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Quarterly Projection Model for the Bank of Ghana

Philip Abradu-Otoo, Ivy Acquaye, Abubakar Addy, Nana Kwame Akosah, James Attuquaye, Simon Harvey, Shalva Mkhatrishvili, Zakari Mumuni, Valeriu Nalban

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ABSTRACT: The paper describes the Quarterly Projection Model (QPM) that underlies the Bank of Ghana Forecasting and Policy Analysis System (FPAS). The New Keynesian semi-structural model incorporates the main features of the Ghanaian economy, transmission channels and policy framework, including an inflation targeting central bank and aggregate demand effects of fiscal policy. The shock propagation mechanisms embedded in the calibrated QPM demonstrate its theoretical consistency, while out-of-sample forecasting accuracy validates its empirical robustness. Another important part of the QPM is endogenous policy credibility, which may aggravate policy trade-offs in the model and make it more realistic for developing economies. Historical track record of real time policy analysis and medium-term forecasting conducted with the QPM – as a component of the broader FPAS analytical organization – establishes its critical role in supporting the Bank's forward-looking monetary policy framework.

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* The authors comprise Bank of Ghana staff and the IMF team that has led the Technical Assistance (TA) project on developing a Forecasting and Policy Analysis System (FPAS) at the Bank of Ghana (BOG). This research is part of the Macroeconomic Research in Low-Income Countries project (Project ID: 60925) supported by the UK's Foreign, Commonwealth and Development Office (FCDO). The TA project has been conducted by ICD since 2019, with support from the second African Regional Technical Assistance Centre in West Africa (AFRITAC West 2). The authors greatly appreciate the BOG management for their support to the FPAS TA project. The authors are also grateful to Martin Fukac for his earlier contributions to the TA project; to Paul Cashin and Philippe Karam for their feedback; to the IMF African Department Ghana team for their collaboration and support to the FPAS TA project; and to participants at an ICD seminar for their helpful comments. The views expressed in this paper are those of the authors and do not necessarily represent the views of the Bank of Ghana, National Bank of Georgia, IMF, its Executive Board, IMF management, or FCDO.

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Contents

I. INTRODUCTION

The Bank of Ghana (BOG) was among the first Sub-Saharan African central banks to adopt inflation targeting (IT) as its monetary policy regime in 2007.[2] Given the complexity of monetary policy transmission, including multiple channels, inherent shock-dependence of economic developments, and transmission lags – all interacting within a dynamic endogenous system – an efficient and informative analytical infrastructure to support forward-looking policy decisions is crucial. Accordingly, the BOG Forecasting and Policy Analysis System (FPAS) was established as the key analytical infrastructure to inform policymakers. It was developed with technical assistance support provided by the IMF, including under the recent TA project involving the co-authors of this paper. Bank of Ghana (2022) provides a comprehensive overview of the evolution of the monetary policy framework at the Bank and its analytical infrastructure – including practical aspects of the BOG FPAS such as the modelling team, forecasting calendar, satellite tools, etc.

The Bank is granted operational independence and monetary financing of the deficit is restricted to curtail fiscal dominance.[3] The primary objective of the Bank is to maintain stability in the general level of prices. The Bank is also engaged in promoting economic growth and ensuring financial stability, without prejudice to the price stability objective and independent of instructions from the Government or any other authority.[4] The BOG, in collaboration with the Ministry of Finance, sets the medium-term inflation target at 8±2 percent. The Bank targets headline CPI inflation. The main operational instrument is the short-term interest rate – the Monetary Policy Rate (MPR) – used to signal the monetary policy stance consistent with delivering price stability. Macroeconomic forecasting has become a central part of the monetary policy formulation since the Bank started implementing the IT framework. As an IT central bank, the BOG pursues a flexible exchange rate system and does not resist the gradual but sustained trend depreciation of its currency. However, intermittent FX operations are undertaken in the foreign exchange market to minimize sharp changes in the exchange rate and to avoid disorderly market conditions.

The ability of the Bank to tame inflation within the target band has often been short-lived, as the economy is frequently hit by multiple adverse shocks, especially of supply-side nature, underpinning the inclusion of a credibility channel in the Bank's Quarterly Projection Model (QPM); see also Bank of Ghana (2022). In line with other IT central banks, the BOG has

[2] The process of instituting independent monetary policies began with the passage of Bank of Ghana Act in 2002 (Act 612). The Act provides for the establishment of a Monetary Policy Committee (MPC) with 7 members comprising the Governor (Chair), 2 Deputies, Head of the Department responsible for economic analysis of the Bank, Head of the Department responsible for Treasury operations of the Bank, and two external members appointed by the Board of Directors of Bank of Ghana. The MPC meets bi-monthly and decisions on the Monetary Policy Rate (MPR) is arrived at by consensus.

[3] These financing restraints received a further boost in 2016 when a zero central bank financing Memorandum of Understanding (MOU) was signed between the Bank and the Ministry of Finance. In addition, the Fiscal Responsibility Act, 2018 (Act 982) capped the fiscal deficit to 5 percent of GDP per year. At the heights of the COVID-19 pandemic, the Fiscal Responsibility Act was suspended.

[4] Bank of Ghana Act, 2002 (Act 612), amended by Act 918 in 2016.

strengthened its communication strategy to ensure transparency in the policy making process and to anchor inflation expectations given the nature of shocks the economy is often battered by. The communication vehicles include, but are not limited to, MPC meeting dates being published one-year ahead; press conferences after each MPC meeting to announce the policy rate decision and motivate it; disseminating data prior to the press conference to generate discussions; and Monetary Policy Reports being produced after each meeting to highlight the key issues the MPC considered before positioning the policy rate. Accordingly, the FPAS analytical infrastructure is utilized not only to inform policymakers internally, but also to communicate policy messages to the general public in a fully consistent way.

This paper describes the BOG QPM – the core of the FPAS – which embodies the main analytical tool used to conduct policy analysis and macroeconomic forecasts at the BOG. The QPM is an extended version of the canonical semi-structural gap model introduced in Berg et al. (2006a, 2006b). It features New Keynesian rigidities, allowing for the monetary policy conduct – via changes in the short-term nominal interest rate – to have real economic effects in the near- to medium-run and, consequently, by affecting the demand-side inflationary pressures to fulfill its price stability objective. The small open economy dimension is accounted for by the important effects of foreign variables and the relevance of the exchange rate dynamics. Important model extensions introduced to reflect Ghana-specific economic characteristics include decomposition of headline CPI into food and non-food indices; introduction of fiscal policy effects; accounting for the limited monetary policy credibility, defined in relation to the historical record of central bank performance in terms of inflation deviations from the target, which could affect the anchoring of inflation expectations.

The model has been proven an essential analytical tool in routinely informing BOG policy making. The QPM’s theoretical consistency – as reflected inter alia by impulse response functions to structural shocks – enables one to build compelling narratives regarding the propagation of shocks. This is further substantiated by the model’s structure, in terms of multiple transmission channels and sectoral developments considered. In addition, its robust data-fit confers the QPM empirical coherence. Accordingly, the model is regularly used to identify and explain both historical developments and construct medium-term projections, including alternative and risk scenarios. All these aspects underly the versatility and superiority of the model in the context of current forward-looking policy regime at the Bank.

This paper contributes to the strand of the literature describing semi-structural gap models used for practical policy analysis and forecasting. The canonical QPM model was introduced in Berg et al. (2006a, 2006b). Various central banks developed modelling tools that have at their core this analytical structure, especially among those adopting inflation targeting or inflation forecast targeting as the operational regime; see Svensson (1997) and Adrian et al. (2018). In particular, the canonical model was tailored and extended to capture relevant channels, country characteristics and policy framework particularities; see Benes et al. (2017) for India, Baksa et al. (2020) for Cambodia, Vlcek et al. (2020) for Rwanda, Baksa et al. (2021) for Morocco, Karam et al. (2021)

for the Philippines, Epstein et al. (2022) for Vietnam. The introduction of the monetary policy credibility channel – whereby past inflation deviations from the target make prices more persistent, create the risk of unanchored inflation expectations, and impair the ability of the central bank to quickly bring inflation back to the target – follows the intuition in Argov et al. (2007), Benes et al. (2017) and Chansriniyom et al. (2020). Practical and real-time implementation of analytical frameworks to study the impact of COVID-19 shocks and the effects of alternative policy packages designed to support the economy are described in Gonzales and Rodriguez (2021). A broad overview of central bank FPAS frameworks implemented within the technical assistance agenda of the IMF is provided in Mæhle et al. (2021).

Closely related papers on the Ghanaian economy include Alichi et al. (2010, 2018) and Harvey and Walley (2021). Alichi et al. (2010, 2018) developed a QPM for Ghana with a single Phillips curve and introduced non-linearities in the inflation process. Harvey and Walley (2021) developed a QPM with separate linear Phillips curves for energy inflation and non-energy inflation to help monetary policy authority understand how shocks to energy prices affect inflation in Ghana, concluding that this decomposition does not necessarily improve the forecasts of the key macroeconomic variables. On the other hand, our paper disaggregates the inflation equation into food and non-food Phillips curves, adequately capturing short-run sectoral inflation dynamics and helping the monetary policy authority to determine the appropriate path of the policy rate. This is important given that the Ghanaian economy is frequently hit by various supply-side shocks with potentially divergent impacts on food and non-food baskets.

The rest of the paper is organized as follows. Section II describes the stylized facts about the Ghanaian economy. These motivate the structure of the BOG QPM, which is extensively covered in Section III. Section IV describes a wide array of model results: impulse response functions and transmission mechanisms, equation decompositions, historical simulations and out-of-sample forecasting performance, the importance of monetary policy credibility channel, and counterfactual simulations of transitioning to different levels of the inflation target. Finally, Section V concludes.

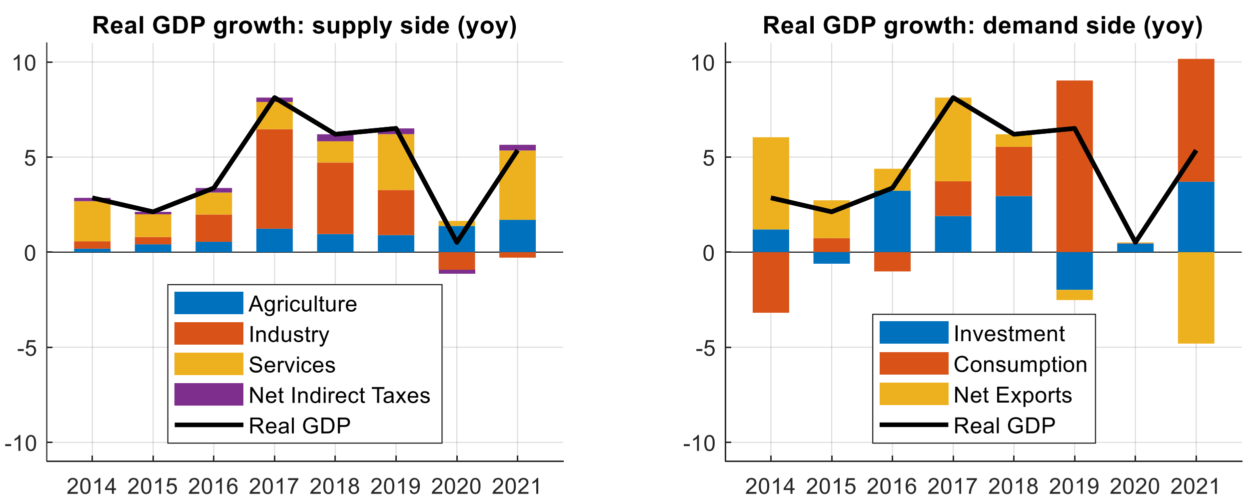
II. Stylized Facts and Model Motivation

Several key stylized facts of the Ghanaian economy are reflected in the model to ensure its relevance for practical macroeconomic policy analysis and monetary policy making.[5] Ghana is a developing small open economy with relatively stable macroeconomic environment over the last few decades. Monetary policy formulation is conducted under the IT framework, formally in place for more than a decade.

[5] The sources of the data presented in this section are: Ghana Statistical Office, Bank of Ghana, International Monetary Fund.

Ghana has instituted continuous reforms and prudent policies to transform its economy for accelerated growth and job creation. The overall growth and stable macroeconomic environment facilitated Ghana's transition from a low-income economy to a lower-middle-income economy in 2011, underpinned by robust services and industry sectors. During the last decade, Ghana has experienced three phases of modest-to-strong economic growth, as the country continued to face challenges to stabilize the economic cycle (Figure 1). Over the period 2014-16, Ghana witnessed a sharp economic slowdown, with average real GDP growth of 2.8 percent (down from an average of 6.6 percent in 2010-13), against the backdrop of monetary policy tightness, oil and gas production challenges, lingering consequences of the power supply constraints, and a drop in export prices of its key commodities. The economic downturn was accompanied by high fiscal deficits, double-digit inflation, and an increased debt burden.

Figure 1: Real GDP growth (percent) and its decomposition (percentage points)

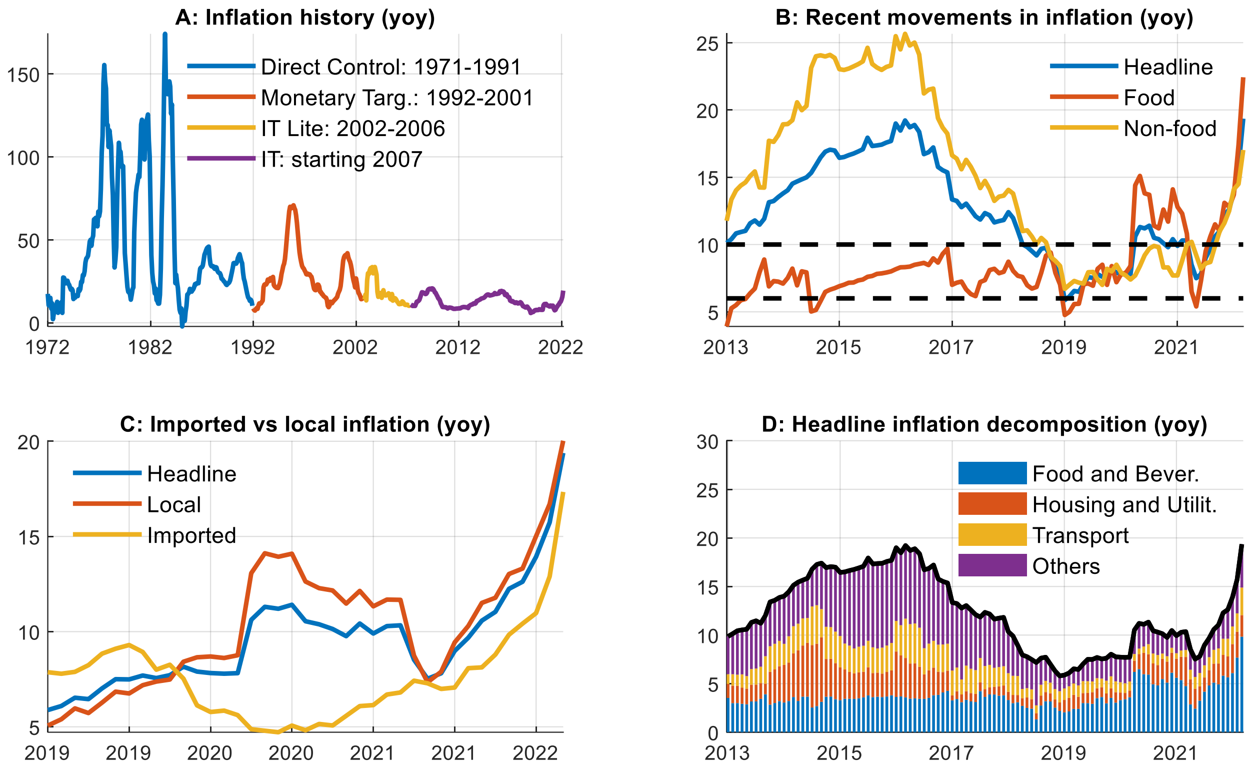


The Ghanaian economy however improved significantly over the period 2017-19, supported by a macroeconomic framework anchored on unwinding the large economic imbalances to restore stability and growth. Bold policy initiatives aimed at fiscal consolidation, focusing on tightening expenditure controls and plugging revenue leakages, as well as complementary tight monetary policy strategies to lower inflation and ensure exchange rate stability. Overall, GDP growth averaged 7.0 percent over the period. The strong growth outturn was broad-based, driven by all major sectors – industry, services and agriculture (Figure 1, left). Ghana's rapid growth was halted by the COVID-19 pandemic starting early-2020, and the country incurred adverse economic impacts due to the global health crisis. Despite the worldwide lockdowns and closures of businesses and borders, the Ghanaian economy held up comparatively well, with GDP growth of 0.4 percent in 2020. The slowdown reflected weak consumption and net exports dynamics, with investment demand being the only significant contributor to GDP growth (Figure 1, right). Yet, avoiding an even more significant downturn in 2020 came at the expense of a record fiscal deficit and public debt, as the Government intervened heavily to support the vulnerable households and businesses through the Coronavirus Alleviation Programme. The economy is assessed to have grown by 5.2 percent in 2021, supported by a good cocoa harvest, mining activity, and services.

Even though inflation is high and relatively persistent, a general moderation in the level and volatility of inflation is clearly apparent since the implementation of the IT framework in 2007 (Figure 2A). But even under IT, inflation outcomes have more often than not been outside the target range (Figure 2B), given Ghana is highly vulnerable to adverse supply shocks. Pre-2019 the developments in headline inflation were predominantly driven by high non-food prices, a trend which was (temporarily) reversed during the pandemic (Figure 2B). Over the years, however, the trajectory of overall inflation has largely reflected the trends in the local inflation (both food and non-food), while the contribution from imported inflation has increased since the second half of 2021, on the back of the continuous depreciation of domestic currency and global price dynamics for food and energy goods (Figure 2C). The varying importance of the major inflation subcomponents over time underscores the relevance of disaggregating inflation into two separate Phillips curves (food and non-food) within the BOG QPM.

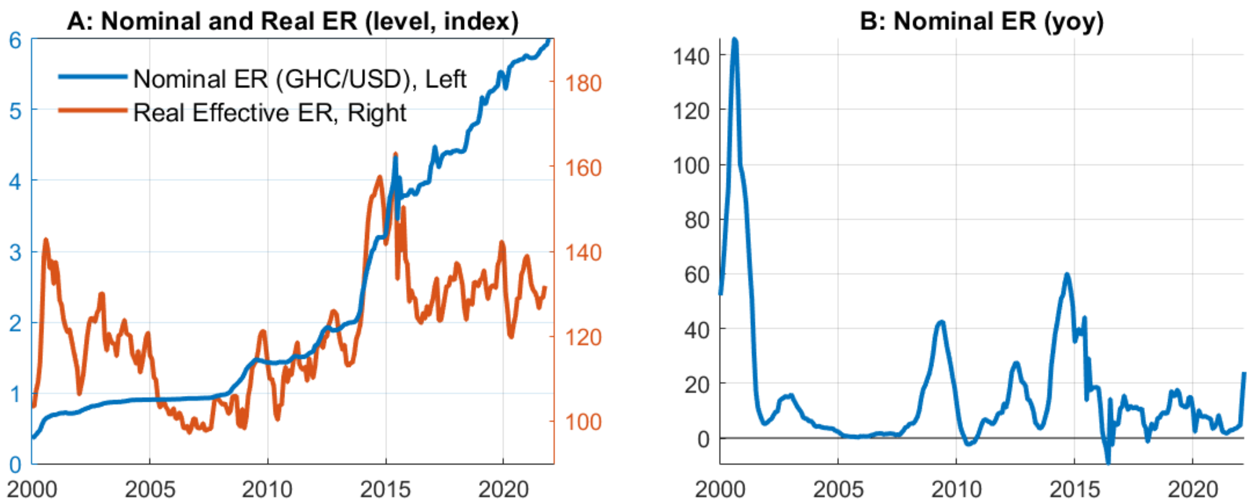
Overall, inflation was successfully tamed within the medium-term target range of 8±2 percent between mid-2010 and December 2012, supported by prudent economic policies and stability in the domestic currency. Thereafter, inflation surged above the target band and peaked at 19.2 percent in March 2016, on the heels of adverse supply-side shocks owing to energy supply challenges during 2014-16 and rapid cedi depreciation. The central bank once again achieved its medium-term inflation target band between April 2018 and March 2020, as prices decelerated continuously and stayed broadly below 8 percent. Inflation climbed abruptly in April 2020 and peaked at 11.4 percent in July 2020, primarily due to the panic buying behavior linked to the three-week partial lockdown in Accra and Kumasi to reduce the spread of COVID-19 infections. Subsequently, inflation dropped sharply to 7.5 percent in May 2021, on the back of well-anchored monetary policy stance, exchange rate stability and favorable food prices base effects from a year ago. The disinflation process was however short-lived, as surging food prices arising partly from adverse climatic conditions delaying harvests, inputs supply bottlenecks compounded by the ongoing Russia-Ukraine war, exchange rate depreciation pass-through, and upward adjustments in petroleum prices and its impact on transportation costs, in concert, led to an abrupt pick-up in inflation to 12.6 percent in December 2021 and a further ascent to 15.7 percent in February 2022. Both food and non-food inflation have surged above the target band, yet the pressures from the food subcomponent dominate. Such exposure to adverse supply shocks causing inflation to frequently deviate from the target motivates the inclusion of the monetary policy credibility channel in the model. Namely, even if such supply shocks have theoretically only one-off impact on inflation, they may still affect inflation expectations if headline figures deviate too much or for too long, as it sometimes does in countries with certain vulnerabilities.

Figure 2: Inflation developments



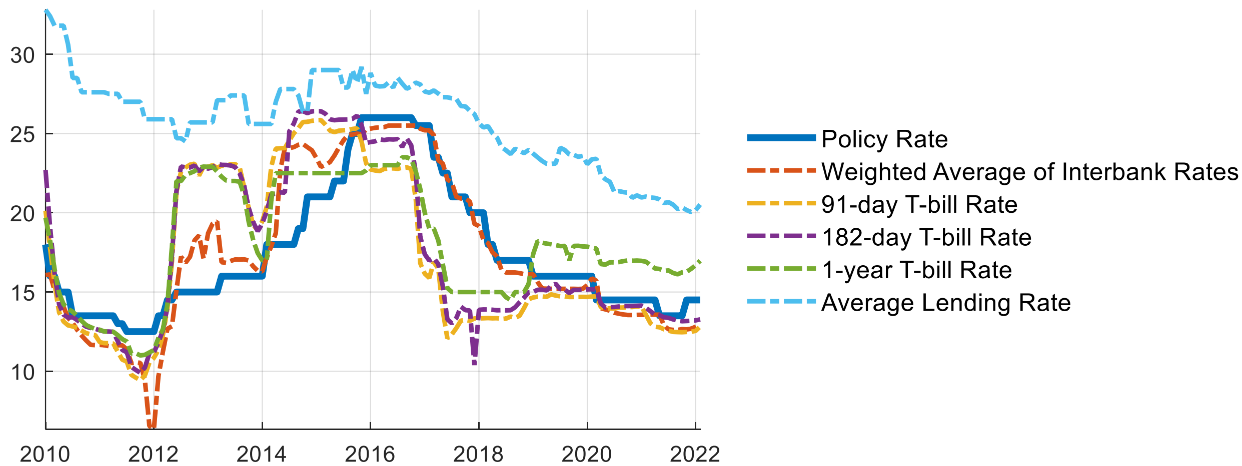
Ghana maintains a flexible exchange rate regime even though the possible impact of the volatility in the foreign exchange market on inflation is carefully monitored and minimized through intermittent FX operations. The cedi remained broadly stable for the most of 2016, after the sharp depreciation in 2014 (Figure 3), supported by a tight monetary policy stance, improved external position underpinned by a marginal increase in export earnings, accompanied by a decline in total imports over that period. From 2017, the cedi registered a relatively stable trend depreciation, including during the pandemic period, in the light of prudent monetary and fiscal policies and strong reserves build-up on the back of significant inflows of foreign direct investments (FDIs) and increased earnings of major commodity exporters. Over the period, the cedi moved on the interbank market from a cumulative annual depreciation against the USD of 15.7 percent in 2015 to a depreciation of 4.1 percent in 2021. However, domestic currency experienced significant pressures in 2022Q1, recording a year-to-date depreciation of 15.4 percent against the USD. This sharp depreciation reflected the impact of the sovereign downgrades by the international rating agencies (citing fiscal uncertainties and rising debt burden), which hampered the access to global capital markets, parliament's impasse on the electronic transaction levy, and – more recently – tighter external financing conditions due to the withdrawal of monetary accommodation in the US.

Figure 3: Exchange rate developments



The steady decline in inflation rate from January 2017 up until the emergence of the pandemic provided some space for monetary policy easing. Accordingly, the MPR was lowered by some 950 basis points, to 16 percent at end-2019 (Figure 4). With some exceptions during excess liquidity episodes, the money market interest rates have broadly tracked the monetary policy rate, in line with the interest rate pass-through mechanism. The fiscal pressures occasioned by the onset of the COVID-19 pandemic led to a slight and temporary upward trend in money market interest rates. Nevertheless, the downward trajectory of the market rates resumed shortly thereafter, with the policy rate declining further to 14.5 percent at the end-2021 and the weighted average interbank rate (the key operational instrument) declining to 12.7 percent. The latter largely reflected improved liquidity conditions in the interbank market, which also transmitted to declining lending rates. However, the surge in inflation from the second half of 2021 vis-à-vis the decline in market interest rates spawned negative real returns on key domestic Treasury securities. Consequently, real monetary conditions loosened, including also due to weaker domestic currency. To realign monetary policy stance and rein in inflation, the central bank increased the policy rate by 250 basis points, to 17 percent in March 2022, and announced additional macroprudential measures to tighten liquidity in the system.

Figure 4: Interest rates (percent)



For an overview of economic developments during the recent period, including the COVID-19 pandemic, see IMF (2021). The economic considerations and transmission mechanisms described above are incorporated in the QPM structure, making it a relevant and practical tool for real-time policy analysis and forecast.

III. Model Structure

The Bank's core model underlying the FPAS is a version of the semi-structural New Keynesian (NK) model used by many central banks and introduced in Berg et al. (2006a, 2006b) as the Quarterly Projection Model (QPM). It is also known as the "gap" model, given that the variables are expressed in deviations from their trends. The QPM serves as an effective tool for forecasting and policy analysis across central banks, particularly in IT settings. Broadly, the QPM reflects how the economy works by explicitly modelling main sectors' dynamics, agents' expectations, and considering the endogeneity of monetary policy.

The QPM approximates two main monetary policy transmission channels – the interest rate channel and the exchange rate channel – with expectations playing a major role.[6] The interest rate channel works through the financial intermediaries, affecting aggregate demand, and then prices. The exchange rate channel works through net exports, which are a component of the aggregate demand and thus affects prices indirectly; in addition, exchange rate impacts domestic inflation directly via the domestic currency price of imported goods entering the CPI basket. QPM is a semi-structural framework, in the sense that although each key behavioral equation has an economic interpretation, the coefficients are reduced-form rather than deep parameters, as in the DSGE (Dynamic Stochastic General Equilibrium) models. However, the NK modeling approach it

[6] Sometimes expectations channel is considered separately.

embeds – in line with the structural models that incorporate monopolistic competition or nominal and real rigidities – allow for short-run non-neutrality of monetary policy, therefore making the QPM suitable as a central bank analytical toolkit; see Ireland (2004).

The core of the BOG's QPM comprises four blocks or (sets of) equations. These are the aggregate demand block, Phillips curves, exchange rate block, and the monetary policy reaction function. Together, they characterize the dynamic interactions of four key macroeconomic variables, namely output gap, inflation, exchange rate and short-term nominal interest rate; see also canonical representations in Berg et al. (2006a, 2006b) and Laxton et al. (2009). A key feature of the model is that monetary aggregates have no explicit role, given the Taylor-type reaction function emphasizes interest rate as the main central bank instrument, with monetary aggregates passively adjusting such as to be fully consistent with the set interest rate level.

The core model is adapted and extended to better capture Ghana-specific characteristics: heterogeneous dynamics of food and non-food prices, fiscal policy effects, monetary policy credibility considerations, imperfect exchange rate flexibility, imperfect interest rate pass-through, etc. Monetary policy is conducted via a forward-looking reaction function aimed at stabilizing inflation in the medium-term, with short-term nominal interest rate gradually reacting to equilibrium (neutral) nominal interest rate, expected deviation of inflation from the target, and output deviation from its potential. The long-term trends and external sector are exogenous and, hence, are taken as given.

The QPM is calibrated rather than estimated, as the latter approach is complicated by small samples, data quality and availability, equation simultaneity and the presence of rational expectations. However, calibration helps matching theoretically-consistent propagation mechanisms and achieve robust data fit – making the QPM useful for practical policy analysis and medium-term forecasting. Furthermore, calibration is the preferred approach at other central banks; e.g., Benes et al. (2017), Baksa et al. (2020), Vlcek et al. (2020), Epstein et al. (2022).

A. Inflation

To ensure that the underlying dynamics in the headline consumer price index (CPI) are captured with sufficient detail, the CPI is disaggregated into its non-food and food subcomponents. This approach allows the model to capture item-specific stylized facts and transmission channels, given their relatively different behavior observed in the data. In addition, separate modelling of food prices provides an efficient shortcut to consider climate change effects within the QPM (although in a reduced-form only), given the causality from weather-related phenomena to the dynamics of agri-food prices and/or value added observed in the case of emerging markets and developing economies.[7] The structure of the two Phillips curve equations is discussed below.[8]

The Phillips Curve for non-food inflation is modelled as a function of its past and expected values, real marginal cost and imported inflation proxy:

$$\left.\begin{aligned}
\pi_t^{nf} &= b_{11}\pi_{t-1}^{nf} + (1-b_{11}-b_{13})\pi_{t+1}^{e,nf} + b_{12}rmc_t^{nf} + b_{13}m_t + \varepsilon_t^{\pi_{nf}} \\
\pi_{t+1}^{e,nf} &= E_t\pi_{t+1}^{nf} + b_{14}incred_t \\
rmc_t^{nf} &= b_{15}\hat{y}_t + (1-b_{15})\hat{z}_t \\
m_t &= (\Delta s_t + \pi_t^* - \Delta\bar{z}_t) \\
incred_t &= b_5 incred_{t-1} + (1-b_5)b_6(4\pi_{t-1} - \bar{\pi}\,) + \varepsilon_t^{incred}
\end{aligned}\right] \quad (1)$$

where π_t^{nf} is quarter-on-quarter annualized (qoq ann.) non-food inflation at time t; $\pi_{t+1}^{e,nf}$ is non-food inflation expectations, modelled as a combination of rational (model-consistent) expectations, $E_t\pi_{t+1}^{nf}$, adjusted by an inflation bias term due to (lack of) policy credibility, denoted $incred_t$ (see details below); rmc_t^{nf} is the real marginal cost in the non-food sector, expressed as a weighted average of output gap (domestic input cost), $\hat{y}_t$, and the real exchange rate (RER) gap (imported input costs), $\hat{z}_t$; m_t is imported inflation proxy, computed as the difference between foreign inflation (π_t^*) expressed in domestic currency (i.e. adjusted with the change in the nominal exchange rate Δs_t) and the change in RER trend ($\Delta\bar{z}_t$); $\varepsilon_t^{\pi_{nf}}$ is the non-food supply shock and ε_t^{incred} is the policy (in)credibility shock.

A note on expectations' formation mechanism: to incorporate a varying degree of anchoring of inflation expectations, these are defined as model-consistent inflation expectations augmented by the "incredibility" term $incred_t$ – reflecting the lack of central bank credibility. The latter is measured as a weighted average of the lag, to capture its slow-moving nature, and the deviation of previous period annual headline inflation ($4\pi_{t-1}$) from the target ($\bar{\pi}$), reflecting the impact of not being able to achieve the inflation target in the past on current central bank credibility.

Similarly, the food sector inflation is modelled as follows:

$$\left.\begin{aligned}
\pi_t^{f} &= b_{21}\pi_{t-1}^{f} + (1-b_{21}-b_{23})\pi_{t+1}^{e,f} + b_{22}rmc_t^{f} + b_{23}m_t + \varepsilon_t^{\pi_f} \\
\pi_{t+1}^{e,f} &= E_t\pi_{t+1}^{f} + b_{24}incred_t \\
rmc_t^{f} &= b_{25}\hat{y}_t + (1-b_{25})\hat{z}_t
\end{aligned}\right] \quad (2)$$

[7] Ongoing work on QPM extensions considers separate modeling of the agriculture value added, oil value added and the non-agriculture-non-oil GDP. The latter comprises primarily manufacturing and services – sectors which reflect fundamental business cycle dynamics and for which monetary policy transmission is relatively stronger. This extension will match, to some extent, the dedicated modelling of food and non-food prices.

[8] All variables are expressed in natural logarithms unless stated otherwise. Structural equations are usually specified for the gaps (denoted with a "hat"), i.e., deviations of actual levels from the medium-term trends (the latter being denoted with a "bar").

where π_t^f is quarter-on-quarter annualized food inflation at time t; $\pi_{t+1}^{e,f}$ is food inflation expectations, also affected by monetary policy credibility; rmc_t^f is the real marginal cost in the food sector; m_t is imported food inflation proxy, defined as above; $\varepsilon_t^{\pi f}$ is the food supply shock. Note that we assume there is only one aggregate measure for central bank credibility, corresponding to the aggregate CPI inflation, which was defined in (1). Imported inflation proxy is also common across the food and non-food sectors.

Similar to the non-food sector, the real marginal cost in the food sector is a weighted average of output gap (domestic input cost) and the real exchange rate gap (imported input costs). However, their relative weights are different across the sectors, with the RER gap being more important for the food sector. In addition, the relative intensity of credibility in the formation of inflation expectations, measured by the parameters b_{14} (non-food sector) and b_{24} (food sector), are different. Imported inflation proxy is common across the sectors, but the elasticity may potentially have different magnitudes. Hence, the key heterogeneity across food and non-food inflation processes is given by the different quantitative importance of various inflation drivers.

The headline CPI is defined as the weighted average of the food and non-food sub-indices:

$$p_t = w \cdot p_t^f + (1 - w) \cdot p_t^{nf} + \varepsilon_t^p \tag{3}$$

where p_t is headline CPI, p_t^f and p_t^{nf} are the food and non-food indices (all in natural logarithms, which simplifies computations), w is the weight of food items in the CPI basket, and ε_t^p captures the approximation error due to observed time variations in the relative weights of the two indexes.

B. Aggregate Demand

An expectational investment-savings (IS) curve or aggregate demand equation, relates monetary policy to real economic activity. Intuitively, the relation can be interpreted as an optimizing household's Euler equation in open economy DSGE models, linking aggregate demand to real interest rate (RIR) and real exchange rate (RER), which together form the real monetary conditions index.[9] In our semi-structural approach, we also consider several additional determinants of domestic output gap. We also take into account that output may react gradually due to inherent persistency and habit formation. Given Ghana's small open economy characteristic, the domestic output is directly impacted by foreign output gap. Finally, given the importance of fiscal policy, we explicitly include the fiscal impulse as a driver of output gap. Accordingly, the aggregate demand equation explains output gap $\hat{y}_t$, measured as the deviation of log real GDP (y_t) from its potential or trend level ($\bar{y}_t$), as follows:

$$\left.\begin{array}{l} \hat{y}_t = \alpha_1 \hat{y}_{t-1} + \alpha_2 E_t \hat{y}_{t+1} - \alpha_3 rmci_t + \alpha_4 \hat{y}_t^* + \alpha_5 fimp_t + \varepsilon_t^y \\ rmci_t = \alpha_6 \hat{r}_t + (1 - \alpha_6)(-\hat{z}_t) \end{array}\right] \tag{4}$$

[9] Studies such as Gali and Monacelli (2005), Ireland (2004), Smets and Wouters (2003, 2007) and others have provided detailed structural derivation of similar microfunded IS curves.

where $rmci_t$ is the real monetary condition index (with higher values reflecting tighter conditions), representing a weighted average of RIR gap $\hat{r}_t$ (defined as the deviation of actual real interest rate, r_t, from its neutral level, $\bar{r}_t$) and RER gap $\hat{z}_t$ (defined as the deviation of actual real exchange rate, z_t, from its trend or medium-run equilibrium, $\bar{z}_t$)[10]; $\hat{y}_t^*$ is the foreign (USA) output gap; $fimp_t$ is the net fiscal impulse measuring the effect of discretionary government expenditures; and ε_t^y is the aggregate demand shock.

The fiscal block is kept reasonably simple and tractable.[11] The headline fiscal deficit (expressed as GDP share) is decomposed into unobserved cyclical and structural components. The former is directly linked to the output gap, while the latter follows a mean-reverting autoregressive process. The fiscal impulse is identified with the shock to the structural deficit process, reflecting the discretionary component of the fiscal policy, which is not related to the cyclical position of the economy or the medium-run fiscal developments. In particular, net fiscal impulse ($fimp_t$) is derived as follows:

$$\left.\begin{array}{l} fimp_t = \varepsilon_t^{def_{str}} \\ def_t = def_{cyc,t} + def_{str,t} \\ def_{cyc,t} = -f_1 \hat{y}_t \\ def_{str,t} = f_2 def_{str,t-1} + (1-f_2) def_{str,ss} + \varepsilon_t^{def_{str}} \end{array}\right] \qquad (5)$$

where def_t is overall fiscal deficit; $def_{cyc,t}$ is cyclical fiscal deficit that captures the effect of automatic stabilizers and mirrors the position of the output gap via the parameter f_1; $def_{str,t}$ is the long-term structural fiscal deficit; $\varepsilon_t^{def_{str}}$ is structural deficit shock. Accordingly, after accounting for cyclical variations (automatic stabilizers) and the structural component, the rest of the changes in the fiscal deficit will be interpreted as discretionary fiscal decisions and will impact current business cycle position.

C. Exchange Rate and UIP

Exchange rate is determined by a modified version of the Uncovered Interest Parity (UIP) condition. As in standard specifications, interest rate differential compensates for the expected exchange rate depreciation and a proxy for sovereign risk premium. Typical modifications involve making exchange rate expectations partly backward-looking. Hence, following inter alia Benes et al. (2002), we allow for certain persistence in exchange rate dynamics and relate the behavior of domestic and foreign interest rates to nominal exchange rate (NER), as follows:

[10] An increase in z_t is defined as depreciation of domestic currency, reflecting a relaxation in financial conditions for exporters, which stimulates domestic demand. Accordingly, RER gap enters with a negative sign in the definition of $rmci_t$.

[11] Given the importance of the fiscal-monetary interactions in Ghana, a more detailed modelling of the fiscal sector is currently under considerations.

$$\left.\begin{array}{l} s_t = s^e_{t+1} + (i^*_t - ib_t + prem_t)/4 + \varepsilon^s_t \\ s^e_{t+1} = c_1 E_t s_{t+1} + (1 - c_1)(s_{t-1} + 2/4 \cdot \Delta\bar{s}_t) \\ \Delta\bar{s}_t = \bar{\pi}_t - \pi^*_t + \Delta\bar{z}_t \end{array}\right] \tag{6}$$

where s_t is the log NER, defined as units of domestic currency per one unit of foreign currency (US dollar); s^e_{t+1} is the next-period expectation for NER, defined as a weighted average of model-consistent rational expectations and a backward-looking term; i^*_t is foreign (US) nominal interest rate; ib_t is domestic nominal money market interest rate; $prem_t$ is sovereign risk premium; ε^s_t is exchange rate (or UIP) shock. The coefficient c_1 captures the degree of forward-looking behaviour in the financial market, or, alternatively, the degree to which the central bank may undertake operations to smooth short-run fluctuation in the FX market. Another way to rationalize the dependence of UIP on past values of the exchange rate, in addition to the (model-consistent) expectations, is through FX portfolio balance adjustment costs (see Bacchetta and Van Wincoop, 2021). The term $\Delta\bar{s}_t$ simply defines the trend nominal depreciation, used to adjust the backward-looking expectations so that it follows the balanced growth path.

D. Interest Rate and Monetary Policy

The QPM is closed with a monetary policy reaction function (i.e., a Taylor-type rule) that relates changes in the policy rate to the Bank's objectives of inflation at target and output at its equilibrium. The interest rate that produces aggregate demand effects is matched with the interbank rate, which differs from the key policy rate by a time-varying zero-mean spread:

$$\left.\begin{array}{l} i_t = g_1 i_{t-1} + (1 - g_1)[E_t\pi_{t+1} + \bar{r}_t + g_2(E_t 4\pi_{t+3} - \bar{\pi}_t) + g_3\hat{y}_t] + \varepsilon^i_t, \\ ib_t = i_t + sp_t \\ sp_t = g_4 sp_{t-1} + \varepsilon^{sp}_t \end{array}\right] \tag{7}$$

where i_t is the short-term nominal key policy interest rate; $\bar{r}_t$ is the real neutral interest rate; $E_t 4\pi_{t+3} - \bar{\pi}$ is three-quarters ahead expected annual inflation deviation from the target; g_1 is an indicator of the degree of interest rate smoothing (or policy inertia); parameters g_2 and g_3 are the relative weights of deviations of expected inflation from target and of output from potential, respectively; ib_t is the interbank rate; sp_t is the spread; ε^i_t and ε^{sp}_t are shocks. While the concern for the inflation-output trade-off is consistent with BOG's flexible IT framework, it is critical that g_2 is greater than 1 for the model to have a unique solution and to enable the monetary policymaker to effectively anchor expectations and future inflation outcomes, referred to as the Taylor principle.

E. External Sector and Long-Run Trends

Due to the small size of the Ghanaian economy relative to the rest of the world, there is no perceptible feedback from the domestic economy to the external sector. Therefore, the latter is treated as exogenous in the Bank's QPM. As such, long-term trends are specified in most cases as univariate processes. Against this background, both the foreign variables (proxied by USA economic data) – such as inflation (π^*_t), output gap ($\hat{y}^*_t$) and real interest rate (r^*_t) – and the long-run trend/equilibrium values of real exchange rate change ($\Delta\bar{z}_t$), potential output growth ($\Delta\bar{y}_t$), inflation target ($\bar{\pi}_t$) and UIP premium ($\overline{prem}_t$) are generally modelled as autoregressive processes (with high enough inertia) that gradually converge to their steady-states:

$$x_t = k_x x_{t-1} + (1 - k_x)x_{ss} + \varepsilon_t^{x_t} \tag{8}$$

where $x_t \in (\pi_t^*, \hat{y}_t^*, r_t^*, \Delta\bar{z}_t, \Delta\bar{y}_t, \bar{\pi}_t, \overline{prem}_t)$; k_x is the persistency parameter of the respective variable; x_{ss} denotes the corresponding steady state value; $\varepsilon_t^{x_t}$ is the disturbance term.

F. Calibration

Like other central banks, the calibration of BOG's QPM covers steady states (based on sample averages), coefficients in dynamic equations, and standard deviations of the shocks. Table 1 provides the parameter values for the key behavioral equations in the model.

Table 1: Calibrated parameters (behavioral equations)

Non-food inflation		*Food inflation*		*Output gap*	
b_{11}	0.7	b_{21}	0.5	a_1	0.4
b_{12}	0.4	b_{22}	0.2	a_2	0.3
b_{13}	0.1	b_{23}	0.1	a_3	0.1
b_{14}	0.5	b_{24}	0.25	a_4	0.1
b_{15}	0.7	a_{25}	0.6	a_5	0.5
				a_6	0.8
Interest rate		*Exchange rate*		*Credibility*	
g_1	0.75	c_1	0.6	b_5	0.5
g_2	1.3			b_6	1.5
g_3	0.1	*Food CPI weight*		*Fiscal sector*	
g_4	0.65	w	0.4312	f_1	0.2
				f_2	0.95

IV. Model Results

A convenient way to communicate the properties of a model is to provide graphic simulations of the model's solution to ascertain how the key macroeconomic variables respond to specific shocks, known as impulse response functions (IRFs). The model equations and parameterization are also employed to filter actual data and decompose the variables into the contributions of the structural factors and shocks, which can be used to judge the model's performance in terms of plausibility of its narrative about historical episodes. In addition, out-of-sample simulations are utilized to appraise the forecasting accuracy of the QPM for key macroeconomic variables. This section also illustrates how the model is applied to assess the importance of the monetary policy credibility and the anchoring of inflation expectations.

A. Impulse Response Functions

This section briefly analyses the impulse response functions implied by the calibrated BOG QPM. In all figures in this subsection, we present dynamic responses of key macroeconomic aggregates (with values being expressed in deviations from the corresponding equilibrium, e.g., for inflation this is represented by the inflation deviation from the target) to several structural shocks of one unit size. In this theoretical exercise we consider one-time single shock simulations starting from the model's general equilibrium, although in practice shocks occur simultaneously and not necessary when all sectors are in equilibrium. Notwithstanding, it is beneficial to keep the simulation setup simple in order to properly explore the model's propagation mechanisms and assess its theoretical consistency.

Figure 5: Aggregate demand shock

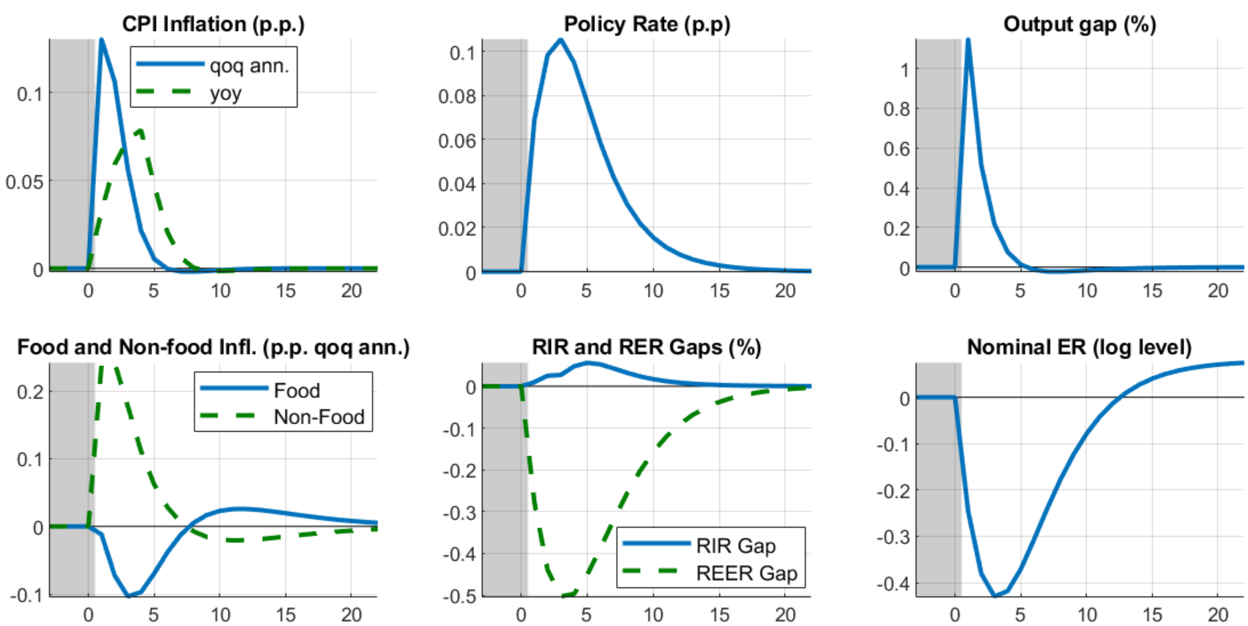


Figure 5 displays the responses to a positive aggregate demand shock. IRFs reveal that such a shock raises overall inflation in the short-run, driven by a surge in non-food inflation. This is the result of the higher demand producing an increase in the domestic component of the real marginal costs, which is relatively more important and has a larger direct pass-through in the case of non-food prices. On the contrary, the shock causes food prices to fall, since the negative real exchange rate gap dominates the effect coming from higher domestic output gap. Intuitively, this is a reflection of the central bank reacting to higher output gap as well as above-target inflation expectations. Namely, policy rate increases lead to appreciation, which drives food inflation down, partly counterbalancing the rise in non-food prices. But the latter still dominates and, therefore, overall CPI inflation increases above the target. The domestic currency strengthens in both nominal and real terms; together with the positive RIR gap this causes tighter monetary conditions, which contribute to the gradual closing of the positive output gap and to the return of inflation to the target. Overall, while the shock occurs only in the first quarter, the model efficiently incorporates the transmission lags which contribute to longer-lasting demand-side inflation pressures, requiring a more persistent policy response to anchor the system back to its equilibrium.

Figure 6 shows the IRFs to a non-food price shock (e.g., an increase in energy prices). The shock results in a pick-up in non-food prices and overall inflation in the first quarter, despite non-food prices declining slightly (as a result of lower marginal costs due to both domestic and imported components – see below). The central bank raises nominal interest rate in response to the uptick in headline inflation expectations, which in turn induces a nominal appreciation and a negative real exchange rate gap (i.e., overvalued currency). RIR gap becomes negative due to higher inflation expectations in the initial periods but turns positive as inflation and inflation expectations decline as a result of tighter monetary policy and overvalued RER. Output declines in the short-term, primarily due to real appreciation dampening aggregate demand through the trade channel. Hence, it is the monetary policy reaction that drives the non-food – and, hence, headline inflation – back to the target. It is worth noting that while such cost-push shocks represent a trade-off for policymakers – with higher inflation being accompanied by negative output gap – in the BOG QPM the central bank is still forced to tighten, since the inflation objective is assumed to be relatively more important than the output gap stability (see also the discussion in one of the next subsections).

Figure 6: Non-food inflation shock

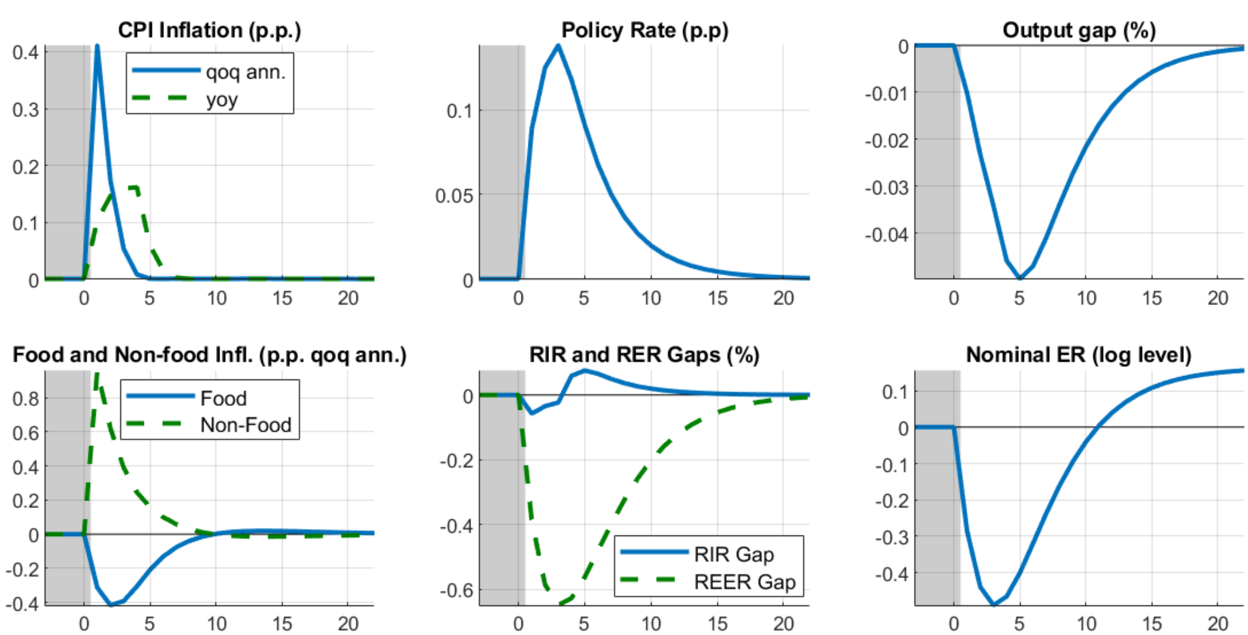


Figure 7 shows the responses to a positive exchange rate shock in the UIP condition (i.e., a depreciation shock, or a risk-off episode of capital outflows). The shock leads to nominal and real exchange rate depreciation, which passes-through to above-target headline inflation. The surge in headline inflation reflects both food and non-food price increases, primarily via the imported component of the real marginal costs as a result of the positive (undervalued) RER gap. Monetary authority responds to these price pressures and the weakening of the domestic currency by raising the short-term interest rate. The RIR gap is negative in the short-run, due to relatively higher inflation expectations initially. Together with real exchange rate depreciation, this leads to looser real monetary conditions, causing a positive output gap in the initial periods after the shock. The gradual increases in both nominal and real interest rates strengthen the domestic currency, which in turn tightens real monetary conditions and contributes to the return of the output and inflation towards their steady state levels.

Figure 7: Exchange rate (UIP) shock

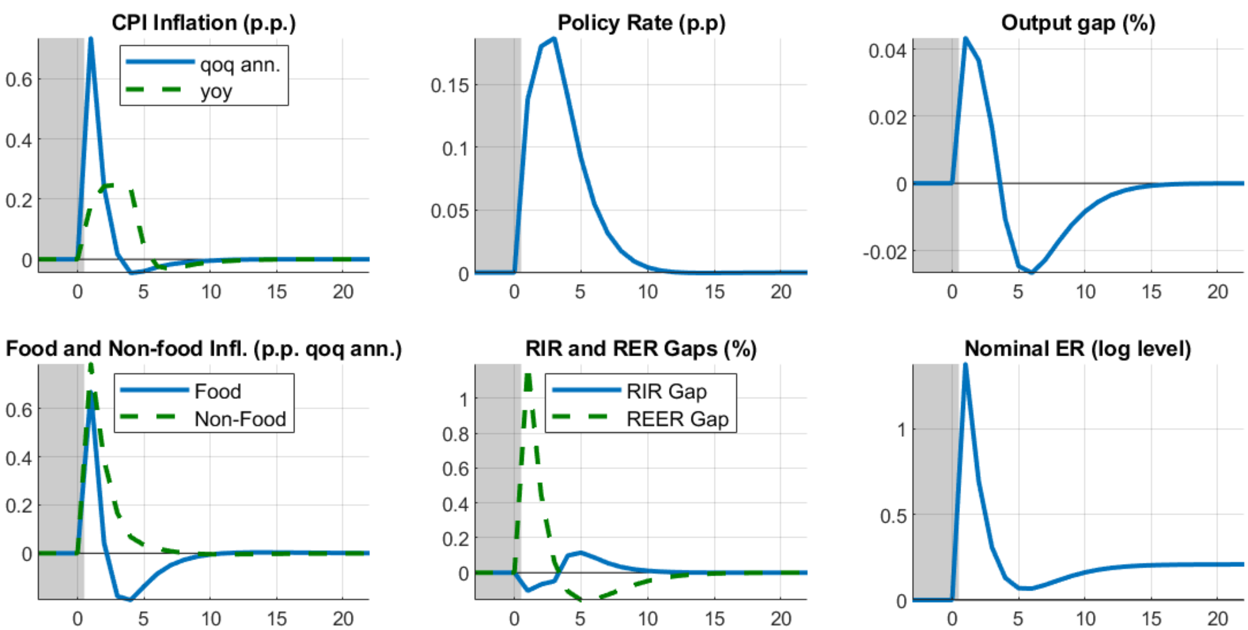


Figure 8 illustrates the impact of an adverse food supply shock, which increases food and aggregate prices, despite non-food inflation declining slightly. To dampen the second-round effects of the adverse food prices shock, the central bank moderately raises the nominal interest rate. The lower-than-proportionate increase in the nominal interest rate results in negative RIR gap (i.e., loose policy stance) in the initial quarters, but the real interest rate rises subsequently as price pressures taper off. Nevertheless, monetary conditions become restrictive due to the steady appreciation in the domestic currency (in both nominal and real terms). Tighter real monetary conditions put a drag on output, with a trough by the fifth quarter following the shock. Output recovers thereafter, as real monetary conditions gradually ease. Note that while headline inflation dynamics is almost quantitatively the same, monetary policy reacts relatively less in this case relative to the reaction to non-food inflation shock. The reason is that food price shocks are generally of a more temporary nature, and the disaggregation implemented in the model properly captures this stylized fact.

The responses to a one-unit positive monetary policy shock are broadly consistent with economic theory; see Figure 9. Contractionary effects of the shocks are reflected in a hump-shaped negative trajectory of the output gap. The transmission works through both components of the real monetary conditions, given short-run price rigidities embedded in the model: RIR gap is tightened via higher nominal and, consequently, real rates, while RER gap becomes overvalued on the account of the nominal appreciation. As a result, food and non-food inflation decline by a maximum of 0.4 and 0.5 percent in quarterly annualized terms, respectively. Consistent with the calibration of higher inertia, non-food prices register their largest decline three quarters after the shock, which is one quarter later than the food prices. The response of headline inflation represents a weighted average of the two components' reactions. Also, the monetary policy shock has a greater impact on non-food inflation than on food inflation, largely due to the assumed higher relative weight of output gap vis-à-vis RER gap in the real marginal cost for non-food items as opposed to food items.

Figure 8: Food inflation shock

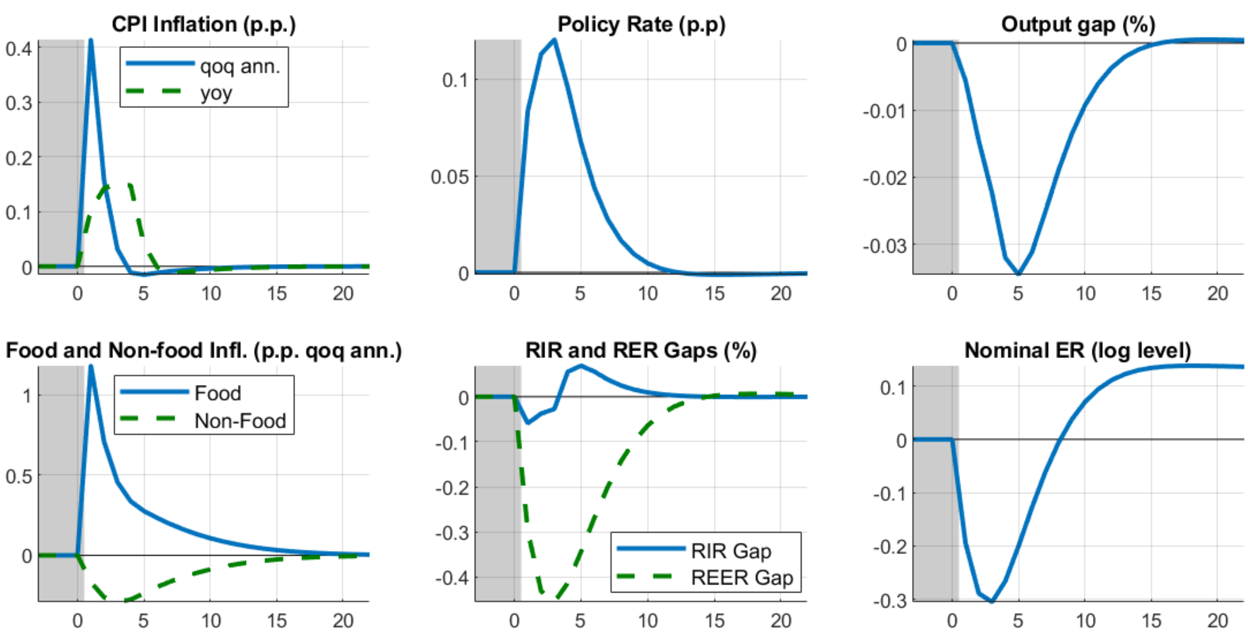
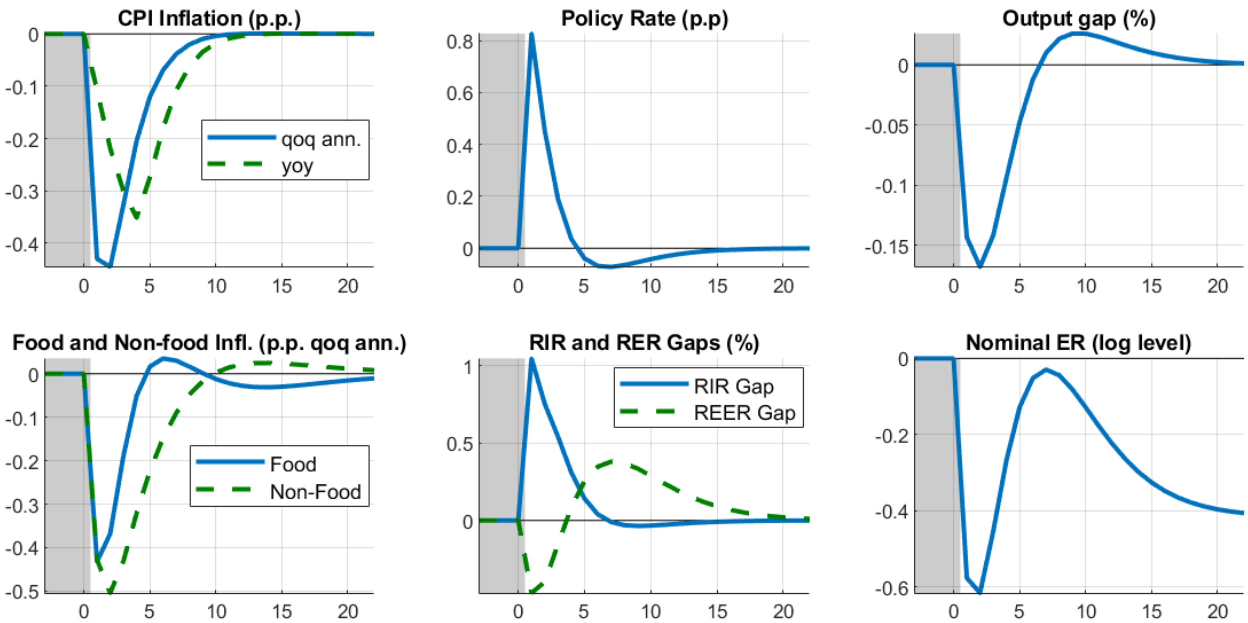


Figure 9: Monetary policy shock

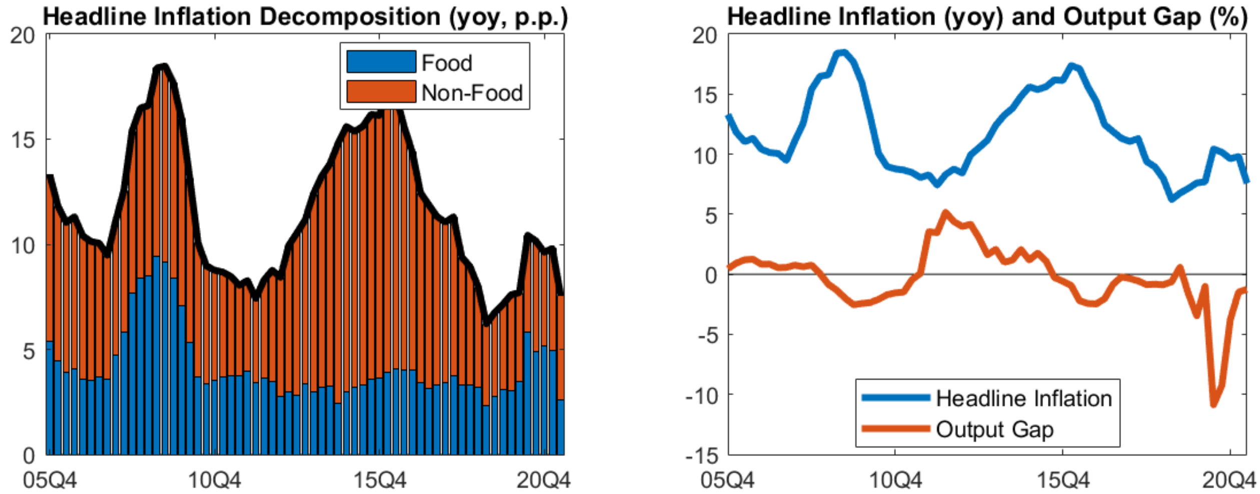


B. Equation Decompositions

One of the advantages of quantitative general equilibrium models of (semi)structural nature is their ability to provide a causal narrative analysis of historical episodes. The Kalman filter (and smoother) estimates the time series of unobserved state vector (like gaps, trends and shocks) which replicate the observed historical data. This subsection investigates how the calibrated model decomposes observed data and other key variables into contributions of their determinants based on the corresponding underlying equations. Overall, the QPM provides a compelling narrative with respect to the historical macroeconomic developments in Ghana, including the key drivers of inflation dynamics and the identification of the business cycle fluctuations.

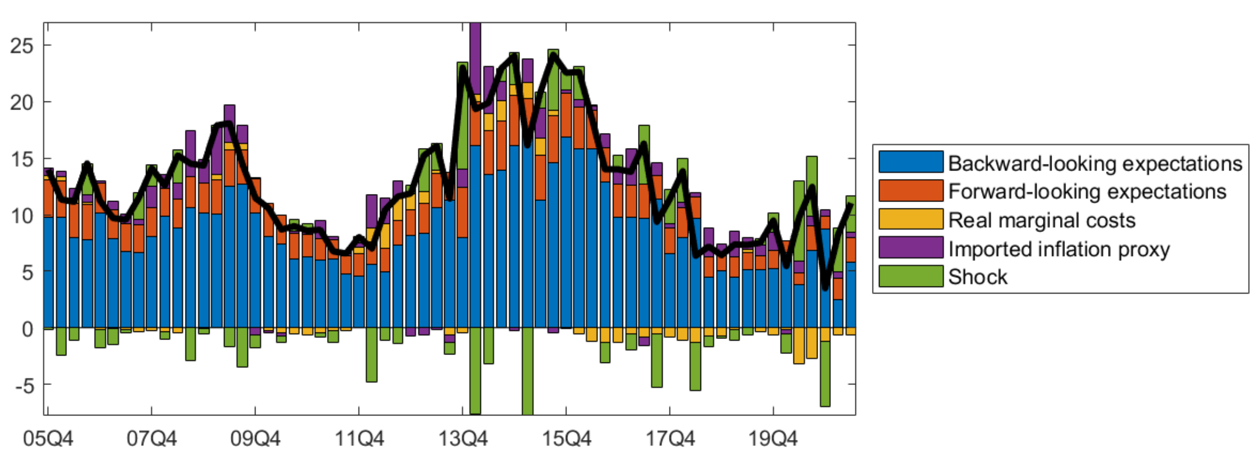
A conspicuous observation captured in Figure 10 is that there are periods during which inflation rises when output gap is falling or becomes more negative, while periods of increasing or more positive output gap (i.e., rising demand-side pressures) are occasionally associated with disinflation. This suggests that supply-side shocks have predominant and consistent contributions to inflation dynamics in Ghana. This is captured by the model in the form of significant contributions from supply-side shocks in Figure 11, which decomposes non-food inflation using the specified Phillips curve framework. This situation represented a major trade-off for the central bank and restrained its ability to maintain low and stable inflation over the years alongside a dynamic GDP growth. Intuitively, the frequent incidence of supply-side shocks is due to the inherent structural constraints and vulnerabilities of the economy. However, such shocks are also identified during the emergence of the COVID-19 pandemic in early 2020.

Figure 10: Inflation and output gap



Consistent with the Ghana's small-open economy characteristic, external factors have also impacted inflation and output over the years. Particularly, the rise in inflation between the late-2007 and early-2009 was partly due to imported inflation, including via soaring global commodity prices and weaker cedi in the context the negative impact of the Great Recession of 2007-09, compounded by the impact of election-related uncertainties on domestic currency. These developments also contributed to raised inflation inertia and expectations. The former is particularly important on the account of slow monetary policy credibility build-up as a result of accumulated past inflation deviations from the target making expectations' formation a more backward-looking process. The disinflationary episode between mid-2009 and end-2011 was attributed to the decline in real marginal costs (related to subdued domestic aggregate demand alongside moderate real exchange rate appreciation – see Figure 12) and lower inflation expectations. In addition, favorable cost-push shocks also supported disinflation.

Figure 11: Non-food inflation (Phillips curve) decomposition, qoq ann.



The general acceleration in inflation during 2012-14 was driven by rising marginal costs and imported inflation via large real exchange rate depreciation (Figure 12). Loose monetary conditions, which boosted aggregate demand, further reinforced the acceleration in inflation during the period (Figure 13). Further spikes in inflation from early-2015 to the first half of 2016 were triggered by adverse cost-push shocks associated with the energy supply challenges, which also negatively impacted domestic aggregate demand. The decline in both real marginal cost and inflation inertia led to a faster disinflation from the second half of 2016 up until 2019Q1. Noticeably, subdued aggregate demand pressures on the back of tighter real monetary conditions (primarily via tighter monetary policy stance; see Figure 13) also facilitated the drop in real marginal costs during this period.

Figure 12: Real marginal costs

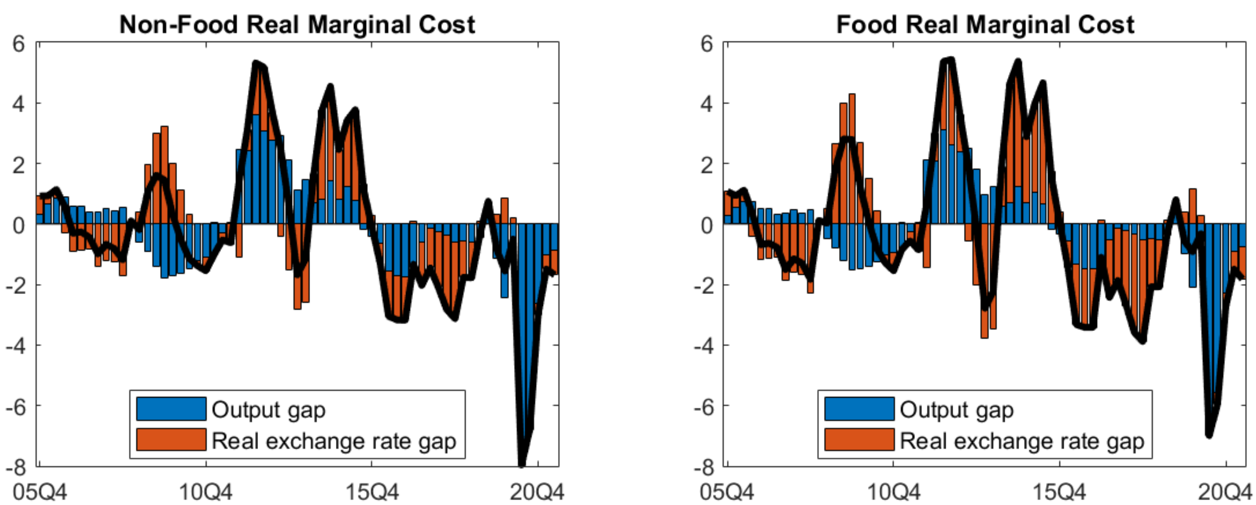


Figure 13: Real monetary conditions

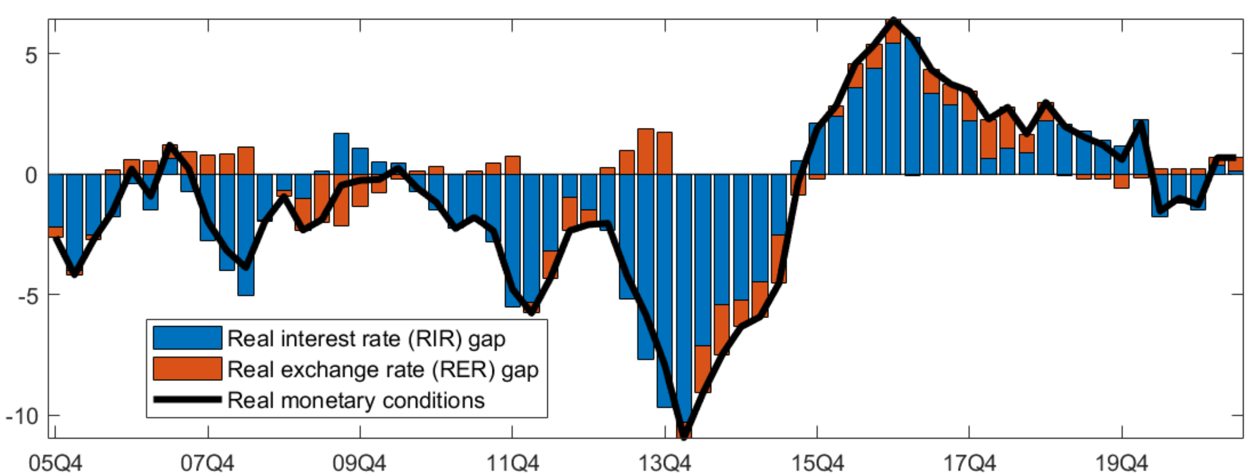
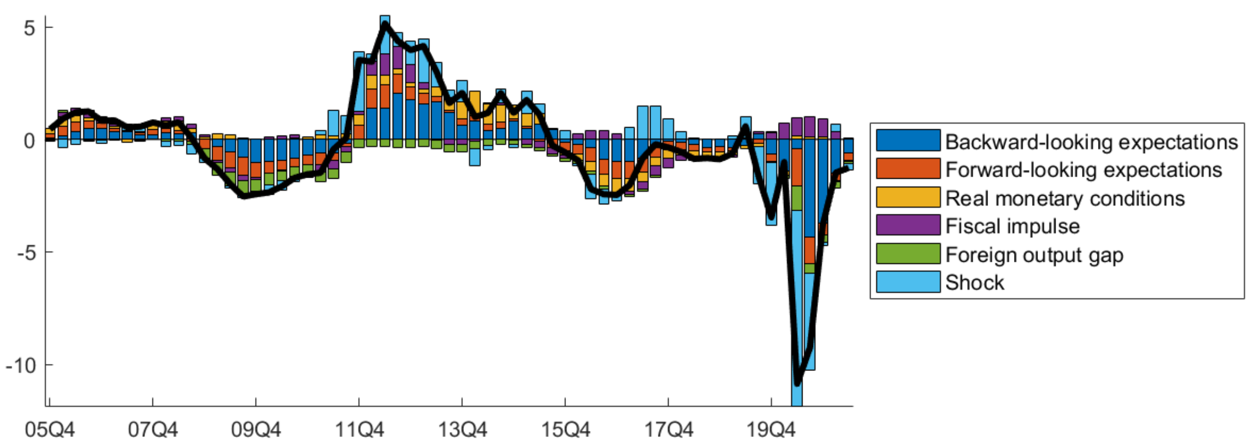


Figure 14 summarizes the IS curve decomposition of the output gap. The negative output gap widened during 2009 due to weaker external demand and negative fiscal impulse, with the latter linked to the post-election fiscal consolidation. The episode of highly positive output gap during 2011-12 was the result of looser fiscal policy, stimulative monetary conditions (Figure 13) and favorable demand shocks, while foreign economies were still recovering from the Great Recession. The abrupt spurt in inflation during 2020Q2 was predominantly driven by the adverse cost-push shocks linked to the COVID-19 containment measures, which also induced a sharp contraction in the output gap. Besides negative demand shocks, the other factors that contributed to the sharp dip in domestic output gap during the period were weaker external demand and greater anticipation of slower domestic economic activities. The extent of contraction in the output gap was conceivably moderated by the provided policy support, with policy rate cuts reflecting an accommodative monetary policy stance (indicated by the contribution of real interest rate gap within the real monetary conditions, Figure 13), and fiscal measures captured by a positive fiscal impulse (Figure 14).

Figure 14: Output gap decomposition (aggregate demand equation), percent



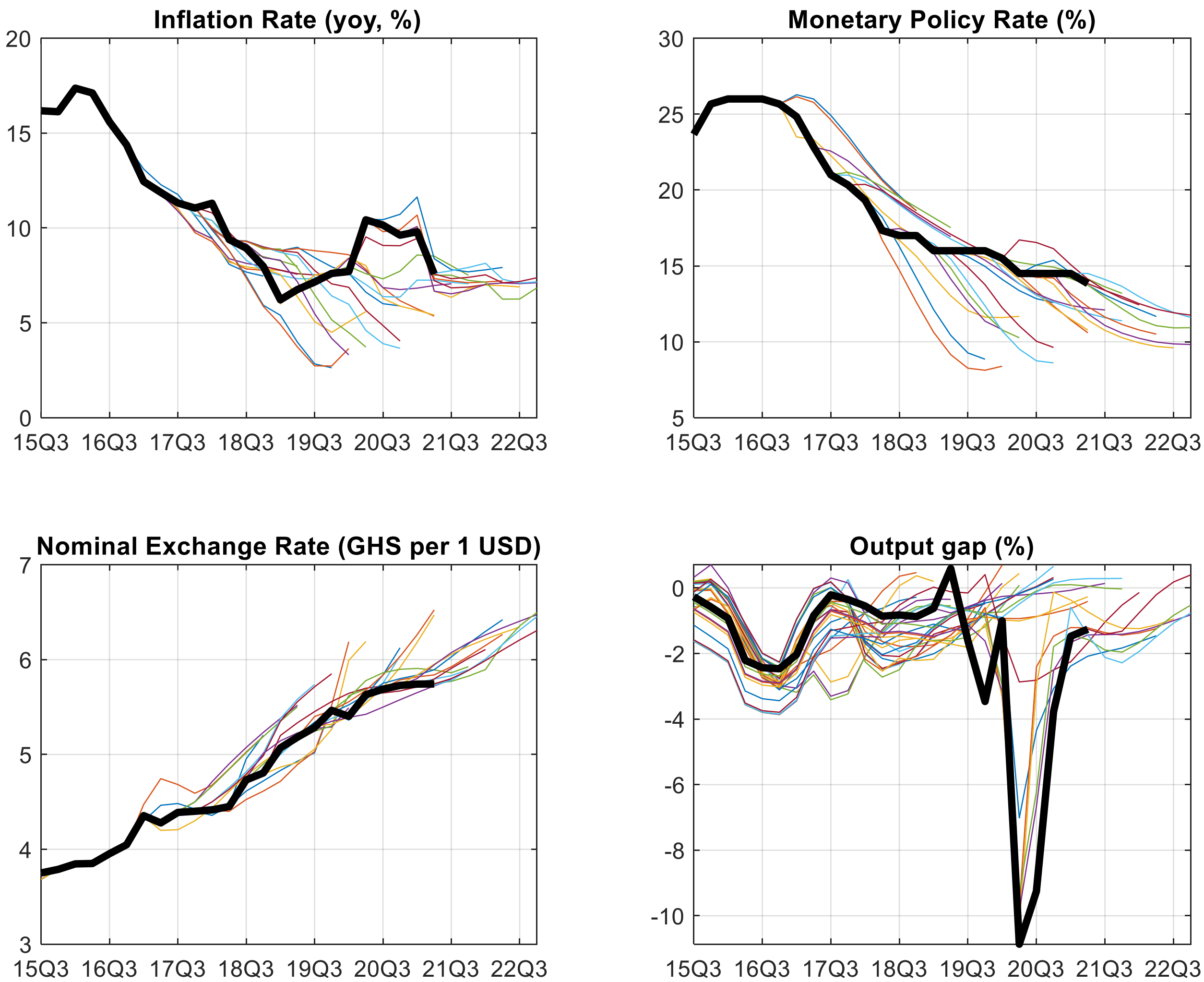
Overall, the economic narrative that the model-based filtering exercise provides is consistent with our understanding of actual historical events. This underlines the realism of the model, as well as its consistency with the characteristics of the Ghana economy.

C. Out-of-sample Forecasting Accuracy

The QPM is used in real-time at the BOG to perform both policy analysis and forecasting. Being a semi-structural framework, QPMs are not necessarily the best at forecasting over the short horizons. For that reason, in practice the current and next quarter values for the key macroeconomic variables are tuned using nowcasting and near-term forecasting methods, which put emphasis on statistical relations and historical patterns; see details in Bank of Ghana (2022).

Afterwards, the medium-term forecasts reflect the QPM-based simulations, conditional on exogenized trajectories for the external sector variables and the near-term outlook. This section provides an overview of the out-of-sample forecasting performance of the Bank's core model. Figure 15 plots the up-to eight-quarter ahead out-of-sample forecasts from 2017Q1 to 2021Q4 for the key macrovariables produced by BOG staff during the regular forecasting cycles covered by the analyzed period.

Figure 15: Out-of-sample forecasts (colored) and actual data (black)



During the recent period, the QPM tended to underestimate inflation (and, hence, interest rate trajectories), except for the time interval between late-2018 and mid-2019 when it showed a somewhat upward bias. This outcome is partly explained by the occurrence of unfavorable sequences of supply-side shocks, as described in the previous subsection. In the case of the exchange rate, the forecasts appear to be broadly in line with the trend depreciation, but occasionally they are biased upward for the medium-term horizons. The output gap forecasts tended to be biased downward in the pre-2020 period. The model was also unable to forecast the significant decline in output gap witnessed during the COVID-19 pandemic, which is natural given the unexpected nature, complexity, and magnitude of the pandemic shock. The more recent forecast points to a fast narrowing of the negative output gap, consistent with the sharp post-pandemic recovery in economic activity. With respect to the policy rate, the QPM forecasts appeared to be broadly biased downwards over the analyzed sample, in line with inflation being often underpredicted, except for the pre-2018 period, when the reverse situation occurred. In response to the projected inflation profile, the most recent QPM forecast points to tighter monetary policy stance to tame emerging price pressures.

To formally assess the relative forecast performance of the Bank's core model, Table 2 shows the one- to eight-quarter ahead root mean squared forecast error (RMSFE) statistics for the five variables of interest, relative to those of a naïve forecast from a random walk model[12], over the period 2017Q1 to 2021Q4. In this case, a ratio of less than one suggests that the Bank's QPM has a smaller RMSFE than the naïve forecast for that specific variable and forecast horizon, and is thus preferred.

Table 2: QPM RMSFE relative to random walk

Variable	Forecast horizon							
	1Q	*2Q*	*3Q*	*4Q*	*5Q*	*6Q*	*7Q*	*8Q*
Policy rate	0.06	0.10	0.14	0.17	0.21	0.25	0.29	0.26
CPI (yoy)	0.10	0.15	0.18	0.19	0.25	0.40	0.46	0.46
Output Gap	0.21	0.33	0.30	0.36	0.29	0.40	0.34	0.41
GDP Growth (yoy)	0.32	0.57	0.55	0.78	0.54	0.72	0.52	0.67
Nominal ER depreciation (qoq ann.)	0.38	1.05	0.70	0.57	0.52	0.83	1.26	1.52

The table unveils that the QPM significantly outperforms a random walk model for all variables, both in the near- and medium-term forecast horizons, except for nominal exchange rate depreciation at three horizons. The significant size of the margin by which the QPM outperforms the random walk benchmark is another manifestation of the QPM's relevance and applicability for the Ghana economy.

[12] The random walk forecasts assume that the variable of interest remains at its last known value over the entire forecast period.

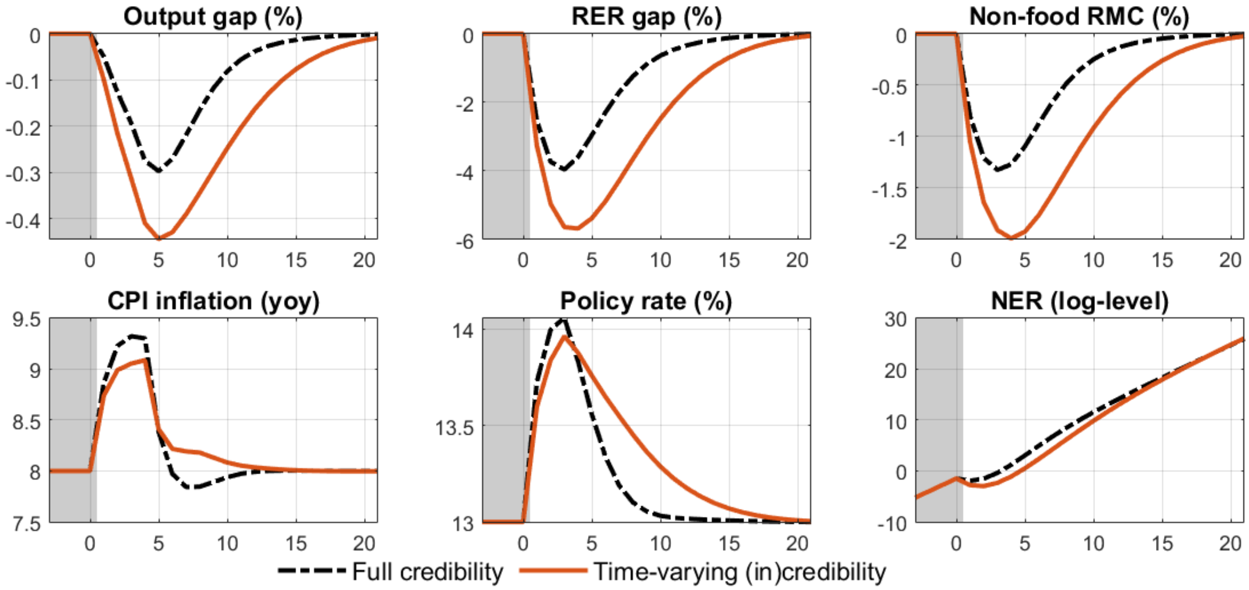
D. Monetary Policy Credibility Channel in the BOG QPM

Full monetary policy credibility is an important implicit assumption in standard macroeconomic models with rational (model-consistent) expectations. Rendering this assumption explicit is useful for allowing to incorporate or experiment with partial and time-varying monetary policy credibility. This is especially important for developing economies, which are in the process of building state-of-the-art monetary policy making processes that as of yet may potentially lack full credibility, as is the case of Bank of Ghana. Partial credibility (or "incredibility") may manifest itself in a number of ways: (i) inflation may become excessively persistent, making it more difficult to manage short-run inflation-output trade-offs (e.g., Erceg and Levin, 2003); (ii) responsiveness of inflation to shocks may become larger, for example through stronger exchange rate pass-through (e.g., Kabundi and Mlachila, 2019 or Aleem and Lahiani, 2014); (iii) an asymmetric inflation bias as a result of low monetary policy credibility (e.g., Cukierman and Gerlach, 2003).

Modeling these in full force requires a non-linear model, as in Argov et al. (2007), Benes et al. (2017), Mkhatrishvili et al. (2019), or Chansriniyom et al. (2020). However, it is also possible to maintain the simplicity of a linear model but still allow for the QPM to incorporate the implications of only partial credibility, up to a first order approximation. The way this is achieved in the BOG QPM has been described above – the incredibility variable adds another layer to inflation persistency, capturing the fact of worse inflation-output trade-offs in developing economies with less than full central bank credibility as a result of poor historical record of price stability objective; see equation block (1). Full credibility implies inflation expectations are efficiently pinned down, similar to advanced economies with demonstrated anchoring of inflation expectations, equivalent to setting $b_6 = 0$. The actual calibration used in the BOG QPM, $b_6 = 1.5$, implies the inflation process shows significant persistence because of the lack of central bank credibility impacting the inflation expectations' formation mechanism and their anchoring to the central bank target.

To compare and contrast the cases of full credibility and the BOG QPM partial credibility, we perform several model simulations. Figure 16 shows the IRFs to a mix of cost-push (inflation) shocks that increase both food and non-food annual inflation by 1 percentage point each (hence, the first-round effect on headline inflation is also of the same magnitude). Full credibility version reflects the situation in which $b_6 = 0$; it implies a sudden jump in inflation, as expected, however it quickly goes back down after the one-off effects wave off from year-on-year computations. For this reason, while monetary policy responds initially, it only does so temporarily. Hence, output decline is also relatively modest.

Figure 16: Cost-push shocks: full credibility vs. time-varying partial credibility



With partial and time-varying credibility as in the BOG QPM, on the other hand, the central bank understands that these inflation shocks, while one-off by their nature, will generate persistently higher inflation via stickier expectations. Hence, monetary policy tightens similarly in the short-term, but remains tight for longer relative to the full credibility case. This implies a stronger exchange rate, other things equal, and a bigger drop in the output gap and hence in real marginal costs. While this helps on the inflation front in the short-run, price increases still turn out to be more persistent, due to only partial credibility – inflation now takes more time to return to the target. The end result is that while the price level increases by similar overall magnitudes in the two cases (as also shown by the same levels of nominal exchange rate at the end of the simulation horizon), output costs are significantly higher in the case of partial credibility. This demonstrates the worse inflation-output trade-off emphasized above.

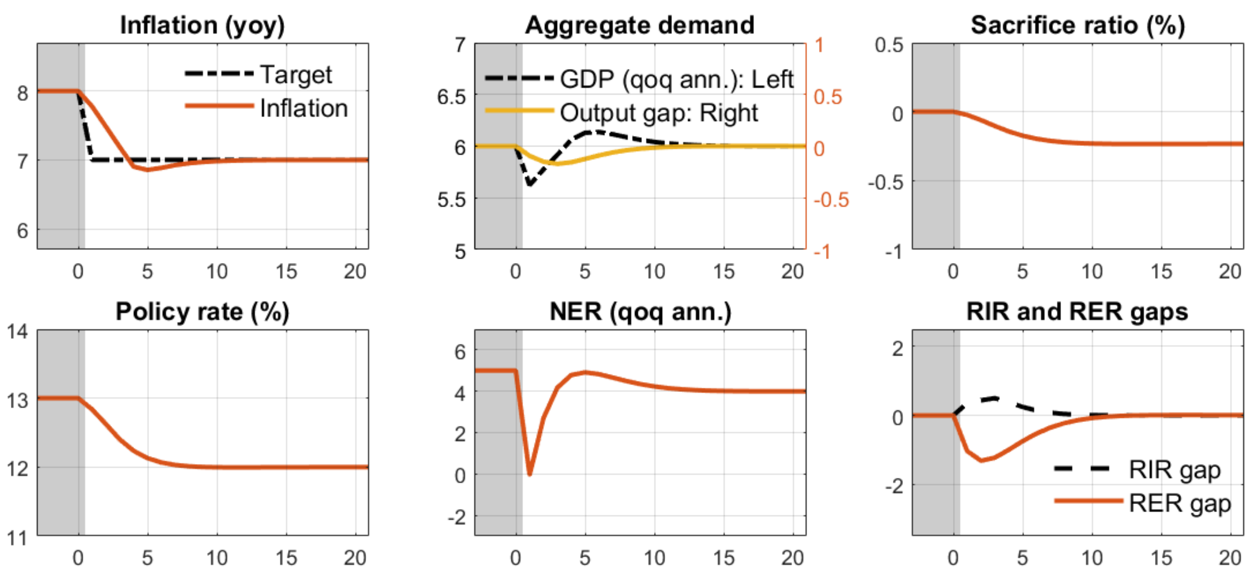
These IRFs show that incorporating partial credibility in a QPM makes it more realistic for developing economies, qualitatively consistent with the empirical and conceptual literature mentioned above. While we showcased the IRFs to cost-push shocks, the credibility block makes impulse responses more persistent – and thus more representative for emerging markets – to other shocks as well. For example, in a standard QPM a risk premium shock resembles an expansionary demand shock – weaker exchange rate provides competitive gains, increases net exports and, hence, output gap. However, in practice the risk premium shocks may be a reflection of lower investment or capital outflows from the economy, potentially leading to a combination of exchange rate depreciation and lower output. Our approach to modeling central bank credibility helps partially in this aspect as well (impulse responses not shown here, but see IRFs in Figure 7) – generating higher inflation (due to exchange rate depreciation) in response to a risk premium shock, but lower output gap relative to a full credibility benchmark, since higher inflation forces monetary policy to be relatively tighter.

E. Simulating Disinflation Scenarios

Simulating a disinflation scenario is one of key analysis in assessing model properties – how realistically it captures such a scenario shows important aspects of the transmission channels. Measuring an output-equivalent cost of disinflating is an efficient way to assess the quantitative realism of a given model calibration, and adjust it if needed. For the particular case of the BOG, lowering inflation target is an important practical aspect, given that the current level of 8 percent is quite high relative to other IT central banks, including from emerging market and developing economies.

Figure 17 shows the transition dynamics in response to a 1 percentage point reduction in the inflation target. In the baseline setup of this scenario, it leads to lower inflation expectations as well. While the credibility channel slows down such dynamics, inflation expectations are still declining, since the simulation starts from a full credibility state and economic agents fully understand and believe this change in policy framework, factoring-in the target reduction into their decisions. Hence, even though the real interest rate tightens as a result of lower inflation expectations, it does so only marginally, as the monetary policy rate starts declining toward the new steady state.

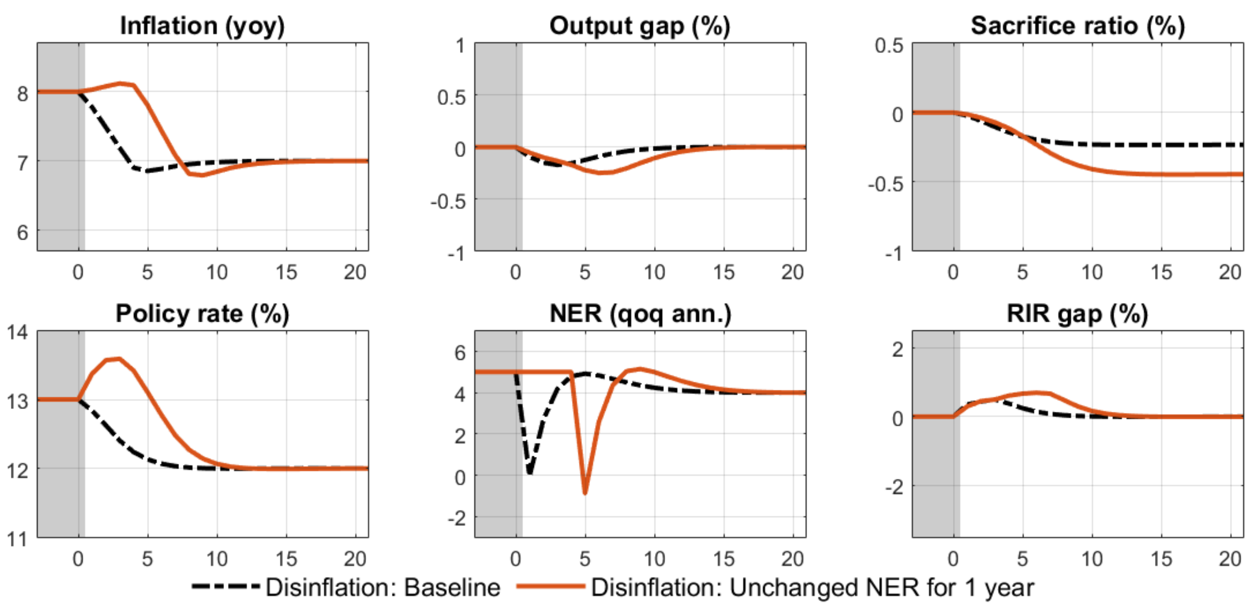
Figure 17: Simulation of reducing inflation target by 1 percentage point



Lowering inflation is also aided by an instantaneous appreciation of the exchange rate level by more than 1 percent in the first quarter (relative to no-disinflation case). This may sound like a central bank announcement having "too much power". However, there are empirical findings that support a view where a central bank trying to adjust its policy rate permanently (which is equivalent to a change in the inflation target) will cause exchange rate changes in a direction different from standard open-economy models. For example, according to Schmitt-Grohe and Uribe (2018) and Carvalho et al. (2021), a monetary shock that reduces nominal interest rates permanently induces an exchange rate appreciation, not depreciation. However, the key crucial assumptions here are rational expectations and full credibility, with very strong effects on economic agents' behavior[13] – everyone believes that the central bank will indeed be able to reduce interest rates permanently, which is only possible if long-term inflation expectations are also reduced permanently.

Overall, with such an assumption in a standard setup disinflation is quick and does not entail significant costs, as measured by a modest sacrifice ratio (cumulative output gaps) of about 0.2-0.3 percent of annual output. Simulating a disinflation scenario where a target reduction is announced one year in advance (not shown) leads to an even lower sacrifice ratio – as anticipating disinflation in advance helps reducing inflation merely through the expectations channel – which may not be a very realistic assessment, thus calling for augmenting the scenario with additional relevant features.

Figure 18: Simulation of reducing inflation target by 1 percentage point: baseline vs. fixed nominal exchange rate for one year



One of such features is incorporating a possibility of a mere announcement of a target reduction not changing price-setters' or financial markets' behavior, at least for some time. Figure 18 shows an example of such a scenario. More specifically, everything is the same as in the scenario above, but with an additional assumption of unchanged exchange rate for one year. Of course, no financial

[13] In addition, the above-mentioned studies were based on advanced economies.

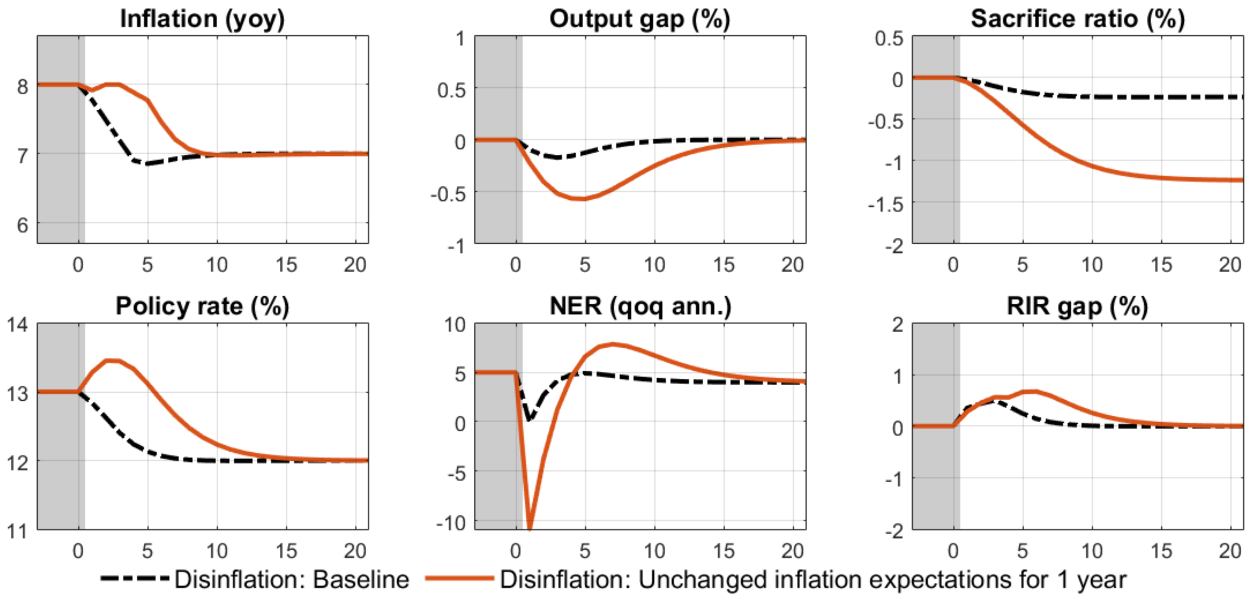
market participant adjusting their action for one year and then everyone doing so may not seem very realistic. Instead, a gradually increasing share of participants who believe disinflation is indeed happening may be more realistic. However, the latter produces roughly the same impulse responses over the medium to long-term. Hence, for illustrative purposes, we present this simplistic setup – forcing the exchange rate market to not react to a disinflation announcement for one year, but afterwards adjusting according to the model's mechanisms.

Contrasting this case (red lines) with a standard disinflation simulation (black lines), we see that instantaneous appreciation of the exchange rate was a key component of making disinflation quick and less costly. If the exchange rate does not adjust instantly, inflation rate is relatively flat and does not follow the newly announced target immediately. Then, as the central bank is comparing this unchanged inflation to a lower target, it is forced to actually tighten the interest rate, not only in real terms but also in nominal terms – policy rate shows an outright increase, which is usually missing in standard disinflation scenarios in canonical macro models. More tightening (relative to the standard case) then leads to lower output gap, which is required to bring inflation down. An exchange rate appreciation after one year, when economic agents see that the central bank is committed to the disinflation plan and willing to tolerate prolonged negative output gap to achieve disinflation, then makes inflation start declining fast. Afterwards, the dynamics are similar, but because it took more time to reach the new equilibrium, the sacrifice ratio is roughly twice as large, of about 0.5 percent of annual GDP.

Another possible feature that can be added to a standard disinflation scenario is incorporating a reduction in the monetary policy credibility. The intuition is that even if the previous inflation target had enough credibility, an announcement of a new one might not be credible enough initially, until the central bank shows the resolve to take actions to achieve the new target. The specific way we model this is shocking the credibility process such that it leads to unchanged inflation expectations for one year, even if economic agents already know the newly announced target. Everything else is the same as in the baseline case. The results are shown on Figure 19.

The results in terms of inflation and policy rate dynamics are similar to the scenario where exchange rate was unchanged for one year (Figure 18). However, the major difference is in terms of the output gap. Since the central bank knows that inflation expectations are no longer providing any support in the task of disinflation, it needs to commit to tight policy, which sharply appreciates the exchange rate on impact, even in the face of a bigger decline in the output gap. The latter is generating a significant sacrifice ratio equal to 1.3 percent of annual GDP.

Figure 19: Simulation of reducing inflation target by 1 percentage point: baseline vs. fixed inflation expectations for one year



The takeaway from this counterfactual scenario is that if inflation expectations are sticky at the old target level, disinflation can be relatively costly. This is in line with some of the empirical findings where disinflation was forced in a low credibility environment; see Erceg and Levin (2003), where as high as 1.7 percent sacrifice ratio is believed to be a reasonable empirical estimate of the cost of Volcker disinflation. What these QPM-based results imply is that (i) good central bank communication and transparency are crucial for anchoring inflation expectations and (ii) pre-emptively guarding against inflation expectations becoming de-anchored is necessary to avoid large costs of re-anchoring them in the future.

V. Conclusion

This paper describes the QPM underlying the BOG Forecasting and Policy Analysis System. The model builds on the canonical four equation semi-structural gap model nested in similar QPMs routinely used in central bank practice. Additional Ghana-specific characteristics considered in the model include heterogeneous dynamics across sub-indices of headline inflation, importance of fiscal policy for aggregate economic developments, and excess persistency of prices as a result of past inflation deviations from the target affecting monetary policy credibility. These extensions ensure QPM’s representativeness and certify its usefulness in efficiently informing policy making in the context of an IT forward-looking monetary policy framework.

The calibrated model displays theoretically consistent transmission channels in the face of relevant structural shocks. Out-of-sample simulations confirm the QPM’s data fit is also robust. These two results – theoretical and empirical coherence – are supported by well-identified historical business cycle dynamics and decompositions into driving forces, including when it comes to disentangling the complex multidimensional nature of the recent COVID-19-related shocks and their effects on the macroeconomic outcomes.

The paper also describes how the model is applied to assess the importance of the monetary policy credibility and the anchoring of inflation expectations. A systematic good track record of central bank performance, consistent with close-to-target inflation outcomes, can influence the price formation mechanisms in the private sector by forcefully aligning expectations to the announced target and reducing the persistency of the inflation process. In the event of a shock, this allows the central bank to stabilize the economy – and to bring inflation to its target – faster and with a smaller cumulative interest rate impulse relative to a situation of damaged credibility or unanchored inflation expectations.

Additional model simulations highlight the complexity of transitioning to a different inflation target. Revealing the new target in advance could produce economic effects starting the announcement date, before the actual implementation of the new target, with both costs and benefits in terms of macroeconomic volatility. In addition, the occurrence of shocks concurrently with the new target regime adoption or sticky behavior on the part of economic agents could entail a very different transition dynamics for the monetary policy conduct, interest rate dynamics, and the sacrifice ratio. The results underscore the highly shock-dependent nature of the disinflation process and call for careful monitoring of economic developments during this period.

The accumulated evidence regarding the experience with the FPAS in general – and the QPM in particular – at the BOG underscores the critical importance of the analytical infrastructure in structuring policy discussions and supporting policy making in real time. The FPAS-related analytical and institutional capacity was developed alongside the evolution of the monetary policy framework and economic progress. By supporting a wider space for policy analysis and enriching the forecast narrative, the QPM strengthens the Bank of Ghana’s forward-looking policy framework and contributes to attaining its price stability objective.

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