1	0.75
γ_2	1.3
γ_3	0.1

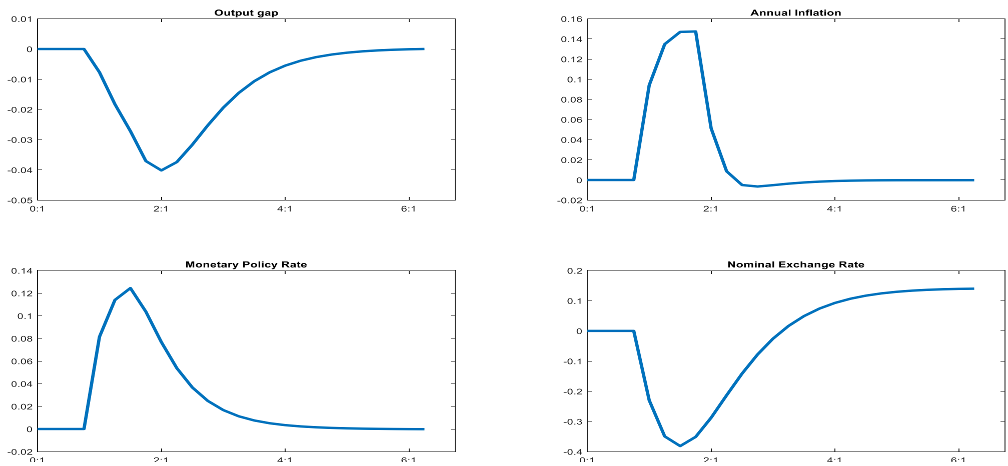
Model results

Impulse response

In addition to analysing the impulse response functions of energy price shock, we discuss the response of inflation, real GDP growth, monetary policy rate, and nominal exchange rate to aggregate demand, aggregate supply, monetary policy, and fiscal shocks. For each shock, we compare the impulse response functions for the model with one Philips curve and the model in which the Phillips curve is disaggregated into energy price equation and non-energy price equation. The goal is to see if the dynamics are consistent with economic theory.

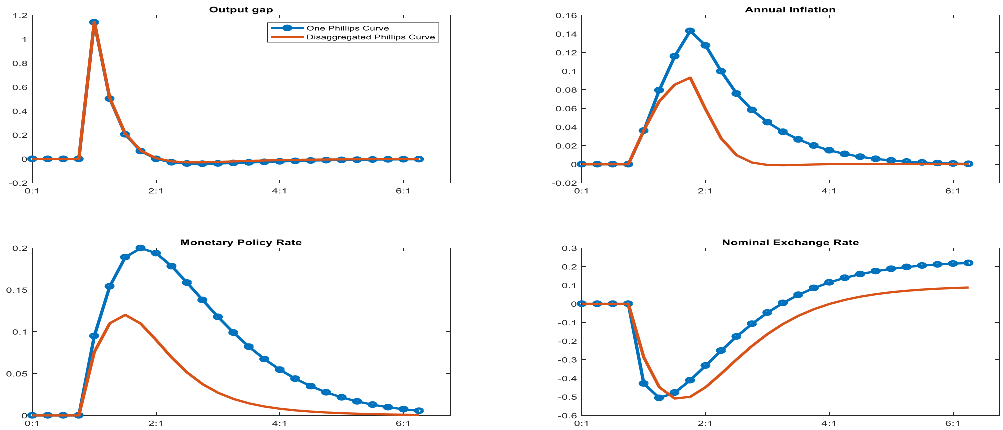
We analyse the effects of energy price shock on output gap, inflation, monetary policy rate, and the nominal exchange rate. The results are shown in Figure 6. Note that the model with one Phillips curve does not have a separate energy equation. As a result, the discussion here is focused mainly on the disaggregated model. A positive energy price shock initially led to higher inflation, which engineered a stronger monetary policy response leading to nominal appreciation of the exchange rate. The combined effect of these responses is to dampen aggregate demand, leading to a widening of the output gap negatively. However, after four quarters, the output gap recovered strongly as inflation declined and monetary policy became more accommodative.

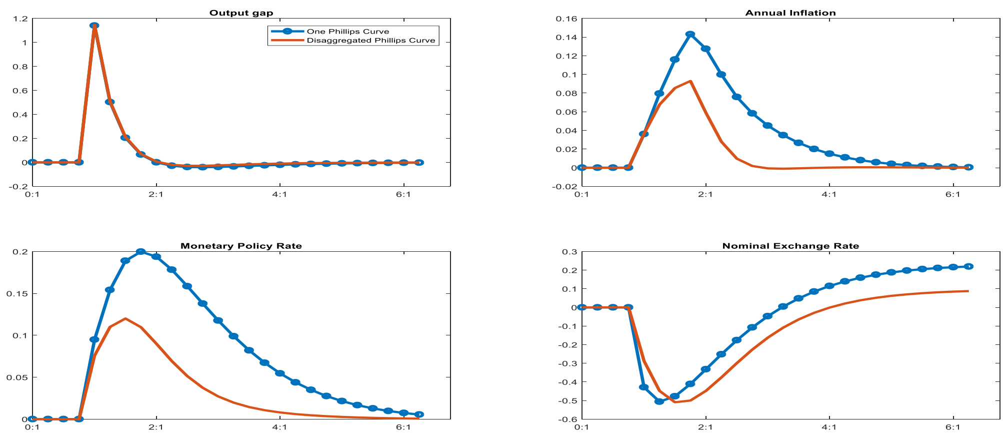
Figure 6: Energy price shock



The results of the aggregate demand shock are shown in Figure 7. In response to an aggregate demand shock, output gap improves sharply for both models, pushing inflation up. The higher inflation results in monetary policy tightening, causing the exchange rate to appreciate. Annual inflation responded stronger to the demand shock, requiring a stronger monetary policy response. This suggests that monetary policy reaction has been stronger in the aggregate model than it would have been if energy price were isolated.

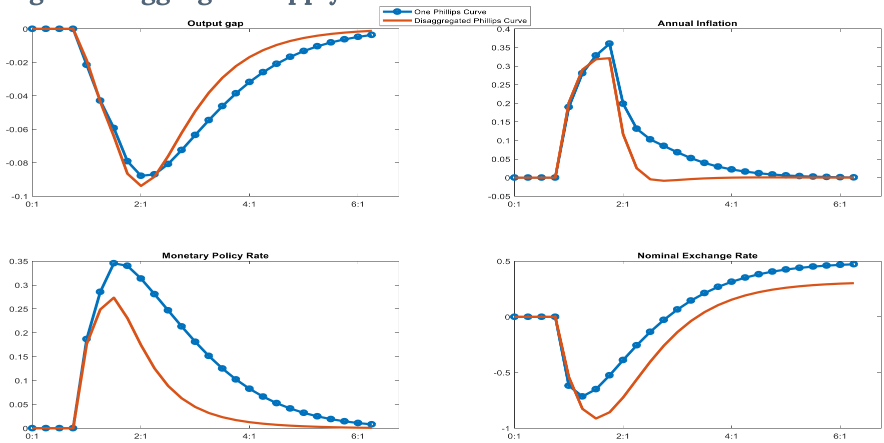
Figure 7: Aggregate demand shock





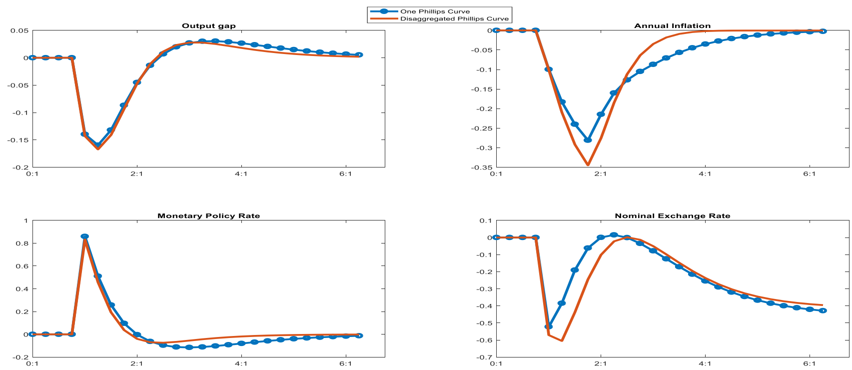
The results of the aggregate supply shock are shown in Figure 8. We measure aggregate supply shock in the disaggregated model as a weighted sum of the shocks to the two price equations. In response to an unfavourable aggregate supply shock (positive cost-push shock), inflation rose for three quarters before declining. As a result, monetary policy responded more forcefully, leading to a decline in output gap for both models. The strong response in the policy rate may have contributed to the nominal appreciation of the domestic currency.

Figure 8: Aggregate supply shock



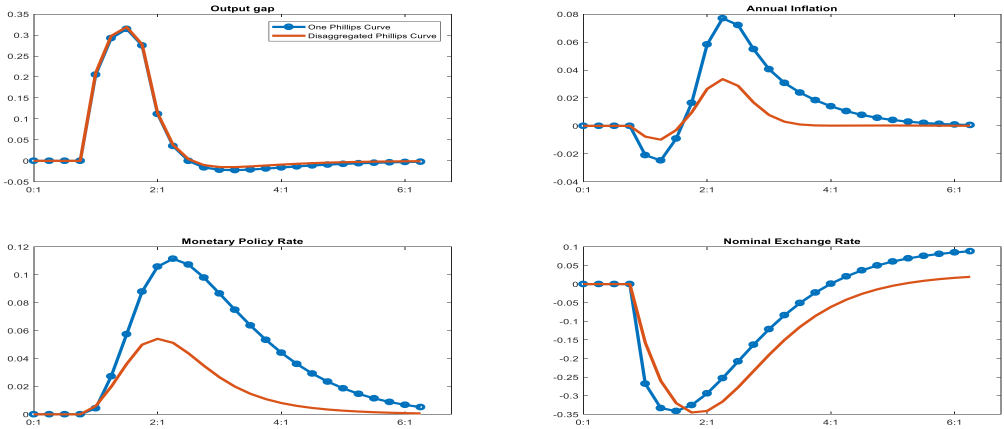
In response to a positive monetary policy shock, inflation fell for three quarters in both models. The nominal exchange rate appreciated sharply and peaked after two quarters (see Figure 9). The net effect of these responses on the real sector was the widening of the negative output gap. The sharp increase in interest rate led to exchange rate appreciation. The results are thus consistent with economic theory and the evidence for emerging market and developing economies.

Figure 9: Monetary policy shock



Finally, our model includes a fiscal block to try to capture the effects of fiscal impulse on macroeconomic variables in the economy. The results of the fiscal impulse are shown in Figure 10. Note that the results are similar to the results discussed under aggregate demand shock. It is consistent with the larger role of fiscal policy in aggregate demand. However, the magnitudes of the response of the various variables are bigger for the aggregate demand shock than the fiscal policy shock. This may be due to the fact that the effect of fiscal policy, although large, is not the only component of aggregate demand.

Figure 10: Fiscal shock



Baseline forecasts of key variables

Figure 11 compares the baseline forecast for inflation, real GDP growth, monetary policy rate, and nominal exchange rate for the two models. The results show that the disaggregated model forecasts lower inflation and, therefore, a lower policy rate than the model with one Phillips curve over the medium term. In addition, both models forecast a depreciation of the nominal exchange rate during the forecast horizon, but more so for the disaggregated model. The disaggregated model forecasts a relatively higher growth than the model with one Phillips curve.

Forecast performance evaluations of the two models are shown in Table 2a and Table 2b. We compute the in-sample forecast Root Mean Square Error for the two models. The results show that forecasts for output and exchange rate perform better in the aggregate model than in disaggregate model. However, the results are better for policy rate, interbank rate, and the real interest rate in the disaggregated model. These mixed results indicate that isolating energy price from the rest of prices in the CPI basket does not necessarily improve the forecasts of the key macroeconomic variables and will, therefore, not necessarily lead to better policy outcomes.

Figure 11: Baseline forecast of inflation for both models

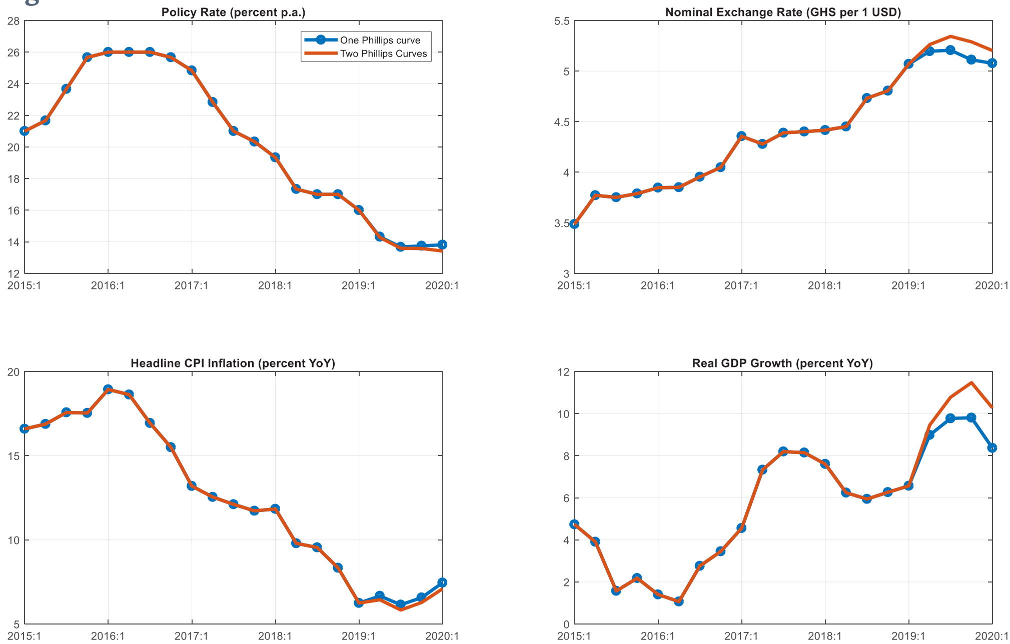


Table 2a: Root mean squared error: One Phillips curve

	1q	2q	3q	4q	5q	6q	7q	8q
Output Gap [Y_gap]	0.51	0.66	0.54	0.31	0.41	0.52	0.52	0.51
YoY GDP growth [d4Y]	0.51	0.66	0.54	0.31	0.81	1.06	0.94	0.60
Policy rate [RCB]	0.85	1.05	1.19	1.41	1.24	1.06	1.15	1.04
Short-term interbank market rate [R]	0.88	1.07	1.25	1.22	0.88	0.71	0.76	0.76
Nominal exchange rate [S]	4.91	3.56	2.52	2.03	1.76	1.46	1.58	1.60
Nominal FX depreciation [dS]	19.63	10.23	8.42	7.97	6.84	6.82	6.22	4.50
Annual inflation [d4P]	0.99	1.68	2.08	2.51	1.89	1.21	0.90	0.47
Real Exchange Rate Gap [Z_gap]	4.40	2.96	2.29	3.32	3.36	2.79	1.98	1.00
Real Interest Rate Gap [RR_gap]	1.24	1.43	1.52	0.95	0.84	0.81	1.02	1.19

Table 2b: Root mean squared error: Two Phillips curves

	1q	2q	3q	4q	5q	6q	7q	8q
Output Gap [Y_gap]	0.65	0.85	0.78	0.55	0.51	0.61	0.66	0.65
YoY GDP growth [d4Y]	0.65	0.85	0.78	0.55	0.97	1.29	1.27	0.95
Policy rate [RCB]	0.72	0.83	1.02	1.27	1.17	1.03	1.12	1.04
Short-term interbank market rate [R]	0.80	0.87	1.05	1.05	0.79	0.66	0.73	0.75
Nominal exchange rate [S]	5.11	3.71	2.85	2.04	1.83	1.60	1.70	1.68
Nominal FX depreciation [dS]	20.44	10.18	8.35	8.16	7.03	6.76	6.35	4.48
Annual inflation [d4P]	0.95	1.63	2.02	2.33	1.82	1.18	0.89	0.47
Real Exchange Rate Gap [Z_gap]	4.67	3.13	2.69	2.93	3.17	2.69	1.85	0.99
Real Interest Rate Gap [RR_gap]	1.07	1.34	1.44	0.95	0.71	0.64	0.79	0.95

6. Conclusions and policy recommendations

This paper addressed four main issues and makes four main contributions to the literature. First, we extend the existing New-Keynesian model to include separate Phillips curves for energy and non-energy inflation. This approach was thought to help improve forecast performance. As a result, the monetary policy authority in Ghana can make informed decisions about the appropriate path of the monetary policy rate in the country. Second, we use the extended model to study the transmission mechanisms of shocks to energy and non-energy inflation in Ghana. This analysis allows us to understand the importance of these shocks in explaining inflation developments in Ghana and their implications for monetary policy. Third, we also compare the forecast performance of the extended model with the existing model. Finally, we incorporate a fiscal block to capture the effects of fiscal deficits on inflation in Ghana.

The results are mixed, indicating that isolating energy price from the rest of prices in the CPI basket does not necessarily improve the forecasts of the key macroeconomic variables, and will, therefore, not necessarily lead to better policy outcomes.

We investigated a fiscal shock and aggregate demand shock and the results were similar. This suggests that fiscal policy shock is a major component of the aggregate demand shock. However, the magnitude of the response to the aggregate demand shock was bigger, implying that the other components of aggregate demand were also important. Therefore, adding the fiscal block to the model allows the monetary policy authorities to capture the separate effects of the fiscal policy shock from the overall aggregate demand shock. This suggests that policy coordination is very critical for macroeconomic stability.

The fact that the two models give us different results, especially with respect to the magnitudes of the responses to shocks, implies that not separating them will lead to some information loss. We, therefore, recommend the separation of volatile items in modelling the Phillips curve to improve forecast performance and ensure a more accurate policy decision. Also, given the importance of fiscal shock in aggregate demand, policy coordination with the fiscal authorities will be necessary to control inflation in Ghana.

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