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ABSTRACT: The paper documents the latest extensions of the Bank of Ghana's Quarterly Projection Model (QPM), used regularly to produce policy analysis and forecasts in support of the Bank's policy processes. The decomposition of GDP allows to separate the agriculture and oil sectors, driven by exogenous and international developments, from non-agriculture non-oil activities, which are more relevant from the central bank's perspective of assessing the business cycle position. Inter-sectoral price spillovers and their role in the formation of inflation expectations are explicitly accounted, with important policy implications. Specific model applications – including impulse response functions and simulations of shocks that affect agricultural production, e.g., those caused by climate disruptions; and counterfactual simulations to evaluate recent policy choices – highlight the usefulness of the extended QPM in providing a more detailed account of the economic developments, enhance forecast coverage, and broaden its underlying narrative, thus strengthening the BOG's forward-looking policy framework.

JEL Classification Numbers:	E32, E37, E47, E52
Keywords:	Ghana; Forecasting and Policy Analysis; Quarterly Projection Model; Monetary Policy; Transmission Mechanism

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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 between 2019-2024, 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 ICD colleagues and management for their continuous feedback; to Adrian Alter, Jianping Zhou, and Nana Akosah for useful comments; 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 an early adopter of inflation targeting (IT) among Sub-Saharan African central banks, officially implementing it as its de facto monetary policy regime starting 2007. Recognizing the intricate nature of monetary policy transmission, which involves multiple channels, shock-dependent economic developments, and transmission lags within a dynamic endogenous system, the BOG established the Forecasting and Policy Analysis System (FPAS) as a critical analytical infrastructure to guide forward-looking policy decisions. Developed with technical assistance from the IMF, including collaboration between the co-authors of this paper, the BOG FPAS encompasses practical elements such as establishing a modeling team, approving a well-structured internal forecast calendar, and developing a range of analytical tools integrated in the policy process. For further details refer to Bank of Ghana (2022), which provides a comprehensive overview of the Bank's evolving monetary policy framework and its associated analytical infrastructure, as well as to IMF (2024) for a summary of BOG FPAS elements developed during the IMF technical assistance project.

Within the IT framework, the BOG is granted operational independence to pursue its primary objective of price stability, currently defined as medium-term headline inflation target of 8±2 percent. The Bank also actively promotes economic growth and ensures financial stability, while maintaining its commitment to price stability and operating independently of any instructions from the Government or other authorities.[2] Operationally, the implementation of monetary policy decisions consistent with the price stability objective is guided by an interest rate-based framework, with the main instrument being the short-term Monetary Policy Rate (MPR). De jure, BOG follows a flexible exchange rate regime, with occasional targeted FX operations to avoid excessive volatility and disorderly market conditions, but without resisting the trend of gradual nominal depreciation of the cedi in line with macroeconomic fundamentals.

Macroeconomic forecasting has become integral to the Bank's monetary policy formulation since the adoption of the IT framework. At the heart of the BOG's FPAS lies the semi-structural Quarterly Projections Model (QPM). Analytical work plays a key role in the BOG policy processes and its forward-looking monetary policy formulation. Model-based results are the foundation of the regular Monetary Policy Committee (MPC) cycles and QPM-based forecasts feature in external communications, including MPC Press Releases and Monetary Policy Reports. The present paper documents the latest version of the BOG's QPM, which includes a number of crucial extensions and additions vis-à-vis the earlier versions presented in Bank of Ghana (2022) and Abradu-Otoo et al. (2022). The continuous evolution of the QPM highlights the adaptability of the analytical work in response to the new economic realities, structural changes, and policymakers' needs, ensuring FPAS's relevance in supporting the monetary policy process. Overall, the BOG's

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

forecasting process is well-grounded and follows best international practices, as advised in Mæhle et al. (2021); see also AFRITAC West 2 (2024) for a brief overview of the BOG FPAS practice.

Following Abradu-Otoo et al. (2022), the BOG's QPM incorporates New Keynesian rigidities, allowing changes in the short-term nominal interest rate to have real economic effects in the near- to medium-run. It is through influencing demand-side inflationary pressures that the monetary policy steers the economy to achieve price stability. The model also accounts for Ghana's small open economy dimension, considering the impact of foreign variables and exchange rate dynamics. Notable extensions documented in Abradu-Otoo et al. (2022) capture further Ghana-specific economic features, such as decomposing headline CPI into food and non-food indices, incorporating fiscal policy effects, and addressing limited monetary policy credibility, defined in relation to historical deviations of inflation from the target which influence the formation of inflation expectations.

The main contribution of this paper lies in documenting the extended QPM currently in use at the BOG, which incorporates additional stylized facts pertaining to the Ghanaian economy vis-à-vis the model version presented in Abradu-Otoo et al. (2022). While the core structure and policy transmission channels embedded in the BOG QPM, following the canonical framework introduced in Berg et al. (2006a, 2006b), remain qualitatively intact, the extensions allow for a more accurate identification of sector-specific shocks, enrich model-based narrative, and provide a sharper monetary policy analysis.

First, GDP is modeled by decomposing aggregate demand into separate equations for agriculture, oil, and non-agriculture non-oil (NANO) sectors. The rationale behind this stems from the observation that the underlying data generating processes for each of these sectors are driven by different factors and shocks, and therefore evolve differently. The agriculture sector, for instance, exhibits volatility due to its dependency on climatic conditions. In contrast, oil sector's performance is heavily influenced by external developments in crude oil prices, over which domestic monetary policy in a small open economy like Ghana has no impact, but which has a significant effect on the exchange rate dynamics given crude oil exports generate important FX inflows. By contrast, developments in the NANO sector – comprising mainly services and manufacturing – provide a better indication about the domestic business cycle position and dynamics, helping to identify the domestic demand-side inflationary pressures more accurately, thus being of particular interest for the monetary policy formulation. The GDP breakdown also allows to match the differential cross-sector impact of pandemic-related lockdowns introduced in 2020, with output gaps in oil and agriculture – two strategic activities exempted from the government-mandated restrictions – largely neutral, but profoundly negative NANO output gap.

Second, the modeling of aggregate supply by decomposing the CPI basket in food and non-food indices adopted in Abradu-Otoo et al. (2022) is adjusted to better reflect additional transmission channels. Given the separation of agriculture sector, food inflation Phillips curve is expanded by an additional term to capture the price pressures emanating from the production of agri-food goods;

see also Vlcek et al. (2020). This channel can approximate, in a non-structural reduced-form manner and without explicitly modeling climate-related variables (which could however be used outside the QPM to form expert judgement and build narratives), the propagation of climate shocks in a model-consistent framework, e.g., unfavorable weather conditions that lead to lower agricultural production will push food prices up, with important implications for the formulation of policy decisions. In addition, anecdotal evidence suggests a tight comovement between food and non-food prices in Ghana, with important spillover effects across the two sectors. To match these, the formation of sector-specific inflation expectations considers headline CPI, and additional cross-sector shock terms are introduced. All these elements enhance the understanding of how supply shocks propagate and the ensuing implications for the formulation of model-based monetary policy recommendations.

Third, the paper presents additional model applications and results. After documenting how the shock propagation differs from Abradu-Otoo et al. (2022), we present how the extended model can be used to analyze the transmission and policy implications of shocks that directly affect agriculture output, e.g., caused by climate phenomena. Counterfactual simulations are presented to highlight the major trade-offs between price stability and economic growth: e.g., a counterfactual interest rate trajectory that follows the Taylor-type reaction function during 2022-23 suggests a tighter policy stance, which would lower inflation rate by about 5 percentage points compared to actual outcomes but at the cost of 1-1.5 percent lower output.

Overall, this paper contributes to the ever-expanding literature on semi-structural gap models used for practical policy analysis and forecasting. The canonical QPM model, introduced by Berg et al. (2006a, 2006b), serves as the foundation for various central banks' modeling toolkit. These tools are particularly relevant for central banks adopting inflation targeting or inflation forecast targeting as their operational regime; see Adrian et al. (2018). However, the canonical model has been customized and extended to account for various specific channels, country characteristics, and policy frameworks. For instance, Benes et al. (2017) tailored the model for India, Baksa et al. (2020) for Cambodia, Vlcek et al. (2020) for Rwanda, Baksa et al. (2021) for Morocco, Epstein et al. (2022) for Vietnam, Al-Sharkas et al. (2023) for Jordan, Dakila Jr. et al. (2024) for the Philippines. Berg et al. (2023) enrich the canonical QPM framework to accentuate the nexus between external and internal balances, to explicitly incorporate fiscal policy, and to partly endogenizes the main macroeconomic trends.

The paper also extends on the scarce stock of literature investigating monetary policy aspects in Ghana. After documenting historical inflation developments across the timeline of Bank of Ghana policy regimes – highlighting the superiority of the current IT framework – Abango et al. (2019) call for strengthening the transmission from interest rate to inflation, supported by improved credibility and transparency. Bleaney et al. (2020) use empirical estimations to confirm that, despite inflation exceeding the target on average, the monetary policy reaction function operates in a theoretically consistent way. A semi-structural model is implemented in Harvey and Walley (2021), focusing on the transmission of energy price shocks. Current QPM version incorporates and extends some of the results in these papers within a fully consistent modeling framework in use of practical monetary policy analysis and forecasting.

Despite all extensions and additional mechanisms, the BOG QPM still presents important shortcomings. For example, the model is linear (by construction) and displays limitations during severe shock events like the COVID-19 pandemic or the recent crisis occasioned by debt sustainability concerns (in practice, BOG staff overcomes these by introducing specific expert judgements in the model). Regarding the economic policies' landscape, the model is parsimoniously considering only interest rate instrument and price stability objective for the central bank, together with a simplified fiscal policy block. In practice, BOG is also focused on financial stability, while the government implementation of fiscal policy relies on a large number of instruments and mechanisms. Future QPM extensions, some of them on-going, will directly address a number of these limitations; see IMF (2024) for additional discussions.

The rest of the paper is organized as follows. Section II presents several stylized facts about the Ghanaian economy that informed the design of the QPM and its extensions. The detailed structure of key equations underlying the current BOG QPM is extensively covered in Section III. Next, Section IV describes a broad set of model-based results: impulse response functions to key structural shocks (in comparison to the previous model version), the importance of GDP and CPI breakdown, and counterfactual simulations to enrich monetary policy analysis. Section V concludes.

II. Stylized Facts and Model Structure Motivation

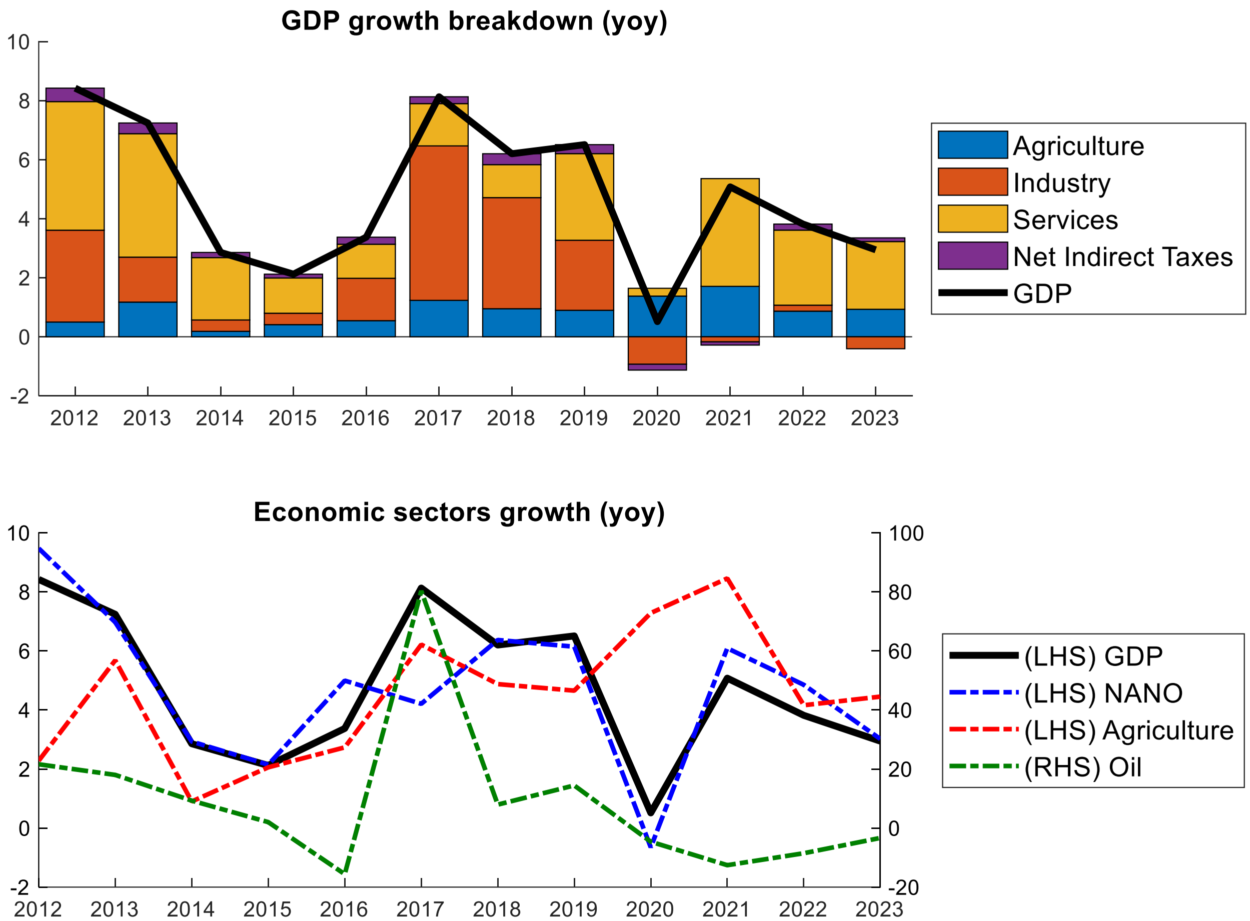
The design of the BOG's QPM and its subsequent extensions consider relevant characteristics of the economy and policy framework. This ensures the model's relevance as the key analytical input into the BOG's policy analysis and forecasting. This section provides an overview of the key stylized facts that informed the structure and calibration of the QPM, focusing on more recent periods and novel elements as compared to Abradu-Otoo et al. (2022).[3]

While manufacturing and services represent the dominant economic activities, the Ghanaian economy has undergone a significant structural change since the emergence of the oil industry in 2010s. As shown in Figure 1, over the previous decade the economy was characterized by strong growth interrupted by occasional shocks. From 2014 to 2023, real GDP growth averaged 4.2 percent, driven by robust activity in all major economic sectors. Over the same period, growth in services averaged 4.7 percent, industrial sector growth averaged 3.5 percent – largely driven by oil production growing by 6.9 percent – and agriculture sector growth averaged 4.6 percent. Conceptually, sectoral growth patterns in agriculture and oil activities differ considerably from the

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

rest of the economy. Ghana's agriculture output is significantly influenced by climatic conditions, given its dependence on the timing and amount of rainfalls. In contrast, the oil sector is responsive to fluctuations in the international crude oil markets. On the other hand, the non-agriculture non-oil (NANO) sector could be considered a better reflection of the domestic business cycle conditions and, implicitly, of demand-side price pressures. Accordingly, the QPM incorporates the decomposition of GDP into oil, agriculture, and non-agriculture non-oil sectors.

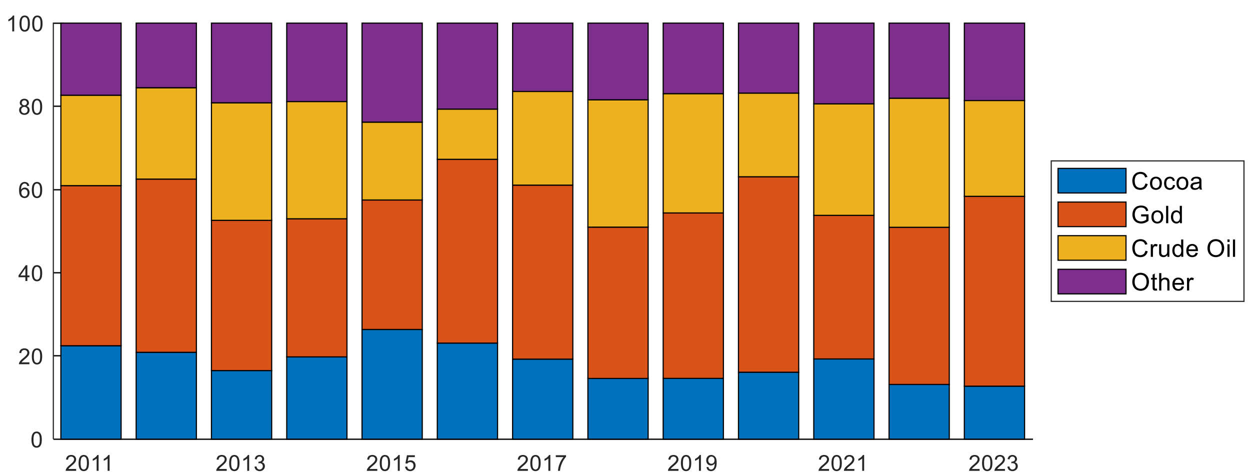
Figure 1: Real GDP growth and sectoral developments



In 2020, Ghana experienced its lowest growth outturn of 0.5 percent, largely due to government-mandated lockdowns and the associated closures of businesses and border restrictions to mitigate the spread of the COVID-19 pandemic. Growth rebounded strongly to 5.1 percent in 2021, demonstrating economic resilience bolstered by countercyclical macroeconomic policies implemented in response to the pandemic shocks. From 2021, however, growth slowed, reaching 2.9 percent in 2023, largely due to an acute economic crisis characterized by constrained domestic financing and loss of access to the international capital markets. This crisis was triggered and amplified by the lingering effects of the pandemic, the Russia's invasion of Ukraine, tightening financing conditions, and a decline in the country's sovereign credit rating on the back of debt sustainability concerns. To restore macroeconomic stability and debt sustainability, the Government initiated a Post COVID-19 Program for Economic Growth (PC-PEG) in 2023. The program, which is supported by a 3-year IMF Extended Credit Facility (ECF) arrangement, includes wide-ranging reforms to build economic resilience and lays the foundation for stronger and more inclusive growth; see details in IMF (2024).

The Ghanaian economy is characterized as a small open economy with a moderately robust trade activity. As a share of nominal GDP, during 2014–2023 total exports averaged 24.2 percent, while total imports averaged 23.8 percent. Figure 2 shows that cocoa, gold, and oil are the country's three core export commodities. From 2014 to 2023, these have collectively accounted for over 80 percent of the export proceeds. This highlights the important role that price and supply conditions of these commodities, determined on the international markets, have on the Ghanaian economy. Imports are largely dominated by intermediate, consumption, and capital goods. While a detailed modeling of trade flows, e.g., as in Al-Sharkas et al. (2023) or Berg et al. (2023), is left for future QPM extensions, the current version – given the abovementioned decomposition of GDP – accounts explicitly for the role of oil exports as a source of foreign currency, such that more intense oil production leads to appreciation pressures.

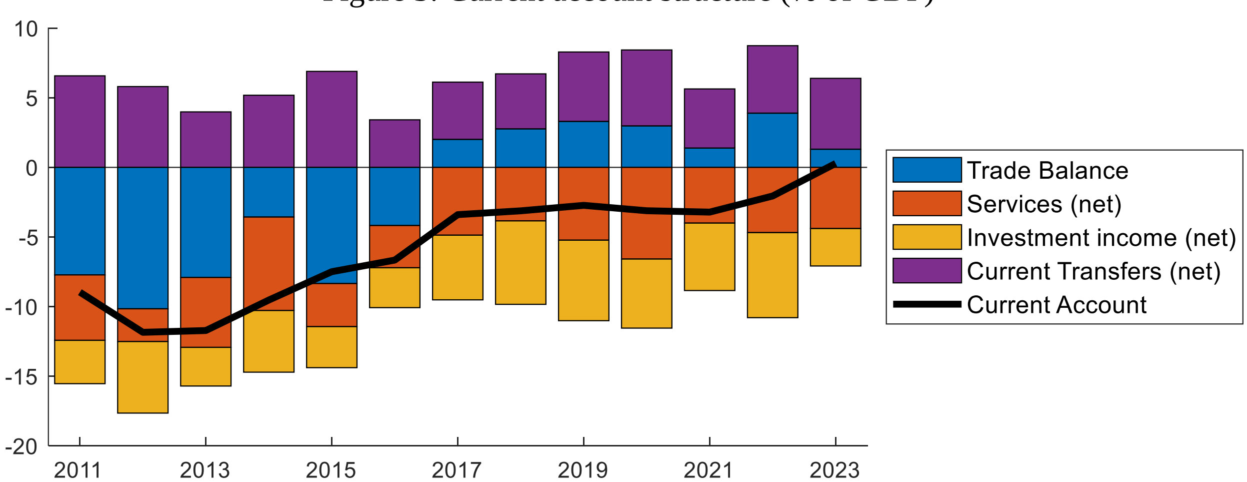
Figure 2: Exports structure (% of total)



Despite a positive trade balance in recent years, the Ghanaian economy has often recorded current account deficits, given the flows in net services and investment income were frequently surpassing the flows in trade balance and net current transfers (Figure 3). Notwithstanding the persistent deficits recorded over the period, it is noteworthy that the current account has improved notably post-2016 compared to the earlier years. This was largely attributed to increased oil production and higher gold exports, which have shifted the trade balance from deficit to surplus. These trends, alongside lower external debt servicing due to the negotiations to restructure public external debt, led to a positive current account balance in 2023. A satellite extension to the QPM which incorporates a detailed fiscal block, including the differentiation between foreign and domestic (currency) debt, accounts in an explicit manner for some of these considerations. This work is being documented and will be presented in a forthcoming working paper; see IMF (2024) for preliminary assessments and results.

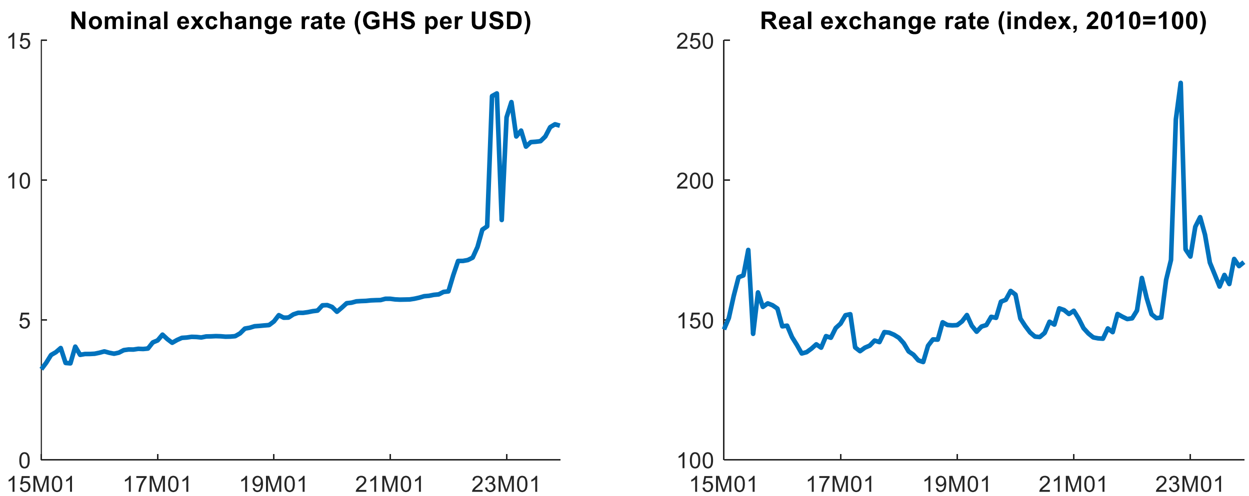
Despite the frequent current account deficits, the real exchange rate vis-à-vis USD has remained broadly stable prior to mid-2022. This was supported by a persistently positive inflation rate differential – including on account of significantly higher inflation target in Ghana against the main trading partners – that has largely compensated the mild and gradual nominal exchange rate depreciation tendency; see Figure 4. From 2014 to 2023, median annual depreciation rate against the USD was 11.3 percent. Over the assessed period, nominal depreciation was high during the occasional crisis episodes, including in 2022 when the country has effectively lost access to the international capital markets due to high premia quoted by investors on the Eurobond instruments, reflecting concerns over fiscal and debt sustainability. Gross reserves, used to smooth the volatility in the foreign exchange market, has averaged approximately 3.7 months of import cover over the period, though it was significantly lower during the recent crisis. As a result of the 3-year IMF Extended Credit Facility arrangement, gross reserves rebounded in 2023 and exchange rate has stabilized.

Figure 3: Current account structure (% of GDP)



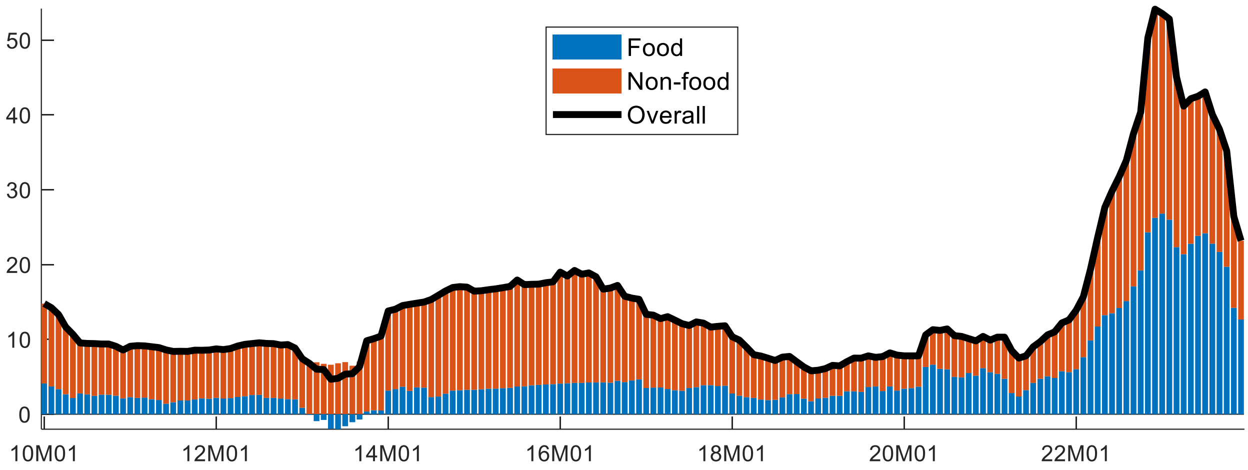
Bank of Ghana's inflation management strategy relies on monetary policy formulation within an inflation targeting (IT) framework, with price stability currently defined as medium-term headline inflation of 8 percent ±2 percentage points. Since the formal adoption of the IT regime in 2007, there has been a noticeable reduction in both volatility and level of headline inflation. In contrast to an average headline inflation of 14.8 percent during the period of the IT regime (2007-2023), headline inflation averaged 48.8 percent during the period of direct control (1972 – 1991), 28.4 percent during the monetary targeting regime (1992 – 2001), and 20.2 percent during the preparatory stage of IT (2002-2006); see also Abradu-Otoo et al. (2022).

Figure 4: Exchange rate developments



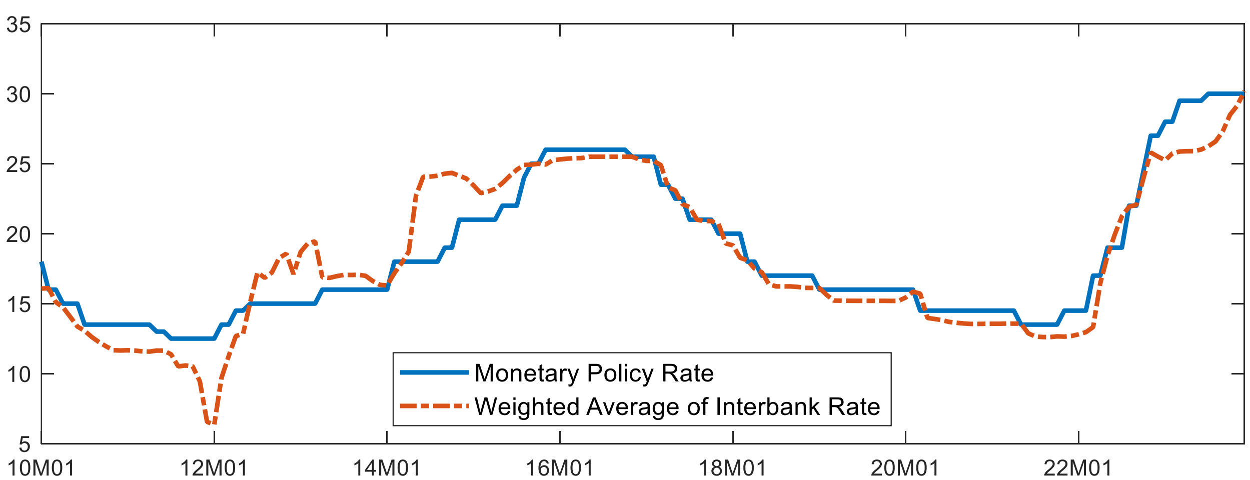
Trends in headline inflation have primarily been driven by supply-side shocks; see Bank of Ghana (2022) and Abradu-Otoo et al. (2022) for detailed analyses. More recently, during and after the COVID-19 pandemic, food supply bottlenecks have played a larger role. Quantitative analysis of price dynamics based on the CPI breakdown shows that non-food inflation explains, on average, about 79.8 percent of headline inflation dynamics between 2014 and 2016 (compared with a share of non-food consumption basket of 56.88 percent), largely reflecting the pass-through effect of power shortages into non-food prices during the period. This trend has been on a downward trajectory, as contribution of non-food inflation to headline inflation has reduced to an average of 62.4 percent between 2017 and 2020, and further down to 51.4 percent between 2021 to 2023 (Figure 5). The sector-specific price dynamics resulted in an upward trend in non-food prices relative to food prices prior to the pandemic, followed by a reversal in recent years. At the same time, anecdotal evidence suggests there are important inter-sectoral linkages that generate spillovers in price formation, which are incorporated in the model via specific adjustment in the inflation expectations' formation process and introduction of additional sectoral shock feedback mechanisms.

Figure 5: Inflation rate breakdown (yoy)



In order to steer inflation to its medium-term target and achieve price stability, the central bank relies on the Monetary Policy Rate, which signals the overall stance of the monetary policy and anchors short-term market interest rates. In line with the inflation targeting regime and the implemented operational framework, the interbank rate has broadly moved in lockstep with the policy rate (Figure 6). This correlation suggests a working interest rate pass-through mechanism, ensuring that changes in the Monetary Policy Rate influence the financing costs of financial intermediaries across the yield curve and, consequently, the retail rates on loans and deposits offered by the banking sector to households, firms, and other retail customers at various maturities, which ultimately impact aggregate demand and price pressures.

Figure 6: Interest rates (%)



Given the fundamentals of the economy, real interest rates have generally been positive and high. For example, from 2014 to 2021 real policy rate averaged 7.15 percent, compared to a negative or close-to-zero real interest rate in advanced economy trading partners. The high real interest rate pertaining to the Ghanaian economy attracted, over the years, large foreign investments and supported overall economic development. However, with the onset of the COVID-19 pandemic, followed by Russia's invasion of Ukraine and loss of access to the international capital markets due to high premia emanating from fiscal sustainability concerns, Ghana began to experience large portfolio reversals. Consequently, the currency depreciated significantly (Figure 4), passing through into inflation and turning the real interest rate negative starting early-2022. Subsequently, the real interest rate turned back positive in late-2023, as a result of the IMF-supported reforms, tight monetary policy stance, relatively stable exchange rate, and effective liquidity sterilization.

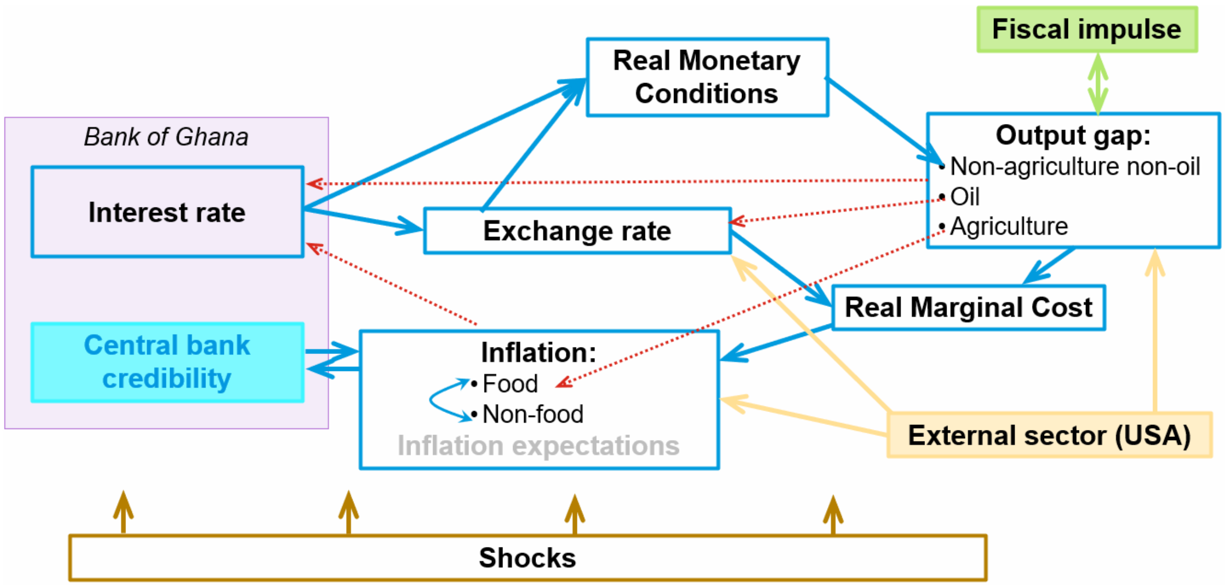
For an overview of economic developments during the recent period, including the post-pandemic developments and the implementation of the ECF agreement, see IMF (2024). The economic considerations and transmission mechanisms described above, some of which have been already introduced in Abradu-Otoo et al. (2022), are further refined or extended in the current QPM structure, making it a relevant and practical tool for real-time policy analysis and forecasting.

III. Model Structure

The QPM structure presented below is in many ways similar to Abradu-Otoo et al. (2022), with certain parts modified and extended in the directions consistent with the stylized facts briefly presented above. The core of the BOG's QPM still follows Berg et al. (2006a, 2006b) and comprises four key blocks of equations: aggregate demand, Phillips curves, uncovered interest rate parity (UIP), and monetary policy reaction function. However, the blocks' specifications are modified to capture the economic dynamics more realistically and improve consistency with the Ghanaian context. Below, all variables (except interest rates and fiscal balance) are expressed in logarithms or gaps (denoted with "hats"), with time subscripts indexing quarters.

Figure 7 presents a birds' eye view of the model, highlighting the key variables and interlinkages between them, as described in detail in this section.

Figure 7: Schematic representation of the model



A. Aggregate Demand

Unlike Abradu-Otoo et al. (2022), where aggregate output gap is modeled using a single equation, in the current extension, total output gap ($\hat{y}_t$) is specified as a weighted average of agriculture output gap ($\hat{y}_t^{agr}$), oil output gap ($\hat{y}_t^{oil}$), and non-agriculture non-oil (NANO) output gap ($\hat{y}_t^{nano}$):

$$\hat{y}_t = \omega_1 \hat{y}_t^{agr} + \omega_2 \hat{y}_t^{oil} + (1 - \omega_1 - \omega_2)\hat{y}_t^{nano} \tag{1}$$

where ω_1 and ω_2 are sector-specific weights for agriculture and oil sectors, respectively.[4]

NANO output gap is modeled using an investment-savings framework, being a function of its lag ($\hat{y}_{t-1}^{nano}$), one-quarter ahead model-consistent rational expectations ($E_t \hat{y}_{t+1}^{nano}$), real monetary conditions index ($rmci_t$), fiscal impulse ($fimp_t$) averaged over the last four quarters in order to smooth the volatility in intra-annual fiscal execution data and to better capture the lagged or persistent effect of fiscal policy measures, foreign output gap ($\hat{y}_t^*$), and a demand shock ($\varepsilon_t^{y^{nano}}$).

$$\hat{y}_t^{nano} = \alpha_1 \hat{y}_{t-1}^{nano} + \alpha_2 E_t \hat{y}_{t+1}^{nano} - \alpha_3 rmci_t + \alpha_4 \textstyle\sum_{i=3}^{0} \frac{1}{4} fimp_{t-i} + \alpha_5 \hat{y}_t^* + \varepsilon_t^{y^{nano}} \tag{2}$$

[4] Current model specification focuses on oil sector only, while future extensions can consider the broader extractive sector, comprising oil, gas, and mining (the latter two industries are currently included in the NANO sector). The extractive sector has overall similar underpinnings to the oil sector, including relevant external demand component and global commodity price effects. These aspects are left for future model developments.

where α_1 is the degree of persistence in NANO output gap, α_2 represents the elasticity of expected NANO output gap, α_3 denotes monetary conditions' pass-through to the real economy and captures the strength of the monetary policy transmission, α_4 measures the effect of government revenue and expenditure policies or net fiscal impulse on aggregate demand, and α_5 is the scale of influence of foreign developments via net exports.

The real monetary condition index ($rmci_t$) is defined as a weighted average of the real interest rate (RIR) gap ($\hat{r}_t$) and the real exchange rate (RER) gap ($\hat{z}_t$):

$$rmci_t = \eta_1 \hat{r}_t + (1 - \eta_1)(-\hat{z}_t) \tag{3}$$

The RIR gap is defined as the deviation of real interest rate from its neutral level while the RER gap is the deviation of real exchange rate from its medium-term trend. The coefficient η_1 captures the relative shares of the two components within the real monetary conditions index.

In Abradu-Otoo et al. (2022), the fiscal impulse is measured as a shock to the structural deficit based on the headline deficit, which is influenced by past decisions, such as debt dynamics and cost of borrowing.[5] The current version emphasizes the impact of more discretionary current policy decisions on the business cycle by replacing the headline deficit with the primary deficit (def_t), which is decomposed into structural ($def_{str,t}$) and cyclical ($def_{cyc,t}$) components. This modeling approach is more standard in QPM framework, being also implemented in Vlcek et al. (2020) and Baksa et al. (2021). Otherwise, the structure of the fiscal block in the current version of the model is similar to Abradu-Otoo et al. (2022):

$$def_t = def_{cyc,t} + def_{str,t} \tag{4}$$

$$def_{cyc,t} = -f_1 \hat{y}_t \tag{5}$$

$$def_{str,t} = f_2 def_{str,t-1} + (1 - f_2) def_{str,ss} + \varepsilon_t^{str\_def} \tag{6}$$

$$fimp_t = \varepsilon_t^{str\_def} \tag{7}$$

The structural primary deficit is modeled as an AR(1) process, converging to its steady state with persistence captured by f_2, and a shock representing the fiscal impulse appearing in the NANO demand equation (1). Cyclical deficit ($def_{cyc,t}$) is linked to the total output gap, where f_1 represents the degree of counter-cyclicality of fiscal policy.

As mentioned earlier, the drivers of agriculture and oil output gaps are exogenous to the model and thus their data generating processes are assumed to follow simple AR(1) processes:

[5] A QPM extension modeling the fiscal-monetary interactions has been developed and is used by the BOG as a satellite tool. This work is currently being documented and will be presented in a forthcoming working paper; see IMF (2024) for a preliminary discussion.

$$\hat{y}_t^{agr} = \sigma_1 \hat{y}_{t-1}^{agr} + \varepsilon_t^{y^{agr}} \tag{8}$$

$$\hat{y}_t^{oil} = \sigma_2 \hat{y}_{t-1}^{oil} + \varepsilon_t^{y^{oil}} \tag{9}$$

The shock in the agricultural gap equation, $\varepsilon_t^{y^{agr}}$, can be interpreted as and approximate the impact of shocks to agricultural output originating, inter alia, from climate-related disruptions.

B. Aggregate Supply

Similarly to Abradu-Otoo et al. (2022), headline CPI is defined as the weighted average of food and non-food indices:

$$p_t = \psi p_t^f + (1-\psi) p_t^{nf} + \varepsilon_t^p \tag{10}$$

where p_t is headline CPI, p_t^f and p_t^{nf} are the food and non-food indices (all in natural logarithms), with ψ being the weight of food items in the CPI basket, and ε_t^p captures the approximation errors due to observed time variations in the relative weights of the two indices and measurement errors due to using logarithms and seasonal adjustment.

One of the key additions relative to Abradu-Otoo et al. (2022) is that both non-food and food indices are modeled to reflect cross-sector spillovers. Shocks to prices of items in the food component spill over into non-food prices and vice versa. Hence, the Phillips curve for non-food inflation is modeled as a function of backward- and forward-looking expectations, real marginal costs, imported inflation proxy, and shocks originating in both sectors:

$$\pi_t^{nf} = \beta_1^{nf} \pi_{t-1}^{nf} + \left(1 - \beta_1^{nf} - \beta_3^{nf}\right) \pi_{t+1}^{e,nf} + \beta_2^{nf} rmc_t^{nf} + \beta_3^{nf} m_t + \beta_4^{nf} \varepsilon_t^{\pi_f} + \varepsilon_t^{\pi_{nf}} \tag{11}$$

where π_t^{nf} is quarter-on-quarter annualized non-food inflation; $\pi_{t+1}^{e,nf}$ is the expected non-food inflation, modeled as a combination of model-consistent rational expectations of headline inflation, $E_t \pi_{t+1}$, adjusted by an inflation bias term due to (lack of) policy credibility, $incred_t$ (see below); β_1^{nf} is the degree of persistence in non-food inflation; β_2^{nf} is the elasticity of non-food inflation with respect to real marginal costs rmc_t^{nf}; β_3^{nf} captures the elasticity of non-food inflation with respect to imported inflation proxy m_t; and β_4^{nf} captures the proportion of food price shock that spills over to the non-food basket, where $\varepsilon_t^{\pi_f}$ is the food supply shock and $\varepsilon_t^{\pi_{nf}}$ is the non-food supply shock.

Inflation expectations are formed based on headline inflation, rather than sector-specific expectations as in Abradu-Otoo et al. (2022), adjusted for a central bank credibility term:

$$\pi_{t+1}^{e,nf} = E_t \pi_{t+1} + \tau_1^{nf} incred_t \tag{12}$$

where τ_1^{nf} captures the impact on expected non-food inflation coming from the lack of monetary policy credibility, i.e., "incredibility". Similar to Abradu-Otoo et al. (2022), $incred_t$ is modeled as a weighted average of the previous quarter's (in)credibility stock and previous quarter deviation of year-on-year inflation from the target $\bar{\pi}_t$, plus a shock ε_t^{incred}, with β_1 being the level of persistence of central bank (in)credibility, and β_2 reflecting the elasticity of inflation gap with respect to the (in)credibility stock:

$$incred_t = \beta_1 incred_{t-1} + (1-\beta_1)\,\beta_2\,(\pi_{t-1}^{yoy} - \bar{\pi}_t) + \varepsilon_t^{incred} \tag{13}$$

As described in more detail in Abradu-Otoo et al. (2022), the specification of the central bank credibility mechanism is related to the intuition that if the historical track record of achieving inflation target is weak, i.e., past headline inflation was predominantly above the target, then the anchoring of inflation expectations could be damaged and inflation dynamics can become entrenched, requiring a more forceful policy response.

Unlike Abradu-Otoo et al. (2022), where total output gap proxies domestic cost pressures, the real marginal cost in the non-food sector (rmc_t^{nf}) is expressed as a function of non-agriculture non-oil output gap only, with weight ϕ^{nf}, in addition to the real exchange rate gap capturing imported input costs:

$$rmc_t^{nf} = \phi^{nf}\hat{y}_t^{nano} + (1-\phi^{nf})\hat{z}_t \tag{14}$$

Similar to Abradu-Otoo et al. (2022), m_t in the non-food Phillips curve is a proxy for imported inflation, computed as the difference between foreign inflation (π_t^*) expressed in domestic currency units (i.e., adjusted with the change in the nominal exchange rate Δs_t), and the change in RER trend, $\Delta\bar{z}_t$:

$$m_t = \Delta s_t + \pi_t^* - \Delta\bar{z}_t \tag{15}$$

Similarly to non-food inflation, the Phillips curve for the dynamics of food prices differs from the version in Abradu-Otoo et al. (2022) by the inclusion of sectoral price spillovers and, crucially, the impact of agriculture output gap. The latter can capture, in a reduced-form manner, the impact on food prices of climate shocks, like rainfalls and droughts, through their effect on food supply. This leads to the following specification for the food sector Phillips curve:

$$\pi_t^f = \beta_1^f \pi_{t-1}^f + \left(1-\beta_1^f-\beta_3^f\right)\pi_{t+1}^{e,f} + \beta_2^f rmc_t^f + \beta_3^f m_t + \beta_4^f \varepsilon_t^{\pi n_f} - \beta_5^f \hat{y}_t^{agr} + \varepsilon_t^{\pi_f} \tag{16}$$

where the definition of the variables is similar to those in the non-food Phillips curve above, with the addition of $\hat{y}_t^{agr}$, the agriculture sector output gap. In the equation above, β_4^f captures the impact/influence of non-food price shock on food inflation, while β_5^f is the elasticity of food inflation with respect to the agriculture output gap. Food inflation expectations are formed as above, using overall, rather than sector-specific expectations. Real marginal costs relevant for food inflation is qualitatively similar to non-food inflation, but the elasticity of food real marginal cost with respect to domestic input costs (ϕ^f) can be different, since demand pressures may materialize differently for the two sets of prices:

$$rmc_t^f = \phi^f \hat{y}_t^{nano} + (1 - \phi^f)\hat{z}_t \tag{17}$$

C. Exchange Rate Dynamics: Uncovered Interest Parity

Relative to Abradu-Otoo et al. (2022), the UIP has been extended to account for oil output in exchange rate developments. Higher oil exports are expected to bring in more foreign exchange, shoring up FX reserves and supporting domestic currency stability. We therefore expect a positive oil output gap to contribute to an appreciation of the nominal exchange rate.[6]

The nominal exchange rate is therefore modeled via a modified version of the UIP condition. Specifically, the nominal exchange rate is mainly determined by the interest rate differential adjusted for sovereign risk premium and oil output gap. Exchange rate expectations are hybrid, reflecting the existence of both inertial backward-looking agents and model-consistent forward-looking ones, together implying the following UIP specification:

$$s_t = s_{t+1}^e + \frac{i_t^* - ib_t + prem_t}{4} - c_1 \hat{y}_t^{oil} + \varepsilon_t^s \tag{18}$$

where s_t is the log of the nominal exchange rate, measured as units of domestic currency per one unit of foreign currency (US dollar), ε_t^s is an exchange rate (or UIP) shock, c_1 is the elasticity of nominal exchange rate with respect to oil output gap, i_t^* represents foreign (US) nominal interest rate, ib_t is the domestic nominal money market (interbank) interest rate, and s_{t+1}^e is the expectation for the nominal exchange rate one period ahead, defined as a weighted average of model-consistent rational expectations and a backward-looking term:

$$s_{t+1}^e = c_2 E_t s_{t+1} + (1 - c_2)\left(s_{t-1} + \tfrac{2}{4}\Delta\bar{s}_t\right) \tag{19}$$

where c_2 is the share of forward-looking agents in exchange rate market and $\Delta\bar{s}_t$ is the trend nominal depreciation (trend real depreciation plus inflation target differential). Finally, $prem_t$ is the sovereign risk premium[7], modeled as an AR(1) converging to its steady state, with b_1 capturing its persistence:

$$prem_t = b_1 prem_{t-1} + (1 - b_1) prem_{ss} + \varepsilon_t^{prem} \tag{20}$$

[6] Gold exports are another important source of foreign currency (Figure 2) and can have similar implications for the exchange rate dynamics. We consider explicitly only the oil sector output in the current QPM specification, given the corresponding decomposition of the GDP block into agriculture, oil, and NANO sectors already provides a satisfactory balance between tractability and realism.

[7] The sovereign risk premium can be rewritten to include the oil output gap currently specified in equation (18). These two alternative specifications are similar in terms of the model propagation mechanisms and overall results.

D. Monetary Policy Reaction Function

The QPM, as in the previous version, is closed with a monetary policy reaction function, i.e., a Taylor-type rule that relates changes in the Monetary Policy Rate to the Bank's objectives of steering inflation to the target with some consideration for developments in the real sector of the economy. However, depending on liquidity considerations on the financial markets, the interest rate that produces aggregate demand effects – the interbank rate – may differ from the policy rate. This difference is captured by a time-varying spread (sp_t), with zero mean in steady state:

$$i_t = \gamma_1 i_{t-1} + (1-\gamma_1)[E_t\pi_{t+1} + \bar{r}_t + \gamma_2(E_t 4\pi_{t+3} - \bar{\pi}_t) + \gamma_3\hat{y}_t] + \varepsilon_t^i \tag{21}$$

$$ib_t = i_t + sp_t \tag{22}$$

$$sp_t = \kappa_1 sp_{t-1} + \varepsilon_t^{sp} \tag{23}$$

where i_t is the short-term nominal key policy interest rate (BOG Monetary Policy Rate), $\bar{r}_t$ is the real neutral rate such that $E_t\pi_{t+1} + \bar{r}_t$ defines the nominal neutral rate; $E_t 4\pi_{t+3}$ is the three-quarter ahead expected year-on-year inflation, $\hat{y}_t$ is the total output gap (note that given the defined BOG mandate and objectives, the policy reaction function considers total output rather than NANO output, which reflects more accurately the demand-side inflationary pressures, as discussed above), ε_t^i and ε_t^{sp} are monetary policy shock and monetary policy transmission (liquidity) shock, respectively, γ_1 is the interest rate smoothing parameter, γ_2 is the weight assigned to the inflation stabilization objective, γ_3 is the weight assigned to the output stabilization objective, and κ_1 is the persistence of the spread between the interbank and policy rates.

E. Trends and External Sector

Given the small open economy assumption, developments in the Ghanaian economy do not have an impact on the rest of the world. Accordingly, external variables – which reflect the US economy – are treated as exogenous in the QPM. Additionally, the gap structure of the model focuses on the business cycle components and does not impose a structural representation on the trends. As such, foreign variables (proxied by USA economic data) – inflation rate (π_t^*), output gap ($\hat{y}_t^*$) and real interest rate (r_t^*) – and (domestic) trends, such as real exchange rate change ($\Delta\bar{z}_t$), potential output growth ($\bar{y}_t$), and inflation target ($\bar{\pi}_t$) are modeled as univariate processes:

$$x_t = k_x x_{t-1} + (1-k_x)x_{ss} + \varepsilon_t^x \tag{24}$$

where k_x captures persistency, x_{ss} denotes the corresponding steady state value, and ε_t^x is a shock.

F. Calibration

The model is calibrated by taking into account various proprieties of the data, features of the monetary policy framework, and expert judgement, to ensure that the transmission mechanisms are theoretically consistent. Several complications with the data (small samples contaminated by structural breaks) and features of the model (simultaneity of key equations, prevalence of unobserved components, and rational expectations) limit the scope for a full-fledge estimation of the QPM. In this respect, by preferring calibration to estimation, we follow the favored approach at other central banks; e.g., Benes et al. (2017), Baksa et al. (2020), Vlcek et al. (2020), Epstein et al. (2022). Table 1 presents the calibrated values of the key structural parameters.

Table 1: Calibrated parameters in key behavioral equations

Non-Food Inflation		**Food Inflation**		**Credibility**		**Food CPI Weight**	
β_1^{nf}	0.7	β_1^{f}	0.5	β_1	0.5	ψ	0.4312
β_2^{nf}	0.4	β_2^{f}	0.2	β_2	1.5		
β_3^{nf}	0.1	β_3^{f}	0.1	τ_1^{nf}	0.5		
β_4^{nf}	0.2	β_4^{f}	0.2				
ϕ^{nf}	0.7	β_5^{f}	1				
		ϕ^{f}	0.6				
NANO Output Gap		**Agriculture Gap**		**Oil Gap**		**Output Shares**	
α_1	0.4	σ_1	0.5	σ_2	0.5	ω_1	0.2
α_2	0.3					ω_2	0.07
α_3	0.1	**RMCI**					
α_4	0.5	η_1	0.8				
α_5	0.1						
Exchange Rate		**Fiscal Sector**				**Interest Rate**	
c_1	0.2	f_1	0.2			γ_1	0.75
c_2	0.6	f_2	0.95			γ_2	1.3
b_1	0.9					γ_3	0.1
						κ_1	0.65

IV. Model Results

This chapter presents the key results. The propagation mechanisms of fundamental shocks and the ensuing monetary policy response to stabilize the economy are depicted using impulse response functions (IRFs). The implications of the introduced interaction between food prices and agriculture output gap within the food inflation Phillips curve – which could approximate, in a reduced-form manner, the effects of climate-related shocks, given the causality from weather phenomena to the dynamics of agri-food prices and quantities observed in the Ghanaian data – are also presented. The sectoral decomposition of aggregate demand allows for a richer analysis of the business cycle dynamics and provides a more realistic assessment of the COVID-19 lockdowns' impact on economic activity across different sectors. Finally, policy trade-offs are highlighted using counterfactual scenario analysis, comparing actual policy trajectory with two alternative interest rate paths.

A. Impulse Response Functions

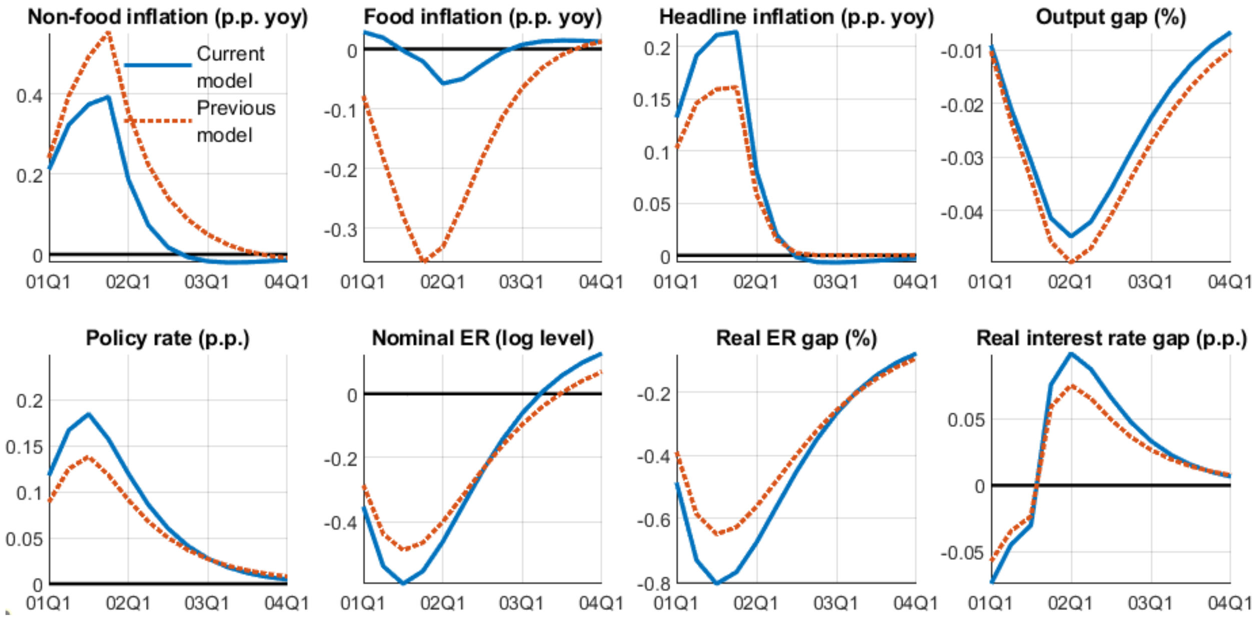
The responses of key macroeconomic variables to main shocks are presented in parallel to the previous model version covered in Abradu-Otoo et al. (2022). This theoretical exercise is conducted under the assumption of the model economy being initially in equilibrium. Then, a one-time single shock is applied to simulate the dynamics of key macroeconomic aggregates. Thus, the IRFs generated from this simple exercise effectively explore the QPM's propagation mechanisms and assess its theoretical consistency, including its relation to the previous model structure. The IRF magnitudes are expressed in deviations from the associated steady state. For example, the annual headline inflation equilibrium is given by the 8 percent inflation target, so inflation responses are presented as percentage points deviation from the target.

Figure 8 displays the IRFs of key macroeconomic variables to an adverse non-food supply shock, such as an unexpected one-off increase in energy prices. In the current model (blue lines), in response to an adverse non-food supply shock overall inflation immediately increases (positive deviations from the target), primarily on the back of a rise in non-food prices (the directly affected sector), while food prices are quasi-stable. In the non-food sector, prices increase directly due to the shock. In contrast, prices in the food sector increase slightly on impact due to spillover effects of the non-food inflation shock on food prices. To steer inflation back to target, the central bank raises nominal interest rates, which lead to a tightening of real monetary conditions – as the real interest rate increases above expected inflation, interest rate stance becomes contractionary (positive real interest rate gap) starting three quarters after the shock, while real exchange rate (ER) appreciates and becomes overvalued (negative real exchange rate gap).[8] Consequently, aggregate demand declines in the short- to medium-run and output gap becomes negative. The tightening of

[8] The result that the central bank actively responds to supply shocks is a salient feature in most QPMs, especially those tailored to emerging markets and developing economies. In situations where there is a limited track record of successfully achieving price stability and weak central bank credibility – factors that contribute to the risk of easily de-anchored inflation expectations – monetary policy may need to prioritize price stability and respond to supply-side shocks at the cost of output losses.

the real monetary conditions and its dampening effects on output (aggregate demand) gradually steer non-food and headline inflation back to target within a period of about eight quarters.

Figure 8: Non-food supply shock



Comparing the IRFs in the current model to the previous version (red dashed lines) documented in Abradu-Otoo et al. (2022), a few insights are noticeable. In response to the adverse non-food supply shock, overall headline inflation increases relatively more in the current (extended) model. This happens on account of the current model considering forward-looking agents in both food and non-food sectors forming their expectations by incorporating the spillovers and second-round effects of the initial non-food supply shock. This results in broadly stable food inflation dynamics and a higher headline inflation outturn. The previous model shows a significant decline in food inflation in response to the non-food supply shock, which is at odds with available anecdotal evidence. In response to the higher inflation outturn, the monetary authority raises the nominal interest rate by a slightly larger margin to ensure that real monetary conditions are sufficiently tight in the current model. Despite the tighter real monetary conditions in the current model, the negative output gap is slightly milder, reflecting the notion that interest rates affect output in a direct way only in the non-agriculture non-oil sector compared to total output in the previous model.

The IRFs to an adverse food supply shock are displayed in Figure 9, with the results and the rationale underpinning the overall dynamics broadly similar to those outlined for the adverse non-food supply shock above. This includes the immediate increase in the non-food prices (unaffected sector) directly attributable to the food supply shock (affected sector) which has spilled over to the non-food sector, and the second-round effects from the associated changes in expectations' formation.

Relative to the previous model, overall headline inflation is once again higher in the current model due to the spillover effects of the food inflation shock on the non-food sector. Accordingly, the monetary authority increases the nominal interest rate, which leads to tighter real monetary conditions in the current model as compared to the previous model. With nominal interest rates primarily affecting output in the NANO sector only (see equation (2), which links the real interest rate component of the monetary conditions index to the NANO output gap, while agriculture and oil sectoral gaps being exogenous), the pass-through effect of the nominal interest rate hike on aggregate output is relatively lower as compared to the previous model where all sectors were affected. This results in a comparatively milder negative output gap.

Figure 9: Food supply shock

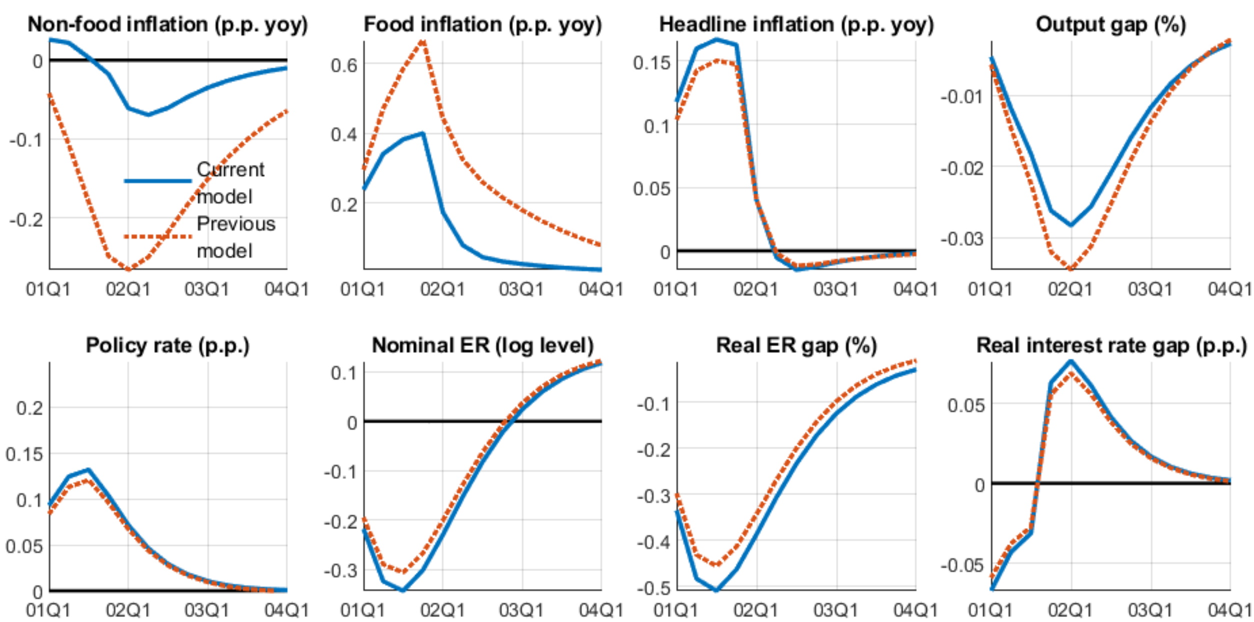
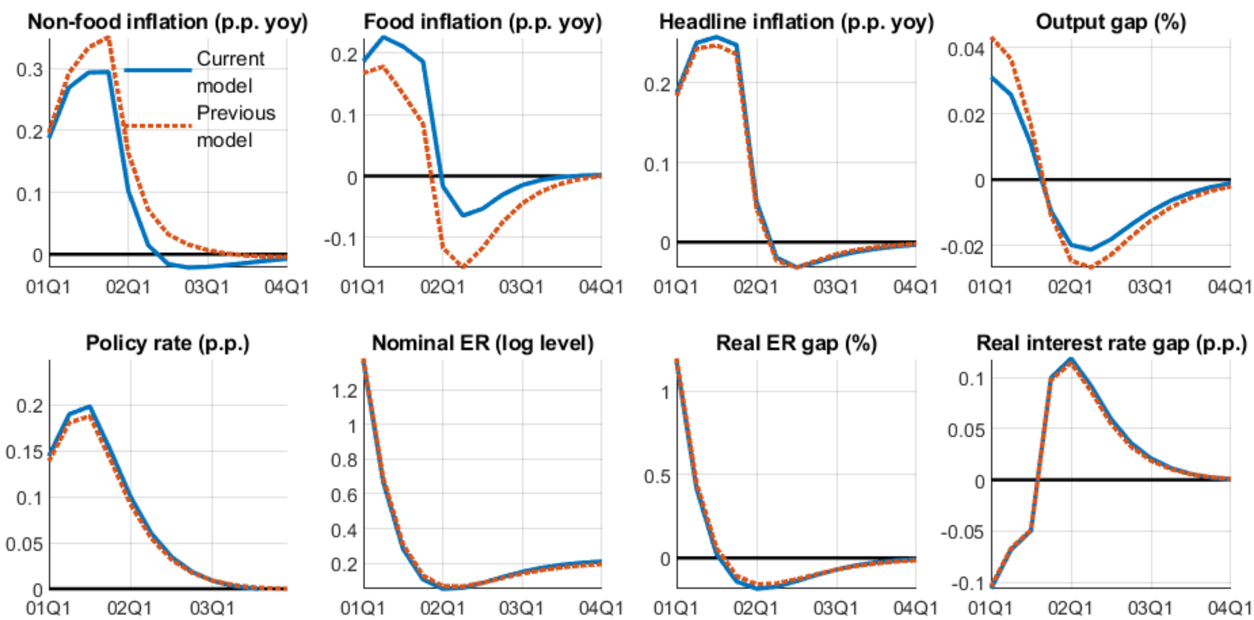


Figure 10 shows the impulse responses to an unexpected exchange rate depreciation shock. Given price rigidities, the onset of the exchange rate shock leads immediately to a nominal and real exchange rate depreciation. This makes domestic goods relatively more competitive relative to foreign-produced ones and stimulates aggregate demand on account of expenditure switching effects, thereby leading to a positive output gap.[9] The real exchange rate depreciation, together with the positive output gap, increases real marginal costs of production in the economy via more expensive inputs of both imported and local origin. This increase in the cost of production leads to a rise in headline inflation, on the back of an increase in both food and non-food prices. In response to the emerging price pressures, the monetary authority raises the nominal interest rate, which brings real interest rates above their neutral levels. Over time, this leads to a strengthening of the domestic currency and tighter real monetary conditions in a manner that steers output and inflation back towards their steady state levels.

Figure 10: Exchange rate depreciation shock



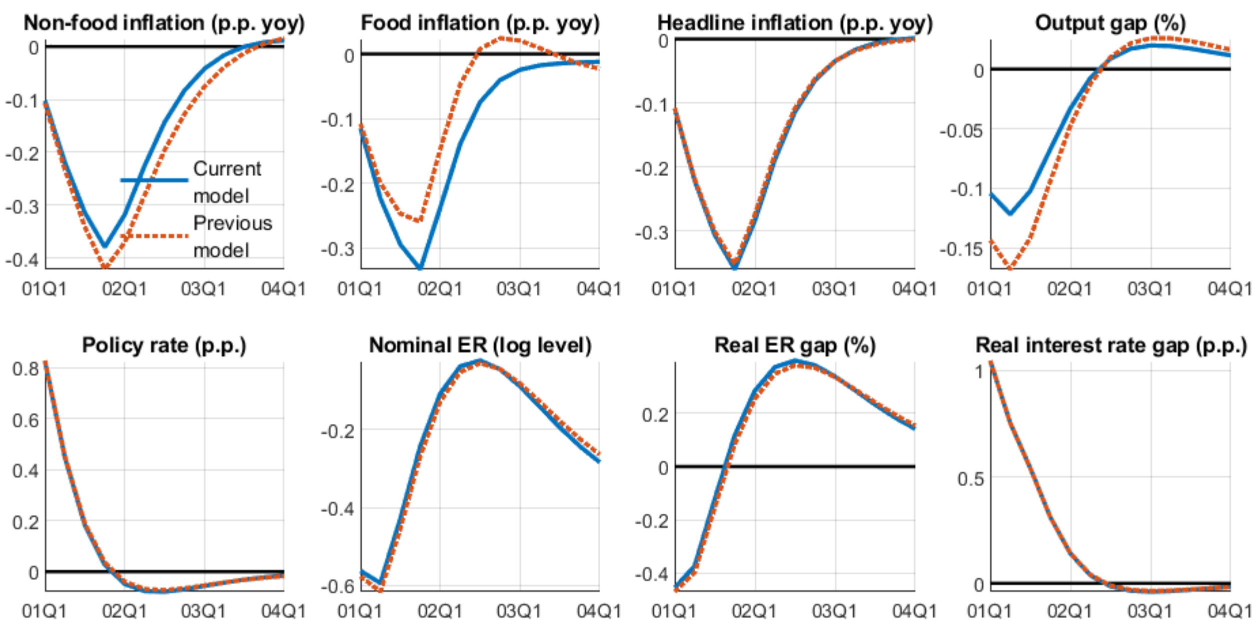
In comparing the impulse responses in the current model with the previous version, three key differences are observed. First, the positive output gap emerging in the short- to medium-run is lower in the current model. This result owes to the fact that the current model disaggregates total output such that the sectors of the economy that are significantly affected by exchange rate

[9] In general, semi-structural gap models, including BOG QPM, have embedded the result that depreciation shocks are expansionary, given the strong net exports channel via undervalued real exchange rate and the corresponding price competitiveness gains it entails. This contrasts with the alternative identification of depreciation shocks originating from capital outflows or risk-off pressures in emerging markets and developing economies, which are likely to be contractionary; see also Berg et al. (2023). In order to properly account for this channel, the QPM would need to be modified by introducing additional elements to produce an unfavorable impact on domestic demand components (investment and consumption), like a term structure of interest rates, credit risk premia, expanding the monetary conditions index concept to a broader financial conditions index, etc. These elements are left for future research.

dynamics are separated from sectors that are not (agriculture and oil); the previous model assumes implicitly that all sectors are impacted, with the same intensity. Second, in response to the exchange rate shock, headline inflation in the current model is slightly higher than that observed in the previous model. This can be attributed to the updated Phillips curve equations which now account for second-round effects and spillovers.[10] Finally, in response to the higher inflation rates observed in the current model during the first few quarters (and despite slightly less expansionary output gap), the monetary authority hikes the nominal interest rate slightly more aggressively as compared to the previous model.

Impulse responses to a monetary policy shock are displayed in Figure 11. Following an unexpected increase in the monetary policy rate, the real interest rate gap is tightened on the back of price rigidity, while the real exchange rate becomes overvalued on account of nominal appreciation. These developments lead to a tightening in real monetary conditions, which dampens aggregate demand and results in a negative output gap. Headline inflation declines below the target, reflecting the slowdown in both non-food and food inflation. To restore equilibrium, monetary authority begins an easing cycle, steering output and inflation back to their steady states.

Figure 11: Monetary policy shock



[10] Through inflation expectations, which now incorporate the dynamics of overall headline inflation in the economy and cross sectoral shocks.

Broadly, the impulse responses in the current model are similar to those observed in the previous model, confirming that the transmission mechanism of monetary policy shocks is qualitatively unaffected. Nonetheless, output gap, though negative in both models, is lower in the current model. This is attributable to the GDP disaggregation, which captures the notion that nominal interest rates affect sectors of the economy disproportionately, rather than uniformly as assumed in the previous model (i.e., the response of total output gap in the previous model is equivalent to the response of NANO output gap in the current model). In addition, the responses of food and non-food inflation are slightly different, though headline inflation remains unchanged across models. These differences can be explained by the updated Phillips curve equations, which allow for inflation expectations in the two sectors to be formed based on the developments in overall inflation in the economy rather than just sector-specific price developments.

B. Interaction between Food Prices and Agriculture Output

The separation of the agriculture sector and food CPI subcomponent, together with their direct interlinkage within the food inflation Phillips curve (equation 16), enables analyses of climate-related shocks in a model-consistent way in a reduced-form setting[11]. Note that given the inherent complexity of modeling climate phenomena – including the distinction between short-term effects (like natural disasters) and long-run developements (like global warming), multiple propagation channels and challenging identification of demand- versus supply-side effects, the better position of fiscal policy to address climate risks, etc. – the approach presented here is simplistic and very limited. Still, the adopted implementation has a practical utility and convenience. In practice, the effects of climate change can be assessed outside the QPM model to inform expert judgement (tunes) that can be applied in the QPM. The calibration in the current model captures the fact that besides being more volatile and less persistent relative to non-food prices, food inflation is directly impacted by agriculture supply (value added) and, implicitly, by climate events like rainfalls and droughts, which are difficult to predict.

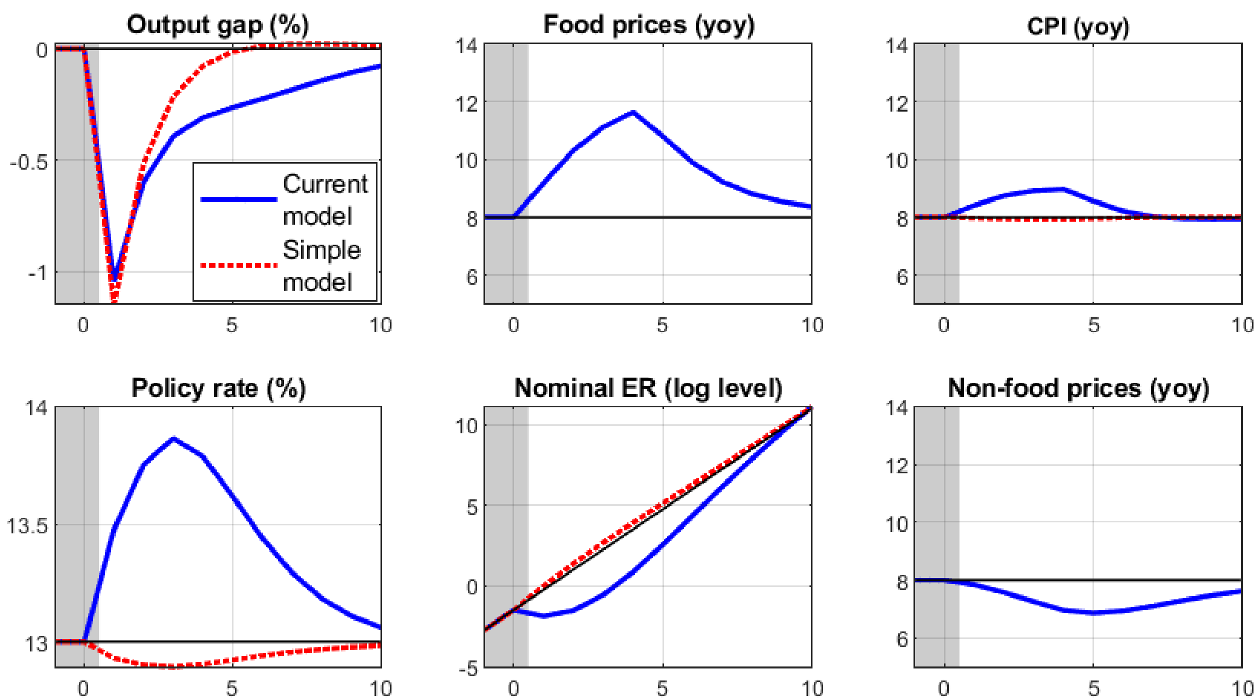
To showcase these additional mechanisms, Figure 12 presents the IRFs to a shock that reduces agricultural output by 5 percent, potentially due to adverse weather conditions in a particular quarter. The current model, where the exercise amounts to simulating the responses to a 5 percent drop in $\varepsilon_t^{y^{agr}}$ in (8), with persistency of the shock determined by σ_1 = 0.5, is compared to a simple one-sector model which does not differentiate between GDP sectors and CPI subcomponents as in the previous model. The corresponding shock is simulated as a 1 percent drop in the aggregate demand equation (equivalent to $\varepsilon_t^{y^{nano}}$ in (2) in a counterfactual model with no sectoral GDP decomposition, i.e., where the share of NANO GDP is 1). This gives the interpretation of the shock scenario reflecting a decline in agriculture value added and, accordingly, aggregate GDP (the

[11] Without explicitly modeling climate variables and and their dynamics.

magnitude is consistent with the 5 percent adverse shock in the current model multiplied by the calibrated 20 percent share of agriculture in total GDP).

The essential implications for monetary policy conduct revealed by the current (multisector) model relative to the previous (one-sector) model lies in its ability to provide an accurate separation of demand- and supply-side price pressures, including those originating from climate disruptions and food production. Figure 12 shows that in the current model (blue lines) a reduced agriculture production on account of a bad harvest implies a decrease in total output and a rise in food – and headline – inflation. Given the risks of inflation expectations being de-anchored and to limit the extent of second round effects, the central bank tightens the interest rate stance, which leads to nominal exchange rate appreciation and slightly lower non-food inflation.

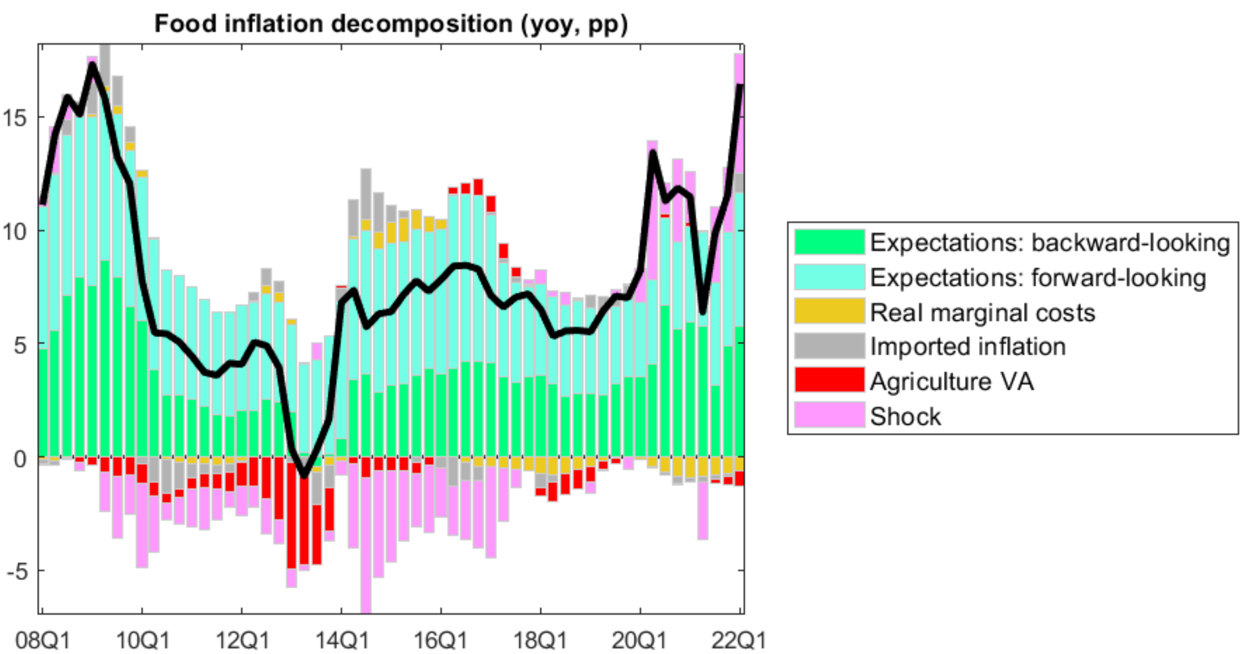
Figure 12: Agriculture output shock: simple one-sector model vs current multi-sector model (magnitudes centered on steady states or balanced growth path)



In contrast, in the simple model with no differentiation of food inflation and agriculture value added (red dashed lines), lower total output gap due to unfavorable agriculture production resembles an adverse demand-type shock and is marginally deflationary, requiring a slightly accommodative interest rate stance. An alternative approach to more realistically analyze adverse agricultural shocks in the one-sector model would be to add also a Phillips curve shock to approximate the impact on CPI via food price increases. The current model builds this structure and intuition in a transparent and explicit manner, avoiding some of the related complications (like running simultaneous shocks scenarios and calibration of their relative magnitudes).

In conclusion, shocks that affect agriculture output, and thus total GDP, act as inflationary supply-type disturbances in the current model, with relatively persistent and non-negligible effects, and as deflationary demand-type disturbances with only marginal effects in the one-sector model. Therefore, there are critical differences in terms of central bank trade-offs and the ensuing implications for the monetary policy conduct, which the extended model can help explicitly account and quantify.

Figure 13: Decomposition of food inflation Phillips curve



The decomposition of annual food inflation based on the Phillips curve (16) is presented in Figure 13, focusing on the subsample 2008Q1-2022Q1. The dynamics of food prices is explained primarily by inflation expectations: backward-looking expectations indicate a moderate amount of persistence and inertia, while forward-looking expectations reflect aggregate price prospects (i.e., for both food and non-food sectors) and intersectoral spillovers, unlike only sector-specific price expectations in Abradu-Otoo et al. (2022). The contribution of agriculture GDP helps explaining the interlinkage between food inflation dynamics and domestic supply of agri-food goods. Importantly, the QPM can now explicitly account for the narrative that was presented in BOG's external publications even before the model was extended. For example, the September 2014 Monetary Policy Report mentions that "conditioned on good harvests, adequate supply of foodstuffs on the market help to moderate food prices and in turn food inflation" (page 6), mapping the negative contribution of agriculture value added over 2014 in Figure 13; the September 2016

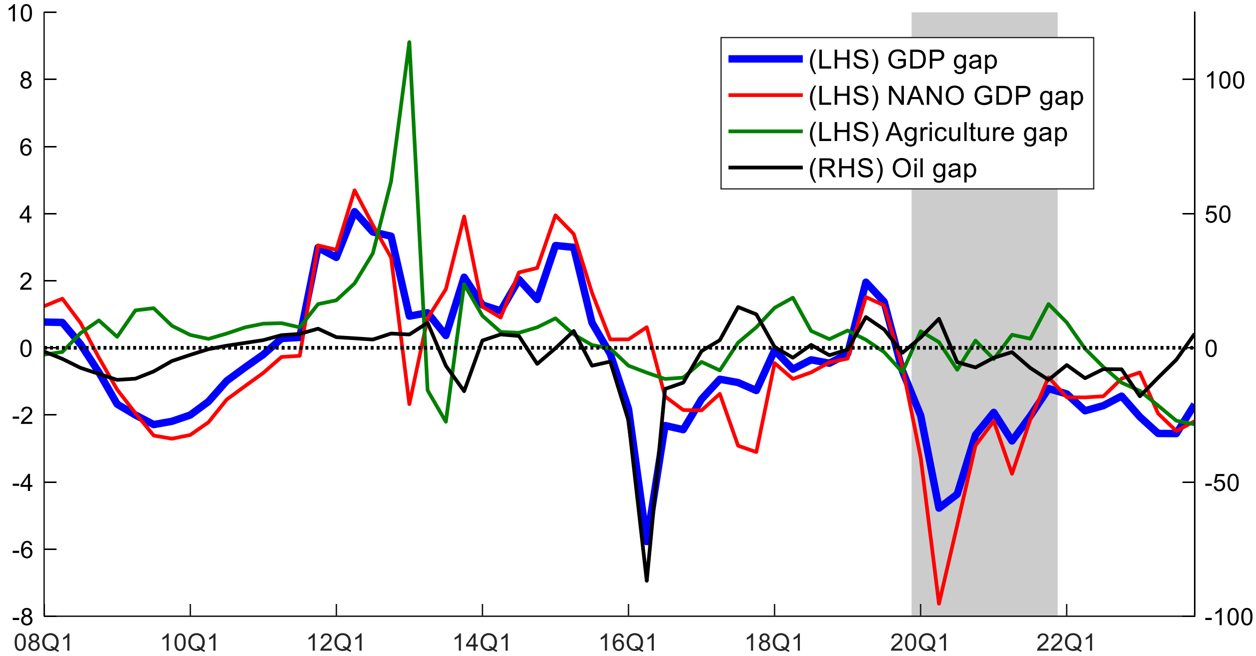
Monetary Policy Report mentions that "the developments in food prices during the harvest season will determine the extent to which food prices will evolve […] as the food season was derailed by the delays in rainfall" (page 15), in line with the positive contribution of agriculture over 2016. See Abradu-Otoo et al. (2022) for other equation decompositions.

C. Sectoral Business Cycle Dynamics

The decomposition of GDP into the three sectors allows for a more granular assessment of the business cycle dynamics in Ghana. The sector-specific developments and their interactions are critical for an accurate assessment of the business cycle position and, accordingly, for the monetary policy conduct. Economic activity in agriculture and oil sectors is driven by idiosyncratic and international events, like rainfall patterns and global geopolitical tensions, which do not follow the aggregate domestic business cycle or monetary policy stance, and are impacting CPI dynamics in a specific way and through certain price subcomponents. On the other hand, non-agriculture non-oil GDP is likely to better capture the domestic demand-side inflationary pressures, especially in the non-food price basket. The monetary policy transmission via interest rates and exchange rate is also relatively stronger in the case of NANO GDP, given the high relevance of financial developments for services, manufacturing, and construction. Accordingly, the GDP decomposition adopted in the BOG QPM, alongside the separation of food and non-food prices, allows for a more accurate evaluation of the fundamental drivers of price dynamics at both sectoral and aggregate levels, provides richer policy analyses, and improves the forecast narratives or relevance of alternative scenarios.

Figure 14 presents the estimated output gaps in aggregate GDP and the three sectors (note that given its high volatility, oil gap is plotted on the right-hand axis). Overall, given the importance of the NANO sector, at 73 percent of total GDP, it is the primary determinant of the aggregate output business cycle (i.e., the red and blue lines display a high degree of comovement). An interesting assessment is provided for the COVID-19 period 2020-21 (grey highlight). The pandemic-induced lockdowns in 2020Q2 were strictly imposed for most business activities in the NANO sector. However, in certain economic activities, mainly agriculture and oil industry, the COVID-related restrictions were less severe or benefited from specific exemptions, given their strategic importance. In line with this industry-level evidence regarding the stringency of the government-mandated lockdowns, estimated output gap is negative and large in non-agriculture non-oil sector, while oil and agriculture sectors registered higher, close-to-neutral, output gaps.

Figure 14: Estimated output gaps in total GDP and the three sectors (%)



Overall, the results presented above suggest the extended QPM featuring the three-sector GDP breakdown provides a more realistic assessment of the business cycle position and dynamics relative to single-sector models that do not allow for a proper differentiation between economic activity in different sectors.

D. Counterfactual Scenarios

In this subsection, the QPM is deployed to construct counterfactual policy scenarios for the hypothetical situation in which the BOG would have implemented different interest rate trajectories as compared to the actual one. These scenarios shed light on the model's ability to provide consistent policy recommendations and underscore the major trade-offs the central bank faced during the recent crisis. In constructing these counterfactual scenarios, we produce model forecasts over the period 2022Q1-2023Q4 conditioning on (i) ex-post full sample estimated structural shocks and (ii) setting the interest rate trajectory and/or interest rate shocks to specific values. This approach is similar to Baldini et al. (2015), Král et al. (2022), Crump et al. (2023) and Darracq Paries et al. (2024), all implemented in comparable contexts.[12]

Figure 17: Counterfactual scenario: Interest rate follows QPM policy reaction function

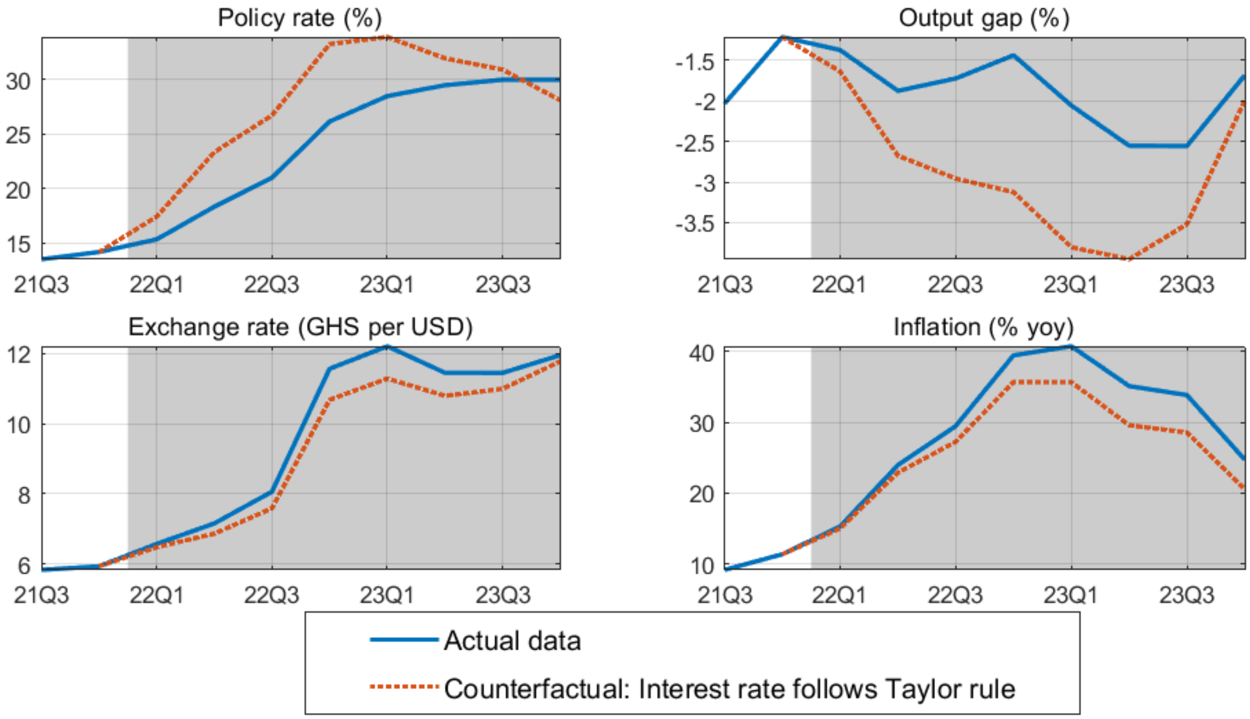


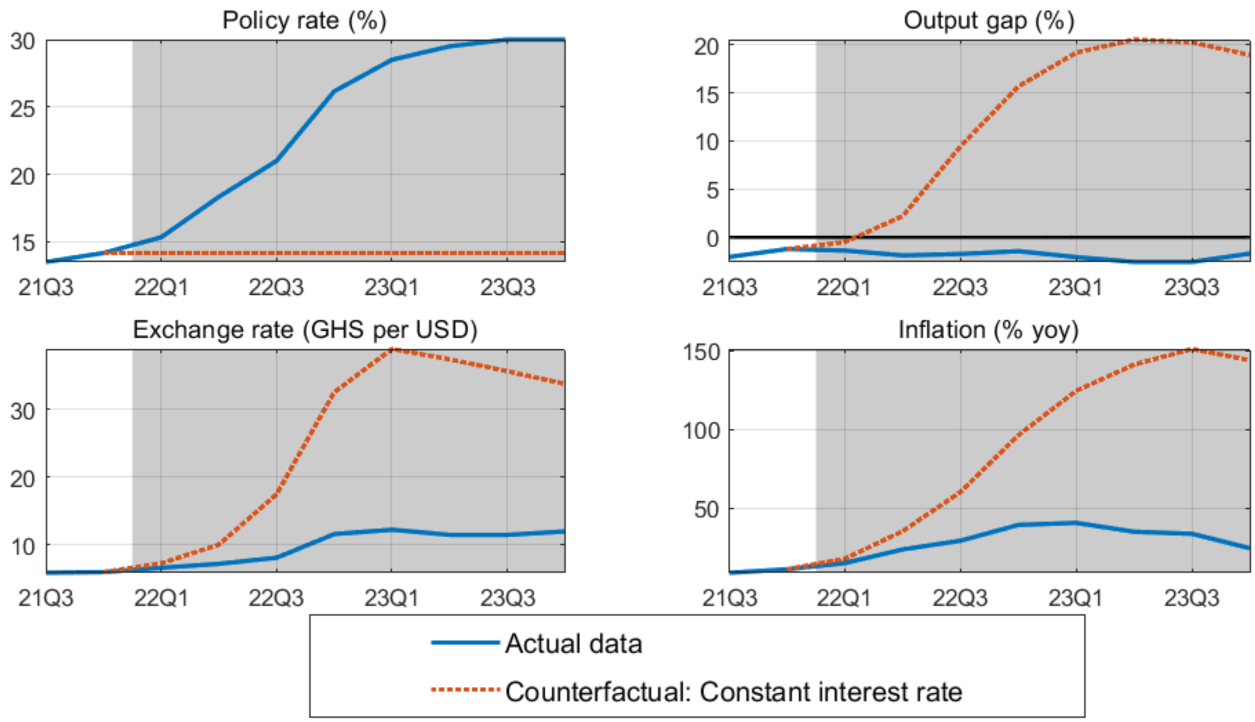
Figure 17 compares the actual implemented interest rate trajectory and corresponding policy trade-offs to a case where there was no monetary policy discretion and the policy rate would have strictly followed the Taylor-type policy reaction function (21). That is, the counterfactual scenario assumes that facing the same set of structural shocks during 2022Q1-2023Q4, the BOG would have delivered the interest rate trajectory consistent with the policy reaction function, i.e., not allowing for any discretionary deviations from the model-implied path. This would have led to higher and faster policy rate adjustments, peaking at a quarterly average of 34 percent in 2023Q1 as opposed to the actual gradual policy adjustments that peaked at an average of 30 percent in 2023Q4. The Taylor-type rule-based policy decisions would have led to lower nominal depreciation and inflation, with annual price dynamics over 2023 being about 5 percentage points

[12] One limitation regarding the implemented procedure relates to the possibility that if the BOG would have followed a different interest rate trajectory, then the structural shocks would have had different values. This concern is mitigated by treating the shocks as unanticipated when simulating counterfactual conditional forecasts. Then, agents' expectations and behavior are not affected by future non-zero shocks, which are treated as unknown, and their values are revealed only after they occur, quarter-by-quarter; see the related discussion in Crump et al. (2023).

lower than the realized one. However, these would have come at the expense of a significantly steeper negative output gap (bottoming out at about –4 percent in mid-2023), implying a weaker real sector activity and higher job losses.

Figure 18 illustrates the results of a (extreme) counterfactual scenario in which monetary policy rate would not have responded to the crisis and would have kept interest rates at the pre-crisis level of 14.2 percent (average over 2021Q4). To make the scenario more realistic, we treat the corresponding monetary policy shocks over the simulation interval as unanticipated initially (2022Q1-Q3) and anticipated thereafter (2022Q4-2023Q4). This approach aligns with the likely loss of central bank credibility and de-anchoring of inflation expectations once the economic agents learn about the lack of central bank intention to react in order to stabilize the economy; see Abradu-Otoo et al. (2022) for additional simulations concerning monetary policy credibility and inflation expectations. The counterfactual scenario shows how overly-stimulative monetary conditions would have led to unanchored expectations and an overheated economy given production capacity constraints (which would have declined sharply because of price instability). The policy trade-offs are reflected in a massive exchange rate depreciation, reaching 40 GHS/USD by 2023Q1, and spiraling inflation above 150 percent by end-2023.

Figure 18: Counterfactual scenario: Constant interest rate



V. CONCLUSION

This paper documents the current version of the BOG's Quarterly Projection Model (QPM) that underpins the Bank's Forecasting and Policy Analysis System (FPAS). It builds on previously presented work in Bank of Ghana (2022) and Abradu-Otoo et al. (2022), which is itself a Ghana-adapted extension of the canonical four-equation semi-structural gap model. The major updates refer to GDP decomposition into agriculture, oil, and non-agriculture non-oil sector, with the latter assumed to represent more accurately the fundamental business cycle dynamics and domestic demand-side price pressures as opposed to total GDP. To ensure inter-sectoral price linkages between food and non-food indices, the formation of inflation expectations across the two sectors considers headline price developments, as well as the corresponding spillovers and second round effects.

While the transmission mechanisms and shock propagation are similar to previous model versions, the impulse responses reveal that under certain conditions monetary policy may have to respond more strongly to affect aggregate output, given its limited impact on oil and agriculture sectors. In addition, when sector-specific price shocks can spill over across different economic activities and where forward-looking agents take into account their second-round effects even if the shocks originate in other sectors, headline inflation is likely to be affected by a larger margin, requiring a stronger policy reaction. The tight association between supply of agriculture goods, which is strongly impacted by weather conditions, allows to approximate and analyze – in a reduced-form way and without explicitly considering climate data in the model – the transmission and monetary policy implications of climate-related shocks.

Policy choices during the 2022-23 economic crisis are evaluated using counterfactual scenarios. The results suggest that the cautious approach to monetary policy rate adjustments adopted by the BOG during the recent tightening cycle, while allowing for somewhat higher inflation, supported the real sector by minimizing output and job losses.

Accumulated evidence since the implementation of the FPAS and practical use of the QPM highlights the critical role of the analytical work in supporting the BOG's policy process. Developed and adapted in tandem with the evolution of the monetary policy framework and the economic structure more broadly, the QPM remains relevant and effective. The latest model extensions provide a more detailed account of the economic developments, enhance forecast coverage and broaden its underlying narrative, thus strengthening the BOG's forward-looking policy framework and contributing to achieving its price stability objective.

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