

INTERNATIONAL MONETARY FUND

A Novel Quarterly Macroeconomic Forecasting Framework

Illustration on the Case of Bosnia and Herzegovina

Tibor Hlédik, Rilind Kabashi, Maria Arakelyan, Belma Čolaković
and Elma Hasanović

WP/26/36

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WORKING PAPER

IMF Working Paper
Institute for Capacity Development

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Prepared by Tibor Hlédik, Rilind Kabashi, Maria Arakelyan, Belma Čolaković and Elma Hasanović

Authorized for distribution by Natan Epstein
February 2026

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ABSTRACT: This paper describes the Quarterly Macro Forecasting Framework (QMFF), which is a novel approach to macroeconomic policy analysis and forecasting. At the core of this framework is a Quarterly Projection Model, with main behavioral equations quantified as deviations of real variables from their trends. The model comprises a simultaneous system of calibrated equations that cover the main sectors of the Financial Programming and Policies framework, as well as key accounting restrictions within and across sectors. By explicitly accounting for trends observed in real variables and relative prices, the framework ensures a balanced growth path and constant expenditure shares relative to nominal GDP. The QMFF is sufficiently flexible to be adapted to different monetary frameworks and exchange rate regimes. After describing the framework, the paper illustrates its implementation for policy analysis and forecasting on the case of Bosnia and Herzegovina. The empirical work with the model includes not only calibration but also testing the model's dynamic and in-sample simulation properties.

RECOMMENDED CITATION: Tibor Hlédik, Rilind Kabashi, Maria Arakelyan, Belma Čolaković and Elma Hasanović (2026). A Novel Quarterly Macroeconomic Forecasting Framework: Illustration on the Case of Bosnia and Herzegovina. IMF Working Paper 26/36.

JEL Classification Numbers:	C54, E32, E17, F41, E60
Keywords:	Semi-structural Modeling; Financial Programming; Macroeconomic Policies; Forecasting and Policy Analysis; Gap Models; Scenario Analysis; Bosnia and Herzegovina
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WORKING PAPERS

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Illustration on the Case of Bosnia and Herzegovina

Prepared by Tibor Hlédik, Rilind Kabashi, Maria Arakelyan, Belma Čolaković and Elma Hasanović¹

¹ The QMFF was developed during a technical assistance project at the Central Bank of Bosnia and Herzegovina (CBBH) delivered by Tibor Hlédik, Rilind Kabashi and Maria Arakelyan (all Joint Vienna Institute during that time) on behalf of the IMF Institute for Capacity Development (ICD). We would like to express our gratitude to the Netherlands Constituency Partnership Program for financing this technical assistance project provided to the CBBH.

We would like to thank the CBBH Office of the Chief Economist staff for providing relevant data inputs and expert judgements necessary for calibration: Belma Hadžihalilović Kasumović, Rade Čolaković, Antonio Musa and Emina Milišić. We are grateful to Ali Alich, Michal Andrlé, Alberto Soler, José Federico Geli Manzano, Yurii Sholomytskyi, Alina Iancu, Andrew Jewell, Andreas Tudyka, and Adrian Musić (all IMF), for their support and useful discussions during our work on the project. We are also grateful to Hervé Joly from the JVI for his support. Finally, we are grateful to Jan Vlček from the Czech National Bank for his valuable technical advice.

For useful comments while drafting this paper, we are grateful to colleagues from the IMF Institute for Capacity Development, in particular Michal Andrlé and Felipe Zanna.

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Glossary

AR	Autoregressive process
BiH.....	Bosnia and Herzegovina
BGP.....	Balanced Growth Path
BoP.....	Balance of Payments
CBBH	Central Bank of Bosnia and Herzegovina
CPI	Consumer Price Index
FDI.....	Foreign Direct Investment
FPP	Financial Programming and Policies
GDP.....	Gross Domestic Product
HP	Hodrick-Prescott
ICD	Institute of Capacity Development, IMF
IMF	International Monetary Fund
IPF.....	Integrated Policy Framework
NTF	Near-term Forecast
QMFF	Quarterly Macro Forecasting Framework
QPM	Quarterly Projection Model
UIP	Uncovered Interest Rate Parity
VAT	Value Added Tax

Executive Summary

This paper describes the Quarterly Macro Forecasting Framework (QMFF), which is a novel approach to macroeconomic policy analysis and forecasting. At the core of this framework is a Quarterly Projection Model (QPM), where main behavioral equations are quantified in terms of deviations of real variables from their long-run trends (“gap model”). The behavioral relationships driving the framework are based on standard macroeconomic theory, including a well-defined balanced growth path (BGP) and stable “great ratios” in the steady state, which is one of the key contributions of the framework. The model comprises a simultaneous system of calibrated equations that cover all main sectors commonly covered by Financial Programming and Policies (FPP), as well as key accounting restrictions within and across these sectors. Indeed, QMFF is driven by a standard QPM that serves as an “engine” for an FPP framework covering all key segments of the economy. Alternatively, it can be viewed as a model-based FPP. The QMFF is gradually brought to data via a combination of empirical approaches and can be easily adapted to accommodate different monetary frameworks and exchange rate regimes, as well as incorporate forward-looking expectations. After describing QMFF, the paper illustrates its implementation to Bosnia and Herzegovina (BiH), a country with a currency board and high capital mobility. However, the paper also discusses the flexibility of QMFF set-up, allowing to accommodate alternative exchange rate regimes as well as enabling incorporating both adaptive and model-consistent forward-looking expectations.

The development of the QMFF is part of a broader ICD agenda to develop macroeconomic frameworks for forecasting and policy analysis, supporting both the department’s technical assistance practice and direct support to Fund Area Departments. These frameworks include Simple Accounting Frameworks, Extended Financial Programming and Policies (FPP) Frameworks, Semi-structural Gap Models (SSGMs), and Structural Simulation Models (DSGE). The QMFF is part of the SSGM analytics and development efforts, which already include the Quarterly Projection Models—workhorse models in many central banks—and FINEX (Berg et al., 2023). The framework is flexible in that it enables incorporating behavioral equations similar to those captured by the IMF’s Integrated Policy Framework (Adrian et al., 2009), as well as FINEX.

Similar to FINEX and other efforts, QMFF also extends the traditional QPM framework to jointly capture fiscal, monetary, and external sector dynamics. While QMFF shares several conceptual and structural features with FINEX—reflecting the common goal of enriching the QPM architecture—it contributes three distinctive enhancements. First, it introduces greater sectoral granularity and full accounting consistency, closely aligned with FPP practices, allowing for more detailed fiscal analysis and policy simulation. Second, QMFF adopts an improved treatment of trends following Andrieu et al. (2009) and Andrieu (2008), yielding a simpler yet parsimonious decomposition of cyclical and structural components. Third, the framework offers enhanced reporting capabilities that improve transparency, communication, and practical usability for policy institutions.

Specifically, the novelty of QMFF consists in combining QPM-style approaches and FPP within a single framework and unified infrastructure, thus merging their respective advantages. From QPM-style models it takes business cycle analysis and forecasting, as well as tractability and the production of automatized reports. From the FPP it takes granularity and full accounting consistency within and across sectors. Therefore, the adoption of the QMFF should be appealing to many central banks and ministries of finance in emerging and

developing economies that currently use QPM-type models; many of them also compile FPP-type tables (not least as part of the relations with the IMF). Further, one of the key advantages of QMFF is that it includes trends in relative prices and real quantities so that the projections produced are consistent with a BGP. To achieve this, the trends are derived and linked in a way that expenditure shares relative to nominal GDP converge to stable shares in the steady state, real expenditure gaps close and both real and nominal growth rates are constant in the long run.

The adoption of the QMFF enables sizable productivity gains in policy analysis and in producing model-consistent macroeconomic forecasts, thus resulting in better policy decisions. Specifically, since the tool uses quarterly data, analytic policy documents and forecasts can be produced at quarterly or annual frequency, which is common and useful in policymaking. The backbone of the framework relies on a semi-structural model consisting of a simultaneous system of behavioral equations specified in terms of gaps, thus bringing the framework in line with current theory and practice. Further, an automatized database system, executing data transformations for all key FPP sectors (real, monetary, external, and fiscal) is used to enhance productivity. Related to this, automatic reports on model diagnostics and forecast output, covering all FPP sectors, are produced to enhance the analytic and forecasting work and thus support the decision-making process in policymaking institutions. In addition, the framework is designed to easily and transparently incorporate judgement and off-model information and generate alternative scenarios.

The QMFF has been implemented on the case of Bosnia and Herzegovina, and this case is used to illustrate its capabilities, although the paper contains extensive discussion how the framework can be adjusted to other cases. The model structure and the granularity of the FPP framework were chosen to be in line with the stylized facts of the BiH economy as well as data availability. The model was calibrated via gradual iterations to achieve plausible dynamic properties and convergence towards steady state values of key nominal expenditure shares to GDP ratios. Moreover, the QMFF was tested extensively using impulse response analysis, shock decompositions and in-sample simulations to ensure it achieves robust overall model properties. The presented results indicate that the model captures some of the episodes of the BiH business cycle well and it is reasonably close to the historical data in in-sample simulations.

1. Introduction

This paper describes the Quarterly Macro Forecasting Framework (QMFF), which is a novel approach to macroeconomic policy analysis and forecasting that combines Quarterly Projection Model-style (QPM) approaches and Financial Programming and Policies (FPP) within a single framework and unified infrastructure. In other words, it expands QPM to include the full real sector (demand components and prices), the fiscal and external balance as well as the monetary statistics. Indeed, the framework is driven by a standard QPM that serves as an ‘engine’ for an FPP framework covering all key segments of the economy. Alternatively, it can be viewed as a model-based FPP.

The QMFF merges the advantages of the two approaches. From QPM-style models it takes business cycle analysis and forecasting, as well as the tractability and the fast production of automatized reports. At the same time, from the FPP it takes granularity and full accounting consistency. The QMFF is designed as a general tool that can accommodate different monetary frameworks and exchange rate regimes, as well as incorporate forward-looking expectations.

The main characteristics of the framework are the following:

- It uses quarterly data, so that analytic policy documents and forecasts can be produced at quarterly or semi-annual frequency.
- The backbone of the framework relies on a semi-structural model consisting of a simultaneous system of behavioral equations specified in terms of gaps.
- The framework is implemented and operated using Matlab/IRIS.²
- An automatized database system, executing data transformations for all key FPP sectors (real, monetary, external, and fiscal) is used to enhance productivity.
- Automatic reports on model diagnostics and forecast output are produced to enhance the analytic and forecasting work supporting the decision-making process in policymaking institutions.
- The framework is designed to easily incorporate judgement and generate alternative scenarios.³

Modelling real GDP expenditure components allows the framework to capture rich economic relationships at business cycle frequencies. It can incorporate monetary policy measures to stabilize business cycles and inflation, including the exchange rate channel. The link between aggregate demand and fiscal policy is established via quantification of the cyclically adjusted primary balance, with fiscal indicators feeding into private consumption and gross investment that in turn feed into the import demand. Additional gap equations are introduced for variables that can be modelled via behavioral equations.

Besides the behavioral gap equations, the framework also includes equations for nominal variables specified as ratios of GDP, mostly from fiscal, external, and monetary sectors. These variables are forecasted using

² IRIS is a free, open-source toolbox for macroeconomic modeling and forecasting in Matlab, originally developed by the IRIS Solutions Team and currently maintained and supported by the Global Projection Model Network. It is freely available for Matlab and Octave from <https://iris.igpmn.org/>.

³ In addition, the framework enables exporting the data and forecasts to a standard Excel-based FPP macroframework, as well linking the results to the IMF’s Debt Dynamics Tool (Acosta Ormaechea and Martinez, 2021), which facilitates tracking public debt dynamics and discussing potential risks and adjustment needs. These extensions are, however, not covered in the paper.

autoregressive convergence of their observed ratios to nominal GDP towards their trend ratios to nominal GDP. QMFF incorporates trends in relative prices and real quantities, ensuring that the projections produced by the macroframework are consistent with BGP. To achieve this, the model trends are derived and linked in a way that nominal expenditure shares relative to nominal GDP converge to stable values in the steady state, real expenditure gaps close and both real and nominal growth rates are constant in the steady state.

The paper provides a detailed outline of this novel framework, illustrates its application in the case of Bosnia and Herzegovina (a currency board regime with high capital mobility and adaptive expectations) and includes guidance on adjusting the framework to other country cases. Section 2 provides an overview of the framework and its key contributions, as well as a detailed description of the model, its key equations, the model's steady state as well as the interlinkages between sectors ensuring the macro-consistency of the framework; it also examines the approaches to model calibration, focusing on model parameters and calibrating the key dynamic equations. Section 3 brings stylized facts for Bosnia and Herzegovina and outlines the necessary data inputs and transformations to operate the framework. Section 4 discusses the tools available to verify the model, highlighting the use of impulse response functions, the decomposition of behavioral equations and in-sample simulations. Section 5 describes the process of producing baseline forecasts, alternative scenarios and forecast comparisons, illustrated on the case of Bosnia and Herzegovina. The last section concludes.

2.The Model

This section starts with an overview of the QMFF, including its key contributions as a novel macroeconomic forecasting framework. The baseline version of the framework is comprehensive in capturing all sectors of the FPP, so all key equations of the model are described below. However, the framework is flexible so that equations can be modified depending on the particular focus of the user, data availability and country specifics. The section also explains how different monetary policy and exchange rate strategies can be captured in the framework before proceeding to a detailed model description. It then proceeds with the steady state of the model, including issues arising from the chosen monetary and exchange rate framework. Finally, the consistency within and between FPP sectors is also discussed.

2.1. Overview of the Model and Key Contributions

The QMFF combines a standard QPM model with an accounting framework consistent with a standard FPP framework so that it is consistent with balanced growth path (BGP). Financial programming is a quantitative approach that the IMF has used for decades in macroeconomic analysis and forecasting, as well as in designing policy scenarios for macroeconomic adjustments. The monetary approach to the balance of payments, which inspires financial programming, is laid out in [IMF \(1977\)](#), [IMF \(1987\)](#), [Polak \(1997\)](#) and [Mussa and Savastano \(1999\)](#). Further, [Barth and Hemphill \(2000\)](#) and [IMF \(n.d.\)](#) include detailed guidelines on the practical application of FPP. In FPP, macroeconomic aggregates are derived from key macroeconomic accounts, which is then used to create consistent macroeconomic forecasts for a country. Because of its prevalence in all areas of the IMF activity (surveillance, lending and capacity development), many central banks and ministries of finance and/or economics in emerging and developing economies maintain and use FPP tables for macroeconomic policy analysis and forecasting (typically using Microsoft Excel). Related to this, FPP-type frameworks are often quite granular, not only because of relevance to policymakers, but also because some accounting identities are applied at a more detailed level rather than in terms of broad categories. This granularity is appropriately reflected in QMFF.

On the other hand, what has generally become known as QPM consists of New-Keynesian semi-structural general equilibrium models, featuring rational expectations. [Berg et al. \(2006a\)](#) and [Berg et al. \(2006b\)](#) provide overviews to QPM-type models, which are or were used in the past by many central banks in emerging and developing economies as the core of their policy analysis and forecasting systems. For instance, [Coats et al. \(2003\)](#) document the calibrated QPM for the Czech Republic, one of the first adopters. [Szilágyi et al. \(2013\)](#) discuss the Hungarian QPM, including Bayesian estimation. [Hlédik et al. \(2016\)](#) describe the extensions of the QPM and its application in North Macedonia. Finally, [Mæhle et al. \(2021\)](#) provide for a survey of recent applications. In QPM models, equation parameters are typically calibrated, and the real variables of the model are defined in terms of gaps, measured as percentage deviations of the model variables from their long-run trends (hence the alternative name “gap models”). The key equations in QPM-style models resemble log-linearized versions of equations from micro-founded models, while the remaining equations are usually *ad hoc*.

The model equations are built to capture the policy transmission mechanism as well as reflect country-specific features. Consequently, these models are widely used for policy analysis and forecasting in many emerging and developing countries, especially for monetary policy.

The current practice in numerous policy institutions in emerging and developing economies is to rely on a QPM model and a detached, Excel-based FPP framework. The reconciliation and mutually consistent analysis of historical data and the forecast generated with these two frameworks is challenging, as they rely on fundamentally different foundations. The key contribution of QMFF, therefore, is to unify QPM with FPP within a single framework with a coherent analytic and forecasting infrastructure. Consequently, the key benefit of QMFF is consistency. In other words, QMFF uses QPM as an engine for the FPP; or QMFF can be viewed as model-based FPP.

Unifying QPM with an FPP framework, however, also brings several challenges. Most notably, QPM models were originally developed for monetary policy analysis, with only limited role for fiscal policy. Therefore, they assume that policymakers set interest rates to close deviations of expected inflation from the inflation target and while doing so, deviations of real variables from trends (which are usually exogenously defined) are gradually closed as well. Besides, QPM models are often relatively small, capturing only several key variables and equations. FPP frameworks, on the other hand, include detailed accounts of all macroeconomic sectors and their interlinkages, paying close attention to growth rates and ratios to GDP in the near to medium term. However, they typically do not capture trends and implicitly ignore long term implications, resulting in inconsistency with BGP. Overall, in their standard applications, neither QPM nor FPP explicitly ensure full accounting consistency with a BGP in terms of both growth rates and shares to GDP. In both theoretical and practical terms, the balanced growth path is a crucial feature of economic variables: in the long run, gaps should close, growth rates of real variables and prices should be reasonable, and nominal ratios should also converge to stable values.

One of the key contributions of the QMFF is the treatment of trends (discussed in detail below) in relative prices and real quantities, ensuring that the projections produced by the macroframework are consistent with BGP. To achieve this, the model trends are derived and linked in a way that nominal expenditure shares relative to nominal GDP converge to stable values in the steady state, real expenditure gaps close and both real and nominal growth rates are constant in the steady state.

While the practical implementation differs, in spirit, the treatment of trends to ensure a balanced growth path follows state-of-the-art approaches from literature and current practice. Most notably, the g3 model of the Czech National Bank, a DSGE model with consistent stock-flow national accounting, was among the first to explicitly deal with trends in sectoral relative prices (Andrle et al. 2009; Andrle, 2008). In addition, FINEX, which is a newly developed gap-trend model of the IMF, provides an extended treatment of components of demand, fiscal, and the balance of payments (Berg et al., 2023). The underlying economic mechanisms and overall modeling strategy of QMFF and FINEX are similar, although QMFF defines all trends as functions of potential GDP and of relative prices, whereas in FINEX trends are modeled separately. In addition, QMFF explicitly addresses all FPP sectors in their granularity and incorporates all related accounting identities.

The behavioral relationships driving the framework are based on standard macroeconomic theory, including a well-defined balanced growth path and stable “great ratios” in the steady state. The framework is flexible, as it enables both adaptive and model-consistent forward-looking expectations, depending on the modelling

strategy. The model is transformed into its reduced-form using the Blanchard-Kahn algorithm (Blanchard and Khan, 1980). The main behavioral equations are specified in terms of gaps that are defined as percentage deviations of any real variable from its trend. Specifically, for variable X_t , the corresponding gap from its trend \bar{X}_t is denoted as \hat{X}_t , with $\hat{X}_t = 100 * \log X_t - 100 * \log \bar{X}_t$. The framework is flexible regarding the calculation of trend levels \bar{X}_t , which can be based on univariate filters (e.g. Hodrick-Prescott) or multivariate filters (e.g. Kalman filtering).

The trends of real expenditure components of GDP are functions of potential GDP and the trend in relative prices.^{4,5} In this way, the resulting trends of real variables ensure constant nominal ratios to nominal (potential) GDP in the long run (See the derivation in Annex A). In other words, one can think of the output gap as nominal GDP divided by nominal potential GDP after log linearization. By using nominal potential GDP as a scaling variable for all nominal shares (real economy, BoP, fiscal, monetary), the log linearization transforms all variables into “output gap units”. For instance, if the steady-state share of nominal consumption to nominal GDP ratio is 60%, the log linearization of this share yields 0.6*consumption gap (plus a relative price gap). Defining expenditure shares relative to nominal potential GDP, enables therefore imposing identities in terms of gaps and later recovering these gaps back into nominal and real values.

As noted above, the framework consists of several behavioral relationships based on macroeconomic theory. This applies to real GDP expenditure components, prices, interest and exchange rates, as well as some of the variables in other sectors. Further, most variables in the external, fiscal and monetary sectors are modelled via autoregressive processes of ratios to nominal GDP converging to a constant steady-state value. These variables follow an AR(1) process on the forecast horizon when no information related to the future path of these variables is available. In case such information becomes available (e.g. likely new FDI, external government borrowing, discretionary decisions of fiscal authorities, etc.), residuals⁶ of the respective AR(1) equation are set in line with the forecasted values or expert judgement (see Section 5). Furthermore, whenever a new behavioral relationship is quantified for any of the variables previously captured by AR(1) processes, it can easily be included into the framework. Specifying equations in terms of behavioral gap relations or AR(1) processes maintains the model in linear form.

The QMFF presented in this paper is a generalized version of the model, originally developed during the Technical Assistance provided by the IMF to the CBBH (see IMF, 2025). Compared to the version used by the CBBH, the model described here has been adapted and recalibrated to be applicable to a broad range of countries.

The general structure of QMFF is captured by Figure 1 below. One of the key properties of the framework is that it assumes the existence of a core semi-structural gap model, QPM, that fulfills some important properties. Specifically, it:

1. Converges to a well-defined steady state.

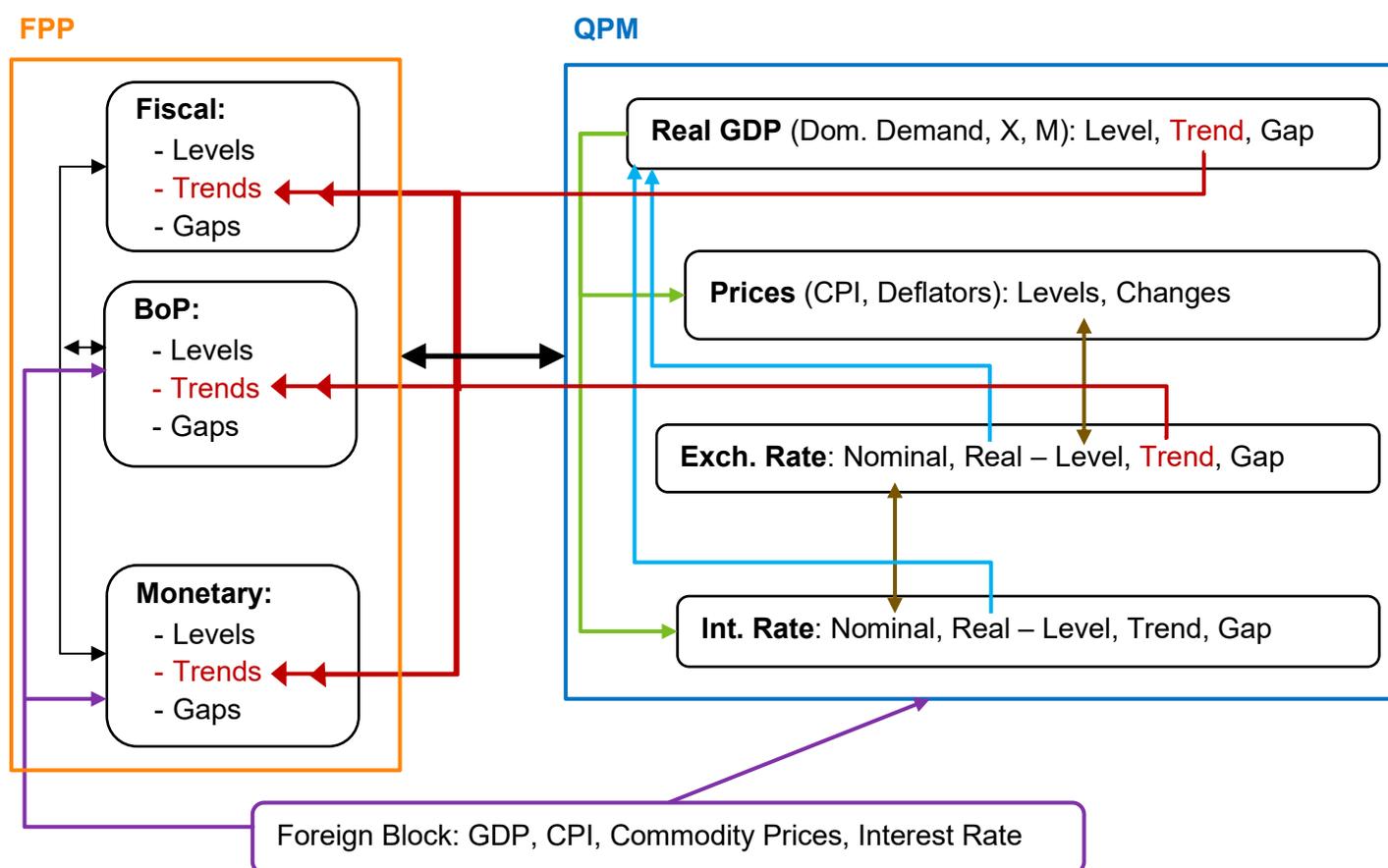
⁴ More than one trend in relative prices can be accommodated. In the example discussed in this paper, two trends in relative prices are used.

⁵ Note that not all real expenditure components of GDP have their corresponding trends in the model. Some variables are determined via identities, with the respective trends and gaps calculated as a function of their components. For instance, in the example with exports below, the trend of total exports, $l_{x_r_bar}$, is defined as a function of exports of goods, $l_{xg_r_bar}$, and exports of services, $l_{xs_r_bar}$.

⁶ Residuals and shocks are used interchangeably in the text.

2. Includes real trends of GDP and real exchange rate, necessary for deriving constant nominal expenditure share to nominal GDP ratios in the steady state
3. Specifies domestic and foreign price levels, as well as levels of minimally three real variables from national accounts⁷ (real GDP, exports and imports)
4. Includes a monetary policy rule that is consistent with the prevailing exchange rate regime and represents well the domestic monetary policy behavior.
5. Features forward-looking model consistent expectation formation in case of a floating exchange rate regime with non-zero level of capital mobility.
6. Is set up in software that promotes flexibility, i.e. easily links the core model to extensions, such as BoP- or fiscal blocks.

Figure 1: General Structure of the QMFF



⁷ The full quarterly national accounts data are not required. Approximations, based on trade and price data, might be used to derive real domestic demand, export and import gaps needed for regular analytic and forecasting work with the model.

In addition to the QPM's schematical description, [Figure 1](#) also depicts the way the core QPM is linked to the key FPP blocks of the QMFF and how those generate feedback loops back into the core QPM (red and orange lines). The real GDP and relative price trends from QPM are entering the FPP blocks, so that all nominal shares measured in terms of nominal potential GDP converge to constant steady state shares. This is achieved via formal derivation of the expenditure shares as functions of trends in relative expenditure volumes and prices. Specifically, all real expenditures trends are a function of potential GDP and trends in relative prices. Imposing these restrictions on model trends is necessary to obtain constant expenditure shares in the long run, and this is what QMFF does systematically and efficiently throughout the whole model structure. The BGP, including constant expenditure shares in the steady state, are crucial preconditions for fiscal and BoP accounting and for achieving stock-flow equilibrium in macroeconomic models.

The feedback from the FPP blocks to QPM, indicated by orange lines, reflects two types of important linkages. First, it reflects accounting identities that are imposed between sectors. The most important identities imposed in QMFF are discussed in [Section 2.6](#) and visualized in [Figure 7](#) below. Second, the feedback reflects the effects of variables that are present in various building blocks of the QMFF. Examples include the presence of BoP variables (such as private transfers), or fiscal variables (such as the cyclically adjusted primary balance) in the consumption of households' equation. These interlinkages are difficult to impose in Excel spreadsheets, but they are straightforward in simultaneous systems like QMFF.

2.2. Exchange Rate Regimes and Monetary Policy Frameworks

One of the strengths of the framework is that it can easily accommodate different exchange rate regimes and monetary policy strategies. We discuss this next before moving to the detailed model description in the next section. The following three equations are sufficiently general to model a wide range of fixed exchange rate regimes, with relevant steady-state values discussed in [Section 2.4](#) (and the adjustments for Philips curves under various regimes discussed in the next section):

$$dla_s = rho_dla_s * dla_{s_{t-1}} + (1 - rho_dla_s) * ss_dla_s + p2 * prem_gap + shk_dla_s$$

$$rs = rs_rw + ss_fix_prem + prem_gap + shk_rs$$

$$prem_gap = -p1 * l_curr_acc_bal2gdp_gap_norm + shk_uip_prem$$

The most restrictive fixed exchange rate regime is the currency board, when the change in the nominal exchange rate, dla_s , is zero and the level of the nominal exchange rate, l_s , cannot be changed. Therefore, the parameters of the equations for the currency board are $ss_dla_s = 0$, $p1 = 0$ and $p2 = 0$. Consequently, for the currency board, $shk_dla_s = 0$. With high capital mobility, the money market rate rs , collapses to $rs_rw + ss_fix_prem$. In these cases, there is no policy rate, and the monetary base is constrained by the stock of foreign reserves.

A conventional fixed exchange rate regime or a crawling peg implies that the central bank intervenes to keep the exchange rate on a trend line, determined by the slope parameter ss_dla_s (which is zero in the case of a conventional peg). The interest rate reaction function is consistent with an arbitrage-free condition under the assumption of full capital mobility: the domestic policy rate, rs , equals the foreign policy rate, rs_rw , and the risk premium. In this case, the risk premium has a constant part, ss_fix_prem , and an endogenous part, $prem_gap$.

The former assumes a constant steady-state value, reflecting structural country features. The latter is endogenous and modeled as a function of the gap of the ratio of current account balance to GDP, $l_curr_acc_bal2gdp_gap$.⁸ The intuition behind this specification is straightforward: as the country's external position deteriorates, approximated by the fall in the current account balance gap, $l_curr_acc_bal2gdp_gap$, the central bank must raise the policy rate to compensate investors for the higher risk attached to the deteriorating external position. Unlike in the currency board case, parameter $p1$ is not zero, and it depends on country specific factors, such as the openness of the economy, the sensitivity of capital flows to the interest rate differential, the credibility of macroeconomic policies and their coordination. In practice its value can be calibrated based on the change in foreign reserves attributable to capital flows that are sensitive to the interest rate differential and the risk premium.

The exchange rate equation specified above is also suitable for modeling floating exchange rate regimes with very low sensitivity of capital flows to the interest rate differential. In such regimes, mostly characterized by underdeveloped money and foreign exchange markets, the exchange rate is driven by macroeconomic fundamentals influencing the current account balance. These are factors such as the fiscal deficit (feeding into increased imports demand), terms of trade shocks (especially important in commodity exporting countries) or changes in FDI, remittances or other BoP items. For these economies, the parameter $p2$ is set to a non-zero value. The specification results in an intuitive exchange rate response to shocks to the external balance: worsening of the current account relative to nominal potential GDP will usually result in depreciation and vice versa. As we assume negligible sensitivity of the domestic financial market to the interest rate differential, the policy rule can be any of the rules specified for the fixed/floating exchange rate regimes (or their weighted average). Nevertheless, for countries transitioning towards inflation targeting it is advisable to choose a Taylor-type interest rate rule designed for floating exchange rate regimes.⁹

The floating regimes are modeled as follows:

$$l_s = s1 * l_s_{t+1} + (1 - s1) * (l_s_{t-1} + 2 * ss_dla_s/4) + (-rs + rs_rw + uip_prem)/4 + shk_dla_s$$

$$rs = t1 * rs_{t-1} + (1 - t1) * (ss_rs + t2 * (d4l_cpi_{t+4} - ss_dla_cpi) + t3 * l_gdp_r_gap) + shk_rs$$

$$uip_prem = ss_prem + prem_gap$$

The exchange rate equation (in levels, l_s) is a generalized form of the uncovered interest rate parity condition (UIP). However, compared to the standard textbook-style UIP specification, we allow for a deviation from rational expectations in terms of the expected nominal exchange rate by including some inertia into expectation formation.¹⁰ In theoretical terms, this inertia is explained by the presence of portfolio adjustment costs. Further, in practice, exchange rates usually do not react to news as dramatically as the standard textbook UIP

⁸ In forward-looking models, the risk premium can be modeled as a function of the discounted future value of the current account, or the country's NFA position. Besides, the risk premium is country specific, and this can be easily adjusted to reflect country-specific features, including fiscal variables.

⁹ The interest rate channel, without an effective and well-functioning foreign exchange market and functional UIP channel, will be weak for both policy rules.

¹⁰ Instead of model consistent expectations at time $t+1$, l_s_{t+1} , we assume expectations are formed as a weighted average of forward-looking model-consistent expectations and backward-looking expectations that are adjusted for the steady-state growth rate of the nominal exchange rate for two periods (to reach $t+1$ from $t-1$ the steady state): $s1 * l_s_{t+1} + (1 - s1) * (l_s_{t-1} + 2 * ss_dla_s/4)$.

equations would suggest. Related to this, markets often put some weight on the level of the exchange rate in the previous period when forming expectations about the future. Further, note that the exchange rate reaction in a floating exchange rate regime, consistent with the UIP, can be derived only in models with model-consistent forward-looking expectations. Finally, this specification ensures that the model has a well-defined steady state for alternative parameter calibrations.

Besides the constant steady-state risk premium, ss_prem , the total risk premium, uip_prem is also a function of the current account (via the endogenous risk premium, $prem_gap$), and it might play an important role in exchange rate determination in countries with functional but shallow foreign exchange markets.¹¹ Further, in the floating exchange rate regime the central bank uses Taylor-type rules, with the policy interest rate, rs , a function of inertia, the deviation of the expected year-over-year (y-o-y) inflation rate from its target, $d4l_cpi_{t+4} - ss_dla_cpi$, and the output gap, $l_gdp_r_gap$.

Beyond the extremes of currency board and freely floating exchange rates, and the intermediate regimes like conventional pegs and crawling pegs, the framework also enables accommodation of managed floats, i.e. different types of hybrid regimes. For instance, the central bank may use foreign exchange interventions (not modeled explicitly) to smooth exchange rate fluctuations, i.e. to achieve a “desired” rate of exchange change. To capture such cases, the exchange rate equation would be modified into a weighted average of the “desired” rate of exchange rate change and the UIP condition. In addition, the interest rate equation would reflect both the standard policy reaction function and the UIP condition. The particular calibration of the two equations would reflect the tightness of exchange rate management, as well as the degree of control of money market interest rates by the central bank, possibly taking into account capital controls¹². For various alternatives how managed floats can be incorporated into small New Keynesian models, see [Beneš et al. \(2008\)](#) and [Beneš et al. \(2013\)](#).

2.3. Detailed Model Description

In this section, we present the main model equations in the following order. First, we start by describing the real economy block which contains the real expenditure items of the GDP and other key variables determining the dynamic properties of this block (such as the real wage bill). Here we bring examples of behavioral equations driving the model (e.g. private consumption), of those based on cross-restrictions (e.g. government consumption) and identities (e.g. output gap) which are at the core of FPP and ensure the macro-accounting consistency of the framework. Second, we lay out the key equations driving the external sector beyond exports and imports that were already included in the real economy block (i.e. private transfers and foreign direct investments) and define the main identities in the balance of payments. Third, we outline the key behavioral equations (e.g. VAT revenues) and cross restriction identities (e.g. primary expenditures) in the fiscal block. We also present the definition of the cyclically adjusted primary balance, which is used to establish a link between fiscal policy and the real economy. Fourth, we detail the equations in the monetary block and describe the modelling of the household and corporate loans. Fifth, we present the price block and again the adjustments needed under various exchange rate regimes.

¹¹ By shallow foreign exchange markets, we mean those markets where current account flows can have an effect on the exchange rate, as opposed to the countries where financial account transactions are dominating the foreign exchange market.

¹² The “desired” exchange rate change must be consistent with the inflation differential and the change in equilibrium real exchange rate, otherwise the “inflation objective” will not be met.

The QMFF includes many identities within and across the main sectors of the financial programming framework (see also Section 2.6). For ease of exposition, only gap equations are shown for the cross-restriction identities below; however, the same restrictions are also imposed in terms of trend real levels and trend real ratios to GDP (maintaining full model linearity). Further, in our description of key model equations below, we will be discussing deviations of real variables from their corresponding trends, without emphasizing that we talk about gaps. Also, in the equations, all variables enter contemporaneously, unless otherwise noted.

2.3.1. Real economy

The real economy block of the QMFF includes all key real expenditure variables of national accounts. Private consumption, $l_c_r_gap$, is assumed to be a function of the real disposable income of households. In absence of reliable data for the latter, it is approximated by output, $l_gdp_r_gap$, and private transfers $l_sec_inc_pt_r_gap$. Tighter real monetary conditions, represented in the model by the real households' lending rate, $rr_lend_hh_lc_gap$, negatively affect private consumption. The effect of fiscal policy on household demand is captured via the cyclically adjusted primary balance, $l_pbal_ca2gdp_gap_norm$, which has a negative impact on consumption demand¹³. The inertia observed in private consumption is captured via lagged private consumption.

$$l_c_r_gap = c1 * l_c_r_gap_{t-1} + c2 * l_gdp_r_gap + c3 * l_sec_inc_pt_r_gap - c4 * l_pbal_ca2gdp_gap_norm - c5 * rr_lend_hh_lc_gap + shk_l_c_r_gap$$

The model also includes an equation on the real wage bill, $l_wb_r_gap$. In line with the standard determinants, the wage bill is a function of inertia and the lagged overall economic growth, $l_gdp_r_gap$. The compensation of government employees, $l_comp_emp_r_gap$, also has a positive impact on the overall wage bill.

$$l_wb_r_gap = w1 * l_wb_r_gap_{t-1} + w2 * l_gdp_r_gap_{t-1} + w3 * l_comp_emp_r_gap + shk_l_wb_r_gap$$

Government consumption, l_g2gdp_gap , is based on an identity and therefore included in the model as a cross-restriction. It is a weighted average of the compensation of government employees, $l_comp_emp2gdp_gap$, and government spending on goods and services, l_gs2gdp_gap . The variable $l_discr_g2gdp_gap$ stands for the discrepancy between government consumption data on the one hand and the sum of compensation of employees and government spending on goods and services on the other hand (see also Section 2.6).

$$b_g * l_g2gdp_gap = b_comp_emp * l_comp_emp2gdp_gap + b_gs * l_gs2gdp_gap + b_discr_g * l_discr_g2gdp_gap + shk_l_g_r_gap$$

The compensation of government employees, $l_comp_emp_r_gap$, and government spending on goods and services, $l_gs_r_gap$, are both a function of the output gap, $l_gdp_r_gap$. The sign of the $g2$ and $g4$ coefficients

¹³ A tighter discretionary fiscal stance reduces private consumption in the model; a similar mechanism holds for government capital expenditures and gross investments below. These mechanisms will yield procyclical outcomes if policymakers tighten fiscal policy during downturns (or loosen in booms). On the other hand, counter-cyclicality is captured by negative coefficients on output gap in equations on compensation of employees and government spending on goods and services. Consequently, procyclicality can be avoided by careful calibration of coefficients in these equations. In addition, depending on country features, fiscal rules can be explicitly imposed in the model to ensure counter-cyclical fiscal behavior.

will depend on the behavior of fiscal authorities in response to economic cycles, with negative signs a reflection of counter-cyclical policy. In addition, there is some inertia in both fiscal spending items. Finally, the discrepancy is defined as an AR(1) process.

$$l_{comp_emp_r_gap} = g1 * l_{comp_emp_r_gap_{t-1}} - g2 * l_{gdp_r_gap} + shk_l_{comp_emp_r_gap}$$

$$l_{gs_r_gap} = g3 * l_{gs_r_gap_{t-1}} - g4 * l_{gdp_r_gap} + shk_l_{gs_r_gap}$$

$$l_{discr_g_r_gap} = g5 * l_{discr_g_r_gap_{t-1}} + shk_l_{discr_g_r_gap}$$

Over the business cycle, total gross investment, $l_{j_r_gap}$, depends on demand generated both domestically and abroad, approximated by domestic output, $l_{gdp_r_gap}$, and foreign effective output, $l_{gdp_rw_gap}$, respectively. FDI inflows, $l_{fin_acc_fdi_r_gap}$, are also assumed to be associated with higher investment demand, affecting private investment. Further, government capital expenditures, $l_{acq_nfa2gdp_gap}$, approximate the effect of public spending on total gross-investment. The cost of capital is captured via real lending rates faced by corporations, $rr_lend_nfc_lc_gap$. Finally, the inertia in gross investment captures the staggered adjustment of investment plans in the face of investment adjustment costs.

$$l_{j_r_gap} = j1 * l_{j_r_gap_{t-1}} + j2 * l_{gdp_rw_gap} - j3 * rr_lend_nfc_lc_gap + j4 * l_{fin_acc_fdi_r_gap} + j5 * l_{acq_nfa2gdp_gap} + j6 * l_{gdp_r_gap} + shk_l_{j_r_gap}$$

In a small open economy, the demand for real exports of goods (from BoP), $l_{xg_r_gap}$, is strongly dependent on foreign demand, $l_{gdp_rw_gap}$. In line with economic theory, exports also depend on the real exchange rate, l_z_gap , capturing price competitiveness.¹⁴ Any increase in the domestic price level that is not accompanied by a corresponding increase in the productivity of the exporting sector should result in a fall in real exports. The specification of the demand for real exports of services (also from BoP), $l_{xs_r_gap}$, is similar to the functional form introduced for the exports of goods (with a potentially different parameterization of the equation).

$$l_{xg_r_gap} = xg1 * l_{xg_r_gap_{t-1}} + xg2 * l_{gdp_rw_gap} + xg3 * l_z_gap + shk_l_{xg_r_gap}$$

$$l_{xs_r_gap} = xs1 * l_{xs_r_gap_{t-1}} + xs2 * l_{gdp_rw_gap} + xs3 * l_z_gap + shk_l_{xs_r_gap}$$

The total exports of goods and services from the national accounts, $l_{x_r_gap}$, are a weighted average of exports of goods and exports of services from the BoP, with corresponding normalized weights of b_{xs}/b_x and b_{xg}/b_x . This cross-restriction ensures consistency between national accounts and the BoP (see also Section 2.6). However, unlike most other cross-restriction identities, which are purely accounting relationships, this equation includes a shock in order to capture observed small discrepancies in history between the two data sources, i.e. national accounts and BoP.

$$b_x * l_{x_r_gap} = b_{xg} * l_{xg_r_gap} + b_{xs} * l_{xs_r_gap} + shk_l_{x_r_gap}$$

¹⁴ Throughout the paper, we express exchange rates as local currency per one unit of foreign currency, i.e. an increase means depreciation of the local currency.

Real imports demand for goods from the BoP, $l_{mg_r_gap}$, is proportionate to the other GDP expenditure components, i.e. private consumption, $l_{c_r_gap}$, investments, $l_{j_r_gap}$, government consumption, $l_{g_r_gap}$, and exports, $l_{x_r_gap}$. This reflects the assumption that total imports are a sum of imports for each component, with mg and ms parameters denoting the shares of each GDP component in the imports of goods and services, respectively. Further, any depreciation of the real exchange rate, l_{z_gap} , results in an imports substitution effect: as foreign goods become more expensive relative to domestic goods, economic agents will tend to substitute foreign goods for domestic ones. This will result in a fall in imports. The specification for the demand for the imports of services from the BoP, $l_{ms_r_gap}$, is identical with the functional form introduced for the import of goods, $l_{mg_r_gap}$.¹⁵ Section 3.4.2 elaborates on the calibration of the import demand equation, including the assumption that each expenditure component Ω (where $\Omega = c, g, j, x$) has a constant share of oil and non-oil imports: $ss_{m\Omega}$ is the share of imported goods except oil in Ω , $ss_{m\Omega o}$ is the share of imported oil in Ω and $1 - ss_{m\Omega} - ss_{m\Omega o}$ is the domestic value-added share in Ω .

$$l_{mg_r_gap} = mg1 * l_{c_r_gap} + mg2 * l_{g_r_gap} + mg3 * l_{j_r_gap} + mg4 * l_{x_r_gap} - mg5 * l_{z_gap} + shk_{l_{mg_r_gap}}$$

$$l_{ms_r_gap} = ms1 * l_{c_r_gap} + ms2 * l_{g_r_gap} + ms3 * l_{j_r_gap} + ms4 * l_{x_r_gap} - ms5 * l_{z_gap} + shk_{l_{ms_r_gap}}$$

$$mg1 = ms1 = b_c * (ss_{mc} + ss_{mco})/b_m; mg2 = ms2 = b_g * (ss_{mg} + ss_{mgo})/b_m$$

$$mg3 = ms3 = b_j * (ss_{mj} + ss_{mjo})/b_m; mg4 = ms4 = b_x * (ss_{mx} + ss_{mxo})/b_m$$

Similar to exports, the total imports of goods and services from the national accounts, $l_{m_r_gap}$, are a weighted average of imports of goods, $l_{mg_r_gap}$, and imports of services, $l_{ms_r_gap}$, from the BoP, with corresponding normalized weights of b_{ms}/b_m and b_{mg}/b_m . This cross-restriction ensures consistency between national accounts and the BoP (see also Section 2.6 and 3.4.2). This equation also includes a shock to capture observed small discrepancies in history between the two data sources, i.e. national accounts and BoP.

$$b_m * l_{m_r_gap} = b_{mg} * l_{mg_r_gap} + b_{ms} * l_{ms_r_gap} + shk_{l_{m_r_gap}}$$

Equations on domestic demand $l_{dd_r_gap}$ and the output gap $l_{gdp_r_gap}$ are identities, capturing the log linearization of national account identities in terms of potential GDP. Coefficients b_c to b_m are steady-state nominal expenditure shares relative to nominal potential GDP.

$$l_{dd_r_gap} = (b_c * l_{c_r_gap} + b_g * l_{g_r_gap} + b_j * l_{j_r_gap}) / (b_c + b_g + b_j)$$

$$l_{gdp_r_gap} = b_c * l_{c_r_gap} + b_g * l_{g_r_gap} + b_j * l_{j_r_gap} + b_x * l_{x_r_gap} - b_m * l_{m_r_gap} + shk_{l_{gdp_r_gap}}$$

¹⁵ This implies that the overall m parameters are equal to the respective mg and ms parameters, as described in Section 3.4.2. When disaggregated data are available and equations can be calibrated based on those data, the two equations might be specified differently, both in terms of equation-specific variables and coefficients. For instance, the relative prices of goods and the relative prices of services might be different depending on where the imports of goods and of services are coming from. In such a case, the relative price gaps in the import demand of goods compared to services would be different.

2.3.2. External block

Beyond exports and imports discussed above, two balance of payments (BoP)¹⁶ items play a particularly important role in most emerging and developing economies: private transfers and foreign direct investments (FDI). Therefore, in the model they are specified via behavioral equations. Private transfers, $l_sec_inc_pt_r_gap$, contribute to the disposable income of households, reflecting the typically large diaspora of many small open economies with significant links to the home country. They are positively related to foreign demand, $l_gdp_rw_gap$, and negatively related to domestic demand, $l_dd_r_gap$. The second important BoP variable is real FDI, $l_fin_acc_fdi_r_gap$, which is a function of lagged FDI and the foreign economies' cyclical position captured by effective foreign demand, $l_gdp_rw_gap$.

$$l_sec_inc_pt_r_gap = r1 * l_sec_inc_pt_r_gap_{t-1} + r2 * l_gdp_rw_gap - r3 * l_dd_r_gap + shk_l_sec_inc_pt_r_gap$$

$$l_fin_acc_fdi_r_gap = f1 * l_fin_acc_fdi_r_gap_{t-1} + f2 * l_gdp_rw_gap + shk_l_fin_acc_fdi_r_gap$$

As noted previously, most other BoP items are modelled via autoregressive processes of ratios to nominal GDP converging to a constant steady-state value. Some items are modelled as identities within the BoP next. Total secondary income in the current account, $l_sec_inc_tot2gdp_gap$, is a weighted average of the secondary income of the government, $l_sec_inc_gg2gdp_gap$, private transfers, $l_sec_inc_pt2gdp_gap$, and social benefits, $l_sec_inc_social2gdp_gap$. In turn, the current account balance is a weighted average of exports and imports of goods and of services (l_xg2gdp_gap , l_xs2gdp_gap , l_mg2gdp_gap and l_ms2gdp_gap), primary income components (which includes primary income of employees, $l_prim_inc_emp2gdp_gap$, investment income of government, $l_prim_inc_inv_gg2gdp_gap$, and of other sectors, $l_prim_inc_inv_oth2gdp_gap$, and other primary income, $l_prim_inc_oth2gdp_gap$) and total secondary income, $l_sec_inc_tot2gdp_gap$. In all cases, weights (denoted with $b_$) are steady-state shares of respective nominal items to nominal GDP.

$$\begin{aligned} b_sec_inc_tot * l_sec_inc_tot2gdp_gap \\ &= b_sec_inc_gg * l_sec_inc_gg2gdp_gap + b_sec_inc_pt * l_sec_inc_pt2gdp_gap \\ &+ b_sec_inc_social * l_sec_inc_social2gdp_gap \end{aligned}$$

$$b_sec_inc_tot = b_sec_inc_gg + b_sec_inc_pt + b_sec_inc_social$$

$$\begin{aligned} b_curr_acc_bal * l_curr_acc_bal2gdp_gap \\ &= b_xg * l_xg2gdp_gap + b_xs * l_xs2gdp_gap - b_mg * l_mg2gdp_gap - b_ms \\ &* l_ms2gdp_gap + b_sec_inc_tot * l_sec_inc_tot2gdp_gap + b_prim_inc_emp \\ &* l_prim_inc_emp2gdp_gap + b_prim_inc_oth * l_prim_inc_oth2gdp_gap \\ &+ b_prim_inc_inv_gg * l_prim_inc_inv_gg2gdp_gap + b_prim_inc_inv_oth \\ &* l_prim_inc_inv_oth2gdp_gap \end{aligned}$$

$$\begin{aligned} b_curr_acc_bal = b_xg + b_xs - b_mg - b_ms + b_sec_inc_tot + b_prim_inc_emp + b_prim_inc_inv_gg \\ + b_prim_inc_inv_oth + b_prim_inc_oth \end{aligned}$$

¹⁶ Unless otherwise noted, BoP items are expressed in net terms. In the financial account, "+" denotes an inflow.

Further, total flows (without foreign reserves) in the financial account of the BoP, $fin_acc_inv2gdp_gap$, are a weighted average of FDI, $l_fin_acc_fdi2gdp_gap$, portfolio investments, $l_fin_acc_port2gdp_gap$, and other investments, i.e. those of deposit money banks, $l_fin_acc_oth_dep2gdp_gap$, government $l_fin_acc_oth_gg2gdp_gap$ and other sectors $l_fin_acc_oth_oth2gdp_gap$. Finally, the total change of foreign reserves, $l_fin_acc_reserves2gdp_gap$, reflects the dynamics in the rest of the BoP and is the weighted average of the current account, $l_curr_acc_bal2gdp_gap$, the capital account, $l_cap_acc_tot2gdp_gap$, the financial account, $l_fin_acc_inv2gdp_gap$, and the errors and omissions, $l_bop_errors2gdp_gap$.

$$\begin{aligned} b_fin_acc_inv * l_fin_acc_inv2gdp_gap \\ = b_fin_acc_fdi * l_fin_acc_fdi2gdp_gap + b_fin_acc_port * l_fin_acc_port2gdp_gap \\ + b_fin_acc_oth_dep * l_fin_acc_oth_dep2gdp_gap + b_fin_acc_oth_gg \\ * l_fin_acc_oth_gg2gdp_gap + b_fin_acc_oth_oth * l_fin_acc_oth_oth2gdp_gap \end{aligned}$$

$$\begin{aligned} b_fin_acc_inv = b_fin_acc_fdi + b_fin_acc_port + b_fin_acc_oth_dep + b_fin_acc_oth_gg \\ + b_fin_acc_oth_oth \end{aligned}$$

$$\begin{aligned} b_fin_acc_reserves * l_fin_acc_reserves2gdp_gap \\ = b_curr_acc_bal * l_curr_acc_bal2gdp_gap + b_fin_acc_inv * l_fin_acc_inv2gdp_gap \\ + b_cap_acc_tot * l_cap_acc_tot2gdp_gap + b_bop_errors * l_bop_errors2gdp_gap \end{aligned}$$

$$b_fin_acc_reserves = b_curr_acc_bal + b_cap_acc_tot + b_fin_acc_inv + b_bop_errors$$

2.3.3. Fiscal block

Fiscal accounts included in QMFF are detailed, and most of the fiscal variables are either based on identities or modelled via autoregressive processes of ratios to nominal GDP converging to a constant steady-state value. The only fiscal variables currently modelled via behavioral relationships are the compensation of employees, $l_comp_emp2gdp_gap$, spending on goods and services, l_gs2gdp_gap (both described above), and VAT revenues, $l_vat_r_gap$. Besides inertia typical for fiscal variables, VAT revenues, $l_vat_r_gap$, are also a function of lagged private consumption, $l_c_r_gap$.

$$l_vat_r_gap = v1 * l_vat_r_gap_{t-1} + v2 * l_c_r_gap_{t-1} + shk_l_vat_r_gap$$

The disaggregated modeling and representation of fiscal variables is of interest to fiscal policymakers, especially when setting particular budget items. Further, even though currently only three fiscal variables are defined in behavioral terms (compensation of employees and spending on goods and services as function of inertia and output gap, and VAT revenues as function of inertia and consumption gap), this set can easily be extended in the future, thus enabling a richer modeling of the fiscal sector. This is therefore a more comprehensive approach compared to most other models, where only overall fiscal categories are related to the output gap (e.g. total revenues, expenditures or the budget deficit).

The rest of the fiscal block is modelled as AR(1) processes or as cross-restriction identities. Indirect taxes, $l_indirect2gdp_gap$, are a weighted average of the value added tax, $l_vat2gdp_gap$, excises, $l_excise2gdp_gap$, customs, $l_cust2gdp_gap$, and other indirect taxes, $l_indirect_oth2gdp_gap$. Further, total revenues, $l_rev2gdp_gap$, are a weighted sum of direct taxes, $l_direct2gdp_gap$, indirect taxes,

$l_indirect2gdp_gap$, social contributions, $l_soc_con2gdp_gap$ and grants, $l_grant_rev2gdp_gap$. In all cases, weights are shares of respective nominal items to nominal GDP.

$$\begin{aligned} b_indirect * l_indirect2gdp_gap \\ = b_vat * l_vat2gdp_gap + b_excise * l_excise2gdp_gap + b_cust * l_cust2gdp_gap \\ + b_indirect_oth * l_indirect_oth2gdp_gap \end{aligned}$$

$$b_indirect = b_vat + b_excise + b_cust + b_indirect_oth$$

$$\begin{aligned} b_rev * l_rev2gdp_gap \\ = b_direct * l_direct2gdp_gap + b_indirect * l_indirect2gdp_gap + b_soc_con \\ * l_soc_con2gdp_gap + b_grant_rev * l_grant_rev2gdp_gap \end{aligned}$$

$$b_rev = b_direct + b_indirect + b_soc_con + b_grant_rev$$

As far as expenditures are concerned, total fiscal expenditures, $l_expend2gdp_gap$, are determined by the compensation of employees, $l_comp_emp2gdp_gap$, expenditures on the use of goods and services, l_gs2gdp_gap , social benefits, $l_soc_ben2gdp_gap$, interest payments, $l_inter2gdp_gap$, subsidies, $l_subs2gdp_gap$, grants and other expenses, $l_grant_exp2gdp_gap$, and net acquisition of capital, $l_acq_nfa2gdp_gap$. Further, primary expenditures, $l_pexpend2gdp_gap$, are the difference between total expenditures, $l_expend2gdp_gap$, and interest payments, $l_inter2gdp_gap$.

$$\begin{aligned} b_expend * l_expend2gdp_gap \\ = b_comp_emp * l_comp_emp2gdp_gap + b_gs * l_gs2gdp_gap + b_soc_ben \\ * l_soc_ben2gdp_gap + b_grant_exp * l_grant_exp2gdp_gap + b_inter * l_inter2gdp_gap \\ + b_subs * l_subs2gdp_gap + b_acq_nfa * l_acq_nfa2gdp_gap \end{aligned}$$

$$b_expend = b_comp_emp + b_gs + b_soc_ben + b_inter + b_subs + b_grant_exp + b_acq_nfa$$

$$b_pexpend * l_pexpend2gdp_gap = b_expend * l_expend2gdp_gap - b_inter * l_inter2gdp_gap$$

$$b_pexpend = b_expend - b_inter$$

The overall fiscal balance, $l_bal2gdp_gap$, is the difference between fiscal revenues, $l_rev2gdp_gap$, and expenditures, $l_expend2gdp_gap$. Similarly, the primary balance, $l_pbal2gdp_gap$, is the difference between fiscal revenues and primary expenditures, $l_pexpend2gdp_gap$.

$$b_bal * l_bal2gdp_gap = b_rev * l_rev2gdp_gap - b_expend * l_expend2gdp_gap$$

$$b_bal = b_rev - b_expend$$

$$b_pbal * l_pbal2gdp_gap = b_rev * l_rev2gdp_gap - b_pexpend * l_pexpend2gdp_gap;$$

$$b_pbal = b_rev - b_pexpend$$

To reflect the impact of the business cycle on fiscal revenues and expenditures, and capture the effect of the fiscal impulse in other behavioral relationships, total revenues, $l_{rev2gdp_gap}$, and primary expenditures, $l_{pexpend2gdp_gap}$, are adjusted for the effect of the business cycle, as captured by the output gap, $l_{gdp_r_gap}$. Elasticity parameters, rev_ca and $pexpend_ca$, for revenues and expenditures, respectively, are used in this adjustment. They are calibrated in a rather standard manner, ensuring that, in expansions, cyclically adjusted revenues are lower, and cyclically adjusted expenditures are higher than respective headline measures (with the opposite holding in recessions). The cyclically adjusted primary balance, $l_{pbal_ca2gdp_gap}$, is then the difference between cyclically adjusted revenues, $l_{rev_ca2gdp_gap}$, and primary expenditures, $l_{pexpend_ca2gdp_gap}$.

$$l_{rev_ca2gdp_gap} = l_{rev2gdp_gap} - rev_ca * l_{gdp_r_gap}$$

$$l_{pexpend_ca2gdp_gap} = l_{pexpend2gdp_gap} + pexpend_ca * l_{gdp_r_gap}$$

$$b_{pbal} * l_{pbal_ca2gdp_gap} = b_{rev} * l_{rev_ca2gdp_gap} - b_{pexpend} * l_{pexpend_ca2gdp_gap}$$

2.3.4. Monetary sector and loans

Almost all monetary sector items are modelled via autoregressive processes of ratios to nominal GDP converging to a constant steady-state value¹⁷. As an exception, to ensure consistency, some monetary sector variables are modelled either as cross-restricted identities within the monetary sector itself or in relation to BoP in the model (discussed next). Other monetary variables are linked to the fiscal sector (Section 2.6). Finally, several monetary variables that are very small are not defined via AR(1) equations and no steady-state values are defined for them. Instead, they are projected using assumptions of zero changes over the forecast horizon. Same as other variables in the framework, monetary sector variables are modeled as flows, i.e. changes in stocks (prefix $d_{}$), whereas the calculation of projected stocks (with the latter common in reporting), is done in the forecast reporting stage.

Changes in reserves of deposit money banks, $l_{d_dmb_reserves2gdp_gap}$, are set to be equal to the changes in central bank liabilities to deposit money banks, $l_{d_cb_lia_dmb2gdp_gap}$. Further, the change in net foreign assets of the deposit money banks accounts, $l_{d_dmb_nfa2gdp_gap}$, is set to be equal to other investments of the banking sector, $l_{fin_acc_oth_dep2gdp_gap}$. Finally, the change in net foreign assets of the monetary authorities, $l_{d_cb_for_ass2gdp_gap}$, is set to be equal to the change in net foreign assets in the BoP, $l_{fin_acc_reserves2gdp_gap}$. In all three cases, respective steady-state values are also restricted in a corresponding manner.

$$b_{d_dmb_reserves} * l_{d_dmb_reserves2gdp_gap} = b_{d_cb_lia_dmb} * l_{d_cb_lia_dmb2gdp_gap}$$

$$b_{d_dmb_reserves} = b_{d_cb_lia_dmb}$$

$$b_{d_dmb_nfa} * l_{d_dmb_nfa2gdp_gap} = -1 * b_{fin_acc_oth_dep} * l_{fin_acc_oth_dep2gdp_gap}$$

¹⁷ This is in line with the dominant approach in most modern models, where effects from the monetary sector to the rest of the economy are limited. However, AR(1) processes could be easily replaced with behavioral equations if needed.

$$b_d_dmb_nfa = b_fin_acc_oth_dep$$

$$b_d_cb_for_ass * l_d_cb_for_ass2gdp_gap = b_fin_acc_reserves * l_fin_acc_reserves2gdp_gap$$

$$b_d_cb_for_ass = b_fin_acc_reserves$$

Further, household and corporate loans are modelled separately. The demand for loans of nonfinancial corporations, $l_loans_nfc_priv_r_gap$, is a function of the lagged output gap, $l_gdp_r_gap$, lagged real interest rates on loans extended to non-financial corporations, $rr_lend_nfc_lc_gap$, and inertia. Naturally, an overheated economy generates additional demand for loans, while interest rates above the neutral level have the opposite effect.

$$\begin{aligned} l_loans_nfc_priv_r_gap &= k1 * l_loans_nfc_priv_r_gap_{t-1} + k2 * l_gdp_r_gap_{t-1} - k3 * rr_lend_nfc_lc_gap_{t-1} \\ &+ shk_l_loans_nfc_priv_r_gap \end{aligned}$$

The demand for loans of households, $l_loans_hh_r_gap$, is a function of its lagged value, the lagged real wage bill, $l_wb_r_gap$, and the lagged real interest rates on loans extended to households, $rr_lend_hh_lc_gap$. The real wage bill above its trend increases the households' ability to service their loans, thus raising the likelihood that banks will extend more loans in the face of high demand.¹⁸ Higher real interest rates make loans less attractive, consequently curbing their demand.

$$\begin{aligned} l_loans_hh_r_gap &= k4 * l_loans_hh_r_gap_{t-1} + k5 * l_wb_r_gap_{t-1} - k6 * rr_lend_hh_lc_gap_{t-1} \\ &+ shk_l_loans_hh_r_gap \end{aligned}$$

The economic cycle, approximated by the output gap, is negatively related to the gaps in the margins between the real policy rate and corresponding real interest rates on loans for non-financial corporations, $margin_rr_lend_nfc_lc_gap$, and for households, $margin_rr_lend_hh_lc_gap$, respectively. In periods of economic recessions, coinciding with negative output gaps, banks consider the deteriorating creditworthiness of agents, and on average they increase their margins.

$$\begin{aligned} margin_rr_lend_nfc_lc_gap &= n1 * margin_rr_lend_nfc_lc_gap_{t-1} - n2 * l_gdp_r_gap + shk_margin_rr_lend_nfc_lc_gap \end{aligned}$$

$$\begin{aligned} margin_rr_lend_hh_lc_gap &= n3 * margin_rr_lend_hh_lc_gap_{t-1} - n4 * l_gdp_r_gap + shk_margin_rr_lend_hh_lc_gap \end{aligned}$$

While loans are currently specified in a rather aggregate form, this block could be modified to capture a richer structure, depending on data availability and structural features of the country. For instance, for partly dollarized economies, where significant shares of loans (and deposits) are denominated in foreign currency, the

¹⁸ This feature is common in several countries in Central, Eastern and Southeastern Europe. Alternatively, the output gap could serve as a proxy for measuring the effect of the cycle on the demand for loans.

corresponding equations could be expanded and generalized. This would introduce an additional channel for exchange rate transmission, with depreciation also have a contractionary impact, in addition to the expansionary effect via expenditure switching captured elsewhere in the model.

2.3.5. Price block

In QMFF, inflation is measured via the change in the consumption deflator, dla_def_c . By expressing all deflators as weighted averages of the GDP deflator and imported prices of oil and non-oil imports (see below), it is much easier to model relative prices. Replacing the consumption deflator with CPI would also bring a methodological inconsistency, given that CPI is calculated as a Laspeyres index, while the national accounts deflators rely on time varying weights. Of course, the framework also includes CPI inflation¹⁹, modeled as a function of the consumption deflator inflation (both measured in terms of quarterly annualized changes) and a residual.

$$dla_cpi = dla_def_c + shk_dla_cpi$$

Related to this, the real exchange rate, l_z , is defined as a ratio of the nominal exchange rate to the euro, l_s , the non-oil imported prices expressed in euros, $l_p_rw_no_eur$, and the GDP deflator, l_def_gdp .

$$l_z = l_s + l_p_rw_no_eur - l_def_gdp$$

The Phillips curve equation for the fixed exchange rate regime, assuming adaptive expectations, indicates that inflation, dla_def_c , depends on lagged inflation and inflation expectations. In this case, expectations are approximated by imported inflation, adjusted to align with the steady-state domestic inflation rate $(1 - ss_mco) * dla_p_rw_no_lc + ss_mco * dla_p_rw_o_lc - (1 - ss_mc - ss_mco) * ss_dla_z_bar$,²⁰ with corresponding parameters fulfilling the homogeneity condition. Inflation further depends on demand pressures, approximated by the output gap, $l_gdp_r_gap$, and imported inflation, captured by the two relative price gaps, l_z_gap and l_zo_gap . The former captures the passthrough of foreign effective prices of consumption goods, while the latter captures the passthrough of world oil prices into domestic prices (see also [Annex B](#)).

$$\begin{aligned} dla_def_c = & a1 * dla_def_c_{t-1} + (1 - a1) * ((1 - ss_mco) * dla_p_rw_no_lc + ss_mco * dla_p_rw_o_lc - (1 \\ & - ss_mc - ss_mco) * ss_dla_z_bar) + a3 * (a4 * l_gdp_r_gap + (1 - a4) * ((1 - ss_mc \\ & - ss_mco) * l_z_gap + (1 - d4 - (1 - ss_mc - ss_mco) - ss_mc) * l_zo_gap)) \\ & + shk_dla_def_c \end{aligned}$$

The Phillips curve for the floating exchange rate regime is identical with the one specified for the fixed exchange rate regime above, with only one difference. Namely, for the floating regime the expected inflation is not modeled based on a contemporaneous variable, but it is specified as a model consistent expectation.

¹⁹ The framework can be easily adapted to model CPI subcomponents separately (e.g., core, food, and fuel), reflecting their heterogeneity in terms of driving forces, statistical properties, and importance for monetary policy reaction and transmission.

²⁰ See also Section 2.4.

$$dla_def_c = a1 * dla_def_c_{t-1} + (1 - a1) * dla_def_c_{t+1} + a3 * (a4 * l_gdp_r_gap + (1 - a4) * ((1 - ss_mc - ss_mco) * l_z_gap + (1 - d4 - (1 - ss_mc - ss_mco) - ss_mc) * l_zo_gap)) + shk_dla_def_c$$

The deflators of imports of goods, l_def_mg , and of services, l_def_ms , are weighted averages of the prices of imported goods excluding oil and prices of oil, both expressed in domestic currency ($l_p_rw_no_lc$ and $l_p_rw_o_lc$, respectively). The total import price deflator, l_def_m , is in turn a weighted average of the deflators of imports of goods and imports of services; effectively it is a function of prices of imported goods excluding oil and prices of oil (in local currency and in euros²¹).

$$l_def_mg = (1 - d4) * l_p_rw_no_lc + d4 * l_p_rw_o_lc + shk_dla_def_mg$$

$$l_def_ms = (1 - d4) * l_p_rw_no_lc + d4 * l_p_rw_o_lc + shk_dla_def_ms$$

$$l_def_m = (b_ms/b_m) * l_def_ms + (b_mg/b_m) * l_def_mg + shk_dla_def_m$$

The prices of imported non-oil goods, $l_p_rw_no_eur$, reflect the structure of the most important imported goods in the economy: imported consumption goods, food and metals. The respective prices, all expressed in euros, are captured by foreign effective CPI, l_cpi_rw , world food prices, l_wfood_eur and world metal prices l_wmet_eur . Further, energy prices are approximated by world oil prices, l_woil_eur . Both current and lagged values of all of these variables are included, as they often affect import prices with some lag. Finally, the local currency imported prices, $l_p_rw_no_lc$ and $l_p_rw_o_lc$ are a function of the respective euro prices and the exchange rate to the euro, l_s .

$$l_p_rw_no_eur = (d1 * (d11 * l_cpi_rw + (1 - d11) * l_cpi_rw_{t-1}) + d2 * (d21 * l_wfood_eur + (1 - d21) * l_wfood_eur_{t-1}) + d3 * (d31 * l_wmet_eur + (1 - d31) * l_wmet_eur_{t-1})) / (1 - d4)$$

$$l_p_rw_o_eur = d41 * l_woil_eur + (1 - d41) * l_woil_eur_{t-1}$$

$$l_p_rw_no_lc = l_p_rw_no_eur + l_s$$

$$l_p_rw_o_lc = l_p_rw_o_eur + l_s$$

National accounts deflators, denoted by $l_def_Ω$ (where $Ω = c, g, j, x$), are a weighted average of the GDP deflator, l_def_gdp , approximating costs of domestic inputs; $l_p_rw_no_lc$, approximating the prices of imported goods except oil, expressed in local currency and $l_p_rw_o_lc$, approximating imported energy prices, captured by the imported oil prices, also in local currency. As discussed earlier, $1 - ss_mΩ - ss_mΩo$ is the domestic value-added share in $Ω$, $ss_mΩ$ is the share of imported goods excluding oil and $ss_mΩo$ is the share of oil.²²

²¹ The framework is currently set up for a country where the euro is an anchor currency. Therefore, where necessary, all import prices are converted to euros (e.g. world commodity prices) and then to local currency; foreign effective inflation is already in euros.

²² As discussed in Section 2.3.1, in the current version of the model, the import intensity of exports and the export and import deflators are the same for both goods and services. Consequently, in the equations below, $ss_mxg = ss_mxs = ss_mx$ and $ss_mxgo = ss_mxso = ss_mxo$.

The respective equations for deflators are shown below. It should be noted that the equation with the private consumption deflator, l_def_c , on the left-hand side effectively defines the GDP deflator, l_def_gdp ; the shock is also named accordingly ($shk_dla_def_gdp$), whereas the shock to the private consumption deflator $shk_dla_def_c$ appears in the consumption deflator equation (i.e. the Phillips curve) discussed above. Finally, in line with the definition of total exports, the total export price deflator, l_def_x , is a weighted average of the deflators of exports of goods, l_def_xg , and exports of services, l_def_xs . For details on the calibration of parameters of all national accounts deflator equations see Section 3.4.3 and Section 3.4.4.

$$l_def_c = (1 - ss_mc - ss_mco) * l_def_gdp + ss_mc * l_p_rw_no_lc + ss_mco * l_p_rw_o_lc + shk_dla_def_gdp$$

$$l_def_g = (1 - ss_mg - ss_mgo) * l_def_gdp + ss_mg * l_p_rw_no_lc + ss_mgo * l_p_rw_o_lc + shk_dla_def_g$$

$$l_def_j = (1 - ss_mj - ss_mjo) * l_def_gdp + ss_mj * l_p_rw_no_lc + ss_mjo * l_p_rw_o_lc + shk_dla_def_j$$

$$l_def_x = (b_xg/b_x) * l_def_xg + (b_xs/b_x) * l_def_xs + shk_dla_def_x$$

$$l_def_xg = (1 - ss_mxg - ss_mxgo) * l_def_gdp + ss_mxg * l_p_rw_no_lc + ss_mxgo * l_p_rw_o_lc + shk_dla_def_xg$$

$$l_def_xs = (1 - ss_mxs - ss_mxso) * l_def_gdp + ss_mxs * l_p_rw_no_lc + ss_mxso * l_p_rw_o_lc + shk_dla_def_xs$$

2.3.6. Foreign variables

The framework has relatively few foreign variables (in this case representing the euro area): foreign effective demand gap, $l_gdp_rw_gap$, foreign effective inflation, dla_cpi_rw , the change in the USD/EUR exchange rate, dla_s_cross , the 3-month EURIBOR, rs_rw , and quarterly changes in world commodity prices in US dollars (oil prices dla_woil_usd , metal prices dla_wmet_usd and food prices dla_wfood_usd). Commodity prices and the change in the USD/EUR exchange rate are modelled as AR(1) processes (with the exchange rate important primarily for the domestic, euro-linked economy). The other foreign variables are modeled in a relatively simple manner, approximating a closed economy and primarily aiming to capture realistic transmission of the foreign shocks to the domestic economy. It should be noted that, for forecasting purposes, the assumptions for foreign variables over the medium term are in any case taken from exogenous sources. Foreign demand, $l_gdp_rw_gap$, is a function of its inertia and the foreign real interest rate, rr_rw_gap . Foreign inflation, dla_cpi_rw , is a function of backward and forward looking expectations (the latter approximated by the inflation target, $dla_cpi_rw_ss$) and foreign demand, $l_gdp_rw_gap$ ²³. The central bank follows an inflation targeting regime, so the foreign interest rate rs_rw is a function of inertia, the foreign neutral interest rate, the deviation of inflation one year ahead from its target and foreign demand.

$$l_gdp_rw_gap = rho_l_gdp_rw_gap * l_gdp_rw_gap\{-1\} - rw1 * rr_rw_gap + shk_l_gdp_rw_gap;$$

²³ A richer model could incorporate commodity prices as well as model-consistent inflation expectations.

$$dla_cpi_rw = rho_dla_cpi_rw * dla_cpi_rw\{-1\} + (1 - rho_dla_cpi_rw) * ss_dla_cpi_rw + rw2 * l_gdp_rw_gap + shk_dla_cpi_rw;$$

$$rs_rw = rho_rs_rw * rs_rw\{-1\} + (1 - rho_rs_rw) * (ss_rr_rw_bar + ss_dla_cpi_rw + rw3 * (d4l_cpi_rw\{4\} - ss_dla_cpi_rw) + rw4 * l_gdp_rw_gap) + shk_rs_rw;$$

2.4. Steady State

The core, behavioral part of the QMFF is relatively small. Therefore, there are only a few steady-state relationships that are important for keeping the model on a balanced growth path, and they are addressed below.

One of the key preconditions for enforcing the balanced growth path in the QMFF is to meet the restrictions imposed on the mutual links between the trends of real variables and relative prices included in the model (derived and explained in [Annex A](#)). Steady-state conditions that must be met in the relevant behavioral equations are also important. They are derived below, followed by a brief discussion on which equations are incorporating them.

Let us start with the definitions of variables required for the steady-state conditions. The real exchange rate, l_z , is defined as a function of the nominal exchange rate level, l_s , the imported price level excluding oil in euros, $l_{p_rw_no_eur}$, and the domestic GDP deflator, l_{def_gdp} :

$$l_z = l_s + l_{p_rw_no_eur} - l_{def_gdp}$$

After differentiating both sides and converting to steady-state constants, we get:

$$ss_dla_z_bar = ss_dla_s + ss_dla_p_rw_no_eur - ss_dla_def_gdp \rightarrow$$

$$ss_dla_def_gdp = ss_dla_s + ss_dla_p_rw_no_eur - ss_dla_z_bar$$

As explained in Section 2.1, the model includes behavioral equation for national accounts deflators that assume that all expenditure deflators can be expressed as a weighted average of the GDP deflator, l_{def_gdp} , non-oil import prices, $l_{p_rw_no_eur}$, and oil import prices, $l_{p_rw_o_eur}$, with all price levels expressed in domestic currency.²⁴ The respective weights are the domestic value-added share in consumption, $1 - ss_mc - ss_mco$, the share of imported goods in consumption excluding oil, ss_mc , and the share of imported oil in consumption, ss_mco . The consumption deflator equation (abstracting from the shock) is:

$$l_{def_c} = (1 - ss_mc - ss_mco) * l_{def_gdp} + ss_mc * (l_{p_rw_no_eur} + l_s) + ss_mco * (l_{p_rw_o_eur} + l_s)$$

²⁴ To facilitate the discussion, the euro prices and the nominal exchange rate will be shown separately in this section.

After differencing, we get the following equation for inflation in the steady state:²⁵

$$ss_dla_cpi = (1 - ss_mc - ss_mco) * ss_dla_def_gdp + ss_mc * (ss_dla_p_rw_no_eur + ss_dla_s) + ss_mco * (ss_dla_p_rw_o_eur + ss_dla_s)$$

By substituting $ss_dla_def_gdp = ss_dla_s + ss_dla_p_rw_no_eur - ss_dla_z_bar$ into the previous equation, we get:

$$\begin{aligned} ss_dla_cpi &= (1 - ss_mc - ss_mco) * (ss_dla_s + ss_dla_p_rw_no_eur - ss_dla_z_bar) + ss_mc \\ &\quad * (ss_dla_p_rw_no_eur + ss_dla_s) + ss_mco * (ss_dla_p_rw_o_eur + ss_dla_s) = \\ &= (1 - ss_mco) * (ss_dla_p_rw_no_eur + ss_dla_s) + ss_mco * (ss_dla_p_rw_o_eur + ss_dla_s) - (1 - ss_mc \\ &\quad - ss_mco) * ss_dla_z_bar \end{aligned}$$

Let us express $ss_dla_def_gdp$:

$$ss_dla_def_gdp = (1/(1 - ss_mc - ss_mco)) * (ss_dla_cpi - ss_mc * ss_dla_p_rw_no_eur - ss_mco * ss_dla_p_rw_o_eur - (ss_mc + ss_mco) * ss_dla_s)$$

After substituting $ss_dla_def_gdp$ into $ss_dla_z_bar$ from above we get:

$$\begin{aligned} ss_dla_z_bar &= (1 + (ss_mc + ss_mco)/(1 - ss_mc - ss_mco)) * ss_dla_s + ss_dla_p_rw_no_eur - (1/(1 \\ &\quad - ss_mc - ss_mco)) * (ss_dla_cpi - ss_mc * ss_dla_p_rw_no_eur - ss_mco \\ &\quad * ss_dla_p_rw_o_eur - (ss_mc + ss_mco) * ss_dla_s) = \\ &= (1/(1 - ss_mc - ss_mco)) * (ss_dla_s + (1 - ss_mc - ss_mco) * ss_dla_p_rw_no_eur - ss_dla_cpi \\ &\quad + ss_mc * ss_dla_p_rw_no_eur + ss_mco * ss_dla_p_rw_o_eur) \end{aligned}$$

Let us express ss_dla_s :

$$ss_dla_s = (1 - ss_mc - ss_mco) * (ss_dla_z_bar - dla_p_rw_no) + ss_dla_cpi - ss_mc * ss_dla_p_rw_no_eur - ss_mco * ss_dla_p_rw_o_eur$$

After deriving these basic steady-state identities, let us discuss how some steady-state parameters depend on the exchange rate regime. It is important to note that, regardless of the exchange rate regime, the slope of the real exchange rate trend, $ss_dla_z_bar$, is determined by the real economy; the central bank has no control over it. Consequently, the slope of the real exchange rate should be calibrated in line with the observed trend in history, or the expected value in the long run.

In a fixed exchange rate regime, the steady-state price growth is given by the following equation:

$$ss_dla_cpi = (1 - ss_mc - ss_mco) * (ss_dla_s + ss_dla_p_rw_no_eur - ss_dla_z_bar) + ss_mc * (ss_dla_p_rw_no_eur + ss_dla_s) + ss_mco * (ss_dla_p_rw_o_eur + ss_dla_s)$$

²⁵ Remember that CPI inflation is a function of the consumption deflator inflation – the two will be equal in the steady state.

From this equation it follows that when the central bank keeps the nominal exchange rate constant ($ss_dla_s = 0$), it has no control over the steady-state inflation rate. Parameters $ss_dla_p_rw_no_eur$, $ss_dla_p_rw_o_eur$, $ss_dla_z_bar$ and the constant shares of import prices (ss_mc and ss_mco) entering into the consumption deflator equation will determine the steady-state inflation rate. In the case of a crawling peg ($ss_dla_s \neq 0$), the central bank can influence the steady-state inflation rate by setting the slope of the crawl. On the other hand, in an inflation targeting regime, the domestic authorities choose the domestic inflation target. Therefore, the trend nominal exchange rate will be a function of the inflation target, the steady-state foreign inflation rate and the slope of the trend of the real exchange rate change.

There is one implication of this steady-state equation for the Phillips curve in a fixed exchange rate regime with adaptive expectations. Remember that the New Keynesian version of the Phillips curve would include model consistent inflation expectations, $dla_def_c_{t+1}$, like in the equation below:

$$dla_def_c = a1 * dla_def_c_{t-1} + (1 - a1) * dla_def_c_{t+1} + a3 * (a4 * l_gdp_r_gap + (1 - a4) * ((1 - ss_mc - ss_mco) * l_z_gap + (1 - d4 - (1 - ss_mc - ss_mco) - ss_mc) * l_zo_gap)) + shk_dla_def_c$$

In this specification, the model consistent inflation expectations will be consistent with the steady-state inflation rate in the long run. If adaptive inflation expectations are imposed instead, it must be ensured that they are consistent with the model's steady state. In this case, it is assumed that inflation expectations are linked to import prices, which is a plausible assumption for many small open economies operating in a fixed exchange rate regime. Specifically, inflation expectations are linked to the weighted average of non-oil and oil imported prices: $(1 - ss_mco) * dla_p_rw_no_lc + ss_mco * dla_p_rw_o_lc$. Note that this specification was altered with a steady-state adjustment constant $-(1 - ss_mc - ss_mco) * ss_dla_z_bar$, which is derived from ss_dla_cpi above. Without this constant, the Phillips curve would not fulfill the homogeneity condition for any calibration of the model, as $(1 - ss_mco) * dla_p_rw_no_lc + ss_mco * dla_p_rw_o_lc$ would not be in line with the steady-state inflation rate (the only exception would be when the trend change of the real exchange rate $ss_dla_z_bar$ would be equal to zero).

The next equation that can cause a problem with the model's steady state when inappropriately parameterized is the UIP equation:

$$l_s = s1 * l_s_{t+1} + (1 - s1) * (l_s_{t-1} + 2 * ss_dla_s/4) + (-rs + rs_rw + uip_prem)/4 + shk_dla_s$$

By introducing inertia into the UIP, specifically by adding the lagged exchange rate instead of having solely the expected exchange rate, it is necessary to also adjust for a possible trend growth in the nominal exchange rate. This is done in the UIP equation above with the introduction of $2 * ss_dla_s/4$. Note that the steady-state change of the nominal exchange rate ss_dla_s is a function of other model parameters, and its value is derived above. Again, any deviation of ss_dla_s from the model consistent derivation will result in a wrong steady state.

Another important steady-state value is "hidden" within uip_prem - namely the steady-state premium ss_prem . It is specified as follows:

$$ss_prem = ss_rr_bar - ss_rr_rw_bar - ss_dla_z_bar + ss_dla_cpi - ss_dla_def_gdp + ss_dla_p_rw_no_eur - ss_dla_cpi_rw$$

These values are derived by transforming the nominal UIP into a real version of the UIP. The initial step is the following steady-state UIP equation:

$$0 = ss_dla_s - ss_rs + ss_rs_rw + ss_uip_prem \rightarrow ss_uip_prem = ss_rs - ss_rs_rw - ss_dla_s$$

Using the following steady-state relationships

$$ss_dla_s = ss_dla_z_bar - ss_dla_p_rw_no_eur + ss_dla_def_gdp^{26}$$

$$ss_rs = ss_rr_bar + ss_dla_cpi$$

$$ss_rs_rw = ss_rr_rw_bar + ss_dla_cpi_rw$$

and substituting them into the equation above

$$ss_uip_prem = ss_rr_bar + ss_dla_cpi - (ss_rr_rw_bar + ss_dla_cpi_rw) - (ss_dla_z_bar - ss_dla_p_rw_no_eur + ss_dla_def_gdp)$$

results in the following steady-state restriction:

$$ss_rr_bar - ss_rr_rw_bar - ss_dla_z_bar + ss_dla_cpi - ss_dla_def_gdp + ss_dla_p_rw_no_eur - ss_dla_cpi_rw$$

2.5. Calibration Strategy

The calibration of the model is an iterative process. It starts with a prototype model, which at the beginning does not necessarily reflect all country-specific features of the transmission mechanism. However, it should already realistically specify the existing exchange rate regime and key monetary transmission channels.

The first-round calibration of the model equation parameters can rely on values that fall within a range of plausible estimates found in the literature. Specifically, initial calibration hints can be found in papers describing calibrated QPM-type models developed for various economies, most notably [Berg et al. \(2006a and 2006b\)](#) and [Coats et al. \(2003\)](#). They propose plausible intervals for the parameterization of the key QPM equations, reflecting the strength of transmission channels, rigidity or real inertia. These calibration values, jointly with the included calibration hints, are useful to obtain a model that has a mathematical solution (regardless of whether it is an adaptive expectation or a forward-looking model). Having such a model, however, is not the end of the calibration process, but rather its starting point.

The main goal of the calibration process is to iteratively develop a model parameterization that results in plausible overall dynamic properties of the model, incorporating country specific features, as well as good

²⁶ This follows from $ss_dla_z_bar = ss_dla_s + ss_dla_p_rw_no_eur - ss_dla_def_gdp$ derived above.

okhistorical decomposition and in-sample forecasting performance²⁷. The emphasis, therefore, is not on obtaining good econometric estimates of individual model equations, but on understanding how overall model properties can be changed by finding a combination of parameter values that jointly result in the desired model properties. These specific examples, together with the discussion on monetary policy and exchange rates in Section 2.1 might be useful in the process of calibrating the model to country specifics.

2.5.1. Calibrating Nominal and Real Rigidities to Obtain Smooth Impulse Responses

Impulse responses (discussed in detail in Section 4.1) can produce oscillatory results in dynamic macroeconomic models. This is often due to specific features in the model structure and the nature of the economic relationships it captures. The initial calibration of the model frequently results in oscillatory impulse responses. Some of the common reasons for this include:

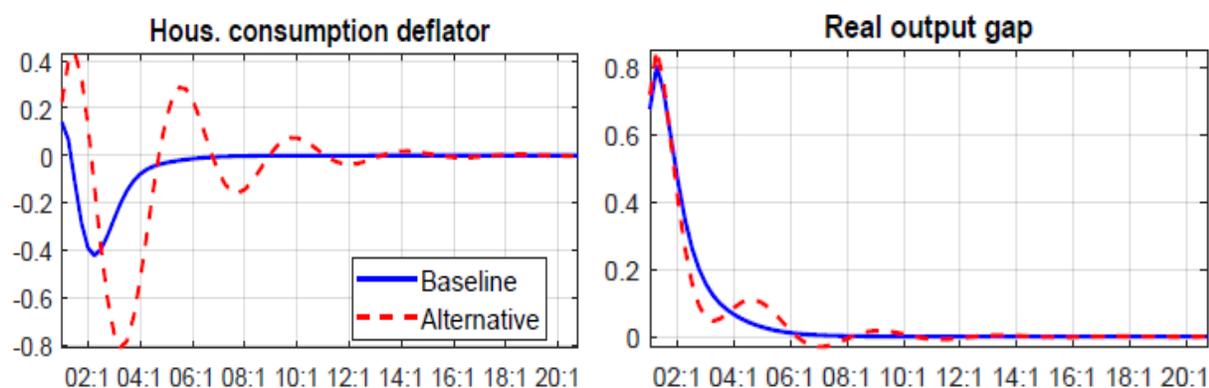
- Lagged adjustment processes when economic variables adjust with a delay in response to shocks.
- Feedback loops within the economy. For example, in models with price adjustment mechanisms (such as the Phillips curve), inflation and output can exhibit oscillatory responses to shocks due to the interaction between price setting and output decisions.
- Monetary and fiscal policy rules that react to economic conditions. If policymakers adjust interest rates in response to deviations in inflation and output (as in a Taylor rule), the resulting policy-induced changes in economic conditions can lead to oscillatory responses. The feedback between policy actions and economic outcomes can create cyclical patterns.

It is advisable to calibrate the model so that these oscillations in impulse response analyses are absent or are short lived.²⁸ The following example compares two calibrations for a floating exchange rate regime version of the model and shows how high degrees of inertia in the Phillips curve and the interest rate rule can result in oscillatory impulse responses. Compared to the calibration of the baseline model, three model parameters were changed in the alternative model specification. The coefficient on lagged inflation in the Phillips curve, a_1 , was increased from 0.4 in the baseline to 0.8 in the alternative. Similarly, a higher inertia in the nominal exchange rate was introduced by decreasing the coefficient on expected nominal exchange rate in the UIP equation, s_1 , from 0.5 to 0.2. Finally, the coefficient on the deviation of expected inflation from target in the monetary policy rule, t_2 , was cut from 0.5 to 0.2, causing a more gradual return of inflation towards target. All these parameter changes were chosen to increase the nominal rigidities in the model; the resulting effects on the impulse responses to a 1 % shock to foreign demand are captured in Figure 2. Both the private consumption deflator and the output gap return smoothly to the steady state in the baseline and strongly oscillate in the alternative calibration, almost doubling the time necessary for the variables to return to the steady state. Such responses would indicate a need for recalibration to achieve smoother and faster returns to the steady state.

²⁷ Discussed in Section 3 for the case of BiH.

²⁸ Avoiding short-term oscillations of impulse responses can sometimes be challenging in adaptive expectation models, as they often include high degree of real and nominal rigidities, one of the sources of oscillations.

Figure 2: Examples of Oscillatory Impulse Responses

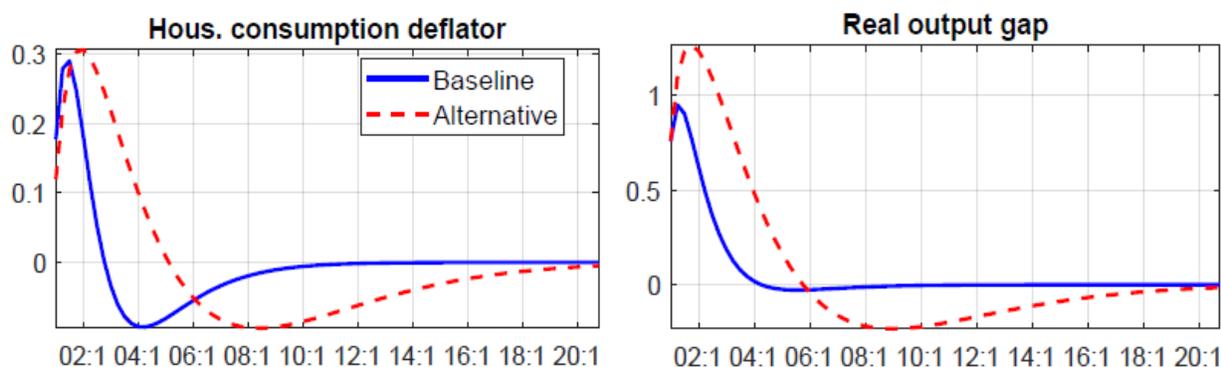


2.5.2. Adjusting Calibration to Ensure a Plausible Speed of Convergence

Some initial model calibrations might result in a slow convergence of the model to its steady state. The slow convergence can be caused either by theoretically not sound model specifications²⁹ or a combination of parameter values resulting in too much inertia. In addition, models with adaptive expectations often converge more slowly, as they lack model consistent expectations that reflect the stabilizing effects of economic policies aimed at closing real gaps in the model.

Figure 3 captures the impulse responses of the output gap and the consumption deflator to a foreign demand shock in the model version with a fixed exchange rate regime. In the alternative scenario, inflation inertia in the Phillips curve α_1 was increased from 0.4 to 0.8; the share of the relative price gap $1 - \alpha_3$ in the real marginal cost was lowered from 0.5 to 0.2; and investment gap inertia j_1 was increased from 0.45 to 0.8. All these changes result in a slower convergence of the model to the steady state after a foreign demand shock, to horizons that seem to be unrealistically long, indicating a need for recalibration.

Figure 3: Examples of Slow Convergence to the Steady State



²⁹ For instance, having a Phillips curve specification with a small weight on the relative price gap (which weakens the convergence in relative prices) and including imported inflation instead.

2.5.3. Imposing Economically Justified Priors

One of the main goals of effective model calibration is to achieve economically and empirically plausible dynamic model properties. The two cases discussed above – reasonable speed of convergence to the steady state and no oscillatory dynamics – are examples of such priors³⁰, although these are more “technical” than economic requirements. An example of an economically intuitive prior that is helpful in a wide range of models is related to the magnitude by which inflation reacts to a shock to aggregate demand. Let us consider the reaction of inflation to a 1% foreign demand shock in an open economy with a fixed exchange rate regime.

There are several factors that need to be considered when thinking about the quantitative effect of a shock. These include the degree of openness, the flexibility of the economy and characteristics of the monetary policy framework. Specifically, less open economies may experience a more pronounced inflation response to a demand shock due to a greater reliance on domestic production and pricing. The central bank’s reaction to shocks and its credibility also play an important role. If the central bank actively targets inflation, it might counteract demand shocks with appropriate monetary policy measures, thereby dampening the inflation response.

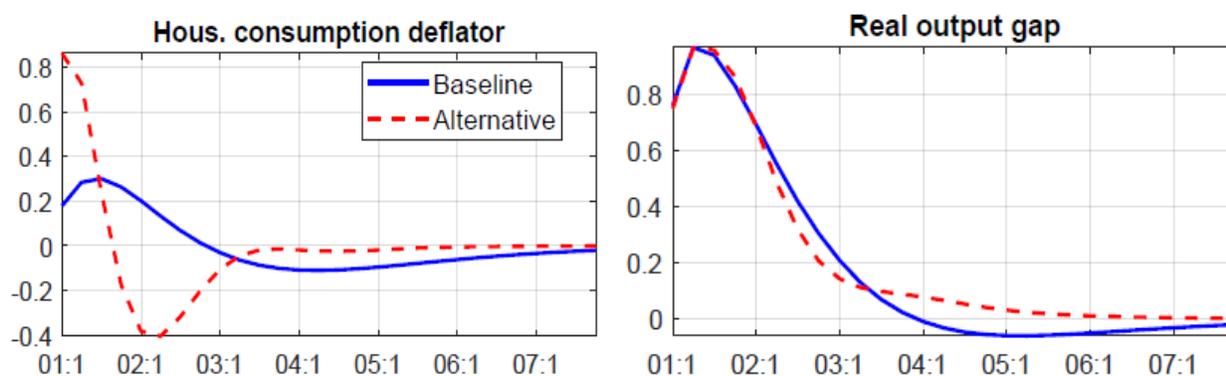
Calibrating models with adaptive expectations is a challenge, and it is almost inevitable that the model’s overall properties will be worse compared to a model featuring forward-looking expectations (in terms of oscillatory movements and the time to return to the steady state). The main reason is that intuitive impulse responses in a floating exchange rate regime cannot be achieved without including the uncovered interest rate parity condition to determine the nominal exchange rate, which is, by definition, a forward-looking concept. But even in a fixed exchange rate regime, the use of a Phillips curve that fulfills the homogeneity condition will imply different impulse responses depending on whether expected inflation is modeled using rational, forward-looking or adaptive expectations.

Figure 4 captures the impulse response to a 1% foreign demand shock, which in turn feeds into an increase of the domestic output gap, resulting in a response of the real output gap and the private consumption deflator of around 1%. The baseline simulation is consistent with the baseline calibration of the fixed exchange rate version of the model with adaptive expectations (see also Section 2.1 and Section 2.4); the alternative scenario replaces adaptive expectations with model consistent forward-looking expectations. Not surprisingly, the difference between the two specifications is large for the response of inflation to the shock. The main reason is the expectation formation applied in the Phillips curve. With adaptive expectations, the initial jump in inflation is driven mainly by the positive output gap. With forward-looking expectations, beyond the output gap effect, current inflation increases also due to high expected inflation. As a result, initial inflation jumps significantly more in the alternative scenario. The reaction of the output gap to the foreign demand shock is similar in both cases, with some differences reflecting the price competitiveness channel, i.e. different responses of the real exchange rate due to inflation.

These simulation results clearly demonstrate that switching to forward-looking expectations would require a revision of the model calibration. This is obvious not only in terms of the very different magnitude of the initial reaction of inflation to the shock, but also in terms of the inflation dynamics and the horizon over which inflation falls after the shock.

³⁰ “Prior” in this context is therefore an expert judgment and it is not related to formal Bayesian estimation.

Figure 4: Impulse Responses with Adaptive and Forward-Looking Expectations

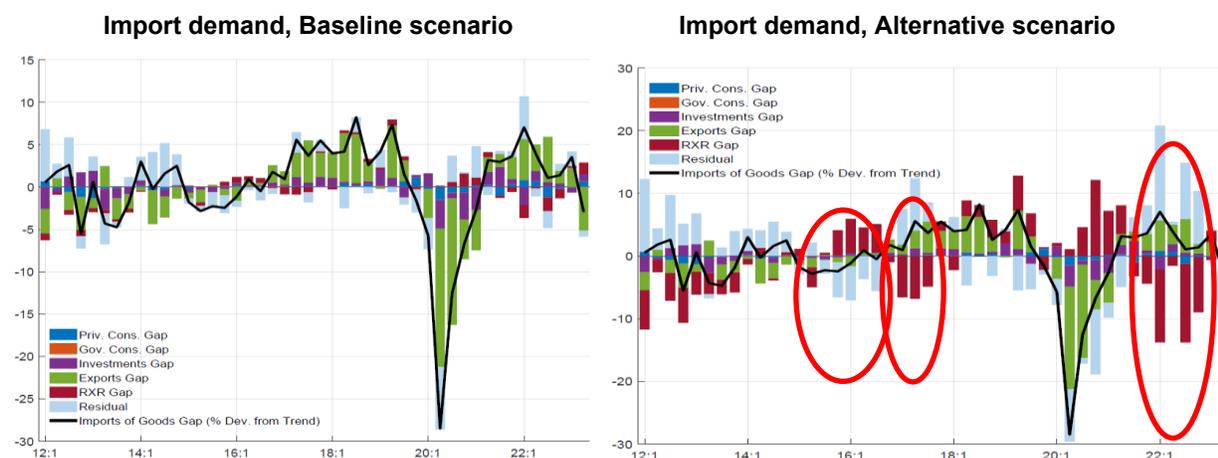


2.5.4. Using Historical Decompositions to Identify Calibration Issues

One important step in model verification is reviewing decomposition graphs, which depict the contribution of the main determinants of model variables to their observed values over time (see Section 4.2 for details and illustration in the case of BiH). The reports produced in the framework contain many such graphs, which are useful for assessing the most important drivers of the economic cycle and price pressures.

The real exchange rate elasticity ($mg5 = ms5 = m5$) in the baseline scenario is set to 0.3; in the alternative scenario it is changed to 2.3 to reflect a much higher sensitivity of import demand to the real exchange rate. The result of this recalibration of the import demand equation can be seen in the decomposition in the right panel of Figure 5. Whenever the real exchange rate is different from zero, the positive contribution of the real exchange rate to imports in the alternative scenario is mitigated by larger shocks in the opposite direction. To put it differently, since the real exchange rate in fact does not have a strong effect on imports, a shock in the opposite direction eliminates most of this effect (“Residual” in the legend). It is a clear signal that the real exchange rate parameter should be smaller.

Figure 5: Historical Decompositions with Different Calibrations of the Import Equation

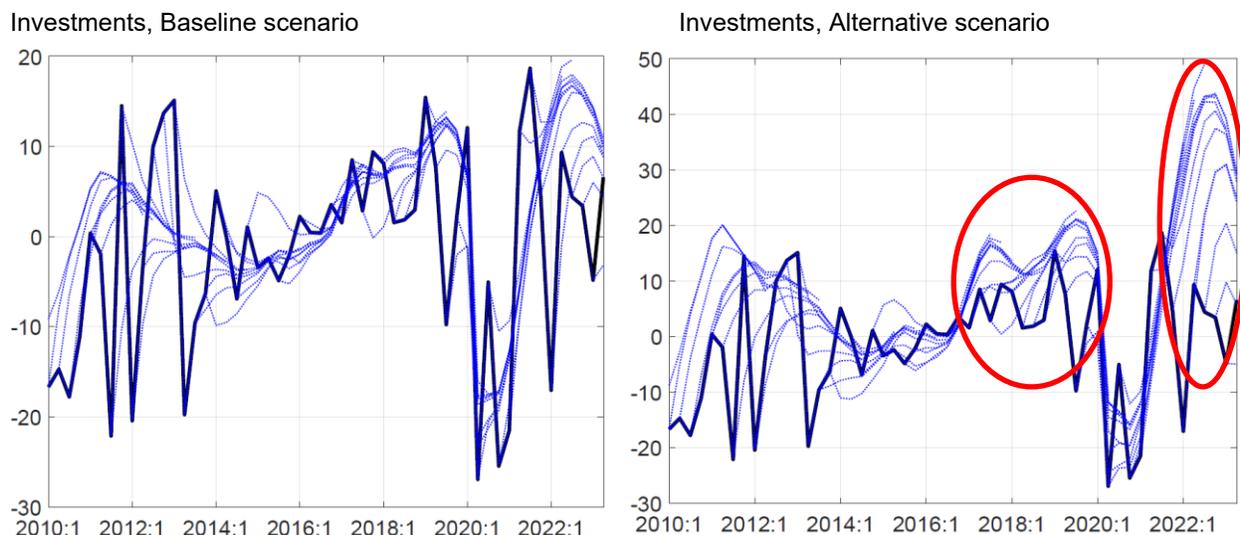


2.5.5. Examining In-sample Simulations to Detect Wrong Calibration

Analyzing in-sample model simulations (Section 4.3 for details and illustration in the case of BiH) and iteratively adjusting the model calibration based on the dynamic properties of the model embedded in these simulations is also an important part of the calibration process. This is not a straightforward exercise, as these dynamic simulations depend on many factors: the selected expectation formation used in simulations (anticipated, not anticipated); the parameterization of the model; the assumed knowledge of foreign variables, etc. Most importantly, as the model is simultaneous, any parameter or a combination of parameters can be the reason behind poor in-sample simulation results. A good knowledge of the model equations, the model's dynamic properties and mutual links between equations is necessary for using this tool successfully in order to improve model calibration.

Figure 6 captures the in-sample simulation results for gross investments, based on the knowledge of the model's exogenous variables. These exogenous variables are imposed in model simulations via unanticipated shocks. In the alternative calibration, the effect of the real interest rate in the investment equation j_3 has been strengthened to 1 (from 0.3 in the baseline). As a result, in-sample simulations significantly overestimate investments most of the time, reflecting an implausibly strong interest rate channel.

Figure 6: In-sample Responses with Different Calibrations of the Investment Equation



2.6. Ensuring Accounting Consistency Across Sectors

The model comprises a simultaneous system of calibrated equations covering all FPP sectors, as well as key accounting restrictions within and across these sectors. Like a standard FPP framework, ensuring accounting consistency across sectors is an essential feature of the QMFF. However, when imposing cross-restrictions in the QMFF setup we need to ensure consistency in terms of gaps and trends, both in real as well as nominal terms. The underlying derivations that ensure this consistency can be found in [Annex A](#). In some cases, introducing the accounting links directly in the model is not necessary or practical. In those cases, the accounting cross-restrictions are imposed at the reporting stage instead. Finally, as discussed below, the incorporation of cross restrictions is often complicated by data issues, i.e. quarterly data availability, quality, granularity or data consistency. In the latter case, the data inconsistency can be quantified and modelled or, alternatively, problematic cross restrictions can be addressed separately based on expert judgement.

Figure 7: Interrelations Among Macroeconomic Accounts

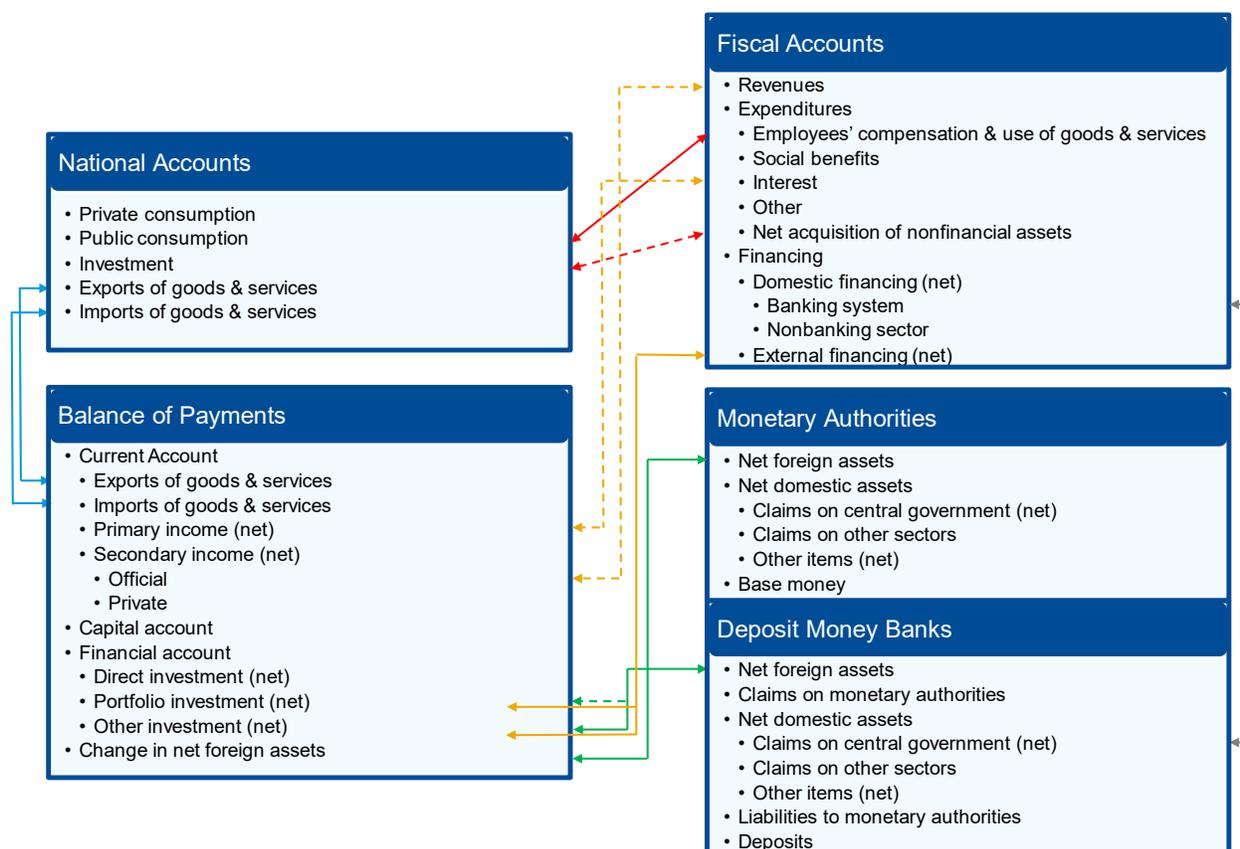


Figure 7 above provides an overview of the key relationships across the real, fiscal, external and monetary accounts captured in the framework.³¹ This includes:

- Consistency between national accounts and the balance of payments.
 - Calibrated behavioral gap equations for exports/imports of goods and exports/imports of services in the BoP enable linking the foreign trade dynamics with external and domestic economic developments. Since net exports directly affect total GDP, which in turn affects other macroeconomic indicators, it is essential to have this cross-sectoral link within the model (as discussed in Section 2.1) to ensure accounting consistency.
- Consistency between national accounts and fiscal accounts.
 - Discrepancies between national accounts and government finance statistics are likely to occur, primarily because of differences in accrual vs. cash accounting methodologies, but also because of country-specific challenges in fiscal data compilation. It is important to consider these discrepancies when establishing accounting consistency between the two sectors, and consequently to address the following links when setting up the framework.

³¹ In Figure 7, dashed arrows indicate that these accounting links are not currently integrated into the model but could be added depending on the country specifics and data availability.

- While not an identity, government consumption in national accounts should be closely related to expenditures on compensation of employees and goods and services in the fiscal accounts. To accommodate the likely discrepancy in the data between the two categories, we take a general approach when introducing this cross-sectoral link and model the discrepancy separately as a mean reverting process. As discussed in Section 2.1, this link is introduced directly into the model.
- Public investment in the national accounts should be consistent with public capital expenditures, i.e. the net acquisition of non-financial assets in the fiscal accounts. Discrepancies are likely to occur in this case too, partially driven by the level of fiscal accounts being used. In the current setup, investment in national accounts does not differentiate between public and private investment. In addition, in line with the common practice in most countries, fiscal data in this case relates only to central government, whereas national accounts data reflect the wider category of the public sector. Consequently, the gross capital formation in the model is linked to capital expenditures from fiscal accounts as one of the explanatory variables in order to broadly capture the relationship between fiscal policy and total investments (see Section 2.1). Depending on data availability and the level of desired granularity, private and public investments in the national accounts can be separated and the latter can be linked to fiscal accounts in a manner similar to the case of government consumption described above, i.e. additionally modeling a discrepancy term as needed.
- Consistency between the balance of payments and monetary accounts.
 - Banking sector external borrowing, partially reflected in the portfolio and other investment categories of the financial account in the BoP, should be consistent with the change in net foreign assets in the deposit money banks accounts of the monetary sector. In the current setup of the model, we only link the other investment from BoP to monetary accounts, which is done within the model (Section 2.1). However, depending on the availability of more granular data and the importance of portfolio flows for the banking sector, this link could be added.
 - Although discrepancies are possible, particularly driven by changes in the valuation of the stocks of reserves, the change in net foreign assets in the BoP should be consistent with the change in net foreign assets of the monetary authorities in the monetary statistics. This is ensured as a cross-restriction in the model (Section 2.1).
- Consistency between the balance of payments and fiscal accounts.
 - Conceptually, fiscal deficits can be financed either from external or domestic sources and this should be imposed in the framework. The former link is discussed here, while the latter is described below. Public sector net external borrowing, partially reflected in the portfolio investment and other investment categories of the financial account in the BoP, should be consistent with the net external financing in the fiscal accounts. However, historical data are not always available at the required granularity to establish this link. Discrepancies usually arise because of availability of data on the official sector borrowing in the BoP, differences in the coverage of the official sector between the BoP and fiscal accounts, or exchange rate fluctuations (averages used in the BoP vs. exact date exchange rates used in the fiscal accounts). To ensure this consistency while also accounting for the discrepancies, this link is established outside of the model in the reporting stage and only for the forecasting horizon (see Section 3 for the BiH case).
 - Additional accounting linkages which are not currently embedded in the framework because of data availability issues (dashed orange lines in Figure 7 above) include: a) linking official transfers

received in the secondary income of the BoP with grant revenues in the fiscal accounts; (b) linking interest payments on foreign debt recorded under primary income in the BoP with interest payments on foreign debt in the fiscal accounts.

- Consistency between fiscal and monetary accounts.
 - As discussed above, fiscal deficits can be financed either from external or domestic sources. Generally, the latter can be divided into two parts: bank (central bank and deposit money banks) and non-bank financing. In a heavily bank-dominated financial sector, domestic financing from the banking system in the fiscal accounts should play an important role and correspond to the change in net claims on central government in the monetary survey. Country specifics and data issues can be quite important in this case, so the framework needs to be adjusted accordingly (see Section 3 for the BiH case).

3. QMFF in Action: The Case of Bosnia and Herzegovina

Section 2 provided a detailed overview of the general model, its key equations, the model's steady state as well as the interlinkages between sectors ensuring the macro-consistency of the framework. This section illustrates the empirical work that has been done to apply the model to Bosnia and Herzegovina. Specifically, it covers data issues, bringing the model close to data via iterative calibration steps, as well as incorporating country-specific features into the model. In this section, we first describe the stylized facts of the economy of Bosnia and Herzegovina, motivating some of the modeling and implementation choices discussed later. We then describe the data used when applying the QMFF to BiH, including country-specific data issues, before proceeding to the calibration of import demand and deflator equations. They are important in terms of understanding the motivation behind certain parameter values of these equations, and they are also useful for revealing how these specifications capture macro-accounting consistency. We also provide some practical suggestions regarding the calibration strategy, which could be applied to a wide range of countries when bringing the model to data.

Before moving to details of these issues, it should be noted that for BiH we use the version of the model with adaptive expectations in the Phillips curve. Since BiH is a country with a currency board and a high capital mobility, the (implicit) monetary policy rate is equal to the euro area interest rate adjusted for an exogenous fixed country risk premium. The calibration is also accordingly adjusted, with $ss_dla_s = 0$ and $p1 = p2 = 0$ (see Section 2 for a detailed discussion of these modeling choices and Annex C for the full list of parameters of the QMFF for BiH). Further, trend levels in history are calculated using the Hodrick-Prescott filter³². Over the forecast horizon, trends evolve in line with the discussion in Section 2 and Annex A. Finally, steady-state ratios to nominal GDP are set equal to the average for the 2021-22 period.

3.1. Stylized Facts

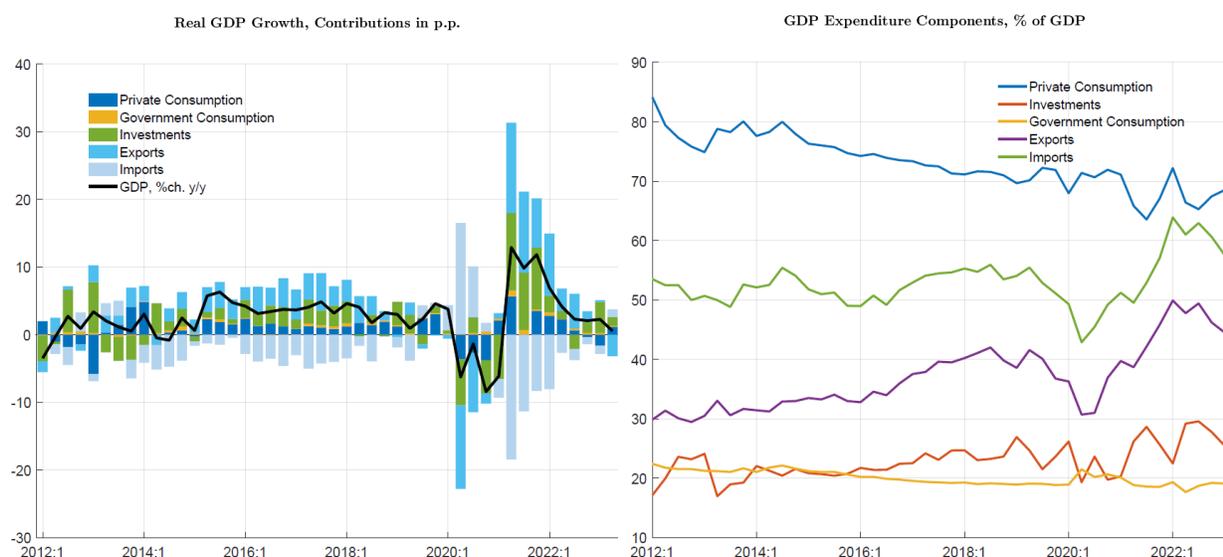
Bosnia and Herzegovina is an upper - middle income economy (Figure 8)³³ with a population of 3.53 million, according to the 2013 Census.³⁴ The country obtained EU candidacy status in December 2022. It has a complex political and institutional structure rooted in the Dayton Peace Agreement of 1995, which ended a nearly four-year war following the breakup of Yugoslavia. The agreement established a decentralized system. According to the BiH Constitution, the government structure consists of multiple layers: the state level; three geo-political sub-state levels, namely the Federation of Bosnia and Herzegovina (FBiH), Republic of Srpska (RS) and Brčko district; and 10 cantons within FBiH.

³² The QMFF framework is set up so that it is straightforward to implement a multivariate Kalman filter. Consequently, the univariate filtration can be replaced with Kalman filtration in the future..

³³ According to the World Bank Group's 2023 country income level classification.

³⁴ The official mid-year statistical estimate for 2023 is lower at 3.42 million.

Figure 8: The BiH Economy: Dynamics and Structure



The country's currency is the convertible mark (BAM), operating under a currency board arrangement with the exchange rate pegged to the euro at BAM 1 per EUR 0.51129. The Central Bank of Bosnia and Herzegovina (CBBH) has the exclusive mandate for monetary and exchange rate policy within the single economic space but does not have a mandate for price stability. The banking supervision is at the sub-state level, with mandates of the banking agencies bordered by the lines of the sub-state geo-political units FBiH and RS. The CBBH has a coordinating role in the banking supervision, which ensures that the same supervisory principles and banking sector legal frameworks are harmonized within the single economic space.

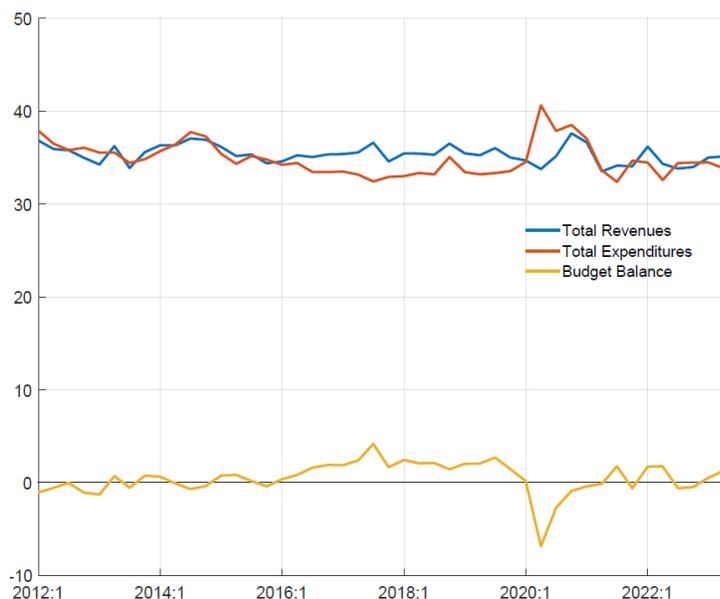
Banks dominate the financial sector, with 87.6% of assets of all financial intermediaries, and total assets at the level of 71% of GDP in 2023. Foreign owned banks (mostly from the EU), account for the largest fraction of banking sector assets. There is no domestic money market rate due to the currency board regime and the historically structural surplus liquidity. Foreign liabilities of banks have been declining since the global financial crisis and stood at historical lows in 2023. Banks rely on domestic sources of financing, primarily domestic sector deposits in national currency, and there is no evidence of frictions on the supply side of lending.

The two domestic capital markets are shallow and underdeveloped. Part of the obstacles to their expansion is also the lack of large domestic institutional investors, such as pension funds and insurance companies. Over the past decade, the majority of turnover was generated in the primary market, through the issuance of public sub-state debt. A traditionally constructed yield curve for government securities is absent, as secondary market transactions are random and infrequent, while most of the debt is held by domestic banks until maturity.

Over the past 10 years, the country has been running a small budget surplus (Figure 9). The fragmented structure of the government creates a great level of fiscal autonomy at the sub-state level: each of the top layers of the government have large autonomy in budgeting and full independence in fiscal policies. The only exception is the indirect taxation policy, which is identical at the single economic space. The main source of revenues for all government levels are the revenues from indirect taxes. Traditionally, the FBiH and RS run deficits and borrow in domestic and international markets (the latter refers to the RS). The overall public debt

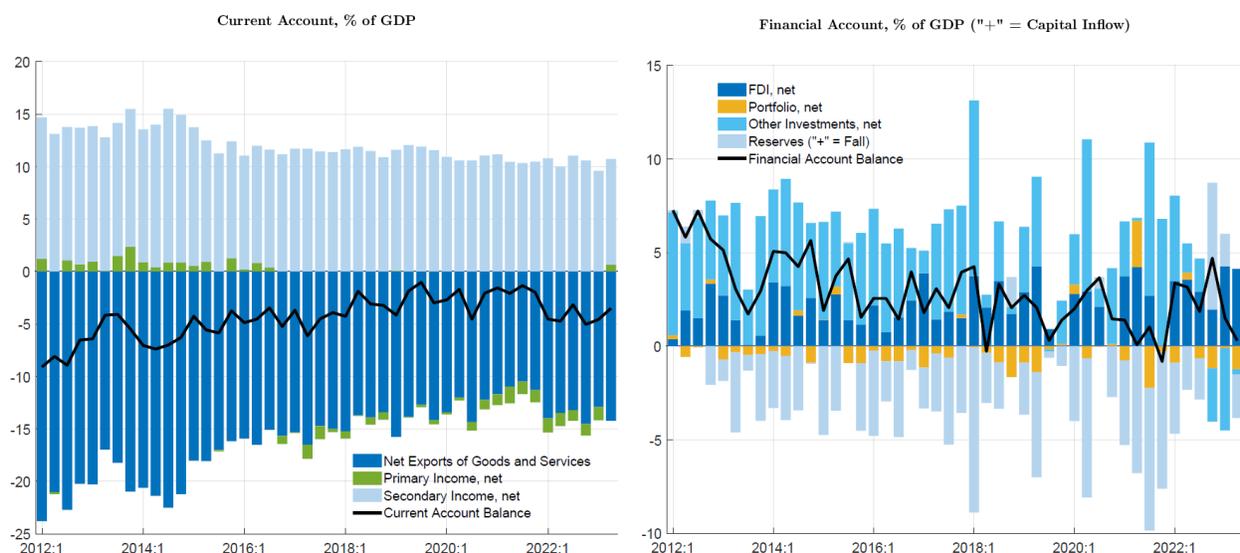
structure is still favorable, with most of the public debt being under concessional terms and still not being considered as too high.

Figure 9: Fiscal Indicators, % of GDP



The country has been historically running current account deficits (Figure 10). The deficits are mainly driven by the deficit in goods and are partially offset by surpluses in services (mainly related to re-exports and tourism inflows). Roughly two thirds of trade in goods is with the EU countries, with an additional 15 percentage points of total being attributed to the non-EU Western Balkan countries. Remittances are an important source of households' income and a factor that reduces current account deficit. The country is traditionally a net external borrower. The net foreign borrowing of government, foreign investment inflows and trade loans are the key financial inflows helping to finance the current account deficit. Apart from the privatization related inflows in early 2000s, the majority of foreign directed investment is in the form of retained earnings of the banking sector.

Figure 10: Current Account Balance and Sources of Financing



3.2. Data Input and Transformations

The first step in the forecasting process involves collecting a database that contains macro-financial data at the country level, along with information on foreign variables. The QMFF is set up at a quarterly frequency; the required data inputs are at a quarterly or monthly frequency. In the case of BiH, the raw input database contains around 100 series, which can be broken down into the following categories:

- foreign variables, i.e. key trading partners' GDP growth and inflation, exchange rates and global commodity prices;
- real sector variables, i.e. national accounts and prices;
- external sector variables (balance of payment statistics);
- fiscal sector variables; and
- monetary sector variables, i.e. monetary authorities and deposit money banks surveys, as well as loans and interest rates.

The raw input database contains historical data, as well as forecast assumptions (for foreign variables, but also for domestic variables as needed). Variables in the raw input database and throughout the QMFF follow a certain naming convention, shown in [Annex D](#). Unlike raw data, almost all variables used in the model are seasonally adjusted (except interest rates and exchange rates).

The processing of the input database includes the following steps implemented in Matlab:

- Converting monthly data to quarterly using different methods, depending on the type of original data.
- Seasonally adjusting the data using the U.S. Census Bureau's X-13 ARIMA-SEATS.
- Additional data transformations, such as deflating nominal series to calculate real variables, calculating logarithms, generating growth rates, generating ratios to nominal GDP, calculating HP filtered gaps.

- Calculating some additional variables. For instance, in the monetary sector, variables are aggregated in the monetary authorities and deposit money banks surveys respectively to ensure consistency within the surveys and then the two surveys are consolidated into the monetary survey.
- Generating foreign effective indicators. Foreign effective CPI, cpi_{rw} , is calculated as the weighted average of the CPI indices (in euros) of BiH's main trade partners, using the normalized shares of these countries in the total imports of goods for BiH as weights. Similarly, foreign effective GDP, gdp_{rw} , is calculated as the weighted average of real GDP levels of the main trade partners, with the normalized shares of the respective countries in total exports of goods from BiH used as weights.

Further, specifics of the variables that have negative values require some additional adjustments before using them in a log-linear model. In particular, several observed variables can switch signs between positive and negative or be negative all the time. This includes variables that are only available in net terms (e.g. net portfolio inflows), monetary variables that enter the model as changes (e.g. changes in bank deposits) or other variables that are always negative because of the features of the economy (e.g. income investment of general government). These variables can cause two issues. First, taking logarithms yields complex numbers. Second, in some cases, the averages of these variables can be negative, thus making it impossible to use them as steady-state values.

To avoid these issues, an adjustment is carried out for all variables in this group. Observed nominal variables are increased by a constant share k of nominal potential GDP ($gdp_{r_bar} * def_{gdp}$), thus ensuring that the levels of these variables are always positive.³⁵ This level adjustment does not affect the real gaps of these variables relative to their HP-trends, as both the actual and the trend levels have been increased. However, the ratios of these variables to GDP and the resulting trends and gaps of this ratio are affected due to the adjustment of the numerator. Therefore, a correction is needed for the steady-state shares of these variables to nominal GDP. Consequently, their steady-state shares relative to GDP are also increased by k . In effect, this ensures that the adjusted variables converge to a correspondingly adjusted constant positive share of nominal GDP. Finally, to ensure accurate reporting, the reverse operation of subtracting the constant share k of nominal potential GDP is carried out when reporting the forecast.

3.3. Country-Specific Data Issues

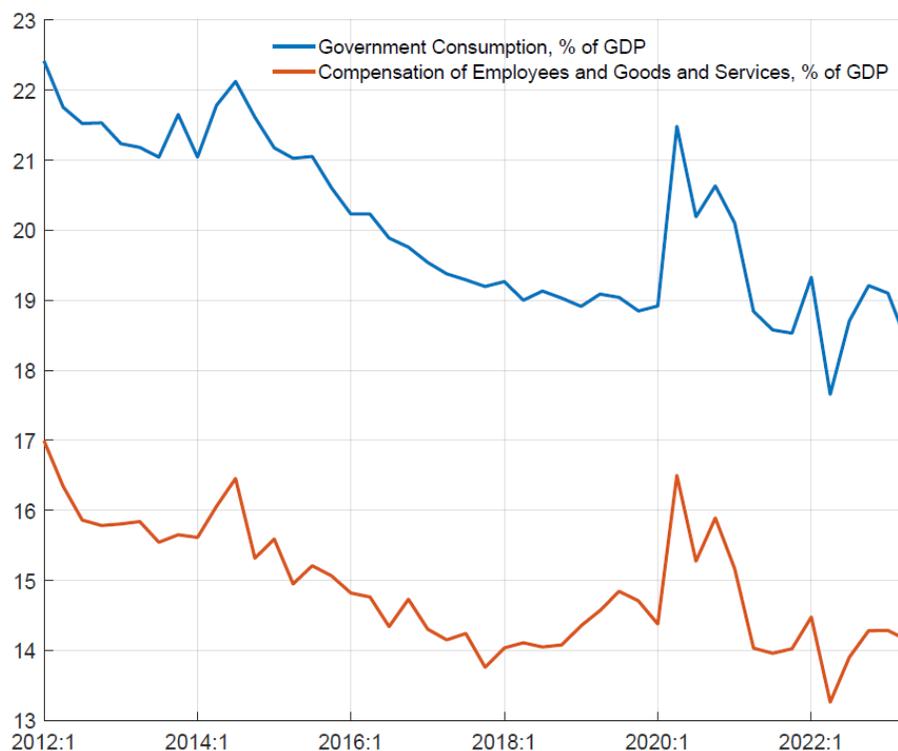
As noted in Section 2.6, ensuring accounting consistency across sectors is an essential feature of the QMFF. However, when imposing within and cross-sectoral identifying restrictions in the QMFF, data availability, quality and granularity may raise some issues that must be addressed. Most of these data issues are common for many countries, and the QMFF is general enough to address them, as discussed in Section 2.6; it can also be modified to other country specifics.

In the case of BiH, there were two issues which had to be explicitly treated, both related to fiscal data. First, there is a sizable discrepancy between national accounts and fiscal accounts, i.e. between government consumption on the one hand, and the sum of compensation of employees and spending on goods and

³⁵ For BiH, k is set to 0.1. Its value should not be too large, but should be large enough to make sure that, after adding k *nominal potential GDP, all variables with level adjustment are always positive.

services on the other (Figure 11). Therefore, as discussed in Section 2.1, we take a general approach when introducing this cross-sectoral linkage and modeling the discrepancy separately as a mean-reverting process.

Figure 11: National Accounts Data vs. Fiscal Statistics



Second, historical data for BiH indicates that there are sizable discrepancies in budget financing in the past, largely reflecting data weaknesses (Figure 12). Therefore, to ensure consistency between monetary and fiscal sectors, we capture non-bank domestic financing of the budget along with any data discrepancies in a residual variable, *fin_dom* (Figure 13), which reflects the part of the financing of the budget deficit that is not explained by domestic bank financing or relevant BoP categories (portfolio investments or other investments of the government).³⁶ This residual financing variable is calculated over the historical period in the data processing stage; it then enters the model and is forecasted as an AR(1) process. Thus, the model yields forecasts for the fiscal balance, the residual financing variable, *fin_dom*, and the external financing recorded in the BoP (green boxes in Figure 13). Having this information, in the forecast reporting stage we then calculate what the overall size of the domestic bank financing of the budget will be over the forecast horizon (i.e. changes in net claims on central government). We make some additional assumptions on how these changes in net claims on central government are distributed between the central bank and deposit money banks' balance sheets in the case of BiH. The share of central bank financing is set to zero to reflect the prohibition of central bank financing of the government. Further, we assume that 80% of the financing is reflected on the asset side of the deposit money banks (and 20% on the liability side).

³⁶ A small part of the discrepancy could also reflect the incorporation of all portfolio investment in external government financing due to insufficient data breakdown.

Figure 12: Sources of Budget Financing

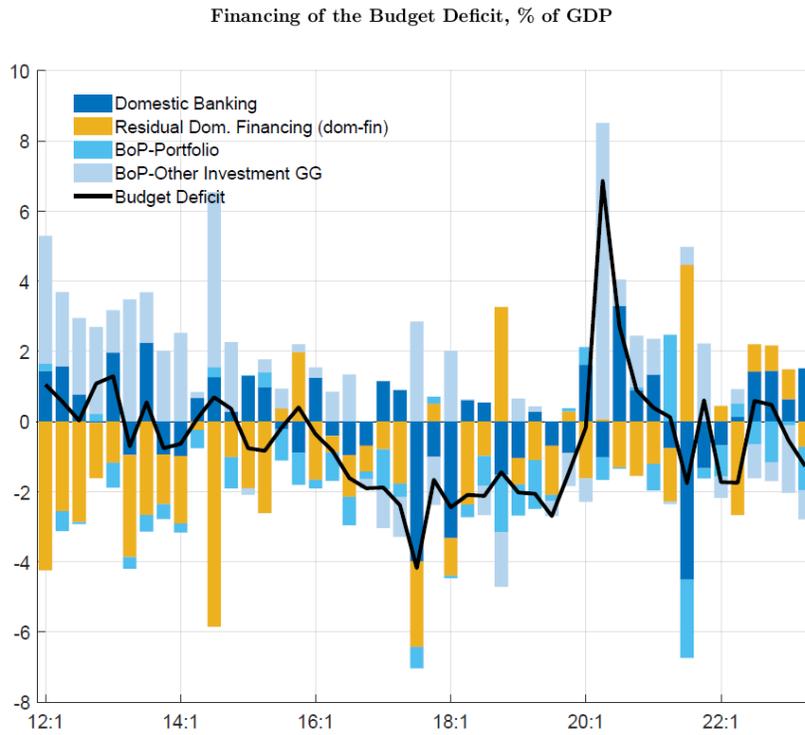
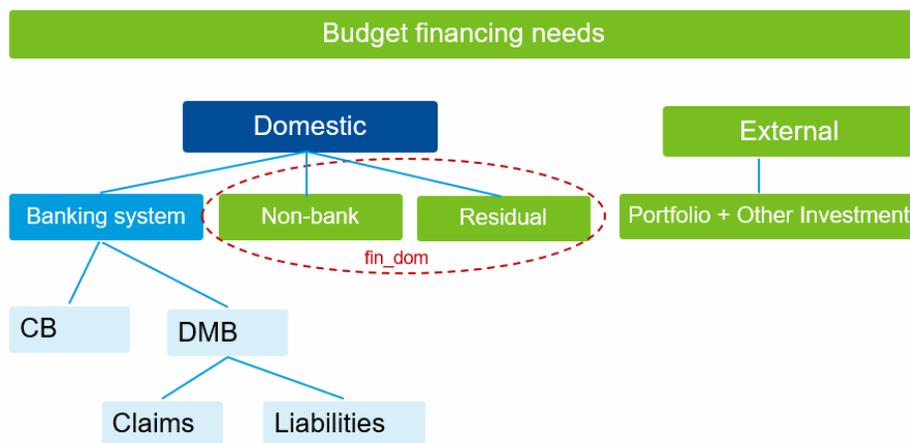


Figure 13: Consistency of Budget Financing with the Rest of the Framework



3.4. Expenditure Shares, Import Demand and Deflators

The QMFF was gradually brought to data on Bosnia and Herzegovina via a combination of empirical approaches. The model parameters were calibrated, while ensuring that they reflect theoretical considerations and ensure a balanced growth path. This section sheds light on the calibration of the shares of expenditure components in GDP and the import demand and the deflator equations for BiH. The calibration strategy of the dynamic equations of the QMFF follows the one discussed in Section 2.5, including some suggestions on adjusting the model to other countries (with adjustments regarding monetary policy and exchange rates discussed in Section 2.1). Parameter values for BiH are shown in Annex C.

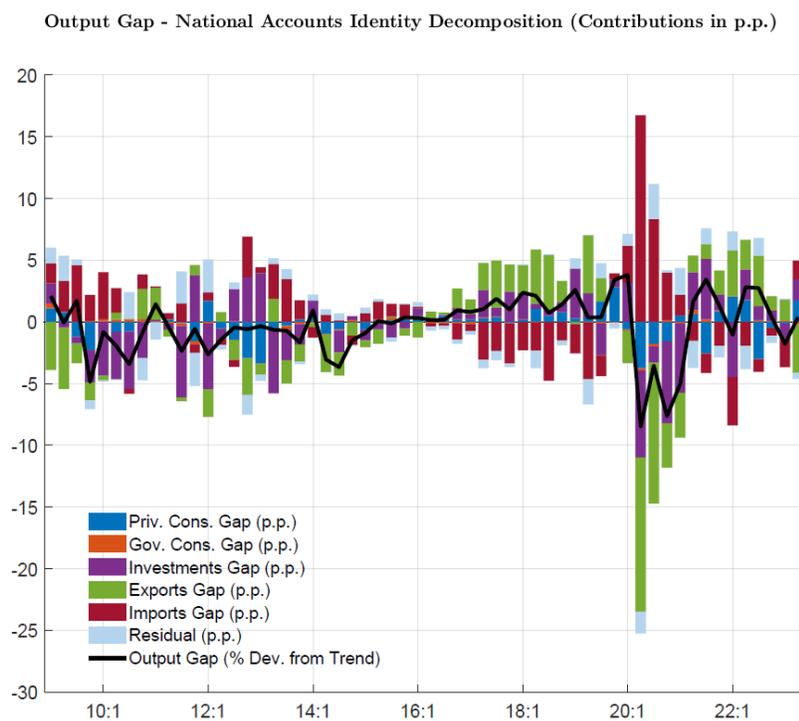
3.4.1. GDP Expenditure Shares

The log-linearization of the national accounts identity links the output gap, $l_gdp_r_gap$, with the real expenditure gaps (see Annex A for the derivation of the identity in terms of gaps; also note the different notation there):

$$l_gdp_r_gap = b_c * l_c_r_gap + b_g * l_g_r_gap + b_j * l_j_r_gap + b_x * l_x_r_gap - b_m * l_m_r_gap + shk_l_gdp_r_gap;$$

In the case of BiH, expenditure shares to GDP (b parameters) were calibrated at their 2021-22 nominal averages. The resulting decomposition of the BiH output gap can be seen in Figure 14.

Figure 14: Log-Linearization of the National Accounts Identity



3.4.2. The Import Demand

As noted in Section 2.1, total imports are a sum of imports for private consumption, investments, government consumption and exports (with shares of each component in imports denoted by mg and ms parameters for imports of goods and of services, respectively), as well as relative prices, l_z_gap . As noted before, the specification and calibration of the demand for services is identical to the one for goods; they could be specified differently, depending on data availability, which would, however, somewhat complicate the algebra below.

$$l_mg_r_gap = mg1 * l_c_r_gap + mg2 * l_g_r_gap + mg3 * l_j_r_gap + mg4 * l_x_r_gap + mg5 * l_z_gap + shk_l_mg_r_gap$$

$$l_ms_r_gap = ms1 * l_c_r_gap + ms2 * l_g_r_gap + ms3 * l_j_r_gap + ms4 * l_x_r_gap + ms5 * l_z_gap + shk_l_ms_r_gap$$

By substituting the above and dropping the shocks for ease of exposition, the following equation is obtained for the total real import demand $l_m_r_gap$:

$$b_m * l_m_r_gap = b_mg * l_mg_r_gap + b_ms * l_ms_r_gap$$

$$l_m_r_gap = m1 * l_c_r_gap + m2 * l_g_r_gap + m3 * l_j_r_gap + m4 * l_x_r_gap + m5 * l_z_gap$$

In the last equation, m parameters replace previous mg and ms parameters. This is feasible as long as respective mg and ms parameters are equal, like in this case (Section 2.1). m parameters are a function of the shares b_Ω of expenditure components Ω in GDP (where $\Omega = c, g, j, x$) and of the import intensity (import shares) of each expenditure component. Regarding the latter, as noted above, we assume that each expenditure component Ω has a constant share of oil and non-oil imports: $ss_m\Omega$ is the share of imported goods except oil in Ω , $ss_m\Omega o$ is the share of imported oil in Ω and $1 - ss_m\Omega - ss_m\Omega o$ is the domestic value-added share in Ω .

$$m1 = b_c * (ss_mc + ss_mco) / b_m; m2 = b_g * (ss_mg + ss_mgo) / b_m$$

$$m3 = b_j * (ss_mj + ss_mjo) / b_m; m4 = b_x * (ss_mx + ss_mxo) / b_m$$

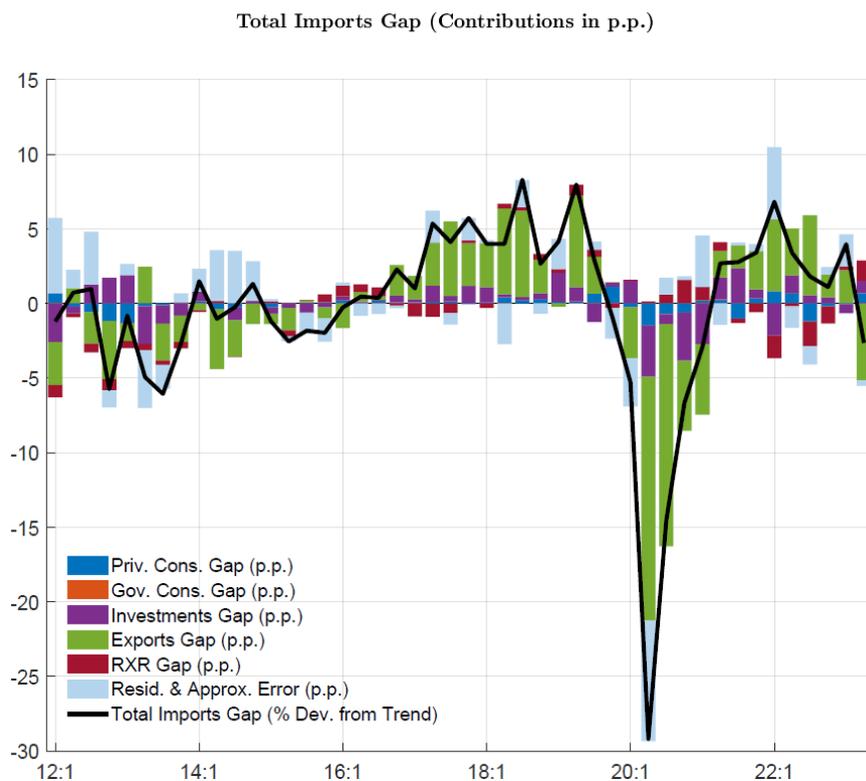
The import intensity of each expenditure component ($ss_m\Omega$ and $ss_m\Omega o$), which determines the m parameters (shares of imports for each expenditure component) can be calculated based on input-output data. However, often such data may not be available, or may not have the necessary level of disaggregation. Therefore, when applying the QMFF to BiH, these parameters were calibrated using an Excel solver routine, which is an ordinary least square estimation of the import demand equation on a constrained parameter space.

Finally, a theoretical restriction was imposed so that the expenditure's import-shares add up to the total import share in GDP, i.e. the total import share in nominal GDP b_m must satisfy the following condition:

$$b_m = b_c * (ss_mc + ss_mco) + b_g * (ss_mg + ss_mgo) + b_j * (ss_mj + ss_mjo) + b_x * (ss_mx + ss_mxo)$$

This specification and calibration result in a fitted import demand that is very close to the observed one for most of the period, with a relatively good decomposition of the total import gap in BiH (Figure 15).

Figure 15: Decomposition of the Total Imports Demand Gap Equation



3.4.3. The Import Deflator

As discussed in Section 2.1, the deflators of imports of goods, l_def_mg , and of services, l_def_ms , are weighted averages of the prices of imported goods excluding oil and the price of oil, both expressed in local currency ($l_p_rw_no_lc$ and $l_p_rw_o_lc$). The total import price deflator, l_def_m , is in turn a weighted average of the deflators of imports of goods and imports of services.

$$l_def_mg = (1 - d4) * l_p_rw_no_lc + d4 * l_p_rw_o_lc + shk_dla_def_mg$$

$$l_def_ms = (1 - d4) * l_p_rw_no_lc + d4 * l_p_rw_o_lc + shk_dla_def_ms$$

$$l_def_m = (b_ms/b_m) * l_def_ms + (b_mg/b_m) * l_def_mg + shk_dla_def_m$$

Depending on data availability, deflators of imports of goods and of services can be specified differently. However, in this case, they are both equal to the overall import deflator; the equations are consequently specified in the same manner. By substituting the above and dropping the shocks for ease of exposition, the

following equation is obtained for the total import deflator, l_{def_m} , which is a function of the euro prices of imported goods excluding oil and prices of oil (converted into local currency):

$$l_{def_m} = (1 - d_4) * l_{p_rw_no_lc} + d_4 * l_{p_rw_o_lc}$$

$$l_{p_rw_no_lc} = l_{p_rw_no_eur} + l_s$$

$$l_{p_rw_o_lc} = l_{p_rw_o_eur} + l_s$$

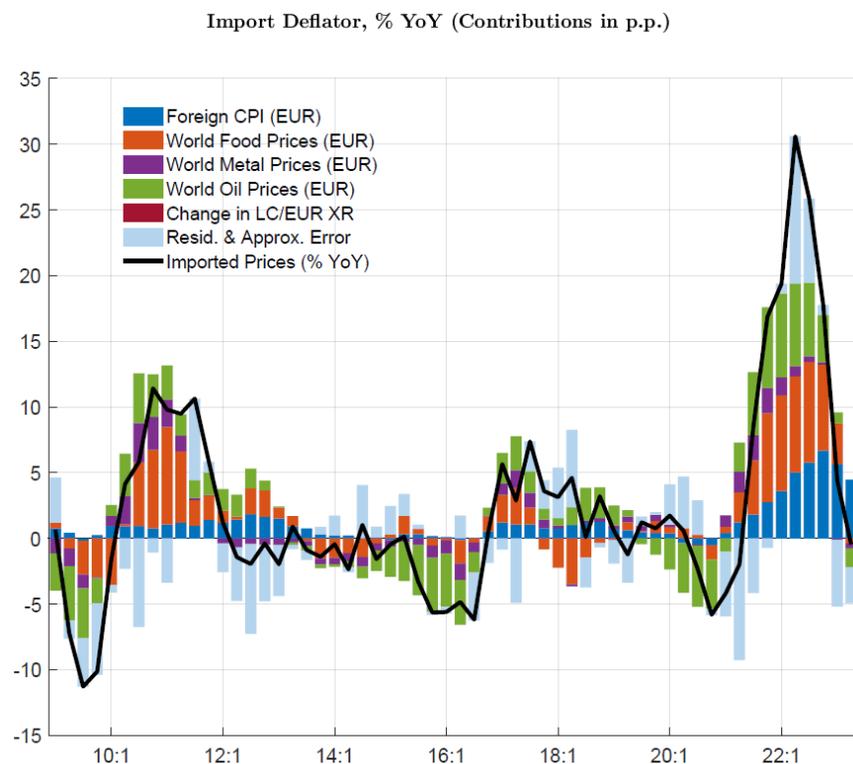
$$l_{p_rw_no_eur} = (d_1 * (d_{11} * l_{cpi_rw} + (1 - d_{11}) * l_{cpi_rw_{t-1}}) + d_2 * (d_{21} * l_{wfood_eur} + (1 - d_{21}) * l_{wfood_eur_{t-1}}) + d_3 * (d_{31} * l_{wmet_eur} + (1 - d_{31}) * l_{wmet_eur_{t-1}})) / (1 - d_4)$$

$$l_{p_rw_o_eur} = d_{41} * l_{woil_eur} + (1 - d_{41}) * l_{woil_eur_{t-1}}$$

The parameters of the import deflator equation can be quantified from detailed import statistics or input-output tables, if available. Since this is not the case for many economies, including BiH, the calibration of the import deflator equation follows a similar strategy to that of the import demand equation.

This specification and calibration of import prices results in a fitted import deflator for Bosnia and Herzegovina that is reasonably close to the observed one for most of the period and the decomposition of the year-on-year changes of the total import deflator in the model is rather good (Figure 16).

Figure 16: Decomposition of the Import Deflator Equation



3.4.4. Other Deflator Equations

Reflecting the discussion on steady states in Section 2.4 and on the demand for imports in Section 3.4.2, national accounts deflators, denoted by $l_def_Ω$ (where $Ω = c, g, j, x$), are a weighted average of the GDP deflator, l_def_gdp , approximating costs of domestic inputs; $l_p_rw_no_lc$, approximating the prices of imported goods except oil expressed in local currency; and $l_p_rw_o_lc$, approximating imported energy prices, captured by the imported oil prices, also expressed in local currency. As noted above, $1 - ss_mΩ - ss_mΩo$ is the domestic value-added share in $Ω$, $ss_mΩ$ is the share of imported goods excluding oil and $ss_mΩo$ is the share of oil, all calibrated for BiH.

The deflator equations are reproduced below. The equation with the private consumption deflator, l_def_c , on the left effectively defines the GDP deflator, l_def_gdp ; the shock is named accordingly, whereas the shock to the private consumption deflator, $shk_dla_def_c$, appears in the consumption deflator equation (i.e. the Phillips curve) discussed previously. In other words, this equation is equivalent to an alternative equation with the GDP deflator on the left-hand side, expressed as a function of the private consumption deflator and imported prices. This specification of deflators and the calibration of $ss_mΩ$ and $ss_mΩo$ parameters discussed above yields fitted deflators that are reasonably close to the observed ones for most of the history. The decompositions of the year-on-year changes of deflators show that they are well explained by the components (Figure 17). Like the total import deflator above, the contributions of import prices ($l_p_rw_no_lc$ and $l_p_rw_o_lc$) to the other deflators reflect the impact of euro prices, with changes in the nominal exchange rate to the euro equal to zero in the case of BiH.

$$l_def_c = (1 - ss_mc - ss_mco) * l_def_gdp + ss_mc * l_p_rw_no_lc + ss_mco * l_p_rw_o_lc + shk_dla_def_gdp$$

$$l_def_g = (1 - ss_mg - ss_mgo) * l_def_gdp + ss_mg * l_p_rw_no_lc + ss_mgo * l_p_rw_o_lc + shk_dla_def_g$$

$$l_def_j = (1 - ss_mj - ss_mjo) * l_def_gdp + ss_mj * l_p_rw_no_lc + ss_mjo * l_p_rw_o_lc + shk_dla_def_j$$

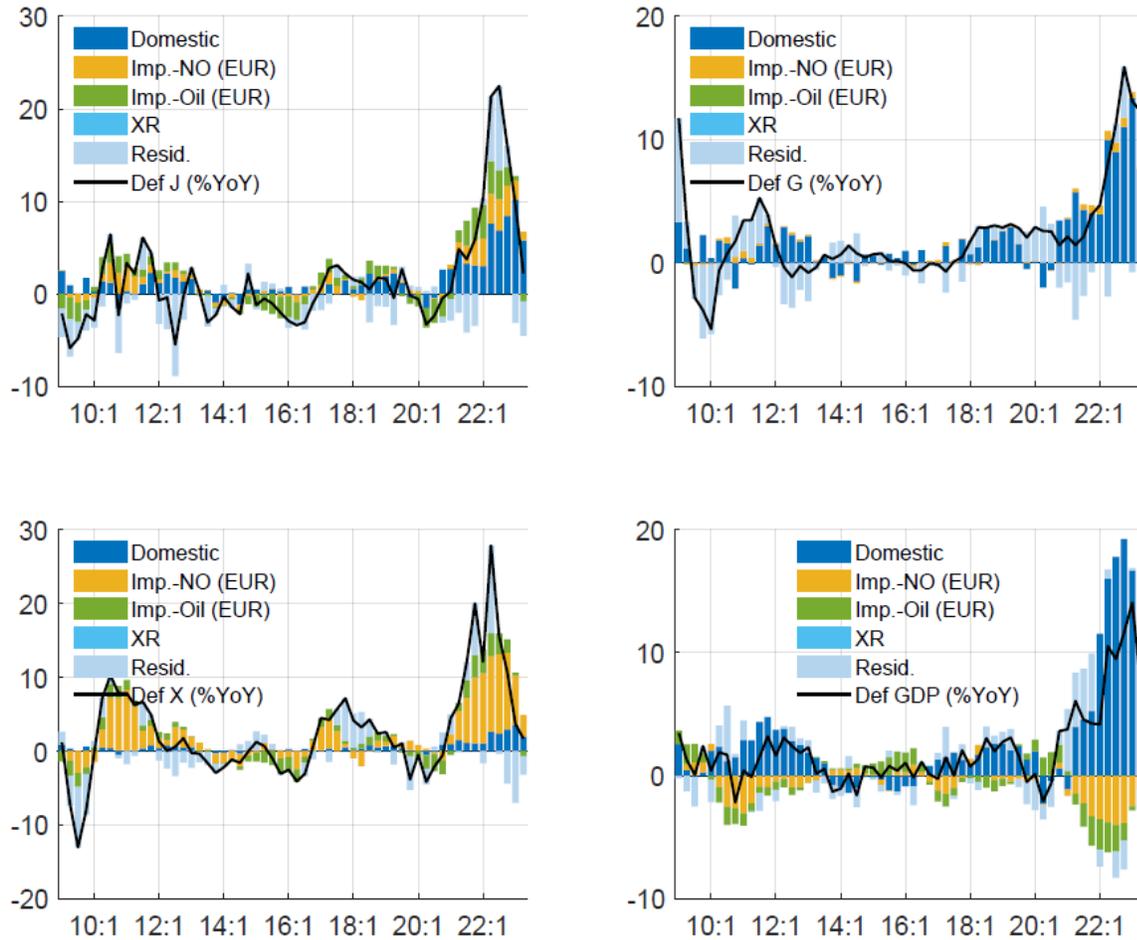
$$l_def_x = (b_xs/b_x) * l_def_xs + (b_xg/b_x) * l_def_xg + shk_dla_def_x$$

$$l_def_xg = (1 - ss_mxg - ss_mxgo) * l_def_gdp + ss_mxg * l_p_rw_no_lc + ss_mxgo * l_p_rw_o_lc + shk_dla_def_xg$$

$$l_def_xs = (1 - ss_mxs - ss_mxso) * l_def_gdp + ss_mxs * l_p_rw_no_lc + ss_mxso * l_p_rw_o_lc + shk_dla_def_xs$$

Figure 17: Decomposition of Investment, Government Consumption, Export and GDP Deflators

Deflators, % YoY (Contributions in p.p.)



4. Model Verification

The behavioral gap equations, the identities and the calibration of the QMFF are empirically verified to ensure that the theoretical restrictions imposed on model parameters are met and that the model reflects and explains the economic relations and captures observed data in the case of BiH as closely as possible. Continuing the previous discussion on calibration, the process of model verification relies on analyzing impulse response functions, historical decompositions, and in-sample simulations. These tools, which are discussed next, should be used extensively in the process of building the model and calibrating it, but also regularly while using the model.

4.1. Impulse Response Functions

The dynamic properties of the QMFF are examined by repeatedly analyzing the model's response to various shocks to understand the model's transmission mechanisms and verify its plausibility. The dynamic response of model variables to shocks, including their magnitude and speed of convergence to the steady-state, should reflect a calibration that is economically intuitive, in line with economic theory and reflecting the country-specific characteristics.

Specifically, there are several characteristics that are expected in a small open economy, such as BiH, operating in a currency board regime. For instance, the role of the foreign business cycle in driving the domestic cycle is very important. This is given not only by the sensitivity of the export sector to foreign demand, but also by the strong reaction of private transfers (reflecting sizable diaspora from Bosnia and Herzegovina) and FDI to the foreign economic cycle. Further, the role of domestic real interest rates in the transmission mechanism is weak, both in terms of the real economy and inflation. There are several reasons for that. Most importantly, the domestic interest rates follow the corresponding rates in the euro area adjusted for the risk premium. The exchange rate serves as the nominal anchor for the domestic economy, so the interest rate channel in the monetary policy transmission mechanism is weaker. In addition, financial market development in countries with fixed exchange rates is often more gradual than in inflation targeting regimes. Demand shocks, generated domestically or abroad, are expected to increase inflation, but the reaction is mostly contained due to the strong anchoring role of the fixed exchange rate in terms of price competitiveness and import substitution.

To illustrate the model's properties, dynamic responses of the model to a 1% shock to foreign demand and to domestic inflation (the consumption deflator) are shown in [Figure 18](#). The shock to foreign demand results in domestic economic growth (Panel 1), reflecting the positive effect of foreign demand on exports, investment, and private consumption (via higher private transfers). The resulting positive output gap generates demand-led inflation pressures that are stronger than the anti-inflationary effect of lower imported prices compared to their domestic counterparts (i.e. real exchange rate appreciation). As nominal interest rates are unchanged and inflation increases, real interest rates become negative and initially contribute to demand. After the initial rise in exports, the positive impact of the shock on the external position (the current account in Panel 2) dies out soon afterwards. This reflects a number of factors: the high sensitivity of imports to domestic demand, the negative effect of the real appreciation on net exports, and the higher long-run share of imports to GDP compared to exports. At the same time, this effect is partially countered by the strong positive response of private transfers

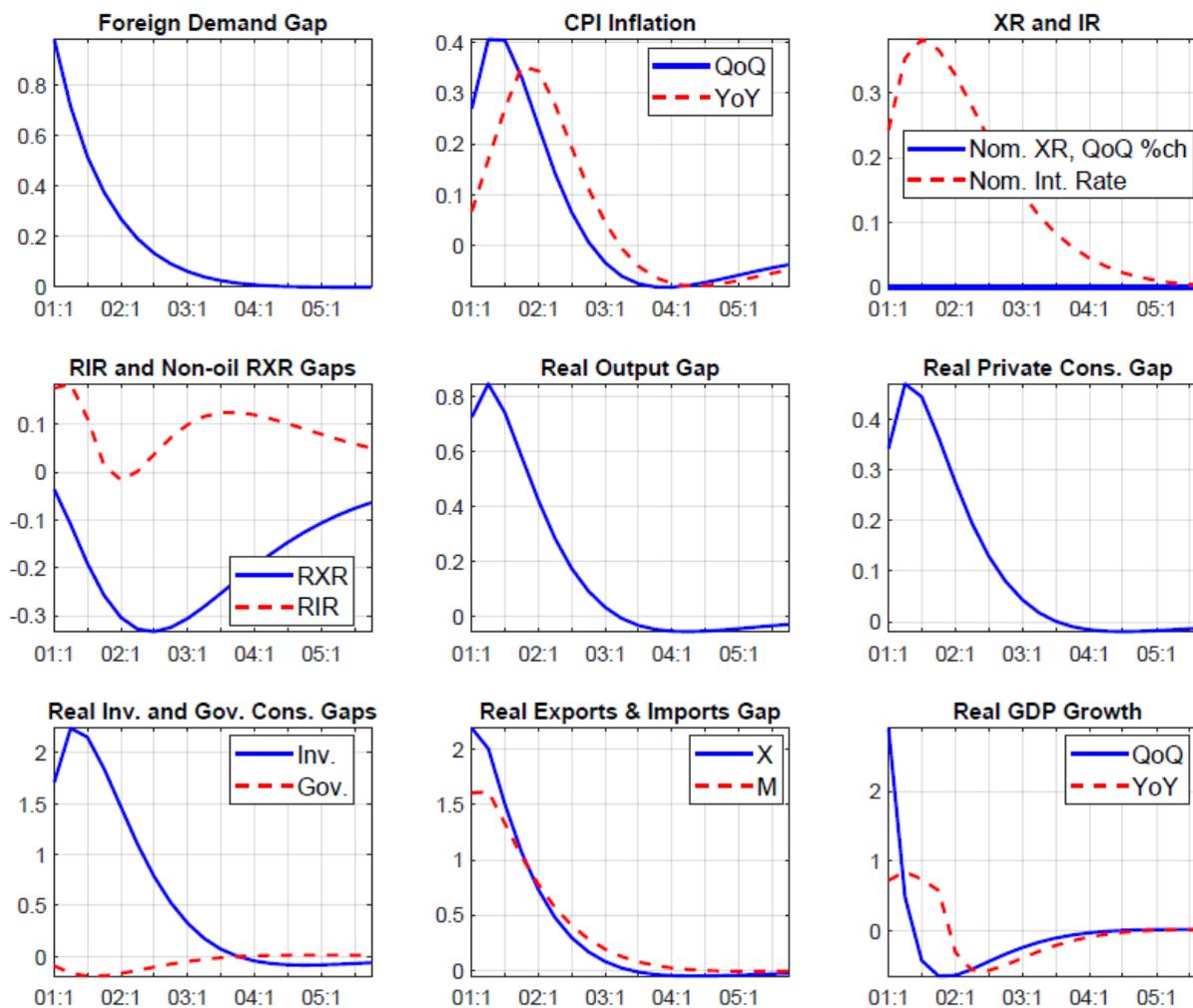
and FDI. Consequently, the overall positive impact of the foreign demand shock on foreign reserves is longer lasting, highlighting the high dependence of a small open economy like BiH on external developments.

Responses to the inflation shock (panels 3 and 4) are likewise intuitive. The initially negative real interest rate supports domestic demand. However, as in most small open economies, the real exchange rate channel dominates, with appreciation resulting in a fall in exports and a rise in imports, and consequently lower domestic output growth. The negative output gap combined with the anti-inflationary effect of lower imported prices (the real exchange rate appreciation) stabilizes inflation after the shock. The response of the current account is rather weak: it worsens initially because of the trade balance, but then it improves as weaker domestic demand results in stabilization of imports and somewhat higher private transfers (not shown).

Figure 18: Impulse Response to a 1% Foreign Demand Shock and Domestic Inflation (Consumption Deflator) Shock, Selected Variables

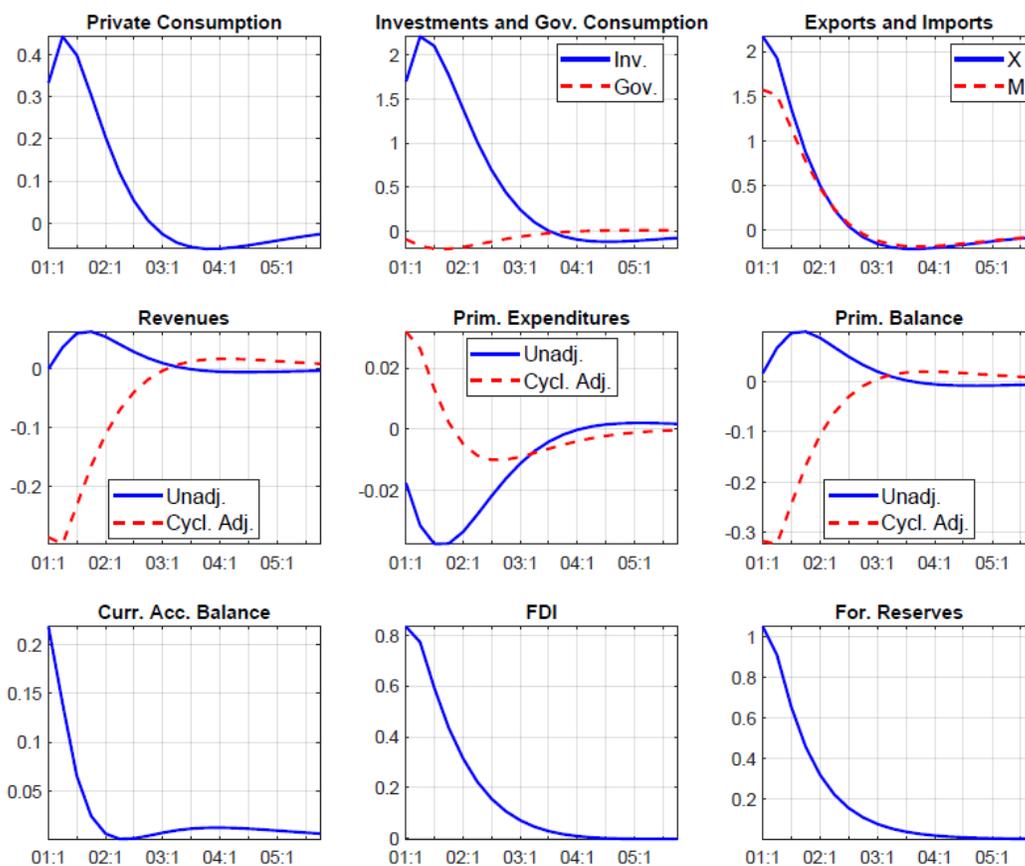
Panel 1

Summary: Responses to a Foreign Demand Gap Shock



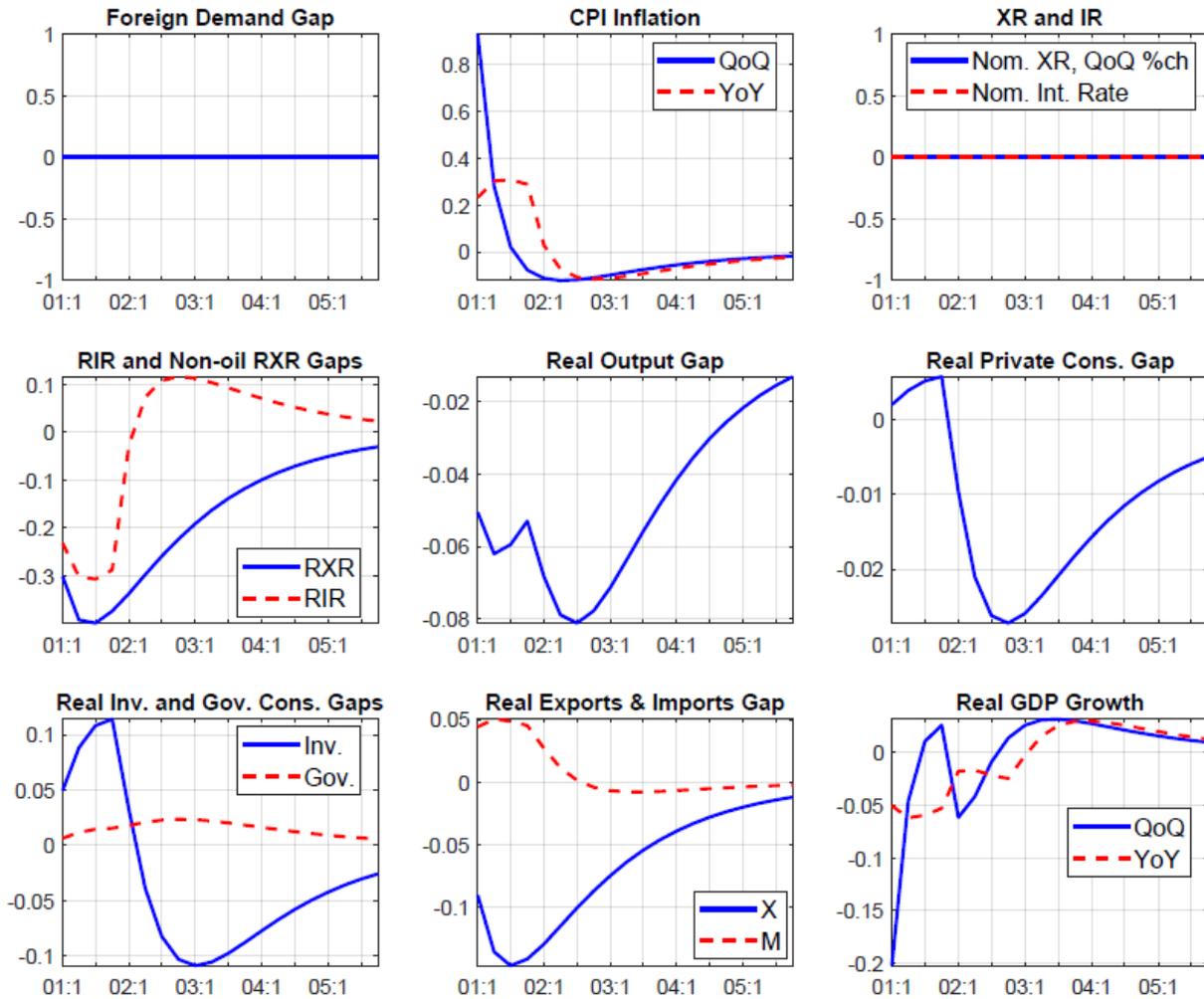
Panel 2

Responses to a Foreign Demand Gap Shock as Deviations of Nom. Ratios to GDP from Trend Ratios



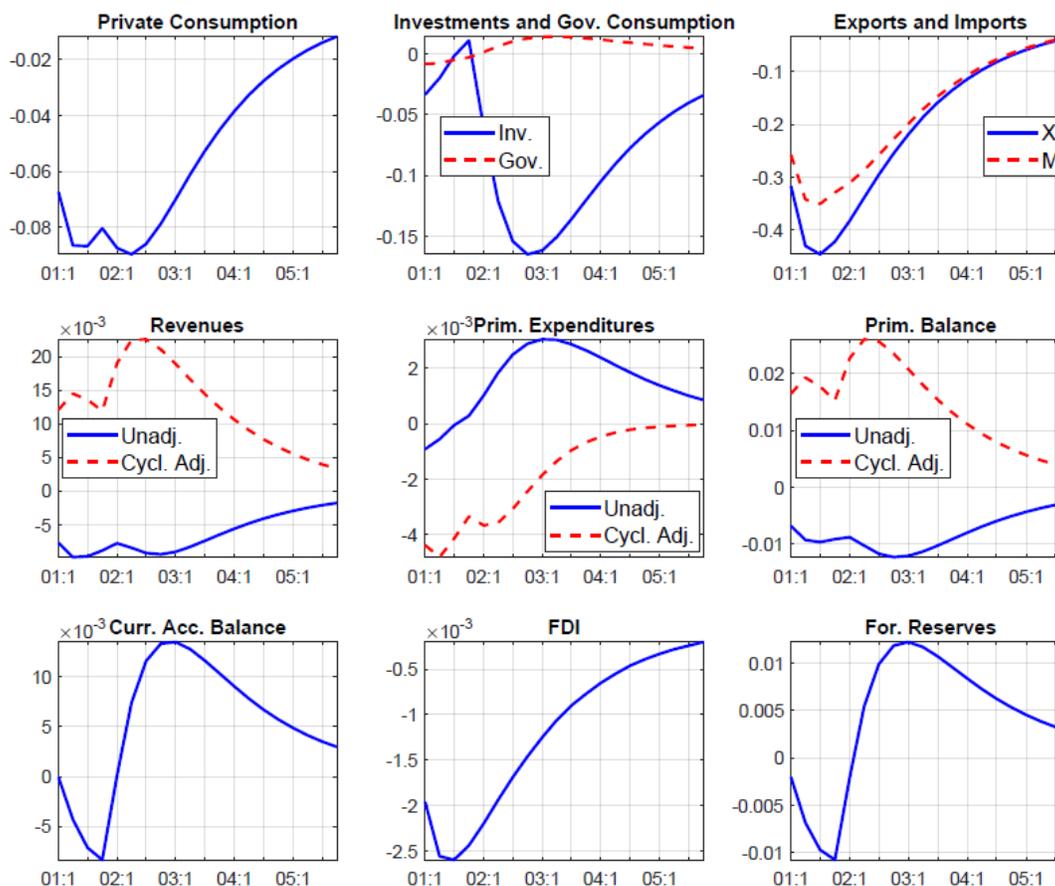
Panel 3

Summary: Responses to a Cons. Defl Shock - Phillips



Panel 4

Responses to a Cons. Defl Shock - Phillips as Deviations of Nom. Ratios to GDP from Trend Ratios



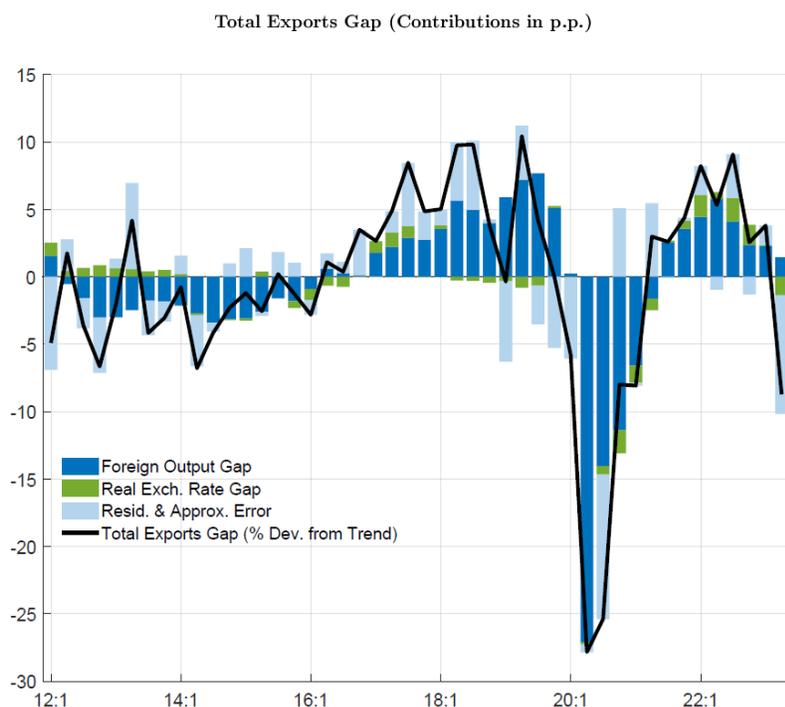
4.2. Historical Decompositions

Decomposition graphs are useful tools for empirical verification of behavioral equations, both in terms of theoretical priors and country specifics (as discussed in Section 2.5). Similarly, they can also be used in checking the calibration of identities (e.g., GDP and import equations, discussed in Section 3.4). They show how well a particular variable can be explained by economic factors, reflecting the model specification and calibration as well as historical movements. In addition, decomposition graphs can be used to identify the business cycle drivers of the forecast (see Section 5.1).

While building the model, decomposition graphs are used extensively to check the specification of equations in terms of selected variables, the lag structure, and the calibration of the parameters. A good specification and calibration will result in a decomposition where variables explain a large share of the past, and the residuals are moderate in size and resemble white noise. When analyzing the goodness of fit, higher weight is given to the recent years, thus mitigating the impact of historical structural changes on the current calibration of the model.

An example of these decomposition graphs³⁷ for the real exports gap for BiH is shown in Figure 19. The graph indicates that the equation has a reasonable fit, with foreign demand playing a dominant role in driving the dynamics of exports. The role of the real exchange rate gap is relatively small, in line with the low price-sensitivity of Bosnian exports. Finally, total exports from national accounts are modelled as a cross-restriction, i.e. a sum of exports of goods and of services from the balance of payments. Consequently, the residual shows the unexplained part in the equations of the two components (goods and services), while the approximation error arises from reconciling exports from the two sources (national accounts and BoP statistics).

Figure 19: Decomposition of the Real Exports Gap Equation



4.3. In-sample Simulations

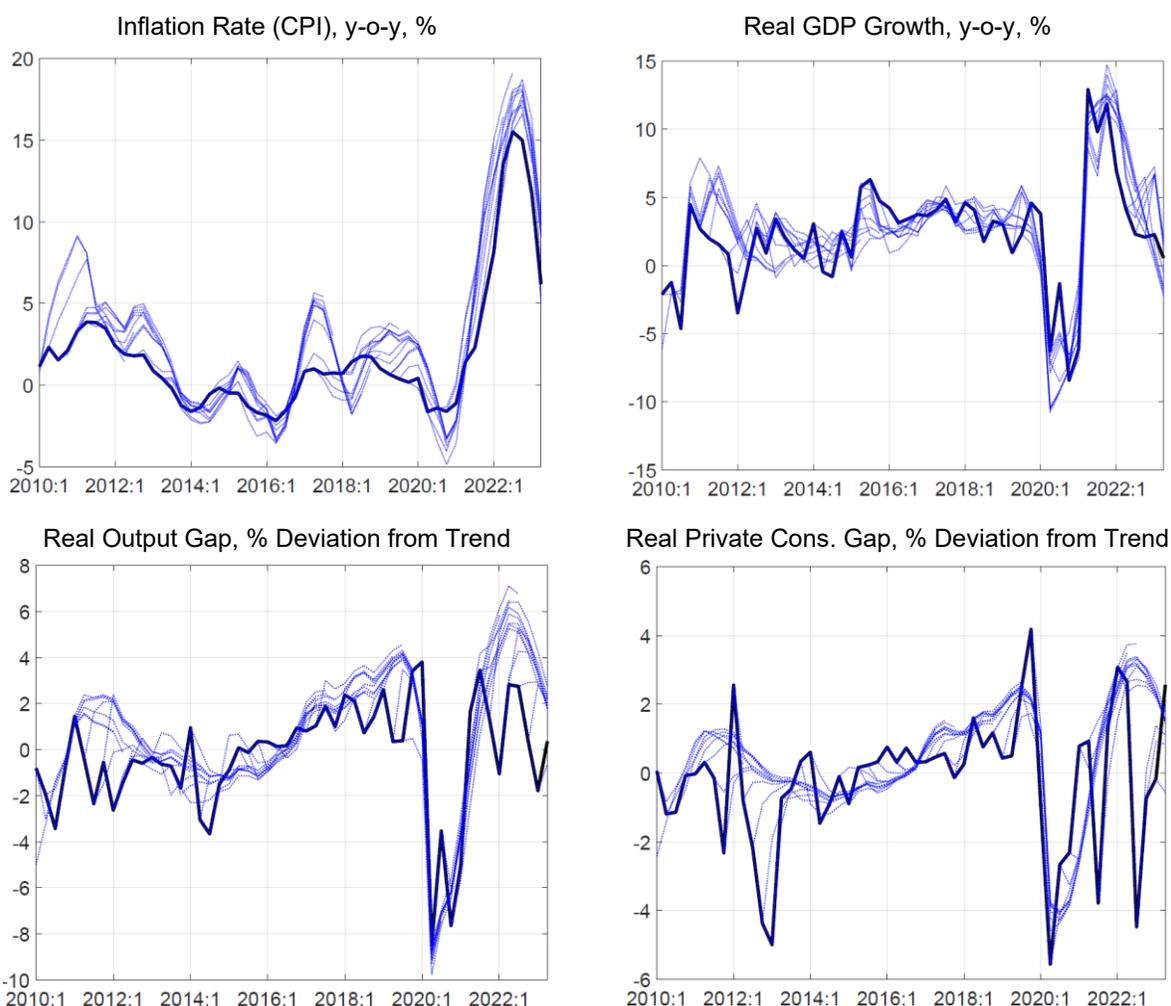
The in-sample simulation results in Figure 20 below are iterative, automatized “forecasts”, produced successively starting in each period for eight quarters ahead. These simulations rely on the model structure and parameters. They are produced under the assumption that exogenous variables are known beforehand for the entire period³⁸. The simulations are mechanical in the sense that no expert judgements are incorporated: only the model solution and exogenous variables are used to assess the dynamic properties of the QMFF. In other words, in-sample simulations show the forecast results that would be obtained if the forecast was executed mechanically in various points in time, assuming full knowledge of the exogenous variables.

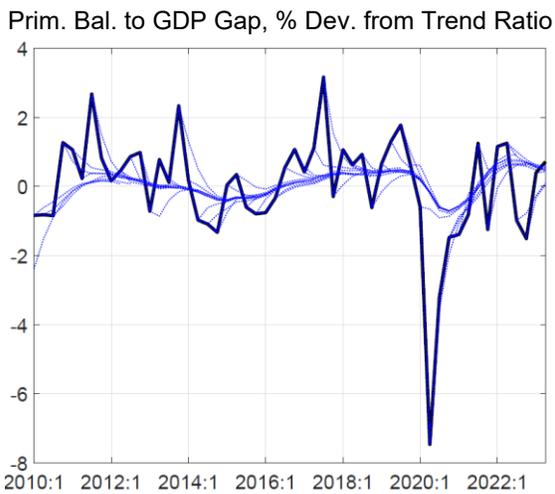
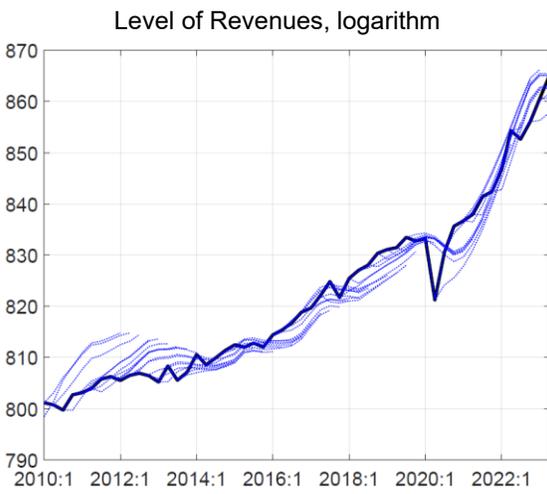
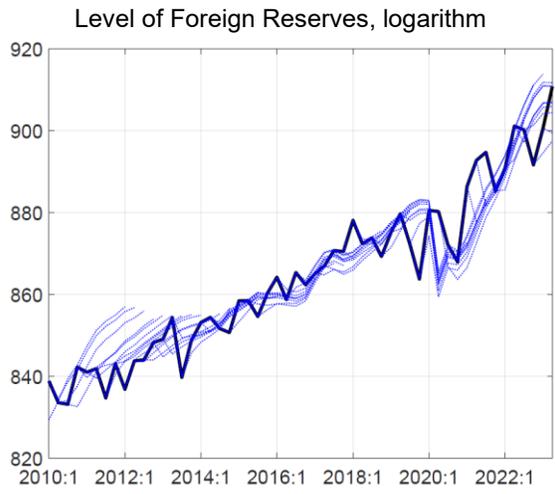
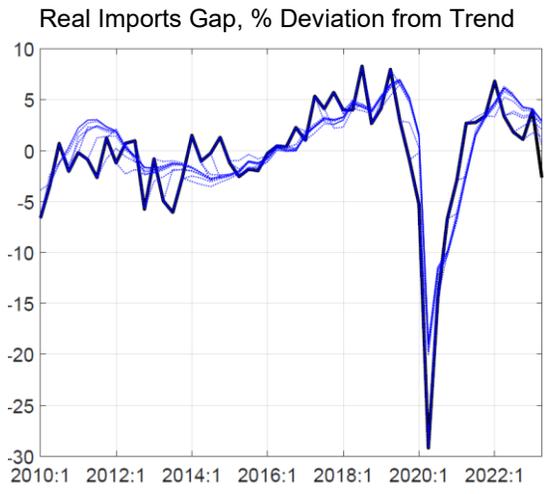
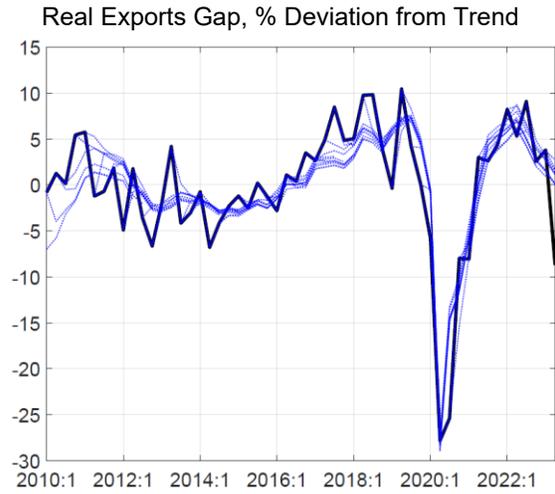
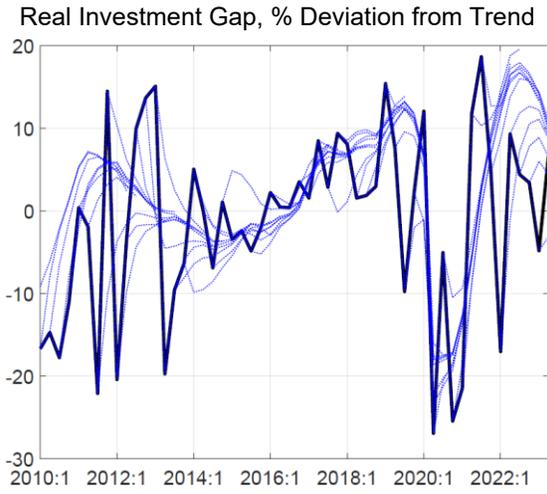
³⁷ In all decomposition graphs in the paper, the lag of the dependent variable is substituted out, i.e. distributed across the variables and the residual.

³⁸ This applies to all exogenous variables in the model: foreign demand, foreign inflation, foreign interest rates, the USD/EUR exchange rate and world commodity prices (oil, food and metals).

To evaluate the performance of the model, the simulations are compared to the actual evolution of each variable. Overall, these results indicate a robust performance of the model for BiH. The in-sample “forecasts” are close to observed variables for most of the behavioral equations; deviations are not systematic, and the model captures the turning points reasonably well. Although many of the variables included in Figure 20 are themselves volatile in history, the dynamic simulations show a reasonable forecast for inflation and real GDP growth. The forecasts of output gap, but also real consumption, investment and export gaps capture the turning points right most of the time, partially reflecting the information from foreign variables. The log-levels of revenues and foreign reserves are also forecasted relatively well. However, the performance of the deviation of the primary budget balance to GDP from its trend ratio is somewhat weaker.

Figure 20: In-sample Simulation Results – Selected Variables





5. Baseline and Alternative Forecasts

Following the data update and calibration of the model discussed in detail in the previous sections, the system is ready for generating forecasts. The process is supported by a comprehensive reporting system, which is easily customizable and transparent about the incorporation of nowcasts and expert judgement. This section provides an overview of the process of producing baseline and alternative scenarios, forecast comparisons, and adding judgement or off-model information, again illustrated on the case of BiH.

5.1. Baseline Forecasts, Nowcasts and Near-term Forecasts

A forecasting round starts with the data input and transformations covered previously. After the discussion of historical developments and initial conditions, the process continues with generating baseline forecasts, which usually involves the incorporation of nowcasts, near-term forecasts (NTF) and off-model information. The framework is designed to easily adopt any additional information on variables in the forecast horizon reflecting nowcasts, near-term forecasts and off-model information or alternative scenarios (Section 5.2). The information added over the forecast horizon is shown transparently in decomposition graphs (of components, not cross-restriction identities) as residuals.

As discussed in Section 2, the model contains equations that define the evolution of all variables in the model; e.g. behavioral equations for the key variables or AR(1) processes for foreign variables and many endogenous variables (fiscal, monetary and external). However, in the near-term, values for any model variable can be taken from other data sources for certain time periods, after which they will be projected using the respective equations in the model. For instance, assumptions for foreign variables are often taken from consensus forecasts or the IMF World Economic Outlook. In addition, for endogenous variables, nowcasts/NTF may be available from actual data (if they are available more quickly than the other variables included in the model), from satellite models, from other sources (e.g. the government budget) or from expert judgement.

A sample of the forecast report for BiH starting from the third quarter of 2023, including assumptions for exogenous variables and nowcasts/NTF and expert judgements for some endogenous variables, is produced in Figure 21, Figure 22 and Table 1 below. The graphs are similar to the ones discussed earlier, whereas the tables depict key variables in annual or quarterly frequency and are set up to resemble a standard FPP-type presentation across sectors.

Figure 21: Baseline Forecast – Selected Variables

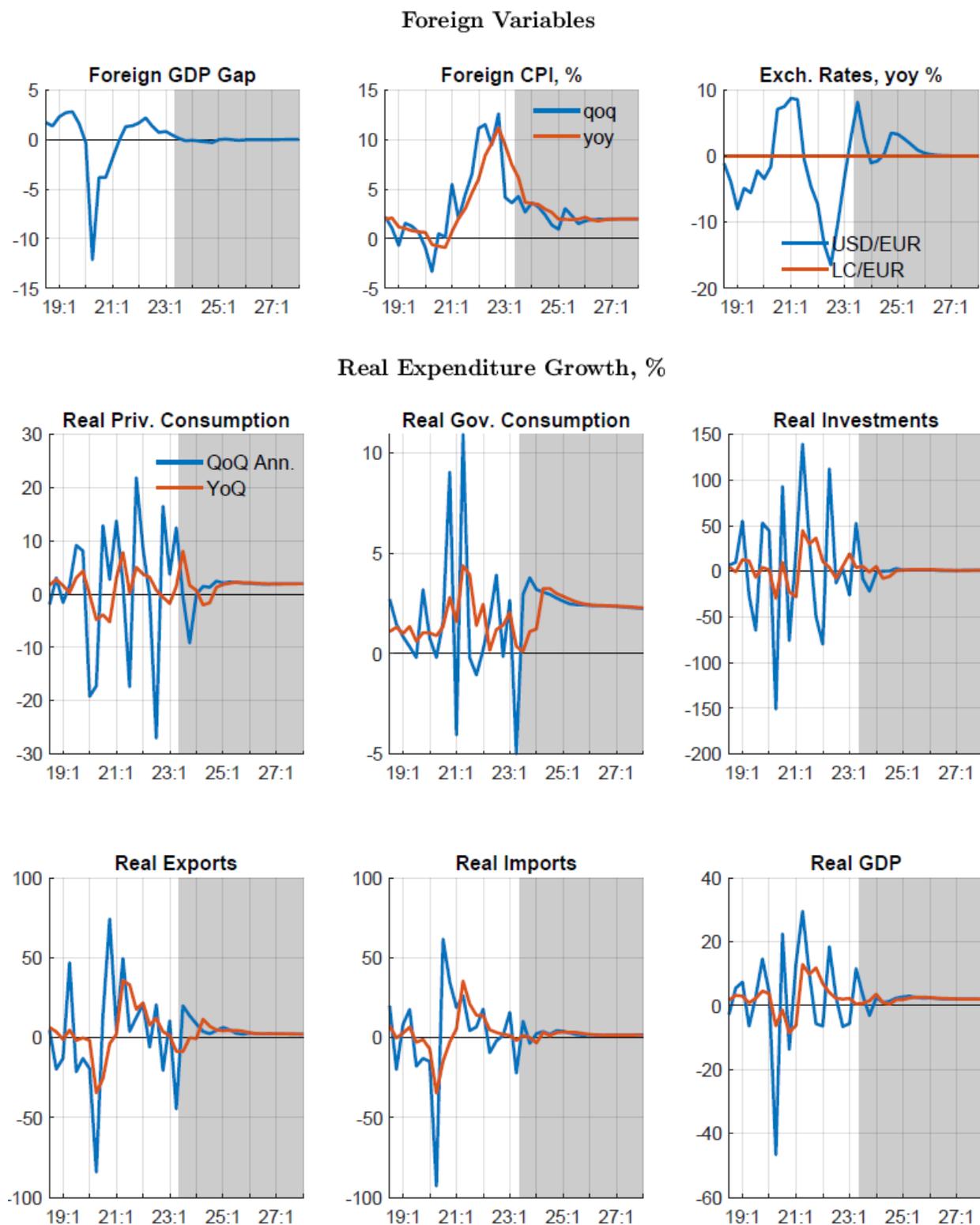


Figure 22: Baseline Forecast – Decomposition of Primary Expenditures to GDP Gap

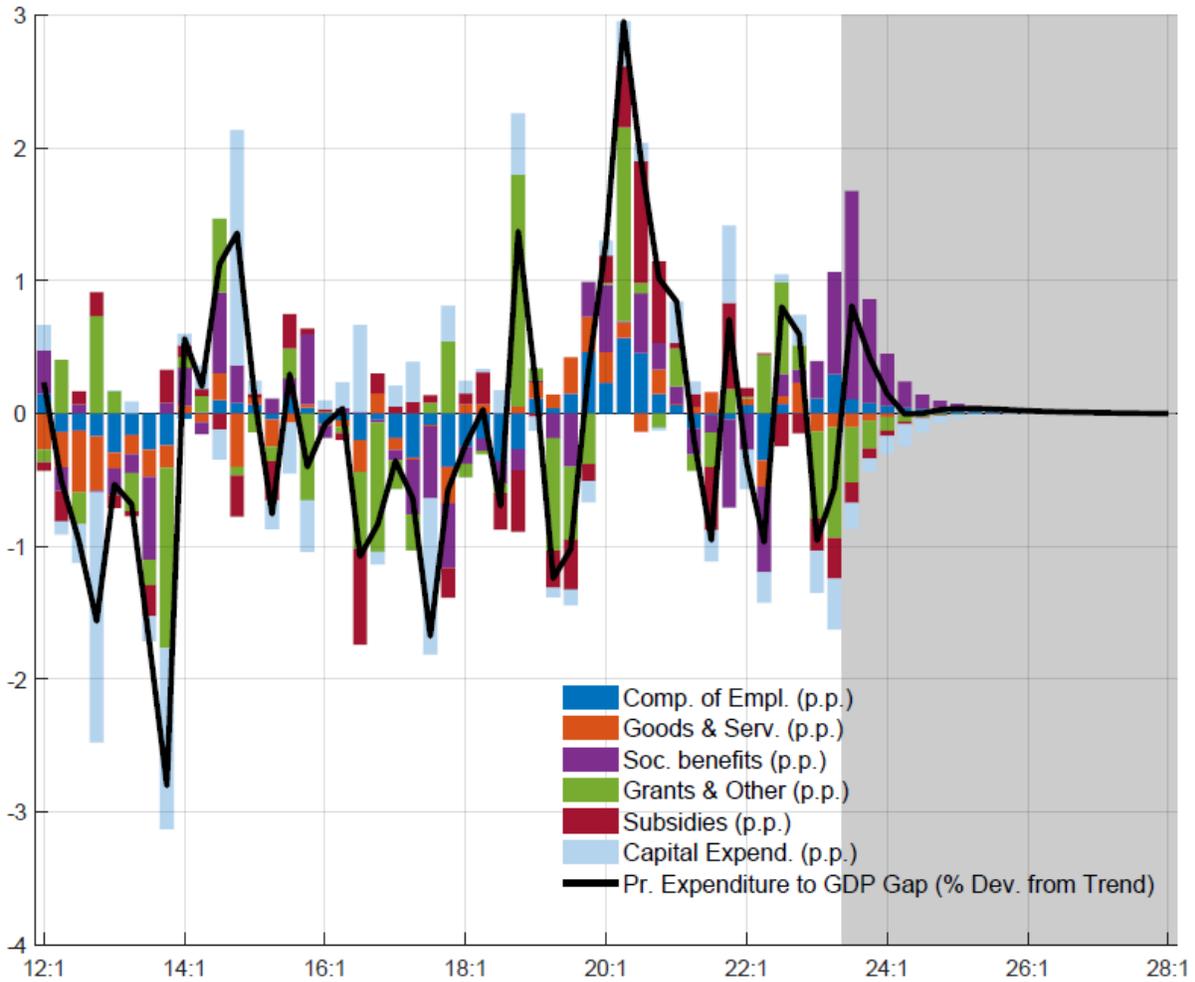


Table 1: Baseline Forecast – Selected Variables

Panel 1

		Quarterly Projections - Summary													
		22:3	22:4	23:1	23:2	23:3	23:4	24:1	24:2	24:3	24:4	25:1	25:2	25:3	25:4
<i>Real Variables</i>															
Real GDP	y-o-y	2.3	2.1	2.3	0.6	0.7	1.6	3.6	1.0	0.5	1.9	1.9	2.4	2.7	2.7
Real GDP	q-o-q (ann.)	2.7	-6.5	-5.6	11.6	3.4	-3.1	2.5	1.1	1.4	2.4	2.8	3.0	2.6	2.4
Real C	y-o-y	0.8	-0.6	-1.8	1.4	8.1	1.7	0.7	-2.0	-1.6	1.3	1.8	2.0	2.3	2.2
Real G	y-o-y	1.2	1.4	2.0	0.4	0.1	1.1	1.2	3.2	3.2	3.0	2.8	2.7	2.6	2.5
Real J	y-o-y	-7.5	5.6	19.1	4.2	5.4	-0.8	5.3	-7.7	-5.6	0.5	1.3	1.7	2.1	1.7
Real X	y-o-y	12.1	3.8	1.2	-8.5	-8.6	-0.1	-0.6	11.6	7.2	4.9	4.3	4.6	4.6	4.0
Real M	y-o-y	3.3	2.0	1.5	-1.7	1.3	0.1	-3.2	3.3	1.2	3.2	3.6	3.3	3.3	2.6
<i>HP Gaps (deviation from trend)</i>															
Output Gap	%	2.7	0.4	-1.8	0.4	0.6	-0.7	-0.7	-0.9	-1.1	-1.0	-0.8	-0.5	-0.4	-0.3
Real C Gap	%	-4.5	-0.7	-0.2	2.6	0.9	-0.1	-0.3	-0.4	-0.5	-0.5	-0.5	-0.3	-0.2	-0.2
Real G Gap	%	0.7	0.2	0.5	-1.2	-0.9	-0.4	-0.2	0.0	0.1	0.2	0.2	0.2	0.2	0.1
Real J Gap	%	4.4	3.4	-4.8	6.6	1.2	-1.9	-2.5	-2.9	-3.0	-2.7	-2.6	-2.2	-1.7	-1.3
Real X Gap	%	9.1	2.6	3.8	-8.7	-6.9	-1.8	-0.5	-0.6	-0.9	-1.1	-0.3	0.1	0.0	-0.1
Real M Gap	%	1.8	1.1	4.0	-2.6	-5.1	-1.2	-0.8	-0.7	-0.8	-0.9	-0.6	-0.4	-0.4	-0.4
<i>Interest Rates and Exchange Rates</i>															
Nominal Rate	%	2.5	3.8	4.6	5.4	5.8	6.0	5.9	5.8	5.6	5.5	5.6	5.8	5.9	5.8
Real Rate	%	-13.0	-11.2	-7.1	-0.8	1.6	3.9	3.0	3.2	4.5	4.9	6.1	6.1	5.2	4.5
Policy RIR Gap	%	-8.6	-6.4	-1.9	4.8	4.4	4.7	2.3	1.6	2.2	2.0	2.9	2.6	1.6	0.8
Real Lending Rate, HH, LC	%	-10.4	-9.8	-6.4	-0.7	1.4	4.5	4.3	5.1	7.0	7.7	9.2	9.3	8.5	7.8
Real Lending Rate, NFC, LC	%	-12.2	-11.1	-7.8	-2.2	-0.0	3.2	3.0	3.9	5.8	6.6	8.1	8.2	7.5	6.8
<i>Exchange Rates</i>															
Real Exch Rate Gap (Non-Oil)	%	5.5	3.8	-0.8	-4.6	-0.8	-0.4	0.3	-0.5	-0.9	-0.5	-0.2	0.2	0.3	0.2
Real Exch Rate Gap (Oil)	%	31.1	23.2	12.2	5.1	48.6	-1.8	-9.4	-8.3	-9.0	-3.1	-1.5	-0.8	-0.4	-0.2
Nominal LC/EUR XR	level	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Nominal LC/EUR XR	y-o-y	0.0	0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Panel 2

Yearly Projections - GDP and Prices, % y-o-y

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2040	2050
<i>Real Variables, %ch</i>														
GDP	3.6	3.9	3.4	2.7	-3.0	7.1	3.8	1.3	1.7	2.4	2.4	2.0	2.0	2.0
Priv. Consumption	2.2	1.4	2.2	2.3	-3.5	4.0	1.8	2.3	-0.4	2.1	2.0	2.0	2.0	2.0
Gov. Consumption	-0.1	1.4	1.3	1.0	1.5	2.8	1.3	0.9	2.7	2.7	2.4	2.1	2.0	2.0
Investments	11.8	10.9	4.0	5.8	-9.3	20.8	2.7	6.5	-2.0	1.7	1.5	1.6	2.0	2.0
Exports	9.0	11.2	7.1	0.5	-16.0	21.9	11.2	-3.9	5.7	4.4	2.7	2.0	2.0	2.0
Imports	7.0	7.4	3.9	1.4	-14.4	18.7	5.9	0.3	1.1	3.2	1.8	1.9	2.0	2.0
<i>Contributions, in pp.</i>														
Priv. Consumption	1.6	1.0	1.6	1.7	-2.5	2.9	1.3	1.4	-0.2	1.4	1.4	1.3	1.3	1.3
Gov. Consumption	-0.0	0.3	0.3	0.2	0.3	0.5	0.3	0.1	0.5	0.5	0.5	0.4	0.4	0.4
Investments	2.6	2.6	1.0	1.4	-2.2	5.4	0.8	1.7	-0.5	0.5	0.4	0.4	0.5	0.5
Exports	3.1	4.2	2.8	0.2	-5.7	8.2	4.7	-1.7	2.4	1.9	1.1	0.9	0.9	0.9
Imports	-3.7	-4.1	-2.2	-0.8	7.2	-9.9	-3.2	-0.3	-0.5	-1.8	-1.0	-1.0	-1.1	-1.1
Dom. Demand	4.2	3.9	2.8	3.3	-4.4	8.8	2.3	3.3	-0.2	2.3	2.2	2.1	2.2	2.2
Net Exports	-0.5	0.1	0.6	-0.6	1.5	-1.7	1.5	-2.0	1.9	0.1	0.2	-0.1	-0.2	-0.2
<i>Nominal Variables, %ch</i>														
GDP	4.2	4.8	5.2	4.4	-2.7	11.8	12.9	8.3	1.4	2.7	4.1	4.0	4.0	4.0
Priv. Consumption	2.0	2.6	3.7	4.0	-3.5	6.5	14.2	9.3	1.0	2.3	3.7	4.0	4.0	4.0
Gov. Consumption	-0.4	1.3	3.9	3.7	3.9	5.3	11.4	7.4	1.9	3.0	4.1	4.1	4.0	4.0
Investments	9.2	13.1	5.3	6.7	-10.7	24.4	20.7	10.0	0.6	1.8	3.2	3.6	4.0	4.0
Exports	6.8	16.6	10.6	0.6	-17.6	32.7	27.6	-5.0	4.8	4.8	4.4	4.0	4.0	4.0
Imports	3.0	12.3	6.7	1.7	-15.8	23.8	29.1	-0.3	3.5	3.5	3.5	3.9	4.0	4.0
<i>Prices & Deflators, %ch.</i>														
CPI Inflation	-1.6	0.8	1.4	0.6	-1.1	2.0	13.1	5.9	1.8	0.3	1.7	2.0	2.0	2.0
GDP	0.5	0.8	1.8	1.7	0.3	4.7	9.0	7.1	-0.3	0.3	1.7	2.0	2.0	2.0
Priv. Cons.	-0.2	1.2	1.5	1.6	-0.0	2.5	12.5	6.9	1.5	0.3	1.7	2.0	2.0	2.0
Gov. Cons.	-0.3	-0.0	2.6	2.7	2.4	2.4	10.1	6.5	-0.8	0.3	1.7	2.0	2.0	2.0
Investments	-2.6	2.2	1.3	1.0	-1.6	3.7	17.6	4.0	2.7	0.2	1.7	2.0	2.0	2.0
Exports	-2.3	5.4	3.5	0.1	-1.8	10.9	16.5	-1.0	-1.0	0.4	1.7	2.0	2.0	2.0
Imports	-4.1	4.9	2.8	0.3	-1.4	4.9	23.4	-0.6	2.3	0.3	1.8	2.0	2.0	2.0

Panel 3

Monetary Survey - Amounts in mill. LC														
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2040	2050
Net Foreign Assets	9604	10668	12331	13781	15803	18863	19003	20008	22032	23467	25200	34590	68689	119790
Foreign Assets	11942	13125	15252	16789	18028	20716	20721	21497	23326	24657	26407	36603	74593	131599
Foreign Liabilities	2338	2457	2921	3009	2225	1854	1718	1489	1293	1189	1207	2013	5904	11809
Net Domestic Assets	10454	11292	11682	12346	12215	12388	13974	15308	15766	16993	18069	21376	30000	42673
Domestic Credit	16966	17914	18560	19593	19563	19790	21160	22874	23116	24442	25973	33171	57322	93369
Claims on CG, net	87	-163	-481	-696	-254	-811	-525	-129	-799	-572	-258	1959	10829	24186
Claims on CG	1681	1722	1834	2103	2536	2582	2641	2633	2097	2279	2530	4304	11399	22085
Liabilities on CG	1594	1885	2315	2798	2790	3393	3167	2762	2896	2851	2788	2345	571	-2101
Other Items Net	-6516	-6605	-6885	-7267	-7364	-7405	-7203	-7575	-7359	-7458	-7913	-11804	-27332	-50706
Broad Money, M2	20058	21960	24013	26127	28018	31251	32977	35316	37799	40460	43270	55966	98688	162463
Currency Outside Banks	3378	3627	3961	4314	5028	5516	6108	6448	6896	7343	7793	9715	16021	25422
Deposits	16680	18332	20052	21813	22989	25735	26869	28868	30902	33117	35477	46251	82668	137042
Memorandum Items														
Velocity (GDP/eop M2)	0.40	0.39	0.37	0.36	0.32	0.33	0.36	0.35	0.33	0.32	0.31	0.29	0.24	0.22
Currency/Broad Money, %	16.8	16.5	16.5	16.5	17.9	17.6	18.5	18.3	18.2	18.1	18.0	17.4	16.2	15.6
CB NFA/Mon. Base, %	115.0	113.2	112.8	114.2	113.3	113.5	107.8	105.5	107.1	104.3	103.2	107.9	120.6	126.6
Broad Money, %yoy	8.0	9.1	8.9	8.4	7.0	10.9	5.4	6.9	6.8	6.8	6.7	6.3	5.3	4.8
Claims on non-Gov, %yoy	3.3	7.1	5.4	6.5	-2.6	3.8	5.2	6.1	3.5	4.1	4.5	4.1	4.0	4.0
Loans to Households, %yoy	3.6	6.4	6.9	7.5	-0.8	5.3	5.1	6.3	3.1	2.7	3.7	4.0	4.0	4.0
Loans to Priv. NFC, %yoy	3.8	7.7	3.7	4.7	-5.0	2.2	4.3	5.4	0.4	2.9	3.6	4.0	4.0	4.0
Broad Money, % of GDP	63.4	66.2	68.7	71.5	78.8	78.1	72.5	71.4	75.4	78.5	80.6	88.7	104.8	115.7
DMB Deposits, % of GDP	52.6	55.1	57.0	59.2	64.0	63.6	58.5	58.3	61.6	64.2	66.0	73.0	87.1	96.6
Claims on non-Gov, % of GDP	51.8	53.0	53.1	54.2	54.3	50.1	46.4	45.4	46.3	47.0	47.2	47.7	47.6	47.6
ow Loans to Households, % of GDP	25.7	26.1	26.6	27.4	27.9	26.2	24.2	23.7	24.1	24.2	24.1	24.1	24.1	24.1
ow Loans to Priv. NFC, % of GDP	24.4	25.1	24.7	24.8	24.3	22.0	20.2	19.7	19.5	19.5	19.4	19.4	19.4	19.4

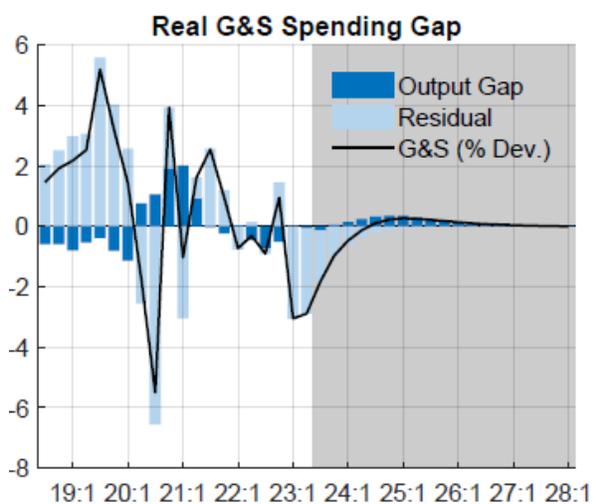
5.2. Alternative Scenarios

Alternative scenarios can be incorporated into the forecast via a transparent adjustment of residuals in the respective equations. The residuals are calculated based on the alternative paths set for the respective variables. In other words, alternative scenarios are technically incorporated into the forecast in the same manner as other additional information, i.e. nowcasts/NTF or off-model information discussed in the previous section.

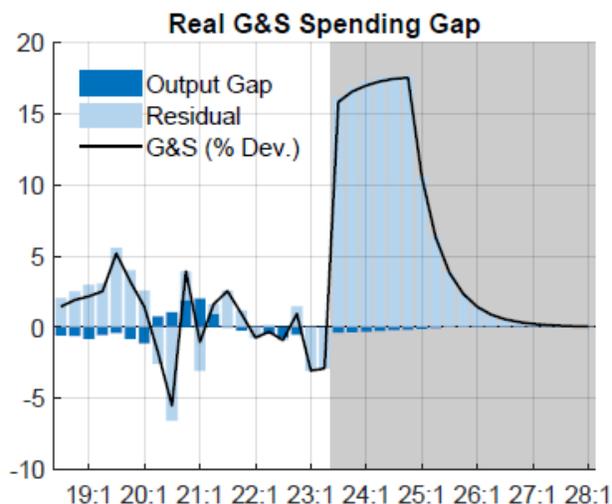
As an example of an alternative scenario, one might explore the impact on the forecast for BiH if the government increases spending on goods and services by one percentage point of GDP over the next six quarters. This is incorporated by imposing so-called hard tunes, i.e. endogenizing residuals in the equation. However, when comparing the decompositions of this variable in the baseline forecast and the alternative scenario (Figure 23), it becomes evident that the latter requires implausibly large shocks, which are unprecedented in history. While technically residuals of any size can be implemented, this can serve as a cross-check for the size of residuals and consequently for the plausibility of the alternative scenario itself. A similar check can be carried out when adding nowcasts/NTF to the baseline forecast – implausibly large shocks usually signal implausible assumptions.

Figure 23: Gap Decomposition of Real Spending on Goods and Services

Baseline forecast

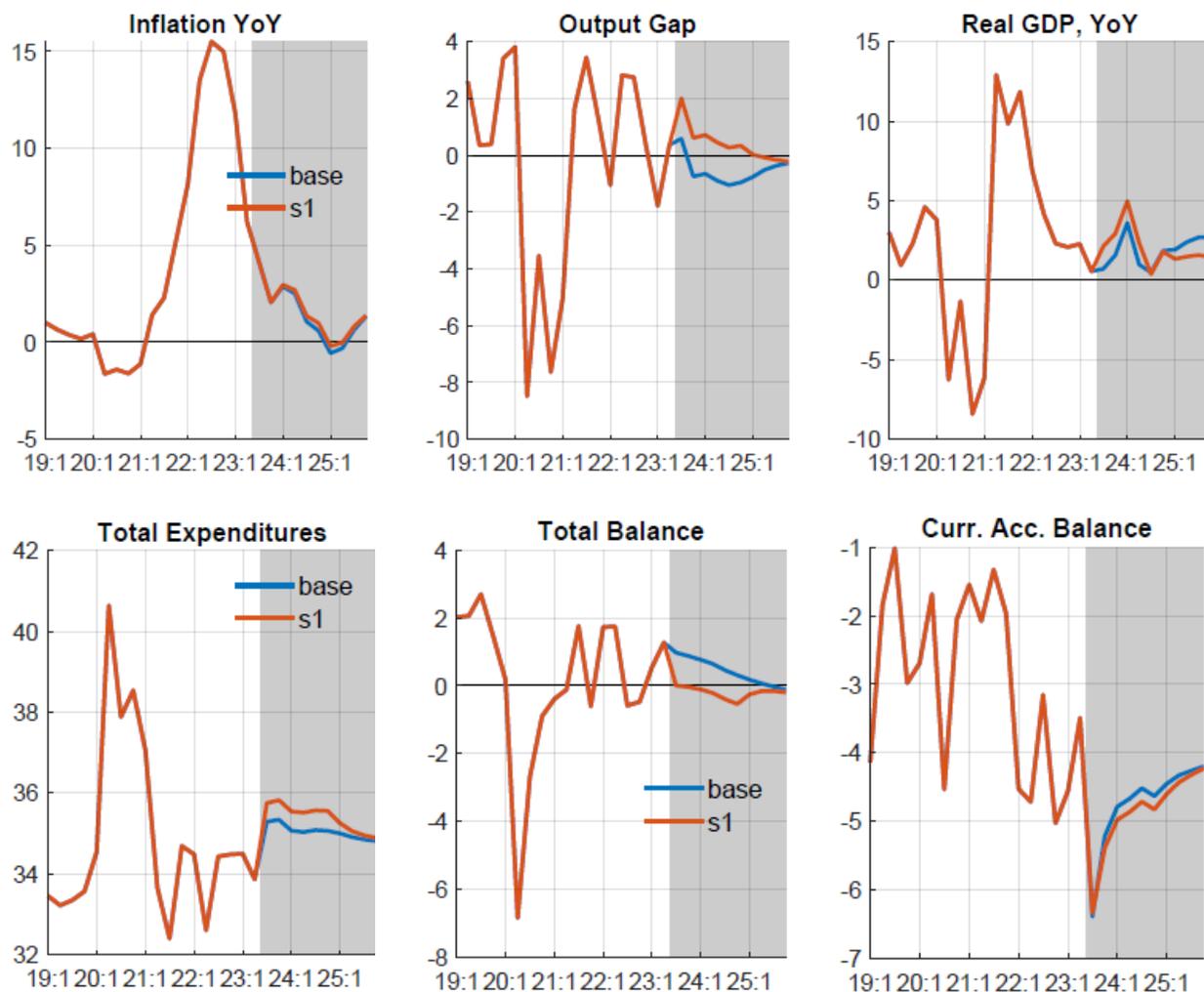


Alternative scenario



A more detailed comparison between the baseline forecast and the alternative scenario (or different forecast vintages) is also possible. Figure 24 shows comparison graphs for some of the key variables for the baseline and alternative scenarios discussed previously. As expected, with higher spending on goods and services in the second half of 2023 and in 2024, total budget expenditures are higher, and the budget balance is much lower. This results in higher aggregate demand and GDP growth, and slightly higher inflation in 2024. However, because of the relatively high import dependence of Bosnia and Herzegovina, the current account deficit is bigger.

Figure 24: Comparison of the Baseline Forecast and the Alternative Scenario – Selected Variables³⁹



³⁹ Total expenditures, total budget balance and the current account balance are all shown as shares of GDP.

6. Closing Remarks

This paper introduces the Quarterly Macro Forecasting Framework (QMFF) - a novel approach for macroeconomic policy analysis and forecasting and presents its application to the economy of Bosnia and Herzegovina. The framework is driven by a standard QPM that serves as an “engine” for an FPP framework covering all key segments of the economy; effectively it can be viewed as model-based FPP. The QMFF has a flexible set-up allowing to accommodate alternative exchange rate regimes as well as enabling incorporating both adaptive and model-consistent forward-looking expectations.

The combination of QPM and FPP approaches preserves the advantage of the tractability of the class of QPM models, while offering the macroeconomic consistency and high granularity of the FPP frameworks. The interaction between the two building blocks of the QMFF (the core macro-model and the sectors covered by FPP) ensures that changes in fiscal policy, monetary policy or the external sector feed into the real economy and vice versa. The model converges to a well-defined steady state and the explicit work with trends in real variables and relative prices results in a balanced growth path and stable expenditure shares relative to nominal GDP. These properties make the QMFF suitable for many emerging markets and developing economies that would like to develop a macroframework with potentially granular fiscal, external and monetary sectors feeding into policy decisions.

Finally, the framework is highly efficient in a forecasting and policy analysis context as it is supported by an extensive reporting system and provides flexibility in terms of incorporating off-model information into the forecast. Consequently, it is straightforward to use QMFF for generating sensitivity analyses or alternative scenarios, which are important inputs to informed policy discussions.

The QMFF has been implemented on the case of Bosnia and Herzegovina. The model structure and the granularity of the FPP framework reflect the stylized facts of the BiH economy, data availability and preferences of the CBBH to conduct policy simulations and forecasts at a sufficient analytic depth. The model was brought to data via iterative calibration steps. Specifically, using BiH data, the paper presents practical suggestions on some desired model properties that are plausible and easily applicable for a wide range of countries. Moreover, we present how the model structure and calibration were tested, using impulse response analysis, shock decompositions and in-sample simulations. The presented results indicate that the model captures some important business cycle properties observed in the BiH economy and tracks the historical data in in-sample simulations reasonably well.

Finally, the paper presents how QMFF can be applied in a practical policy process. Specifically, we show how the automatized database system, including data transformations for all model variables, is used to enhance productivity. The advantages of the reporting system are illustrated by specific examples of model diagnostics and forecast output. They underpin the analytical and forecasting work entering the decision-making process. In addition, we also present how the framework is suited for easy and transparent incorporation of expert judgement and off-model information and for generating alternative and scenarios.

Annexes

Annex A. Deriving Trends Consistent with Balanced Growth Path and National Accounts Identity Specified in Terms of Gaps

This annex includes the derivation of the trends of the real variables of the QMFF. They are a function of potential GDP and two independent trends in relative prices, so that the resulting trends of real variables of QMFF are consistent with constant nominal national accounts' expenditure ratios to GDP in the long run.

Let's introduce the following notations:

P^Y, P^C, P^M = GDP, private consumption and import deflators.

P^{NO}, P^O = non-oil and oil import prices, respectively, expressed in domestic currency.

Y, C = real GDP, real private consumption, respectively.

T^Y, T^C = trends in real GDP and real private consumption, respectively

$T^{\frac{P^{NO}}{P^Y}}$ = trend in the relative prices $\frac{P^{NO}}{P^Y}$ and $\frac{P^O}{P^{NO}}$

We assume that consumption goods are produced using a constant share of domestic intermediate products and imported goods, therefore the consumption deflator will be a function of the domestic value-added price, captured by the GDP deflator, and import prices, captured by the import deflator. Specifically, we assume:

$$P^C = (P^Y)^{\alpha^{CY}} \cdot (P^{NO})^{\alpha^{CNO}} \cdot (P^O)^{\alpha^{CO}} \cdot \exp(\varepsilon^{P^C})$$

where α^{CY} is the domestic value-added share, α^{CNO} is the non-oil import share, $1 - \alpha^{CY} - \alpha^{CNO}$ is the oil import share of C, that is $\alpha^{CO} = 1 - \alpha^{CY} - \alpha^{CNO}$.

Be aware of one of the implications of the homogeneity condition, used later in the derivations of model-based equations: $1 - \alpha^{CY} = \alpha^{CNO} + \alpha^{CO}$.

The relative price of consumption deflator to GDP deflator, therefore, can be expressed as follows:

$$\frac{\frac{P^C \cdot C}{P^Y \cdot T^Y}}{T^{Csh}} = \frac{\frac{\frac{P^C}{P^Y} \cdot T^{PY} \cdot \frac{C}{T^C} \cdot T^C}{T^{PY}}}{T^{Csh}}$$

where T^Ω is the trend of real variable Ω ; where $\Omega = Y, C, G, J, X, M$.

T^{Csh} is the trend that stationarizes the nominal C to nominal Y ratio.

$$\frac{P^C}{P^Y} = \frac{(P^Y)^{\alpha^{CY}} \cdot (P^{NO})^{\alpha^{CNO}} \cdot (P^O)^{\alpha^{CO}} \cdot \exp(\varepsilon^{PC})}{P^Y} = \frac{(P^Y)^{\alpha^{CY}} \cdot (P^{NO})^{\alpha^{CNO}} \cdot (P^O)^{\alpha^{CO}} \cdot \exp(\varepsilon^{PC})}{(P^Y)^{\alpha^{CY}} \cdot (P^Y)^{1-\alpha^{CY}}} =$$

$$= \frac{(P^{NO})^{\alpha^{CNO}} \cdot (P^O)^{\alpha^{CO}} \cdot \exp(\varepsilon^{PC})}{(P^Y)^{1-\alpha^{CY}}} =$$

$$\frac{(P^{NO})^{1-\alpha^{CY}} \cdot (P^O)^{\alpha^{CO}} \cdot \exp(\varepsilon^{PC})}{(P^Y)^{1-\alpha^{CY}} \cdot (P^{NO})^{1-\alpha^{CY}-\alpha^{CNO}}} = \left(\frac{P^{NO}}{P^Y}\right)^{1-\alpha^{CY}} \frac{(P^O)^{\alpha^{CO}} \cdot \exp(\varepsilon^{PC})}{(P^{NO})^{1-\alpha^{CY}-\alpha^{CNO}}} = \left(\frac{P^{NO}}{P^Y}\right)^{1-\alpha^{CY}} \cdot \left(\frac{P^O}{P^{NO}}\right)^{\alpha^{CO}} \cdot \exp(\varepsilon^{PC})$$

Let's denote $\frac{P^{NO}}{P^Y} = Q^{NO}$ and the trend in Q^{NO} as $T^{Q^{NO}}$; $\frac{P^O}{P^{NO}} = Q^O$ and the trend in Q^O as T^{Q^O} .

$$\frac{P^C}{P^Y} = (Q^{NO})^{1-\alpha^{CY}} \cdot (Q^O)^{\alpha^{CO}} \cdot \exp(\varepsilon^{PC}) \rightarrow T^{\frac{P^C}{P^Y}} = (T^{Q^{NO}})^{1-\alpha^{CY}} \cdot (T^{Q^O})^{\alpha^{CO}}$$

$$\frac{\frac{P^C \cdot C}{P^Y \cdot T^C}}{T^{C_{sh}}} = \dots = \frac{\frac{Q^{NO}^{1-\alpha^{CY}} \cdot Q^O^{\alpha^{CO}}}{(T^{Q^{NO}})^{1-\alpha^{CY}} \cdot (T^{Q^O})^{\alpha^{CO}}} \cdot ((T^{Q^{NO}})^{1-\alpha^{CY}} \cdot (T^{Q^O})^{\alpha^{CO}} \cdot \frac{C}{T^C} \cdot \frac{T^C}{T^Y})}{T^{C_{sh}}}$$

$$= \left(\left(\frac{Q^{NO}}{T^{Q^{NO}}} \right)^{1-\alpha^{CY}} \cdot \left(\frac{Q^O}{T^{Q^O}} \right)^{\alpha^{CO}} \cdot \frac{C}{T^C} \right) \cdot \frac{((T^{Q^{NO}})^{1-\alpha^{CY}} \cdot (T^{Q^O})^{\alpha^{CO}} \cdot T^C}{T^{C_{sh}} \cdot T^Y}$$

Since $T^{C_{sh}}$ stationarizes the nominal C to Y ratio, then $\frac{((T^{Q^{NO}})^{1-\alpha^{CY}} \cdot (T^{Q^O})^{\alpha^{CO}} \cdot T^C}{T^{C_{sh}} \cdot T^Y} = sh^C$

$\rightarrow sh^C T^{C_{sh}} = \frac{((T^{Q^{NO}})^{1-\alpha^{CY}} \cdot (T^{Q^O})^{\alpha^{CO}} \cdot T^C}{T^Y}$, or in logarithmic form:

$$\log(T^C) = \log(T^Y) - (1 - \alpha^{CY}) \cdot \log(T^{Q^{NO}}) - \alpha^{CO} \cdot \log(T^{Q^O}) + \log(sh^C) + \log(T^{C_{sh}})$$

Stationarity of $\frac{\frac{P^C \cdot C}{P^Y \cdot T^Y}}{T^{C_{sh}}}$ around sh^C in the long run requires, $T^{C_{sh}} = 1 \rightarrow$

$$\log(T^{C_{sh}}) = (1 - \alpha^{CY}) \cdot \log(T^{Q^{NO}}) + \alpha^{CO} \cdot \log(T^{Q^O}) + \log(T^C) - \log(T^Y) - \log(sh^C)$$

The log-linearization of $\frac{\frac{P^C \cdot C}{P^Y \cdot T^Y}}{T^{C_{sh}}}$ then yields:

$$sh^C \cdot ((1 - \alpha^{CY}) \cdot Q^{NO\,gap} + \alpha^{CO} \cdot Q^{O\,gap} + C^{gap})$$

where sh^C is the steady-state share of nominal C on nominal Y.

Based on the derivation above, let's list the key trend equations derived above that are included into the model for any real variable Ω_t :

$$\log(T_t^\Omega) = \log(T_t^Y) - (1 - \alpha^{\Omega Y}) \cdot \log(T^{Q^{NO}}) - \alpha^{\Omega O} \cdot \log(T^{Q^O}) + \log(sh^\Omega) + dis_t^{T^\Omega}$$

$$\Delta dis_t^{T^\Omega} = \varrho_1 \cdot \Delta dis_{t-1}^{T^\Omega} - \varrho_2 \cdot dis_{t-1}^{T^\Omega} + \varepsilon^{\Delta dis T^\Omega}$$

$$\Omega_t^{gap} = \log(\Omega_t^n) - \log(T_t^{\Omega 2Y^n})$$

$$\Omega 2Y_t^n = \log(\Omega_t) + \log(T_t^\Omega) - (\log(P_t^Y) + \log(T_t^Y))$$

$$T_t^{\Omega 2Y^n} = (1 - \alpha^{\Omega Y}) \cdot \log(T^{Q^{NO}}) + \alpha^{\Omega O} \cdot \log(T^{Q^O}) + \log(T_t^\Omega) - \log(T_t^Y) + dis_t^{T^{\Omega 2Y^n}}$$

$$dis_t^{T^{\Omega 2Y^n}} = \varrho_3 \cdot dis_{t-1}^{T^{\Omega 2Y^n}} + \varepsilon^{\Delta dis T^{\Omega 2Y^n}}$$

$$\Omega 2Y_t^{ngap} = \Omega 2Y_t^n - T_t^{\Omega 2Y^n}$$

Note that $\varepsilon^{\Delta dis T^\Omega}$ resp. $dis_t^{T^{\Omega 2Y^n}}$ are discrepancies identified in HP filtered trends of T^Ω resp. $T^{\Omega 2Y^n}$ relative to the trends theoretically derived above. Equations

$$\Delta dis_t^{T^\Omega} = \varrho_1 \cdot \Delta dis_{t-1}^{T^\Omega} - \varrho_2 \cdot dis_{t-1}^{T^\Omega} + \varepsilon^{\Delta dis T^\Omega} \text{ and } dis_t^{T^{\Omega 2Y^n}} = \varrho_3 \cdot dis_{t-1}^{T^{\Omega 2Y^n}} + \varepsilon^{\Delta dis T^{\Omega 2Y^n}}$$

ensure that these discrepancies gradually converge to zero, without large one-time jumps. The convergence of these discrepancies to zero is a necessary condition for the balanced growth path properties of QMFF.

Finally, the derivations above make it possible to derive the national accounts identity in terms of gaps.

$$\text{Let's remind that } \frac{P^C \cdot C}{P^Y \cdot T^Y} = \left(\left(\frac{Q^{NO}}{T^{Q^{NO}}} \right)^{1-\alpha^{CY}} \cdot \left(\frac{Q^O}{T^{Q^O}} \right)^{\alpha^{CO}} \cdot \frac{C}{T^C} \right) \cdot \frac{((T^{Q^{NO}})^{1-\alpha^{CY}} \cdot (T^{Q^O})^{\alpha^{CO}} \cdot T^C)}{T^Y}$$

The log-linearization of $\frac{P^C \cdot C}{P^Y \cdot T^Y}$, therefore, yields: $sh^C \cdot ((1 - \alpha^{CY}) \cdot Q^{NO gap} + \alpha^{CO} \cdot Q^{CO gap} + C^{gap})$, where sh^C is the steady-state share of nominal C on nominal Y.

The national accounts identity is defined as follows:

$$P^Y \cdot Y = P^C \cdot C + P^G \cdot G + P^J \cdot J + P^X \cdot X - P^M \cdot M$$

where: Y, C, G, J, X, M are real GDP, private consumption, government consumption, investment, exports and imports, respectively, and P^Y, P^C, P^G, P^J, P^X are corresponding deflators.

After dividing both sides by $P^Y \cdot T^Y$ and log-linearization of all expenditure items (identically as it was done for C above) we get the following:

$$\begin{aligned} Y^{gap} &= sh^C \cdot ((1 - \alpha^{CY}) \cdot Q^{NO gap} + \alpha^{CO} \cdot Q^{CO gap} + C^{gap}) + sh^G \cdot ((1 - \alpha^{GY}) \cdot Q^{NO gap} + \alpha^{GO} \cdot Q^{GO gap} + G^{gap}) + sh^J \cdot \\ &((1 - \alpha^{JY}) \cdot Q^{NO gap} + \alpha^{JO} \cdot Q^{JO gap} + J^{gap}) + sh^X \cdot ((1 - \alpha^{XY}) \cdot Q^{NO gap} + \alpha^{XO} \cdot Q^{XO gap} + CX^{gap}) - sh^M \cdot \\ &\left(\frac{sh^{MNO}}{sh^M} \cdot Q^{NO gap} + \frac{sh^{MO}}{sh^M} \cdot Q^{O gap} + M^{gap} \right) = \dots \end{aligned}$$

$$= sh^C \cdot C^{gap} + sh^G \cdot G^{gap} + sh^J \cdot J^{gap} + sh^X \cdot X^{gap} - sh^M M^{gap} + (sh^C \cdot (1 - \alpha^{CY}) + sh^G \cdot (1 - \alpha^{GY}) + sh^J \cdot (1 - \alpha^{JY}) + sh^X \cdot (1 - \alpha^{XY}) - sh^{MNO}) \cdot Q^{NOgap} + (sh^C \cdot \alpha^{CO} + sh^G \cdot \alpha^{GO} + sh^J \cdot \alpha^{JO} + sh^X \cdot \alpha^{XO} - sh^{MO}) \cdot Q^{COgap},$$

where $sh^{MNO} + sh^{MO} = sh^M$.

Since we assume constant import shares in consumption, government consumption, investment and exports, the total import share equals the sum of import shares of all expenditure of C, G, J and X, for both imported consumption goods $sh^{MNO} = sh^C \cdot (1 - \alpha^{CY}) + sh^G \cdot (1 - \alpha^{GY}) + sh^J \cdot (1 - \alpha^{JY}) + sh^X \cdot (1 - \alpha^{XY})$, and crude oil, $sh^{MO} = sh^C \cdot \alpha^{CO} + sh^G \cdot \alpha^{GO} + sh^J \cdot \alpha^{JO} + sh^X \cdot \alpha^{XO}$.

Consequently: $Y^{gap} = sh^C \cdot C^{gap} + sh^G \cdot G^{gap} + sh^J \cdot J^{gap} + sh^X \cdot X^{gap} - sh^M M^{gap}$

Annex B. Derivation of the Import Price Channel in the Phillips Curve

Let's define:

$Z = \frac{P^{MNO} * e}{P^Y}$, where P^{MNO} is the non-oil import price deflator, P^Y is the GDP deflator, e is the nominal exchange rate.

$Z_O = \frac{P^{MO} * e}{P^{MNO} * e} = \frac{P^{MO}}{P^{MNO}}$, where P^{MO} is the oil import price deflator.

We would like to derive the relative price of imported consumption goods (P^{MC}) to the consumption deflator (P^C), to account for the import price channel in the Phillips curve:

$$\frac{P^{MC}}{P^C} = \frac{P^{MC}}{(P^Y)^{\beta^{CY}} * (P^{MNO} * e)^{\beta^{CMNO}} * (P^{MO} * e)^{1 - \beta^{CY} - \beta^{CMNO}}} = \frac{(P^{MNO} * e)^{\beta^{MNO}} * (P^{MO} * e)^{1 - \beta^{MNO}}}{(P^Y)^{\beta^{CY}} * (P^{MNO} * e)^{\beta^{CMNO}} * (P^{MO} * e)^{1 - \beta^{CY} - \beta^{CMNO}}} =$$

$$\frac{(P^{MNO} * e)^{\beta^C}}{(P^Y)^{\beta^C}} * \frac{(P^{MNO} * e)^{\beta^{MNO}}}{(P^{MNO} * e)^{\beta^C} * (P^{MNO} * e)^{\beta^{CMNO}}} *$$

$$\frac{(P^{MO} * e)^{1 - \beta^{MNO}}}{(P^{MO} * e)^{1 - \beta^{CY} - \beta^{CMNO}}} = Z^{\beta^C} * \frac{(P^{MNO} * e)^{\beta^{MNO} - \beta^C - \beta^{CMNO}}}{(P^{MO} * e)^{(1 - \beta^{CY} - \beta^{CMNO} - 1 + \beta^{MNO})}} = Z^{\beta^C} * \frac{(P^{MNO} * e)^{\beta^{MNO} - \beta^{CY} - \beta^{CMNO}}}{(P^{MO} * e)^{\beta^{MNO} - \beta^{CY} - \beta^{CMNO}}} = Z^{\beta^{CY}} *$$

$$Z_O^{\beta^{MNO} - \beta^{CY} - \beta^{CMNO}}$$

$$\log\left(\frac{P^{MC}}{P^{YC}}\right) = \beta^{CY} * \log(Z) + (\beta^{MNO} - \beta^{CY} - \beta^{CMNO}) * \log(Z_O)$$

Annex C. Parameter Values for Bosnia and Herzegovina⁴⁰

$\rho_{dla_s} = 0.5$; $ss_{dla_s} = 0$; $ss_{fix_prem} = 2$;

$p_1 = 0$; $p_2 = 0$;

$c_1 = 0.35$; $c_2 = 0.10$; $c_3 = 0.10$; $c_4 = 0.25$; $c_5 = 0.05$;

$w_1 = 0.5$; $w_2 = 0.2$; $w_3 = 0.25$;

$b_g = 0.189$; $b_{comp_emp} = 0.087$; $b_{gs} = 0.055$; $b_{discr_g} = b_g - b_{comp_emp} - b_{gs}$;

$g_1 = 0.6$; $g_2 = 0.17$;

$g_3 = 0.6$; $g_4 = 0.17$;

$g_5 = 0.6$;

$j_1 = 0.45$; $j_2 = 0.9$; $j_3 = 0.3$; $j_4 = 0.02$; $j_5 = 0.1$; $j_6 = 0.4$;

$xg_1 = 0.2$; $xg_2 = 2$; $xg_3 = 0.3$;

$xs_1 = 0.2$; $xs_2 = 3$; $xs_3 = 0.3$;

$b_x = 0.45$; $b_{xs} = 0.11$; $b_{xg} = b_x - b_{xs}$;

$mg_1 = ms_1 = m_1 = 0.27$; $mg_2 = ms_2 = m_2 = 0.016$; $mg_3 = ms_3 = m_3 = 0.126$

$mg_4 = ms_4 = 0.588$; $mg_5 = ms_5 = m_5 = 0.3$;

$b_m = 0.574$; $b_{ms} = 0.034$; $b_{mg} = b_m - b_{ms}$;

$b_c = 0.673$; $b_g = 0.189$; $b_j = 0.262$; $b_x = 0.45$; $b_m = 0.574$;

$r_1 = 0.3$; $r_2 = 2.2$; $r_3 = 0.3$;

$f_1 = 0.2$; $f_2 = 30$;

$b_{sec_inc_gg} = 0.001$; $b_{sec_inc_pt} = 0.074$; $b_{sec_inc_social} = 0.031$;

$b_{prim_inc_emp} = 0.026$; $b_{prim_inc_oth} = 0.002$;

$b_{prim_inc_inv_gg} = -0.004$; $b_{prim_inc_inv_oth} = -0.036$;

$b_{fin_acc_fdi} = 0.028$; $b_{fin_acc_port} = -0.004$; $b_{fin_acc_oth_dep} = -0.008$;

$b_{fin_acc_oth_gg} = 0.002$; $b_{fin_acc_oth_oth} = 0.035$;

$b_{cap_acc_tot} = 0.008$; $b_{bop_errors} = 0.004$;

$v_1 = 0.3$; $v_2 = 1$;

$b_{vat} = 0.112$; $b_{excise} = 0.031$; $b_{cust} = 0.009$; $b_{indirect_oth} = 0.017$;

⁴⁰ Parameters are shown in the order in which they appear in the main text (rounded to the third decimal point). In some cases, due to the level adjustment of variables, b parameters (which are equal to steady-state ratios to GDP) are increased by a k share of nominal potential GDP (see Section 3.2). For ease of exposition, here those parameters are shown without this adjustment. As noted previously, some parameters used in the CBBH model may differ.

$b_{direct} = 0.007$; $b_{soc_con} = 0.144$; $b_{grant_rev} = 0.016$;

$b_{soc_ben} = 0.138$; $b_{grant_exp} = 0.03$; $b_{inter} = 0.005$; $b_{subs} = 0.015$; $b_{acq_nfa} = 0.017$;

$rev_ca = 0.9$; $pexpend_ca = 0.2$;

$b_{d_cb_lia_dmb} = 0.015$; $b_{fin_acc_oth_dep} = -0.008$; $b_{fin_acc_reserves} = 0.035$;

$k1 = 0.25$; $k2 = 0.15$; $k3 = 0.02$;

$k4 = 0.25$; $k5 = 0.9$; $k6 = 0.02$;

$n1 = 0.8$; $n2 = 0.3$;

$n3 = 0.8$; $n4 = 0.3$;

$a1 = 0.4$; $a3 = 0.5$; $a4 = 0.5$; $ss_dla_z_bar = 0$;

$ss_mc = 0.2$; $ss_mg = 0.05$; $ss_mj = 0.22$; $ss_mx = 0.7$;

$ss_mco = 0.03$; $ss_mgo = 0$; $ss_mjo = 0.056$; $ss_mxc = 0.05$;

$d1 = 0.6$; $d2 = 0.25$; $d3 = 0.05$; $d4 = 0.1$;

$d11 = 1$; $d21 = 0$; $d31 = 0$; $d41 = 0.5$;

$\rho_{l_gdp_rw_gap} = 0.75$; $\rho_{l_gdp_rw_gap} = 0.1$;

$\rho_{dla_cpi_rw} = 0.4$; $\rho_{dla_cpi_rw} = 0.25$; $ss_dla_cpi_rw = 2$

$\rho_{rs_rw} = 0.7$; $ss_rr_rw_bar = 2$; $\rho_{rs_rw} = 1.5$; $\rho_{rs_rw} = 0.5$;

Annex D. Variable Naming Convention

Convention	Description
l_* (small L + underscore)	The variable is expressed as a natural logarithm (multiplied by 100)
*_r	Variables in real terms, deflated with the appropriate deflator
d_*	First difference operator
*_usd; *_eur; *_lc	The currency in which the variable is expressed: USD, EUR or local currency (applied only for variables also expressed in currencies other than the local currency)
st_*	Stock variable
dla_*	Log-approximated QoQ growth rate of the variable, in annualized terms
d4l_*	Log-approximated YoY growth rate of the variable
l_*_gap	Gap of a variable
l_*_bar	Trend of a variable
*2gdp	Ratio of the variable relative to nominal GDP (in %)
*_rw	“Rest of the World” or foreign variables
ss_*	Steady-state value

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PUBLICATIONS

A Novel Quarterly Macroeconomic Forecasting Framework: Illustration on the Case of Bosnia and Herzegovina
Working Paper No. WP/2026/036