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Quarterly Projection Model for Belarus: Methodological Aspects and Practical Applications

Anatoly Kharitonchik, 2023

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ABSTRACT: The paper presents a Quarterly Projection Model (QPM) for the Belarusian economy. The model has a New Keynesian basis and considers the key characteristics of the Belarusian economy and the monetary sphere. Simulations within the QPM made it possible to study the reaction of the key Belarusian macroeconomic indicators to the impact of shocks, as well as to substantiate differences in the behavior of the economic system under the impact of shocks with different designs of monetary and exchange rate policies. The QPM application to empirical data on Belarus made it possible to assess the dynamics of unobserved macroeconomic indicators, the stance of monetary, exchange rate and fiscal policies, drivers of inflationary processes and the economic cycle. A scenario macroeconomic forecast for Belarus for 2023–2024 has been developed based on the QPM.

Keywords: QPM, model, GDP, output gap, equilibrium level, inflation, monetary policy, interest rate, exchange rate, impulse-response function, specification, calibration, simulation

JEL: E17, E32, E52, C32, C54

1. Introduction

High-quality and affordable economic analysis is highly demanded by citizens, businesses, and government agencies in the modern world. The changes in political, social, and economic conditions in Belarus and neighboring countries only increase the need for expert assessments of the current economic situation and forecasts. It is important that these assessments are supported by reliable analytical and forecasting tools. Such a toolkit should meet the requirements of adequacy to the reality being approximated, internal consistency of the results obtained, be understandable for experts and explainable for business and the public, not bulky, and as simple as possible to maintain.

The above reasoning served as motivation for the development of a Quarterly Projection Model (hereinafter referred to as QPM) for the Belarusian economy. QPM is a semi-structural gap model that is a useful tool for analyzing the current state of the economy, monetary, exchange rate and fiscal policies, macroeconomic forecasting, as well as simulations of scenarios for changing approaches to implementing economic policy. QPM-type models have gained widespread use in the environment of international organizations, as well as central banks, as they provide effective decision-making support in the field of monetary policy.[1]

QPM has a flexible structure that allows incorporating expert judgments, is relatively simple to maintain, enables to explain the story of what is happening in the economy in a clear and internally consistent way, to form forecast scenarios, and to develop recommendations for the application of certain measures of economic policy.

Unlike econometric models, QPM has a more reliable theoretical justification, generally based on microeconomic principles. Unlike full structural models (hereinafter referred to as DSGE), strict structural constraints are not imposed on the parameters of semi-structural models, and most microeconomic variables are approximated by macroeconomic indicators. In conditions of limited statistical data for the Belarusian economy and the presence of multiple structural shifts, estimating structural parameters is significantly difficult.

In addition to the non-strict adherence to microeconomic foundations, one of the limitations of the QPM proposed in this study is its linearity. This makes it difficult to estimate unobserved variables over a deep historical period characterized by changes in monetary

[1] See: Demidenko et al., 2016, Benes et al., 2017, Musil et al., 2018, Bokan & Ravnik, 2018, Hlédic et al., 2018, Grui & Vdovychenko, 2019, Abradu-Otoo et al., 2022.

and exchange rate policies in Belarus. The linear form of the model does not allow for different specifications of equations and parameter calibration for different time periods. Therefore, we focus more on the recent period, as reliable estimation of the current economic conditions is critical for forecasting.

We expand the typical "canonical" QPM structure to account for the specifics of the Belarusian economy. The model proposed in this study incorporates: 1) the influence of foreign trade operations and deepening isolation of the Belarusian financial sector on the dynamics of the Belarusian ruble exchange rate and domestic interest rates; 2) the National Bank of Belarus' (hereinafter referred to as National Bank) conduct of partially non-sterilized FX interventions to smooth the dynamics of the exchange rate; 3) only partial control of the National Bank over the short-term money market interest rate; 4) incomplete and prolonged transmission of changes in the short-term money market interest rate to lending and deposit rates; 5) the impact of fiscal policy and active state regulation of wages on economic activity; 6) differences in the driving forces of core and non-core inflation; 7) the impact on the domestic economy of not one, but several countries – key economic partners of Belarus.

Application of the QPM to empirical data allowed for the justification of Belarus's entry into recession in late 2021 and its significant deepening under the impact of tightening sanctions by Western countries in the first half of 2022. At the same time, the potential GDP growth of Belarus dropped to around 0% in the second quarter of 2022, and its recovery to a sustainable pace of 1% per year may take several years. Despite the weakness of domestic demand, inflationary processes intensified in the first half of 2022 due to an explosive increase in inflation expectations against the backdrop of increased uncertainty and risks, as well as an increase in the undervaluation of the Belarusian ruble in terms of the real effective exchange rate (hereinafter referred to as REER). Lending and deposit market interest rates in 2022 fell below their neutral levels due to the restrained reaction of the National Bank to the inflation shock.

Based on the QPM, a scenario macroeconomic forecast has been developed for Belarus for 2023-2024. The baseline scenario assumes the continuation of existing sanction restrictions, moderate weakening of business activity in Belarus' trade partner countries, and gradual reduction of external inflationary pressure. Approaches to the implementation of domestic economic policy will remain unchanged, with no significant increase in unsecured money emission being considered. Simulations within the framework of the baseline scenario show that as the economy adapts to sanctions, Belarus can demonstrate weak recovery GDP growth of about 0.4% and 1.4% in 2023 and 2024, respectively. Inflation will remain above the target due to increased inflationary expectations and is forecast to be around 8-10% in 2023-2024. A gradual return of REER to equilibrium level is expected in 2023-2024 as the trade surplus decreases.

An alternative scenario assumes the continuation of passive monetary policy and a significant increase in unsecured money emission in 2023. This could provide average GDP growth of around 2.3% in 2023-2024, but inflation could approach 10% by the end of 2023 and 15% in 2024. As a result, rising prices will begin to suppress economic activity, and by the second half of 2024, the Belarusian economy will move into recession.

In the following sections we discuss the basic methodological aspects of building the QPM for the Belarusian economy and test the model on empirical data. Section 2 presents the typical "canonical" structure of QPM and the main characteristics of the model. The accumulated experience of applying QPM to the economy of Belarus is studied in section 3. Section 4 presents the basic specification of the QPM for the Belarusian economy and discusses issues related to the calibration of model parameters. The verification of the QPM parameter calibration, including an analysis of impulse-response functions of key macroeconomic indicators to shocks, is presented in section 5. The retrospective dynamics of key macroeconomic indicators are discussed in section 6. Section 7 provides an application of the QPM for scenario forecasting. The conclusions are drawn in section 8.

2. Methodological aspects of QPM

Mathematically, QPM is a system of equations that represents a steady state of the economy, satisfying equilibrium conditions in the long run. QPM is based on reduced-form (log-linear) equations of a complete Dynamic Stochastic General Equilibrium (DSGE) model. This means that the key equations in QPM have an economic interpretation. However, some components of QPM are ad-hoc elements, which distinguishes it from DSGE. For example, QPM has a rudimentary supply block, where most trends (equilibrium components) of economic variables are represented as stochastic processes that guarantee convergence of indicators to an exogenously defined steady state in the medium term (Berg et al., 2006a). Moreover, QPM parameters are not derived from structural parameters, such as the discount rate or the elasticity of intertemporal substitution, but are directly calibrated or, less frequently, estimated. As a result, the QPM structure does not fully satisfy the relevant market clearing conditions and consistency of stocks and flows (Mæhle et al., 2021). Therefore, QPM is often referred to as a semi-structural model. Its advantages over full

DSGE models lie in greater flexibility in approximating empirical data and accounting for country-specific features, as well as simplifying work with the model.

QPM is a gap model (Mæhle et al., 2021). The key equations in QPM are presented in deviations (gaps) of macroeconomic variables from their equilibrium levels, where equilibrium is defined as a level of an economic indicator that does not exert upward or downward pressure on inflation (inflation level corresponds to inflation expectations).

Overall, QPM combines the main ideas of the New Keynesian theory regarding market imperfections and the presence of nominal and real rigidities in the economy, and the New Neoclassical Macroeconomics and Real Business Cycle theory, which include rational expectations in DSGE models.

The key characteristics of QPM can be systematized as follows:

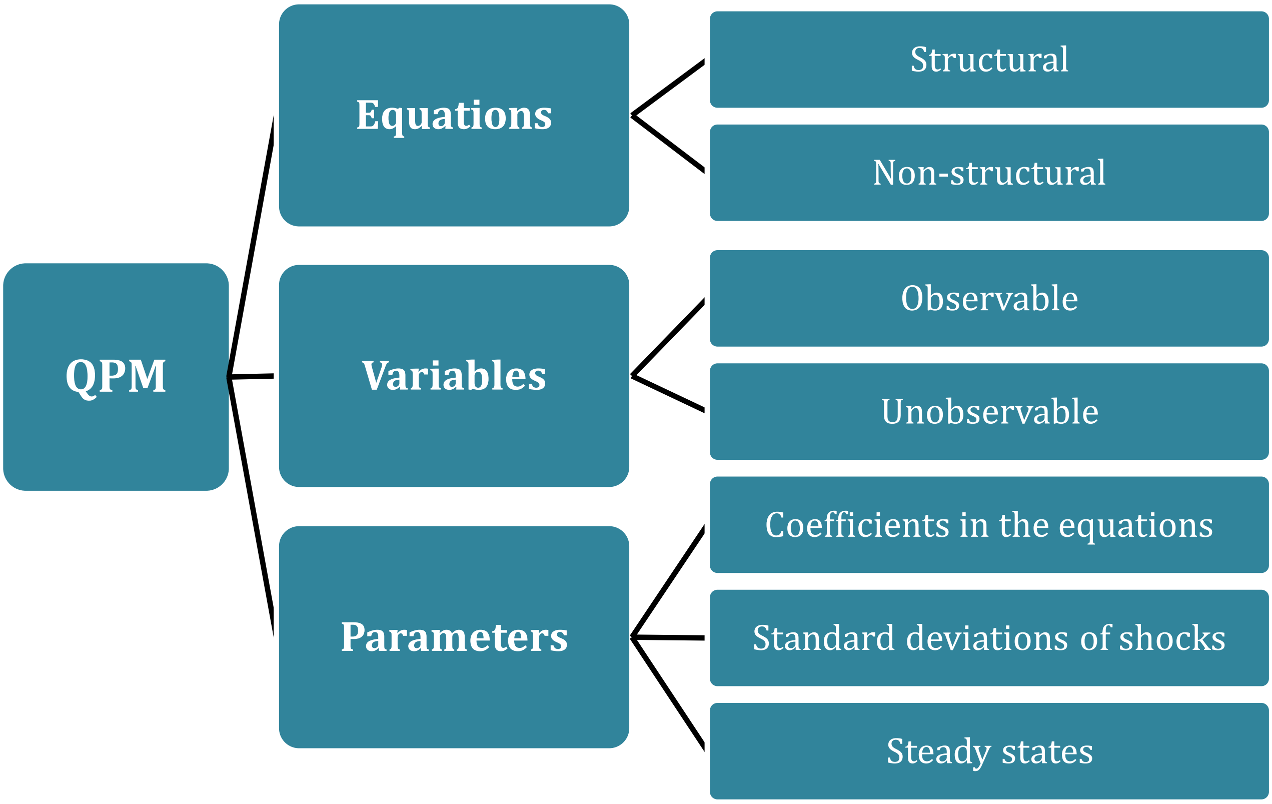
- semi-structural gap model. QPM analyzes cycles (gaps) around trends and works with flows. Structural equations have an economic interpretation. Trends are modeled as stochastic processes converging to a sustainable levels;
- general equilibrium model. QPM has an exogenously determined steady state of the economic system as a whole, rather than its individual sectors or markets;
- New Keynesian foundation. QPM incorporates price and wage rigidity as well as imperfect markets;
- stochastic model. Structural shocks present in QPM equations;
- forward-looking structure. Rational (model-consistent) expectations are given great importance in QPM structural equations.

Structurally, QPM consists of three elements: variables, equations, and parameters (Figure 1). QPM contains two types of variables: observable and unobservable.[2] Observable variables are measurable based on statistical data. These include GDP, inflation, nominal interest rates, and exchange rates. Unobservable variables cannot be measured based on hard data. However, identifying them is essential to our understanding of the current state of the country's economy. We can identify three groups of unobservable variables. Equilibrium components of time series of variables approximate their trend dynamics, which are determined by structural economic factors. Gaps represent deviations of actual variables from equilibrium levels,

[2] QPM variables are presented in natural logarithms times 100, except for interest rates and growth rates, which are presented in annualized percentages or percentage points. Seasonality is preliminarily eliminated in the time series of QPM variables.

and their dynamics are determined by cyclical factors. Shocks are also unobservable variables identified within QPM due to its stochastic nature. Examples of unobservable variables include potential (or equilibrium) GDP, output gap (deviation of actual GDP from equilibrium), equilibrium exchange rate, neutral interest rate, and others. Special econometric methods, with the most common being filtering methods, are used to estimate unobservable variables. In QPM, a multivariate Kalman filter is typically used.

Figure 1: QPM structure



Source: developed by the author based on materials from the International Monetary Fund (hereinafter referred to as the IMF).

QPM equations specify a model and are divided into structural and non-structural ones. Structural equations have an economic interpretation and are based on the full DSGE model equations. A typical (or "canonical") QPM specification for small open economies contains four structural equations (Berg et al., 2006a; 2006b; Mæhle et al., 2021):

- an aggregate demand equation (1) approximated by the output gap ($\hat{y}_t$), which is the deviation of real GDP (y_t) from potential (equilibrium) level ($\bar{y}_t$). The output gap is determined by persistence ($\hat{y}_{t-1}$) and rational expectations ($E_t\hat{y}_{t+1}$), the monetary conditions index (mci_t), which is a weighted combination of gaps of money market real interest rate and the real effective exchange rate (with the opposite sign when using direct quotes), foreign output gap ($\hat{y}_t^*$), and demand shock ($\varepsilon_t^{\hat{y}}$):

$$\hat{y}_t = a_1\hat{y}_{t-1} + a_2E_t\hat{y}_{t+1} - a_3mci_t + a_4\hat{y}_t^* + \varepsilon_t^{\hat{y}}. \quad (1)$$

- New Keynesian Phillips curve (2), which determines the dynamics of inflation (π_t). Inflation is measured as the annualized change in the consumer price index over the quarter. Inflation is determined by the persistence (π_{t-1}), rational expectations ($E_t\pi_{t+1}$), real marginal costs (rmc_t), approximated by a weighted combination of output gap and the real effective exchange rate gap, and an inflation shock (ε_t^{π}):

$$\pi_t = b_1E_t\pi_{t+1} + (1 - b_1) * \pi_{t-1} + b_3rmc_t + \varepsilon_t^{\pi}. \quad (2)$$

- The uncovered interest rate parity condition (3), which determines the dynamics of the nominal exchange rate (s_t).[3] Typically, a direct quotation of the national currency per unit of foreign currency is used. The exchange rate is determined by expectations of its level in the future period (E_ts_{t+1}), the difference between interest rates on assets in the national (i_t) and foreign currencies (i_t^*), adjusted for a risk premium ($prem_t$), and an exchange rate shock (ε_t^s):

$$s_t = E_ts_{t+1} + \frac{i_t^* - i_t + prem_t}{4} + \varepsilon_t^s. \quad (3)$$

- The monetary policy reaction function (4), which determines the dynamics of the nominal interest rate in the money market (i_t). It is assumed that forward-looking monetary policy is implemented, aimed at stabilizing inflation at the target level and smoothing the business cycle. The level of the relevant interest rate in the current period is established based on its neutral level (i_t^n), the expected deviation of inflation from the target ($E_t\pi_{t+4}^4 - \pi_{t+4}^T$), and the current output gap ($\hat{y}_t$). The inertia component (i_{t-1}) allows for the observed practice of central banks avoiding sharp changes in the interest rate, while the shock (ε_t^i) represents discretionary actions by monetary authorities:

$$i_t = c_1i_{t-1} + (1 - c_1) * (i_t^n + c_2 * (E_t\pi_{t+4}^4 - \pi_{t+4}^T) + c_3\hat{y}_t) + \varepsilon_t^i. \quad (4)$$

Non-structural equations of the model include equations that describe the dynamics of the equilibrium components of time series. With rare exceptions, equilibrium components are modeled as stochastic processes with an exogenously determined sustainable

[3] In Berg et al., 2006a, 2006b, the uncovered interest rate parity condition is written in real terms.

level.[4] In addition, non-structural equations can include equations that calculate changes in variables, as well as identities.

QPM contains three groups of parameters. Firstly, these are the coefficients in the equations for the variables that determine the dynamic properties of the model. For example, the coefficient a_3 determines the influence of monetary conditions on the output gap, and the coefficient b_3 determines the degree of costs pass-through to prices. Secondly, these are the standard deviations of shocks, which determine the volatility of unobservable variables. For example, the ratio of the standard deviations of demand shocks ($\varepsilon_t^{\hat{y}}$) and inflation (ε_t^{π}) will have a significant impact on the dynamics of the output gap and its correlation with inflation. And thirdly, these are the sustainable values of the variables that determine the steady state of the model. For example, the sustainable growth rate of real GDP to which the actual GDP growth will converge in a steady state.

This section presents a typical structure of QPM. In practice, it can be expanded to take into account country-specific features. As noted by Mæhle et al. (2021), various country specific QPMs incorporate effects of fiscal policy and changes in terms of trade on aggregate demand, multiple Phillips curves (for core inflation, regulated or energy prices, etc.), a block of money supply under actual monetary targeting, persistence in exchange rates dynamics and their various regimes, etc.

3. Application of QPM to the Belarusian economy

QPM-type models for the Belarusian economy began to be used in the second half of the 2000s. M. Demidenko (2008) presented a QPM that describes the functioning of three transmission channels: interest rate, exchange rate, and partially expectations. An important characteristic of the model is the inclusion of the fixed exchange rate regime that was used in Belarus in the first decade of the 21st century. Otherwise, the model adhered to typical specifications and was used at the National Bank until the mid-2010s.

In 2013-2014, the Eurasian Economic Commission (EEC) jointly with the Eurasian Development Bank (EDB) developed an Integrated System of Models (ISM) for

[4] Exceptions include the real equilibrium interest rate, which, as a rule, is modeled either through the real version of the uncovered interest rate parity condition, or through linking the equilibrium rate with the dynamics of the equilibrium GDP.

macroeconomic analysis and forecasting in the EAEU (Demidenko et al., 2016). The ISM consists of interconnected QPMs for the EAEU countries and the external sector. The structure of the country-specific QPMs, including for the Belarusian economy, is presented in five blocks: 1) aggregate demand; 2) aggregate supply; 3) monetary policy rule; 4) uncovered interest rate parity condition; 5) fiscal impulse. The ISM is currently used by the EEC and EDB for macroeconomic analysis and forecasting. However, the changes in the functioning conditions of the Belarusian and Russian economies in 2022 require the re-specification and recalibration of country specific QPMs, at least to account for the changed approaches to the implementation of monetary and exchange rate policies.

In 2017-2018, the National Bank of the Republic of Belarus, with the support of an IMF technical mission, implemented an updated Forecasting and Policy Analysis System. The core of this system became a QPM with a typical structure, supplemented by a block on bank credit dollarization and an intermediate target of monetary policy – broad money. This model is currently used to support decision-making in the area of monetary policy at the National Bank. However, due to the National Bank's explicit departure from maintaining interest rates at levels that would achieve the inflation target (which is also indirectly assumed when using the monetary base as the operational target of policy) and the increasing isolation of Belarus' financial sector, the specifications of the monetary policy reaction function and the equation for the exchange rate require modification. To the best of our knowledge, no such modifications have been made to the QPM to date. It should be noted that the participants of the technical mission of the IMF, K. Musil, M. Pranovich, and J. Vlček, presented a QPM for Belarus, which, among other things, included a block on the fiscal sector and directive lending (Musil et. al, 2018). However, this version was ultimately not used by the National Bank, as the fiscal sector and directive lending are not represented in the National Bank's model.[5]

A feature of the QPM developed by A. Bezborodova and J. Vlček (2018) is the consideration of the term structure of interest rates in the Belarusian economy. A. Bezborodova and J. Vlček concluded that the interest rate channel of the transmission mechanism in the Republic of Belarus is functional and found that long-term interest rates for legal entities are more responsive to changes in the interbank market interest rate (hereinafter referred to as IBL rate) compared to long-term interest rates for individuals. Otherwise, the specification is typical for models of countries with a small open economy,

[5] For the QPM model of the National Bank of Belarus, see (in Russ.): https://www.nbrb.by/mp/theoretical-materials/model-srednesrochnogo-proektirovaniya-mp.pdf.

inflation targeting, and free capital flows. The developed model was not used by the National Bank for forecasting and monetary policy design but was used as a tool to verify the results of filtering unobservable variables over the historical range.

A. Kharitonchik (2020) presented a QPM for the Belarusian economy that takes into account four channels of the monetary policy transmission mechanism (interest rate, credit, exchange rate, and expectations), nonlinearity and asymmetry of the exchange rate pass-through effect on inflation, and an endogenous process of forming inflation expectations dependent on the trust of economic agents in monetary authorities. The complex structure of the model allows for the study of the monetary policy transmission mechanism but makes the model difficult to apply to estimate unobservable variables on historical data and forecasting.

QPMs were also developed for Belarus (Mironchik et al., 2018; Kuznetsov et al., 2020), which have specifications similar to the Laubach-Williams model (Laubach & Williams, 2003). These models were used to estimate the neutral interest rate in the Republic of Belarus, as well as other unobservable variables in the EDB member states.

Previously developed QPM versions for the Belarusian economy need to be rethought with the consideration of the internal and external economic changes that have occurred. From a model specification perspective, it is necessary to consider at least the following aspects.

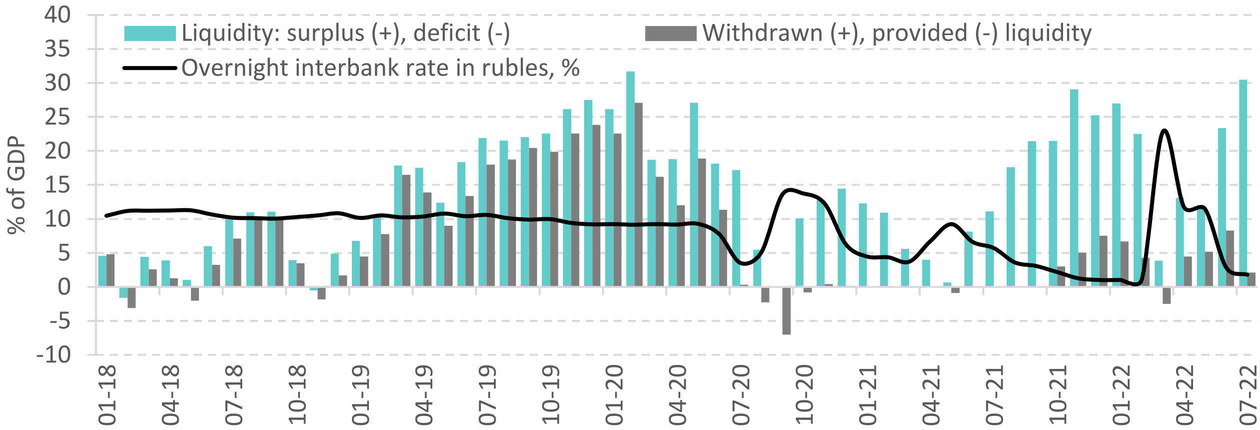
Firstly, since mid-2020, the National Bank has effectively abandoned the policy of maintaining the money market rate at levels that would correspond to achieving the inflation target in the medium term. Since mid-2020, the National Bank has introduced restrictions on liquidity regulation operations in the banking system, and since July 6, 2022, it has effectively abstained from regulating liquidity with standard tools.[6] As a result, in 2020-2022, the volatility of the IBL rate has significantly increased, and under conditions of a structural liquidity surplus in the banking system, it could remain close to the zero mark for a long time (Figure 2).

The dynamics of the money market indicate that the balance of liquidity supply and demand is being achieved directly by the market, and the National Bank only intervenes during periods of shock impact on the economy. This may also mean that the National Bank is not actively seeking to maintain the money supply at a level that corresponds to achieving the inflation target, as envisaged by the monetary targeting regime. It is entirely possible to assume that such a policy of the National Bank is dictated by pressure from the government, which

[6] From July 6, 2022, the National Bank suspended auction operations to regulate liquidity. See more (in Russ.): https://www.nbrb.by/info/about_auction_operations.

requires accelerating the pace of economic growth through monetary emission. The National Bank's departure from regulating the liquidity of the banking system in the face of its significant surplus may be indicative, designed to emphasize the inefficiency of emission as a source of sustainable economic growth under structural institutional constraints. If this hypothesis is correct and economic activity in Belarus remains weak in 2023 with increased inflation, then a gradual return to interest rate management policy and inflation control by the National Bank can be expected in 2023-2024.

Figure 2: The state of liquidity of the banking system in Belarus in 2018–2022



Source: author's calculations based on data from the National Bank of Belarus, Belstat.

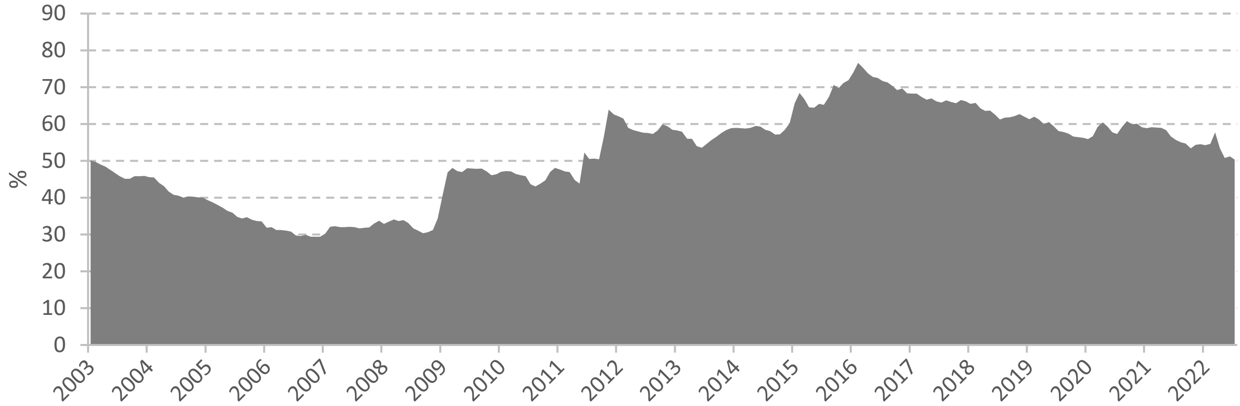
Secondly, the introduction of sanctions in 2020-2022 against the real and financial sectors of the Belarusian economy strengthens the isolation of the financial system.[7] Conducting financial transactions is difficult, and placing government securities on western capital markets is practically impossible. This makes the concept of uncovered interest rate parity not entirely suitable for modeling the dynamics of the Belarusian ruble exchange rate and requires taking into account foreign trade operations and the National Bank's FX interventions. At the same time, the differential of interest rates on assets in national and foreign currency may remain a significant factor in exchange rate formation due to the high dollarization of deposits in Belarus and the increasing importance of Russia as an economic partner (see figures 3 and 4).

[7] For the EU sanctions policy towards Belarus, see: https://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-against-belarus/.

For the US sanctions policy towards Belarus, see: https://home.treasury.gov/policy-issues/financial-sanctions/sanctions-programs-and-country-information/belarus-sanctions.

For the UK sanctions policy towards Belarus, see: https://www.gov.uk/government/publications/financial-sanctions-belarus.

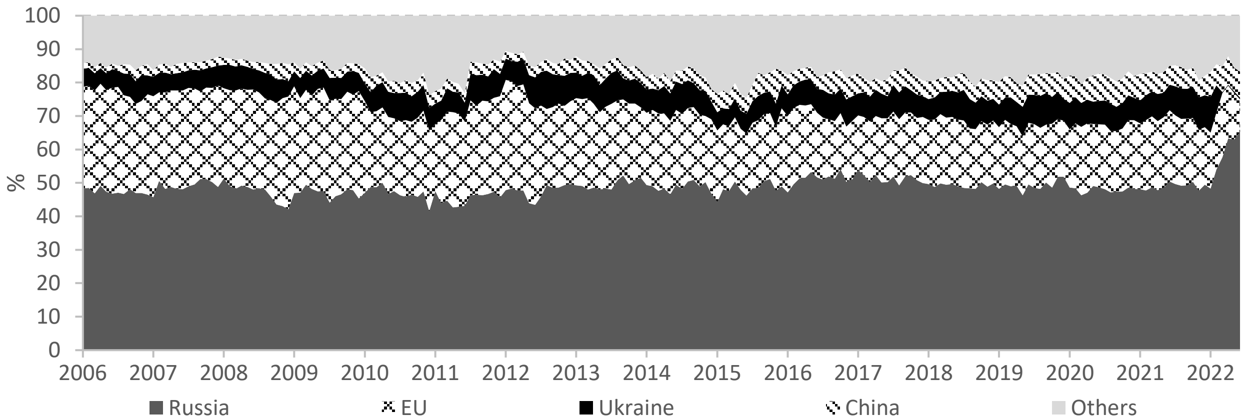
Figure 3: The share of the foreign exchange component in the broad money in Belarus



Source: author's calculations based on data from the National Bank of Belarus.

Thirdly, the deepening financial isolation of the Belarusian economy reduces the significance of external factors in shaping the real equilibrium interest rate. In all developed models, except for the model of A. Bezborodova and J. Vlček (2018), the equilibrium rate was modeled through the real version of the uncovered interest rate parity. In the conditions that have emerged by the end of 2022, it is more justified to model the equilibrium rate through its linkage to potential GDP and the real equilibrium exchange rate.

Figure 4: Country structure of foreign trade turnover of goods in Belarus

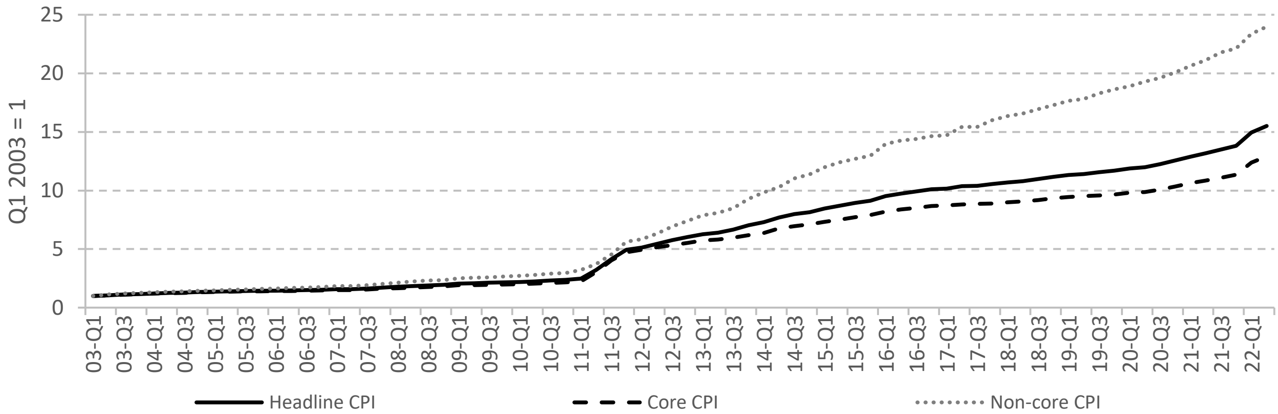


Source: author's calculations based on data from the Belstat.

Fourthly, in 2020-2022 fiscal policy played an active role in the Belarusian economy. In 2020, significant support was provided to agricultural organizations, in 2021 to the Belarusian metallurgical plant, and in 2022 state banks were recapitalized. In all QPM models developed for Belarus previously, except for the EEC and EDB ISM, the fiscal sector was absent.

Fifthly, administrative price regulation is widely used in Belarus. Only in the model of the National Bank and one of its preliminary versions presented by experts from the IMF technical mission (Musil et al., 2018), inflation is divided into core and non-core components. Such a division is important for the correct identification of unobserved variables, as core and non-core inflation are formed under the influence of different factors, and for most of the historical period there has been a trend of faster growth in the non-core component (Figure 5).

Figure 5: Dynamics of relative prices in Belarus



Source: author's calculations based on data from the National Bank of Belarus, Belstat.

4. QPM structure for Belarus

The QPM for Belarus consists of eight blocks, four of which are typical for models of small open economies, and four are specific.

4.1 Aggregate demand

The block of aggregate demand describes the dynamics of the output gap ($\hat{y}_t$), which represents the deviation of real GDP (y_t) from its potential (equilibrium) level ($\bar{y}_t$)[8]:

$$y_t = \bar{y}_t + \hat{y}_t. \tag{5}$$

Equilibrium GDP is modeled as a random walk process with drift (6), while the growth of equilibrium GDP ($\Delta\bar{y}_t$) is represented as an autoregressive process (7), which ensures convergence of GDP growth rate to a sustainable level (Δy_{ss}) in the long run.

[8] Variables in QPM are presented as 100 * natural logarithm, except for interest rates and growth rates, which are presented in annualized percentages. For example, the annualized real GDP growth (Δy_t) is calculated using the formula: $\Delta y_t = 4 * (y_t - y_{t-1})$. All variables in QPM (except for nominal interest rates, nominal exchange rates and oil prices) are preliminary adjusted for seasonality.

$$\bar{y}_t = \bar{y}_{t-1} + \Delta\bar{y}_t/4 + \varepsilon_t^{\bar{y}}, \tag{6}$$

$$\Delta\bar{y}_t = ab_1\Delta\bar{y}_{t-1} + (1 - ab_1) * \Delta\bar{y}_{ss} + \varepsilon_t^{\Delta\bar{y}}. \tag{7}$$

This specification of equilibrium GDP is designed to account for two types of shocks that affect its dynamics. First, there is a shock to the level of equilibrium GDP ($\varepsilon_t^{\bar{y}}$), which leads to an instantaneous shift in the level of equilibrium GDP. After the shock period, the dynamics of the indicator return to the trend trajectory. Second, there is a shock to the growth rate of equilibrium GDP ($\varepsilon_t^{\Delta\bar{y}}$), which leads to a prolonged deviation of the growth rate of equilibrium output from its sustainable value. The distinction between these two types of shocks simplifies the estimation of unobserved variables in shock periods, especially in 2022, when the GDP of Belarus experienced a sharp decline due to sanction measures.

The sustainable growth rate of GDP ($\Delta\bar{y}_{ss}$) is calibrated at 1%, which is close to the average growth rate of GDP in Belarus from 2014-2021 and corresponds to estimates by international financial organizations.[9] The parameter ab_1 is set at 0.90, as equilibrium components typically exhibit smoothed dynamics and high inertia.

The output gap approximates the state of the economic cycle and is modeled in accordance with equation (8):

$$\hat{y}_t = a_1\hat{y}_{t-1} + a_2E_t\hat{y}_{t+1} - a_3mci_{t-1} + a_4\hat{y}_t^* + a_5r\widehat{wage}_{t-1} + a_6fi_t + \varepsilon_t^{\hat{y}}. \tag{8}$$

The key factors driving output gap are monetary conditions (mci_t), fiscal impulse (fi_t), real wages gap ($r\widehat{wage}_t$), and external demand ($\hat{y}_t^*$). As some economic agents may make decisions based on rational expectations, equation (8) includes the variable of expected output gap ($E_t\hat{y}_{t+1}$). The inertia component ($\hat{y}_{t-1}$) is incorporated into equation (8) due to the prolonged impact of economic factors on output gap. The demand shock ($\varepsilon_t^{\hat{y}}$) approximates the impact on output gap of factors not unaccounted directly in the model. Parameters a_1, a_2, a_3, a_4, a_5, a_6 are calibrated to 0.50, 0.10, 0.20, 0.30, 0.10, and 0.10, respectively.

Monetary conditions approximate the impact of monetary and exchange rate policies on economic activity through two main transmission channels: interest rate and exchange rate.

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[9] See: IMF Republic of Belarus: Staff Concluding Statement of the 2021 Article IV Mission (URL: https://www.imf.org/en/News/Articles/2021/12/17/republic-of-belarus-staff-concluding-statement-of-the-2021-article-iv-mission); Vinokurov et al., 2022.

$$mci_t = m_1 * (m_2\hat{r}_t + m_3\widehat{r\_l}_t + (1 - m_2 - m_3) * \widehat{r\_d}_t) - (1 - m_1) * \hat{z}_t. \quad (9)$$

In the developed model, according to equation (9), monetary conditions are a weighted combination of the components of the interest rate and the REER. Positive values of monetary conditions indicate their restraining effect on economic activity, while negative values indicate a stimulative effect.

The interest rate component characterizes the state of the interest rate policy of the National Bank and commercial banks, and is calculated as a weighted arithmetic average of the gaps between real interest rates on assets denominated in Belarusian rubles: IBL ($\hat{r}_t$), newly issued market loans ($\widehat{r\_l}_t$), and new time deposits ($\widehat{r\_d}_t$).

Positive gaps in interest rates on loans and deposits indicate that real interest rates exceed their equilibrium (neutral) levels. This indicates that real interest rates are higher than the marginal return on capital (in the form of production or savings). In such conditions, investment and consumption in the current period will bring less utility compared to the future, which, all else being equal, should lead to a slowdown in their growth rates in the short term.

The IBL gap is added to the monetary conditions index to take into account the possible impact of the central bank's monetary policy on non-price lending conditions. Thus, it is quite possible that during a prolonged period of excess liquidity in the banking system, which is not absorbed by the central bank, banks will begin to lower their lending requirements and expand their lending range to minimize missed opportunities. Thus, the inclusion of the IBL gap in the monetary conditions index allows for an indirect consideration of the functioning of the credit channel of monetary transmission.

The REER ($\hat{z}_t$) gap approximates the intra-temporal substitution between imported and non-imported goods, as well as the price competitiveness of Belarusian producers. An excess of the actual REER level over the equilibrium level indicates undervaluation of the Belarusian ruble. This means that foreign goods become more expensive compared to domestic ones, which stimulates Belarusian exports and consumption of domestic products within the country. As a result, other things being equal, GDP growth rates accelerate.

The weight of the interest rate component in the monetary conditions index (m_1) is assumed to be 0.50, which is close to the degree of dollarization of banking contracts in

Belarus.[10] Moreover, such calibration generally corresponds to the comparative significance of the GDP response to interest rate and exchange rate shocks, as estimated from empirical data.[11] The parameter m_2 is calibrated at 0.20, which is close to the estimate of the significance of the credit channel in the response of lending to a monetary policy impulse.[12] The parameter m_3 is assumed to be 0.40.

4.2 Fiscal sector and wages

Due to limited statistical data on the Belarusian budget and the tendency to truncate them, calculations and modeling of the structural budget balance within the QPM framework are heavily impeded. We use one of the possible specifications for the fiscal block proposed in the IMF study (Mæhle et al., 2021). The approach consists of using the deviation of real non-interest government spending[13] (rfx_t) from its equilibrium level ($\overline{rfx}$), i.e., the budget expenditure gap ($\widehat{rfx}_t$), to determine the fiscal impulse (fi_t). Due to the prolonged influence of fiscal policy on economic activity, we average the values of the budget expenditure gap over four consecutive quarters and use the resulting indicator as the fiscal impulse. The change in real equilibrium government spending ($\Delta\overline{rfx}_t$) is modeled as an autoregressive process with convergence to a sustainable growth rate ($\Delta\overline{rfx}_{ss}$), assumed to be 1%, the same as the growth rate of equilibrium GDP.[14] Parameters f_1 and f_2 are calibrated to be 0.50 and 0.90, respectively.

$$rfx_t = \widehat{rfx}_t + \overline{rfx}_t, \tag{10}$$

$$\widehat{rfx}_t = f_1\widehat{rfx}_{t-1} + \varepsilon_t^{\widehat{rfx}}, \tag{11}$$

$$\Delta\overline{rfx}_t = f_2\Delta\overline{rfx}_{t-1} + (1 - f_2) * \Delta\overline{rfx}_{ss} + \varepsilon_t^{\Delta\overline{rfx}}, \tag{12}$$

$$fi_t = (\widehat{rfx}_t + \widehat{rfx}_{t-1} + \widehat{rfx}_{t-2} + \widehat{rfx}_{t-3})/4. \tag{13}$$

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[10] As of October 1, 2022, 38% of the claims of the Belarusian financial sector on other sectors and 55.3% of deposits placed in the financial sector were denominated in foreign currency.

[11] See: Kharitonchik & Dmitriev, 2018.

[12] See: Kharitonchik & Utseshava, 2019.

[13] The real expenditures of the consolidated budget of the Belarusian general government are calculated by adjusting nominal expenditures for the GDP deflator.

[14] The ratio of nominal non-interest budget expenditures to the nominal GDP of Belarus has been quite stable since 2017 and fluctuated around 36%.

Wages are included in the model due to the significant role of administrative influence on their level and changes in the Belarusian economy (Miksjuk et al., 2015). We assume that nominal wages ($wage_t$) are sticky and model their growth ($\Delta wage_t$) similar to the Phillips curve in the specification proposed in Musil et al. (2018):

$$\Delta wage_t = aa_1 E_t \Delta wage_{t+1} + (1 - aa_1) * \Delta wage_{t-1} + aa_2 \hat{y}_t - aa_3\, r\widehat{wag}e_{t-1} + \varepsilon_t^{\Delta wage}. \qquad (14)$$

According to equation (14), the dynamics of wages depends on the cyclical position of the economy, which is approximated by the output gap. The coefficient aa_2 is calibrated to 0.25, which determines the rigidity of nominal wages. The dynamics of nominal wages have a negative correlation with the real wages gap ($\widehat{rwage}_t$), meaning that it accelerates if real wages ($rwage_t$) are below their equilibrium level ($\overline{rwage}_t$), and decelerates otherwise. The equation (14) also includes components of rational expectations ($E_t \Delta wage_{t+1}$) and inertia ($\Delta wage_{t-1}$) as factors explaining the dynamics of wages. Factors not directly included in equation (14) are approximated by a shock to the growth of nominal wages ($\varepsilon_t^{\Delta wage}$). The parameters aa_1 and aa_3 are calibrated to 0.50, as in Musil et al. (2018).

Real wages, as defined by equation (15), are calculated by adjusting nominal wages for the consumer price index (cpi_t) and are decomposed into unobservable components: the real wages gap and the equilibrium wages, according to equation (16). The wages gap is included in the output gap equations (8) as a factor of domestic demand and in the equations for core inflation (24-25) as a determinant of domestic inflationary pressure.

The change in the equilibrium real wages ($\Delta\overline{rwage}_t$) is modeled as a function of the growth of the equilibrium GDP ($\Delta\bar{y}_t$) according to equation (17). Due to different deflators (the consumer price index (CPI) for wages and the GDP deflator for GDP), we introduce the parameter $wedge$, which is set to 3, to better link the dynamics of real wages and GDP. Other factors that affect the dynamics of equilibrium wages are approximated by a shock ($\varepsilon_t^{\Delta\overline{rwage}}$). The parameter value of aa_4 is set to 0.85.

$$rwage_t = wage_t - cpi_t, \qquad (15)$$

$$rwage_t = \overline{rwage}_t + r\widehat{wag}e_t, \qquad (16)$$

$$\Delta\overline{rwage}_t = aa_4 \Delta\overline{rwage}_{t-1} + (1 - aa_4) * (\Delta\bar{y}_t + wedge) + \varepsilon_t^{\Delta\overline{rwage}}. \qquad (17)$$

4.3 Inflation block

The inflation block in the model is represented by modified New Keynesian Phillips curves. The growth of the aggregate consumer price index (π_t) is used as a measure of inflation, which is the target indicator for the monetary policy of the National Bank of Belarus:

$$\pi_t = 4 * (cpi_t - cpi_{t-1}). \qquad (18)$$

We separate inflation into its core (π_{core_t})and non-core ($\pi_{noncore_t}$) components in accordance with equation (19). Core inflation characterizes the change in prices that are not directly subject to administrative regulation, and in Belarus includes prices for individual services and non-food products as well as food products. It should be noted that the items included in core inflation may be subject to regulatory impact through a number of other instruments, such as established maximum monthly price growth rates or maximum markups for trade and importers.[15] Non-core inflation characterizes the change in administratively regulated prices and prices of fruits and vegetables. As the QPM is linear and the weights of the core and non-core components in the headline inflation change annually, equation (19) includes a measurement shock (ε_t^{π}). The weight of the core component in the aggregate CPI reflects the parameter $weight$, which is assumed to have a value of 0.7153.

The linkage between core and non-core inflation is carried out through the relative price (rp_t) in accordance with equation (20). The relative price is decomposed into an equilibrium component ($\overline{rp}_t$) and a gap component ($\widehat{rp}_t$), and the change in the equilibrium component ($\Delta\overline{rp}_t$) is modeled as an autoregressive process with an exogenously determined steady state ($\Delta\overline{rp}_{ss}$), which is assumed to be (-0.80) based on historical data. The parameter rr_1 is calibrated to be 0.90.

$$rp_t = cpi_{core_t} - cpi_t, \qquad (20)$$

$$rp_t = \widehat{rp}_t + \overline{rp}_t, \qquad (21)$$

$$\Delta\overline{rp}_t = rr_1\Delta\overline{rp}_{t-1} + (1 - rr_1) * \Delta\overline{rp}_{ss} + \varepsilon_t^{\Delta\overline{rp}}. \qquad (22)$$

[15] See: Resolution of the Council of Ministers of the Republic of Belarus, October 19, 2022, No. 713 "On the price regulation system".

Modeling of core inflation is based on the assumption of price stickiness in the short run, i.e., there is assumed to be incomplete one-time transformation of costs into prices.

$$\pi_{core_t} = 4 * (cpi_{core_t} - cpi_{core_{t-1}}), \tag{23}$$

$$\pi_{core_t} = b_1 E_t \pi_{core_{t+1}} + (1 - b_1 - b_2) * \pi_{core_{t-1}} + b_2 \pi_{imp_t} + b_3 rmc_t + \varepsilon_t^{\pi core}. \tag{24}$$

The dynamics of core inflation are determined by inflation expectations, which are partially rational ($E_t \pi_{core_{t+1}}$) and partially adaptive ($\pi_{core_{t-1}}$), imported inflation (π_{imp_t}), real marginal costs (rmc_t), and an inflation shock ($\varepsilon_t^{\pi core}$), in which inflation factors not taken into account in the model are approximated.

When the economy is in a steady state, core inflation corresponds to inflation expectations, which is ensured by the imposed restriction that the coefficients on lagged, expected, and imported inflation are equal to one in equation (24). It should be noted that including a lagged variable for core inflation also makes it possible to take into account the persistency of inflationary processes, which is observed in practice due to the prolonged effect of inflationary factors on prices. The specification of equation (24) assumes that inflation does not have a predetermined tendency to converge to a certain level – in the equilibria, it is equal to inflation expectations. This also means that managing and controlling inflation expectations is a necessary condition for effective implementation of monetary policy. The parameter b_1 approximates the share of economic agents who base their expectations on rational assumptions. The value of the coefficient b_1 is assumed to be 0.35.

Real marginal costs (rmc_t) approximate the additional costs of producing an additional unit of output. The parameter b_3 characterizes the stickiness of prices in the economy and is calibrated to be 0.50, as in the work of Musil et al. (2018). The higher the value of the parameter b_3, the smaller the output losses will be required when implementing monetary policy aimed at reducing inflation.

In accordance with equation (25), real marginal costs are a combination of output gap, wages gap, and REER gap:

$$rmc_t = k_1 \hat{y}_t + k_2 r\widehat{wage}_t + (1 - k_1 - k_2) * (\hat{z}_t - \widehat{rp}_t). \tag{25}$$

Positive values of real marginal costs indicate their inflationary pressure, while negative values indicate their disinflationary pressure. Output and wages gaps approximate the costs of domestic producers. The wages gap characterizes labor costs, while the output gap includes all other domestic costs (e.g. depreciation).

The REER gap approximates the costs of importers. Including the REER gap in the cost structure ensures that in the long term, the price dynamics in Belarus and trading partner countries are in line with the relative version of purchasing power parity. Thus, exceeding the equilibrium level of the REER implies undervaluation of the Belarusian ruble: Belarusian goods become cheaper than foreign counterparts. Among other things, this will create pressure to increase the prices of Belarusian goods to align them with foreign ones. However, the REER gap is adjusted for the relative price gap to ensure the steady state, as equation (25) approximates the marginal costs for the core, not the headline inflation.

The significance of the output and wages gaps in real marginal costs is determined by the parameters k_1 and k_2, respectively, which are taken to be 0.50 and 0.30. We calibrate these parameters based on the share of Belarusian goods in retail trade, the structure of costs for production and sale of goods in Belarus, and the calibration presented in Musil et al. (2018).[16] Additionally, we take into account the inclusion of imported inflation (π_{imp_t}) in equation (24): the direct accounting for the influence of foreign prices and nominal exchange rates on domestic prices in Belarus should lead to higher values of parameters k_1 and k_2.

According to equation (26), imported inflation approximates the direct impact of changes in the nominal effective exchange rate (NEER, Δs_t) and prices in trading partner countries (π_t^*) on the core inflation in Belarus. The component of imported inflation is not present in the canonical version of QPM (Berg et al., 2006a; 2006b; Mæhle et al., 2021). However, in Belarus, the exchange rate pass-through remains fast and significant (Kharitonchik, 2019a; Kuznetsov et al., 2019), which requires the consideration of this factor when modeling core inflation for the correct identification of unobservable variables. It should be noted that the change in NEER in equation (26) is corrected for the change in the equilibrium real exchange rate ($\Delta\bar{z}_t$), since equilibrium variables, according to the methodology of QPM construction, are inflation-neutral – their change does not lead to additional inflationary or disinflationary pressure.

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[16] The share of domestic goods sales in the retail turnover of Belarus was 59.2% in 2021 and 61.1% in January-September 2022. Labor costs accounted for 16.7% of the total expenses of organizations for production and sales in 2021, and 17.1% in January-September 2022. Import of raw materials, materials, and components accounted for 23.9% of the expenses of organizations in January-September 2022. In the study of Musil et al. (2018), the value of parameter k_1 is assumed to be 0.45, and the value of parameter k_2 is 0.30.

$$\pi_{imp_t} = \pi_t^* + \Delta s_t - (\Delta\bar{z}_t - \Delta\overline{rp}_t). \tag{26}$$

To model non-core inflation, we use the specification proposed by Musil et al. (2018). It should be noted that due to administrative regulation, the dynamics of non-core inflation may be volatile and decisions on price adjustments may be made with a significant lag after the impact of economic shocks. In accordance with equation (27), we link the dynamics of non-core inflation to rational ($E_t\pi_{noncore_{t+1}}$) and adaptive expectations($\pi_{noncore_{t-1}}$), the oil price gap ($\widehat{rp\_oil_t}$), and the REER gap ($\hat{z}_t$) adjusted for relative prices. The parameters bb_1, bb_2, and bb_3 are calibrated to be 0.70, 0.15, and 0.15, respectively.

$$\pi_{noncore_t} = bb_1 E_t \pi_{noncore_{t+1}} + (1 - bb_1) * \pi_{noncore_{t-1}} + bb_2 \widehat{rp_{oil}}_t + bb_3 * (\hat{z}_t + + \frac{weight}{1-weight} * \widehat{rp}_t) + \varepsilon_t^{\pi_{noncore}}, \tag{27}$$

$$\pi_{noncore_t} = 4 * (cpi_{noncore_t} - cpi_{noncore_{t-1}}). \tag{28}$$

4.4 Exchange rate and foreign trade blocks

We model the NEER (s_t) as a combination of the exchange rate obtained from the modified version of uncovered interest rate parity (s_t^{uip}) and the exchange rate corresponding to the state of external trade (s_t^{bop}). The parameter h_1 determines the degree of influence of external trade on the exchange rate and is calibrated to be 0.30.

$$s_t = (1 - h_1) * s_t^{uip} + h_1 s_t^{bop} + \varepsilon_t^s. \tag{29}$$

Equation (29) in our model differs from the canonical specification and those presented in previous models for Belarus. As noted earlier, accounting for the state of foreign trade is necessary for modeling the exchange rate due to the deepening isolation of Belarus' financial sector and possible difficulties with arbitrage. For the specification of foreign trade operations, we use the approach presented in Mæhle et al. (2021).

The physical volumes of exports and imports of goods and services (x_t and m_t) are decomposed into equilibrium components ($\bar{x}_t$ and $\overline{m}_t$) and gaps ($\hat{x}_t$ and $\widehat{m}_t$):

$$x_t = \bar{x}_t + \hat{x}_t, \tag{30}$$

$$m_t = \overline{m}_t + \widehat{m}_t. \tag{31}$$

The equilibrium components of exports and imports ($\bar{x}_t$ and $\overline{m}_t$) are modeled similarly to the equilibrium GDP as random walk processes with drift (32–33), while their growth rates ($\Delta\bar{x}_t$ and $\Delta\overline{m}_t$) are represented as autoregressive processes ensuring convergence to sustainable levels ($\Delta\bar{x}_{ss}$ and $\Delta\overline{m}_{ss}$) in the long run (34–35).[17]

$$\bar{x}_t = \bar{x}_{t-1} + \Delta\bar{x}_t/4 + \varepsilon_t^{\bar{x}}, \tag{32}$$

$$\overline{m}_t = \overline{m}_{t-1} + \Delta\overline{m}_t/4 + \varepsilon_t^{\overline{m}}, \tag{33}$$

$$\Delta\bar{x}_t = u_1\Delta\bar{x}_{t-1} + (1 - u_1) * \Delta\bar{x}_{ss} + \varepsilon_t^{\Delta\bar{x}}, \tag{34}$$

$$\Delta\overline{m}_t = uu_1\Delta\overline{m}_{t-1} + (1 - uu_1) * \Delta\overline{m}_{ss} + \varepsilon_t^{\Delta\overline{m}}. \tag{35}$$

The exports gap ($\hat{x}_t$) is modeled as a function of external demand, approximated by the foreign output gap ($\hat{y}_t^*$), and the REER gap ($\hat{z}_t$), which characterizes the price competitiveness of Belarusian exporters. The parameters c_2 and c_3 determine the degree of influence of the output gap and the REER gap on the exports gap and are calibrated based on available empirical data to be 0.50 and 0.25, respectively. Including the lagged exports gap component ($\hat{x}_{t-1}$) with a parameter of c_1 equal to 0.50 in equation (36) allows for a better replication of historical data, as the influence of external demand and exchange rates on exports is stretched over time. Factors of exports dynamics not directly accounted for in the model are approximated by the shock ($\varepsilon_t^{\hat{x}}$).

$$\hat{x}_t = c_1\hat{x}_{t-1} + c_2\hat{y}_t^* + c_3\hat{z}_t + \varepsilon_t^{\hat{x}}. \tag{36}$$

The imports gap ($\widehat{m}_t$) is modeled as a function of the output gap ($\hat{y}_t$), which approximates a demand for imports, and the REER gap ($\hat{z}_t$). In contrast to equation (36) for the exports gap, the sign for the exchange rate in equation (37) for the imports gap is negative: the undervaluation of the Belarusian ruble increases the price competitiveness of Belarusian goods and stimulates exports, but at the same time leads to higher prices for foreign goods compared to Belarusian goods, which limits imports. The parameters d_1, d_2, and d_3 are taken to be 0.60, 1.00, and 0.20, respectively.

$$\widehat{m}_t = d_1\widehat{m}_{t-1} + d_2\hat{y}_t - d_3\hat{z}_t + \varepsilon_t^{\widehat{m}}. \tag{37}$$

[17] Sustainable growth rates of physical volumes of exports and imports are calibrated equal to 2% per year, parameters u_1 and uu_1 are taken equal to 0.80 and 0.90, respectively.

In addition to the physical volumes of exports and imports, their prices also affect the trade balance. In the QPM, we model terms of trade, which represent the ratio of exports prices to imports prices. Terms of trade (tot_t) are decomposed into an equilibrium component ($\overline{tot}_t$) and a gap ($\widehat{tot}_t$). The terms of trade gap and the growth of their equilibrium component ($\Delta\overline{tot}_t$) are modeled as autoregressive processes with zero mean and an exogenously determined sustainable level ($\Delta\overline{tot}_{ss}$) equal to 2% respectively. The parameters r_1 and r_2 are set to 0.50 and 0.90, respectively.

$$tot_t = \widehat{tot}_t + \overline{tot}_t, \tag{38}$$

$$\widehat{tot}_t = r_1 \widehat{tot}_{t-1} + \varepsilon_t^{\widehat{tot}}, \tag{39}$$

$$\Delta\overline{tot}_t = r_2 \Delta\overline{tot}_{t-1} + (1 - r_2) * \Delta\overline{tot}_{ss} + \varepsilon_t^{\Delta\overline{tot}}. \tag{40}$$

As a result, the deviation of the balance of trade in goods and services from its equilibrium level ($\widehat{bop}_t$) is approximated by the physical volumes of net exports gap, adjusted for the terms of trade gap:

$$\widehat{bop}_t = \widehat{tot}_t + \hat{x}_t - \widehat{m}_t. \tag{41}$$

Deviation of the balance of trade in goods and services from its equilibrium level directly affects the NEER. However, in Belarus, the National Bank conducts FX interventions to smooth out exchange rate dynamics. To account for this factor, we add a trend change in the NEER ($\Delta\bar{s}_t$) to equation (42) for the exchange rate (s_t^{bop}), which corresponds to the state of foreign trade. The trend change in the NEER is calculated as the sum of the differential of inflation targets in Belarus (π_t^T) and trading partner countries (π_{ss}^*) and the equilibrium change in the REER ($\Delta\bar{z}_t$) in accordance with equation (43).

$$s_t^{bop} = s_{t-1} + \frac{\Delta\bar{s}_t}{4} - \widehat{bop}_t, \tag{42}$$

$$\Delta\bar{s}_t = \Delta\bar{z}_t + (\pi_t^T - \pi_{ss}^*). \tag{43}$$

The second component of the NEER equation (29) represents a modified version of uncovered interest rate parity (44):

$$s_t^{uip} = E_t s_{t+1} + \frac{i_t^* - i_t + prem_t}{4}. \tag{44}$$

The exchange rate (s_t^{uip}) obtained from the modified version of uncovered interest rate parity is determined by the expectations of the exchange rate in the next period ($E_t s_{t+1}$) and the difference in nominal interest rates in the money market in Belarus (i_t) and abroad (i_t^*), adjusted for the risk premium on assets denominated in Belarusian rubles ($prem_t$).

Expectations of the NEER have two components: rational (s_{t+1}) and adaptive (s_{t+1}^{nf}). The inclusion of adaptive expectations allows for the inertia of exchange rate dynamics observed in historical data, as well as the influence of National Bank interventions on exchange rate formation. The parameter h_2 determines the proportion of economic agents with rational expectations. Its value, according to Musil et al. (2018), is assumed to be 0.55.

$$E_t s_{t+1} = h_2 s_{t+1} + (1 - h_2) * s_{t+1}^{nf}. \quad (45)$$

It is assumed that adaptive expectations are formed through a naïve forecast. This means that economic agents have an idea of the trend change in the exchange rate and use these estimates to extrapolate the level of the exchange rate. The appearance of a multiplier equal to two in equation (46) is explained as follows: the expected exchange rate in period $t + 1$ equals the exchange rate value in period $t - 1$, adjusted for its trend change over two consecutive periods.

$$s_{t+1}^{nf} = s_{t-1} + \frac{2\Delta\bar{s}_t}{4}. \quad (46)$$

The change in the real effective exchange rate (Δz_t) is determined based on the dynamics of the NEER and the difference in inflation rates between Belarus and its trading partners:

$$\Delta z_t = \Delta s_t + \pi_t^* - \pi_t. \quad (47)$$

The REER (z_t) is decomposed into its equilibrium component ($\bar{z}_t$) and the gap ($\hat{z}_t$). The growth of the equilibrium REER is modeled as an autoregressive process with a sustainable rate ($\Delta\bar{z}_{ss}$) of 2%. The parameter z_1 determines the speed of convergence of the growth of the equilibrium REER to the sustainable rate, and is calibrated to be 0.75.

$$z_t = \bar{z}_t + \hat{z}_t, \quad (48)$$

$$\Delta\bar{z}_t = z_1 \Delta\bar{z}_{t-1} + (1 - z_1) * \Delta\bar{z}_{ss} + \varepsilon_t^{\Delta\bar{z}}. \quad (49)$$

Thus, the proposed specification of the exchange rate and foreign trade blocks (29–49) allows for the influence of foreign trade operations on exchange rate dynamics and the conduct of FX interventions by the National Bank. At the same time, the specification of equations (29–49) does not impede convergence of the exchange rate to its equilibrium level in the long run.

4.5 Monetary policy reaction function

As noted in section 3, in recent years, the National Bank has reduced its degree of control over the interest rates of the money market and does not actively seek to maintain the money supply at a level consistent with achieving the inflation target. We also assume that such behavior by the National Bank will be temporary, and in 2023-2024 it may return to active monetary policy. In this regard, we present the monetary policy reaction function as quasi-inflation targeting with incomplete sterilization of FX interventions:

$$i_t = mpr * i_t^{IT} + (1 - mpr) * i_t^{UIP} + \varepsilon_t^i. \quad (50)$$

In accordance with equation (50), the level of the nominal IBL rate (i_t) is influenced by two components: the rate i_t^{IT}, corresponding to inflation targeting, and the rate i_t^{UIP}, which is formed in the interbank market with incomplete sterilization of FX interventions. The shock (ε_t^i) is included in equation (50) to account for discretionary monetary policy measures.

The degree of preference of the National Bank for implementing one or another approach to monetary policy is determined by the parameter mpr. Since we assume the National Bank will return to active policy within 1-2 years, the mpr parameter is calibrated to be equal to 0.90. Lower values lead to high volatility of the economic system described by the QPM under the influence of shocks, which prevents it from balancing for several years after the shock. In section 5, we provide simulations of prolonged implementation of passive monetary policy with a low value of the mpr parameter.

We do not include in the monetary policy reaction function (50) the rate that balances the demand and supply of money in the economy at a given intermediate policy target – the broad money supply.[18] Despite the National Bank's stated transition to a monetary targeting regime in 2015, its actions from 2015 to Q2 2020 were more in line with inflation targeting. At the same time, the National Bank allowed significant deviations of the broad money supply from the target if they did not contradict the inflation dynamics near the target level. As shown in section 6, the dynamics of the IBL rate in 2015 and in certain periods from 2020-2022 are accurately described by the rate i_t^{UIP}, and from 2016 to mid-2020 by the rate i_t^{IT}.

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[18] See: Musil et al., 2018, Mæhle et al., 2021.

The interest rate i_t^{UIP}, which arises in the interbank market due to incomplete sterilization of foreign exchange interventions, is modeled using the uncovered interest rate parity condition equation (51) with the addition of an ad-hoc inertia component (i_{t-1}) and a weighting of the expected ($E_t \Delta s_{t+1}$) and current (Δs_t) exchange rate changes for better replication of actual data. The parameters x_1 and x_2 are assumed to be 0.30 and 0.50, respectively. It is assumed that when the Belarusian ruble weakens or interest rates on foreign currency-denominated assets increase, there is an increase in demand for foreign currency in the Belarusian market. This can lead to the National Bank selling foreign currency to smooth exchange rate dynamics, which translates into a reduction in banking system liquidity and an increase in the IBL rate. The opposite is true when the exchange rate strengthens.

$$i_t^{UIP} = x_1 i_{t-1} + (1 - u_1) * (i_t^* + prem_t + x_2 E_t \Delta s_{t+1} + (1 - x_2) * \Delta s_t). \quad (51)$$

The interest rate corresponding to the implementation of monetary policy in inflation targeting regime is represented by the modified Taylor rule:

$$i_t^{IT} = mm_1 i_{t-1} + (1 - mm_1) * (i_t^n + mm_2 * (E_t \pi_{t+3}^4 - \pi_{t+3}^T) + mm_3 \hat{y}_t) \quad (52)$$

The interest rate i_t^{IT} is calculated by adding a markup to the neutral interest rate (i_t^n), which is determined based on the expected deviation of inflation from the target ($E_t \pi_{t+3}^4 - \pi_{t+3}^T$) and the state of the economy in the business cycle, approximated by the output gap ($\hat{y}_t$). The parameters mm_2 and mm_3 determine the scale of the National Bank's reaction to changes in inflation and output gap and are calibrated to be equal to 0.50 and 0.25, respectively. The lagged component (i_{t-1}) provides smoothness to the dynamics of the interest rate with a coefficient mm_1 equal to 0.50. In practice, central banks aim to avoid excessive volatility in interest rates when implementing inflation targeting regime. Thus, in inflation targeting, the central bank uses monetary policy measures to respond to expected deviations of inflation from the target, while seeking to smooth fluctuations in the economic cycle. The use of expected inflation is due to the presence of lags in the transmission mechanism.

Including the neutral nominal interest rate in equation (52) ensures convergence of the nominal IBL rate to the neutral level in the long term. It should be noted that to satisfy the Taylor principle, it is sufficient for the coefficient mm_2 to be greater than zero.

The neutral nominal interest rate of the central bank (i_t^n) is calculated by summing the real equilibrium interest rate of the central bank ($\bar{r}_t$) and expected inflation ($E_t \pi_{t+1}^4$).

$$i_t^n = \bar{r}_t + E_t\pi_{t+1}^4. \quad (53)$$

The real equilibrium IBL rate is an unobservable variable. In each period, the actual real interest rate (r_t), calculated by adjusting the nominal rate for expected inflation according to equation (54), may deviate from the equilibrium rate due to monetary policy measures or other factors, such as liquidity shocks. The deviation of the real IBL rate from its equilibrium level determines the real IBL rate gap ($\hat{r}_t$) in accordance with equation (55).

$$r_t = i_t - E_t\pi_{t+1}^4, \quad (54)$$

$$r_t = \bar{r}_t + \hat{r}_t. \quad (55)$$

In the QPM, it is assumed that the real equilibrium IBL rate depends on changes in potential GDP ($\Delta\bar{y}_t$) and the equilibrium REER ($\Delta\bar{z}_t$). Such a specification of equation (56) differs from most previously developed models, including that used by the National Bank of Belarus, where the equilibrium rate is modeled from the real version of the uncovered interest rate parity. As noted in section 3, the link between the equilibrium rate and potential GDP and the equilibrium REER may more closely correspond to the emerging situation of increasing financial isolation of the Belarusian economy.

$$\bar{r}_t = w_1\bar{r}_{t-1} + (1 - w_1) * (\Delta\bar{y}_t + \Delta\bar{z}_t) + \varepsilon_t^{\bar{r}}. \quad (56)$$

The increase in potential GDP in equation (56) approximates the marginal yield on capital, while the inclusion of the equilibrium REER is intended to account for the impact of exchange rate changes on the profitability of foreign currency investments, which is relevant for Belarus as a country with a small open economy. The lagged variable of the equilibrium rate ($\bar{r}_{t-1}$) accounts for the inertia of the equilibrium rate dynamics, which is due to the prolonged influence of factors on it.[19] The shock of the real equilibrium rate ($\varepsilon_t^{\bar{r}}$) approximates the impact of factors not directly accounted for in equation (56). Among these factors, one can denote the rate of time preferences, which is inversely related to the savings rate. As shown in the study by Jordà et al. (2020), during economic crises, economic agents may increase their savings for a "rainy day," which can push the equilibrium rate downwards.

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[19] The $w_1$parameter is calibrated to 0.70.

4.6 Interest rates of the loans and deposits markets

A feature of the QPM developed in this study is the inclusion of interest rates on ruble market loans and ruble new time deposits in the model structure. Their inclusion allows for a more complete approximation of the monetary conditions of the functioning of the Belarusian economy, since it is the interest rates on loans and deposits, and not the IBL, that directly affect the behavior of firms and households.

The model assumes that changes in the IBL interest rate are transmitted to the lending interest rates in accordance with the regularity identified in Kharitonchik (2019b): the reaction of the average interest rate on ruble market loans to the population and firms (i_l_t) in Belarus to changes in the IBL rate is incomplete and reaches its maximum value within two quarters after the shock. The average rate on new ruble time deposits (i_d_t) for the population and organizations is modeled in a similar way based on unpublished results of econometric analysis. As a result, the specification of equations (57–58) is presented in the form of an error correction mechanism for changes in nominal interest rates on loans (Δi_l_t) and deposits (Δi_d_t).[20]

$$\Delta i\_l_t = s_1 \Delta i_t + s_2 \Delta i_{t-1} + s_3 * (i\_l_{t-1} - s_4 i_{t-1} - s_5) + \varepsilon_t^{\Delta i\_l}, \tag{57}$$

$$\Delta i\_d_t = q_1 \Delta i_t + q_2 \Delta i_{t-1} + q_3 * (i\_l_{t-1} - q_4 i_{t-1} - q_5) + \varepsilon_t^{\Delta i\_d}, \tag{58}$$

$$\Delta i\_l_t = i\_l_t - i\_l_{t-1}, \tag{59}$$

$$\Delta i\_d_t = i\_d_t - i\_d_{t-1}. \tag{60}$$

Real interest rates on loans (r_l_t) and deposits (r_d_t) are calculated by adjusting nominal rates for expected inflation and are decomposed into equilibrium components ($\overline{r\_l}_t$ and $\overline{r\_d}_t$) and gaps ($\widehat{r\_l}_t$ and $\widehat{r\_d}_t$):

$$r\_l_t = i\_l_t - E_t \pi_{t+1}^4, \tag{61}$$

$$r\_d_t = i\_d_t - E_t \pi_{t+1}^4, \tag{62}$$

[20] The values of the parameters of equation (57) are calibrated based on the results of the study by A. Kharitonchik (2019b): s_1 = 0.15, s_2 = 0.10, s_3 = -0.15, s_4 = 0.70, s_5 = 4.70. At the same time, the value of the s_5 parameter is adjusted so that QPM has a unique steady state. To calibrate the parameters of equation (58), error correction models for interest rates on deposits were estimated using the approach presented in Kharitonchik (2019b): q_1 = 0.50, q_2 = 0.20, q_3 = -0.30, q_4 = 0.85, q_5 = 1.35.

$$r\_l_t = \overline{r\_l}_t + \widehat{r\_l}_t, \quad (63)$$

$$r\_d_t = \overline{r\_d}_t + \widehat{r\_d}_t. \quad (64)$$

Real equilibrium rates for loans and deposits are determined by adding equilibrium spreads ($\overline{spread}_t^l$ and $\overline{spread}_t^d$) to the real equilibrium IBL rate. These spreads are modeled as autoregressive processes converging to sustainable levels ($\overline{spread}_{ss}^l$ and $\overline{spread}_{ss}^d$), calibrated based on historical data at 2.0 and 0.0, respectively. The parameter values of w_2 and w_3 are set at 0.90.

$$\overline{r\_l}_t = \bar{r}_t + \overline{spread}_t^l, \quad (65)$$

$$\overline{r\_d}_t = \bar{r}_t + \overline{spread}_t^d, \quad (66)$$

$$\overline{spread}_t^l = w_2 \overline{spread}_{t-1}^l + (1 - w_2) * \overline{spread}_{ss}^l + \varepsilon_t^{\overline{spread}^l}, \quad (67)$$

$$\overline{spread}_t^d = w_3 \overline{spread}_{t-1}^d + (1 - w_3) * \overline{spread}_{ss}^d + \varepsilon_t^{\overline{spread}^d}. \quad (68)$$

4.7 External sector

Belarus can be classified as a country with a small open economy. Exports and imports of goods and services account for approximately 60% of GDP each. Therefore, the QPM includes a block for the external sector, which describes the dynamics of output gap, inflation, money market interest rates, and exchange rates in Belarus' trading partner countries, as well as oil prices. The external variables for the output gap ($\hat{y}_t^*$), inflation (π_t^*), and nominal interest rate (i_t^*) are effective, i.e., they are weighted according to the significance of the economic partner. In the QPM, Belarus' economic partners are Russia, the EU (Eurozone for inflation and interest rates), China, and the US, which approximate the rest of the world. The parameters w^{ru}, w^{eu}, and w^{cn} define the significance of Russia, the EU (Eurozone), and China in the effective external variables, respectively. Based on the structure of foreign trade operations, the FDI, and the probable reorientation of trade flows towards Russia in the near future, their values are calibrated to 0.60, 0.15, and 0.05, respectively.

$$\hat{y}_t^* = w^{ru}\hat{y}_t^{ru} + w^{eu}\hat{y}_t^{eu} + w^{cn}\hat{y}_t^{cn} + (1 - w^{ru} - w^{eu} - w^{cn}) * \hat{y}_t^{us}, \quad (69)$$

$$\pi_t^* = w^{ru}\pi_t^{ru} + w^{eu}\pi_t^{eu} + w^{cn}\pi_t^{cn} + (1 - w^{ru} - w^{eu} - w^{cn}) * \pi_t^{us}, \quad (70)$$

$$i_t^* = w^{ru}i_t^{ru} + w^{eu}i_t^{eu} + w^{cn}i_t^{cn} + (1 - w^{ru} - w^{eu} - w^{cn}) * i_t^{us}. \quad (71)$$

The equations describing the dynamics of external sector variables for individual countries are not structural but are represented by autoregressive processes with exogenously determined steady states. The estimation of unobservable components of external variables is carried out using one-dimensional filters with expert judgments, and transformed data is directly entered into the model. The complete structure of the model is presented in Appendix A.

4.8 Calibration of the QPM parameters

All parameters of the QPM were calibrated rather than estimated. This is because the macroeconomic time series for Belarus are relatively short and subject to multiple structural breaks. Additionally, monetary policy and exchange rate regimes in Belarus have changed several times in the 21st century. Applying estimation to such data poses a high risk of imprecise parameter identification. As noted in Mæhle et al. (2021), parameters of QPM models developed with technical support from the IMF are almost always calibrated rather than estimated.

The QPM contains three groups of parameters. First, there are coefficients for the variables in the equations that determine the dynamic properties of the model. Calibration of these parameters is usually based on available recommendations, expert judgments, and results from scientific research. It is also important to consider that unobserved equilibrium indicators usually exhibit smooth dynamics. Second, there are standard deviations of shocks that determine the volatility of unobserved variables and have a significant impact on their estimation. Calibration of these parameters is based on the historical volatility of time series of variables, assuming that gaps are more volatile than trends.[21] And third, there are steady state values of variables that determine the steady state of the model. Calibration of these parameters is usually based on the average values of variables (in case of structural breaks – for the most relevant period) or the results of scientific research.

The model parameters were calibrated to account for stylized facts of the Belarusian economy, monetary and exchange rate policy regimes, as well as the functioning of the transmission mechanism. When calibrating, recommendations for emerging market countries presented in Berg et al. (2006a; 2006b) were considered, as well as values reported in previously published studies and expert judgments. Calibration was based on the recent period of about 5-7 years, as this was when structural imbalances in the Belarusian economy were most

[21] When calibrating standard deviations, it is not their absolute values that matter, but the ratios of the values of the standard deviations of the variables.

pronounced and monetary policy and exchange rate regimes were changing. The calibrated values of the model parameters are presented in Appendix A.[22]

To check the realism of the parameter calibration, we used methods proposed in Mæhle et al. (2021): 1) economic consistency demonstrated by impulse-response functions; 2) the model's ability to realistically explain historical macroeconomic variables dynamics; 3) accuracy of forecasting on historical data (in-sample simulations). The results of applying these methods are presented in sections 5 and 6.

Quarterly economic indicators of Belarus and trading partner countries were used as input data for the QPM. The multivariate Kalman filter was used to estimate unobserved components.

5. Dynamic characteristics of the QPM

5.1 Responses of macroeconomic indicators to economic shocks: baseline specification

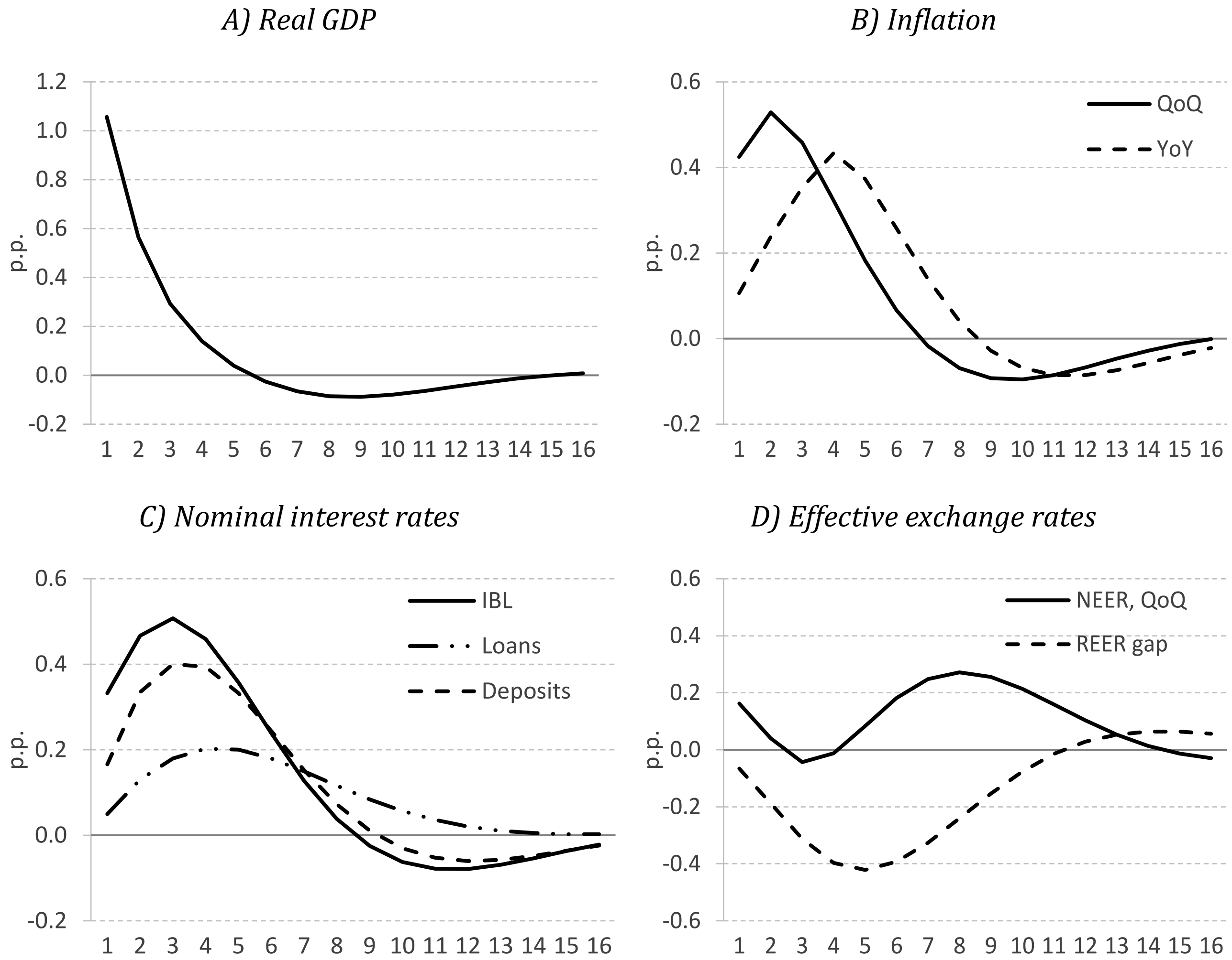
We conducted simulations (using the baseline specification and calibration of the QPM) of the behavior of the economic system in response to five major macroeconomic shocks: a shock to domestic demand, an inflation shock, a currency shock, a monetary policy shock, and a fiscal policy shock. The shocks in the simulations are considered unexpected: the system is in a steady state before the shock occurs, and economic agents have no information about a potential occurrence of the shock.

A shock to domestic demand leads to an increase in GDP above its equilibrium level, creating a positive output gap (Figure 6.A). Inflationary pressure increases and leads to a significant acceleration of inflation during the six months following the shock (Figure 6.B). Monetary authorities respond to the deviation of inflation from the target by raising the IBL rate, which is quickly transmitted to ruble deposit rates and, with a lag and greater inertia, to lending rates (Figure 6.C). Increasing interest rates on ruble assets prevents a strong weakening of the nominal exchange rate, pressure on which is exerted by the growth of imports during the shock period (Figure 6.D). Taking into account the increased inflation, the REER enters the overvalued range, which, along with the rate hikes, gradually begins to lead to a weakening of net exports and domestic demand. As a result, the positive output gap begins to close, and GDP

[22] Appendix A presents the values of the coefficients for variable equations and steady states. Standard deviations of shocks are available on request.

returns to its equilibrium level. Inflationary pressure weakens, allowing the National Bank to gradually return interest rates to neutral levels.

Figure 6: Impulse-response functions to domestic demand shock under the QPM

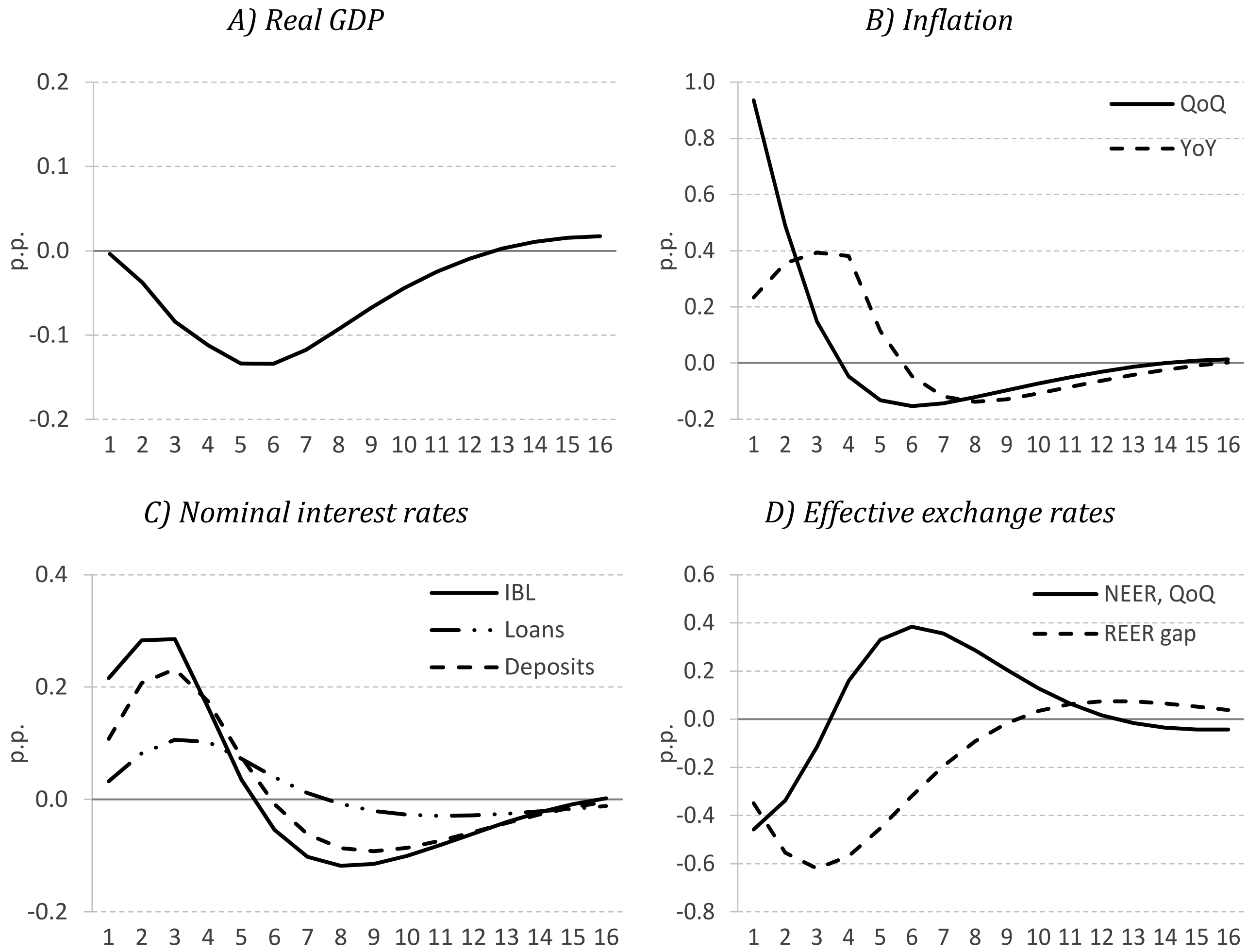


Source: author's calculations based on the QPM.

Note: hereinafter, the impulse-response functions are presented in terms of deviations of variables from their equilibrium levels. QoQ is the annualized growth rate in the indicator in period *t* in relation to period *t-1*. YoY is the growth rate in the indicator in period *t* in relation to period *t-4*.

In the QPM, an inflation shock is modeled as an exogenous increase in the annualized core inflation by 1 percentage point. Due to the link between the dynamics of core and non-core inflation through relative prices embedded in the QPM, the non-core CPI also increases, leading to an increase in the overall CPI (Figure 7.B). The National Bank responds to the increase in inflation by raising interest rates (Figure 7.C). This leads to an increase in demand for savings in national currency, strengthening the NEER and creating overvaluation of the Belarusian ruble (Figure 7.D). With a time lag, overvaluation of the REER and the rise in interest rates begin to dampen economic activity, resulting in a negative output gap (Figure 7.A). As a result, inflationary pressures begin to ease, allowing the National Bank to enter a cycle of rate cuts, which gradually supports the return of the exchange rate and GDP to equilibrium levels.

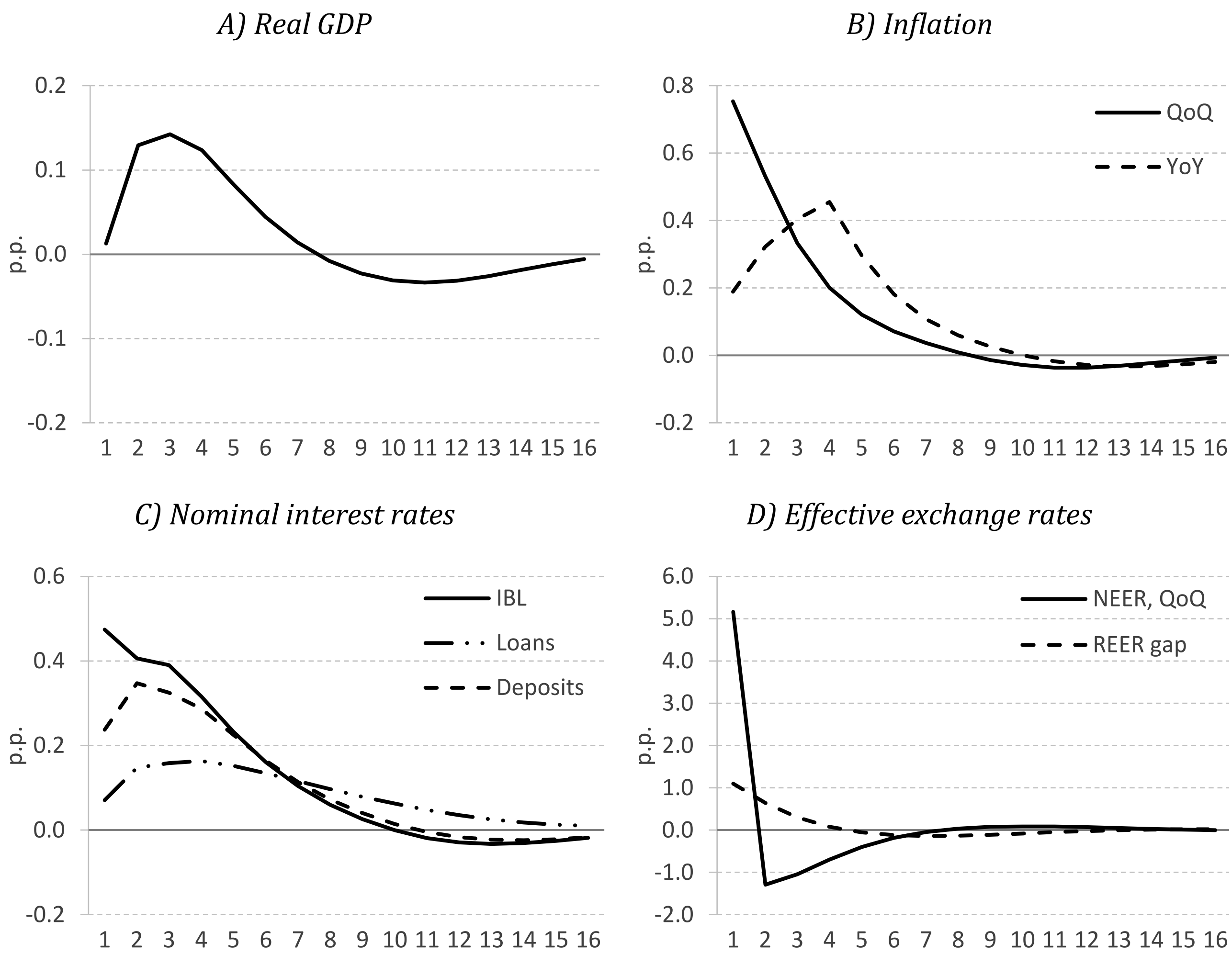
Figure 7: Impulse-response functions to inflation shock under the QPM



Source: author's calculations based on the QPM.

An exchange rate shock is associated with a sharp weakening of the Belarusian ruble (Figure 8.D), which creates inflationary pressure and leads to a significant increase in inflation (Figure 8.B). Due to the acceleration of price growth, the REER weakens to a lesser extent compared to the NEER, but undervaluation of the Belarusian ruble is still formed (Figure 8.D). The National Bank reacts to the inflation surge by raising the monetary policy rate, which gradually translates into loans and deposits rates (Figure 8.C). Since the reaction of loans and deposits rates to changes in the monetary policy rate lags behind, their impact on domestic demand in the short term has a limited restraining effect. As a result, the increase in net exports due to the undervaluation of the ruble outweighs, and GDP increases over three quarters after the shock, creating a positive output gap (Figure 8.A). Subsequently, the effects of the higher rates on the exchange rate and domestic demand begin to prevail, which is reflected in the gradual return of the REER and GDP to equilibrium. Inflationary pressure decreases, allowing the National Bank to return interest rates to neutral levels.

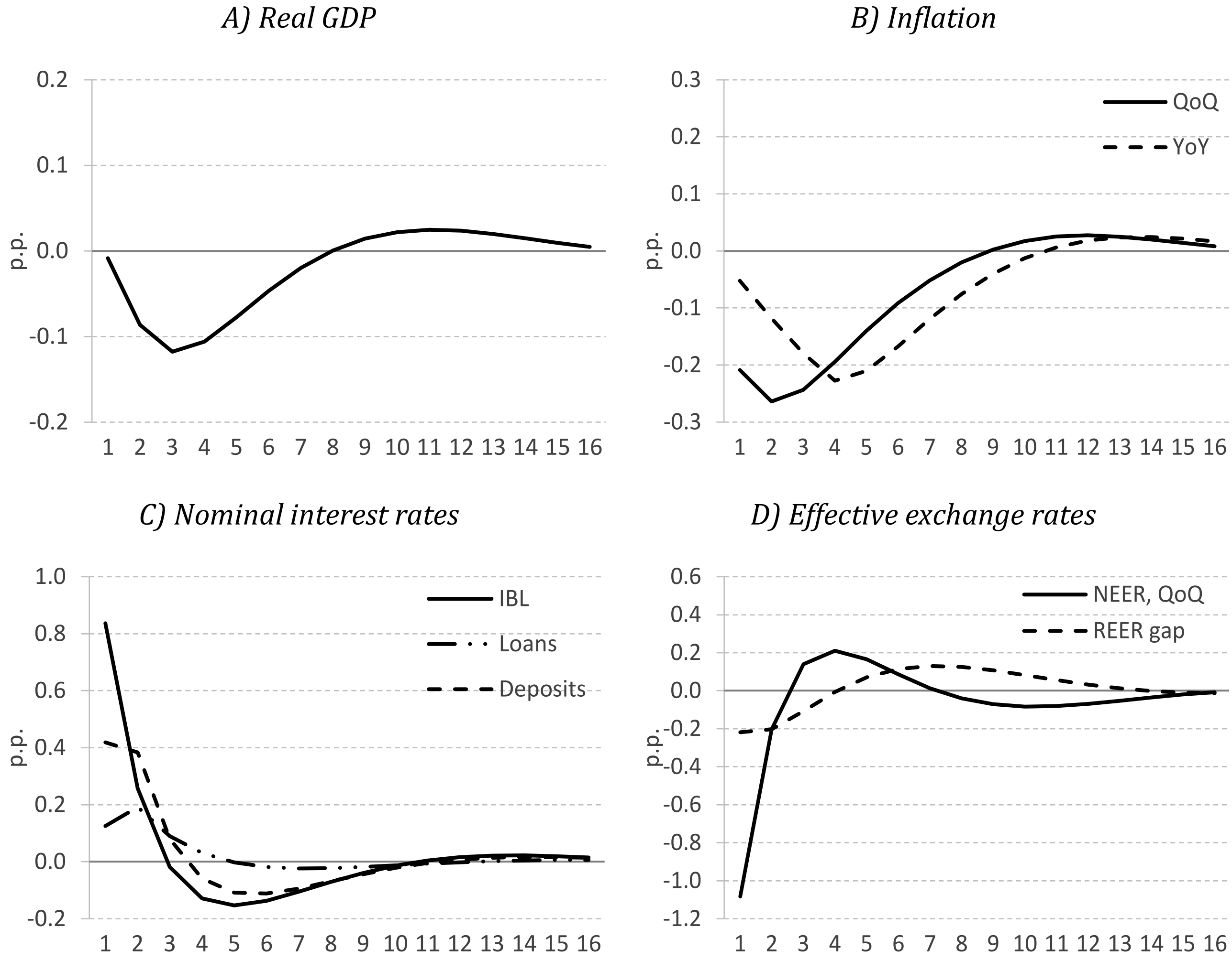
Figure 8: Impulse-response functions to exchange rate shock under the QPM



Source: author's calculations based on the QPM.

The monetary policy shock is modeled as an unexpected change in the IBL rate. An increase in the IBL rate leads to higher interest rates on ruble deposits (Figure 9.C). This increases the attractiveness of savings in Belarusian rubles and results in a rise in net supply (or a decrease in net demand) in the foreign exchange market, which is reflected in the strengthening of the Belarusian ruble and the formation of a small overvaluation, which stimulates import growth (Figure 9.D). An increase in the IBL rate also leads to a gradual increase in the cost of ruble borrowing (Figure 9.C). Taking into account the increased lending risks for banks due to higher interest rates, tight monetary conditions are formed, which lead to a slowdown in economic activity (Figure 9.A). The reduction in aggregate demand, along with the strengthening of the national currency, results in a slowdown in inflation (Figure 9.B). As inflation deviates below the target level, the National Bank begins to lower the IBL rate, returning it to a neutral level. The reduction in the IBL rate is transmitted with a lag to the loans-deposits market rates and quickly leads to the weakening of the Belarusian ruble due to the expectations channel of the transmission mechanism and an increase in imports. As a result, the restrictive stance of monetary conditions weakens, which supports the gradual return of GDP to its equilibrium level and inflation to the target.

Figure 9: Impulse-response functions to monetary policy shock under the QPM

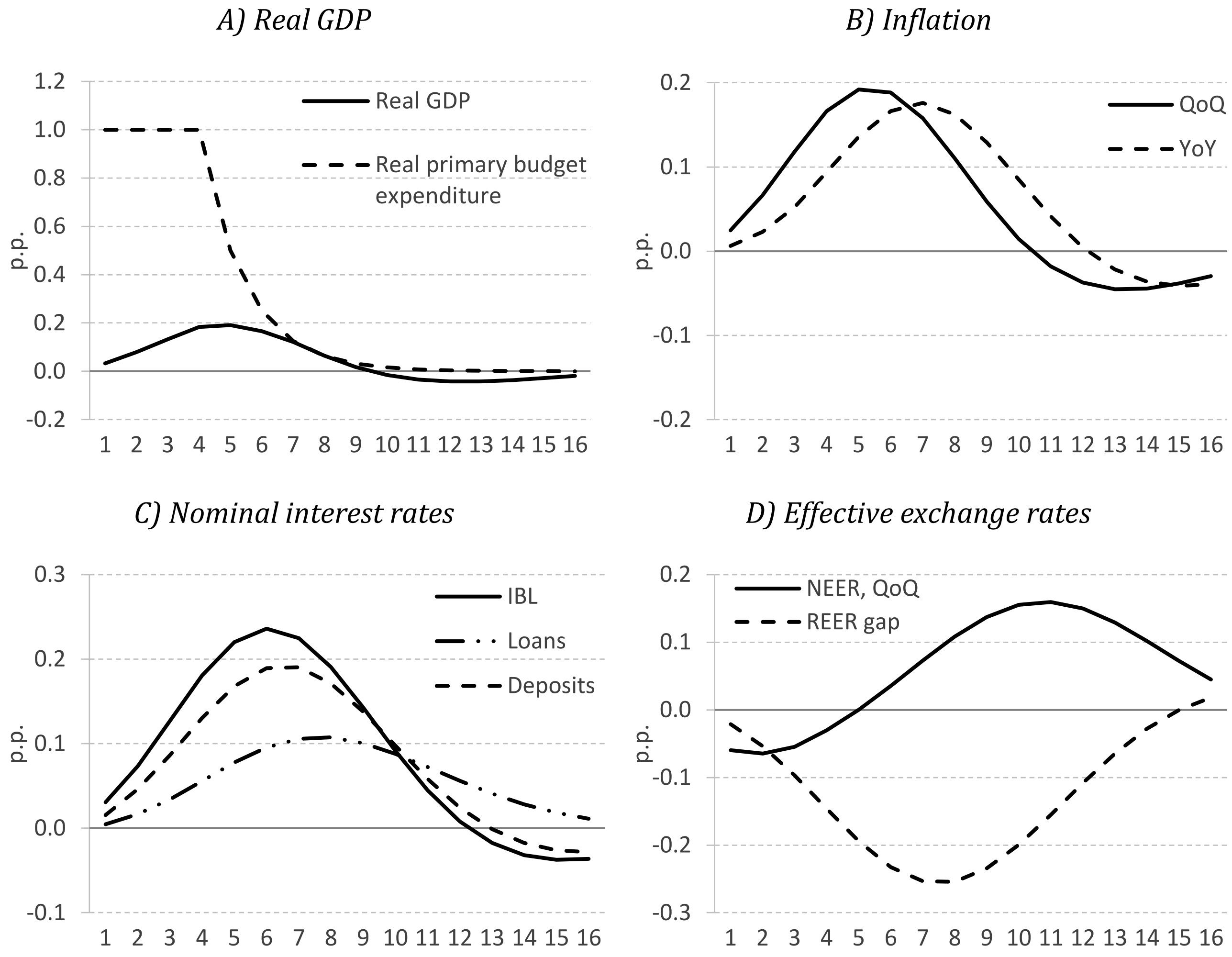


Source: author's calculations based on the QPM.

We model a fiscal policy shock as a one-percentage-point excess of real primary government expenditure above its equilibrium level for a one year (Figure 10.A). With an active monetary policy, the impact of the fiscal shock on economic activity will be limited: in response to increased inflationary risks, the National Bank raises interest rates (Figure 10.C). Along with FX interventions, this allows the nominal exchange rate to remain virtually unchanged for several quarters (Figure 10.D). However, in the future, due to the contraction of net exports, there is pressure to weaken the national currency

(Figure 10.D). Incentives for import growth diminish, which helps bring GDP closer to its potential level and allows interest rates to gradually begin to decline.

Figure 10: Impulse-response functions to fiscal policy shock under the QPM



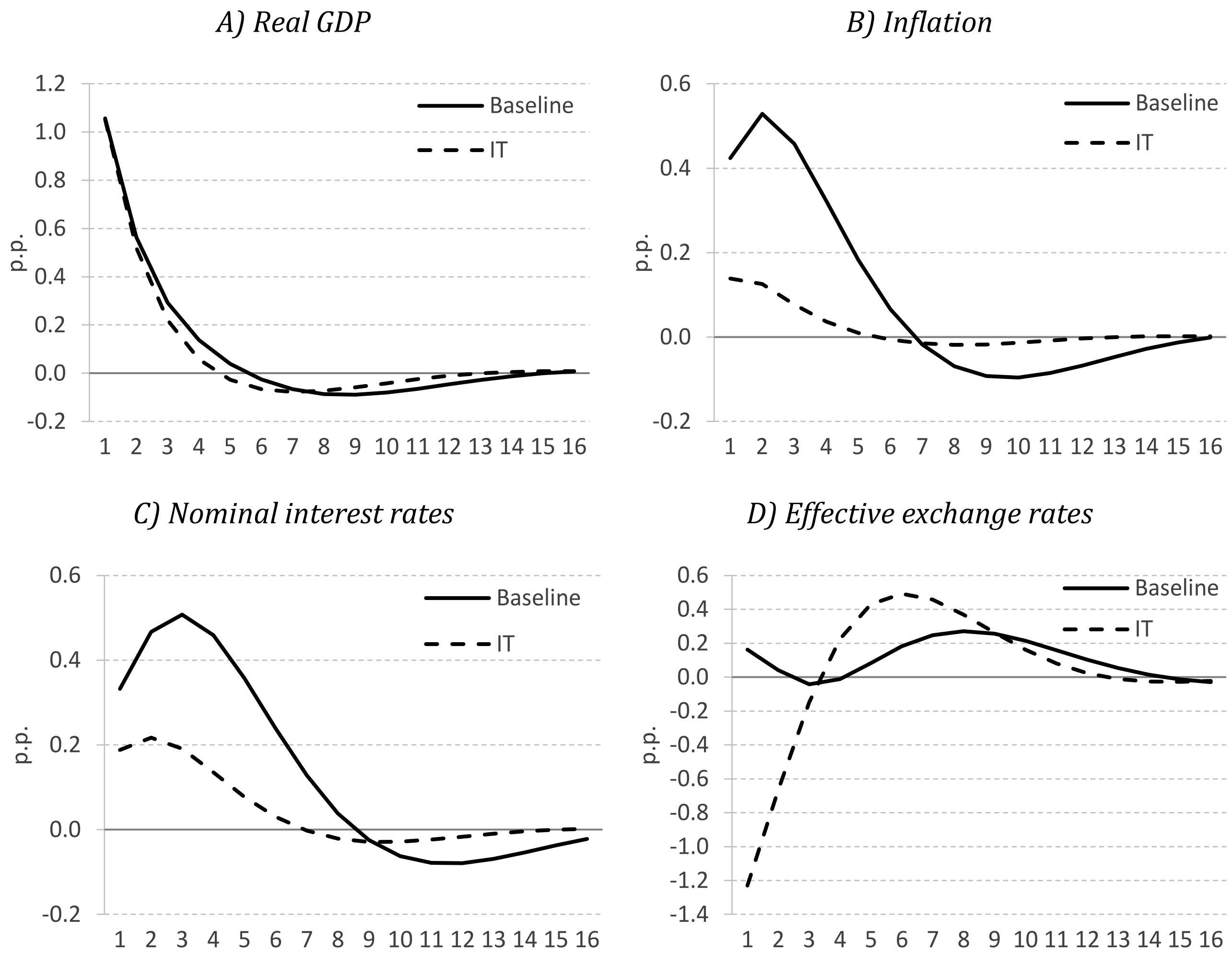
Source: author's calculations based on the QPM.

5.2 Responses of macroeconomic indicators to economic shocks: alternative calibrations

We conducted simulations of a domestic demand shock using the QPM with alternative parameters calibrations and compared impulse-response functions to illustrate the potential impact of changes in monetary and exchange rate policies on the behavior of the economic system. We consider two alternative scenarios.

The first alternative scenario involves the National Bank transitioning to full-fledged inflation targeting and more flexible exchange rate formation in the absence of significant barriers to capital movements. To simulate the scenario, we change the value of parameter h_1 from 0.3 in the baseline calibration to 0 in the alternative, and the value of parameter mpr from 0.9 to 1.0, respectively. It should be noted that the scenario assumes significant easing of sanctions against Belarus, making its realization in the near future unlikely. However, simulating the scenario is useful for discussing reforms in the Belarusian economy and monetary environment.

Figure 11: Comparison of impulse-response functions to a domestic demand shock in the QPM with baseline calibration and transition to inflation targeting



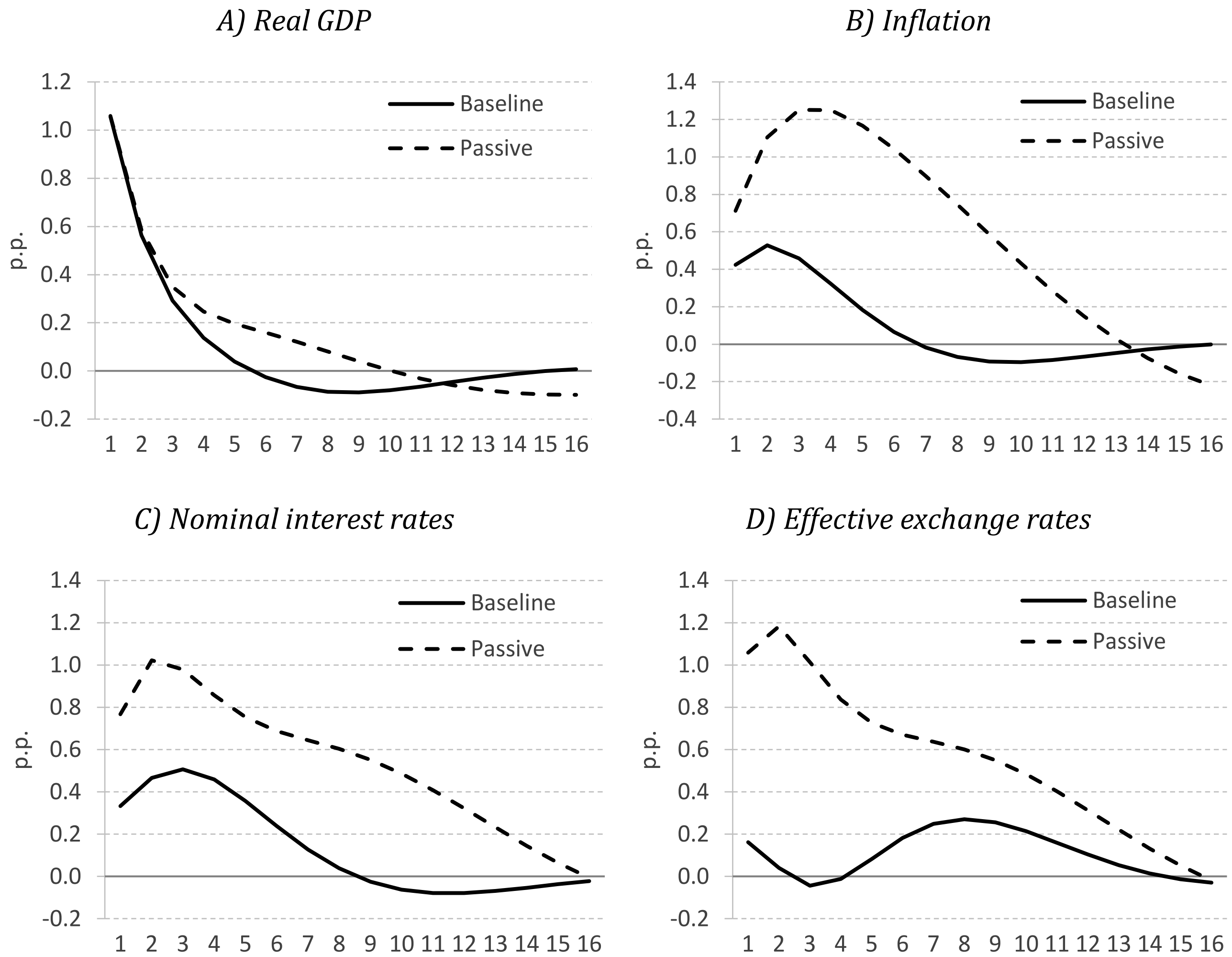
Source: author's calculations based on the QPM.

Note: impulse-response functions are presented in terms of deviations of variables from their equilibrium levels. Baseline – baseline calibration, IT – alternative calibration (transition to inflation targeting).

As the results of the simulations shown in Figure 11 indicate, transitioning to inflation targeting and increasing exchange rate flexibility may significantly reduce the volatility of inflation and interest rates in response to the domestic demand shock. This is primarily due to the more active role of the exchange rate as an automatic stabilizer. Since the exchange rate is more responsive to changes in interest rates, the National Bank needs a smaller change in the IBL rate to return inflation to the target.

The second alternative scenario involves the National Bank implementing a passive monetary policy: significant restrictions on cross-border capital flows, unsterilized FX interventions by the National Bank, and the absence of control over the money market rate. To simulate the scenario, we change the value of parameter h_1 from 0.3 in the baseline calibration to 1.0 in the alternative, and the value of parameter mpr from 0.9 to 0.0, respectively. The second alternative scenario can be considered as a probable behavior of the Belarusian economy in response to shocks while maintaining the current sanctions regime and the current approach to monetary and economic policy in Belarus.

Figure 12: Comparison of impulse-response functions to a domestic demand shock in the QPM with baseline calibration and passive monetary policy



Source: author's calculations based on the QPM.

Note: impulse-response functions are presented in terms of deviations of variables from their equilibrium levels. Baseline – baseline calibration, Passive – alternative calibration (passive monetary policy).

The prolonged implementation of a passive policy by the National Bank, including significant restrictions on capital flows, unsterilized currency interventions, and lack of control over the IBL interest rate, may be associated with increased macroeconomic volatility in response to demand shock (Figure 12). Convergence of the economic system to a steady state will require significant time and will be accompanied by a prolonged period of high inflation, high nominal interest rates, and depreciation of the national currency.

5.3 In-sample simulations

In-sample simulations were used as an additional procedure to verify the adequacy of the calibration of the QPM. To do this, the root mean squared errors (RMSE) of key QPM macro variables are calculated and compared to the RMSE of a random walk model. The simulations were carried out for the period from the first quarter of 2007 to the fourth quarter of 2021. The first half of 2022 was not taken into account because during this period, the economy of Belarus was subjected to sanctions shock that cannot be forecasted based solely on the historical dynamics of macro variables. When conducting simulations, it is assumed that all exogenous variables in the model are known.[23] All other observable variables are only known up to the quarter preceding the forecast period. Expert judgments were not taken into account in the simulations. The results of the in-sample forecast are presented in Table 1 and Appendix B.

Table 1: Forecast accuracy based on historical data from 2007 to 2021

Variable	The ratio of RMSEs for QPM over random walk, for the forecast horizon quarters ahead					
	1Q	2Q	3Q	4Q	5Q	6Q
Headline inflation, % YoY	0.45	0.52	0.58	0.64	0.66	0.67
Core inflation, % YoY	0.55	0.64	0.72	0.80	0.83	0.85
Real GDP, % YoY	0.68	0.58	0.62	0.70	0.83	0.82
NEER, % QoQ	1.06	0.80	0.76	0.77	0.79	0.81
Nominal IBL rate, %	0.90	0.78	0.86	0.84	0.75	0.74
Nominal rate on ruble market loans, %	0.82	0.81	0.83	0.87	0.88	0.88
Nominal rate on ruble time deposits, %	0.83	0.79	0.85	0.89	0.79	0.76

Source: author's calculations based on the QPM.

Note: YoY is the growth rate quarter to the corresponding quarter of the previous year. QoQ is the annualized growth rate quarter to the previous quarter.

The simulation results show that the accuracy of the QPM is higher than that of the random walk model for all variables considered. It should be noted that the QPM is calibrated to the economic conditions that existed by mid-2022. Therefore, the accuracy of the historical

[23] We also make known fiscal expenditure, terms of trade, and non-core inflation, whose equations specification in the model is simplified.

data forecast may be low due to a number of shocks and changes in monetary policy and exchange rate regimes. For example, the average annual GDP growth rate slowed from 6.4% in 2007-2011 to 0.6% in 2012-2021, and in 2015, the National Bank switched from exchange rate targeting to a managed float regime. The accuracy of the forecast for interest rates, exchange rates, and GDP significantly improves when simulated from the first quarter of 2016 after the transition to managed floating exchange rate regime (Table 2).

Table 2: Forecast accuracy based on historical data from 2016 to 2021

Variable	The ratio of RMSEs for QPM over random walk, for the forecast horizon quarters ahead					
	1Q	2Q	3Q	4Q	5Q	6Q
Headline inflation, % YoY	0.35	0.33	0.40	0.51	0.60	0.72
Core inflation, % YoY	0.53	0.45	0.49	0.63	0.73	0.86
Real GDP, % YoY	0.35	0.40	0.49	0.41	0.31	0.38
NEER, % QoQ	0.88	0.57	0.62	0.77	0.67	0.66
Nominal IBL rate, %	0.67	0.33	0.31	0.35	0.33	0.28
Nominal rate on ruble market loans, %	0.59	0.51	0.47	0.46	0.45	0.45
Nominal rate on ruble time deposits, %	0.76	0.54	0.52	0.60	0.62	0.62

Source: author's calculations based on the QPM.

Note: YoY is the growth rate quarter to the corresponding quarter of the previous year. QoQ is the annualized growth rate quarter to the previous quarter.

6. Retrospective dynamics of key macroeconomic indicators

The QPM allows for the assessment of the current state of the economy, the identification of the key drivers of GDP and inflation dynamics, and the assessment of the nature of monetary, exchange rate, and fiscal policy. Since the QPM separates macroeconomic variables into observable and unobservable components, methods of multivariate filtering are used for the coherent estimation of unobservable components. In this study, the Kalman filter was applied to quarterly data from the first quarter of 2003 to the third quarter of 2022.[24] We applied the Kalman filter twice. The first time, we restricted the sample to the fourth quarter of 2021. This is because in the first and second quarters of 2022, the Belarusian economy was

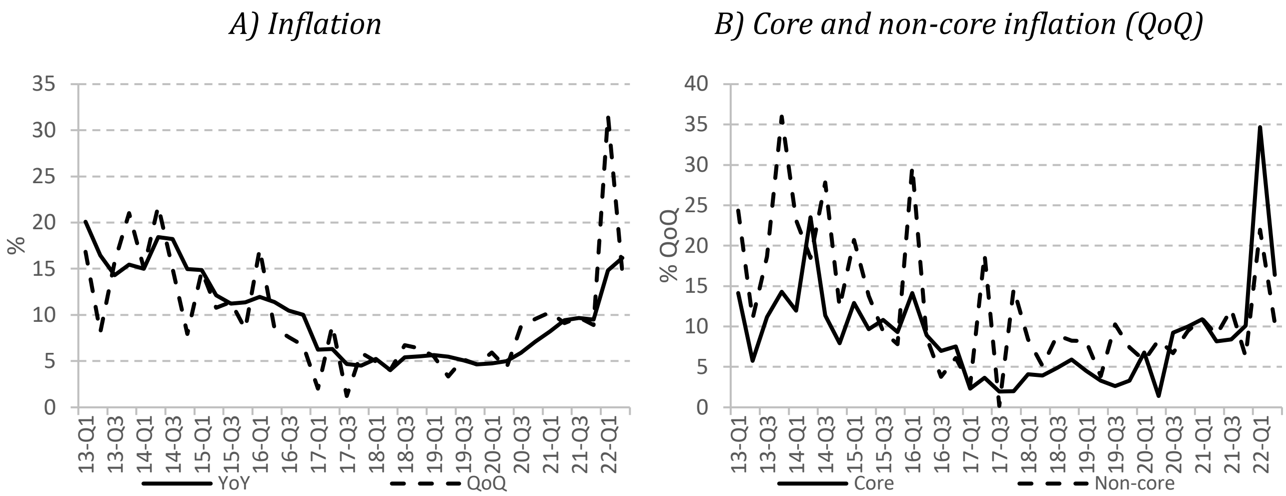
[24] At the time of applying the Kalman filter, there were no empirical data for some indicators for Q3 2022. In this regard, their values in this period are presented by expert estimates based on the available high-frequency data, and the filtering results in Section 6 are considered only up to Q2 2022.

hit by a strong sanctions shock. QPM is unable to predict such exogenous shocks, so the model seeks to explain (taking into account the constraints imposed by specification and calibration) the behavior of macro variables based on the information embedded in QPM. This leads to a significant reevaluation of the dynamics of unobservable variables in 2019-2021 when applying Kalman filtering to the entire sample. To address this problem, we apply the filter to the sample ending in the fourth quarter of 2021, introduce expert judgments so that the dynamics of unobservable variables in 2019-2021 do not undergo significant changes, substantially expand the standard deviations of shocks to equilibrium GDP, exports, and imports, as well as their equilibrium growth rates in the first and second quarters of 2022, and run the Kalman filter on the full sample.[25]

6.1 Inflation: dynamics and determinants

From 2015 to 2017, Belarus experienced a period of disinflation, with the growth of consumer prices dropping to unambiguous levels (Figure 13.A). During this period, both core and non-core inflation significantly slowed down (Figure 13.B).[26]

Figure 13: Inflation dynamics in Belarus in 2013–2022



Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

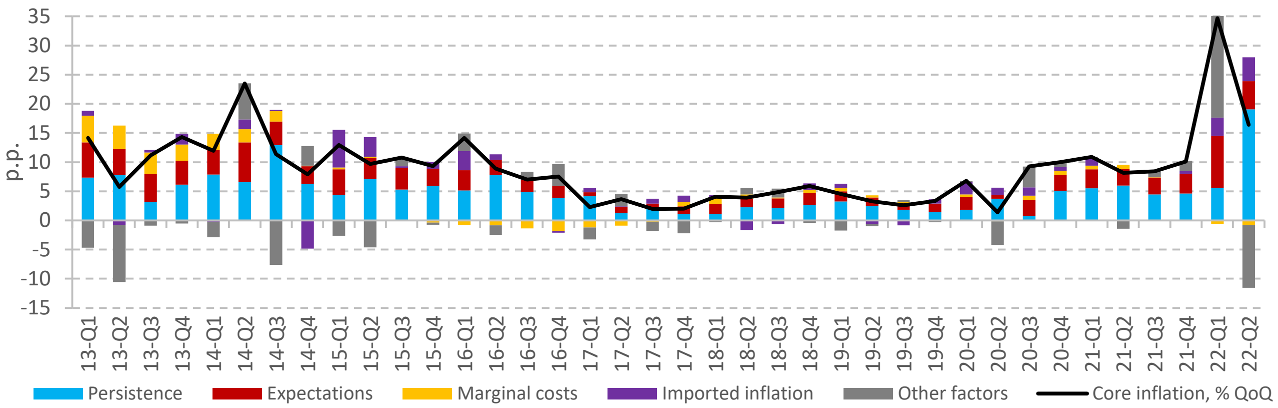
[25] We provide expert judgements for REER gap, equilibrium REER growth, output gap, equilibrium GDP growth, exports gap, imports gap, equilibrium real IBL rate, equilibrium lending and deposit rate spreads, relative price gap, wages gap, and equilibrium real wages growth.

[26] Deceleration of non-core inflation in 2015–2017 was largely a consequence of the administrative regulations. If in 2013–2014 administratively regulated prices grew by more than 20% per year, then in 2015–2016 by an average of 13% per year, then in 2017 – by 8%.

The disinflationary pressure in 2015-2017 came from both real marginal costs and imported inflation, including a slowdown in price growth in Belarus's main trading partner, Russia (Figure 14). Additionally, the National Bank's shift towards active inflation-fighting policies, the establishment of an explicit inflation target, and increased exchange rate flexibility contributed to increased credibility of monetary authorities and helped to reduce inflation expectations (Figure 14). This reduction in inflation expectations during the period is supported by estimates from D. Kruk's econometric modeling study (Kruk, 2020a).

The recession in the Belarusian economy, accompanied by significant negative output and wages gaps (Figure 15), created pressure to lower real marginal costs from 2015 to 2017. This pressure more than offset the inflationary impact of the undervalued Belarusian ruble until the end of 2017. From the end of 2017 to mid-2020, inflation in Belarus fluctuated near the 5% target level (Figure 13.A). The inflationary impact of marginal costs was minimal (Figure 15), imported inflation did not exert additional inflationary pressure, and inflation expectations remained historically low (Figure 14).

Figure 14: Decomposition of core inflation in Belarus in 2013–2022



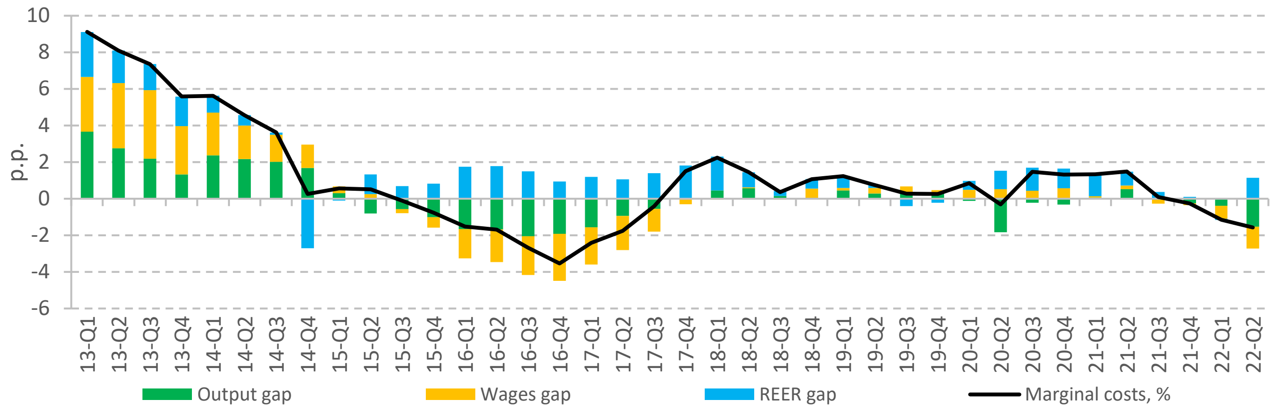
Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

In the second half of 2020, inflation in Belarus began to accelerate due to the weakening of the Belarusian ruble, the increase in inflation expectations against the backdrop of a socio-political crisis, and the increase in imported inflation in the context of a global rise in commodity prices, transportation costs, and supply delays (Figure 14). Additional inflationary pressure in 2020 was exerted by a pace of real wages growth that exceeded equilibrium level, which could have been achieved using administrative resources (Figure 15). Since monetary policy has effectively ceased to be actively used to contain inflation since mid-2020, the effect of most of the factors mentioned has persisted in 2021, at the end of which consumer price inflation in Belarus reached 10%.

In the first quarter of 2022, inflation in Belarus significantly accelerated, and its annualized value for the quarter exceeded 30% – the highest since 2011 (Figure 13.A). The surge in inflation within the QPM framework is explained by a shock that incorporates a massive increase in inflation and devaluation expectations in the context of the introduction of tough sanctions against Russia and Belarus after the Russian invasion of Ukraine (Figure 14). In the second quarter of 2022, there was a corrective slowdown in inflation against the backdrop of a decline in economic activity and a decrease in real wages (Figure 15). At the same time, the growth rate of prices remained historically high due to the increase in the costs of enterprises associated with the restructuring of production, logistics, and financial chains, as well as the increased undervaluation of the Belarusian ruble.

Figure 15: Decomposition of real marginal costs in Belarus in 2013–2022



Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

6.2 GDP and output gap

After 2009, and especially after the internal financial crisis in 2011, GDP growth in Belarus slowed significantly (Figure 16). The slowdown in the growth rate of the Belarusian economy is largely due to a decrease in the efficiency of the use of production factors and was accompanied by a decrease in the potential output growth rate (Figure 16).[27]

The Belarusian authorities' desire to "disguise" the slowdown in economic growth after 2009 was expressed in maintaining a significant positive output gap in 2010-2014 (Figure 17). The active stimulation of the economy through the directive increases in wages, fiscal policy, and

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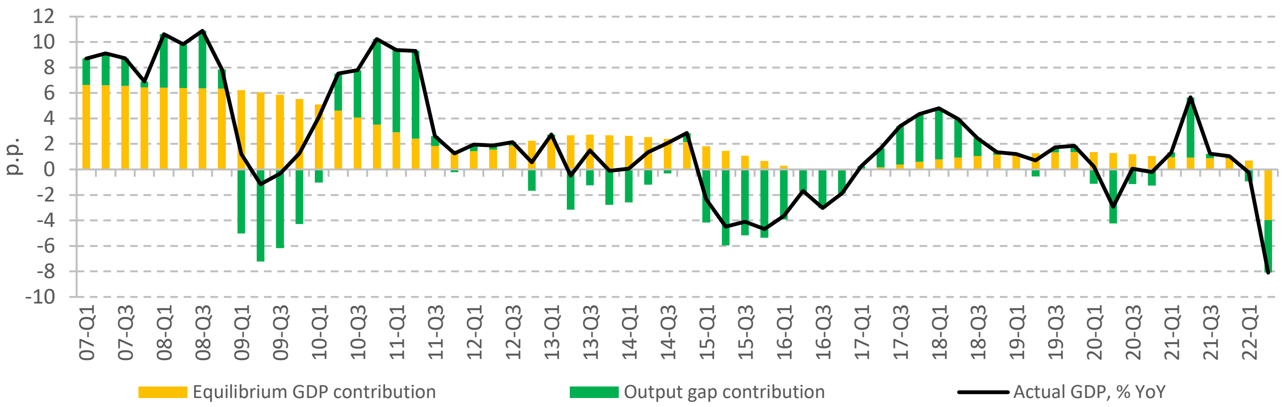
[27] An analysis of the reasons for the slowdown in economic growth in Belarus after 2009 can be found in the studies of D. Kruk (Kruk, 2018; 2020b), V. Kamkou (2020), N. Mironchik & A. Levikhina (2020), World Bank (2018).

directive lending led to overheating of the economy until 2015 (Figure 18) and became one of the main reasons for the currency and banking crisis of 2011 and the currency crisis of 2014-2015.[28] Additional support for the Belarusian economy until 2014 was provided by relatively high GDP growth rates in Russia, largely due to high oil prices (Figure 18).

Figure 16: Decomposition of the GDP growth rate (YoY) in Belarus in 2007–2022



Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

In early 2015, the Belarusian economy entered a recession, which lasted until the third quarter of 2016 (Figure 17). The deep cyclical downturn of 2015-2016 was the result of the erroneous policy of targeting the exchange rate in combination with excessive stimulation of domestic demand, which led to significant overvaluation of the Belarusian ruble at the end of 2014, as well as a decline in external demand due to the economic downturn in Russia. The increase in inflationary risks due to the devaluation of the Belarusian ruble required significant tightening of monetary policy by the National Bank at the beginning of 2015, which, along with a reduction in fiscal support for the economy and restrictions on directive lending, became a factor in the prolonged economic downturn in Belarus (Figure 18).

Since the end of 2016, the Belarusian economy entered a phase of recovery, which lasted until the beginning of 2018. As inflation and inflation expectations decreased, monetary conditions eased, which contributed to the recovery of credit activity and supported the process of economic recovery (Figure 18). In 2018-2019, the Belarusian GDP moved close to an equilibrium trajectory, and the output gap was close to zero (Figure 17). This was due to monetary conditions that were close to neutral, a conservative budget policy, and a recovered external demand (Figure 18).

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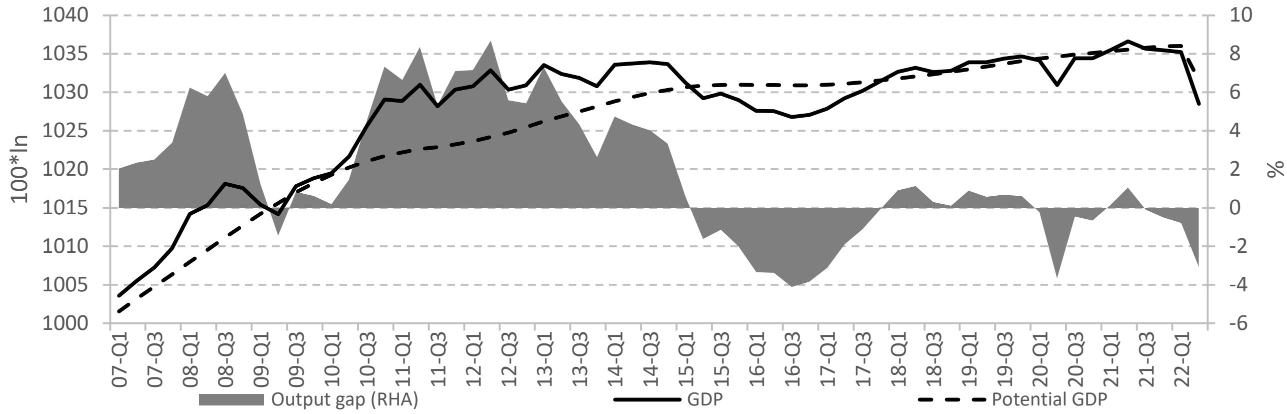
[28] A study of the causes of currency crises in Belarus is given in Miksjuk et al. (2015).

Figure 17: Dynamics of the real GDP and output gap in Belarus in 2007–2022

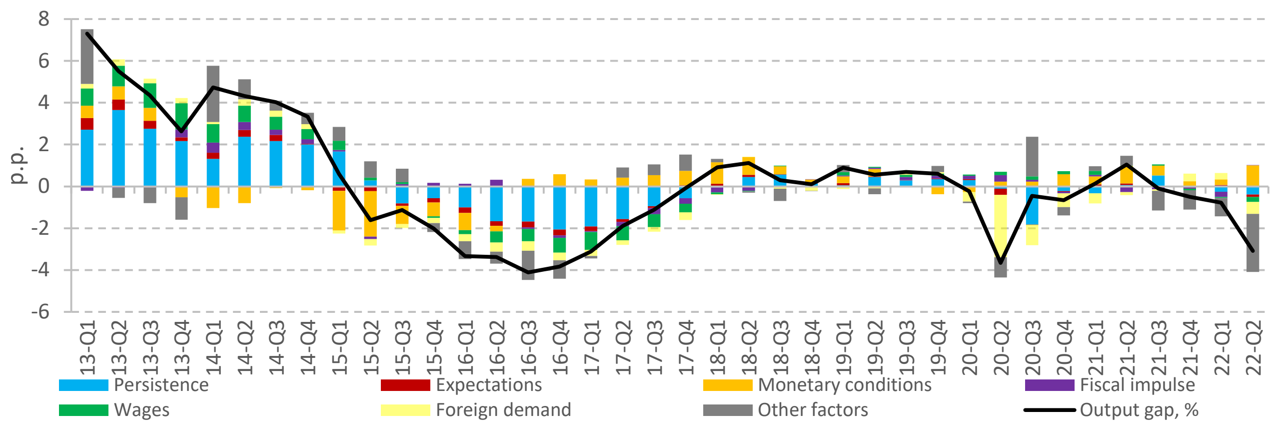


Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

At the beginning of 2020, the Belarusian economy was hit hard by the decline in external demand and the worsening economic sentiments within the country, as the COVID-19 pandemic entered an acute phase. However, the decline in Belarusian GDP was short-lived, and by early 2021 the negative output gap that had formed in the first quarter of 2020 closed. The rapid recovery of the economy was supported by the strengthened global demand for raw materials, including potassium and other fertilizers, timber, petroleum products, and others. The undervaluation of the Belarusian ruble, which had persisted throughout 2021, provided additional support to exports.

Figure 18: Decomposition of the output gap in Belarus in 2013–2022



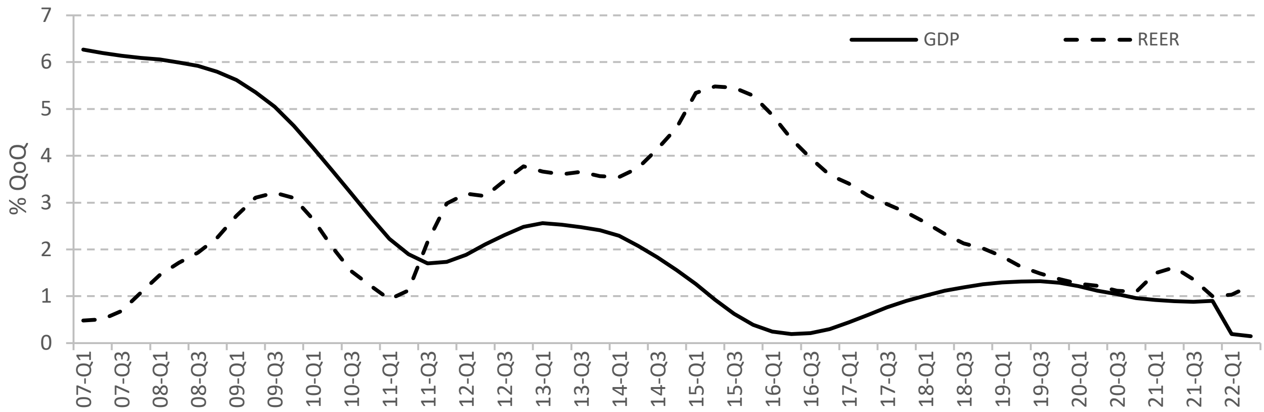
Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

The period of rapid growth of the Belarusian economy was short-lived, as the volume of GDP began to contract from the third quarter of 2021 (after seasonal adjustment). The investment depression, which had worsened after the social-political crisis of 2020, and the gradual strengthening of the Western countries' sanctioning influence began to outweigh the favorable conditions in global markets. As a result, the Belarusian economy began to enter a recession again: GDP continued to decline in the fourth quarter of 2021 and the first quarter of 2022 (Figure 17).

The recession in the Belarusian economy deepened in the second quarter of 2022 due to the tightening of sanctions by Western countries and increased toxicity in interactions with Belarusian counterparts. GDP, after seasonal adjustment, decreased by more than 6% compared to the first quarter of 2022. Under the QPM framework it is assumed that sanctions will have a prolonged impact on Belarus's GDP. This means that the decline in GDP in 2022 is largely structural and related to a decrease in equilibrium output (Figure 16).[29] However, secondary effects of the sanctions have resulted in a weakening of domestic demand, which has led to an expansion of the negative output gap (Figure 16). Since the impact of sanctions is not directly accounted for in the QPM, its influence on the output gap is reflected in the demand shock (other factors in Figure 18).

Figure 19: The growth rates (QoQ) of potential GDP and equilibrium REER in Belarus in 2007–2022



Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

The potential GDP growth of Belarus in 2022, based on the QPM, is estimated to be close to 0% (Figure 19). Its sharp decline reflects the effects of the tightening of sanctions on Belarus and Russia. However, even before 2022, potential GDP growth was estimated to be close to 1%, which is an extremely low value for an emerging market country. Serious obstacles to unlocking the potential of the Belarusian economy include institutional constraints, an insufficiently reformed

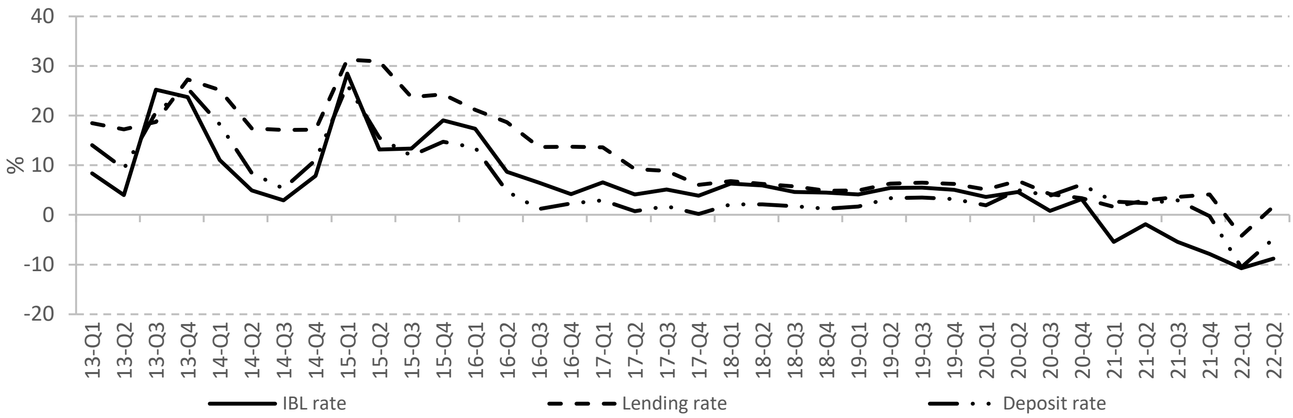
[29] To take into account the structural break in the QPM, the standard deviations of equilibrium GDP shock ($\varepsilon_t^{\bar{y}}$) and equilibrium GDP growth ($\varepsilon_t^{\Delta\bar{y}}$) were expanded based on expert judgments.

state-owned enterprise sector, imbalances in the redistribution of financial resources in the economy, and negative demographic trends.

6.3 Monetary and exchange rate policy

Before 2015, the National Bank of Belarus primarily target the exchange rate of Belarusian ruble to the US dollar. In this regime, considering not fully closed financial account, the National Bank had limited opportunities to manage domestic interest rates of the credit-deposit market. Their dynamics were largely determined by external factors and characterized by increased volatility (Figure 20).

Figure 20: Real interest rates dynamics in Belarus in 2013–2022

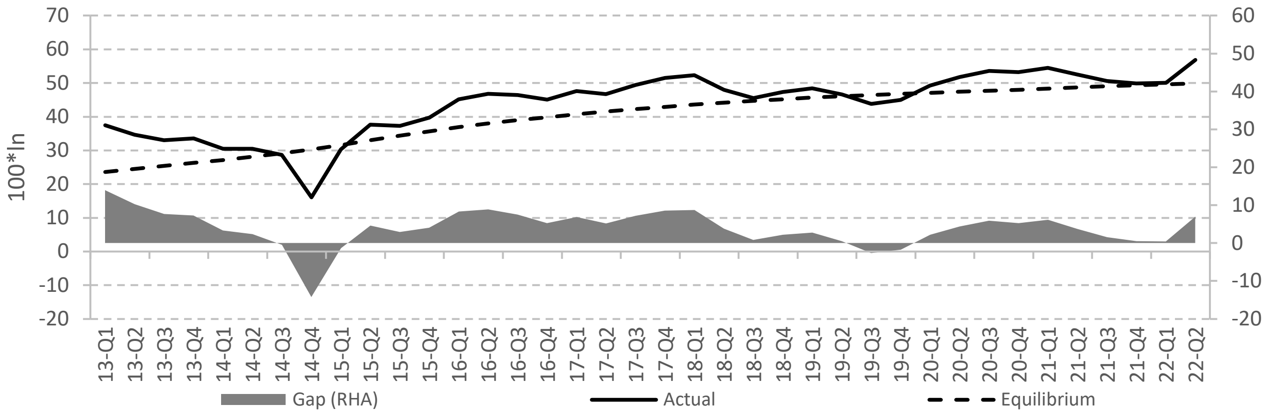


Source: author's calculations based on the QPM.

Significant undervaluation of the Belarusian ruble, which formed after the currency crisis in 2011, allowed the National Bank to use the exchange rate targeting regime relatively successfully until 2014. However, in 2014, there was a change in the external conditions: sanctions were imposed on Russia, and oil prices fell, which led to a 68.5% devaluation of the Russian ruble to the US dollar in December 2014 compared to December 2013. Maintaining the policy of targeting the exchange rate of the Belarusian ruble to the US dollar against this background led to a significant overvaluation of the Belarusian currency by the end of 2014 (Figure 21). In such conditions, the net demand for foreign currency on the domestic market sharply increased, which, in the conditions of limited international reserve assets, forced the National Bank to gradually devalue the Belarusian ruble against the dollar during 2015 and also announce a transition to a monetary targeting and increased flexibility of exchange rate formation.[30, 31]

Transition to a managed floating exchange rate regime was accompanied by the formation of undervaluation of the Belarusian ruble, which persisted until the third quarter of 2018, when the national currency approached the equilibrium level. The ruble again entered the undervaluation area in 2020 as a result of the rush demand for foreign currency in March 2020 and after the presidential elections in August 2020 (Figure 21).

Figure 21: REER dynamics in Belarus in 2013–2022



Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

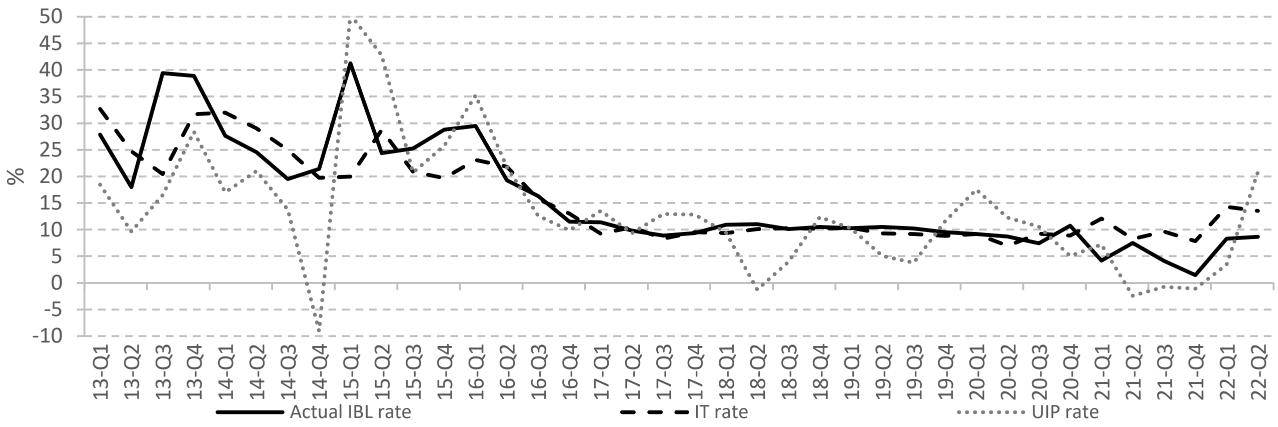
The results of the QPM show that the application of monetary targeting in 2015 – the first half of 2016 led to high volatility of interest rates, which in general sharply increased in real terms (Figure 20). During this period, the National Bank sought to manage the money supply, which, in conditions of unstable money demand, caused strong fluctuations in the price of money. From mid-2016, the dynamics of the IBL rate in Belarus almost completely repeated the trajectory of the QPM-estimated interest rate corresponding to the inflation targeting regime (Figure 22). This may mean that in conditions of an unstable money demand function, the National Bank de facto

[30] In November 2014 the population and organizations bought foreign currency in the Belarusian domestic market in the amount of $0.5 billion (on a net basis), in December 2014 – in the amount of $1.35 billion. The gold and foreign exchange reserves of the National Bank decreased in November 2014 by $0.2 billion, in December 2014 by another $0.76 billion, and amounted to $5.06 billion as of January 1, 2015 (less than 1.4 months of imports of goods and services). The Belarusian ruble depreciated against the dollar by 10.1% in December 2014 and another 29.4% in January 2015.

[31] On the decisions of the National Bank on the transition to monetary targeting and increasing the flexibility of exchange rate, see (in Russ.): https://www.nbrb.by/press/3659 and https://www.nbrb.by/press/4118.

switched to active management of interest rates from mid-2016.[32] Implicit inflation targeting continued until mid-2020, after which the National Bank, as noted in section 3, practically switched to a passive policy, possibly under pressure from the government (Figure 22).

Figure 22: Nominal IBL rate dynamics in Belarus in 2013–2022



Source: author's calculations based on the QPM.

Note: IT rate (i_t^{IT}) – nominal IBL rate corresponding to the implementation of monetary policy in the inflation targeting regime. UIP rate(i_t^{UIP}) – nominal IBL rate in the case of a passive monetary policy with non-sterilized interventions in the foreign exchange market.

The increase in real interest rates in the credit and deposit market in 2015 created restrictive monetary conditions (Figure 23). The IBL interest rate and rate on term deposits exceeded their equilibrium levels up to mid-2016 and began to actively decline in the second quarter of 2016, as the situation on the domestic financial market stabilized and the National Bank de facto shifted to using the IBL rate as an operational target of monetary policy.[33] Lending interest rates remained elevated relative to their equilibrium values up to the end of 2017 due to the persistence of high risks and economic uncertainty, including the two-fold increase in the share of problem assets of banks in 2016.[34] In 2018-2019, which can be characterized as a period of macroeconomic stability, interest rates in the credit and deposit market were maintained close to their equilibrium levels (Figure 23).

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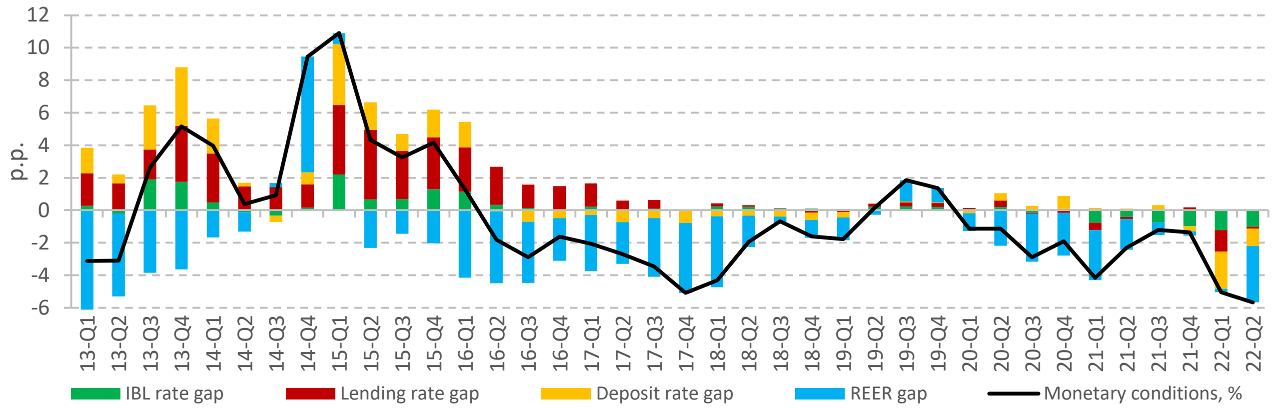
[32] Officially, the change in the operational benchmark of monetary policy from the monetary base to the interbank rate took place on January 1, 2018. See (in Russ.): https://www.nbrb.by/press/6991.

[33] The decrease in deposit rates in 2016 was also associated with the administrative levers of the National Bank, which recommended banks to lower rates. See (in Russ.): https://neg.by/novosti/otkrytj/stavki-pora-snizhat-no-ochen-akkuratno/.

[34] The share of problem assets in the assets of banks exposed to credit risk increased from 6.8% at the beginning of 2016 to 14.9% as of November 1, 2016. By the beginning of 2017, the share decreased to 12.8% and remained at this level at the beginning of 2018.

Figure 23: Monetary conditions decomposition in Belarus in 2013–2022



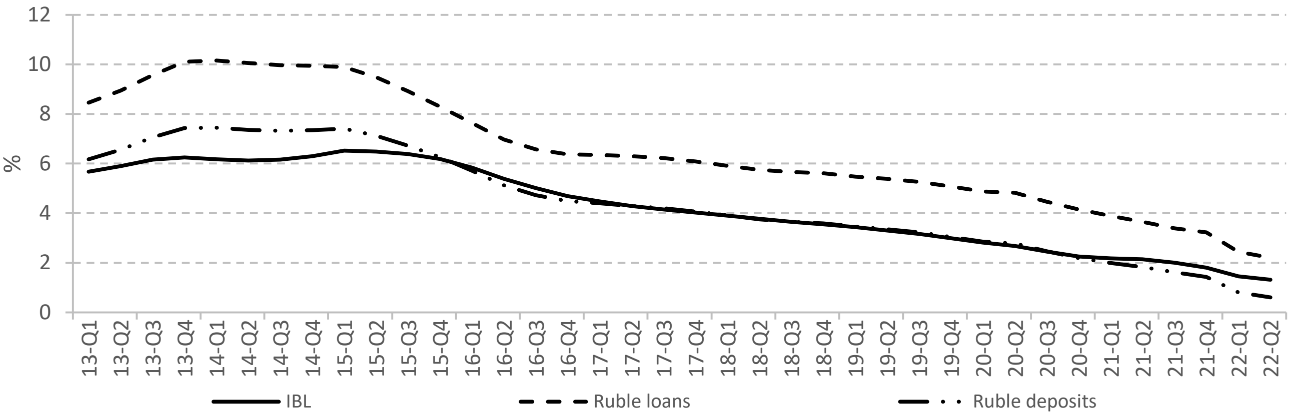
Source: author's calculations based on the QPM.

During the acute phase of the pandemic in the second quarter of 2020, due to increased risks for the financial sector, interest rates moved into the restrictive area. Since mid-2020, the National Bank stopped using the IBL rate as the operational target of monetary policy, and the rate began to be almost entirely determined by the liquidity position of the banking sector. From September to November 2020, the IBL rate remained elevated relative to its equilibrium level due to the deterioration of the liquidity position of the banking system during the socio-political crisis. Deposit rates also exceeded neutral values, while lending rates remained close to equilibrium. In 2021, the IBL rate fell below the equilibrium level due to a structural liquidity surplus, and the resulting monetary conditions remained soft throughout 2022. Deposit rates fell below equilibrium by the end of 2021 (Figure 23).

The results of the QPM application show that important indicators for monetary policy, such as equilibrium real interest rates of the credit-deposit market, have decreased in recent years and as of the second quarter of 2022 are estimated at around 0.6% for new fixed-term ruble deposits, 1.3% for the ruble IBL, and 2.2% for new ruble market loans (Figure 24). The decrease in equilibrium interest rate levels mainly reflects the slowdown in the pace of the equilibrium REER, and in 2022 it also reflects the slower growth rate of Belarus' potential GDP (Figure 25.A).

It should be noted that in the context of the introduction of strict financial sanctions against Belarus and Russia, limitations, and complications in the use of the dollar, euro, and other major currencies in economic activities by Belarusian economic agents, the risks of lending and saving in these currencies rose. This may explain the decrease in the equilibrium credit and deposit spreads identified within the framework of the QPM in 2022 (Figure 25.B).

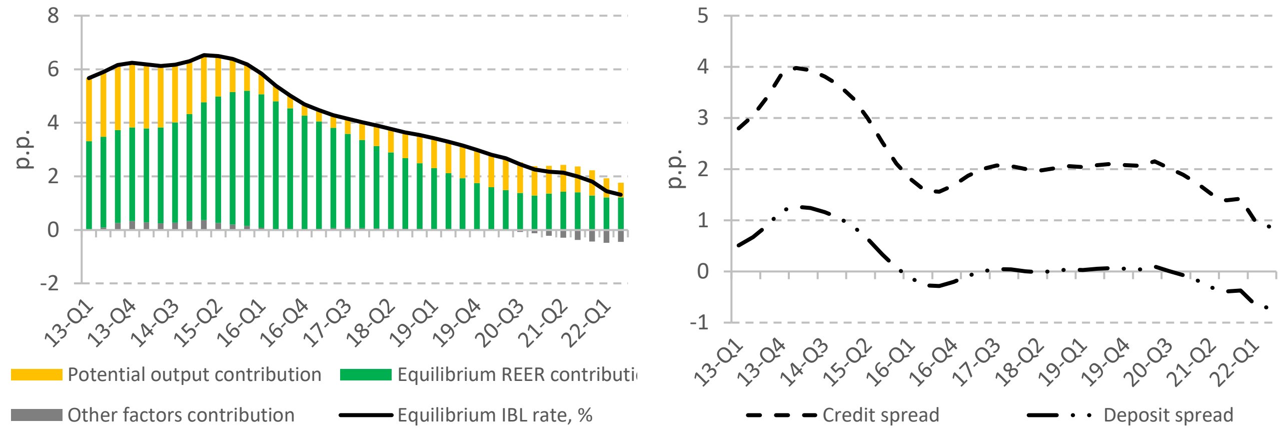
Figure 24: Dynamics of equilibrium interest rates of the credit and deposit market in Belarus in 2013–2022



Source: author's calculations based on the QPM.

Figure 25: Decomposition of real equilibrium IBL rate and dynamics of equilibrium spreads in Belarus in 2013–2022

A) Decomposition of real equilibrium IBL rate *B) Equilibrium spreads*

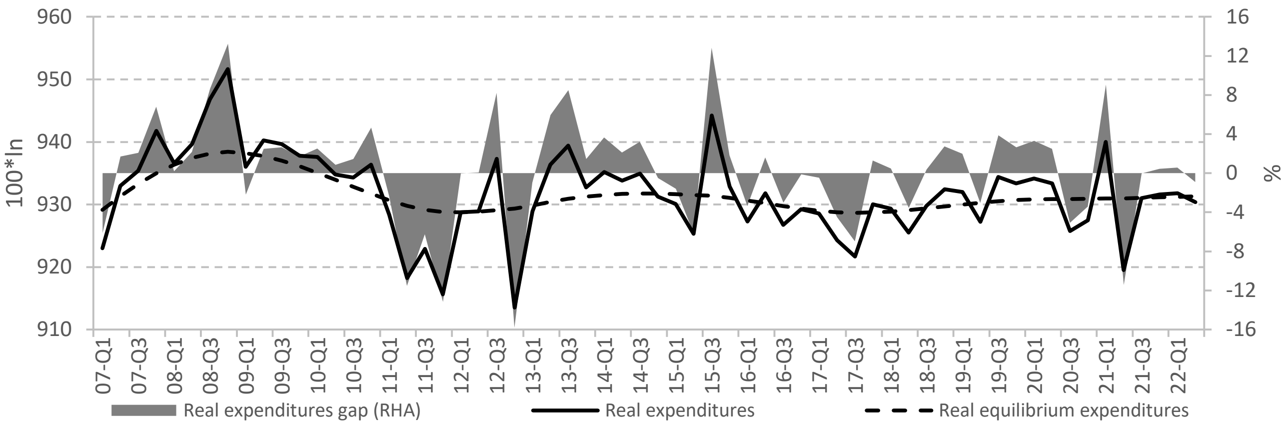


Source: author's calculations based on the QPM.

6.4 Fiscal policy stance

The application of the QPM has allowed for tracking changes in the state of fiscal policy in Belarus in the 21st century. Prior to the currency crisis of 2014-2015, the fiscal policy was generally stimulative: except for the period of hyperinflation in 2011 and several quarters at the turn of 2012-2013, real non-interest budget expenditure exceeded their equilibrium volume (Figure 26). During the crisis period of 2015-2016, a fiscal adjustment was implemented: budget expenditures were reduced due to a fall in the revenue base and an increase in threats to debt sustainability.[35] However, as M. Sidorenko (2020) writes, the expenditure reduction during this period was suboptimal and focused on capital investments.

Figure 26: Dynamics of real non-interest expenditure of the general government budget in Belarus in 2007–2022



Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data. Real budget expenditure is calculated by adjusting nominal expenditure for the GDP deflator. The QPM includes non-interest budget expenditure.

The gradual stabilization of the macroeconomic situation in Belarus allowed the government to restore the volume of budget expenditures closer to the neutral level by the beginning of 2018. Up to the period of social and political instability in the third and fourth quarters of 2020 budget spending slightly exceeded its equilibrium volume, signaling a stimulative fiscal policy. After the third quarter of 2020, the fiscal policy became restrictive again in conditions of significant volumes of debt payments and a limited space for increasing budget revenues due to the weak potential economic growth. In 2021-2022, the dynamics of budget expenditures as a whole were close to equilibrium (Figure 26).

Overall, fiscal policy in Belarus over the past 15 years has generally been procyclical: an increased volume of real budget expenditures relative to the trend correlated with a positive output gap, while a lowered volume of expenditures correlated with a negative output gap (Figure 27).

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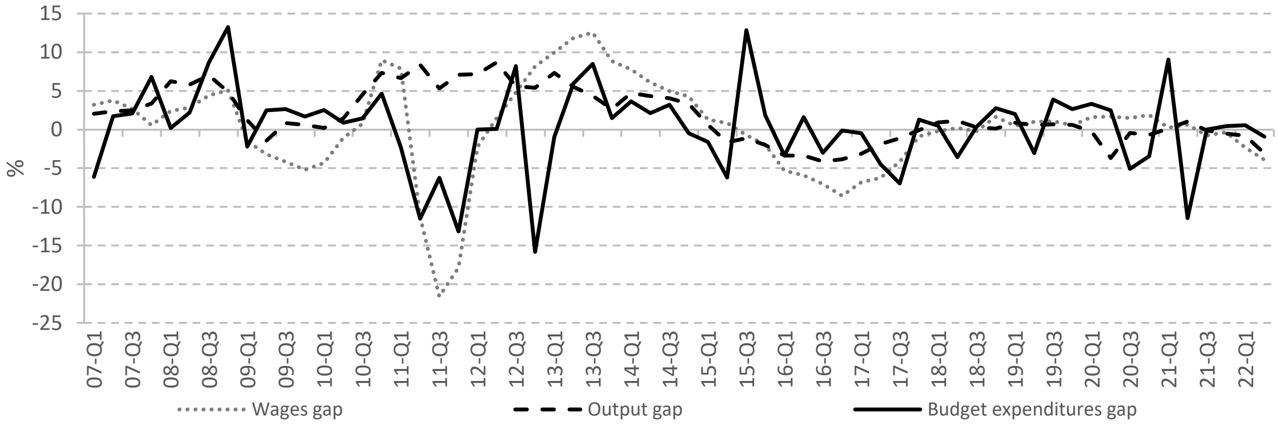
[35] One-time bursts of budget spending during 2015–2022 associated, as a rule, with the provision of state support to individual state-owned enterprises and organizations. At various times, state support was provided, among other things, to Gomselmash, agricultural organizations, the Belarusian Metallurgical Plant, and state banks.

Figure 27: Output gap, real budget expenditure gap and real wages gap in Belarus in 2007–2022



Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

7. Scenario macroeconomic forecast for Belarus based on the QPM

One of the purposes of QPM is to prepare an internally consistent macroeconomic forecast. Due to the methodological features of QPM, modeling-based forecasting is typically done on a medium-term horizon (usually up to three years), after which the dynamics of the economic system approach an equilibrium trajectory.[36] It is important to note that in central bank environments, the key objective of using QPM is not to produce the most accurate forecast, but to support decision-making in the area of monetary policy. Simulations within the model allow for the assessment of the trajectory of the short-term money market interest rate that corresponds to achieving the inflation target over the medium term. Additionally, due to the presence of structural relationships, the forecasting results are relatively straightforward to understand and explain, which can contribute to the improvement of central bank communications.

The forecasting process within QPM (after initial conditions are estimated using the Kalman filter) typically involves five stages:

1) development of a baseline forecast scenario for external economic conditions. The specification of the external sector in QPM is greatly simplified. Therefore, the

[36] It should be noted that the rate of convergence of the economic system to equilibrium depends on the calibration and specification of the QPM. However, a correctly specified and calibrated QPM has a unique steady state.

forecast of external conditions is developed outside the model based on consensus forecasts, other sources, and expert judgments, and is incorporated into QPM;

2) short-term forecast of key macroeconomic indicators for the current quarter and 1-2 quarters ahead using alternative methods. On a short-term horizons, econometric models and expert assessments may be more accurate compared to QPM due to the greater volume of available high-frequency information and the high inertia of macro variables;

3) incorporation of expert judgements into QPM. Researchers usually have more information than is included in the model. For example, the size and trajectory of the inflation target, expected economic policy measures (price regulation, directed lending, fiscal measures, etc.). Calculations of the impact of such measures on key macro indicators require the use of alternative methods and are included in QPM in the form of shocks;

4) medium-term forecasting within the baseline scenario, which incorporates all of the previous steps;

5) development of alternative forecast scenarios in the above sequence.

7.1 Baseline scenario

In terms of external conditions, the baseline scenario of the macroeconomic forecast for Belarus is based on the forecast presented in the IMF WEO (October 2022), as well as expert assessments taking into account the information available as of mid-November 2022. A moderate weakening of business activity in Belarus' trading partners is assumed, with inflation remaining elevated but gradually slowing (Table 3). The baseline scenario assumes the absence of extreme escalation of military confrontation in Ukraine and the continuation of sanctions against Belarus throughout the forecast horizon.

Table 3: External conditions scenario for macroeconomic forecast for Belarus for 2023–2024

Indicator	2023	2024
US real GDP, % YoY	1.0	1.2
EU real GDP, % YoY	0.7	2.1
Russia's real GDP, % YoY	-2.3	1.5
China real GDP, % YoY	4.4	4.5
Inflation (CPI) in the US, % YoY (average)	3.8	2.2
Inflation (CPI) in the Eurozone, % YoY (average)	6.3	2.7
Inflation (CPI) in Russia, % YoY (average)	5.0	4.8
Inflation (CPI) in China, % YoY (average)	2.2	1.9
FED funds effective rate, % (average)	4.3	3.4
ECB rate on the deposit facility, % (average)	2.4	2.1
MIACR 1d in Russia, % (average)	7.6	6.7
SHIBOR 3m in China, % (average)	1.8	2.6
Brent, $/bbl. (average)	89	83

Source: author's calculations.

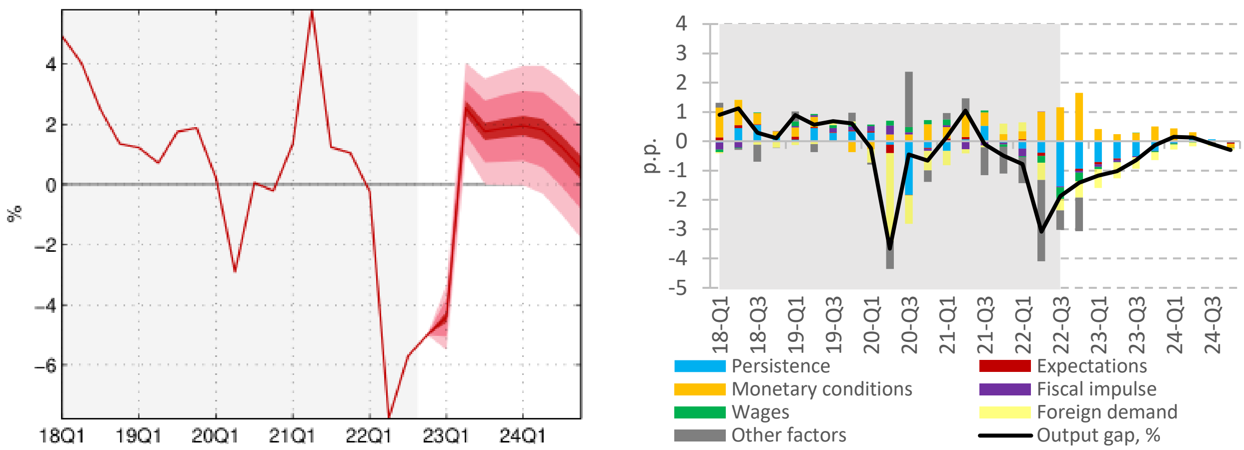
Note: YoY is the growth rate quarter to the corresponding quarter of the previous year.

The forecast includes expert assessments of real GDP growth, nominal wages, core and non-core inflation, nominal interest rates, and the nominal effective exchange rate of the Belarusian ruble for the fourth quarter of 2022. The inflation target based on communications from Belarusian officials is set at 8% at the end of 2023 and 6% at the end of 2024. Non-core inflation for 2023 is assumed to be 8%, in line with the inflation target. It is assumed that the shock of tightening price regulation in the fourth quarter of 2022 will be stretched over time, but in 2023, price growth will gradually compensate for the administrative reduction in October 2022. In terms of monetary policy, the forecast assumes the return of the National Bank to active regulation of banking liquidity by the end of 2023. It is also assumed that support for the Belarusian ruble from non-residents' currency sales will persist for most of 2023 but will weaken. Significant growth in unsecured monetary emission is not included in the forecast. In terms of fiscal policy, a neutral stance is assumed for the forecast horizon.

Simulations within the framework of the baseline scenario based on QPM show that as the Belarusian economy adapts to sanctions, it may demonstrate weak recovery GDP growth of about 0.4% and 1.4% respectively in 2023 and 2024, which, however, does not compensate for the decline in 2022 (Figure 28).

Figure 28: GDP forecast in Belarus in 2022–2024 (baseline scenario)

A) Real GDP (YoY) *B) Output gap*

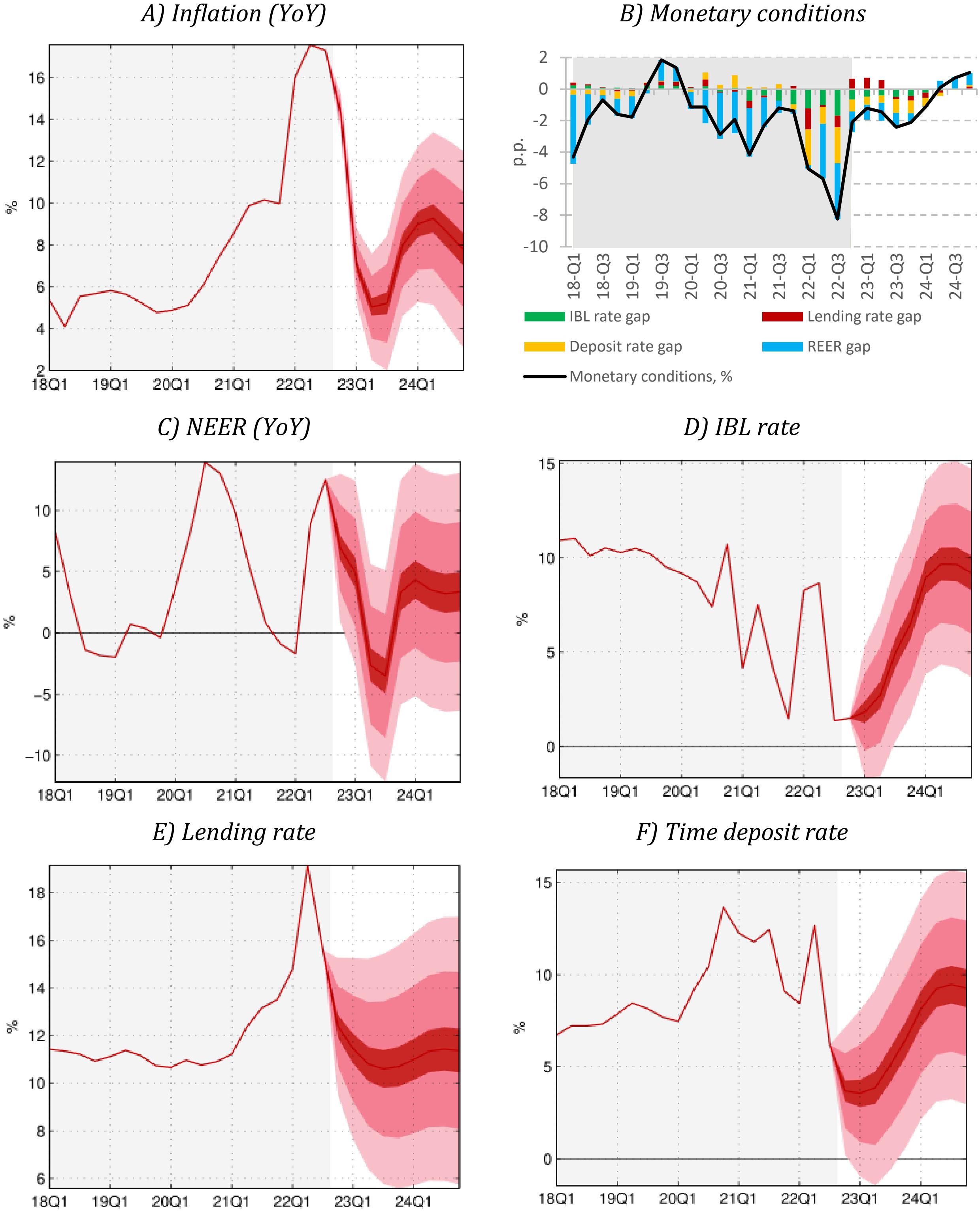


Source: author's calculations based on the QPM.

Note: based on seasonally adjusted data. The ranges in the figures correspond to the 15%, 50%, and 75% confidence intervals.

Inflation is expected to remain above the target due to elevated inflation expectations and is projected to be around 8-10% in 2023-2024, except for a temporary period of decline below 6% in the spring-summer of 2023 due to the high base effect of 2022 (Figure 29.A). The gradual return of the REER to its equilibrium level in 2023-2024 is expected as the trade surplus shrinks, corresponding to a depreciation of the nominal effective exchange rate of the ruble by approximately 3-5% annually in 2023 and 2024 (Figure 29.C). This will contribute to a reduction in the stimulative effect of monetary conditions (Figure 29.B). The IBL rate will remain below the neutral level in 2023 and approach it in 2024, provided that the National Bank returns to active liquidity regulation of banks, corresponding to an IBL rate range of 8-10% in 2024 (Figure 29.D).

Figure 29: Forecasts of inflation and monetary conditions in Belarus in 2022–2024 (baseline scenario)



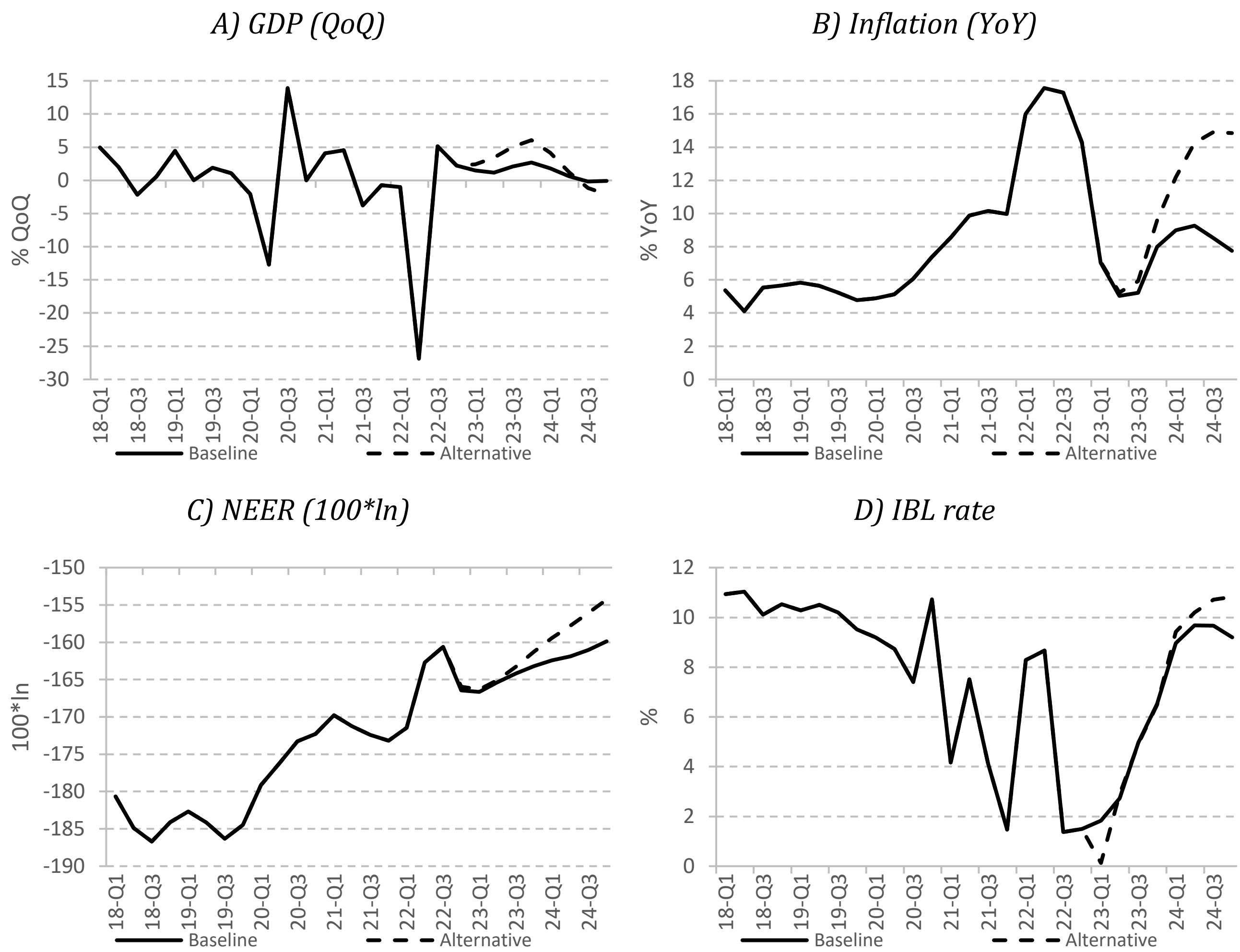
Source: author's calculations based on the QPM.

Note: based on seasonally adjusted data. The ranges in the figures correspond to the 15%, 50%, and 75% confidence intervals.

7.2 Alternative scenario

The alternative scenario assumes the continuation of passive monetary policy and a significant increase in unsecured money emission in 2023. We assume additional emission through a shock to real budgetary expenditures and calibrate it in such a way that the growth of real expenditures in 2023 exceeds their growth in the baseline scenario by approximately 10.5-11 percentage points. Such calibration is generally close to the assumption of additional growth in "quasi-fiscal" emission operations at 4% of GDP in 2023, which is close to the average rate of change in directed lending debt in 2011-2014.[37]

Figure 30: Comparison of the baseline and alternative forecast scenarios



Source: author's calculations based on the QPM.

Note: based on seasonally adjusted data. The ranges in the figures correspond to the 15%, 50%, and 75% confidence intervals.

Additional unsecured emission can contribute to achieving an average annual GDP growth of around 2.3% in 2023-2024, but inflation will approach 10% by

[37] See: Musil et al., 2018.

the end of 2023 and 15% in 2024. As a result, rising prices will begin to depress economic activity, and already in the second half of 2024, the Belarusian economy will enter a recession (Figure 30).

We offer a scenario macroeconomic forecast for Belarus for 2023-2024 as a demonstration of the forecasting capabilities of the developed QPM. The forecast scenarios contain a small number of expert judgments, and they should be considered primarily as simulation experiments. The simulation results are generally considered realistic. However, the implementation of scenarios in practice depends on the fulfillment of the underlying assumptions.

8. Conclusion

In this study, the QPM for Belarus was proposed and tested. The model takes into account the most important characteristics of the Belarusian economy and monetary sphere, including the consequences of deepening isolation of the financial sector of the Belarusian economy, conducting partially non-sterilized FX interventions by the National Bank, and incomplete control by the National Bank over interbank interest rates.

Within the framework of the QPM, simulations were carried out to study the reaction of key macroeconomic indicators to shocks, differences in the behavior of the economic system under the influence of shocks under different designs of monetary and exchange rate policies were justified, the accuracy of the forecast on historical data was assessed, an analysis of the state of the economy, monetary, exchange rate and fiscal policies was conducted, and a macroeconomic forecast for Belarus for the medium term was presented. The results obtained indicate the adequacy of the proposed QPM and the possibility of its application for preparing analytics and forecasts for the Belarusian economy.

The QPM proposed in this paper only approximates our understanding of reality and does not claim to be absolutely true. We intentionally allow for a large number of simplifications in order to build a model suitable for everyday use. Nevertheless, the results obtained within the QPM are internally consistent, do not contradict economic logic, and adequately describe the changes that have occurred in the Belarusian economy, as well as its state in 2022.

The structure and calibration of the developed QPM are not set in stone. Changes constantly occur in the economy that require regular accounting in modeling. This necessitates periodic checking of the model's properties and its adequacy to changing conditions. In the future, it is highly likely that the QPM will require recalibration and possibly re-specification, which will be a direction for further research.

It is important to note that scenarios of changes in political and economic institutions in Belarus, both towards greater inclusiveness and extractivity, are beyond the scope of this study. Such structural changes will also be reflected in changes in the behavior of economic agents, their interactions, shifts in economic policy priorities, and adjustments to the long-term sustainable growth rates of basic macroeconomic indicators. All of this will require a deep re-specification and recalibration of the QPM, which will depend on the nature, scale, and speed of the reforms. Analysis of the impact of possible structural changes on the structure of the QPM is one of the directions for future research.

Literature

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Appendix A

Structure and calibration of the QPM for Belarus

Aggregate demand block and monetary conditions

$$y_t = \bar{y}_t + \hat{y}_t \quad (A.1)$$

$$\Delta 4y_t = y_t - y_{t-4} \quad (A.2)$$

$$\Delta y_t = 4 * (y_t - y_{t-1}) \quad (A.3)$$

$$\bar{y}_t = \bar{y}_{t-1} + \Delta\bar{y}_t/4 + \varepsilon_t^{\bar{y}} \quad (A.4)$$

$$\Delta\bar{y}_t = ab_1\Delta\bar{y}_{t-1} + (1 - ab_1) * \Delta\bar{y}_{ss} + \varepsilon_t^{\Delta\bar{y}} \quad (A.5)$$

$$\Delta 4\bar{y}_t = \bar{y}_t - \bar{y}_{t-4} \quad (A.6)$$

$$\hat{y}_t = a_1\hat{y}_{t-1} + a_2E_t\hat{y}_{t+1} - a_3mci_{t-1} + a_4\hat{y}_t^* + a_5r\widehat{wage}_{t-1} + a_6fi_t + \varepsilon_t^{\hat{y}} \quad (A.7)$$

$$E_t\hat{y}_{t+1} = \hat{y}_{t+1} \quad (A.8)$$

$$mci_t = m_1 * (m_2\hat{r}_t + m_3\widehat{r\_l}_t + (1 - m_2 - m_3) * \widehat{r\_d}_t) - (1 - m_1) * \hat{z}_t \quad (A.9)$$

Fiscal sector and wages

$$rfx_t = \widehat{rfx}_t + \overline{rfx}_t \quad (A.10)$$

$$\widehat{rfx}_t = f_1\widehat{rfx}_{t-1} + \varepsilon_t^{\widehat{rfx}} \quad (A.11)$$

$$\Delta\overline{rfx}_t = f_2\Delta\overline{rfx}_{t-1} + (1 - f_2) * \Delta\overline{rfx}_{ss} + \varepsilon_t^{\Delta\overline{rfx}} \quad (A.12)$$

$$\Delta\overline{rfx}_t = 4 * (\Delta\overline{rfx}_t - \Delta\overline{rfx}_{t-1}) \quad (A.13)$$

$$fi_t = (\widehat{rfx}_t + \widehat{rfx}_{t-1} + \widehat{rfx}_{t-2} + \widehat{rfx}_{t-3})/4 \quad (A.14)$$

$$\Delta wage_t = aa_1 E_t \Delta wage_{t+1} + (1 - aa_1) * \Delta wage_{t-1} + aa_2 \hat{y}_t - aa_3\ r\widehat{wag}e_{t-1} + \varepsilon_t^{\Delta wage} \quad (A.15)$$

$$\Delta wage_t = 4 * (wage_t - wage_{t-1}) \quad (A.16)$$

$$\Delta 4wage_t = wage_t - wage_{t-4} \quad (A.17)$$

$$E_t \Delta wage_{t+1} = \Delta wage_{t+1} \quad (A.18)$$

$$rwage_t = wage_t - cpi_t \quad (A.19)$$

$$\Delta 4rwage_t = rwage_t - rwage_{t-4} \quad (A.20)$$

$$\Delta rwage_t = 4 * (rwage_t - rwage_{t-1}) \quad (A.21)$$

$$rwage_t = \overline{rwage}_t + r\widehat{wag}e_t \quad (A.22)$$

$$\Delta\overline{rwage}_t = aa_4 \Delta\overline{rwage}_{t-1} + (1 - aa_4) * (\Delta\bar{y}_t + wedge) + \varepsilon_t^{\Delta\overline{rwage}} \quad (A.23)$$

$$\Delta\overline{rwage}_t = 4 * (\overline{rwage}_t - \overline{rwage}_{t-1}) \quad (A.24)$$

Inflation block

$$\pi_t = 4 * (cpi_t - cpi_{t-1}) \quad (A.25)$$

$$\pi_t^4 = cpi_t - cpi_{t-4} \quad (A.26)$$

$$\pi_t = weight * \pi_{core_t} + (1 - weight) * \pi_{noncore_t} + \varepsilon_t^{\pi} \quad (A.27)$$

$$rp_t = cpi_{core_t} - cpi_t \quad (A.28)$$

$$rp_t = \widehat{rp}_t + \overline{rp}_t \quad (A.29)$$

$$\Delta\overline{rp}_t = rr_1 \Delta\overline{rp}_{t-1} + (1 - rr_1) * \Delta\overline{rp}_{ss} + \varepsilon_t^{\Delta\overline{rp}} \quad (A.30)$$

$$\Delta\overline{rp}_t = 4 * (\Delta\overline{rp}_t - \Delta\overline{rp}_{t-1}) \quad (A.31)$$

$$\pi_{core_t} = 4 * (cpi_{core_t} - cpi_{core_{t-1}}) \quad (A.32)$$

$$\pi_{core_t} = b_1 E_t \pi_{core_{t+1}} + (1 - b_1 - b_2) * \pi_{core_{t-1}} + b_2 \pi_{imp_t} + b_3 rmc_t + \varepsilon_t^{\pi core} \quad (A.33)$$

$$rmc_t = k_1 \hat{y}_t + k_2 r\widehat{wage}_t + (1 - k_1 - k_2) * (\hat{z}_t - \widehat{rp}_t) \quad (A.34)$$

$$\pi_{imp_t} = \pi_t^* + \Delta s_t - (\Delta \bar{z}_t - \Delta \overline{rp}_t) \quad (A.35)$$

$$\pi_{core_t}^4 = cpi_{core_t} - cpi_{core_{t-4}} \quad (A.36)$$

$$\pi_{noncore_t} = bb_1 E_t \pi_{noncore_{t+1}} + (1 - bb_1) * \pi_{noncore_{t-1}} + bb_2 \widehat{rp\_oil}_t + \\ + bb_3 * (\hat{z}_t + \frac{weight}{1-weight} * \widehat{rp}_t) + \varepsilon_t^{\pi noncore} \quad (A.37)$$

$$\pi_{noncore_t} = 4 * (cpi_{noncore_t} - cpi_{noncore_{t-1}}) \quad (A.38)$$

$$\pi_{noncore_t}^4 = cpi_{noncore_t} - cpi_{noncore_{t-4}} \quad (A.39)$$

$$E_t \pi_{t+3}^4 = \pi_{t+3}^4 \quad (A.40)$$

$$E_t \pi_{t+1}^4 = \pi_{t+1}^4 \quad (A.41)$$

$$E_t \pi_{core_{t+1}} = \pi_{core_{t+1}} \quad (A.42)$$

$$E_t \pi_{noncore_{t+1}} = \pi_t - \frac{1}{1-weight} * (weight * \Delta \overline{rp}_t + \varepsilon_t^{\pi}) \quad (A.43)$$

$$\pi_t^T = tar_1 \pi_{t-1}^T + (1 - tar_1) * \pi_{ss}^T + \varepsilon_t^{\pi^T} \quad (A.44)$$

Exchange rate

$$s_t = (1 - h_1) * s_t^{uip} + h_1 s_t^{bop} + \varepsilon_t^s \quad (A.45)$$

$$s_t^{bop} = s_{t-1} + \frac{\Delta \bar{s}_t}{4} - \widehat{bop}_t \quad (A.46)$$

$$\Delta \bar{s}_t = \Delta \bar{z}_t + \pi_t^T - \pi_{ss}^* \quad (A.47)$$

$$s_t^{uip} = E_t s_{t+1} + \frac{i_t^* - i_t + prem_t}{4} \quad (A.48)$$

$$E_t s_{t+1} = h_2 s_{t+1} + (1 - h_2) * s_{t+1}^{nf} \tag{A.49}$$

$$s_{t+1}^{nf} = s_{t-1} + \frac{2\Delta\bar{s}_t}{4} \tag{A.50}$$

$$\Delta s_t = 4 * (s_t - s_{t-1}) \tag{A.51}$$

$$\Delta 4 s_t = s_t - s_{t-4} \tag{A.52}$$

$$E_t \Delta s_{t+1} = \Delta s_{t+1} \tag{A.53}$$

$$\Delta z_t = \Delta s_t + \pi_t^* - \pi_t \tag{A.54}$$

$$\Delta z_t = 4 * (z_t - z_{t-1}) \tag{A.55}$$

$$\Delta 4 z_t = z_t - z_{t-4} \tag{A.56}$$

$$z_t = \bar{z}_t + \hat{z}_t \tag{A.57}$$

$$\Delta\bar{z}_t = z_1 \Delta\bar{z}_{t-1} + (1 - z_1) * \Delta\bar{z}_{ss} + \varepsilon_t^{\Delta\bar{z}} \tag{A.58}$$

$$\Delta\bar{z}_t = 4 * (\bar{z}_t - \bar{z}_{t-1}) \tag{A.59}$$

$$\Delta 4\bar{z}_t = \bar{z}_t - \bar{z}_{t-4} \tag{A.60}$$

$$prem_t = \overline{prem}_t + \widehat{prem}_t \tag{A.61}$$

$$\overline{prem}_t = pr_1 \overline{prem}_{t-1} + (1 - pr_1) * \overline{prem}_{ss} + \varepsilon_t^{\overline{prem}} \tag{A.62}$$

$$\widehat{prem}_t = pr_2 \widehat{prem}_{t-1} + \varepsilon_t^{\widehat{prem}} \tag{A.63}$$

Foreign trade

$$x_t = \bar{x}_t + \hat{x}_t \tag{A.64}$$

$$\Delta\bar{x}_t = u_1 \Delta\bar{x}_{t-1} + (1 - u_1) * \Delta\bar{x}_{ss} + \varepsilon_t^{\Delta\bar{x}} \tag{A.65}$$

$$\bar{x}_t = \bar{x}_{t-1} + \Delta\bar{x}_t / 4 + \varepsilon_t^{\bar{x}} \tag{A.66}$$

$$\hat{x}_t = c_1\hat{x}_{t-1} + c_2\hat{y}_t^* + c_3\hat{z}_t + \varepsilon_t^{\hat{x}} \quad (A.67)$$

$$\Delta 4\bar{x}_t = \bar{x}_t - \bar{x}_{t-4} \quad (A.68)$$

$$\Delta 4x_t = x_t - x_{t-4} \quad (A.69)$$

$$\Delta x_t = 4 * (x_t - x_{t-1}) \quad (A.70)$$

$$m_t = \overline{m}_t + \widehat{m}_t \quad (A.71)$$

$$\Delta\overline{m}_t = uu_1\Delta\overline{m}_{t-1} + (1 - uu_1) * \Delta\overline{m}_{ss} + \varepsilon_t^{\Delta\overline{m}} \quad (A.72)$$

$$\overline{m}_t = \overline{m}_{t-1} + \Delta\overline{m}_t/4 + \varepsilon_t^{\overline{m}} \quad (A.73)$$

$$\widehat{m}_t = d_1\widehat{m}_{t-1} + d_2\hat{y}_t - d_3\hat{z}_t + \varepsilon_t^{\widehat{m}} \quad (A.74)$$

$$\Delta 4\overline{m}_t = \overline{m}_t - \overline{m}_{t-4} \quad (A.75)$$

$$\Delta 4m_t = m_t - m_{t-4} \quad (A.76)$$

$$\Delta m_t = 4 * (m_t - m_{t-1}) \quad (A.77)$$

$$tot_t = \widehat{tot}_t + \overline{tot}_t \quad (A.78)$$

$$\widehat{tot}_t = r_1\widehat{tot}_{t-1} + \varepsilon_t^{\widehat{tot}} \quad (A.79)$$

$$\Delta\overline{tot}_t = r_2\Delta\overline{tot}_{t-1} + (1 - r_2) * \Delta\overline{tot}_{ss} + \varepsilon_t^{\Delta\overline{tot}} \quad (A.80)$$

$$\Delta\overline{tot}_t = 4 * (\Delta\overline{tot}_t - \Delta\overline{tot}_{t-1}) \quad (A.81)$$

$$\widehat{bop}_t = \widehat{tot}_t + \hat{x}_t - \widehat{m}_t \quad (A.82)$$

Monetary policy reaction function

$$i_t = mpr * i_t^{IT} + (1 - mpr) * i_t^{UIP} + \varepsilon_t^i \quad (A.83)$$

$$i_t^{UIP} = x_1 i_{t-1} + (1 - u_1) * (i_t^* + prem_t + x_2 E_t\Delta s_{t+1} + (1 - x_2) * \Delta s_t) \quad (A.84)$$

$$i_t^{IT} = mm_1 i_{t-1} + (1 - mm_1) * (i_t^n + mm_2 * (E_t \pi_{t+3}^4 - \pi_{t+3}^T) + mm_3 \hat{y}_t) \quad (A.85)$$

$$i_t^n = \bar{r}_t + E_t \pi_{t+1}^4 \quad (A.86)$$

$$r_t = i_t - E_t \pi_{t+1}^4 \quad (A.87)$$

$$r_t = \bar{r}_t + \hat{r}_t \quad (A.88)$$

$$\bar{r}_t = w_1 \bar{r}_{t-1} + (1 - w_1) * (\Delta \bar{y}_t + \Delta \bar{z}_t) + \varepsilon_t^{\bar{r}} \quad (A.89)$$

Interest rates of the loans and deposits market

$$\Delta i\_l_t = s_1 \Delta i_t + s_2 \Delta i_{t-1} + s_3 (i\_l_{t-1} - s_4 i_{t-1} - s_5) + \varepsilon_t^{\Delta i\_l} \quad (A.90)$$

$$\Delta i\_l_t = i\_l_t - i\_l_{t-1} \quad (A.91)$$

$$r\_l_t = i\_l_t - E_t \pi_{t+1}^4 \quad (A.92)$$

$$r\_l_t = \overline{r\_l}_t + \widehat{r\_l}_t \quad (A.93)$$

$$\overline{r\_l}_t = \bar{r}_t + \overline{spread}_t^l \quad (A.94)$$

$$spread_t^l = \overline{spread}_t^l + \widehat{spread}_t^l \quad (A.95)$$

$$spread_t^l = i\_l_t - i_t \quad (A.96)$$

$$\overline{spread}_t^l = w_2 \overline{spread}_{t-1}^l + (1 - w_2) * \overline{spread}_{ss}^l + \varepsilon_t^{\overline{spread}^l} \quad (A.97)$$

$$\Delta i\_d_t = q_1 \Delta i_t + q_2 \Delta i_{t-1} + q_3 (i\_l_{t-1} - q_4 i_{t-1} - q_5) + \varepsilon_t^{\Delta i\_d} \quad (A.98)$$

$$\Delta i\_d_t = i\_d_t - i\_d_{t-1} \quad (A.99)$$

$$r\_d_t = i\_d_t - E_t \pi_{t+1}^4 \quad (A.100)$$

$$r\_d_t = \overline{r\_d}_t + \widehat{r\_d}_t \quad (A.101)$$

$$\overline{r\_d}_t = \bar{r}_t + \overline{spread}_t^d \quad (A.102)$$

$$spread_t^d = \overline{spread}_t^d + \widehat{spread}_t^d \quad \text{(A.103)}$$

$$spread_t^d = i\_d_t - i_t \quad \text{(A.104)}$$

$$\overline{spread}_t^d = w_3 \overline{spread}_{t-1}^d + (1 - w_3) * \overline{spread}_{ss}^d + \varepsilon_t^{\overline{spread}^d} \quad \text{(A.105)}$$

External sector

$$\hat{y}_t^* = w^{ru}\hat{y}_t^{ru} + w^{eu}\hat{y}_t^{eu} + w^{cn}\hat{y}_t^{cn} + (1 - w^{ru} - w^{eu} - w^{cn}) * \hat{y}_t^{us} \quad \text{(A.106)}$$

$$\hat{y}_t^{ru} = a^{y\_ru}\hat{y}_{t-1}^{ru} + \varepsilon_t^{\hat{y}^{ru}} \quad \text{(A.107)}$$

$$\hat{y}_t^{eu} = a^{y\_eu}\hat{y}_{t-1}^{eu} + \varepsilon_t^{\hat{y}^{eu}} \quad \text{(A.108)}$$

$$\hat{y}_t^{cn} = a^{y\_cn}\hat{y}_{t-1}^{cn} + \varepsilon_t^{\hat{y}^{cn}} \quad \text{(A.109)}$$

$$\hat{y}_t^{us} = a^{y\_us}\hat{y}_{t-1}^{us} + \varepsilon_t^{\hat{y}^{us}} \quad \text{(A.110)}$$

$$\pi_t^* = w^{ru}\pi_t^{ru} + w^{eu}\pi_t^{eu} + w^{cn}\pi_t^{cn} + (1 - w^{ru} - w^{eu} - w^{cn}) * \pi_t^{us} \quad \text{(A.111)}$$

$$\pi 4_t^* = \frac{\pi_t^* + \pi_{t-1}^* + \pi_{t-2}^* + \pi_{t-3}^*}{4} \quad \text{(A.112)}$$

$$\pi_t^{ru} = b^{\pi\_ru}\pi_{t-1}^{ru} + (1 - b^{\pi\_ru}) * \pi_{ss}^{ru} + \varepsilon_t^{\pi^{ru}} \quad \text{(A.113)}$$

$$\pi 4_t^{ru} = cpi_t^{ru} - cpi_{t-4}^{ru} \quad \text{(A.114)}$$

$$\pi_t^{ru} = 4 * (cpi_t^{ru} - cpi_{t-1}^{ru}) \quad \text{(A.115)}$$

$$\pi_t^{eu} = b^{\pi\_eu}\pi_{t-1}^{eu} + (1 - b^{\pi\_eu}) * \pi_{ss}^{eu} + \varepsilon_t^{\pi^{eu}} \quad \text{(A.116)}$$

$$\pi 4_t^{eu} = cpi_t^{eu} - cpi_{t-4}^{eu} \quad \text{(A.117)}$$

$$\pi_t^{eu} = 4 * (cpi_t^{eu} - cpi_{t-1}^{eu}) \quad \text{(A.118)}$$

$$\pi_t^{cn} = b^{\pi\_cn}\pi_{t-1}^{cn} + (1 - b^{\pi\_cn}) * \pi_{ss}^{cn} + \varepsilon_t^{\pi^{cn}} \quad \text{(A.119)}$$

$$\pi4_t^{cn} = cpi_t^{cn} - cpi_{t-4}^{cn} \tag{A.120}$$

$$\pi_t^{cn} = 4 * (cpi_t^{cn} - cpi_{t-1}^{cn}) \tag{A.121}$$

$$\pi_t^{us} = b^{\pi\_us}\pi_{t-1}^{us} + (1 - b^{\pi\_us}) * \pi_{ss}^{us} + \varepsilon_t^{\pi^{us}} \tag{A.122}$$

$$\pi4_t^{us} = cpi_t^{us} - cpi_{t-4}^{us} \tag{A.123}$$

$$\pi_t^{us} = 4 * (cpi_t^{us} - cpi_{t-1}^{us}) \tag{A.124}$$

$$i_t^* = w^{ru}i_t^{ru} + w^{eu}i_t^{eu} + w^{cn}i_t^{cn} + (1 - w^{ru} - w^{eu} - w^{cn}) * i_t^{us} \tag{A.125}$$

$$\bar{r}_t^* = w^{ru}\bar{r}_t^{ru} + w^{eu}\bar{r}_t^{eu} + w^{cn}\bar{r}_t^{cn} + (1 - w^{ru} - w^{eu} - w^{cn}) * \bar{r}_t^{us} \tag{A.126}$$

$$r_t^* = w^{ru}r_t^{ru} + w^{eu}r_t^{eu} + w^{cn}r_t^{cn} + (1 - w^{ru} - w^{eu} - w^{cn}) * r_t^{us} \tag{A.127}$$

$$\hat{r}_t^* = r_t^* - \bar{r}_t^* \tag{A.128}$$

$$i_t^{ru} = c^{i\_ru}i_{t-1}^{ru} + \left(1 - c^{i\_ru}\right) * (\bar{r}_{ss}^{ru} + \pi_{ss}^{ru}) + \varepsilon_t^{i^{ru}} \tag{A.129}$$

$$\bar{r}_t^{ru} = c^{r\_ru}\bar{r}_{t-1}^{ru} + (1 - c^{r\_ru}) * \bar{r}_{ss}^{ru} + \varepsilon_t^{\bar{r}^{ru}} \tag{A.130}$$

$$r_t^{ru} = i_t^{ru} - \pi4_{t+1}^{ru} \tag{A.131}$$

$$\hat{r}_t^{ru} = r_t^{ru} - \bar{r}_t^{ru} \tag{A.132}$$

$$i_t^{eu} = c^{i\_eu}i_{t-1}^{eu} + \left(1 - c^{i\_eu}\right) * (\bar{r}_{ss}^{eu} + \pi_{ss}^{eu}) + \varepsilon_t^{i^{eu}} \tag{A.133}$$

$$\bar{r}_t^{eu} = c^{r\_eu}\bar{r}_{t-1}^{eu} + (1 - c^{r\_eu}) * \bar{r}_{ss}^{eu} + \varepsilon_t^{\bar{r}^{eu}} \tag{A.134}$$

$$r_t^{eu} = i_t^{eu} - \pi4_{t+1}^{eu} \tag{A.135}$$

$$\hat{r}_t^{eu} = r_t^{eu} - \bar{r}_t^{eu} \tag{A.136}$$

$$i_t^{cn} = c^{i\_cn}i_{t-1}^{cn} + \left(1 - c^{i\_cn}\right) * (\bar{r}_{ss}^{cn} + \pi_{ss}^{cn}) + \varepsilon_t^{i^{cn}} \tag{A.137}$$

$$\bar{r}_t^{cn} = c^{r\_cn}\bar{r}_{t-1}^{cn} + (1 - c^{r\_cn}) * \bar{r}_{ss}^{cn} + \varepsilon_t^{\bar{r}^{cn}} \tag{A.138}$$

$$r_t^{cn} = i_t^{cn} - \pi 4_{t+1}^{cn} \tag{A.139}$$

$$\hat{r}_t^{cn} = r_t^{cn} - \bar{r}_t^{cn} \tag{A.140}$$

$$i_t^{us} = c^{i\_us} i_{t-1}^{us} + \left(1 - c^{i\_us}\right) * (\bar{r}_{ss}^{us} + \pi_{ss}^{us}) + \varepsilon_t^{i^{us}} \tag{A.141}$$

$$\bar{r}_t^{us} = c^{r\_us} \bar{r}_{t-1}^{us} + (1 - c^{r\_us}) * \bar{r}_{ss}^{us} + \varepsilon_t^{\bar{r}^{us}} \tag{A.142}$$

$$r_t^{us} = i_t^{us} - \pi 4_{t+1}^{us} \tag{A.143}$$

$$\hat{r}_t^{us} = r_t^{us} - \bar{r}_t^{us} \tag{A.144}$$

$$rp\_oil_t = p\_oil_t - cpi_t^{us} \tag{A.145}$$

$$rp\_oil_t = \overline{rp\_oil}_t + \widehat{rp\_oil}_t \tag{A.146}$$

$$\Delta rp\_oil_t = 4 * (rp\_oil_t - rp\_oil_{t-1}) \tag{A.147}$$

$$\Delta 4 rp\_oil_t = rp\_oil_t - rp\_oil_{t-4} \tag{A.148}$$

$$\Delta \overline{rp\_oil}_t = 4 * (\overline{rp\_oil}_t - \overline{rp\_oil}_{t-1}) \tag{A.149}$$

$$\Delta \overline{rp\_oil}_t = o_1 \Delta \overline{rp\_oil}_{t-1} + (1 - o_1) * \Delta \overline{rp\_oil}_{ss} + \varepsilon_t^{\Delta \overline{rp\_oil}} \tag{A.150}$$

$$\widehat{rp\_oil}_t = o_2 \widehat{rp\_oil}_{t-1} + \varepsilon_t^{\widehat{rp\_oil}} \tag{A.151}$$

Table A.1: QPM variables

Designation	Variable
y_t	Real GDP
$\bar{y}_t$	Equilibrium (potential) real GDP
$\hat{y}_t$	Output gap (deviation of real GDP from the equilibrium level)
Δy_t	Annualized real GDP growth
$\Delta 4 y_t$	Growth of real GDP period to corresponding period of previous year

Continuation of the table A.1

Designation	Variable
$\Delta\bar{y}_t$	Annualized real equilibrium GDP growth
$\Delta 4\bar{y}_t$	Growth of real equilibrium GDP period to corresponding period of previous year
$E_t\hat{y}_{t+1}$	Output gap expected in period t+1
mci_t	Monetary conditions index
rfx_t	Real non-interest budget expenditures of the general government
$\overline{rfx}_t$	Equilibrium real non-interest budget expenditures
$\widehat{rfx}_t$	Budget expenditures gap (deviation of real non-interest budget expenditures from the equilibrium level)
$\Delta\overline{rfx}_t$	Annualized equilibrium real non-interest budget expenditures growth
fi_t	Fiscal impulse
$\Delta wage_t$	Annualized growth rate of nominal wages
$wage_t$	Nominal wages
$\Delta 4wage_t$	Growth rate of nominal wages period to corresponding period of previous year
$E_t\Delta wage_{t+1}$	Expected growth rate of nominal wages in period t+1
$rwage_t$	Real wages
$\Delta 4rwage_t$	Growth rate of real wages period to corresponding period of previous year
$\Delta rwage_t$	Annualized growth rate of real wages
$\overline{rwage}_t$	Equilibrium real wages
$\widehat{rwage}_t$	Wages gap (deviation of real wages from equilibrium level)
$\Delta\overline{rwage}_t$	Annualized growth rate of equilibrium real wages
π_t	Inflation (annualized growth rate of consumer price index)
cpi_t	Headline consumer price index
π_t^4	Growth rate of consumer price index period to corresponding period of previous year

Continuation of the table A.1

Designation	Variable
rp_t	Relative price (the ratio of the core consumer price index to the headline index)
$\widehat{rp}_t$	Relative price gap
$\overline{rp}_t$	Equilibrium relative price
$\Delta\overline{rp}_t$	Annualized growth rate of equilibrium relative price
$cpi_{core\,t}$	Core consumer price index
$\pi_{core\,t}$	Core inflation (annualized growth rate of the core consumer price index)
$\pi^4_{core\,t}$	Growth rate of core consumer price index period to corresponding period of previous year
rmc_t	Real marginal costs
$\pi_{imp\,t}$	Imported inflation
$\pi_{noncore\,t}$	Non-core inflation (annualized growth rate of the non-core consumer price index)
$cpi_{noncore\,t}$	Non-core consumer price index
$\pi^4_{noncore\,t}$	Growth rate of non-core consumer price index period to corresponding period of previous year
$E_t\pi^4_{t+1}$	Expected growth rate of consumer price index period to corresponding period of previous year in period t+1
$E_t\pi^4_{t+3}$	Expected growth rate of consumer price index period to corresponding period of previous year in period t+3
$E_t\pi_{core\,t+1}$	Expected core inflation in period t+1
$E_t\pi_{noncore\,t+1}$	Expected non-core inflation in period t+1
π^T_t	Inflation target
s_t	Nominal effective exchange rate of the Belarusian ruble (NEER)
s^{bop}_t	NEER determined by foreign trade conditions
s^{uip}_t	NEER determined by uncovered interest rate parity
$\Delta\bar{s}_t$	Annualized growth rate of trend NEER
$E_t s_{t+1}$	Expected NEER in period t+1

Continuation of the table A.1

Designation	Variable
s_{t+1}^{nf}	Naïve forecast of NEER for period t+1
Δs_t	Annualized growth of NEER
$\Delta 4s_t$	Growth of NEER period to corresponding period of previous year
$E_t\Delta s_{t+1}$	Annualized growth of NEER expected in period t+1
z_t	Real effective exchange rate of the Belarusian ruble (REER)
Δz_t	Annualized growth of REER
$\Delta 4z_t$	Growth of REER period to corresponding period of previous year
$\bar{z}_t$	Equilibrium REER
$\hat{z}_t$	REER gap (deviation of REER from the equilibrium level)
$\Delta\bar{z}_t$	Annualized growth of equilibrium REER
$\Delta 4\bar{z}_t$	Growth of equilibrium REER period to corresponding period of previous year
$prem_t$	Risk premium for investments in assets denominated in Belarusian rubles
$\overline{prem}_t$	Equilibrium risk premium for investments in assets denominated in Belarusian rubles
$\widehat{prem}_t$	Gap of risk premium for investments in assets denominated in Belarusian rubles
x_t	Physical volume of exports of goods and services
$\bar{x}_t$	Equilibrium physical volume of exports
$\hat{x}_t$	Exports gap (deviation of the physical volume of exports from the equilibrium level)
$\Delta\bar{x}_t$	Annualized growth of equilibrium physical volume of exports
$\Delta 4\bar{x}_t$	Growth of equilibrium physical volume of exports period to corresponding period of previous year
$\Delta 4x_t$	Growth of physical volume of exports period to corresponding period of previous year
Δx_t	Annualized growth of physical volume of exports
m_t	Physical volume of imports of goods and services

Continuation of the table A.1

Designation	Variable
$\bar{m}_t$	Equilibrium physical volume of imports
$\hat{m}_t$	Imports gap (deviation of the physical volume of imports from the equilibrium level)
$\Delta\bar{m}_t$	Annualized growth of the equilibrium physical volume of imports
$\Delta4\bar{m}_t$	Growth of equilibrium physical volume of imports period to corresponding period of previous year
$\Delta4m_t$	Growth of physical volume of imports period to corresponding period of previous year
Δm_t	Annualized growth of physical volume of imports
tot_t	Terms of trade (ratio of export prices to import prices)
$\overline{tot}_t$	Equilibrium terms of trade
$\widehat{tot}_t$	Terms of trade gap
$\Delta\overline{tot}_t$	Annualized growth of equilibrium terms of trade
$\widehat{bop}_t$	Approximation of the foreign trade balance gap (deviation of the value of the foreign trade balance from the equilibrium level)
i_t	Nominal IBL interest rate
i_t^{UIP}	Nominal IBL rate when conducting passive monetary policy with non-sterilized interventions in the foreign exchange market
i_t^{IT}	Nominal IBL rate corresponding to the implementation of inflation targeting monetary policy
i_t^n	Neutral nominal IBL rate
r_t	Real IBL interest rate
$\bar{r}_t$	Equilibrium real IBL rate
$\hat{r}_t$	IBL rate gap (deviation of the real IBL rate from the equilibrium level)
i_l_t	Nominal interest rate on new market ruble loans to individuals and organizations
Δi_l_t	Change in nominal interest rate on new market ruble loans to individuals and organizations

Continuation of the table A.1

Designation	Variable
r_l_t	Real interest rate on new market ruble loans to individuals and organizations
$\overline{r\_l}_t$	Equilibrium real interest rate on new market ruble loans to individuals and organizations
$\widehat{r\_l}_t$	Lending rate gap
$spread_t^l$	Spread of nominal lending rate to nominal IBL rate (credit spread)
$\overline{spread}_t^l$	Equilibrium credit spread
$\widehat{spread}_t^l$	Credit spread gap
i_d_t	Nominal interest rate on new ruble time deposits for individuals and organizations
Δi_d_t	Change in nominal interest rate on new ruble time deposits for individuals and organizations
r_d_t	Real interest rate on new ruble time deposits for individuals and organizations
$\overline{r\_d}_t$	Equilibrium real interest rate on new ruble time deposits for individuals and organizations
$\widehat{r\_d}_t$	Deposit rate gap
$spread_t^d$	Spread of nominal interest rate on deposits to nominal IBL rate (deposit spread)
$\overline{spread}_t^d$	Equilibrium deposit spread
$\widehat{spread}_t^d$	Deposit spread gap
$\hat{y}_t^*$	Aggregate output gap in countries - Belarus' trading partners
$\hat{y}_t^{ru}$	Output gap in Russia
$\hat{y}_t^{eu}$	Output gap in the EU
$\hat{y}_t^{cn}$	Output gap in China
$\hat{y}_t^{us}$	Output gap in the US
π_t^*	Aggregate annualized growth rate of the consumer price index (inflation) in countries – Belarus' trading partners

Continuation of the table A.1

Designation	Variable
$\pi4_t^*$	Growth of consumer price index in countries – Belarus' trading partners period to corresponding period of previous year
π_t^{ru}	Annualized growth in consumer price index in Russia
$\pi4_t^{ru}$	Growth in consumer price index in Russia period to corresponding period of previous year
cpi_t^{ru}	Consumer price index in Russia
π_t^{eu}	Annualized growth in consumer price index in the Eurozone
$\pi4_t^{eu}$	Growth in consumer price index in the Eurozone period to corresponding period of previous year
cpi_t^{eu}	Consumer price index in the Eurozone
π_t^{cn}	Annualized growth in consumer price index in China
$\pi4_t^{cn}$	Growth in consumer price index in China period to corresponding period of previous year
cpi_t^{cn}	Consumer price index in China
π_t^{us}	Annualized growth in consumer price index in the US
$\pi4_t^{us}$	Growth in consumer price index in the US period to corresponding period of previous year
cpi_t^{us}	Consumer price index in the US
i_t^*	Aggregate nominal IBL rate in countries - Belarus' trading partners
$\bar{r}_t^*$	Aggregate equilibrium real IBL rate in countries - Belarus' trading partners
r_t^*	Aggregate real IBL rate in countries - Belarus' trading partners
$\hat{r}_t^*$	Gap of aggregate real IBL rate in countries - Belarus' trading partners
i_t^{ru}	Nominal IBL rate in Russia
$\bar{r}_t^{ru}$	Equilibrium real IBL rate in Russia
r_t^{ru}	Real IBL rate in Russia
$\hat{r}_t^{ru}$	Real IBL rate gap in Russia

Continuation of the table A.1

Designation	Variable
i_t^{eu}	Nominal IBL rate in the Eurozone
$\bar{r}_t^{eu}$	Equilibrium real IBL rate in the Eurozone
r_t^{eu}	Real IBL rate in the Eurozone
$\hat{r}_t^{eu}$	Real IBL rate gap in the Eurozone
i_t^{cn}	Nominal IBL rate in China
$\bar{r}_t^{cn}$	Equilibrium real IBL rate in China
r_t^{cn}	Real IBL rate in China
$\hat{r}_t^{cn}$	Real IBL rate gap in China
i_t^{us}	Nominal IBL rate in the US
$\bar{r}_t^{us}$	Equilibrium real IBL rate in the US
r_t^{us}	Real IBL rate in the US
$\hat{r}_t^{us}$	Real IBL rate gap in the US
p_oil_t	Nominal price of Brent crude oil (oil price)
rp_oil_t	Relative oil price
Δrp_oil_t	Annualized growth of the relative oil price
$\Delta 4rp\_oil_t$	Growth of the relative oil price period to corresponding period of previous year
$\overline{rp\_oil}_t$	Equilibrium relative oil price
$\widehat{rp\_oil}_t$	Relative oil price gap
$\Delta\overline{rp\_oil}_t$	Annualized growth of the equilibrium relative oil price
$\varepsilon_t^{\bar{y}}$	Shock to the level of equilibrium GDP
$\varepsilon_t^{\Delta\bar{y}}$	Shock to the growth of equilibrium GDP
$\varepsilon_t^{\hat{y}}$	Demand shock (output gap shock)
$\varepsilon_t^{\widehat{rfx}}$	Budget expenditures gap shock
$\varepsilon_t^{\Delta\overline{rfx}}$	Shock to the growth of equilibrium budget expenditures
$\varepsilon_t^{\Delta wage}$	Nominal wages shock

Continuation of the table A.1

Designation	Variable
$\varepsilon_t^{\Delta \overline{rwage}}$	Shock to real equilibrium wages growth
ε_t^{π}	Inflation measurement shock
$\varepsilon_t^{\Delta \overline{rp}}$	Equilibrium relative price growth shock
$\varepsilon_t^{\pi_{core}}$	Core inflation shock
$\varepsilon_t^{\pi_{noncore}}$	Non-core inflation shock
$\varepsilon_t^{\pi^T}$	Inflation target shock
ε_t^{s}	Shock to NEER
$\varepsilon_t^{\Delta \bar{z}}$	Equilibrium REER growth shock
$\varepsilon_t^{\overline{prem}}$	Equilibrium risk premium shock
$\varepsilon_t^{\widehat{prem}}$	Risk premium gap shock
$\varepsilon_t^{\Delta \bar{x}}$	Equilibrium exports growth shock
$\varepsilon_t^{\bar{x}}$	Equilibrium exports level shock
$\varepsilon_t^{\hat{x}}$	Exports gap shock
$\varepsilon_t^{\Delta \bar{m}}$	Equilibrium imports growth shock
$\varepsilon_t^{\bar{m}}$	Equilibrium imports level shock
$\varepsilon_t^{\hat{m}}$	Imports gap shock
$\varepsilon_t^{\widehat{tot}}$	Terms of trade gap shock
$\varepsilon_t^{\Delta \overline{tot}}$	Equilibrium terms of trade growth shock
ε_t^{i}	Nominal IBL rate shock (monetary policy shock)
$\varepsilon_t^{\bar{r}}$	Equilibrium real IBL rate shock
$\varepsilon_t^{\Delta i\_l}$	Nominal lending rate change shock
$\varepsilon_t^{\overline{spread}^l}$	Equilibrium credit spread shock
$\varepsilon_t^{\Delta i\_d}$	Nominal deposit rate change shock
$\varepsilon_t^{\overline{spread}^d}$	Equilibrium deposit spread shock
$\varepsilon_t^{\hat{y}^{ru}}$	Russia output gap shock

End of the table A.1

Designation	Variable
$\varepsilon_t^{\hat{y}^{eu}}$	EU output gap shock
$\varepsilon_t^{\hat{y}^{cn}}$	China output gap shock
$\varepsilon_t^{\hat{y}^{us}}$	US output gap shock
$\varepsilon_t^{\pi^{ru}}$	Russia inflation shock
$\varepsilon_t^{\pi^{eu}}$	Eurozone inflation shock
$\varepsilon_t^{\pi^{cn}}$	China inflation shock
$\varepsilon_t^{\pi^{us}}$	US inflation shock
$\varepsilon_t^{i^{ru}}$	Shock of nominal IBL rate in Russia
$\varepsilon_t^{\bar{r}^{ru}}$	Shock of equilibrium real IBL rate in Russia
$\varepsilon_t^{i^{eu}}$	Shock of nominal IBL rate in the Eurozone
$\varepsilon_t^{\bar{r}^{eu}}$	Shock of equilibrium real IBL rate in the Eurozone
$\varepsilon_t^{i^{cn}}$	Shock of nominal IBL rate in China
$\varepsilon_t^{\bar{r}^{cn}}$	Shock of equilibrium real IBL rate in China
$\varepsilon_t^{i^{us}}$	Shock of nominal IBL rate in the US
$\varepsilon_t^{\bar{r}^{us}}$	Shock of equilibrium real IBL rate in the US
$\varepsilon_t^{\Delta\overline{rp\_oil}}$	Shock of equilibrium relative oil price growth
$\varepsilon_t^{\widehat{rp\_oil}}$	Shock of relative oil price gap

Source: author's calculations.

Table A.2: Calibration of the QPM parameters

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
ab_1	0.90	k_2	0.30	$\Delta\overline{tot}_{ss}$	2.00	a^{y_eu}	0.50
$\Delta\bar{y}_{ss}$	1.00	bb_1	0.70	mpr	0.90	a^{y_cn}	0.50
a_1	0.50	bb_2	0.15	x_1	0.30	a^{y_us}	0.50
a_2	0.10	bb_3	0.15	x_2	0.30	b^{π_ru}	0.60
a_3	0.20	tar_1	0.90	mm_1	0.50	π_{ss}^{ru}	4.00
a_4	0.30	π_{ss}^{T}	6.00	mm_2	0.50	b^{π_eu}	0.60
a_5	0.10	h_1	0.30	mm_3	0.25	π_{ss}^{eu}	2.00
a_6	0.10	π_{ss}^{*}	3.20	w_1	0.70	b^{π_cn}	0.60
m_1	0.50	h_2	0.55	s_1	0.15	π_{ss}^{cn}	2.00
m_2	0.20	z_1	0.75	s_2	0.10	b^{π_us}	0.60
m_3	0.40	$\Delta\bar{z}_{ss}$	2.00	s_3	-0.15	π_{ss}^{us}	2.00
f_1	0.50	pr_1	0.80	s_4	0.70	c^{i_ru}	0.75
f_2	0.90	pr_2	0.50	s_5	4.70	$\bar{r}_{ss}^{ru}$	2.00
$\Delta\overline{rfx}_{ss}$	1.00	$\overline{prem}_{ss}$	-0.35	w_2	0.90	c^{r_ru}	0.90
aa_1	0.50	u_1	0.80	$\overline{spread}_{ss}^{l}$	2.00	c^{i_eu}	0.75
aa_2	0.25	$\Delta\bar{x}_{ss}$	2.00	q_1	0.50	$\bar{r}_{ss}^{eu}$	0.00
aa_3	0.50	c_1	0.50	q_2	0.20	c^{r_eu}	0.90
aa_4	0.85	c_2	0.50	q_3	-0.30	c^{i_cn}	0.75
$wedge$	3.00	c_3	0.25	q_4	0.85	$\bar{r}_{ss}^{cn}$	1.00
$weight$	0.7153	uu_1	0.90	q_5	1.35	c^{r_cn}	0.90
rr_1	0.90	$\Delta\bar{m}_{ss}$	2.00	w_3	0.90	c^{i_us}	0.75
$\Delta\overline{rp}_{ss}$	-0.80	d_1	0.60	$\overline{spread}_{ss}^{d}$	0.00	$\bar{r}_{ss}^{us}$	0.50
b_1	0.35	d_2	1.00	w^{ru}	0.60	c^{r_us}	0.90
b_2	0.10	d_3	0.20	w^{eu}	0.15	o_1	0.90
b_3	0.50	r_1	0.50	w^{cn}	0.05	$\Delta\overline{rp\_oil}_{ss}$	-2.00
k_1	0.50	r_2	0.90	a^{y_ru}	0.50	o_2	0.50

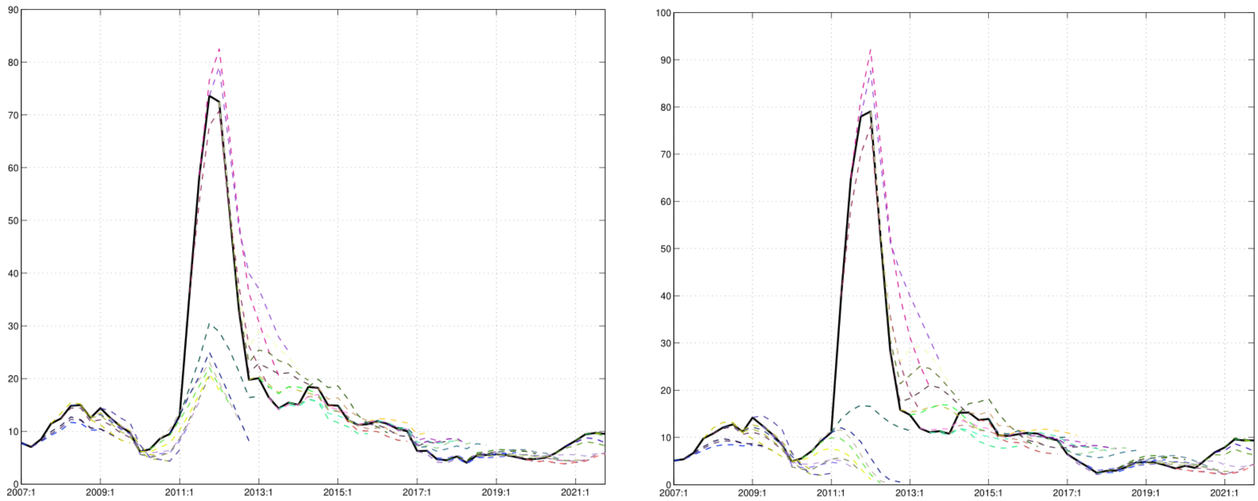
Source: author's calculations.

Appendix B

In-sample simulations under the QPM

Figure B.1: Inflation, % YoY

A) Headline inflation *B) Core inflation*

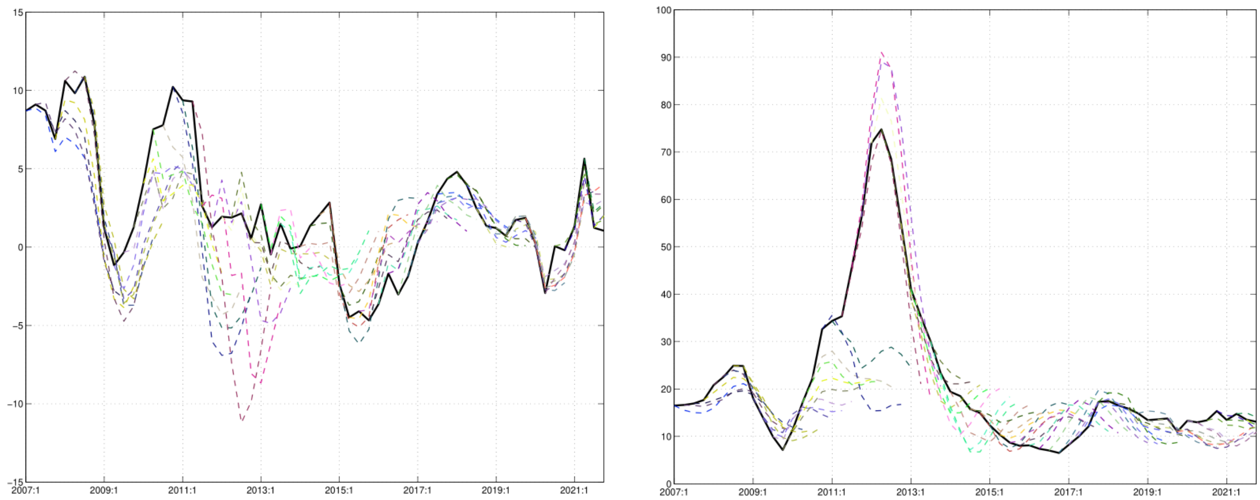


Source: author's calculations based on the QPM.

Note: based on seasonally adjusted logarithmic data.

Figure B.2: Real GDP and nominal wages, % YoY

A) Real GDP growth rate *B) Nominal wages growth rate*

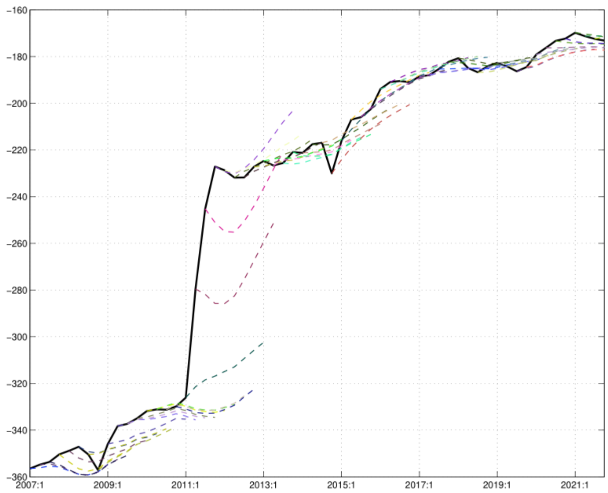


Source: author's calculations based on the QPM.

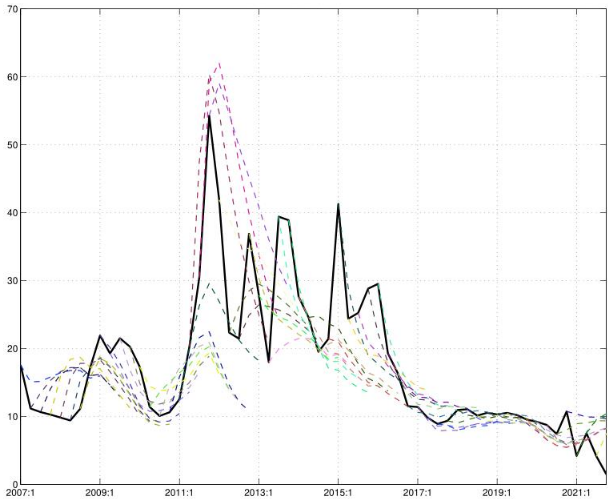
Note: based on seasonally adjusted logarithmic data.

Figure B.3: Belarusian ruble nominal effective exchange rate and nominal interbank market interest rate

*A) NEER, 100*ln*



B) IBL rate, %

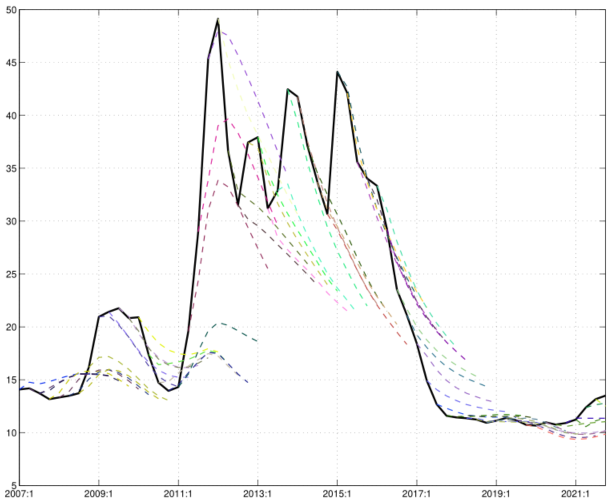


Source: author's calculations based on the QPM.

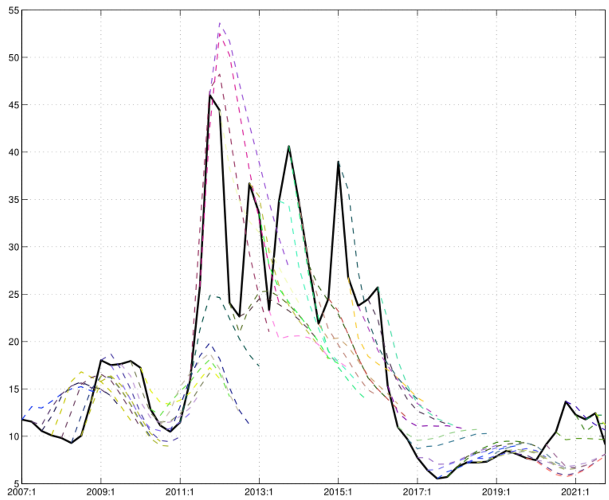
Note: based on seasonally adjusted logarithmic data.

Figure B.4: Nominal interest rates on new ruble loans and deposits, %

A) Rate on market loans



B) Rate on time deposits



Source: author's calculations based on the QPM.