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# A Quarterly Projection Model for the WAEMU

Carlos de Resende, Alsim Fall, and Demba Sy

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**A Quarterly Projection Model for the WAEMU**Prepared by Carlos de Resende,<sup>□</sup>Alsim Fall<sup>†</sup> and Demba Sy<sup>‡</sup>

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**ABSTRACT:** This study describes a semi-structural New-Keynesian Quarterly Projection Model (QPM) for the WAEMU zone. In the context of a fixed exchange rate regime and relatively tight capital controls, the central bank for the WAEMU monetary union (*Banque Centrale des États de l'Afrique de l'Ouest*, BCEAO) can exert some influence on the domestic money markets and interest rates. We adjusted the canonical version of a New Keynesian semi-structural Quarterly Projection Model (QPM) to capture that feature and other aspects specific to the BCEAO monetary policy framework, including an implicit foreign exchange reserve target. The model, which is parametrized through a mix of calibration and Bayesian estimation techniques, displays dynamic properties for the main variables in response to various shocks that are in line with theoretical priors and empirical evidence. Medium-term forecasts considering the Covid-19 pandemic produce sensible results when compared with forecast produced by a standard VAR. Moments computed from artificial data generated with the model match well those observed in the data. Overall, the model displays desirable analytical properties and sensible data-matching and forecasting capabilities and could, therefore, be used by the BCEAO to identify relevant shocks, map their propagation into the WAEMU regional economy, and better support its monetary policy decisions.

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# A Quarterly Projection Model for the WAEMU

Prepared by by Carlos de Resende, Alsim Fall, and Demba Sy<sup>1</sup>

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<sup>1</sup> The authors, who are staff from the Bank of Western African States (BCEAO) and the IMF, greatly appreciate the useful comments and suggestions received from Felipe Zanna (ICD), Paul Cashin (ICD), and Cecilia Melo Fernandes (MCM) during the IMF Working Paper review process, and from discussions with Malik Shukayev (University of Alberta), Ales Bulir (IMF/STI), Yaroslav Hul (ICD), and participants at an Africa Training Institute seminar. The views expressed in this paper are those of the authors and do not necessarily represent the views of the BCEAO or the IMF, its Executive Board or Management.

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## I. INTRODUCTION

Since institutional reform implemented in 2010, the West African Economic and Monetary Union (WAEMU) has experienced a major turning point regarding monetary policy. In particular, the reform has allowed the Central Bank of West African States (BCEAO) to modernize its monetary policy framework, bringing it closer to international best practices<sup>2</sup>. The current institutional environment, characterized by a fixed exchange rate regime with capital controls and implicit targets for the level of international reserves and inflation, allows the BCEAO to pursue its main objective of price stability.

At the operational level, meeting the new challenges brought about by the reformed framework requires the enhancement of the BCEAO's macroeconomic analysis and forecasting systems. Extending the BCEAO's analytical capacities using modern tools that can help inform the decisions of monetary authorities is a natural desired step.

This study presents a semi-structural New-Keynesian quarterly projection model (QPM) for the WAEMU region (QPM-WAEMU) that accounts for the main specific economic characteristics of the regional economy. Similar models—see, for example, Andrieu et al. (2013); Dizioli and Schmittmann (2015); Botha et al. (2017); Musil et al. (2018); Laxton et al. (2018); and Baksa et al. (2020)—have been used by several central banks in emerging and developing countries, many in the context of technical assistance and cooperation with the IMF, as the basis for their *Forecasting and Policy Analysis Systems* (FPAS). See Mæhle et al. (2021) for a description of IMF capacity development work on FPAS in the central banks of emerging and developing countries.

The internal structure of the model allows for a coherent account of the interactions between main macroeconomic aggregates and captures the most relevant shocks for the WAEMU regional economy and their propagation channels, while producing reaction functions to these shocks that can help inform the BCEAO's policy decisions. Insights from QPMs can be used as a basis for structuring debates on the choice of relevant policy actions, the definition of associated risks, and the effects of discretionary policies. In providing a tool for different counterfactual exercises regarding alternative policies, models such as the QPM-WAEMU allow for greater transparency in policy decisions and communication (Alichi et al., 2015).

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<sup>2</sup> The WAMU institutional reform that came into force in 2010 clarified the objective of monetary policy, which now focuses primarily on price stability instead of targeting net foreign assets in the context of fixed exchange rate regime. The reform also established the operational and formal independence of the BCEAO by giving it the means to strengthen its credibility and the effectiveness of its action. Thus, the stance of monetary policy is now entrusted to a new internal body of the Central Bank, the Monetary Policy Committee (MPC), rather than to a political body as before. On the other hand, this reform imposes new obligations on the BCEAO, notably in terms of reporting to the state authorities, transparency vis-à-vis the market, and information for the public.

The specific aspects to the WAEMU zone captured by the QPM-WAEMU model include the fixed exchange rate regime that pegs the regional currency to the Euro, the reasonably effective capital controls and, consequently, some (limited, imperfect) capacity of the BCEAO to influence money markets in the WAEMU countries. Furthermore, to guarantee the fixed exchange rate parity, the model features a reaction function that allows the BCEAO to *de facto* indirectly target the level of foreign exchange (FX) reserves through the incorporation of a risk premium in the monetary policy decision rule. We model this risk premium as a decreasing function of foreign exchange reserves relative to a threshold.

Model validation techniques, including pseudo out-of-sample forecasts, comparison of moments from the data and the model, and of forecasting performance against a standard benchmark (i.e., a Structural VAR, or SVAR), and the analysis of impulse responses, are carried out to assess the model's ability to reproduce observed data and behavior consistent with priors. The model performs well along all these dimensions and can therefore be used by the BCEAO to identify the main macroeconomic shocks hitting the WAEMU, analyze the transmission channels associated with these shocks, and produce coherent medium-term forecasts that internalize the main features of the WAEMU institutional set up, including the behavior of the central bank. Given its desirable properties, the model provides a useful guide for the BCEAO to measure and track the potential economic effects of its decisions and to understand the trade-offs it faces.

The remainder of the paper is organized as follows: Section II describes the BCEAO's monetary policy framework and provides an overview of the main recent macroeconomic developments in the WAEMU area. Section III describes the QPM-WAEMU model. Section IV focuses on the calibration and parameter estimation procedure and discusses the performance the model in terms of its ability to match data from the WAEMU and produce forecasts that compare well with those produced by a SVAR. Section V analyses the dynamic properties of the model through impulse response functions, which can sensibly replicate usual priors about the reaction of key macroeconomic variables to standard shocks. Section VI discusses out-of-sample forecasts of key macroeconomic variables based on a set of assumptions about the international environment and the orientation of domestic policies to combat the effects of the Covid-19 pandemic. The concluding remarks are presented in Section VII.

## **II. THE BCEAO'S MONETARY POLICY FRAMEWORK AND RECENT MACROECONOMIC DEVELOPMENTS IN THE WAEMU**

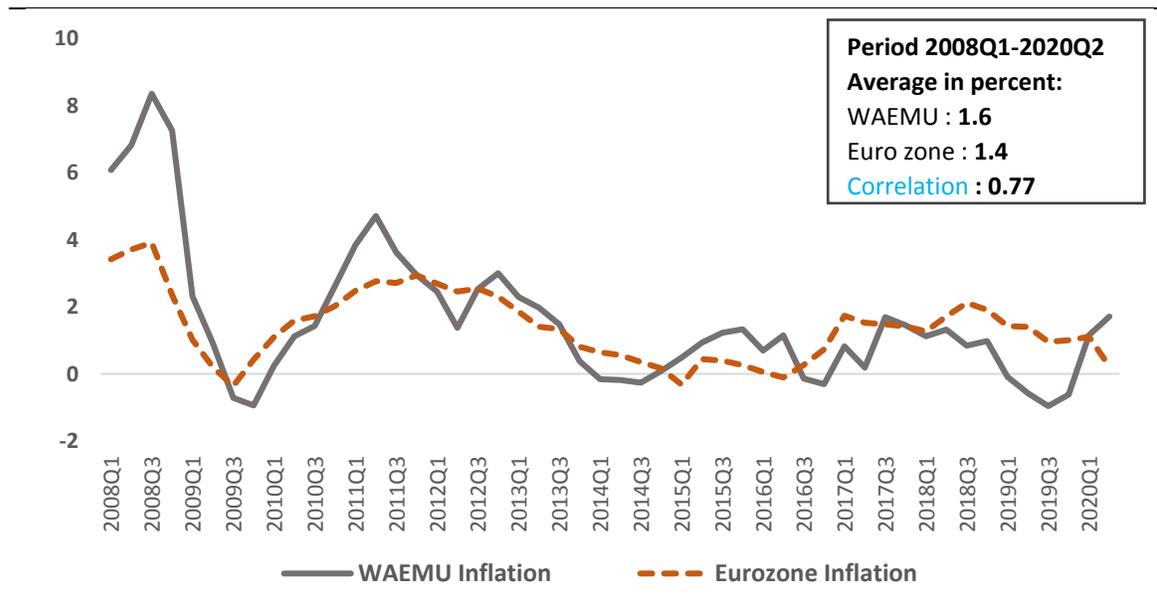
### **A. A monetary policy framework based on fixed exchange rate and capital controls**

The BCEAO is the central bank for the eight countries in the WAEMU zone. In addition to conducting the single monetary policy, it is responsible for the management of payment systems, foreign exchange reserve management, banking supervision, and financial stability. The BCEAO's primary objective is price stability (cf. Article 8 of its Statutes). It operates

within a monetary policy framework based on the pegging of the community currency (the CFA Franc, CFAF) to the euro<sup>3</sup>, together with an explicit inflation target of 2 percent year-on-year and a margin of +/- 1 percent over a two-year horizon. The BCEAO also supports the economic policies of WAEMU member states with a view to healthy and sustainable economic growth and the further integration of member countries into the WAEMU.

As a result of the peg, the WAEMU generally displays a relatively low and stable inflation rate, which closely follows the inflation of the euro zone (correlation coefficient of 0.77; see Figure 1), in line with keeping the purchasing power parity (PPP) with the euro.

**Figure 1: Year-on-Year Inflation Rate in the WAEMU and euro zone (in percent)**



Sources: BCEAO and OECD.

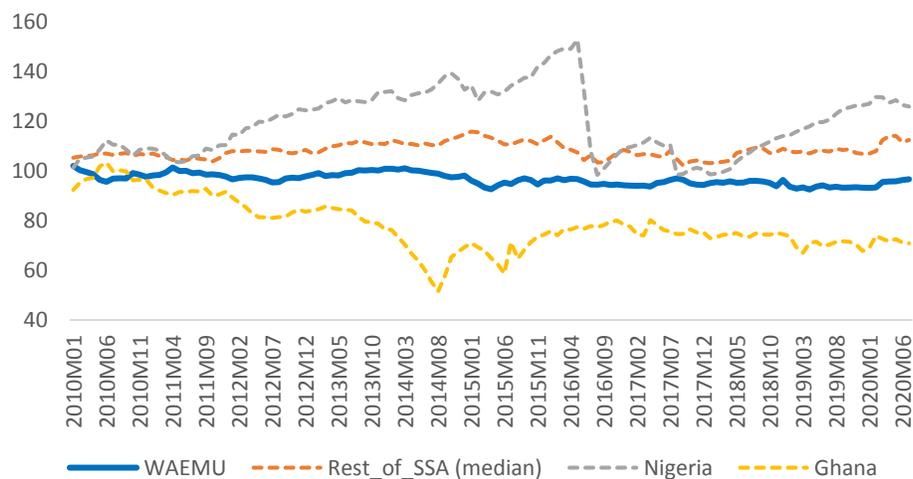
Overall, the BCEAO's monetary policy framework has benefited the WAEMU by fostering price stability. Since 1999, inflation in the WAEMU has hovered around an average of 2 percent per year, compared to a median of over 6% in other sub-Saharan African countries. Inflation volatility has also been moderated by favorable terms of trade developments. The combination of a stable nominal effective exchange rate and lower inflation rates relative to its major trading partners has contributed to a mild depreciation (0.6 percent) of the real effective exchange rate (REER) over the past decade (Figure 2), in contrast to developments in other SSA countries, where the REER has on average appreciated slightly over this period.

To help preserve the parity of the nominal exchange rate and retain some power to implement independent monetary policy, the BCEAO imposes controls of capital flows, especially outflows, and centralizes the management of foreign reserves on behalf of

<sup>3</sup> Since its creation on 26 December 1945, the CFA franc has been pegged to the French franc (FF) and then to the euro since the launch of the European currency on <sup>1</sup> January 1999.

WAEMU member-countries. In particular, since the 1994 devaluation of the CFAF, the BCEAO carries out de facto FX reserve targeting through a rigorous monitoring of the evolution of the currency coverage ratio (CCR)—measured by the ratio of foreign exchange reserves to the BCEAO’s demand monetary liabilities (Figure 3). In practice, the BCEAO tightens its monetary policy, by adjusting its key rate upwards, in response to a significant reduction in the CCR (see Figure 6 and subsequent comments)<sup>4</sup>.

**Figure 2: Real effective exchange rates in the WAEMU and sub-Saharan Africa (increase = appreciation)**



Sources: Authors’ calculations and Darvas (2012a, 2012b and 2012c), available at <http://www.bruegel.org>.

Controls and restrictions on capital movements with WAEMU non-residents apply only to outgoing flows<sup>5</sup>. The low mobility of capital in the WAEMU zone is reflected in the standardized KOPEN index by Chinn and Ito (2006). Based on that metric, the degree of capital openness in the region has sharply dropped since 1997, from 0.4 to 0.17, well below the average for Africa which stood at 0.32 in 2019 (Figure 4.1).

These restrictions on financial account transactions give the BCEAO some leeway for monetary policy, as evidenced by the evolution of the Monetary Independence index (MI) by Aizenman, Chinn, and Ito (2008). See Figure 4.2.

<sup>4</sup> There is no formal rule for targeting the CCR. However, the WAEMU Treaty provides that the MPC shall take appropriate measures to raise the CCR when it falls below 20%, on average, for three consecutive months. Figure 6 illustrates how the BCEAO policy rate reacted to the decline in the CCR in the mid-2010s.

<sup>5</sup> Capital control mechanisms are identical in all eight member countries and are jointly administered by the national Ministries of Finance and the BCEAO. In general, prior approval from the Ministry of Finance is required for almost all outward capital transfers, except for transfers of funds from the liquidation of investments, loan repayments and transactions in foreign exchange or commodity derivatives. In contrast, capital inflows from non-WAEMU countries are generally free. Although capital flow restrictions are applied to outgoing flows, they may limit inward capital flows if agents internalize the restrictions to repatriate capital at a later time.

**Figure 3: Evolution of the currency coverage ratio – CCR (in percent)**

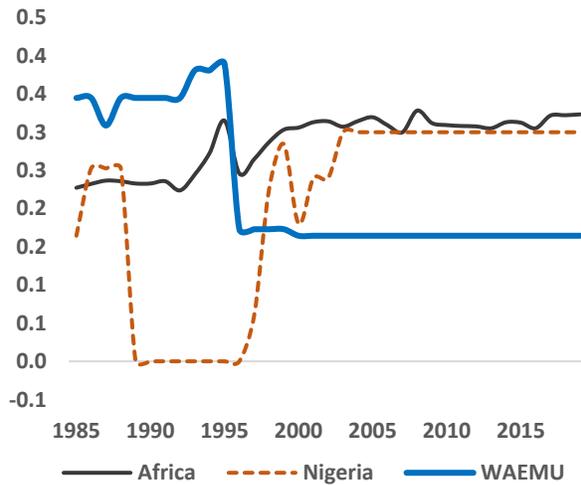


Source: BCEAO

Note: The currency coverage ratio (CCR) is the ratio of outstanding foreign exchange reserves to the Central Bank's demand monetary liabilities. It measures the availability of foreign exchange reserves needed to ensure the convertibility of the stock of currency issued by the BCEAO.

**Figure 4: Indices of Capital Mobility and Monetary Independence**

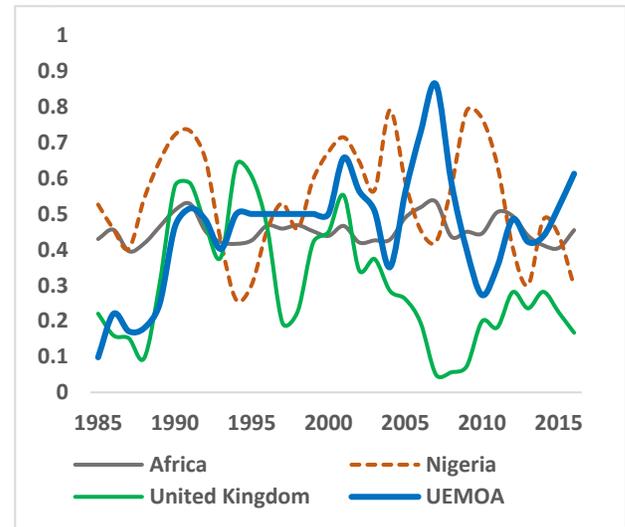
4.1 : Chinn-Ito standardized KOPEN index measuring the degree of capital mobility (1985-2019)



Source: Chinn and Ito (2006).

Note: the standardized KOPEN index ranges from 0 (complete closure of capital account) to 1 (perfect mobility of capital).

4.2 : Aizenman-Chinn-Ito MI index measuring the degree of monetary independence (1985-2016)



Source: Aizenman, Chinn, and Ito (2008).

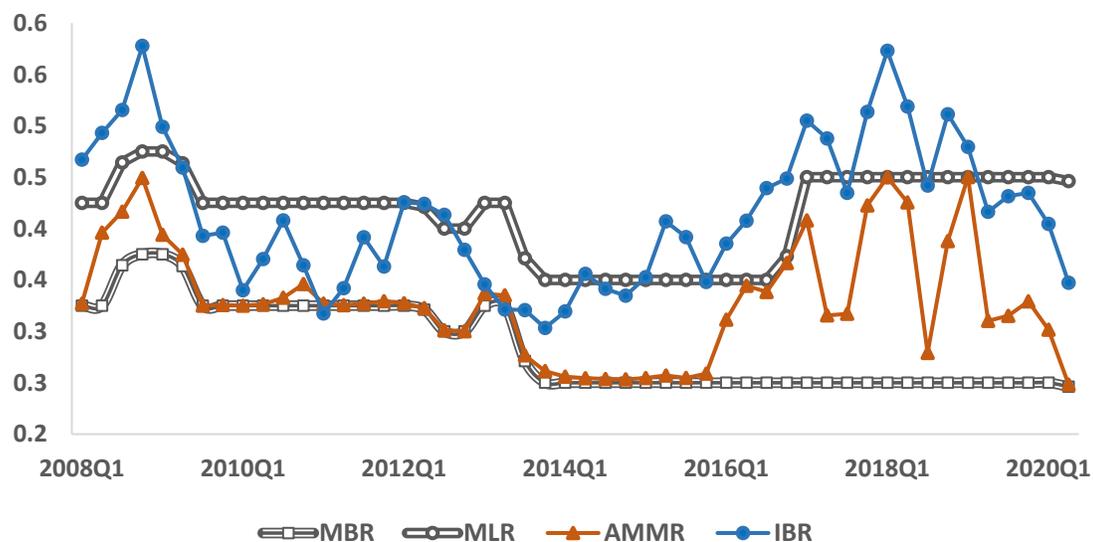
Note: The Monetary Independence (MI) index ranges from 0 to 1 depending on the degree of independence of monetary policy.

## B. The implementation of monetary policy in the WAEMU

In the short term, shocks to the WAEMU and/or euro area economies may lead to temporary deviations from the long-run equilibrium REER between the CFAF and the euro and, consequently, may affect price stability in the WAEMU. Thanks to the capital controls, the BCEAO can influence, to some extent, interest rates in domestic money markets and react to these shocks to bring inflation back towards its 2 percent target, while securing the peg with the euro.

The implementation of monetary policy is carried out using market instruments and indirect liquidity regulation—including policy interest rates within a corridor and reserve requirements—to steer the average one-week interbank rate (IBR), which applies to short-term loans between WAEMU banks. Besides the nominal exchange rate, the IBR is also an operational target of the BCEAO.

**Figure 5: Policy and Market Interest Rates (Annual, in percent)**



Source: BCEAO

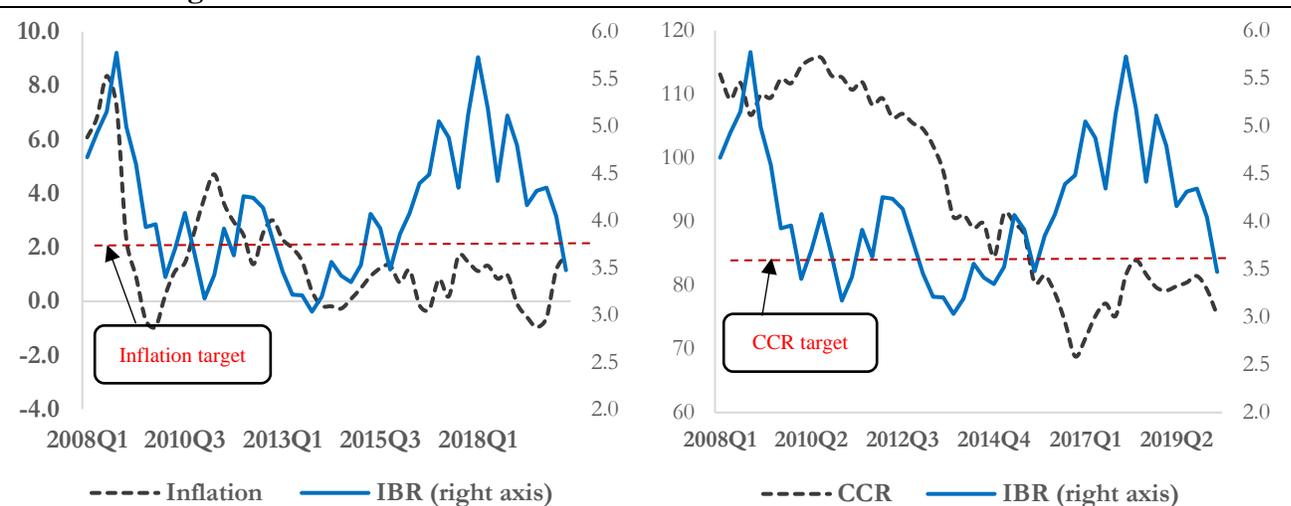
Note: The Minimum Bid Rate (MBR) and the Maximum Lending Rate (MLR) are the key rates set by the Monetary Policy Committee (MPC). The average money market rate (AMMR) results from the BCEAO's main liquidity injection operations (one-week and one-month window) and the interbank market rate (IBR) reflects interbank transactions with a maturity of one week.

From an operational point of view, the BCEAO aims at keeping the IBR within a corridor formed by its key interest rates—the floor is the "Minimum Bid Rate" (MBR), at which commercial banks submit bids to weekly and monthly liquidity auctions by the BCEAO, and the ceiling is the "Maximum Lending Rate" (MLR), at which banks can borrow from the

BCEAO at any given time outside of open-market operations (Figure 5).<sup>6</sup> Liquidity injections are implemented by auction against eligible collateral and the main policy rates (floor and ceiling) and the reserve requirement ratio are set by the Monetary Policy Committee (MPC) at its quarterly meetings.

Based on the results of the weekly and monthly BCEAO auctions, the average money market rate (AMMR) is determined as the weighted average cost of liquidity offered by the Central Bank through open-market operations. Differently from the IBR, the AMMR has always operated within the BCEAO's interest rate corridor. The IBR, however, is often higher than the BCEAO ceiling rate. See, for example, the period 2015–2019 (Figure 5), when the BCEAO tightened its policy stance in a context of low inflation to ensure a level of foreign exchange reserves compatible with maintaining the fixed parity of the CFA Franc<sup>7</sup>. A key policy challenge for the BCEAO arises from this type of situation in that any trade-offs between fulfilling its inflation mandate and preserving the peg will be resolved in favor of the latter.

**Figure 6: The BCEAO's Interbank Target Interest Rate vis-à-vis its Inflation and Foreign Reserves Targets**



Source: BCEAO

Note: The currency coverage ratio (CCR) is the ratio of outstanding foreign exchange reserves to the Central Bank's demand monetary liabilities. It measures the availability of foreign exchange reserves necessary to ensure the convertibility of the stock of currency issued in CFA franc by the BCEAO.

Note the comovements the between the BCEAO's target interest rate (IBR) and the inflation rate from 2008 to end-2015 (Figure 6, left chart), when the money supply coverage by of FX

<sup>6</sup> The ceiling rate is currently set at 200 basis points above the minimum bid rate.

<sup>7</sup> In addition, some banks heavily have recourse to the BCEAO to finance investment projects, while others accumulated excess liquidity. During 2012–2015, when some banks refinanced large government securities portfolios, the BCEAO reacted by (i) rationing the demand for refinancing (implicitly abandoning the interest rate targeting framework); and (ii) introducing different quantitative limits on the amount it would refinance per bank. These factors also help explain the surge in the interest rates within that period.

reserves indicated by the CCR was consistently above target (right chart). When the stock of FX reserves is sufficiently high, the BCEAO's commitment to the peg is not binding and its key policy rate reacts more to deviations of inflation from the target. For instance, between 2016 and 2019, when the CCR fell below target, the tightening of monetary policy seems incompatible with the low levels of the inflation rate. Rather, with the CCR falling below a certain threshold, the defense of the peg became binding and monetary policy was tightened significantly. During that period, the rise in the IBR concomitant with the marked fall in the CCR is especially observed when the latter falls below the 85 percent coverage.

This negative correlation between the IBR and the CCR—over the period 2015–2019 are documented in Table 1. Contemporaneous and advanced correlation coefficients are consistent with the notion that the BCEAO has tightened its monetary policy in response to the decline in FX reserves and to mitigate the pressures for currency depreciation to defend the peg.

More recently, the easing of monetary policy initiated in 2020, to limit the adverse effects of the COVID-19 pandemic on economic activity, has again led to a decline in the coverage rate of monetary issuance. This situation also highlights the limited room for maneuver available to the BCEAO to maintain the support for the post-pandemic recovery, given the increasingly binding constraint on FX reserves and the defense of the peg.

These developments highlight the important additional monetary policy trade-off that the BCEAO faces, relative to central banks operating under more flexible exchange rate regimes. Within the current framework based on a hard peg and capital controls, strong reactions to shocks that cause inflation and output to deviate from their desired levels may not be possible without jeopardizing the peg.

**Table 1: Correlation between Inflation, Output Gap, and the Currency Coverage Ratio, 2015Q1 - 2019Q1**

	$Inf_t$	$Output\_gap_t$	$CCR_t$
$IBR_t$	-0.054 (0.837)	0.409* (0.103)	-0.419* (0.094)
$IBR_{t+1}$	-0.050 (0.854)	0.438* (0.089)	-0.509** (0.044)
$IBR_{t+2}$	-0.164 (0.558)	0.375 (0.168)	-0.443* (0.098)
$IBR_{t+3}$	-0.103 (0.725)	0.226 (0.436)	-0.323 (0.260)

Source: Authors' calculations.

Note: The number of stars (\*\*\*) (\*\*), (\*) indicates the level of significance of the correlation coefficient at the 1percent, 5percent and 10percent thresholds respectively. The figures in brackets correspond to the  $t$ -stat of the correlation coefficient.

Meaning of variables: interbank market rate ( $IBR$ ) per annum in percent, year-on-year inflation rate ( $Inf$ ), output gap obtained using the HP filter ( $Output\_gap$ ) in percent, foreign exchange reserve coverage rate ( $CCR$ ) in percent.

### C. Stylized facts: Recent macroeconomic developments in the WAEMU

The WAEMU countries form a small open economy with the euro zone as its main partner. WAEMU is a net importer of petroleum products and foodstuffs, which account for a large share of its external purchases. It is also a major exporter of agricultural products (cocoa, gold, cotton, cashew nuts, palm oil, palm kernel oil, rubber, etc.).

- **Economic growth**

Over the period 2012–2019, the WAEMU zone experienced unprecedented economic dynamism. The average annual growth of real GDP was 6.3 percent during these eight years. Thus, the region has overcome the poor performance recorded in the past, where average growth was less than 2 percent during the 1980s and 1990s, and between 3 percent and 4 percent during the 2000s.

The sustained expansion of economic activity over the recent period was particularly driven by a series of factors that have occurred in the zone, in particular (i) the consolidation of the macroeconomic framework and the improvement of macroeconomic management, which have fostered a better business climate and created the basis for robust growth; (ii) debt relief, in the context of Heavily Indebted Poor Country (HIPC) initiative, which restored budgetary margins; (iii) the strengthening of commercial and financial links with emerging economies, and (iv) the implementation of national emergency plans.

This acceleration in GDP growth is essentially driven by domestic demand, particularly investment (Figure 7.1). Indeed, the massive efforts made by governments and the private sector to build an attractive business environment through the construction of basic socio-economic infrastructure and the development of the domestic productive sector explain the rapid growth of investment, which rose to an average of 13 percent per year over the 2012–2019 period, compared with 8.6 percent between 2000 and 2011.

- **Inflation**

Inflation is structurally low in the WAEMU zone, averaging 1.2 percent between 2010 and 2019, a level comparable to that of developed countries. For instance, the inflation rate in the euro area averaged around 0.9 percent over the same period.

Component analysis shows that core inflation in the WAEMU, which accounts for 48 percent of overall inflation, is particularly stable with a coefficient of variation of 1.1, while food and energy products, which account for 43 percent and 9 percent respectively, have coefficients of variation closer to 2.

- **Fiscal deficit and public debt**

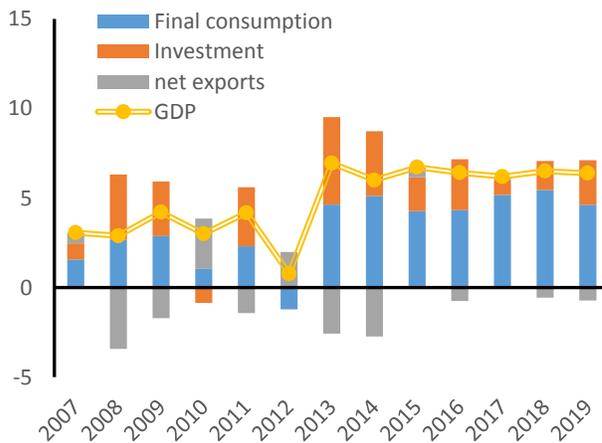
The smooth and efficient functioning of an economic union with a single fixed exchange rate currency relies heavily on budgetary discipline and coordination. Absent such a mechanism, the discretionary stance of a Member State's fiscal policy can lead to distortions and undermine the viability of the economic and monetary union under the fixed exchange rate.

Since 1998, WAEMU has had a set of common budgetary rules and national public finance management mechanisms to facilitate budgetary discipline and coordination among member states. In 2015, a new framework was adopted, including a set of convergence criteria to be met by 2019. This fiscal convergence framework includes a public debt ceiling of 70 percent of GDP and introduces an operational rule setting the budget deficit at a maximum of 3 percent of GDP. The overall budget deficit of the Union averages 2.9 percent of GDP over the period 2008–2019. However, over the 2015–2018 period, a persistent fiscal stimulus was noted with an average annual deficit of 3.5 percent (Figure 7.3).

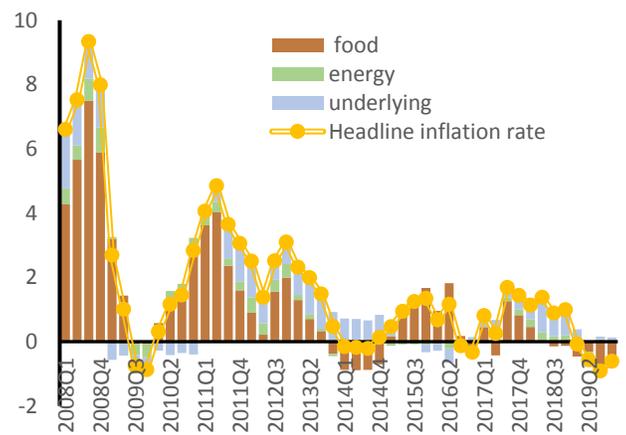
Public debt in the area remains well contained despite a strong evolution over the recent period. It stands at 43.7 percent of GDP at the end of 2019. The external component of the debt remains dominant with a proportion of 67 percent of the total.

**Figure 7: WAEMU’s recent macroeconomic developments**

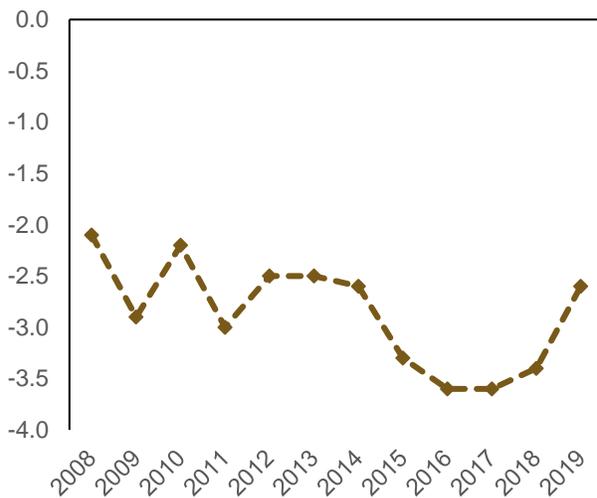
**7.1: Real GDP growth - demand side (in percent)**



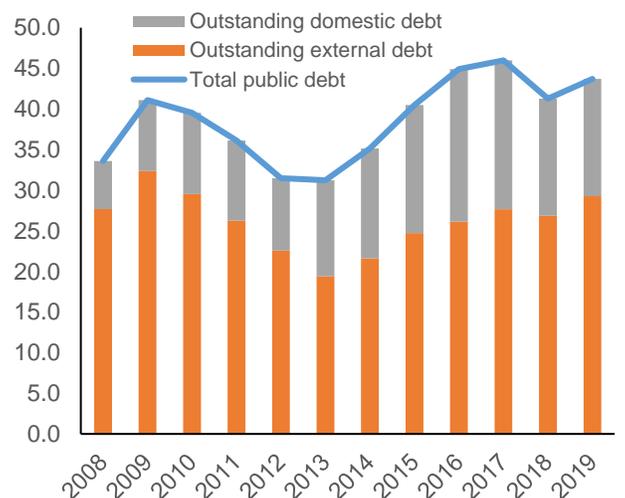
**7.2: Inflation and its components (in percent)**



**7.3: WAEMU’s Overall budget balance (percent of GDP)**



**7.4: Government debt (percent of GDP)**



Source: BCEAO

### III. THE MODEL

This section describes the QPM-WAEMU. To this end, a major leitmotiv has been to “*be as faithful as possible to the economic reality of the WAEMU*”. In addition, the model must be coherent and relevant to provide medium-term macroeconomic forecasts and allow for risk analysis in the monetary policy formulation process. Furthermore, it must reproduce as perfectly as possible the transmission mechanism of the monetary policy, the behavior of the BCEAO and the economic data.

The structure of the semi-structural model developed in this paper is similar to those successfully used by many central banks for policy analysis since the 2000s. The model is broadly based on the version that Fukac and Pagan (2010) have called the third generation (3G) of models. It combines, features inspired by New Keynesian notions of nominal and real rigidities and the role of aggregate demand in determining output with Real Business Cycle concepts of dynamic stochastic general equilibrium (DSGE) modelling, including rational expectations (Berg et al., 2006).

The core of the model consists of five blocks:

1. an aggregate demand block (IS curve),
2. an aggregate supply block (Phillips curve),
3. an uncovered interest rate parity condition,
4. a monetary policy reaction function,
5. a budget/fiscal block.

We note that the model does not consider a breakdown of aggregate demand in sub components, nor does it explicitly include separate block of equations for the balance of payments as in Berg et al. (2022).

#### A. Aggregate demand

The aggregate demand relationship is based on the open economy version of the traditional IS curve and on the log-linearization of Euler equation derived from the optimization of household consumption and includes the assumption of consumption patterns.

It takes the following form:

$$\hat{y}_t = b_1 \hat{y}_{t-1} + (1 - b_1) \hat{y}_{t+1} - b_2 mci_t + b_3 \hat{y}_t^* + b_6 f_t^{imp} + \varepsilon_t^y, \quad (1)$$

where  $\hat{y}_t$  is the output gap defined as the deviation of the logarithm of actual output from its potential or long-term level and  $mci_t$  is given by:

$$mci_t = b_4 (\hat{r}_t + cr\_prem_t) + (1 - b_4) (-\hat{z}_t).$$

The variable  $mci_t$  represents an index of real monetary conditions (ICMR), defined as a weighted average of the deviations of the real interest rate from its neutral (non-inflationary and non-deflationary) level,  $\hat{r}_t$ , plus the credit risk premium ( $cr\_prem_t$ ) on loans, and deviations of the real exchange rate (RER) from its trend,  $\hat{z}_t$ .<sup>8</sup> The RER is defined as the nominal exchange rate (value in CFAF per unit of foreign currency represented by the euro), adjusted for the foreign and domestic price differential,  $z_t = s_t + p_t^* - p_t$  where  $s_t$  is the (log of the) nominal euro/CFAF market exchange rate (this is the parity determined in the markets and not the official exchange rate),  $p_t^*$  is the (log of the) foreign price index and  $p_t$  is the (log of the) of the price level in the WAEMU zone. An increase (decrease) of  $z_t$  reflects a depreciation (appreciation) of the real exchange rate (RER).<sup>9</sup>

The variable  $\hat{y}_t^*$  is the global output gap while  $f_t^{imp}$  represents the fiscal policy impulse. It refers to the effect of fiscal policy on the business cycle.

## B. New Keynesian Phillips curve

The Phillips curve is made up of a block of four equations reflecting the dynamics of the inflation rate. Indeed, the inflation rate is disaggregated into three components, namely

### 1. Underlying inflation:

$$\pi_t^{core} = a_1 \pi_{t-1}^{core} + (1 - a_1) \pi_{t+1}^{core} + a_2 rmc_t + \varepsilon_t^{core}, \quad (2)$$

where  $rmc_t = a_3 \hat{y}_t + (1 - a_3)(\hat{z}_t - \widehat{rp}_t^{core})$ .

### 2. Food inflation

$$\pi_t^{food} = a_{21} \pi_{t-1}^{food} + (1 - a_{21}) \pi_{t+1}^{food} + a_{22} rmc_t^{food} + \varepsilon_t^{food}, \quad (3)$$

where  $rmc_t^{food} = a_{23}(\widehat{rp}_t^{WFOOD} + \hat{z}_t - \widehat{rp}_t^{food}) + (1 - a_{23})\hat{y}_t$ .

### 3. Energy inflation

$$\pi_t^{nrg} = a_{31} \pi_{t-1}^{nrg} + (1 - a_{31}) \pi_{t+1}^{nrg} + a_{32} rmc_t^{nrg} + \varepsilon_t^{nrg}, \quad (4)$$

where  $rmc_t^{nrg} = \widehat{rp}_t^{WOIL} + \hat{z}_t - \widehat{rp}_t^{nrg}$ .

### 4. Overall inflation

$$\pi_t = w_t^{nrg} \pi_t^{nrg} + w_t^{food} \pi_t^{food} + (1 - w_t^{nrg} - w_t^{food}) \pi_t^{core}. \quad (5)$$

<sup>8</sup> The minus sign in  $\hat{z}_t$  follows from the convention used to define the exchange rate (an increase constitutes a depreciation of the RER).

<sup>9</sup> Key variables of the model are expressed as “gaps,” i.e., as deviations from their long-run trends or equilibrium paths (such as potential output, neutral real interest rate, long-run equilibrium real exchange rate etc.). These non-observable long-run trends are estimated simultaneously from the multivariate filtering approach based on the Kalman Filter (KF) needed for the solution and simulation of the model.

Equation (2) represents the Phillips curve (inflation dynamics) associated with core inflation, ( $\pi_t^{core}$ ), defined as the consumer price index (CPI) excluding the food and energy components. This relationship expresses the core inflation rate in terms of its past ( $\pi_{t-1}^{core}$ ) and future values ( $E_t \pi_{t+1}^{core}$ ) and the real marginal cost ( $rmc_t$ ). The Phillips curve version is based on behaviour that may be forward-looking for some and backward-looking for others<sup>10</sup>.

The real marginal cost of firms is a weighted average of the RER gap and the output gap. It is related to domestic producers (through the output gap  $\hat{y}_t$ ) and imports (through the RER  $\hat{z}_t$ ). The real marginal cost also depends on the relative price  $\hat{r}p_t^{core}$  (the ratio of the underlying price to the CPI) to reflect the degree of substitution of goods resulting from consumer arbitrage. The coefficient  $a_2$  measures the influence of real marginal cost on inflation and gives an indication of the "sacrifice ratio", i.e. the loss of output growth points that would be required to reduce the inflation rate by 1 percentage point. The error term  $\varepsilon_t^{core}$  corresponds to the supply shock.

By analogy, the hybrid Phillips curve associated with the food and energy components (equations 3 to 4) is interpreted in the same way.

The variables  $\pi_t^{food}$  and  $\pi_t^{nrg}$  represent the inflation rates for food and energy goods respectively,  $rmc_t^{food}$  and  $rmc_t^{nrg}$  their real marginal costs,  $\hat{r}p_t^{WFOOD}$  the relative price of food goods on the international market expressed in euro (ratio between the international food price and the general level of international prices),  $\hat{r}p_t^{food}$  the relative domestic price of food goods (ratio between the food price and the CPI),  $\hat{r}p_t^{WOIL}$  the relative international price of energy expressed in euro (ratio between the international price of energy and the general level of international prices),  $\hat{r}p_t^{nrg}$  the relative domestic energy price (ratio between the energy price and the CPI),  $\varepsilon_t^{food}$  the supply shock on food products,  $\varepsilon_t^{nrg}$  the supply shock on energy products. Finally, the inflation rate is the weighted average of its three components (equation 5).

### C. Uncovered interest rate parity

The financial relations of the domestic economy with the rest of the world can be formalised using the uncovered interest rate parity condition.

Equation (6), a version of the UIRP applied to a floating exchange rate regime. It describes the relationship between changes in domestic and foreign interest rates and changes in the nominal exchange rate.

$$s_t = E_t s_{t+1} + (i_t^* - i_t + prem_t)/4 + \varepsilon_t^s, \quad (6)$$

where:

<sup>10</sup> The version of the Phillips curves (3)-(5) have structural elements derived from the optimisation of local goods producers and importing firms in an environment of monopolistic competition and nominal rigidity à la Calvo (1983) with the indexation of the inflation rate to its past values.

- $s_t$  is the nominal exchange rate, defined in units of FCFA per unit of euro.
- $i_t$  is the annualized domestic nominal interest rate.
- $i_t^*$  is the annualized foreign nominal interest rate.
- $prem_t$  is the risk premium needed to eliminate arbitrage gains between domestic and foreign currency financial investments; it can be interpreted as reflecting the fragility of the economic and financial situation vis-à-vis the rest of the world.
- $\varepsilon_t^S$  is an independent and identically distributed shock.

Dividing the term in brackets by 4 thus converts the rates to a quarterly frequency. The formulation of the UIP described by equation (6) does not allow the model to show exchange rate persistence in line with observations on the behaviour of floating exchange rates. Indeed, the purely forward-looking behaviour of investors, as described by equation (6), forces the current exchange rate to adjust immediately to the foreign-domestic interest rate differential and to the evolution of the risk premium while the observed exchange rate shows smaller variations.

To consider the persistence of the exchange rate in line with the observations, the UIP condition is reformulated as follows:

$$s_t = e_1 \left( s_{t-1} + \frac{2}{4} \Delta \bar{s}_t \right) + (1 - e_1) E_t s_{t+1} + \frac{(i_t^* - i_t + prem_t)}{4} + \varepsilon_t^S, \quad (7)$$

where  $\Delta \bar{s}_t = \bar{\pi}_t - \bar{\pi}_t^* + \Delta \bar{z}_t$  is the change in the long-term target exchange rate. In this case, the value of the coefficient  $e_1 \in [0,1]$  determines the degree of exchange rate persistence. Note that relations (6) and (7) are identical when  $e_1 = 0$ .

On the other hand, if the monetary authorities decide to intervene in the foreign exchange market by steering the exchange rate in line with their stability objectives, the PNC condition (equation 7) takes the following form (see Berg, Karam and Laxton, 2006):

$$s_t = h_2 \left( s_{t-1} + \frac{\Delta s_t^T}{4} \right) + (1 - h_2) \left[ e_1 \left( s_{t-1} + \frac{2}{4} * \Delta \bar{s}_t \right) + (1 - e_1) E_t s_{t+1} + (i_t^* - i_t + prem_t) \right] / 4 + \varepsilon_t^S. \quad (8)$$

This relationship reflects the willingness of the monetary authorities to move the exchange rate along a path consistent with macroeconomic stability objectives. Indeed,  $\Delta s^T$  is the desired change in the exchange rate, which depends on the differential between the domestic inflation target ( $\bar{\pi}_t$ ) and the rest of the world ( $\bar{\pi}_t^*$ ) and the variation of the real exchange rate from its equilibrium level ( $\Delta \bar{z}_t$ ). The coefficient  $h_2$  reflects the degree of exchange rate rigidity/flexibility. In extreme situations, the exchange rate regime is fixed when  $h_2 = 1$  or floating if  $h_2 = 0$  (in this case equations 8 and 7 are identical). In the case of WAEMU, the

parameter  $h_2$  is close to unity.<sup>11</sup>

Moreover, since the CFAF has remained pegged to the French franc and then to the euro since its creation, and has only undergone one devaluation in 1994, the desired variation of the exchange rate is then fixed at zero ( $\Delta s^T = 0$ ). Similarly, the variation of the real exchange rate in the long term is assumed to be zero ( $\Delta \bar{z}_t = 0$ ) in line with the long-term validity of purchasing power parity (PPP).

#### D. Monetary policy rule

The monetary policy reaction function is generally compatible with a floating exchange rate regime. However, it can be adapted to consider the objective of exchange rate control. The model uses a standard, albeit slightly modified, rule similar to those of central banks targeting inflation and external currency stability (Stone et al., 2009; Benlamine et al., 2018).

From a strategic point of view, the BCEAO aims to stabilise inflation by maintaining the exchange rate at a fixed level and steering short-term interest rates in order to mitigate macroeconomic fluctuations. The pegged exchange rate is guaranteed by the uncovered interest parity (UIP) condition as follows:

$$i_{UIPt} = h_1[4(E_t s_{t+1} - s_t) + i_t^* + prem_t]. \quad (9)$$

On this basis, the monetary policy rule is written as follow:

$$i_t = i_{UIPt} + (1 - h_1)\{g_1 i_{t-1} + (1 - g_1)[i_t^n + g_2(E_t \pi_{t+3} - \pi_t^T) + g_3 \hat{y}_t + g_4(prem_t - \overline{prem})]\} + \varepsilon_t^i \quad (10)$$

where  $i_t$  is the Central Bank's target interest rate (the annualised interest rate of weekly interbank market operations),  $i_t^n$  the neutral interest rate (the interest rate that prevails in the absence of an output gap and inflation),  $\pi_t^T$  the central bank's inflation target,  $\overline{prem}$  the steady state risk premium and  $\varepsilon_t^i$  the monetary policy shock.<sup>12</sup>

The equation describes the evolution of short-term interest rates consistent with the UIP condition and macroeconomic stability objectives. In other words, the monetary policy is implemented to defend the fixed exchange rate parity while ensuring macroeconomic

<sup>11</sup> The local currency, the CFA, is defined in relation to the euro according to a fixed parity. However, for manual exchange operations, the regulations authorize a maximum commission of 2% in relation to the official value of the euro in CFAF. Observations indicate that this margin authorized by the texts is not always respected.

<sup>12</sup> The neutral interest rate is calculated as the sum of the estimated (unobserved) long-run trend for the real interest rate,  $\bar{r}_t$  and inflation expectations,  $E_t \pi_{t+1}$ . Equation (10) provides the model's structural restriction to be used by the Kalman Filter procedure: the policy-neutral rate corresponds to the nominal interest that would prevail if inflation were at the target, the output gap at zero, and the country-risk premium at the steady state.

stability.

The coefficient  $h_1$  indicates the degree of control that the Central Bank exercises over the domestic money market to stabilise the economy. If  $h_1 = 0$  then the issuing bank retains full control over macroeconomic stability. If  $h_1 = 1$  then monetary policy becomes ineffective as the target interest rate adjusts to that of the anchor currency country.

The introduction of the risk premium is of particular importance for modelling developing economies characterised by the fragility of their productive and financial systems. This variable reflects the difficulties encountered by these countries in ensuring the sustainability of their balances of payments, due to the weight of sovereign external debt, fluctuations in exports and massive capital outflows. When the exchange rate regime is flexible, an increase in the risk premium would lead to a systematic depreciation of the exchange rate (equation 7). For a fixed exchange rate regime, monetary policy adjustments are needed to maintain exchange rate parity and preserve macroeconomic stability. Thus, the risk premium appears twice in the reaction function, acting on the UIP condition and on the BCEAO arbitrage function against macroeconomic fluctuations.

Concerning the WAEMU zone, the BCEAO applies *de facto* indirect targeting of foreign exchange reserves to maintain exchange rate parity. Under these conditions, the risk premium is used to analyse the macroeconomic effects of a rapid decline in foreign exchange reserves on the WAEMU economy. The risk premium equation is formulated as follows:

$$\begin{aligned} prem_t = & \rho^{prem} prem_{t-1} + (1 - \rho^{prem}) \overline{prem} + p_6 (b_t - b_t^{tar}) \\ & - p_7 (resv_t - resv^{tar}) + \varepsilon_t^{prem}, \end{aligned} \quad (11)$$

where  $resv_t$  is the currency coverage ratio (CCR), which is the ratio of foreign exchange reserves to the Central Bank's demand liabilities. The target value of the CCR  $resv^{tar}$  is implicitly set by the BCEAO. Thus, a fall in reserves from their target level causes an increase in the risk premium and consequently a monetary policy reaction.

The risk premium also depends on the deviation of the debt/GDP ratio  $b_t$  from its target level  $b_t^{tar}$ . It is expected that the sensitivity of the risk premium to the debt/GDP ratio will be much lower than that of the risk premium to reserves (i.e.,  $p_6 \ll p_7$ ). Moreover, the risk of over-indebtedness in the WAEMU zone remains moderate given that public debt is relatively low (50.4 percent of GDP in 2020) and, especially, because a large part (44.1 percent of total debt and 69 percent of externa debt) is concessional. Over the past 15 years, the increase in debt in WAEMU countries due to new Eurobond issuances has not translated into an increase in spreads on the international financial markets. Considering the above, parameter  $p_6$  was set at 0.01.<sup>13</sup>

In turn, monetary policy contributes to the convergence of the MER towards its target level,

<sup>13</sup> For robustness, a sensitivity analysis to large variations of  $p_6$ , carried out in Annex 3, shows that for higher values of  $p_6$  (e.g.,  $p_6 = 0.5$ ), the monetary policy response to a demand shock becomes very strong and counter intuitive. Moreover, in the event of a shock to the fiscal deficit, monetary policy reactions appear disproportionate to recent history of economies for cases where  $p_6$  equals 0.5 or 0.1.

according to the following specification:

$$resv_t = \rho^{resv} resv_{t-1} + (1 - \rho^{resv}) resv^{tar} + p_8(i_t - i_t^{bar}) + p_9(z_t - \bar{z}_t) + \varepsilon_t^{resv}. \quad (12)$$

The effects of the interest rate on the level of foreign exchange reserves in the WAEMU zone deserve to be discussed. Indeed, a contraction of foreign exchange reserves, reflecting a risk of nominal depreciation, can be countered by a tightening of monetary policy through quantities and costs. Firstly, the reduction in the refinancing of the BCEAO results in a mechanical improvement in the coverage rate of monetary issuance by foreign exchange reserves. Secondly, through its effects on domestic demand and price competitiveness, a tightening of monetary policy moderates the growth rate of imports and favors exports. Third, higher interest rates in the domestic capital market encourage banks to increase their recourse to external borrowing from foreign correspondents to finance their cash needs. It also encourages governments to mobilize external resources (drawings, bond issues, etc.). These combined effects of monetary policy give the Central Bank the capacity to regulate the level of foreign exchange reserves.

### E. Fiscal block

The relationship between the real sphere and public finances is characterised by a system of equations reflecting the behaviour of the budget deficit and public debt (see Kumhof and Laxton, 2009 and Baksa et al., 2020). The dynamics of the cyclical deficit  $cd_t$  is described by the following equation:

$$cd_t = \rho^{FP}(cd_{t-1} - p_4 \hat{y}_t) + (1 - \rho^{FP})(cd_t^{tar} - p_2 b_t^{dev}) + \varepsilon_t^{cd}, \quad (13)$$

where  $b_t^{dev} = p_{21}(b_t - b_t^{tar}) + (1 - p_{21})E_t b_{t+1}^{dev}$  is the measure of the deviation of the debt/GDP ratio  $b_t$  from its target level  $b_t^{tar}$ . The variable  $cd_t^{tar}$  is the level of the deficit as a percentage of GDP that stabilises the debt/GDP ratio

Relationship (13) suggests that the deficit reacts in a partially countercyclical way to fluctuations in economic activity through the coefficient  $p_4$ . In addition, the deficit adjusts downwards (upwards) when the debt/GDP ratio is above (below) the target. This characterisation of the deficit is better suited to the economic context of WAEMU countries. Indeed, observations on the WAEMU zone show that deficits increase in periods of unfavourable economic conditions through increased expenditure (social assistance measures) and/or reduced tax revenues (tax cuts). The most recent example relates to the social assistance programs put in place by governments to mitigate the effects of the Covid-19 global health crisis on households and some businesses. This deficit behaviour is considered by the countercyclical mechanism.

Furthermore, states implement strategies to reduce their deficits when the debt/GDP ratio becomes significant. This deficit control policy is part of the economic and financial programs concluded with the IMF, but also of multilateral surveillance in the WAEMU zone.

The "fiscal impulse" ( $f_t^{imp}$ ) is defined as the change in the cyclical budget deficit  $cd_t$  plus a

shock. An increase (decrease) in the cyclical deficit corresponds to a positive (negative) value of the fiscal impulse  $f_t^{imp}$  in equation 1.

$$f_t^{imp} = (cd_t - cd_{t-1}) + \varepsilon_t^{f^{imp}}.$$

If the output gap  $\hat{y}_t$  is zero and the debt coincides with its target, then the cyclical deficit becomes equal to its target value  $cd_t^{tar}$ .

The primary deficit  $pd_t$  consists of the cyclical deficit  $cd_t$  and a non-cyclical component  $\varepsilon_t^{pd}$ . The primary deficit is made up of the cyclical deficit and a non-cyclical component, i.e.:

$$pd_t = cd_t + \varepsilon_t^{pd}. \quad (14)$$

The budget deficit  $def_t$  is the sum of the primary deficit  $pd_t$  and interest on debt  $id_t$ , i.e.:

$$def_t = pd_t + id_t. \quad (15)$$

Finally, the dynamics of the public debt can be written as follows:

$$b_t = \frac{b_{t-1}}{1 + (\pi_t + g_t)} + def_t, \quad (16)$$

where  $g_t$  is the growth rate of real GDP.

## IV. DATA, CALIBRATION, BAYESIAN ESTIMATION, AND MODEL VALIDATION

### A. Data

The data used in the study are quarterly and cover the period from Q1-2008 to Q2-2020. They include macroeconomic data for the WAEMU, namely real GDP, the Harmonised Index of Consumer Prices (HICP) and its food, energy and underlying components, the nominal interest rate (weighted average rate of the one-week interbank market) and the currency coverage rate, as well as the overall budget deficit of the member states of the WAEMU zone<sup>14</sup>. This information was collected from the BCEAO database.

For the rest of the world, the data used are for the G20 group and include real GDP, the consumer price index, and the food price index. They are provided by the OECD. In addition, the 3-month US Treasury bill rate (used as a proxy for international short-term interest rates), the price of a barrel of Brent crude oil and the nominal exchange rate of the CFAF against the euro (€/CFAF) are taken from the online database of [www.investing.org](http://www.investing.org).

Detailed information on the data and their origins is given in Table A. 1 in Annex 1.

<sup>14</sup> The available data on the EU budget deficit are annual in frequency. However, a quarterly adjustment has been made using the linear *match-last* interpolation method.

## B. Calibration and Bayesian Estimation

To optimise the search for a stable solution for the model, the approach used consists of calibrating a certain number of parameters while the others are subject to Bayesian estimation.

The calibration is based on the one hand, on the analysis of the characteristics of the economy of the WAEMU zone using non-model data (correlation analysis, econometric regressions, expert opinions) and, on the other hand, on the experience of central banks of comparable emerging and developing countries in the development of QPM models.

The calibration information of parameters and steady state variables is presented in Table A.2.1 of Annex 2.

The estimated parameters are presented in the appendix, in Tables A.2.2 (a priori distributions) and A.2.3 (a posteriori distributions). The confidence intervals presented in Table A.2.3 show that all estimated parameters are significantly different from zero at the 5percent level.

The estimated value of the parameter  $h_2$  (0.97), reflects the fixed parity of the exchange rate regime with, however, slight variations in the exchange rate as indicated in subsection III.3. The level of parameter  $h_1$  is estimated at 0.43. The coefficients associated with aggregate demand and supply functions are relatively like those found in the literature on the development of general equilibrium models for developing economies.

## C. Model validation

This section presents evidence to validate the model's specification and calibration as a reasonable representation of the economies in the WAEMU region.

### Data vs. Model: comparison of moments

The evaluation of the adjustment of the QPM model to the observed data constitutes a relevant means of measuring its degree of accuracy. This is done by comparing the generated moments with those observed. The analysis suggests that the main variables of the study are satisfactorily reproduced by the model.

Indeed, the data presented in Table 2 show that the means of the variables simulated by the model remain close to those of the data. Furthermore, the tests for equality of means confirm the absence of significant differences between the observed and simulated means.

As regards the variances, statistically significant differences are noted on the components of the inflation rate, with risks of error of 10percent for the underlying and energy components and 5percent for the food component. For the food component, the observed volatility is lower than that simulated by the model. Overall, the volatility of the overall inflation rate does not deviate significantly from its observed level, despite the differences noted for its components.

**Table 2: Comparison of observed and model-generated moments**

Variables	Average		Standard deviation		Equality tests	
	Obs. ( $\mu_O$ )	Model ( $\mu_M$ )	Obs. ( $\sigma_O$ )	Model ( $\sigma_M$ )	H0 : $\mu_O = \mu_M$	H0 : $\sigma_O^2 = \sigma_M^2$
Output gap	-0,69	-0,71	0,77	0,75	0,52 (0,60)	1,03 (0,90)
Overall inflation rate	1,60	1,63	2,08	2,15	0,08 (0,94)	0,94 (0,83)
Underlying inflation rate	0,88	0,95	2,37	1,93	0,02 (0,87)	2,34* (0,09)
Food inflation rate	2,66	2,31	5,93	4,35	0,20 (0,84)	3,13** (0,043)
Energy inflation rate	1,24	1,46	4,86	6,60	0,18 (0,85)	0,54* (0,03)
Interest rate	4,13	4,10	0,73	0,69	0,24 (0,81)	0,89 (0,70)
Exchange rate	648,9	649,0	0,55	0,52	6,54 (0,68)	1,24 (0,32)
Reserves	94,4	95,3	4,77	4,68	0,32 (0,75)	1,04 (0,88)

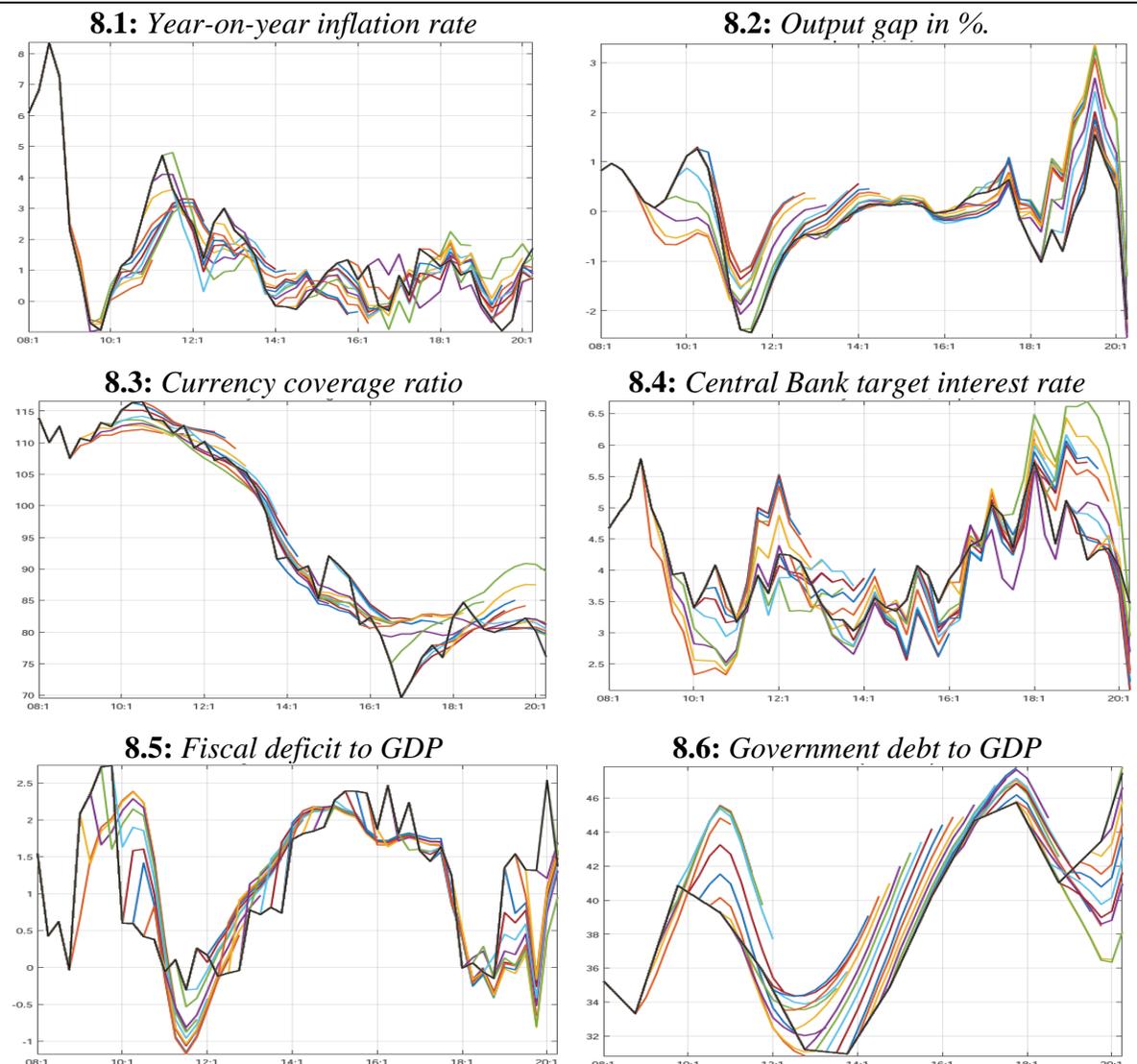
Source: Authors calculations

Notes: The tests of equality of means and variances are based on the Fischer statistic (F-test). The values in brackets denote the respective probabilities (*p-values*) associated with the F-test values, indicating the areas of rejection of H0 (probability of rejecting H0 with a risk of error equal to *p-value*). The number of stars (\*\*), (\*), (\*) means that the H0 hypothesis is rejected with respective risks of error of 1percent, 5percent and 10percent.

### Pseudo out-of-sample forecasts

The predictive power of the model is evaluated using a pseudo-out-of-sample forecasting exercise. This consists of defining a sub-set of exogenous data in the sample to carry out a succession of forecasts, over eight (8) quarters, of key variables in the economy. The forecasts obtained are then compared with the observed values in the sample. The exogenous variables are the international variables, the risk premium, and the equilibrium real exchange rate. The latter two variables are unobservable but determined by the model.

The graphs in Figure 8 show the evolution of the realized and projected values of the following variables: inflation rate, output gap, foreign exchange reserve coverage ratio, central bank target interest rate, budget deficit to GDP and public debt to GDP.

**Figure 8: Pseudo out-of-sample forecasts 2009Q1-2020Q2**

Source: Authors' calculations.

Legend: the black line represents actual, observed values of selected variables, while the lines in color represent their projected values at particular quarters in the forecasting period.

Examination of the graphs in Figure 8 shows that, overall, the model has good forecasting capabilities, since the projected values do not diverge from observations. The model's forecasting performance is particularly good when the WAEMU economies are hit by shocks of relatively small magnitude.

### Model vs. SVAR: comparison of forecasts

To refine the analysis of the quality of the forecasts, a comparison of the forecasting performance of the model with that of the Structural Vector Autoregression VAR model (SVAR) based on the main variables of the model was carried out (*see* Table 3).

The SVAR approach adopted include the main variables of interest which are the output gap, the inflation rate, the currency coverage ratio (international reserves), the foreign output gap and the monetary policy interest rate. After controlling the time series properties of these variables using unit root tests (ADF and PP), the VAR estimate is made based on the appropriate lag length.

In the identification strategy, we impose some restrictions based on the following practical guidelines: (i) the contemporaneous shocks to the other endogenous variables do not affect the foreign GDP, (ii) monetary policy actions do not affect the subset of domestic macroeconomic variables within the same quarter, (iii) reserves do not affect GDP and inflation in the short term and (iv) there is no contemporaneous effect of inflation to GDP. In addition, we retain that monetary policy shock cannot affect real variables in the long term.

**Table 3: Comparison of RMSEs of the QPM model with those of the SVAR model**

Variables	Model	RMSE								Average	Ratio (*)
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8		
Inflation	QPM	0.47	0.58	0.71	0.76	0.89	0.94	0.98	0.98	<b>0.79</b>	<b>0.59</b>
	SVAR	0.74	1.14	1.35	1.44	1.48	1.49	1.50	1.51	<b>1.33</b>	
Output gap	QPM	0.23	0.44	0.60	0.71	0.76	0.75	0.73	0.69	<b>0.61</b>	<b>0.52</b>
	SVAR	0.61	1.05	1.21	1.27	1.31	1.33	1.35	1.37	<b>1.19</b>	
CCR	QPM	2.51	3.29	3.88	4.13	4.60	4.76	5.10	5.35	<b>4.20</b>	<b>1.03</b>
	SVAR	2.90	3.65	4.09	4.23	4.35	4.39	4.42	4.44	<b>4.06</b>	
Interest rate	QPM	0.36	0.44	0.51	0.59	0.64	0.68	0.70	0.73	<b>0.58</b>	<b>0.95</b>
	SVAR	0.38	0.48	0.57	0.64	0.67	0.70	0.72	0.73	<b>0.61</b>	

Source: Authors' calculations.

(\*) A value that is less than 1 for the ratio between the RMSE from the QPM and the SVAR indicates that forecasts made using the QPM are more precise—in the sense of lower root-square mean error—than those using the SVAR.

This analysis shows that the RMSE of the model is lower (ratio <1) for inflation, the output gap and the interest rate. On the other hand, the SVAR model produces forecasts with lower standard deviations than the QPM model for the currency coverage rate.

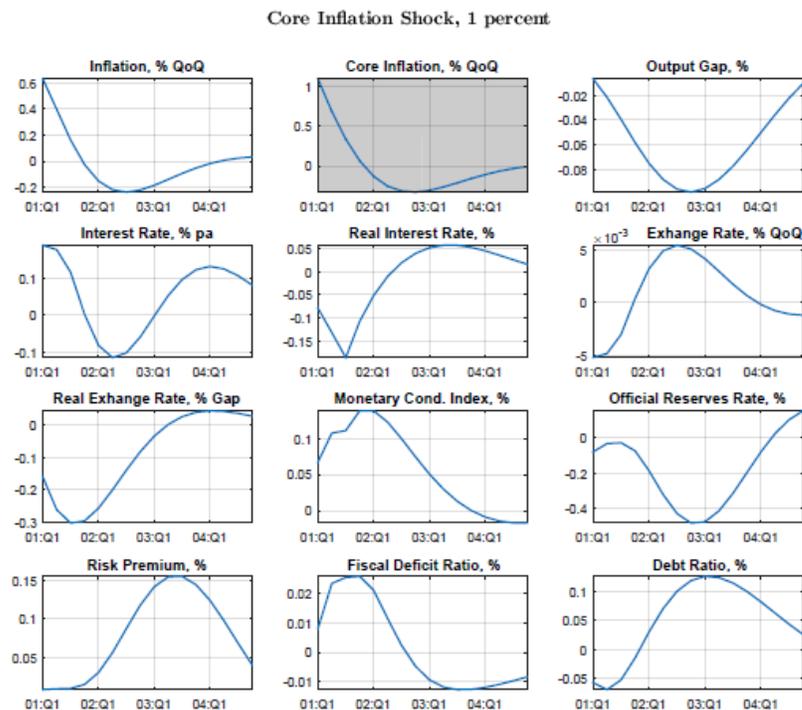
## V. IMPULSE RESPONSES

This subsection examines the dynamic properties of the model by studying the transmission channels of exogenous shocks. Six types of shocks have been simulated: an aggregate demand shock, a supply shock, a monetary policy shock, a fiscal shock, a shock to foreign exchange reserves and a global demand shock.

### A. Cost-push shock

A cost-push shock is simulated through a 1 percent increase in the inflation rate excluding energy and food products, compared to its equilibrium level. The increase in core inflation mechanically translates into an increase of 0.6 percent in headline inflation.

**Figure 9: Impulse responses to a cost-push shock**



Source: Authors' calculations.

This upward trend in prices is then gradually mitigated by the tightening of real monetary conditions (real interest rate and real exchange rate). Indeed, the tightening of monetary policy allows demand to be reduced which, in turn, would reduce inflation. The shock also induces an appreciation of the real exchange rate which shifts part of the domestic demand towards foreign products (trade balance effect), thus moderating the inflationary push.

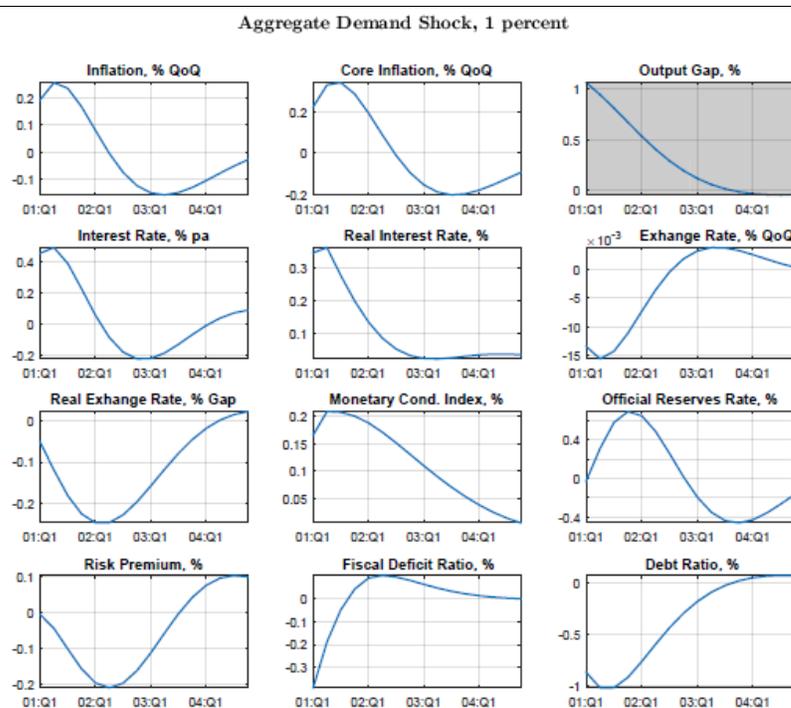
The deterioration of the trade balance and the rise in the interest rate produce contrasting effects on foreign exchange reserves, which show an instantaneous fall followed by a gradual rise and an undulatory evolution towards its target level. The fall in output causes an increase in the budget deficit ratio and the public debt ratio.

Furthermore, this simulation shows that supply shocks are characterized by a negative correlation between inflation and the output gap. In this context, disinflation could be costly in terms of the sacrifice ratio. Thus, appropriate responses to supply shocks constitute an important challenge for the central bank, which must accept a certain loss of output, trying to bring the inflation rate back to its target level.

## B. Aggregate demand shock

An unexpected 1 percent increase in aggregate demand relative to its long-term level translates into a pressure on the general price level of around 0.2 percent. In line with its objective of price stability, the monetary authorities must react by tightening monetary policy, via an increase of almost 50 basis points in the target rate, to ease inflationary pressure and restore equilibrium. This leads to a downward adjustment of output and prices resulting from the increase in the real interest rate and the temporary appreciation of the real exchange rate. The rise in the real interest rate affects the expectations of rational agents, who would postpone part of their consumption in favor of savings. In addition, this upward trend in the real interest rate discourages investment. On the other hand, the appreciation of the real exchange rate deflates the demand for local products by reducing the costs of imported products.

**Figure 10: Impulse responses to a demand shock**



Source: Authors' calculations.

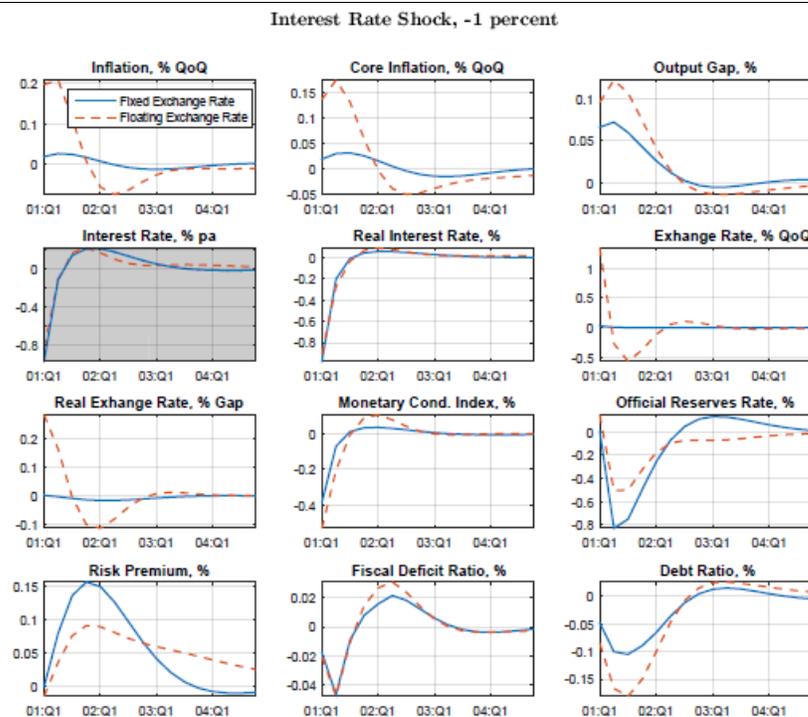
Following the shock, output would return to long-term equilibrium after 12 quarters. The inflation rate would return to its target level after 16 quarters, as would the real exchange rate. The demand shock shows a positive correlation between inflation and the output gap.

It is important to note that the variations in the exchange rate are negligible (of the order of 10<sup>-3</sup>) for both the supply and demand shocks, due to the fixed parity of the currency with the European currency ( $h_2 = 0.97$ ). On the other hand, the demand shock reduces the risk premium by favoring foreign currency inflows and the reduction of the public debt ratio.

### C. Monetary policy shock

The simulation of a one-off easing of monetary policy (a 1percent cut in the WAEMU interbank market rate (IBR) is carried out to examine its effects on domestic macroeconomic conditions and external equilibrium (see Figure 11). Together with the interpretation of the results under the fixed exchange rate regime, in force in the WAEMU zone ( $h_2 = 0.97$ ,  $h_1 = 0.43$ ; curves in blue), the hypothetical case of a flexible exchange rate regime associated with the WAEMU data is studied ( $h_2 = 0$ ,  $h_1 = 0$ ; curves in red).

**Figure 11: Impulse responses to a monetary policy shock**



Source: Authors' calculations.

An instantaneous drop of 1percent in the BCEAO target rate corresponds to an increase in the supply of liquidity on the money market. This additional liquidity increases the capacity of economic agents (governments and the private sector) to transform domestic currency into international currency for the settlement of transactions with foreign partners (debt repayment, import settlement, etc.). This situation is reflected in a currency coverage rate (CCR) decrease.

Consequently, this easing of monetary policy led to a decrease in the CCR of 0.8 points after one quarter, thus increasing the external vulnerability of the sub-regional economy. This leads to an increase in the risk premium of almost 0.15 points. A tightening of monetary policy is thus necessary to avoid a depreciation of the exchange rate. The improvement in domestic financing conditions reduces the fiscal deficit ratio through its countercyclical effects on economic activity. The decline in the public debt ratio results from both the increase in GDP and the improvement in the fiscal deficit.

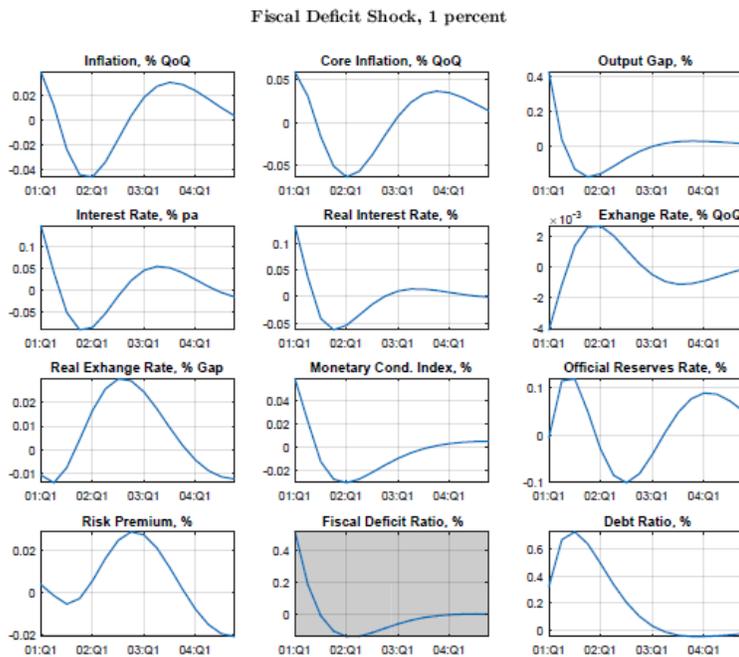
This simulation shows that the easing of monetary policy, with a view to supporting the economic programs of WAEMU countries<sup>15</sup>, preserves the internal macroeconomic stability of the economy, as evidenced by the low variations in the inflation rate and output. However, this orientation is not without cost, as it tends to accentuate the external vulnerability of the economy through the decline in reserves and the increase in the risk premium.

Under the hypothesis of a floating exchange rate regime (curves in red), the impact of monetary expansion on foreign exchange reserves and on the risk premium would have been limited by the systematic depreciation of the nominal and real exchange rates, which would have improved economic competitiveness. At the same time, the exchange rate adjustment would have had a *pass-through* effect on inflation and output, thus pushing the central bank to reorient monetary policy.

### D. Fiscal policy shock

Figure 12 depicts the effect of a 1 percentage point shock to the budget deficit, reflecting an expansionary fiscal policy that is decoupled from the business cycle. The result is a fiscal impulse that increases the debt/GDP ratio while punctually stimulating production, with a slight increase in inflation relative to its target. These developments make it necessary for the BCEAO to react by tightening monetary policy, especially as the risk premium is expected to increase over the medium term.

**Figure 12: Impulse responses to a fiscal policy shock**



Source: Authors' calculations.

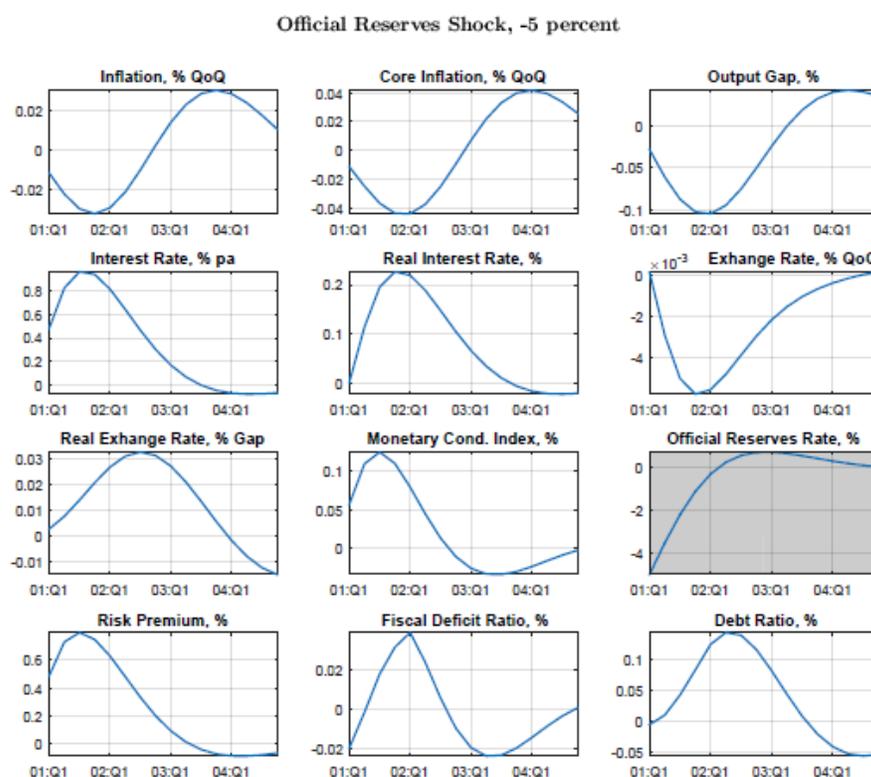
<sup>15</sup> The securities and bills admitted as collateral for refinancing operations are mainly issued by WAEMU States.

### E. Foreign exchange reserve shock

An unexpected decrease in the coverage rate of the money supply (-5 percentage points) may result from an unexpected drop in capital inflows. This shock increases the risk premium and leads the BCEAO to tighten its monetary policy by increasing the target interest rate by 50 basis points, which will lead to weaker economic activity and lower inflation.

The resulting depreciation of the real exchange rate raises foreign prices and encourages the production of domestic and export goods. Increasing competitiveness of local firms supports economic activity and inflation in the medium term. In total, foreign exchange reserves are replenished after 6 quarters.

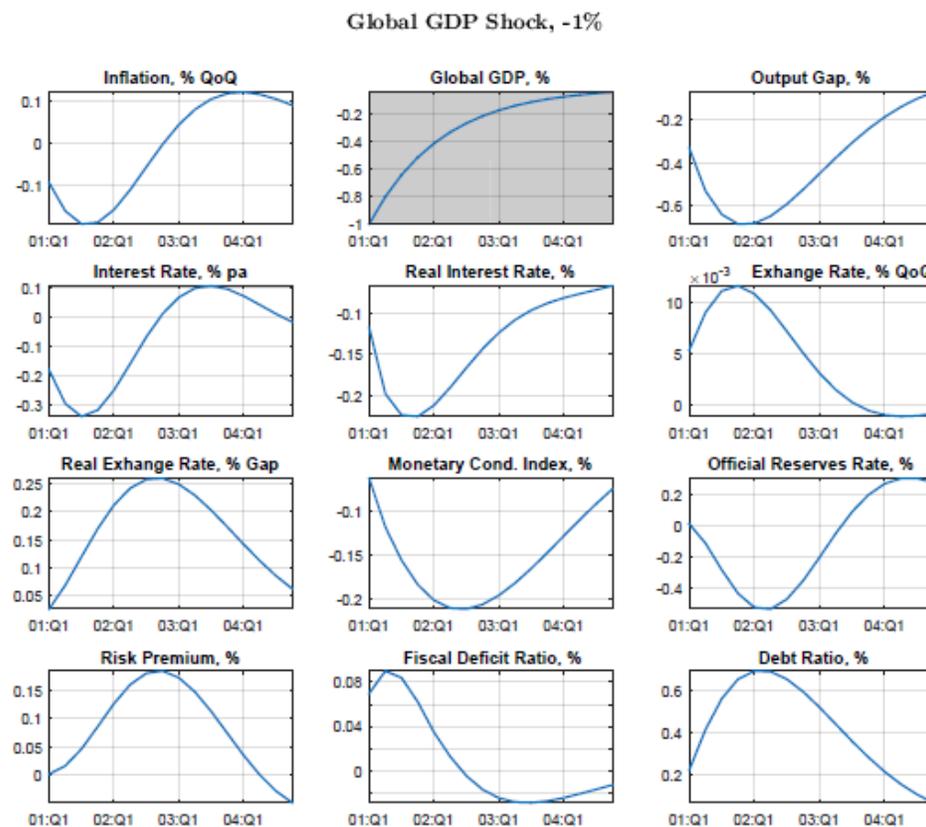
**Figure 13: Impulse responses to a shock to foreign reserves**



Source: Authors' calculations.

### F. Global demand shock

A 1 percent contraction in global demand leads to a widening of the domestic output gap by more than 0.6 percentage points after three quarters, a fall in the general price level of around 0.2 percent and a decline in foreign exchange reserves. To promote a recovery in activity, the budget deficit is widening, which increases the debt and worsens the risk premium. On the other hand, monetary policy is temporarily loosened, but the Central Bank's target rate will have to rise later to counter the decline in foreign exchange reserves. The return to long-run equilibrium of the output gap and the inflation rate will take almost 16 quarters.

**Figure 14: Impulse responses to a global demand shock**

Source: Authors' calculations.

## VI. FORECAST

The purpose of forecasting exercises is to facilitate monetary policy decision-making. Indeed, rather than making unconditional forecasts, the QPM model is essentially designed to forecast paths for the Central Bank's target interest rate that are consistent with macroeconomic stability objectives. The main scenario retained in this study is declined through projection assumptions of external and internal variables over an eight-quarter period (2020Q3-2022Q3).

### A. Assumptions about the Foreign Economy and International Prices

In terms of the international economy, the rapid spread of the pandemic and the restrictive measures put in place have caused a sharp and sudden contraction in activity during 2020. However, the latest IMF forecasts indicate a recovery of activity in 2021. In response to the health crisis, the central banks, notably the FED and the ECB, eased their monetary policy from March 2020 onwards and then announced that they would continue this accommodating stance by maintaining key rates at (or close to) zero by 2022. On the commodity markets, oil prices, after a significant decline in the first half of 2020, should gradually recover in 2021 and 2022.

Thus, the assumptions made at the international level can be summarized as follows:

- a) The output gap is kept negative until the second quarter of 2022, when the world economy could return to its production potential.
- b) The interest rate on US Treasury bills has been on a downward trend from 0.09 percent to 0.03 percent, over eight quarters.
- c) The price of crude oil would gradually increase to \$60.
- d) Global inflation (G20 countries) should quickly return to its level of the last five years, i.e., 3.5 percent, as demand picks up against a backdrop of falling supply capacity.

## **B. Assumptions about the Domestic Economy**

Domestically, the rapid fall in domestic demand reflects the effects of the pandemic containment measures on supply and demand as well as the decline in external demand. These disruptions lead to a decline in production potential and a slight increase in domestic prices (especially food prices) in the last two quarters of 2020. Prices are then expected to fall to the level of euro area prices due to the fixed parity between the currencies of the two areas.

In response to the deterioration in activity, WAEMU countries have implemented countercyclical fiscal policies aimed at mitigating the negative effects of the pandemic. In this context, the budget deficit and public debt targets have been temporarily raised by 3 to 5 percentage points in 2020. In this context, the increase in the risk premium on public debt could be moderated by the easing of international financial conditions.

For its part, the BCEAO took a series of measures to limit the negative impact of the pandemic on the banking system and promote economic recovery. The main measures are: *i*) making unlimited liquidity offers on refinancing windows at a fixed rate equivalent to the key floor rate, *ii*) lowering the floor rate by 50 basis points, *iii*) allowing the postponement of claims for companies and individuals affected by the health crisis, *iv*) relaxing the prudential system and *v*) promoting digital means of payment.

For 2021, the Central Bank, in a context marked by a satisfactory level of foreign exchange reserves and the absence of pressure on prices, planned to continue its unlimited liquidity injection operations at a fixed rate. Under these conditions, interest rates would remain at low levels in 2021.

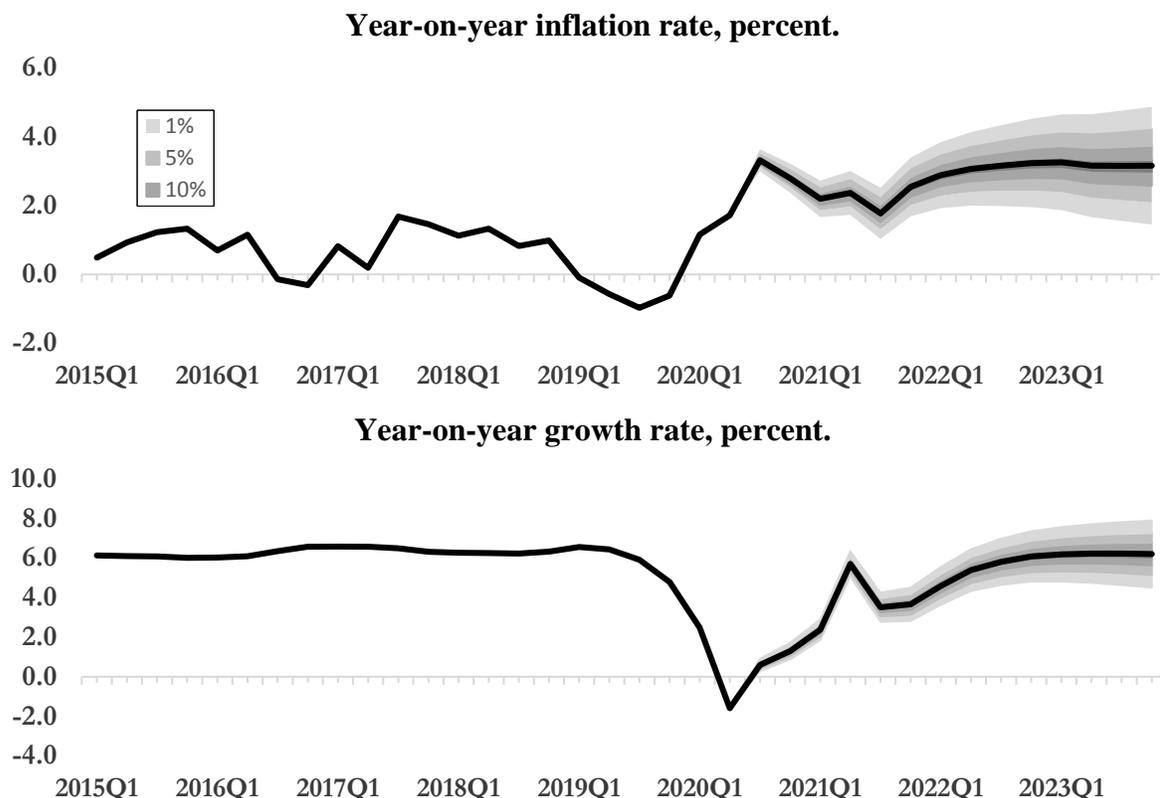
Therefore, the assumptions made for the internal environment are as follows:

- a) WAEMU countries are putting in place fiscal stimuli to mitigate the impact of the decline in domestic activity. To this end, the budget deficit to GDP ratio is set at 5 percent in 2020 and 4 percent in 2021 and 2022.
- b) The easing of monetary policy beyond the levels required by the central bank's reaction function allows for a negative shock to the target interest rate of -2.5 percentage points.

### C. Results

The forecasts simulated by the model, based on the above-mentioned assumptions, show that the impact of the pandemic should be gradually absorbed in the WAEMU zone (Figure 15). Inflation is expected to rise slightly in 2021 at 2.2 percent after 2.1 percent in 2020. This level of inflation is consistent with the upward trend in inflation in the euro zone in relation to the consistency of purchasing power parity. The inflation rate is expected to rise in 2022 and 2023.

**Figure 15: Forecast of inflation and growth rate**



Source: Author's calculations.

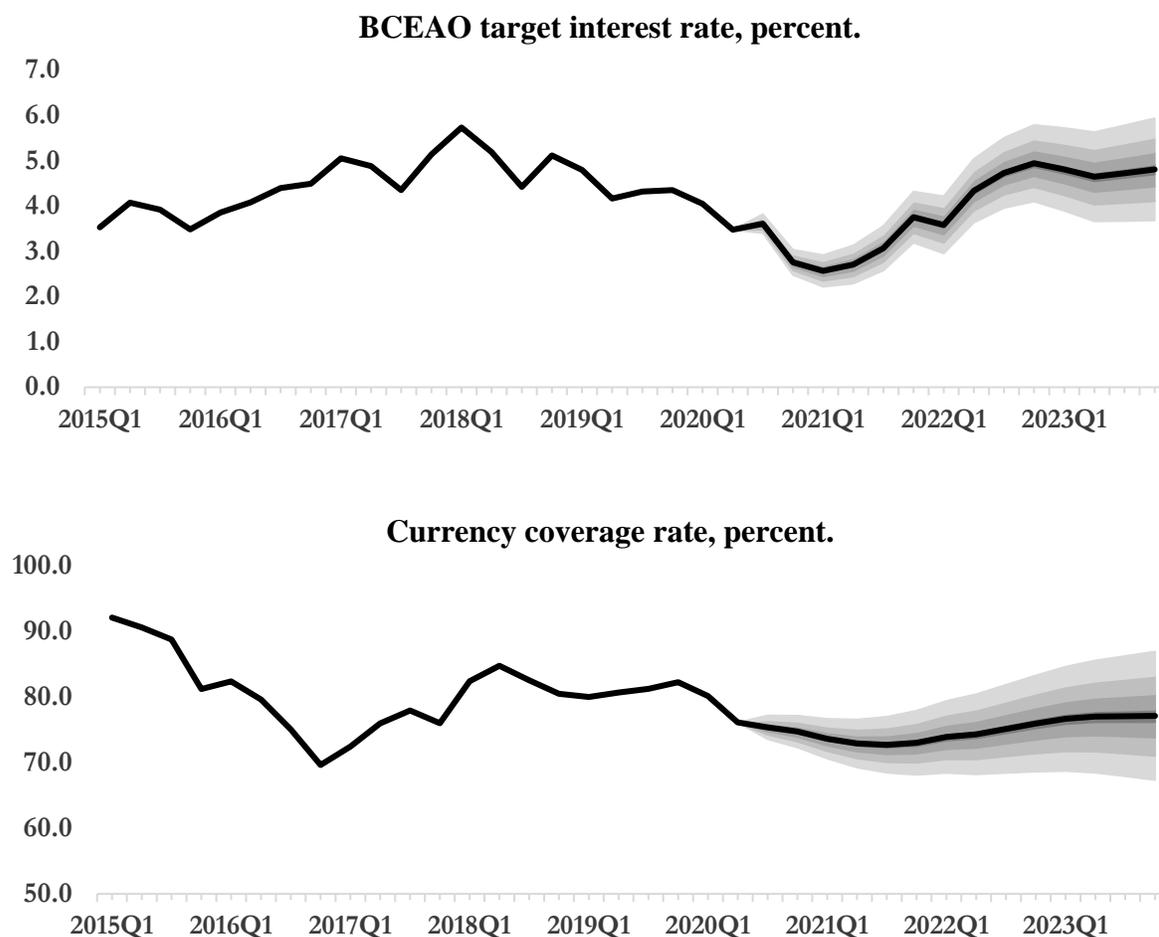
After a sharp slowdown in economic growth in 2020 (0.7 percent), a rebound was expected in 2021 (4 percent), followed by a slight acceleration in 2022 (5.5 percent). This development will be driven by the gradual recovery of external demand, the implementation of the WAEMU countries' recovery plans and the intervention of the BCEAO to ease financing conditions.

The coverage rate of monetary issuance by foreign exchange reserves should remain below the 80 percent mark until 2022 before rising slightly in 2023. It would evolve in the medium term around 75 percent. However, the level of reserves will depend on the trade-off between the States in terms of financing their budget deficits in local currency or in foreign currency.

As for monetary policy, in the short term it should remain accommodating in 2021 and should begin to tighten gradually with an increase in the target interest rate to approach its neutral level. This tightening is essentially explained by the evolution of foreign exchange

reserves, which are struggling to return to their level of the previous decade, in a context where inflation and the output gap are generally under control.

**Figure 16: Forecast of the CB's target interest rate and currency coverage rate**



Source: Author's calculations.

It seems appropriate to recall that the interest rate forecast is not a commitment to future decisions by the Central Bank. Rather, it is the expected path of the interest rate if all assumptions materialize as expected. Therefore, developments in external or domestic factors that differ from expectations could affect future decisions taken by the Central Bank.

## VII. CONCLUSIONS

The BCEAO has made significant efforts in recent years to strengthen its framework for monetary policy analysis and management. However, the analytical and forecasting capabilities of a central bank are part of a continuous improvement process, in line with advances in economic theory, technological progress and international experience.

In this perspective, the present study has proposed a semi-structural neo-Keynesian macroeconomic model (the QPM-WAEMU model) adapted to the economic context of the WAEMU zone. The QPM-WAEMU model is calibrated based on lessons learned from the existing literature on QPM models, off-model econometric estimates and Bayesian estimation. Validation tests of the calibration were carried out through the analysis of the consistency of the data simulated by the model and the evaluation of the quality of the recursive pseudo out-of-sample forecasts. The consistency of the model was also tested with the analysis of impulse shock simulations.

Overall, one-off shocks to internal and external variables lead to slight variations in the inflation rate, which remains structurally low, mainly due to the pegging of the CFAF to the euro, in line with the long-term purchasing power parity between these two currencies. The simulations also show that an easing of monetary policy puts downward pressure on foreign exchange reserves and thus increases the external vulnerability of the WAEMU. As a result, the implementation of a monetary policy to support the economy could, in the long run, come up against the constraint of building up a minimum stock of foreign exchange reserves, which is a guarantee of the viability and credibility of the exchange rate targeting regime.

Finally, the model is used to perform out-of-sample forecasting and to assess the medium-term economic impact of the Covid-19 pandemic. In this respect, it shows good forecasting ability for key economic variables based on a set of assumptions stacked into a single scenario. Similar to the analysis resulting from the impulse shocks, the forecasts show that the constraint on foreign exchange reserves should lead to a tightening of monetary policy from 2022 onwards, after a period of monetary easing (2020-2021) linked to the Covid-19 crisis.

Overall, the model captures the transmission mechanisms of monetary policy (operational channels) and the set of relevant shocks affecting the economies of the monetary union. The model should also help to strengthen communication on the monetary policy stance while providing better visibility on the constraints and trade-offs associated with the decisions.

Finally, the QPM-WAEMU model has several limitations that need to be addressed in the future. Indeed, this model does not explicitly integrate balance of payments flows or monetary variables. Similarly, aggregate demand could be disaggregated into agricultural and non-agricultural components, given the weight of the primary sector in the economy.

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### **Laws and Regulations**

- Treaty of the West African Monetary Union (2010)
- Regulation No. 09/201/CM/WAEMU on the external financial relations of the WAEMU States.
- Decision No. 397/12/2010 on the rules, instruments and procedures for the implementation of the currency and credit policy of the BCEAO.
- Decision No. 24/2013/CPM/BCEAO amending and supplementing Decision No. 397/12/2010 of 6 December 2010 on the rules, instruments and procedures for implementing the currency and credit policy of the BCEAO.

## ANNEXES

### Annex 1: Data sources

**Table A1: Data used in the model and sources**

VARIABLES	SOURCES
<b>Internal variables : WAEMU</b>	
Real GDP Consumer Price Index Core price index (excluding food and energy) Food price index Energy Product Price Index Weight of components of overall inflation Target interest rate Budgetary balance of WAEMU countries	BCEAO
<b>External variables</b>	
3-month US Treasury bill rate. G20 real GDP G20 Consumer Price Index Oil price per barrel (Brent) World food prices Exchange rate (euro/FCFA)	Bloomberg OECD OECD investing.com OECD investing.com

**Annex 2: Calibration, à priori distributions and estimated parameters**Table A.2.1: *Calibrated parameters*

Parameter	Value	Description
$b_5$	0.7	<i>Persistence of the credit risk premium</i>
$e_1$	0.5	<i>Forward-looking expectations on foreign exchange markets</i>
$g_2$	1.0	<i>Weight given to inflation in the CB's reaction function</i>
$g_3$	1.0	<i>Weight given to the output gap in the CB's reaction function</i>
$p_2$	1.0	<i>Government response to deviations of the debt/GDP ratio from its target</i>
$p_3$	0.1	<i>Sensitivity of the fiscal impulse to shocks to the debt target</i>
$p_4$	0.3	<i>Deficit sensitivity to GDP fluctuations (countercyclical fiscal rule)</i>
$p_6$	0.01	<i>Sensitivity of the country risk premium to deviations of the debt/GDP ratio from its target</i>
$p_8$	0.9	<i>Sensitivity of the MCT to the target interest rate</i>
$p_9$	0.5	<i>Sensitivity of the MER to the nominal exchange rate</i>
$\rho^{prem}$	0.8	<i>Persistence of the risk premium</i>
$\sigma_{\varepsilon^s}$	1.5	<i>Volatility of the nominal exchange rate shock</i>
$\sigma_{\varepsilon^i}$	1.5	<i>Volatility of the target interest rate shock</i>
$\sigma_{\varepsilon^{prem}}$	1.0	<i>Volatility of the risk premium shock</i>
$\sigma_{\varepsilon^{resv}}$	1.0	<i>Volatility of the shock on the MCT</i>
<b>Steady state</b>		
$\Delta s^T$	0.0	<i>Change in steady state nominal exchange rate</i>
$\Delta \bar{z}$	0.0	<i>Change in steady state real exchange rate</i>
$\bar{\pi}^*$	2.0	<i>Long-term foreign inflation rate</i>
$\bar{\pi}$	2.0	<i>Inflation rate target</i>
$\bar{g}_Y$	6.5	<i>Steady state growth rate economic growth rate</i>
$\overline{prem}$	2.0	<i>Steady state risk premium</i>
$resv^{tar}$	85.0	<i>Target of Currency Coverage Ratio (CCR)</i>
$b_t^{tar}$	45.0	<i>Target of public debt ratio</i>
$\bar{r}^*$	2.0	<i>Equilibrium foreign interest rate</i>
$\bar{r}$	2.0	<i>Equilibrium real interest rate</i>
$\bar{r}$	Eq. 10	<i>Equilibrium interest rate calculated from the equilibrium relationship of equation 10</i>
$\overline{r\pi}^f$	+1.0	<i>Trend change in the relative food price</i>
$\overline{r\pi}^{core}$	-0.5	<i>Trend change in the relative core price</i>

Table A. 2.2: *À priori distribution of parameters*

<b>Parameter</b>	<b>Type of distribution</b>	<b>Average</b>	<b>Standard deviation</b>	<b>Description</b>
$b_1$	Normal	0.9	0.1	<i>Persistence of the output gap</i>
$b_2$	Normal	0.15	0.01	<i>Pass-through of real monetary conditions</i>
$b_3$	Normal	0.3	0.01	<i>Impact of foreign demand on domestic production</i>
$b_4$	Beta	0.4	0.03	<i>Weight of the real interest rate in the real marginal cost index,</i>
$b_6$	Normal	0.6	0.01	<i>Impact of the fiscal impulse on the output gap</i>
$a_1$	Normal	0.8	0.25	<i>Persistent core inflation</i>
$a_2$	Normal	0.2	0.2	<i>Impact of <math>rmct</math> on core inflation</i>
$a_3$	Normal	0.6	0.2	<i>Share of imported goods in marginal business costs (<math>1 - a_3</math>)</i>
$a_{21}$	Normal	0.6	0.1	<i>Persistent food inflation</i>
$a_{22}$	Beta	0.5	0.15	<i>Impact of real marginal cost on food prices</i>
$a_{23}$	Beta	0.9	0.01	<i>Weight of relative food prices and the output gap on the <math>rmc_t</math> food</i>
$a_{31}$	Beta	0.7	0.03	<i>Energy inflation persists</i>
$a_{32}$	Beta	0.2	0.2	<i>Passthrough of world oil prices on domestic prices</i>
$h_2$	Normal	0.95	0.1	<i>Degree of rigidity of the exchange rate regime</i>
$g_1$	Normal	0.2	0.1	<i>Persistence of the target rate in the CB reaction function</i>
$h_1$	Normal	0.4	0.1	<i>Weight given to exchange rate stability in the interest rate rule</i>
$p_7$	Normal	0.1	0.01	<i>Sensitivity of the risk premium to the MCT</i>
$\rho^{resv}$	Normal	0.8	0.1	<i>Persistence of the MCT</i>
$\sigma_{\varepsilon y}$	Reverse Gamma	0.5	1.0	<i>Volatility of the demand shock</i>
$\sigma_{\varepsilon^{core}}$	Reverse Gamma	1.0	3.0	<i>Volatility of the shock to underlying inflation</i>
$\sigma_{\varepsilon^{food}}$	Reverse Gamma	5.0	3.0	<i>Volatility of the food inflation shock</i>
$\sigma_{\varepsilon^{nrj}}$	Reverse Gamma	8.0	3.0	<i>Volatility of the energy inflation shock</i>

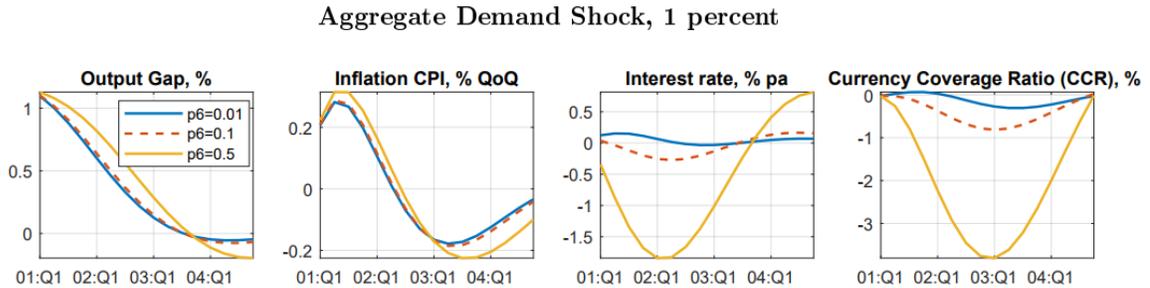
Table A. 2.3: *Estimation of parameters*

Parameter	Mode	Critical values	
		0.25%	97.5%
$b_1$	0.92	0.71	0.98
$b_2$	0.15	0.13	0.17
$b_3$	0.28	0.27	0.30
$b_4$	0.39	0.34	0.45
$b_6$	0.59	0.58	0.62
$a_1$	0.73	0.64	0.84
$a_2$	0.35	0.14	0.59
$a_3$	0.44	0.12	0.74
$a_{21}$	0.69	0.81	0.93
$a_{22}$	0.23	0.08	0.36
$a_{23}$	0.92	0.90	0.94
$a_{31}$	0.79	0.76	0.83
$a_{32}$	0.13	0.11	0.16
$h_2$	0.97	0.95	0.99
$g_1$	0.45	0.23	0.57
$h_1$	0.43	0.30	0.57
$p_7$	0.09	0.077	0.116
$\rho^{resv}$	0.76	0.57	0.92
$\sigma_{\varepsilon^y}$	0.71	0.55	1.01
$\sigma_{\varepsilon^{core}}$	4.01	3.33	4.48
$\sigma_{\varepsilon^{food}}$	9.79	8.10	12.31
$\sigma_{\varepsilon^{nrj}}$	8.54	7.21	10.89

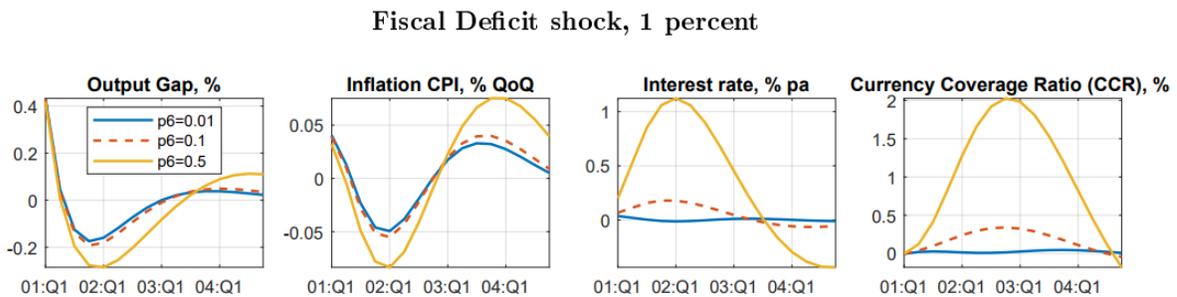
### Annex 3: Sensitivity analysis to the calibration of parameter $p_6$

This annex discusses sensitivity analysis of the behavior of the model under the different values of  $p_6$ . Figures A.3.1 and A.3.2 display impulse responses to standard aggregate demand and fiscal policy shocks.

**Figure A.3.1: Aggregate demand shock for different values of  $p_6$**



**Figure A.3.2: Fiscal policy shock for different values of parameter  $p_6$**



The response of main variables to a demand shock under different values of  $p_6$  is overall stronger for larger values. In particular, for  $p_6 = 0.5$ , the monetary policy response becomes very strong and counter intuitive considering the history of WAEMU economies. For  $p_6 = 0.1$ , the responses of key variables are close to those under the calibrated value ( $p_6 = 0.01$ ) but the monetary policy response is not as expected.

Considering the fiscal shock (i.e., to the fiscal deficit), responses of variables under different values of  $p_6$  increase for higher values. However, for cases where  $p_6$  equals 0.5 and 0.1, monetary policy reactions are not in line with recent economic history of WAEMU economies.

We conclude that the calibrated value of  $p_6$  is within the range of (low) values that seem to capture best the economic history of WAEMU economies.



**PUBLICATIONS**