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Macroeconomic model for analysis and forecasting of the Uzbekistan economy

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Annotation

This report presents the results of the development of a model for macroeconomic analysis and forecasting of the Uzbekistan economy, created to be integrated into the general system of macroeconomic forecasting and analysis of economic processes in the EDB member countries. More detailed information on the integrated system of models (ISM) is presented in the joint report of the Eurasian Development Bank and the Eurasian Economic Commission (EDB, 2016).

Structure of the report: a description of the integration of Uzbekistan's model into the model complex used by the EDB. The specific economic features of Uzbekistan taken into account in the model are presented. The structure of the model and calibration of parameters are explained. Methodological aspects, analysis of sensitivity of the model to various macroeconomic shocks and its predictive ability are considered. The appendices detail the statistical data with an indication of sources and provide a system of equations.

Keywords: macroeconomic modelling, forecasting, GDP, inflation, exchange rate, demand, monetary policy, budget, transmission mechanism, macroeconomic shocks.

JEL: C68, E27, E32, E52, E58, F37, F41.

The electronic version of the document can be found at (https://eabr.org/en/analytics/special-reports/macroeconomic-model-for-analysis-and-forecasting-of-the-uzbekistan-economy/)

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SUMMARY

This report presents the results of developing a model, which as part of the ISM allows the analysing and forecasting of Uzbekistan's economic development on a medium-term horizon, as well as the assessment of the impact of various domestic and external shocks on the country's economy. Above all, this project is focused on the Eurasian Development Bank's objectives involving macroeconomic analysis and forecasting of the economies of the Bank's member countries, taking into account cross-country effects.

Although this project does not aim to analyse and address Uzbekistan's structural problems, focusing more on aggregate macroeconomic indicators, it provides an opportunity to quantitatively analyse various economic policy scenarios, including Uzbekistan's cooperation with countries in the EDB region. In addition, the developed model approach helps to assess the level of synchronisation of business cycles of the Bank's member countries and the processes of economic convergence. The presented model also allows the assessment of the risks to macroeconomic stability of Uzbekistan, taking into account the specifics of budgetary and monetary policy implementation.

In general, the model of the Uzbek economy is similar to other ISM models and includes blocks for aggregate demand, aggregate supply, the fiscal sector, monetary policy, and the labour market. A separate area is the remittances sector, taking into account its impact on the country's economic performance (the same approach was used for the economies of Armenia, Tajikistan and Kyrgyzstan). The parameters of the model were calibrated in such a way as to take into account stylised facts about the Uzbek economy, monetary and exchange rate policy regimes, as well as the functioning of the transmission mechanism.

In preparing the modelling framework, we conducted a retrospective analysis with an assessment of the current state of the economy and identified key drivers of macro variables, taking into account the specifics of Uzbekistan's monetary and fiscal policy. Structural changes in Uzbekistan's economy since 2017, when the country embarked on a liberalisation course, were taken into account during the filtering process.

INTRODUCTION

As part of the expansion of the EDB's modelling package covering the economies of Armenia, Belarus, Kazakhstan, Kyrgyzstan, Russia and Tajikistan, a modelling block is being introduced to analyse the economy of Uzbekistan. The model block as a tool allows modelling of the economy's response to macroeconomic shocks and the development of scenario forecasts, both for individual countries and taking into account their mutual influence (with countries not coordinating monetary and fiscal policies).

The model provides internally consistent medium-term forecasts for the Uzbek economy and allows for a wide range of estimation experiments, including:

- analysing real and nominal shocks and their transmission mechanisms;
- assessing the impact of fiscal policy on monetary policy decisions;
- scenario analyses based on various economic assumptions;
- studying the impact on Uzbekistan's economy of global processes built on changes in both structural parameters (e.g., a sustained slowdown in the economy's potential growth) and cyclical ones (e.g., caused by a temporary deterioration in the country's terms of trade due to a global recession).

MODEL OF THE UZBEKISTAN ECONOMY AS PART OF THE EDB ISM

The EDB's ISM comprises a set of semi-structural models based on a new neoclassical synthesis. The transmission mechanism of monetary policy in the models is based on the New Keynesian approach, emphasising the presence of both nominal and real rigidities in the economy, which determine the non-neutrality of monetary policy in the short and medium term. At the same time, the models incorporate the developments of the new classical theory and real business cycle theory: the inclusion of rational expectations in dynamic stochastic general equilibrium models. An important feature of the ISM is the presence of cross-country interaction, which allows identification of the level and mechanism of impact and propagation of shocks within the EDB region of operations.

The model for macroeconomic analysis and forecasting of Uzbekistan's economy is similar in many respects to models of other remittance-dependent economies: Tajikistan, Armenia and Kyrgyzstan. The model is semi-structural, so all presented shocks are orthogonal in nature and each embedded equation and economic variable has its own interpretation. In terms of modelling the monetary policy transmission mechanism, the model incorporates the basic principles of monetary policy as well as general equilibrium — such as, for example, long-run monetary neutrality. The exchange rate and the interest rate comprise the basic monetary instruments, and transmission through the fiscal channel is modelled through the equilibrium fiscal balance.

The semi-structural form was chosen as a model tool — as an extension of the model approach used for ISM, and as the most suitable form for modelling developing economies that require flexible specification while preserving the principle of optimality (all agents optimise their behaviour, as in the classical DSGE [Dynamic Stochastic General Equilibrium] model).

The model's parameterisation was carried out by calibration, taking into account both the specific features of the semi-structural model's construction and the specific features of the Uzbekistan economy. An important feature was the fact that the reform policy in Uzbekistan, initiated since 2017, has significantly adjusted the economic scape and prospects of the economy, affecting a fairly wide range of areas. Therefore, it was not sensible to use exclusively the interrelationships developed using longer time series.

The following sections of the report present the structure of the model: the main blocks with a set of equations characterising them, as well as the features of the chosen parameterisation. It is important to note that, when building the model, the principle of rationality of agents' behaviour and their expectations was incorporated, while the model's compliance with economic theory and the specific way the Uzbek economy functions remained fundamental.

The model, as well as all IMS blocks, is implemented using the open source toolkit for macroeconomic modelling and forecasting IRIS in the MatLab software environment. This software suite allows us to:

- perform data conversion,
- calibrate the model,
- filter data on the selected time horizon,
- decompose the channels of influence of shocks,
- receive forecasts and generate ready-made reports.

In addition, the model provides an assessment of the quality of the forecasts by comparing the estimated results with historical data.

SPECIFIC ECONOMIC FEATURES OF UZBEKISTAN TAKEN INTO ACCOUNT IN THE MODEL

This section provides a description of the economic processes in Uzbekistan that were taken into account in the calibration of model parameters and implemented in the model.

Changes in the time series, as well as the structural shift analysis, allow us to distinguish two key periods in Uzbekistan’s economy: pre-2017, before the start of economic reforms and exchange rate liberalization, and after 2017, when a number of policy initiatives had a dramatic impact on the country’s economic potential.

The politics of reform

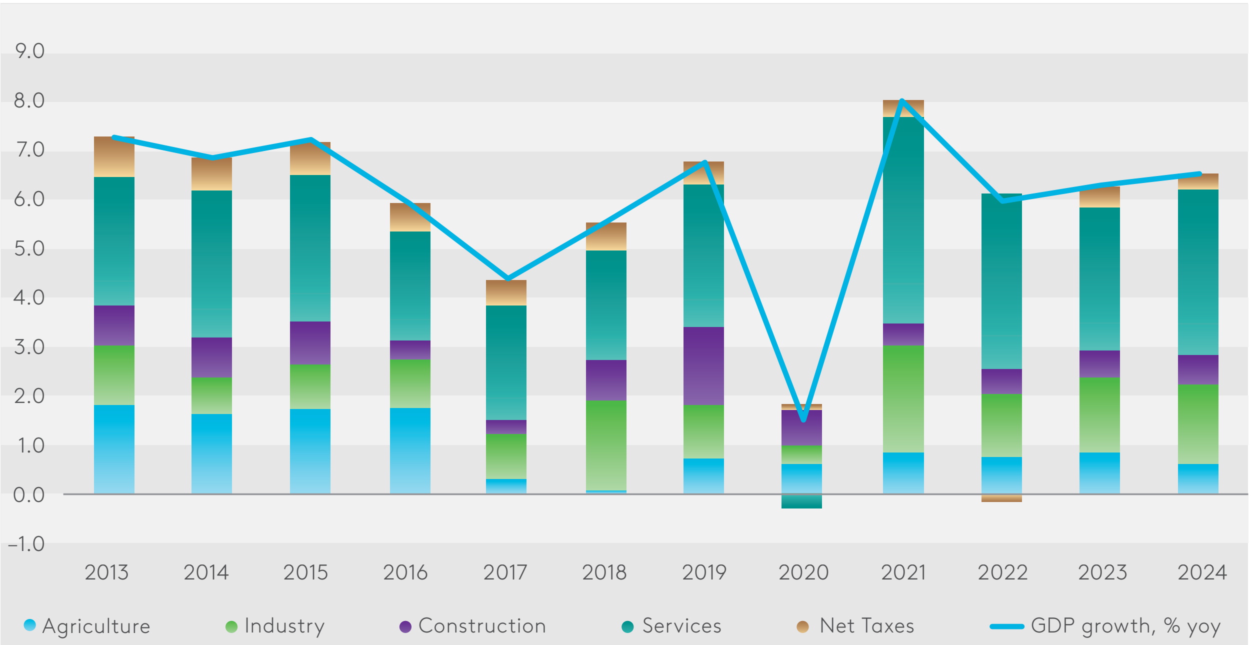
Since 2017, the Uzbek government has launched ambitious reforms aimed at improving the business and investment climate. Key among them are exchange rate liberalisation and tax policy optimisation. In September 2017, the reform of the currency system lifted restrictions on the free exchange of currency in the country, thus ensuring a transition to “more market-oriented” principles. In 2019, the government continued to reform foreign exchange policy, and already in August 2019 made an important decision bringing the country closer to a market economy: commercial banks were authorised to sell foreign currency in cash.

Significant changes took place in the area of price liberalisation, primarily for bread and energy. In addition, in October 2018, in order to stimulate trade and reduce costs, the government abolished the need for an export permit and abolished licensing requirements for wholesale trade enterprises. On the taxation side, a flat tax of 12 per cent on personal income and corporate profits was introduced in 2019. Additional changes included narrowing the gap in the tax burden between the general and simplified taxation regimes. The previous system created incentives for business fragmentation and going into the shadows. The new rules made it possible to reduce the burden on enterprises under the general taxation regime.

The transformations introduced primarily affected the country's economic growth — while at the beginning of the reforms (in 2017), economic growth slowed to 4.4%, it accelerated to 5.5% in 2018 (Figure 1) and only fell below this level in 2020 — during the pandemic. Since 2017, the industrial sector has played a decisive role in GDP trends, while on the other hand the contribution from the agriculture and services sectors declined. Uzbekistan's economy has recovered quickly from the negative impact of COVID-19 and GDP growth has been steadily improving since 2022, reaching 6.5 per cent by the end of 2024.

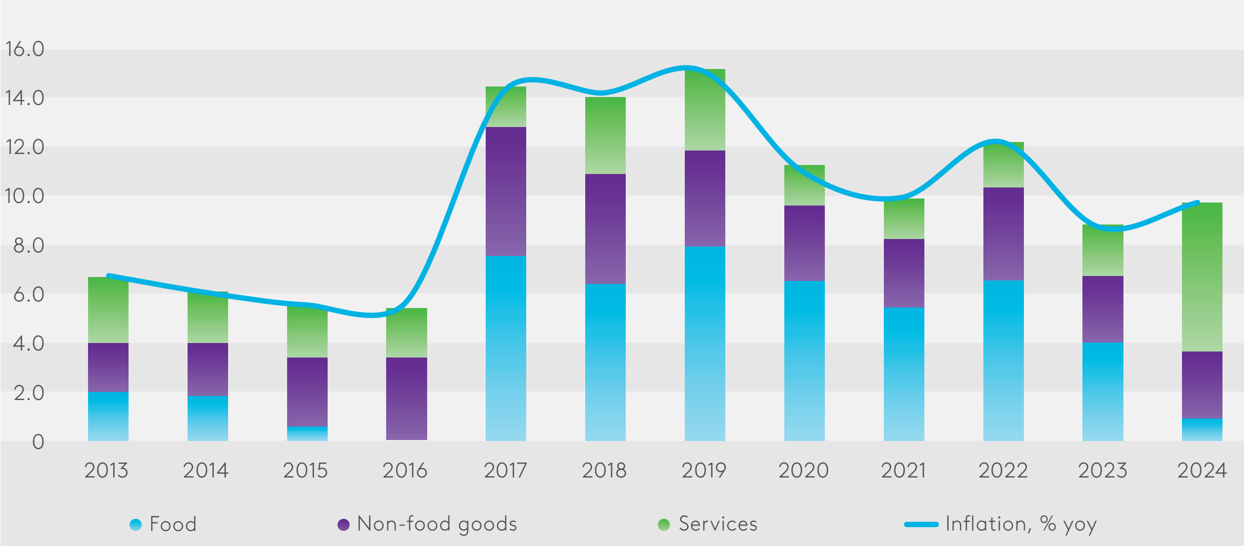
During the period of economic transformation (2017–2019), inflation accelerated sharply (Figure 2). Such trends were the result of many factors, the main one being the liberalisation of the exchange rate. As a result, there was a weakening of the national currency, and price growth in early 2018 reached its maximum value, amounting to 20.1% in annual terms. Overall, inflation was in the range of 14–15 per cent for 2018–2019. Against the backdrop of COVID-19, there was some reduction in inflationary pressures, but the rate of price growth still remained in double digits in 2020–2024. The increased contribution of the services sector to consumer price growth in 2024 is due to tariff liberalisation aimed at bringing prices to market levels. As the effect on housing and communal services from the increase in tariffs is exhausted, the contribution of services to inflation will decrease. The main contribution to inflation is from food prices. Thanks to this feature, the world food prices component (deviation from the trend) is taken into account in the modelling block for inflation.

↓ Figure 1. Contribution of industries to GDP growth in Uzbekistan, %



Source: Statistical Agency under the President of the Republic of Uzbekistan, authors' calculations

↓ **Figure 2. Uzbekistan inflation and its main components, p.p.**



Source: Statistical Agency under the President of the Republic of Uzbekistan, authors' calculations

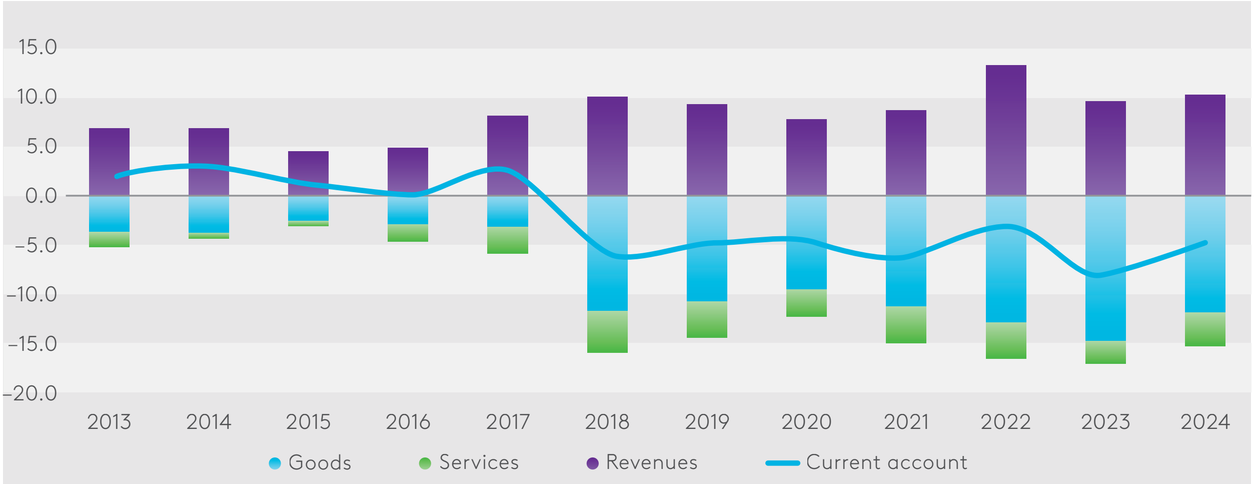
The reform policy was also reflected in the balance of payments indicators. The current account deteriorated sharply — its balance shifted from surplus to deficit, which averaged 5.4% of GDP in 2018–2024 (Figure 3). This change was made possible by three main factors, mainly centred in the trade balance:

- trade liberalisation in the form of the introduction of free currency convertibility (in October 2017 and June 2018);
- a credit policy that favours the growth of imports of machinery and equipment;
- changes in foreign exchange reserve policy: the CBU moved from active accumulation of reserves to relative neutrality, which resulted in some exchange rate flexibility.

Together, all these factors led to an increase in imports of goods from 17.8% of GDP in 2017 to 31.1% of GDP in 2018. In the post-liberalisation period (2018–2024), import growth averaged 16.5%. A positive factor in the widening trade deficit remains the fact that the bulk of imports between 2017 and 2024 comprised machinery and equipment (about 44%) and chemical products (about 17%), indicating the investment bias of imports.

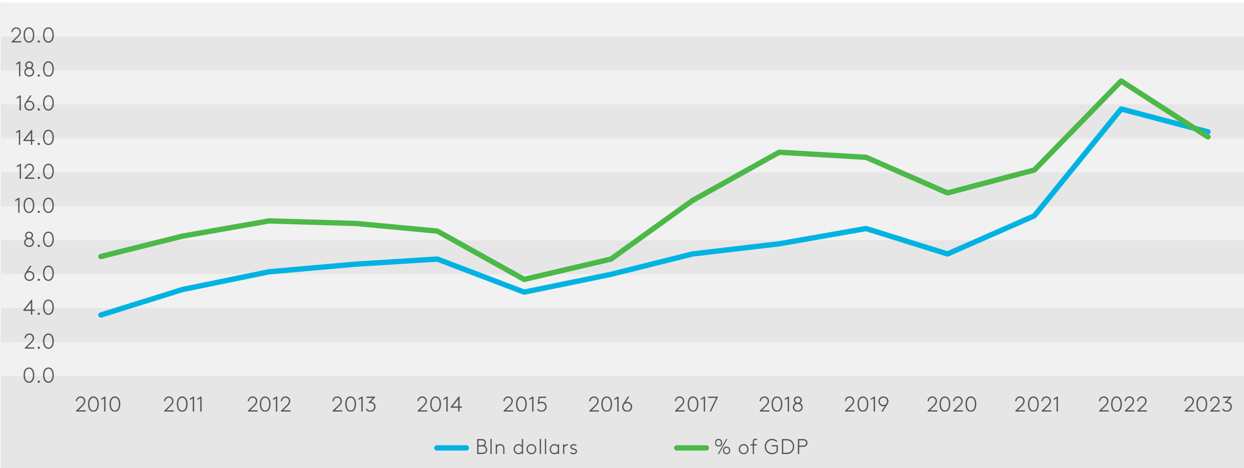
The weakening exchange rate has boosted export growth, with exports averaging 10.3 per cent between 2018 and 2024, compared to 0.2 per cent decrease between 2013 and 2017. Exports have remained predominantly commodity-based, with gold being the main export commodity with a share of about 40 per cent of total exports.

↓ Figure 3. Uzbekistan's current account balance, % of GDP



Source: Central Bank of Uzbekistan, authors' calculations.

↓ Figure 4. Remittances to Uzbekistan, USD billion



Source: World Bank, authors' calculations.

Despite the fact that the key role in the formation of the current account is played by the trade balance, remittances also make a significant contribution to trends (about 13% of GDP). However, in 2022, their share rose to 17%, and the main contribution came from Russia. Due to the importance of this indicator for economic growth trends, data on remittances were taken into account in the aggregate demand block of the model. However, the model parameterisation was based on data up to 2022, as the sharp increase in remittances from Russia to Uzbekistan in 2022 was mostly temporary. In 2023, the share of remittances to GDP decreased again, to 13.9% (Figure 4).

STRUCTURE OF THE UZBEKISTAN MODEL

The model of the Uzbek economy in its structure corresponds to other ISM models. It includes blocks of aggregate demand, aggregate supply, the fiscal sector, monetary policy, and the labour market. A separate area is the remittance sector and its impact on the country's economic performance (the same approach is used for the economies of Armenia, Tajikistan and Kyrgyzstan). In total, the model for Uzbekistan contains eight blocks.

Aggregate demand

The aggregate demand block describes the real GDP trend (y_t) as the sum of the output gap ($\hat{y}_t$) and the potential (equilibrium) level ($\bar{y}_t$)[1]

$$y_t = \bar{y}_t + \hat{y}_t \tag{1}$$

Equilibrium GDP growth ($\Delta\bar{y}_t$) is modelled as an autoregressive process (2), which ensures that the GDP growth rate converges to a sustainable level ($\Delta\bar{y}_{ss}$) in the long run

$$\Delta\bar{y}_t = ab_1\Delta\bar{y}_{t-1} + (1 - ab_1)\cdot\Delta\bar{y}_{ss} + ab_2\cdot(\Delta\overline{qremit}_t - \Delta\overline{qremit}_{ss}) + \varepsilon_t^{\Delta\bar{y}} \tag{2}$$

The sustainable GDP growth rate ($\Delta\bar{y}_{ss}$) is calibrated as 5.5%, which is close to the IMF long-term forecast and in line with the EDB estimates (Vinokurov E. et al., 2022). The parameter ab_1 is taken as equal to 0.85, since equilibrium components are usually characterised by smooth trends and high inertia. The deviation of the increase in the equilibrium volume of remittances ($\Delta\overline{qremit}_t$) from its steady-state level ($\Delta\overline{qremit}_{ss}$) is included in equation (2) because of the significant and long-lasting impact of labour migrants' transfers on economic activity in Uzbekistan. The parameter ab_2 is calibrated at 0.02. Its low value is explained by the high volatility of remittances, but in general it is close to the calibration for other countries in the EDB ISM where the economy is also highly dependent on remittances: in Tajikistan and Kyrgyzstan — over 30% of GDP. The shock ($\varepsilon_t^{\Delta\bar{y}}$) approximates the impact on equilibrium GDP growth of factors not directly accounted for in the model and leads to a prolonged deviation of the equilibrium output growth rate from its steady-state value.

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

The output gap approximates the state of the economic cycle and is modelled in accordance with equation (3):

$$\hat{y}_t = a_1\hat{y}_{t-1} + a_2E_t\hat{y}_{t+1} - a_3mci_{t-1} + a_4\hat{y}_t^* + a_5\widehat{def2gdp}_t + a_6\widehat{qremit}_t^{uzs} + \varepsilon_t^{\hat{y}} \tag{3}$$

The key factors driving the output gap are monetary conditions (mci_t), the fiscal impulse ($\widehat{def2gdp}_t$), the remittance gap ($\widehat{qremit}_t^{uzs}$) and external demand ($\hat{y}_t^*$). Since some economic agents may make decisions based on rational expectations, equation (3) includes an expected output gap variable ($E_t\hat{y}_{t+1}$). The inertia component ($\hat{y}_{t-1}$) is incorporated into equation (3) because of the lingering effects of economic factors on the output gap rather than a one-step effect. The demand shock ($\varepsilon_t^{\hat{y}}$) approximates the effect on the output gap of factors not directly accounted for in the model. The parameters a_1, a_2, a_3, a_4, a_5, and a_6 are calibrated to be 0.60, 0.10, 0.10, 0.20, 0.15, and 0.02, respectively.

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

$$mci_t = a_7 \cdot (\hat{r}_t + \widehat{sp}_t) - (1 - a_7) \cdot \hat{z}_t \tag{4}$$

In the developed model, in accordance with equation (4), monetary conditions are a weighted combination of the interest rate and real effective exchange rate (REER) components. Positive values of monetary conditions indicate their restraining character, while negative values indicate their stimulative character.

The interest rate component characterises the state of the interest rate policy of the Central Bank of Uzbekistan and is calculated as the sum of deviations of the real money market interest rate and the credit interest rate spread to the money market interest rate from their equilibrium levels. The money market rate gap ($\hat{r}$) characterises the state of CBU interest rate policy, while the inclusion of the credit spread gap ($\widehat{sp}_t$) is designed to take into account the nature of commercial banks' interest rate policy. Positive interest rate and credit spread gaps imply that real rates are above their equilibrium (neutral) levels. This indicates that the levels of real rates exceed the marginal return on capital (in the form of production or savings). Under such conditions, investment and consumption in the current period have a lower utility compared to the future, which, other things being equal, should be reflected in a reduction of their growth rates in the short run.

The REER gap ($\hat{z}_t$) approximates the intratemporal substitution between imported and non-imported goods, as well as the price competitiveness of Uzbek producers. The excess of the actual REER over the equilibrium level indicates that the sum is undervalued. This means that foreign goods become more expensive than domestic goods, which stimulates Uzbek 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 (a_7) is assumed to be 0.60. The comparative closedness of the Uzbek economy predetermines a more significant impact of the interest rate (compared to the exchange rate) on economic activity. In addition, the forex share of bank contracts in Uzbekistan is close to 0.40.

Budget sector

The fiscal sector is modelled similarly to the specifications for other EDB member countries in the Bank's ISM, and the budget surplus/deficit to GDP ratio is used in the calculations. The observed fiscal balance ($def2gdp_t$)[2] is decomposed into two components: structural balance ($\overline{def2gdp_t}$) and cyclical balance ($\widehat{def2gdp_t}$).

$$def2gdp_t = \overline{def2gdp_t} + \widehat{def2gdp_t} \tag{5}$$

$$\begin{gathered} def2gdp_t = f_1 def2gdp_{t-1} + \\ +(1-f_1)\cdot(\overline{def2gdp}_t^{tar} - f_2\cdot(def2gdp_{t-1} - \overline{def2gdp}_{t-1}^{tar}) - f_3\hat{y}_t) + \varepsilon_t^{def2gdp} \end{gathered} \tag{6}$$

$$\overline{def2gdp_t} = f_4\overline{def2gdp_{t-1}} + (1-f_4)\cdot\overline{def2gdp_t}^{tar} + \varepsilon_t^{\overline{def2gdp}} \tag{7}$$

$$\overline{def2gdp_t}^{tar} = f_5\overline{def2gdp}_{t-1}^{tar} + (1-f_5)\cdot\overline{def2gdp_t}^{ss} + \varepsilon_t^{\overline{def2gdp}^{tar}} \tag{8}$$

The structural balance of the budget ($\overline{def2gdp_t}$) should be in line with the government's medium-term targets ($\overline{def2gdp}_t^{tar}$), but may deviate from the target trajectory for a long time. The duration of the deviation is determined by the inertia of the structural balance (f_4 = 0.80), and the shock $\varepsilon_t^{\overline{def2gdp}}$ approximates the factors leading to such deviations (7). The target trajectory of the budget balance fluctuates around a certain sustainable level ($\overline{def2gdp}_t^{ss}$), which is a parameter of fiscal policy and is determined by assumption (calibrated equal to 0.7% of GDP based on the long-term forecast of the Ministry of Finance of Uzbekistan) (8).

The cyclical budget balance ($\widehat{def2gdp_t}$) represents the deviation of the observed balance from the structural balance (5). It is assumed that the observed budget balance deviates from the structural one due to the impact of automatic stabilisers (f_3 = 0.25) and the government's reaction to the previous deviation of the budget

[2] A positive/negative total deficit corresponds to a negative/positive total balance.

balance from the target ($f_2 = 0.25$) (6). It should be taken into account that calibration of the parameters of the fiscal policy rule is highly uncertain, as fiscal policy measures are largely discretionary in nature. In this regard, the parameter values at the coefficients of equation (6) can be adjusted taking into account expert judgements of analysts regarding the assumed fiscal policy rule.

Remittances

Net inflow of remittances to Uzbekistan (the difference between inflows to and outflows from the country) is an important factor in shaping domestic demand, which influences long-term macroeconomic trends in the Uzbek economy. This influence is taken into account by including the remittances block in the model.

Remittances are measured in dollars ($remit_t$) and modelled in real terms in accordance with equation (9). Since the vast majority of Uzbek labour migrants go to work in Russia, real remittances ($qremit_t$) adjusted for inflation in the US (cpi_t^{us}), are pegged to Russia by introducing the real exchange rate of the Russian rouble to the US dollar in equation (9) (z_t^{ru}).

$$qremit_t = remit_t - cpi_t^{us} + z_t^{ru} \tag{9}$$

$$qremit_t = \overline{qremit}_t + \widehat{qremit}_t \tag{10}$$

$$\Delta\overline{qremit}_t = q_1 \Delta\overline{qremit}_{t-1} + (1 - q_1) \cdot \Delta\overline{qremit}_{ss} + \varepsilon_t^{\Delta\overline{qremit}} \tag{11}$$

$$\widehat{qremit}_t^{uzs} = \widehat{qremit}_t + \hat{z}_t^{usd} - \hat{z}_t^{ru} \tag{12}$$

$$\widehat{qremit}_t^{uzs} = q_2 \widehat{qremit}_{t-1}^{uzs} + q_3 \hat{y}_t^{ru} - q_4 \hat{z}_t^{rub} + \varepsilon_t^{\widehat{qremit}^{uzs}} \tag{13}$$

Real remittances are split into two unobserved variables in accordance with equation (10): trend ($\overline{qremit}_t$) and cyclical ($\widehat{qremit}_t$). The remittances trend ($\Delta\overline{qremit}_t$) is an autoregressive process in accordance with equation (11) with an exogenously determined steady-state rate ($\Delta\overline{qremit}_{ss}$), calibrated equal to 9% based on historical data. The remittance gap, which directly affects domestic demand, is recalculated in sums in accordance with equation (12) by adjusting the cyclical component ($\widehat{qremit}_t$) for the real exchange rate gaps of the sum and the Russian rouble to the US dollar, respectively ($\hat{z}_t^{usd}$) and ($\hat{z}_t^{ru}$). The remittance gap ($\widehat{qremit}_t^{uzs}$) is assumed to depend on the cyclical position of the Russian economy ($\hat{y}_t^{ru}$) and the real exchange rate gap of the sum to the Russian rouble ($\hat{z}_t^{rub}$) in accordance with equation (13). Parameters q_2, q_3, q_4 are calibrated on the basis of econometric estimates equal to 0.60, 2.00 and 0.20, respectively.

Labour market

The main element of the labour market is wages (while we assume that Uzbekistan still has a high share of the shadow sector, which may distort economic effects). We assume inflexibility of nominal wages ($wage_t$) and model their growth ($\Delta wage_t$) similarly to the Phillips curve in a specification close to other EDB IMS country blocks:

$$\Delta wage_t = aa_1 E_t \Delta wage_{t+1} + (1 - aa_1) \cdot \Delta wage_{t-1} + aa_2 \hat{y}_t - aa_3 \widehat{rwage}_{t-1} + \varepsilon_t^{\Delta wage} \tag{14}$$

In accordance with equation (14), wage trends depend on the cyclical position of the economy, approximated by the output gap. In this case, coefficient aa_2 is calibrated equal to 0.5, which determines the inflexibility of nominal wages. Nominal wage trends negatively correlate with the real wage gap ($\widehat{rwage}_t$), that is, they accelerate if real wages ($rwage_t$) are below their equilibrium level ($\overline{rwage}_t$), and decelerate otherwise. Equation (14) also includes the components of rational expectations ($E_t \Delta wage_{t+1}$) and inertia ($\Delta wage_{t-1}$) as factors explaining wage trends. The factors not directly accounted for in equation (14) are approximated by a shock to nominal wage growth ($\varepsilon_t^{\Delta wage}$). The parameters aa_1 and aa_3 are calibrated equal to 0.50.

Real wages are calculated in accordance with equation (15) by adjusting nominal wages for the consumer price index (cpi_t) and decomposed into unobserved components: the gap and equilibrium wages in accordance with equation (16). The real wage gap is included in the equations for the output gap as a factor of domestic demand and in the equations for inflation as a determinant of domestic inflationary pressures.

The change in the equilibrium real wage ($\Delta\overline{rwage}_t$) is modelled as a function of the increase in equilibrium GDP ($\Delta\overline{y}_t$) in accordance with equation (17). Other factors affecting the equilibrium wage trend are approximated by a shock ($\varepsilon_t^{\Delta\overline{rwage}}$). The values of the parameter aa_4 are assumed to be 0.85.

$$rwage_t = wage_t - cpi_t \tag{15}$$

$$rwage_t = \overline{rwage}_t + \widehat{rwage}_t \tag{16}$$

$$\Delta\overline{rwage}_t = aa_4 \Delta\overline{rwage}_{t-1} + (1 - aa_4) \cdot \Delta\overline{y}_t + \varepsilon_t^{\Delta\overline{rwage}} \tag{17}$$

Inflation

The inflation block in the model comprises a modified New Keynesian Phillips curve. The growth of the composite consumer price index (π_t), which is the CBU monetary policy target, is used as a measure of inflation:

$$\pi_t = 4 \cdot (cpi_t - cpi_{t-1}) \tag{18}$$

Inflation modelling is based on the postulate that prices are inflexible in the short run, i.e. incomplete one-time transformation of costs into prices is assumed:

$$\pi_t = b_1 E_t \pi_{t+1} + (1 - b_1 - b_2) \cdot \pi_{t-1} + b_2 \pi_{imp_t} + b_3 rmc_t + \varepsilon_t^{\pi} \tag{19}$$

Inflation trends are determined by inflation expectations, which are partly rational ($E_t\pi_{t+1}$) and partly adaptive (π_{t-1}), imported inflation (π_{imp_t}) real marginal costs (rmc_t) and an inflation shock ε_t^{π}, which approximates inflation factors not accounted for in the model.

When the economy is in a stable equilibrium state, inflation corresponds to inflation expectations, which is ensured by the implemented restriction that the sum of coefficients for lagged, expected and imported inflation in equation (19) is equal to one. It should be noted that the inclusion of the lagged inflation variable also allows one to take into account the inertia of inflationary processes observed in practice due to the prolonged impact of inflationary factors on prices. 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 equal to 0.35.

Real marginal cost (rmc_t) approximates the additional cost of producing an additional unit of output. The parameter b_3 characterises price rigidity in the economy and is calibrated at 0.10 based on estimates from empirical data.

In accordance with equation (20), real marginal costs are a combination of output gaps, wages, REERs and world food prices:

$$rmc_t = (1 - k_1 - k_2 - k_3) \cdot \hat{y}_t + k_1 \widehat{rwage}_t + k_2 \hat{z}_t + k_3 \cdot (\widehat{qfood}_t + \hat{z}_t^{usd}) \tag{20}$$

Positive values of real marginal costs indicate their pro-inflationary impact, while negative values indicate their disinflationary impact. Output and wage gaps approximate the costs of domestic producers. The wage gap characterises labour costs, while the output gap characterises all other domestic costs (e.g. depreciation costs).

The REER gap approximates importers' costs. The inclusion of the REER gap in the costs ensures that in the long-run the price trends in Uzbekistan and trading partner countries are in line with the relative version of purchasing power parity. The gap of world food prices ($\widehat{qfood}_t$) is included in equation (20) due to the importance of food items in the Uzbekistan population's consumer basket. The significant impact of world food prices on inflation trends in Uzbekistan is confirmed by the results of empirical studies (CBU, 2020).

The parameters k_1, k_2, and k_3 characterise the significance of the components of real marginal costs. Their calibration is based on the results of econometric estimations on empirical data: $k_1 = 0.30$, $k_2 = 0.20$, and $k_3 = 0.05$.

In accordance with equation (21) imported inflation approximates the direct impact of changes in the NEER and prices in the trading partner countries on inflation in Uzbekistan. It should be noted that the change in the NEER in equation (21) is adjusted for the change in the equilibrium REER ($\Delta \overline{z}_t$), as equilibrium variables are inflation-neutral in accordance with the model's construction methodology — their change leads neither to additional pro-inflationary nor disinflationary pressure.

$$\begin{aligned}\pi_{imp_t} = \pi_t^{us} - t_{eur} \cdot \Delta z_t^{eu} - t_{cny} \cdot \Delta z_t^{cn} - t_{byn} \cdot \Delta z_t^{by} - t_{kzt} \cdot \Delta z_t^{kz} - \\ - t_{amd} \cdot \Delta z_t^{am} - t_{kgs} \cdot \Delta z_t^{kg} - t_{rub} \cdot \Delta z_t^{ru} + \Delta s_t^{usd} - \Delta \overline{z}_t\end{aligned} \tag{21}$$

Exchange rate block

We model the nominal exchange rate of the sum to the US dollar (s_t^{usd}) based on a modified version of uncovered interest rate parity (22).

$$s_t^{usd} = (1 - erp) \cdot \left(E_t s_{t+1}^{usd} + \frac{i_t^{us} - i_t + prem_t}{4} \right) + erp \cdot \overline{s}_t^{usd^T} + \varepsilon_t^{s^{usd}} \tag{22}$$

The exchange rate is determined by exchange rate expectations in the forthcoming period ($E_t s_{t+1}^{usd}$) and the difference between nominal interest rates of the money market in Uzbekistan (i_t) and the USA (i_t^{us}), adjusted for the risk premium for investments in assets denominated in sums ($prem_t$).

Exchange rate expectations have two components (23): rational ($E_t s_{t+1}^{usd}$) and adaptive (s_{t+1}^{nf}). The inclusion of adaptive expectations allows us to take into account the inertia of exchange rate movements observed in historical data. The parameter h_1 determines the share of economic agents with rational expectations. Its value is assumed to be equal to 0.50.

$$E_t s_{t+1}^{usd} = h_1 s_{t+1}^{usd} + (1 - h_1) \cdot s_{t+1}^{nf} \tag{23}$$

It is assumed that adaptive expectations are formed by means of a "naive" forecast. This means that economic agents have an idea of the trend change in the exchange rate ($\Delta \overline{s}_t^{usd}$) and use these estimates to extrapolate the exchange rate level.

$$s_{t+1}^{nf} = s_{t-1}^{usd} + \frac{2 \Delta \overline{s}_t^{usd}}{4} \tag{24}$$

Since the CBU intervenes in the foreign exchange market to smooth exchange rate volatility, the exchange rate is not fully floating. To account for this factor, we introduce in equation (22) the target exchange rate ($\overline{s}_t^{usd^T}$), whose trends ($\Delta\overline{s}_t^{usd^T}$) are modelled as an autoregressive process with convergence to the trend change of the exchange rate ($\Delta\overline{s}_t^{usd}$) in accordance with equation (25). The trend change in the exchange rate is calculated as the sum of the differential of inflation targets in Uzbekistan (π_t^T) and the United States (π_{ss}^{us}) and the equilibrium change in the real exchange rate of the sum to the US dollar ($\Delta\overline{z}_t^{usd}$) in accordance with equation (26). The specification of equations (22–26) implies that the CBU intervenes to smooth fluctuations of the sum exchange rate, but does not prevent its long-run trend in accordance with the equilibrium trajectory.

$$\Delta\overline{s}_t^{usd^T} = h_2\Delta\overline{s}_{t-1}^{usd^T} + (1-h_2)\cdot\Delta\overline{s}_t^{usd} \tag{25}$$

$$\Delta\overline{s}_t^{usd} = \Delta\overline{z}_t^{usd} + (\pi_t^T - \pi_{ss}^{us}) \tag{26}$$

The real exchange rate of the sum to the US dollar (z_t^{usd}) is determined on the basis of nominal exchange rate trends and the differential of consumer prices between Uzbekistan and the USA:

$$z_t^{usd} = s_t^{usd} + cpi_t^{us} - cpi_t \tag{27}$$

The real exchange rate (z_t^{usd}) is decomposed into an equilibrium component ($\overline{z}_t^{usd}$) and a gap ($\hat{z}_t^{usd}$) (28). The equilibrium exchange rate appreciation ($\Delta\overline{z}_t^{usd}$) is modelled as an autoregressive process with a steady rate ($\Delta\overline{z}_t^{usd^{ss}}$) equal to 0% based on historical data (29). The parameter z_1 determines the rate of convergence of the equilibrium exchange rate increment with the steady-state level and is calibrated to be 0.80. It is assumed that the equilibrium exchange rate is affected by the trends in remittances, with the scale of their effect being determined by the parameter z_2, calibrated at 0.02.

$$z_t^{usd} = \overline{z}_t^{usd} + \hat{z}_t^{usd} \tag{28}$$

$$\Delta\overline{z}_t^{usd} = z_1\Delta\overline{z}_{t-1}^{usd} + (1-z_1)\cdot\Delta\overline{z}_t^{usd^{ss}} - z_2\cdot(\Delta\overline{qremit}_t - \Delta\overline{qremit}_{ss}) + \varepsilon_t^{\Delta\overline{z}^{usd}} \tag{29}$$

The real effective exchange rate of the sum (z_t) is calculated as the sum of the equilibrium component ($\overline{z}_t$) and the gap ($\hat{z}_t$), each of the summands being calculated on the basis of the adjustment of corresponding components of the real exchange rate of the sum to the US dollar for the corresponding components of real exchange rates of currencies of countries that are Uzbekistan's trading partners to the US dollar.

Monetary policy rule

The CBU is in the process of transition to full-scale inflation targeting, and based on formal indicators the monetary policy regime can be classified as inflation targeting-lite. Currency interventions are sterilised and should not affect the short-term money market rate. Therefore, the CBU is assumed to control the money market rate and use it as an operational benchmark. As a result, we model the money market interest rate (i_t) in accordance with the modified Taylor rule:

$$i_t = m_1 i_{t-1} + (1 - m_1) \cdot (i_t^n + m_2 \cdot (E_t \pi_{t+3}^4 - \pi_{t+3}^T) + m_3 \hat{y}_t) + \varepsilon_t^i \tag{30}$$

The rate i_t is calculated by adding to the neutral interest rate (i_t^n) a mark-up determined on the basis of the expected deviation of inflation from the target ($E_t \pi_{t+3}^4 - \pi_{t+3}^T$) and the position of the economy in the business cycle approximated by the output gap ($\hat{y}_t$). The parameters m_2 and m_3 define the magnitude of the CBU's response to changes in inflation and the output gap and are calibrated to be 0.50 and 0.25, respectively. The lag component (i_{t-1}) ensures smoothing of the rate trend with the coefficient m_1, equal to 0.60: in practice, central banks tend to avoid excessive rate volatility when applying the inflation targeting regime. Thus, in inflation targeting, the central bank responds with monetary policy measures to the expected deviation of inflation from the target, while seeking to smooth out fluctuations in the economic cycle. The use of expected inflation is driven by transmission mechanism lags. The shock (ε_t^i) is included in equation (30) to account for discretionary monetary policy measures.

Inclusion of the neutral nominal interest rate in equation (30) ensures convergence of the nominal money market rate to the neutral level in the long run. It should be noted that, when including the neutral rate in equation (30), it is sufficient for the coefficient m_2 to be greater than zero in order to comply with the Taylor principle.

The neutral nominal money market rate (i_t^n) is calculated by summing the real equilibrium money market rate ($\overline{r}_t$) and expected inflation: ($E_t \pi_{t+1}^4$)

$$i_t^n = \overline{r}_t + E_t \pi_{t+1}^4 \tag{31}$$

The real equilibrium money market rate is an unobserved variable. In each period of time, the actual real rate (r_t), calculated by adjusting the nominal rate for expected inflation in accordance with equation (32), may deviate from the equilibrium rate under the influence of monetary policy measures or other factors, such as liquidity shocks. The deviation of the real rate from its equilibrium level determines the real money market interest rate gap ($\hat{r}_t$) in accordance with equation (33).

$$r_t = i_t - E_t \pi_{t+1}^4 \tag{32}$$

$$r_t = \overline{r}_t + \hat{r}_t \tag{33}$$

The QPM assumes that the real equilibrium money market rate ($\overline{r}_t$) is derived from the real version of uncovered interest rate parity (34) as a function of the real equilibrium money market rate in the United States ($\overline{r}_t^{us}$), the expected change in the real exchange rate of the sum to the US dollar ($E_t\Delta\overline{z}_{t+1}^{usd}$), and the equilibrium risk premium on investments in sum-denominated assets ($\overline{prem}_t$).

$$\overline{r}_t = w_1\overline{r}_{t-1} + (1-w_1)\cdot(\overline{r}_t^{us} + E_t\Delta\overline{z}_{t+1}^{usd} + \overline{prem}_t) + \varepsilon_t^{\overline{r}} \tag{34}$$

External sector

The relationship between the model for Uzbekistan and the model for the external sector and the blocks for other EDB member states of the Bank's ISM is set through four main channels. The first channel, foreign trade, implies the impact of cyclical fluctuations in economic activity in the EDB member countries and the external sector on the output gap in Uzbekistan. The second channel, inflationary, involves the impact of foreign exchange rates and external inflation on trends in consumer prices in Uzbekistan. The third channel, labour, involves the impact of economic activity in Russia on the volume of remittances of labour migrants to Uzbekistan. The fourth channel, financial, involves the impact of global interest rates on exchange rate movements in Uzbekistan through uncovered interest rate parity.

Calibrating model parameters

All model parameters were calibrated rather than estimated. This is due to the fact that the time series of Uzbekistan's macro-indicators are too short for estimation and subject to multiple structural shifts.

The model contains three groups of parameters. Firstly, coefficients on the variables in the system of equations that determine the dynamic properties of the model. Calibration of these parameters is usually based on available recommendations, expert judgements and results of scientific research. In addition, it should be taken into account that unobserved equilibrium indicators are usually characterised by smoothed trends.

Secondly, standard deviations of shocks, which determine the volatility of unobserved variables and have a significant impact on their estimation. Accordingly, these parameters are calibrated on the basis of historical volatility of the time series of variables with the assumption that gaps are more volatile than trends[3].

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

And thirdly, stable values of variables, which determine the steady state of the model. Calibration of the last group of parameters is usually based on the average values of variables (in case of structural shifts — for the most relevant period for the current conditions) or on the results of scientific research.

The model parameters were calibrated to take into account the stylised facts of the Uzbek economy, monetary and exchange rate policy regimes, and the functioning of the transmission mechanism. The calibration took into account recommendations for emerging market economies, values from previously published studies, and expert judgements. At the same time, we based the calibration on the period from 2017, as this is the time when the approaches to economic policy changed. The calibrated values of the model parameters are presented in Appendix D.

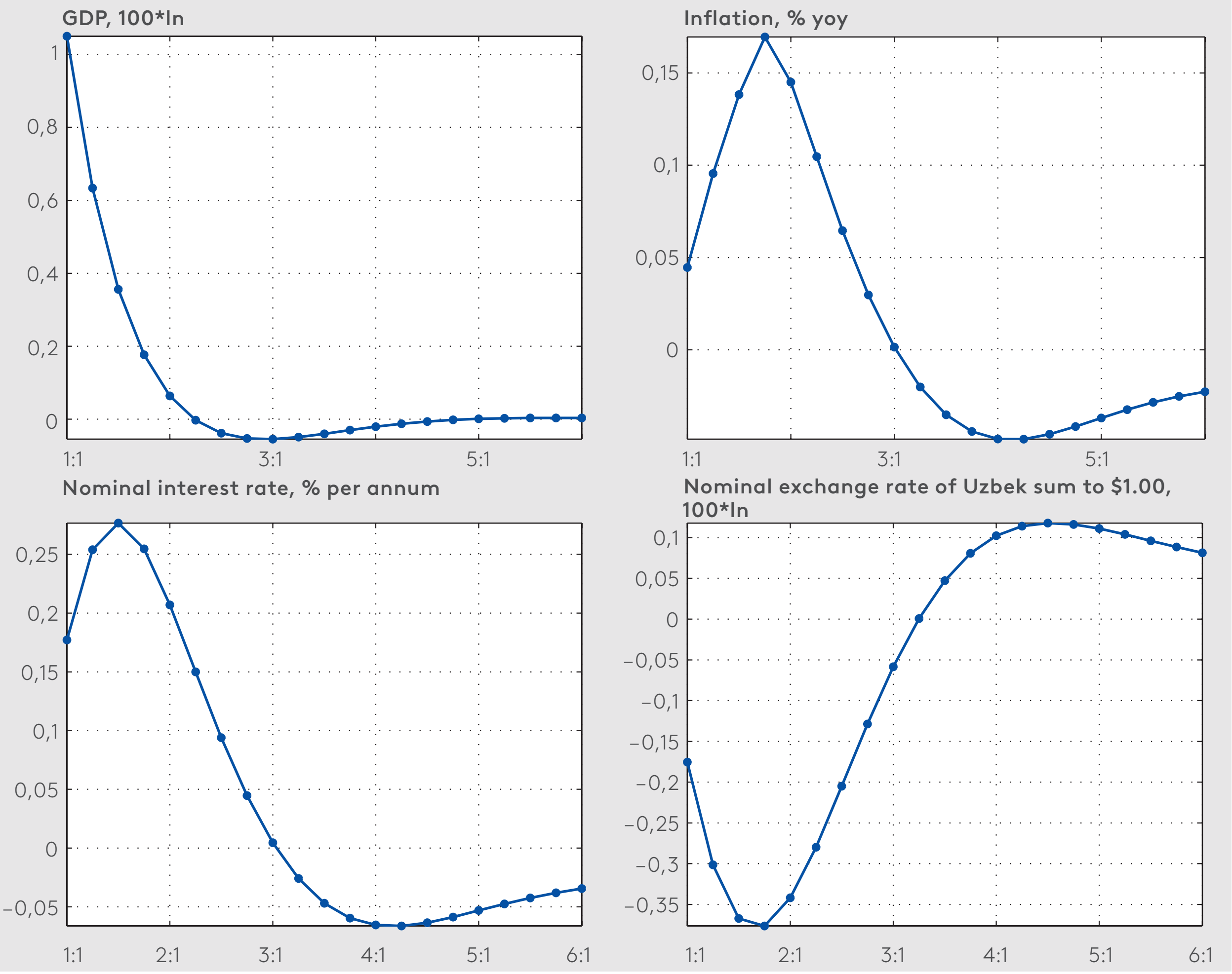
Economic indicators of Uzbekistan and trading partner countries with a quarterly frequency were used as input data for QPM. The multivariate Kalman filter was used to estimate unobserved components.

SENSITIVITY ANALYSIS OF ECONOMIC VARIABLES OF THE MODEL TO MACROECONOMIC SHOCKS

Simulations of the economic system's behaviour in response to five major macroeconomic shocks were conducted: aggregate demand shock, inflation shock, exchange rate shock, monetary policy shock, and fiscal policy shock. Shocks in simulations are treated as unexpected: the system is in a stable equilibrium state before the shock and economic agents had no information about the possible shock.

Aggregate demand shock

↓ Figure 5. Aggregate demand shock impulse response functions



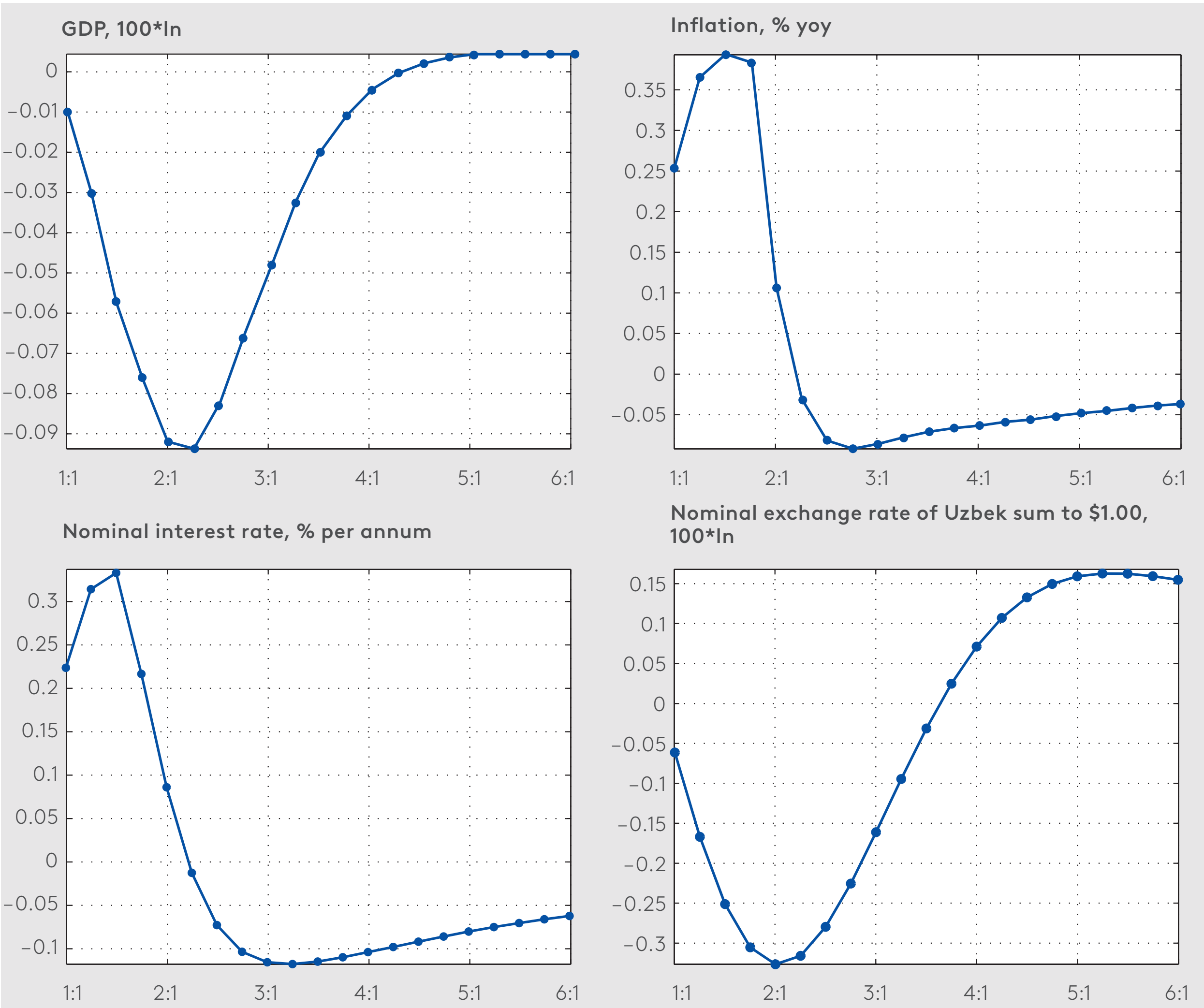
Note: hereinafter impulse response functions are presented in deviations of variables from their equilibrium levels. QoQ = annualised change of the indicator in period t in relation to period t–1. YoY = change of the indicator in period t in relation to period t–4.

Source: authors' calculations based on QPM.

The aggregate demand shock leads to an increase in GDP above its equilibrium level, which forms a positive output gap (Figure 5). Inflationary pressure increases and is reflected in a significant acceleration of inflation in the year after the shock. The CBU responds to the deviation of inflation from the target by raising the interest rate. An increase in interest rates leads to an increase in demand for assets denominated in sums, which drives a slight appreciation of the nominal exchange rate. Given the increased inflation, the REER moves into the overvaluation zone, which along with the increase in interest rates begins to gradually lead to a weakening of economic activity. As a result, the positive output gap starts to close — GDP returns to the equilibrium level. Inflationary pressure weakens, which allows the CBU to gradually return the interest rate to the neutral level.

Inflation shock

↓ **Figure 6. Inflation shock impulse response functions**

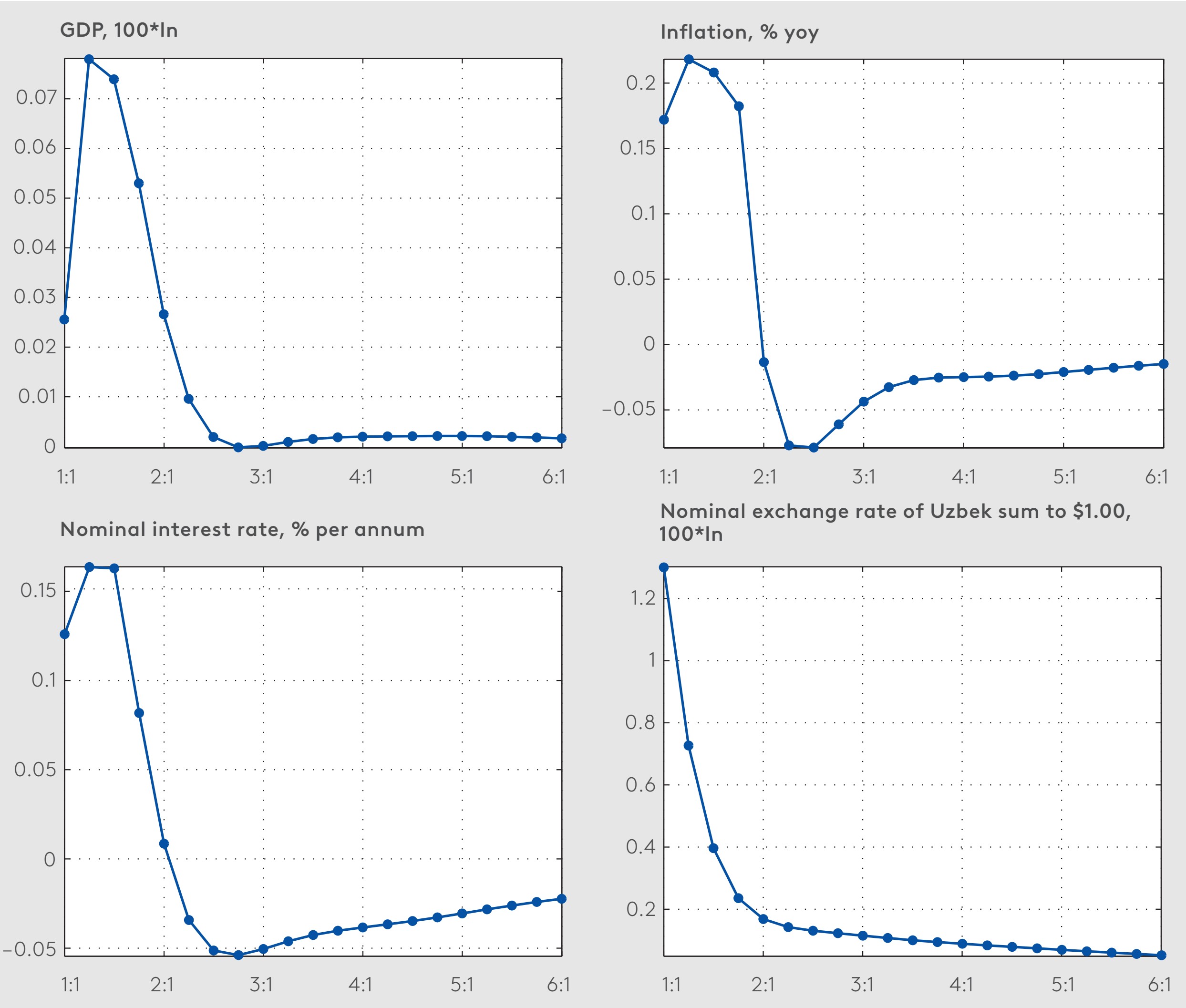


Source: authors' calculations based on QPM.

The inflation shock in the QPM is modelled as an exogenous increase in annualised quarterly inflation by 1 p.p. The CBU reacts to the acceleration of inflation by raising interest rates (Figure 6). This leads to an increase in demand for savings in the national currency, strengthening of the NEER, and overvaluation of the sum. With a time lag, REER's overvaluation and rising interest rates begin to restrain economic activity, which is expressed in the opening of a negative output gap. As a result, inflationary pressure starts to weaken, and this allows the CBU to switch to a cycle of rate cuts, which, in turn, favours a gradual return of the exchange rate and GDP to equilibrium levels.

Exchange rate shock

↓ **Figure 7. Exchange rate shock impulse response functions**

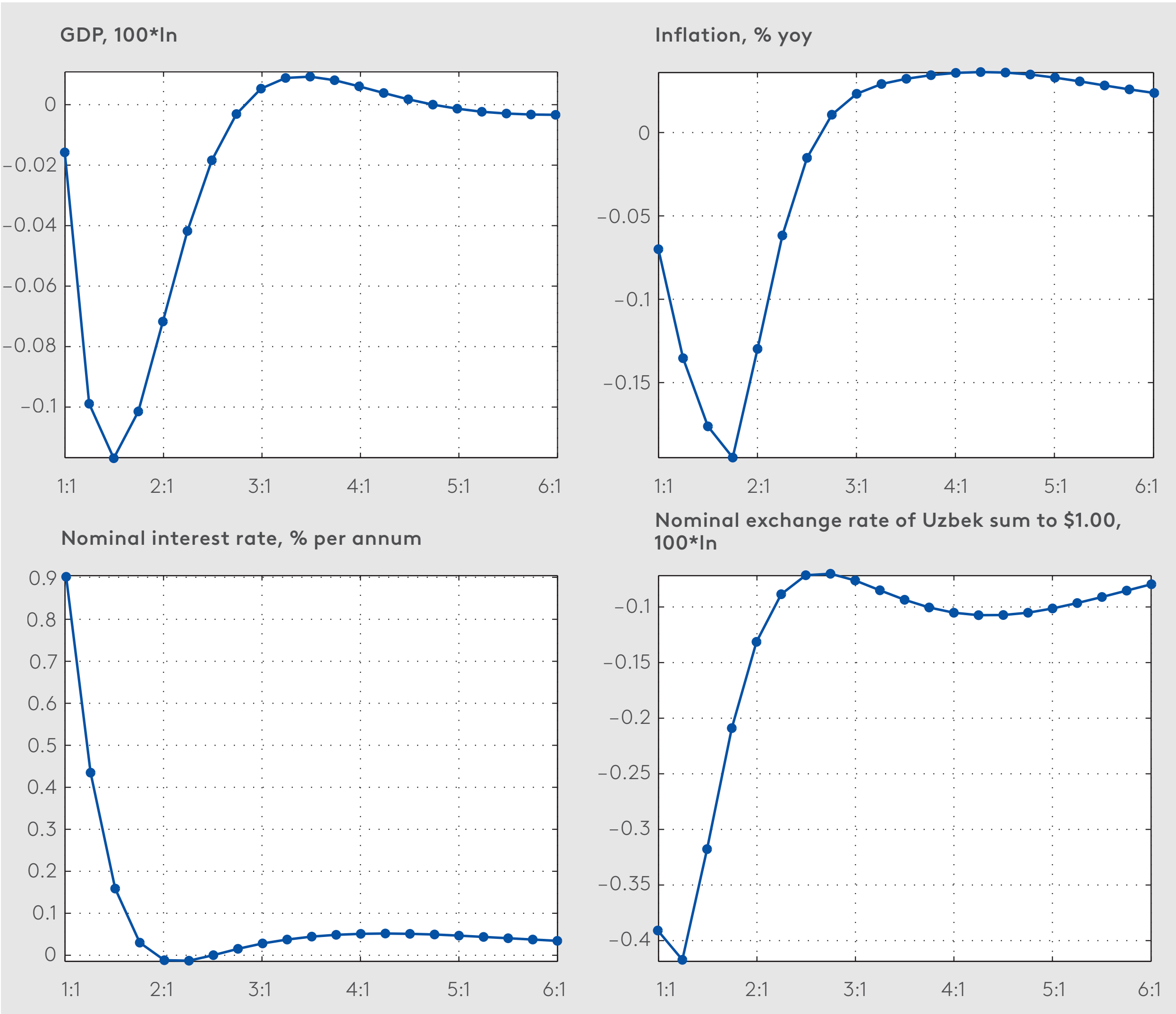


Source: authors' calculations based on QPM.

The exchange rate shock comes with a sharp weakening of the NEER, which creates inflationary pressure and causes a significant increase in inflation (Figure 7). Due to the acceleration of price growth, the REER weakens to a lesser extent than the NEER, however, the sum is undervalued. The CBU reacts to the inflation surge by increasing the interest rate, which is gradually translated into credit market rates. The increase in net exports due to the undervaluation of the sum outweighs the effect of the rate hike in the short run, and GDP rises in the two quarters after the shock, which forms a positive output gap. Thereafter, the effects of 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 pressures diminish, allowing the CBU to return interest rates to neutral levels.

Monetary policy shock

↓ **Figure 8. Monetary policy shock impulse response functions**



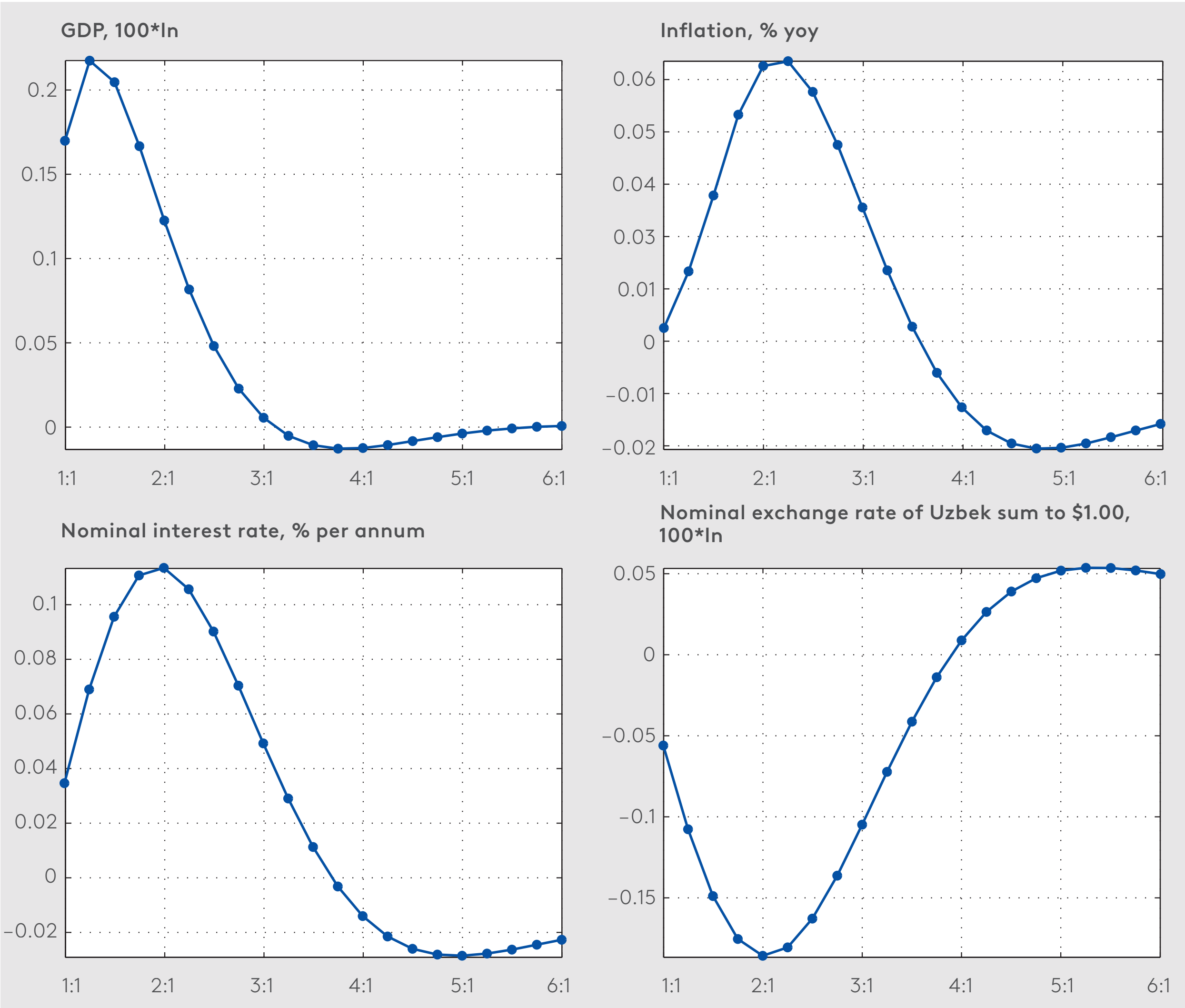
Source: authors' calculations based on QPM.

A monetary policy shock is modelled as an unexpected change in the money market rate. This increases the attractiveness of savings in the sum and causes an increase in net supply (or a reduction in net demand) in the foreign exchange market, which is reflected in the strengthening of the sum and its slight overvaluation. This stimulates the growth of imports. Restraining monetary conditions emerge, which lead to a weakening of economic activity (Figure 8). The decrease in aggregate demand along with a strengthening of the national currency are expressed in the slowdown of inflation. As inflation deviates downwards from the target level, the CBU starts to reduce the interest rate, bringing it back to the neutral level. The lowering of the rate is reflected in the credit market rates and rather quickly leads to the weakening of the sum — due to the action of the expectations channel of the transmission mechanism and the increase in imports. As a result, the restrictive nature of monetary conditions is weakened, which supports a gradual return of GDP to the equilibrium level and inflation to the target.

Fiscal policy shock

The fiscal policy shock is modelled as an expansion of the budget deficit by 1% of GDP, which leads to an increase in domestic demand and GDP growth (Figure 9). Under active monetary policy, the impact of the fiscal shock on economic activity will be limited: the CBU raises interest rates in response to increased inflation risks. This allows the nominal exchange rate to strengthen slightly. However, further pressure on the national currency to weaken comes from the reduction of net exports.

↓ **Figure 9. Fiscal shock impulse response functions**



Source: authors' calculations based on QPM.

ANALYSIS OF THE IMPACT OF MACROECONOMIC SHOCKS ON THE ECONOMY OF UZBEKISTAN UNDER VARIOUS MACROECONOMIC POLICY SCENARIOS

In this section we have estimated the response of key economic indicators of Uzbekistan to underlying macroeconomic shocks under two alternative scenarios of monetary and exchange rate policies.

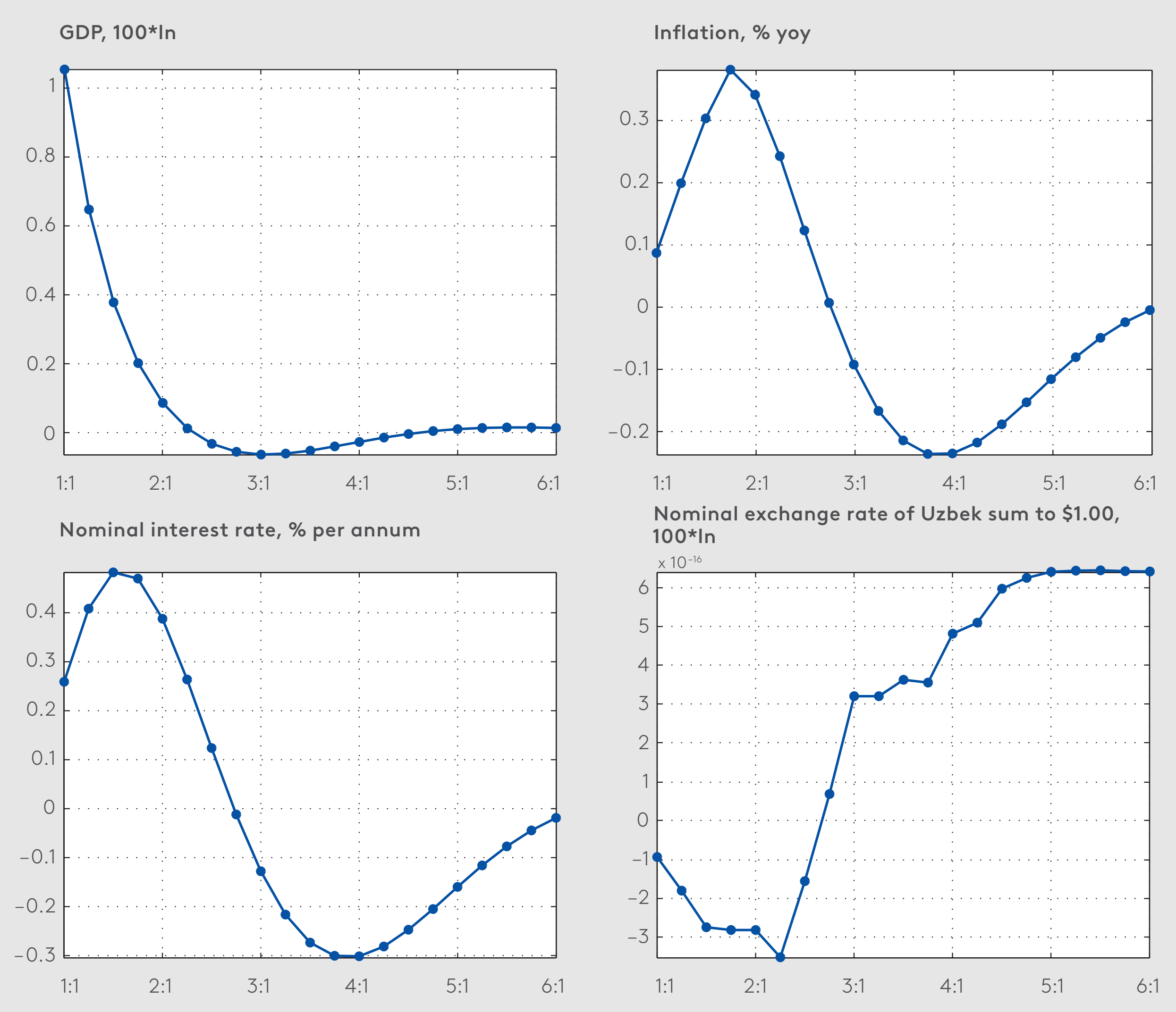
The first alternative scenario assumes that the Central Bank of Uzbekistan returns to a fixed exchange rate regime. To simulate this scenario, the value of the parameter *erp* was adjusted from 0.10 in the baseline calibration to 1.00 in the alternative calibration. It is assumed that the CBU retains control over the money market interest rate. This means that the issuance or withdrawal of sums through the currency channel will be sterilised. Consequently, the monetary policy reaction function in this scenario remains in the same specifications and calibration as in the baseline model.

The simulation results for the first alternative scenario (Figures 10–12) show that key macro-indicators of the Uzbek economy will become much more volatile in response to shocks in the event of a return to the fixed exchange rate regime. The stabilisation of the economic system and its return to equilibrium would take longer, as the exchange rate does not change in response to shocks and ceases to perform its crucial function of absorbing them.

The second alternative scenario assumes the implementation of a full-scale inflation targeting regime. For its simulation, the value of the parameter *erp* was adjusted from 0.10 in the baseline calibration to 0.00 in the alternative calibration. Also, the value of parameter m_2 was increased from 0.50 to 1.00 to reflect greater commitment of the Central Bank of Uzbekistan to achieve the inflation target under full-scale inflation targeting.

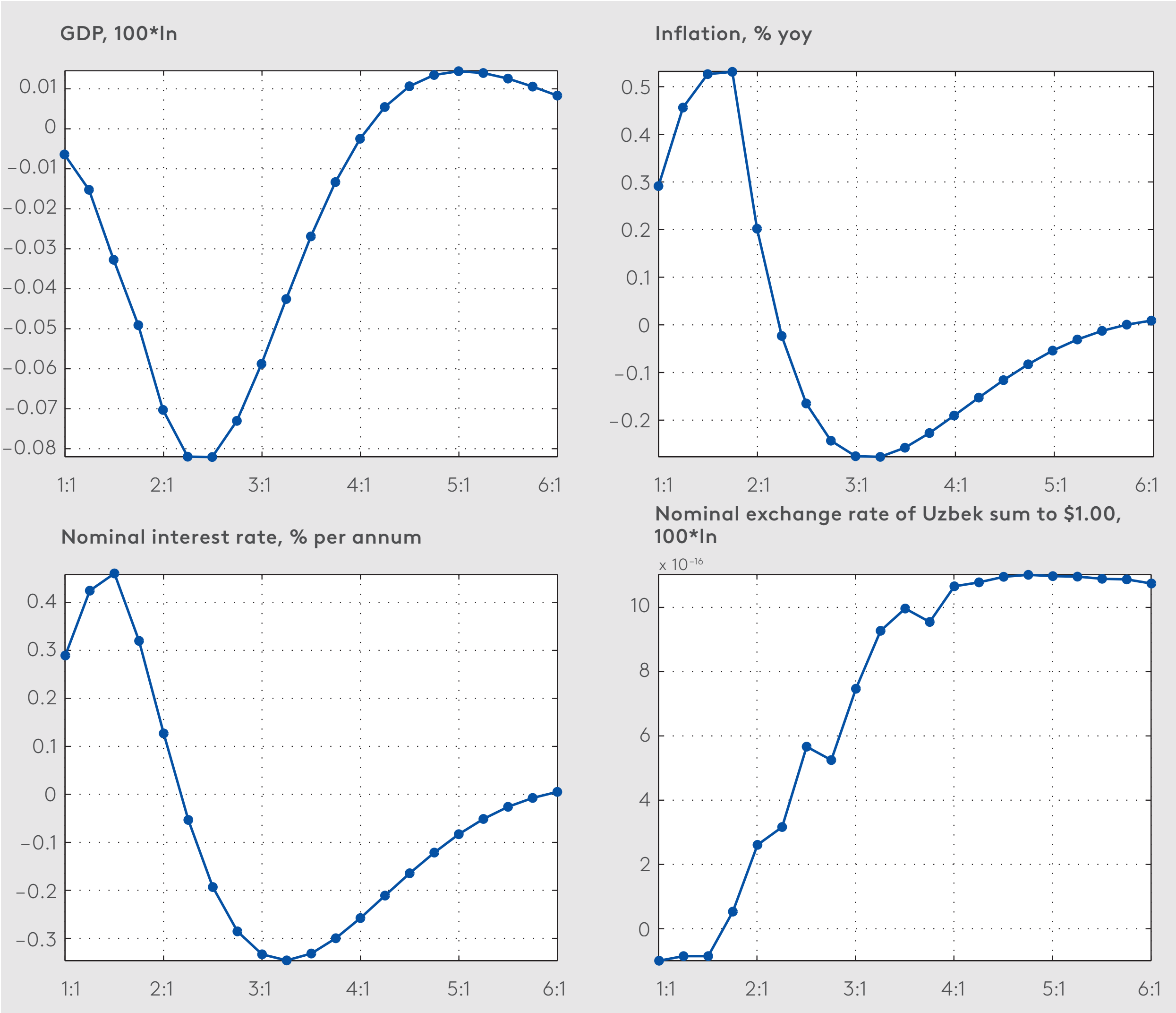
The simulation results for the second alternative scenario (Figures 13–15) show that GDP and inflation will become less volatile in response to shocks, and a smaller monetary policy response will be needed to bring the economy back to equilibrium. In contrast to a fixed exchange rate regime with full-scale inflation targeting, the exchange rate of the sum will be determined by market factors, which will allow it to absorb shocks effectively.

↓ Figure 10. Aggregate demand shock impulse response functions under the first alternative scenario



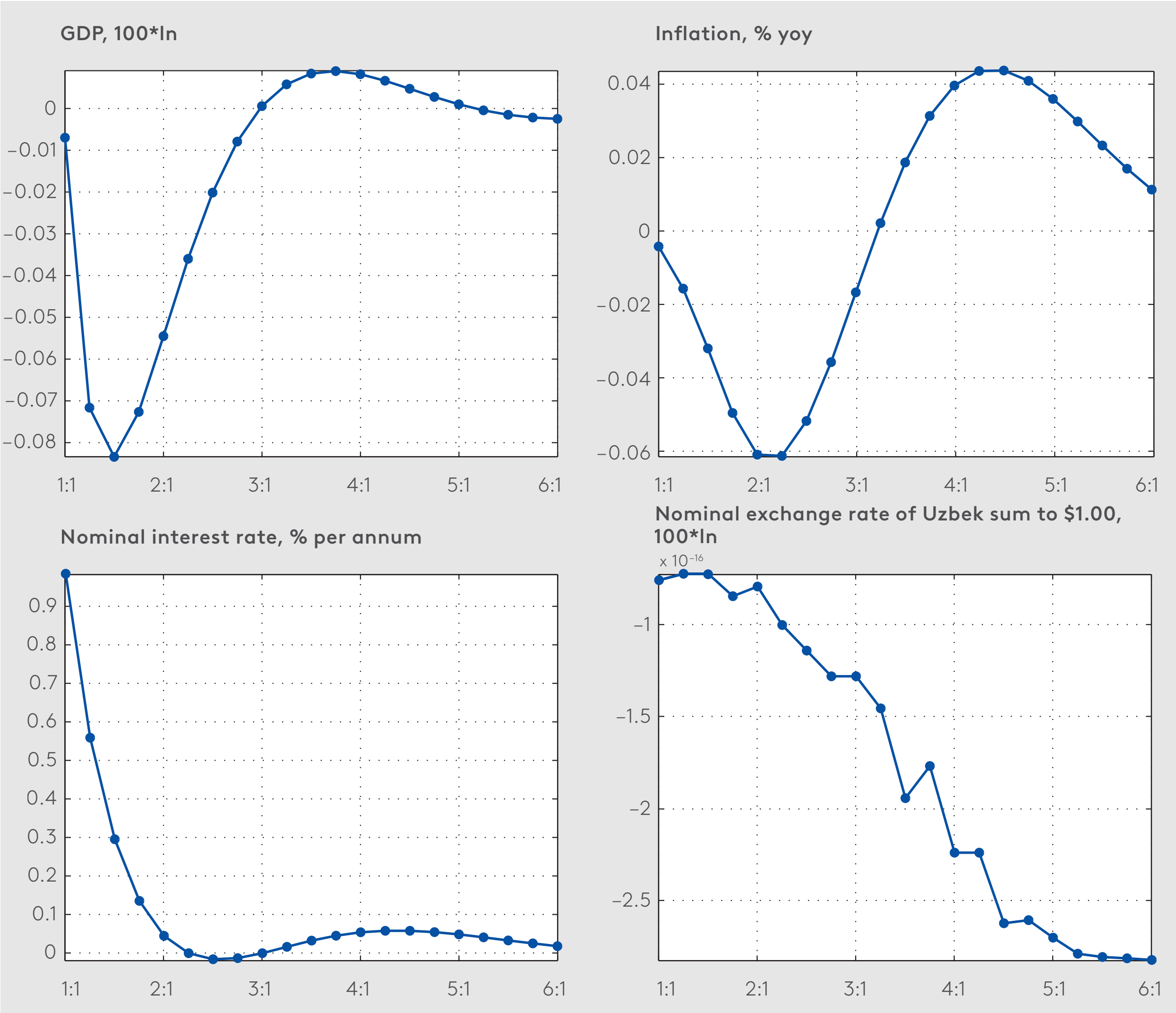
Source: authors' calculations based on QPM.

↓ Figure 11. Inflation shock impulse response functions under the first alternative scenario



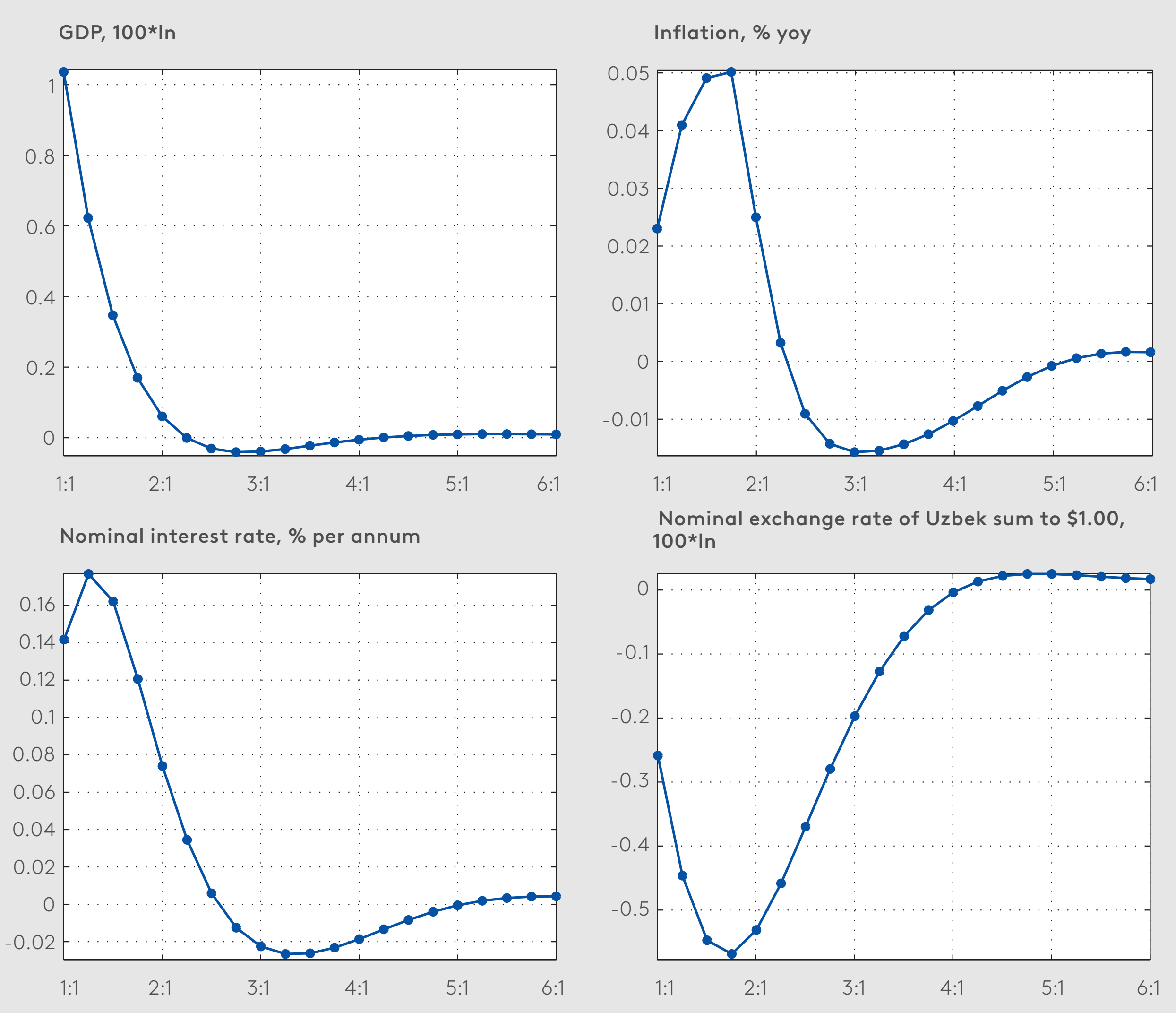
Source: authors' calculations based on QPM.

↓ Figure 12. Monetary policy shock impulse response functions under the first alternative scenario



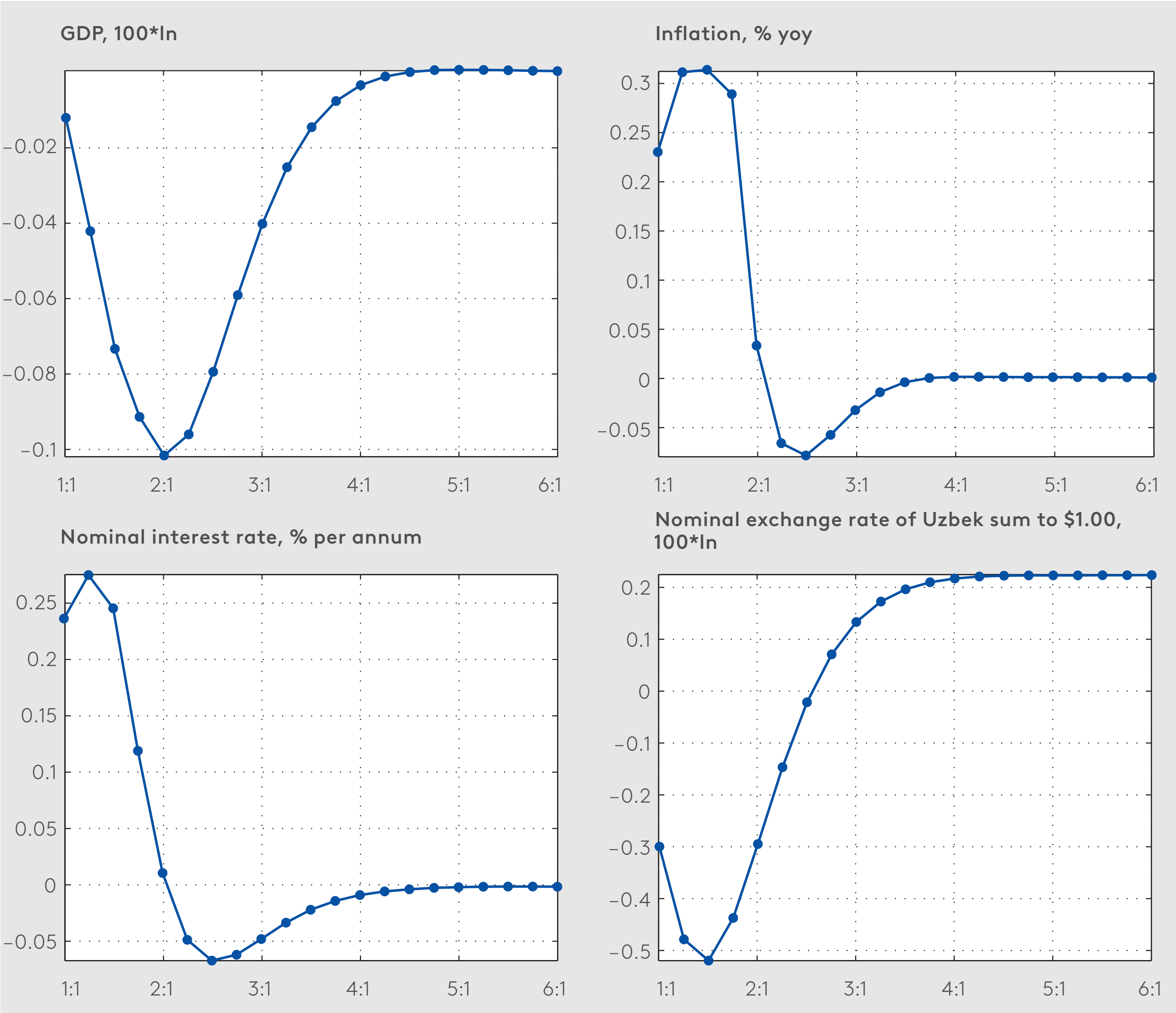
Source: author's calculations based on QPM.

↓ Figure 13. Aggregate demand shock impulse response functions under the second alternative scenario



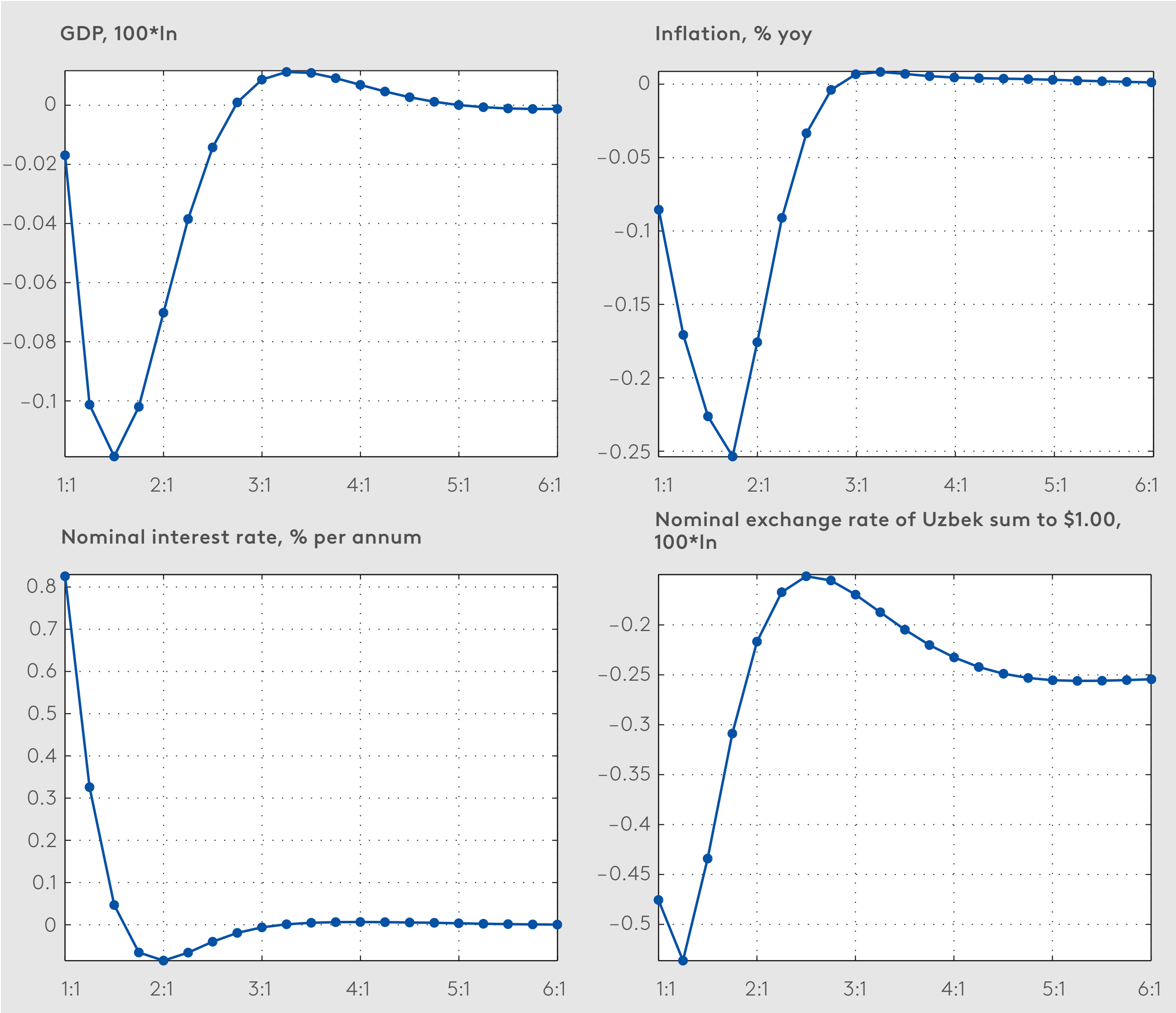
Source: authors' calculations based on QPM.

↓ Figure 14. Inflation shock impulse response functions under the second alternative scenario



Source: authors' calculations based on QPM.

↓ Figure 15. Monetary policy shock impulse response functions under the second alternative scenario



Source: authors' calculations based on QPM.

ANALYSING THE PREDICTIVE POWER OF THE MODEL USING HISTORICAL DATA

To evaluate the predictive properties of the model, simulation using historical data is performed. Based on the simulation, the RMSEs of the key QPM macro variables are calculated and compared with the RMSEs of the random walk model. The simulations are performed for the period from Q1 2008 to Q4 2022. The simulations assume that all exogenous variables (the external sector for Uzbekistan) in the model are known[4]. All other observed variables are known only up to the quarter preceding the forecast period. The results of the forecasts using historical data are presented in Table 1.

↓ **Table 1. Forecasts' accuracy using historical data from 2008 to 2022.**

Indicator	Ratio of RMSE for QPM to RMSE for the random walk model at the forecast horizon				
	Q1	Q2	Q3	Q4	Q8
Inflation, % QoQ	1.36	1.63	1.61	1.59	1.27
Real GDP, % QoQ	0.54	0.55	0.66	0.75	0.61
Nominal exchange rate of sum to dollar, % QoQ	1.51	0.81	0.75	0.78	0.85
Nominal interbank lending rate, %	2.20	3.17	2.68	2.74	2.04
Nominal wages, % QoQ	0.77	0.79	0.69	0.72	0.69
Net inflow of remittances, 100*ln	0.44	0.34	0.32	0.34	0.51

Source: author's development based on QPM.
Note: QoQ = annualised growth rate, quarter-on-quarter.

The forecast results show that the accuracy of the QPM is higher than that of the random walk model for most of the main macroeconomic variables. The exceptions are inflation and the money market rate. The accuracy of the forecasts using historical data for these variables may be low, as the approaches to the implementation of monetary policy, the extent of the government's distorting influence on the economy, and the quality of published statistics have changed significantly since the start of structural reforms in 2017.

[4] We also reveal the fiscal deficit, whose equation specification in the model is simplistic because fiscal policy is highly discretionary, the inflation target, which is a monetary policy variable, as well as the equilibrium risk premium and the change in the equilibrium real exchange rate of the sum to the US dollar due to the extreme high volatility of the exchange rate when exchange rate policy significantly changed after the start of economic liberalisation in 2017

The accuracy of the inflation forecasts over the medium-term horizon (eight quarters) is significantly improved in simulations from 2018 (Table 2). Also, we cannot rule out that inflation is strongly affected by administrative price regulation, the impact of which, due to the methodological specifics of the EDB IMS construction, is taken into account as part of the inflation shock and reduces the predictive quality of models using historical data. The accuracy of the exchange rate forecasts increases significantly, while the accuracy of the money market interest rate forecasts remains low. It is quite possible that the forecasts' accuracy in the latter case is affected by the shocks of the pandemic in 2020 and the materialising of geopolitical risks in 2022, which cannot be predicted solely by QPM.

↓ Table 2. Forecasts' accuracy using historical data from 2018 to 2022.

Indicator	Ratio of RMSE for QPM to RMSE for the random walk model at the forecast horizon				
	Q1	Q2	Q3	Q4	Q8
Inflation, % QoQ	1.58	1.54	1.80	1.66	0.76
Real GDP, % QoQ	0.50	0.61	0.69	0.64	0.66
Nominal exchange rate of sum to dollar, % QoQ	0.51	0.26	0.22	0.22	0.19
Nominal interbank lending rate, %	1.18	1.39	1.60	1.82	2.16
Nominal wages, % QoQ	0.55	0.61	0.78	0.77	0.98
Dollar volume of remittances, 100*ln	0.50	0.41	0.33	0.30	0.69

Source: author's development based on QPM.
Note: QoQ = annualised growth rate, quarter-on-quarter.

CONCLUSION

The developed model for the analysis and forecasting of Uzbekistan's economy allows us to solve a whole set of problems, including modelling of fiscal and monetary policy and preparation of macroeconomic forecasts for the country under various scenarios. It is built in the form of a New Keynesian model with the inclusion of a block of monetary and fiscal elements for medium-term forecasting.

The design of the model delivers a simple and ready-to-use tool, which is an extension of the ISM implemented at the EDB. It allows us to analyse Uzbekistan's economy in accordance with common criteria for EDB member countries and to answer questions about the convergence of Uzbekistan's GDP with other countries in the region, as well as the specific features of Uzbekistan's response to monetary policy shocks and its fiscal sustainability.

ANNEX A.
SOURCES OF STATISTICAL DATA

Statistics for the medium-term model of the Uzbekistan economy

Monthly data

Variable	Description	Source
uzs_usd	Nominal exchange rate of the sum to the US dollar	Central Bank of Uzbekistan
cpi_mom	Month-on-month inflation according to the composite consumer price index	Statistical Agency of the President of the Republic of Uzbekistan
i_avg_bnk	Average bank money market rate in Uzbekistan, % per annum	Central Bank of Uzbekistan
i_avg_loans_bnk	Average bank rate on loans in sums in Uzbekistan, % per annum	Central Bank of Uzbekistan
wage_su	Average monthly nominal salary, thousand Uzbek sums	Statistical Agency of the President of the Republic of Uzbekistan

Quarterly data

Variable	Description	Source
gdp_nom_su	Nominal GDP (total), million Uzbek sums	Statistical Agency of the President of the Republic of Uzbekistan
gdp_su	GDP in constant prices, total, million Uzbek sums	Statistical Agency of the President of the Republic of Uzbekistan
bop_trans_uz_su	Remittance inflows to Uzbekistan in the balance of payments, USD million.	Central Bank of Uzbekistan
bop_trans_oth_su	Remittances paid from Uzbekistan in the balance of payments, USD million.	Central Bank of Uzbekistan
rev_su	Budget revenues, billion Uzbek sums	Ministry of Economy and Finance of Uzbekistan
exp_su	Budget expenditures, billion Uzbek sums	Ministry of Economy and Finance of Uzbekistan

Annual data

Variable	Description	Source
bal_tot	Budget balance, billion Uzbek sums	Ministry of Economy and Finance of Uzbekistan
rev_tot	Budget revenues, billion Uzbek sums	Ministry of Economy and Finance of Uzbekistan
exp_tot	Budget expenditures, billion Uzbek sums	Ministry of Economy and Finance of Uzbekistan

ANNEX B. QPM STRUCTURE AND CALIBRATION FOR UZBEKISTAN

The aggregate demand block and monetary conditions

$$y_t = \bar{y}_t + \hat{y}_t \tag{A.1}$$

$$\Delta 4y_t = y_t - y_{t-4} \tag{A.2}$$

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

$$\Delta \bar{y}_t = 4 \cdot (\bar{y}_t - \bar{y}_{t-1}) \tag{A.4.1}$$

$$\Delta 4\bar{y}_t = \bar{y}_t - \bar{y}_{t-4} \tag{A.4.2}$$

$$\Delta \bar{y}_t = ab_1 \Delta \bar{y}_{t-1} + (1 - ab_1) \cdot \Delta \bar{y}_{ss} + ab_2 \cdot (\Delta \overline{qremit}_t - \Delta \overline{qremit}_{ss}) + \varepsilon_t^{\Delta \bar{y}} \tag{A.5}$$

$$\hat{y}_t = a_1 \hat{y}_{t-1} + a_2 E_t \hat{y}_{t+1} - a_3 mci_{t-1} + a_4 \hat{y}_t^* + a_5 \widehat{def2gdp}_t + a_6 \widehat{qremit}_t^{uzs} + \varepsilon_t^{\hat{y}} \tag{A.6}$$

$$E_t \hat{y}_{t+1} = \hat{y}_{t+1} \tag{A.7}$$

$$mci_t = a_7 \cdot (\hat{r}_t + \widehat{sp}_t) - (1 - a_7) \cdot \hat{z}_t \tag{A.8}$$

Fiscal sector

$$def2gdp_t = \overline{def2gdp}_t + \widehat{def2gdp}_t \tag{A.9}$$

$$\begin{aligned} def2gdp_t &= f_1 def2gdp_{t-1} + \\ &+ (1 - f_1) \cdot (\overline{def2gdp}_t^{tar} - f_2 \cdot (def2gdp_{t-1} - \overline{def2gdp}_{t-1}^{tar}) - f_3 \hat{y}_t) + \varepsilon_t^{def2gdp} \end{aligned} \tag{A.10}$$

$$\overline{def2gdp}_t = f_4 \overline{def2gdp}_{t-1} + (1 - f_4) \cdot \overline{def2gdp}_t^{tar} + \varepsilon_t^{\overline{def2gdp}} \tag{A.11}$$

$$\overline{def2gdp}_t^{tar} = f_5 \overline{def2gdp}_{t-1}^{tar} + (1 - f_5) \cdot \overline{def2gdp}_t^{ss} + \varepsilon_t^{\overline{def2gdp}^{tar}} \tag{A.12}$$

Remittances

$$qremit_t = remit_t - cpi_t^{us} + z_t^{ru} \tag{A.13}$$

$$qremit_t = \overline{qremit}_t + \widehat{qremit}_t \tag{A.14}$$

$$\Delta\overline{qremit}_t = q_1 \Delta\overline{qremit}_{t-1} + (1-q_1)\cdot\Delta\overline{qremit}_{ss} + \varepsilon_t^{\Delta\overline{qremit}} \tag{A.15}$$

$$\widehat{qremit}_t^{uzs} = \widehat{qremit}_t + \hat{z}_t^{usd} - \hat{z}_t^{ru} \tag{A.16}$$

$$\widehat{qremit}_t^{uzs} = q_2 \widehat{qremit}_{t-1}^{uzs} + q_3 \hat{y}_t^{ru} - q_4 \hat{z}_t^{rub} + \varepsilon_t^{\widehat{qremit}^{uzs}} \tag{A.17}$$

$$\Delta\overline{qremit}_t = 4\cdot(\overline{qremit}_t - \overline{qremit}_{t-1}) \tag{A.18}$$

$$\Delta remit_t = 4\cdot(remit_t - remit_{t-1}) \tag{A.19}$$

$$\Delta 4remit_t = remit_t - remit_{t-4} \tag{A.20}$$

Labour market

$$\Delta wage_t = aa_1 E_t \Delta wage_{t+1} + (1-aa_1)\cdot\Delta wage_{t-1} + aa_2 \hat{y}_t - aa_3 \widehat{rwage}_{t-1} + \varepsilon_t^{\Delta wage} \tag{A.21}$$

$$\Delta wage_t = 4 \cdot (wage_t - wage_{t-1}) \tag{A.22}$$

$$\Delta 4wage_t = wage_t - wage_{t-4} \tag{A.23}$$

$$E_t \Delta wage_{t+1} = wage_t - \Delta wage_{t+1} \tag{A.24}$$

$$rwage_t = wage_t - cpi_t \tag{A.25}$$

$$\Delta 4rwage_t = rwage_t - rwage_{t-4} \tag{A.26}$$

$$\Delta rwage_t = 4 \cdot (rwage_t - rwage_{t-1}) \tag{A.27}$$

$$rwage_t = \overline{rwage}_t + \widehat{rwage}_t \tag{A.28}$$

$$\Delta\overline{rwage}_t = aa_4 \Delta\overline{rwage}_{t-1} + (1-aa_4)\cdot\Delta\bar{y}_t + \varepsilon_t^{\Delta\overline{rwage}} \tag{A.29}$$

$$\Delta\overline{rwage}_t = 4\cdot(\overline{rwage}_t - \overline{rwage}_{t-1}) \tag{A.30}$$

Inflation block

$$\pi_t = 4 \cdot (cpi_t - cpi_{t-1}) \tag{A.31}$$

$$\pi_t^4 = cpi_t - cpi_{t-4} \tag{A.32}$$

$$\pi_t = b_1 E_t \pi_{t+1} + (1 - b_1 - b_2) \cdot \pi_{t-1} + b_2 \pi_{imp_t} + b_3 rmc_t + \varepsilon_t^{\pi} \tag{A.33}$$

$$rmc_t = (1 - k_1 - k_2 - k_3) \cdot \hat{y}_t + k_1 \widehat{rwage}_t + k_2 \hat{z}_t + k_3 \cdot (\widehat{qfood}_t + \hat{z}_t^{usd}) \tag{A.34}$$

$$\begin{aligned} \pi_{imp_t} = \pi_t^{us} - t_{eur} \cdot \Delta z_t^{eu} - t_{cny} \cdot \Delta z_t^{cn} - t_{byn} \cdot \Delta z_t^{by} - t_{kzt} \cdot \Delta z_t^{kz} - \\ - t_{amd} \cdot \Delta z_t^{am} - t_{kgs} \cdot \Delta z_t^{kg} - t_{rub} \cdot \Delta z_t^{ru} + \Delta s_t^{usd} - \Delta \overline{z}_t \end{aligned} \tag{A.35}$$

$$E_t \pi_{t+3}^4 = \pi_{t+3}^4 \tag{A.36}$$

$$E_t \pi_{t+1}^4 = \pi_{t+1}^4 \tag{A.37}$$

$$E_t \pi_{t+1} = \pi_{t+1} \tag{A.38}$$

$$\pi_t^T = tar_1 \pi_{t-1}^T + (1 - tar_1) \cdot \pi_{ss}^T + \varepsilon_t^{\pi^T} \tag{A.39}$$

Exchange rate

$$s_t^{usd} = (1 - erp) \cdot \left(E_t s_{t+1}^{usd} + \frac{i_t^{us} - i_t + prem_t}{4} \right) + erp \cdot \overline{s}_t^{usd^T} + \varepsilon_t^{s^{usd}} \tag{A.40}$$

$$\Delta \overline{s}_t^{usd^T} = h_2 \Delta \overline{s}_{t-1}^{usd^T} + (1 - h_2) \cdot \Delta \overline{s}_t^{usd} \tag{A.41}$$

$$\Delta \overline{s}_t^{usd} = \Delta \overline{z}_t^{usd} + (\pi_t^T - \pi_{ss}^{us}) \tag{A.42}$$

$$E_t s_{t+1}^{usd} = h_1 s_{t+1}^{usd} + (1 - h_1) \cdot s_{t+1}^{nf} \tag{A.43}$$

$$s_{t+1}^{nf} = s_{t-1}^{usd} + \frac{2 \Delta \overline{s}_t^{usd}}{4} \tag{A.44}$$

$$\Delta s_t^{usd} = 4 \cdot (s_t^{usd} - s_{t-1}^{usd}) \tag{A.45}$$

$$\Delta \overline{s}_t^{usd^T} = 4 \cdot (\overline{s}_t^{usd^T} - \overline{s}_{t-1}^{usd^T}) \tag{A.46}$$

$$E_t \Delta z_{t+1}^{usd} = \Delta z_{t+1}^{usd} \tag{A.47}$$

$$z_t^{usd} = s_t^{usd} + cpi_t^{us} - cpi_t \tag{A.48}$$

$$\Delta z_t^{usd} = 4 \cdot (z_t^{usd} - z_{t-1}^{usd}) \tag{A.49}$$

$$\Delta \overline{z}_t^{usd} = 4 \cdot (\overline{z}_t^{usd} - \overline{z}_{t-1}^{usd}) \tag{A.50}$$

$$\Delta 4\overline{z}_t^{usd} = \overline{z}_t^{usd} - \overline{z}_{t-4}^{usd} \tag{A.51}$$

$$z_t^{usd} = \overline{z}_t^{usd} + \hat{z}_t^{usd} \tag{A.52}$$

$$\Delta \overline{z}_t^{usd} = z_1 \Delta \overline{z}_{t-1}^{usd} + (1 - z_1) \cdot \Delta \overline{z}_t^{usd^{ss}} - z_2 \cdot (\Delta \overline{qremit}_t - \Delta \overline{qremit}_{ss}) + \varepsilon_t^{\Delta \overline{z}^{usd}} \tag{A.53}$$

$$z_t = \overline{z}_t + \hat{z}_t \tag{A.54}$$

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

$$\Delta \overline{z}_t = 4 \cdot (\overline{z}_t - \overline{z}_{t-1}) \tag{A.56}$$

$$\Delta 4\overline{z}_t = \overline{z}_t - \overline{z}_{t-4} \tag{A.57}$$

$$\begin{aligned} \overline{z}_t = {} & t_{usd}\overline{z}_t^{usd} + t_{eur} \cdot (\overline{z}_t^{usd} - \overline{z}_t^{eu}) + t_{cny} \cdot (\overline{z}_t^{usd} - \overline{z}_t^{cn}) + t_{byn} \cdot (\overline{z}_t^{usd} - \overline{z}_t^{by}) + \\ & + t_{kzt} \cdot (\overline{z}_t^{usd} - \overline{z}_t^{kz}) + t_{amd} \cdot (\overline{z}_t^{usd} - \overline{z}_t^{am}) + t_{kgs} \cdot (\overline{z}_t^{usd} - \overline{z}_t^{kg}) + t_{rub} \cdot (\overline{z}_t^{usd} - \overline{z}_t^{ru}) \end{aligned} \tag{A.58}$$

$$\begin{aligned} \hat{z}_t = {} & t_{usd}\hat{z}_t^{usd} + t_{eur} \cdot (\hat{z}_t^{usd} - \hat{z}_t^{eu}) + t_{cny} \cdot (\hat{z}_t^{usd} - \hat{z}_t^{cn}) + t_{byn} \cdot (\hat{z}_t^{usd} - \hat{z}_t^{by}) + \\ & + t_{kzt} \cdot (\hat{z}_t^{usd} - \hat{z}_t^{kz}) + t_{amd} \cdot (\hat{z}_t^{usd} - \hat{z}_t^{am}) + t_{kgs} \cdot (\hat{z}_t^{usd} - \hat{z}_t^{kg}) + t_{rub} \cdot (\hat{z}_t^{usd} - \hat{z}_t^{ru}) \end{aligned} \tag{A.59}$$

$$prem_t = \overline{prem}_t + \widehat{prem}_t \tag{A.60}$$

$$\overline{prem}_t = pr_1 \overline{prem}_{t-1} + (1 - pr_1) \cdot \overline{prem}_{ss} - pr_2 \cdot (\Delta \overline{qremit}_t - \Delta \overline{qremit}_{ss}) + \varepsilon_t^{\overline{prem}} \tag{A.61}$$

$$\widehat{prem}_t = pr_3 \widehat{prem}_{t-1} + \varepsilon_t^{\widehat{prem}} \tag{A.62}$$

Monetary policy reaction function

$$i_t = m_1 i_{t-1} + (1 - m_1) \cdot (i_t^n + m_2 \cdot (E_t \pi_{t+3}^4 - \pi_{t+3}^T) + m_3 \hat{y}_t) + \varepsilon_t^i \tag{A.63}$$

$$i_t^n = \overline{r}_t + E_t \pi_{t+1}^4 \tag{A.64}$$

$$r_t = i_t - E_t \pi_{t+1}^4 \tag{A.65}$$

$$r_t = \overline{r}_t + \hat{r}_t \tag{A.66}$$

$$\overline{r}_t = w_1 \overline{r}_{t-1} + (1 - w_1) \cdot (\overline{r}_t^{us} + E_t \Delta \overline{z}_{t+1}^{usd} + \overline{prem}_t) + \varepsilon_t^{\overline{r}} \tag{A.67}$$

$$sp_t = \overline{sp}_t + \widehat{sp}_t \tag{A.68}$$

$$\overline{sp}_t = w_2 \overline{sp}_{t-1} + (1 - w_2) \cdot \overline{sp}_t^{ss} + \varepsilon_t^{\overline{sp}} \tag{A.69}$$

$$\widehat{sp}_t = w_3 \widehat{sp}_{t-1} + \varepsilon_t^{\widehat{sp}} \tag{A.70}$$

External sector

$$\begin{aligned} \hat{y}_t^* = {} & w^{ru} \hat{y}_t^{ru} + w^{eu} \hat{y}_t^{eu} + w^{cn} \hat{y}_t^{cn} + w^{us} \hat{y}_t^{us} + w^{by} \hat{y}_t^{by} + \\ & + w^{am} \hat{y}_t^{am} + w^{kz} \hat{y}_t^{kz} + w^{kg} \hat{y}_t^{kg} + w^{ow} \hat{y}_t^{ow} \end{aligned} \tag{A.71}$$

APPENDIX C.
QPM VARIABLES FOR UZBEKISTAN

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	Annualised real GDP growth
$\Delta 4y_t$	Real GDP growth, period to the corresponding period of the previous year
$\Delta \bar{y}_t$	Annualised growth of equilibrium real GDP
$\Delta 4\bar{y}_t$	Growth of equilibrium real GDP, period to the corresponding period of the previous year
$E_t\hat{y}_{t+1}$	Output gap expected in period t+1
mci_t	Monetary conditions index
$def2gdp_t$	Observed budget surplus/deficit to GDP
$\overline{def2gdp}_t$	Structural budget surplus/deficit
$\widehat{def2gdp}_t$	Cyclical budget surplus/deficit (deviation of the budget surplus/deficit from the equilibrium level)
$\overline{def2gdp}_t^{tar}$	Budgetary target surplus/deficit
$remit_t$	Net remittance inflows to Uzbekistan (in USD)
$\Delta remit_t$	Annualised increase in net remittance inflows to Uzbekistan
$\Delta 4remit_t$	Growth in net remittance inflows to Uzbekistan, period to the corresponding period of the previous year
$qremit_t$	Real net remittance inflows to Uzbekistan
$\overline{qremit}_t$	Equilibrium net remittance inflows to Uzbekistan
$\widehat{qremit}_t$	Gap in net remittance inflows to Uzbekistan
$\Delta\overline{qremit}_t$	Annualised growth in equilibrium net remittance inflows to Uzbekistan
$\widehat{qremit}_t^{uzs}$	Sum equivalent of the gap in net remittance inflows to Uzbekistan
$\Delta wage_t$	Annualised nominal wage growth
$wage_t$	Nominal salary

$\Delta 4wage_t$	Growth of nominal wages, period to the corresponding period of the previous year
$E_t\Delta wage_{t+1}$	Nominal wage growth expected in period t+1
$rwage_t$	Real salary
$\Delta 4rwage_t$	Real wage growth, period to the corresponding period of the previous year
$\Delta rwage_t$	Annualised real wage growth
$\overline{rwage}_t$	Equilibrium real wage
$\widehat{rwage}_t$	Wage gap (deviation of real wages from the equilibrium level)
$\Delta\overline{rwage}_t$	Annualised growth of equilibrium real wages
π_t	Inflation (annualised increase in the consumer price index)
cpi_t	Consumer price index
π_t^4	Consumer price index growth, period to the corresponding period of the previous year
rmc_t	Real marginal costs
π_{imp_t}	Imported inflation
$\widehat{qfood}_t$	Gap in global food price index
$E_t\pi_{t+1}^4$	Increase in consumer price index, period to the corresponding period of the previous year, expected in period t+1
$E_t\pi_{t+3}^4$	Increase in consumer price index, period to the corresponding period of the previous year, expected in period t+3
$E_t\pi_{t+1}$	Inflation expected in period t+1
π_t^T	Inflation target (target)
s_t^{usd}	Nominal exchange rate of the sum to the US dollar
$\overline{s}_t^{usd^T}$	Targeted nominal exchange rate of the sum to the US dollar
$\Delta\overline{s}_t^{usd}$	Trend nominal exchange rate of the sum to the US dollar, annualised change for the quarter
$E_t s_{t+1}^{usd}$	Nominal exchange rate of the sum to the US dollar expected in period t+1
s_{t+1}^{nf}	«Naive» forecast of the exchange rate of the sum to the US dollar for the period t+1
Δs_t^{usd}	Annualised appreciation of the sum to the US dollar exchange rate
$\Delta\overline{s}_t^{usd^T}$	Annualised increase in the target exchange rate of the sum to the US dollar
$E_t\Delta\overline{z}_{t+1}^{usd}$	Annualised appreciation of the sum to the US dollar exchange rate expected in period t+1
z_t^{usd}	Real exchange rate of the sum to the US dollar

Δz_t^{usd}	Annualised appreciation of the sum to the US dollar exchange rate
$\overline{z}_t^{usd}$	Equilibrium real exchange rate of the sum to the US dollar
$\hat{z}_t^{usd}$	Gap in the real exchange rate of the sum to to the US dollar
$\Delta\overline{z}_t^{usd}$	Annualised increase in the equilibrium exchange rate of the sum to the US dollar
$\Delta 4\overline{z}_t^{usd}$	Increase in the equilibrium exchange rate of the sum to the US dollar, period to the corresponding period of the previous year
$\hat{z}_t^{rub}$	Gap in the real exchange rate of sum to the Russian rouble
z_t	Real effective sum rate
$\overline{z}_t$	Real equilibrium effective exchange rate of the sum
$\hat{z}_t$	Gap in the real effective exchange rate of the sum
Δz_t	Annualised appreciation of the real effective exchange rate of the sum
$\Delta\overline{z}_t$	Annualised growth of the real equilibrium effective exchange rate of the sum
$\Delta 4\overline{z}_t$	Growth of real equilibrium effective exchange rate of the sum, period to the corresponding period of the previous year
$prem_t$	Risk premium for investments in assets denominated in sums
$\overline{prem}_t$	Equilibrium risk premium for investments in assets denominated in sums
$\widehat{prem}_t$	Risk premium gap for investments in assets denominated in sums
i_t	Nominal interest rate of the money market
i_t^n	Neutral nominal money market interest rate
r_t	Money market real interest rate
$\overline{r}_t$	Equilibrium real money market interest rate
$\hat{r}_t$	Money market rate gap (deviation of the real money market interest rate from the equilibrium level)
sp_t	Spread of the nominal lending rate to the nominal money market rate (credit spread)
$\overline{sp}_t$	Equilibrium credit spread
$\widehat{sp}_t$	Credit spread gap
$\hat{y}_t^*$	Aggregate output gap in Uzbekistan's trading partner countries
$\hat{y}_t^{ru}$	Output gap in Russia
$\hat{y}_t^{eu}$	Output gap in the euro area
$\hat{y}_t^{cn}$	Output gap in China

$\hat{y}_t^{us}$	Output gap in the US
$\hat{y}_t^{by}$	Output gap in Belarus
$\hat{y}_t^{am}$	Output gap in Armenia
$\hat{y}_t^{kz}$	Output gap in Kazakhstan
$\hat{y}_t^{kg}$	Output gap in the Kyrgyz Republic
$\hat{y}_t^{ow}$	Output gap in the rest of the world
π_t^*	Aggregate annualised growth of consumer price index (inflation) in Uzbekistan's trading partner countries
π_t^{us}	Annualised increase in the US consumer price index
π_{ss}^{us}	US inflation target
cpi_t^{us}	Consumer price index in the US
z_t^{ru}	Real exchange rate of the Russian rouble to the US dollar
Δz_t^{eu}	Annualised appreciation of the real euro/dollar exchange rate
Δz_t^{cn}	Annualised appreciation of the real exchange rate of the Chinese yuan to the US dollar
Δz_t^{by}	Annualised real exchange rate appreciation of the Belarusian rouble to the US dollar
Δz_t^{kz}	Annualised appreciation of the real exchange rate of the Kazakhstani tenge to the US dollar
Δz_t^{am}	Annualised appreciation of the real exchange rate of the Armenian dram to the US dollar
Δz_t^{kg}	Annualised appreciation of the real exchange rate of the Kyrgyz som to the US dollar
Δz_t^{ru}	Annualised appreciation of the real exchange rate of the Russian rouble to the US dollar
i_t^{us}	Nominal money market interest rate in the US
$\bar{r}_t^{us}$	Equilibrium real money market interest rate in the US
$\bar{z}_t^{eu}$	Real equilibrium euro/dollar exchange rate
$\bar{z}_t^{cn}$	Real equilibrium exchange rate of the Chinese yuan to the US dollar
$\bar{z}_t^{by}$	Real equilibrium exchange rate of the Belarusian rouble to the US dollar
$\bar{z}_t^{kz}$	Real equilibrium exchange rate of the Kazakhstani tenge to the US dollar
$\bar{z}_t^{am}$	Real equilibrium exchange rate of the Armenian dram to the US dollar
$\bar{z}_t^{kg}$	Real equilibrium exchange rate of the Kyrgyz som to the US dollar

$\overline{z}_t^{ru}$	Real equilibrium exchange rate of the Russian rouble to the US dollar
$\hat{z}_t^{eu}$	Gap in the real exchange rate of the euro to the US dollar
$\hat{z}_t^{cn}$	Gap in the real exchange rate of the Chinese yuan to the US dollar
$\hat{z}_t^{by}$	Gap in the real exchange rate of the Belarusian rouble to the US dollar
$\hat{z}_t^{kz}$	Real exchange rate gap between the Kazakhstani tenge and the dollar
$\hat{z}_t^{am}$	Gap in the real exchange rate of the Armenian dram to the US dollar
$\hat{z}_t^{kg}$	Gap in the real exchange rate of the Kyrgyz som to the US dollar
$\hat{z}_t^{ru}$	Gap in the real exchange rate of the Russian rouble to the US dollar
$\varepsilon_t^{\Delta\overline{y}}$	Equilibrium GDP growth shock
$\varepsilon_t^{\hat{y}}$	Aggregate demand shock (output gap shock)
$\varepsilon_t^{def2gdp}$	Fiscal policy shock
$\varepsilon_t^{\overline{def2gdp}}$	Structural budget balance shock
$\varepsilon_t^{\overline{def2gdp}^{tar}}$	Budget balance target shock
$\varepsilon_t^{\widehat{qremit}^{uzs}}$	Net remittance inflow disruption shock
$\varepsilon_t^{\Delta\overline{qremit}}$	Growth shock to equilibrium net remittance inflows
$\varepsilon_t^{\Delta wage}$	Nominal wage shock
$\varepsilon_t^{\Delta\overline{rwage}}$	Real equilibrium wage growth shock
ε_t^{π}	Inflation shock
$\varepsilon_t^{\pi^T}$	Inflation target shock
$\varepsilon_t^{s^{usd}}$	Shock of nominal exchange rate of the sum to the US dollar
$\varepsilon_t^{\Delta\overline{z}^{usd}}$	Shock of growth of the real equilibrium exchange rate of the sum to the US dollar
$\varepsilon_t^{\overline{prem}}$	Equilibrium risk premium shock
$\varepsilon_t^{\widehat{prem}}$	Risk premium rupture shock
ε_t^{i}	Nominal money market rate shock (monetary policy shock)
$\varepsilon_t^{\overline{r}}$	Shock to the real equilibrium money market rate
$\varepsilon_t^{\overline{sp}}$	Equilibrium credit spread shock
$\varepsilon_t^{\widehat{sp}}$	Credit spread rupture shock

APPENDIX D. CALIBRATION OF MODEL PARAMETERS

Calibrating QPM coefficients

Parameter	Significance	Parameter	Significance	Parameter	Significance
ab_1	0.85	aa_2	0.50	t_{eur}	0.0707
ab_2	0.02	aa_3	0.50	t_{cny}	0.1757
$\Delta\overline{y}_{ss}$	5.50	aa_4	0.85	t_{byn}	0.0094
a_1	0.60	b_1	0.35	t_{kzt}	0.0933
a_2	0.10	b_2	0.40	t_{amd}	0.0003
a_3	0.10	b_3	0.10	t_{kgs}	0.0285
a_4	0.20	k_1	0.30	t_{rub}	0.1699
a_5	0.15	k_2	0.20	m_1	0.60
a_6	0.02	k_3	0.05	m_2	0.50
a_7	0.60	tar_1	0.90	m_3	0.25
f_1	0.75	π^T_{ss}	5.00	w_1	0.70
f_2	0.25	erp	0.10	w_2	0.85
f_3	0.25	h_1	0.50	w_3	0.75
f_4	0.80	h_2	0.85	$\overline{sp}^{ss}_t$	7.00
f_5	0.90	z_1	0.80	w^{ru}	0.1357
$\overline{def2gdp}^{ss}_t$	0.70	z_2	0.02	w^{eu}	0.0227
q_1	0.75	$\Delta\overline{z}^{usd^{ss}}_t$	0.00	w^{cn}	0.1341
q_2	0.60	pr_1	0.75	w^{by}	0.0042
q_3	2.00	pr_2	0.01	w^{am}	0.0005
q_4	0.20	pr_3	0.70	w^{kz}	0.0847
$\Delta\overline{qremit}_{ss}$	9.00	$\overline{prem}_{ss}$	3.00	w^{kg}	0.0494
aa_1	0.50	t_{usd}	0.4447	w^{ow}	0.5679
				w^{us}	0.0008

Calibration of standard deviations of QPM shocks

Parameter	Significance	Parameter	Significance	Parameter	Significance
$\varepsilon_t^{\Delta\bar{y}}$	0.40	$\varepsilon_t^{\Delta wage}$	3.00	$\varepsilon_t^{\overline{prem}}$	0.20
$\varepsilon_t^{\hat{y}}$	0.80	$\varepsilon_t^{\Delta\overline{rwage}}$	1.00	$\varepsilon_t^{\widehat{prem}}$	2.00
$\varepsilon_t^{def2gdp}$	2.00	ε_t^{π}	2.50	ε_t^{i}	3.00
$\varepsilon_t^{\overline{def2gdp}}$	0.40	$\varepsilon_t^{\pi^T}$	1.50	$\varepsilon_t^{\bar{r}}$	0.50
$\varepsilon_t^{\overline{def2gdp}^{tar}}$	0.40	$\varepsilon_t^{s^{usd}}$	5.00	$\varepsilon_t^{\overline{sp}}$	0.10
$\varepsilon_t^{\Delta\overline{qremit}}$	1.50	$\varepsilon_t^{\Delta\bar{z}^{usd}}$	0.50	$\varepsilon_t^{\widehat{sp}}$	1.00
$\varepsilon_t^{\widehat{qremit}^{uzs}}$	3.00				

LIST OF FIGURES

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LIST OF ABBREVIATIONS

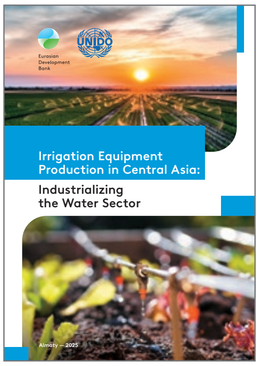
GDP	gross domestic product
EDB, Bank	Eurasian Development Bank
ISM	integrated system of models
IMF	International Monetary Fund
NEER	nominal effective exchange rate
REER	real effective exchange rate
United States, USA	United States of America
CBU	Central Bank of Uzbekistan
COVID-19	respiratory infection caused by the SARS-CoV-2 coronavirus
QPM	Quarterly Projection Model
RMSE	root mean square error
ln	natural logarithm
%	percentage
USD	US dollar
QoQ	quarter to quarter
bln	billion
p.p.	percentage point

RESEARCH AT THE EDB WEBSITE

Macroeconomic Outlook
(RU/EN)

Macroeconomic Outlook 2025–2027

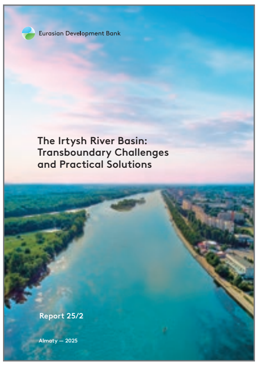
The Eurasian Development Bank (EDB) has published its Macroeconomic Outlook, summarising a preliminary overview of economic developments in the Bank's member states in 2024, along with key macroeconomic projections for countries in the region for 2025, as well as for 2026 and 2027.



Report
(RU/EN)

Irrigation Equipment Production in Central Asia: Industrializing the Water Sector

Irrigation equipment production in Central Asia is becoming a strategic area for ensuring food security and efficient water resource management. A new report by EDB and UNIDO provides a detailed analysis of the current state of the market, a forecast of its development and recommendations for creating conditions for local production.



Report 25/2
(RU/EN)

The Irtysh River Basin: Transboundary Challenges and Practical Solutions

A recent study by the Eurasian Development Bank, titled "The Irtysh River Basin: Transboundary Challenges and Practical Solutions," presents the findings of a diagnostic analysis and a forecasting model of the basin's water resources. The study identifies the positions of the three countries involved and puts forward a series of practical solutions, including investment recommendations.

Report 25/1
(RU/EN)

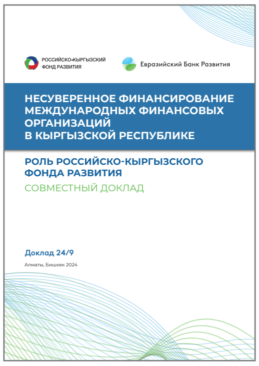
Mutual Investments on the Eurasian Continent: New and Traditional Partners

The report contains detailed information on the scale, dynamics, geographical and sectoral structure of mutual direct investment stock between the countries of the Eurasian region, on the one hand, and China, Türkiye, Iran, and the Gulf states, on the other hand, for the period from 2016 to the first half of 2024.

Report 24/10
(RU/EN)

EDB Monitoring of Mutual Investments — 2024. Eurasian Region

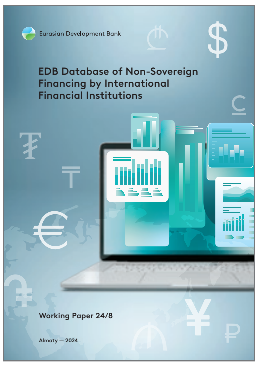
The report contains detailed information on the scale, dynamics, geographical and sectoral structure of mutual direct investments of the Eurasian region from 2016 to 1H of 2024.



Report 24/9
(RU)

Non-sovereign financing of international financial organizations in the Kyrgyz Republic

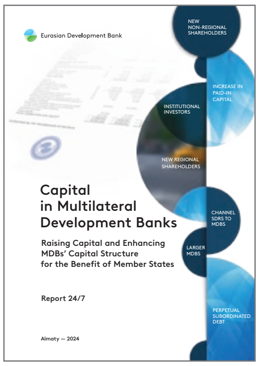
The report contains a comprehensive analysis of non-sovereign financing operations by international financial institutions in the Kyrgyz Republic over the last decade.



Report 24/8
(RU/EN)

EDB Database of Non-Sovereign Financing by International Financial Institutions

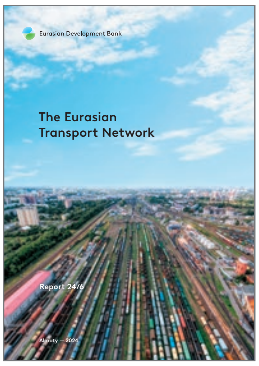
Non-Sovereign Financing (NSF) Database is EDB's new analytical project. The EDB Database is a dynamic tool for timely monitoring and analysis of non-sovereign operations of IFIs in the Eurasian region.



Report 24/7
(RU/EN)

Capital in Multilateral Development Banks

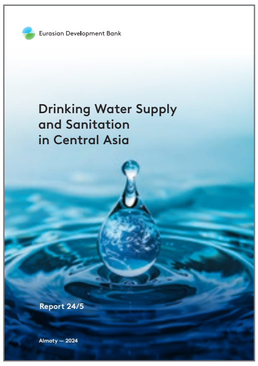
This paper covers the whole 'MDB family' of institutions but highlights regional and sub-regional MDBs because of their specifics of raising shareholders' capital. The study discusses seven standard and novel options for increasing capital



Report 24/6
(RU/EN)

The Eurasian Transport Network

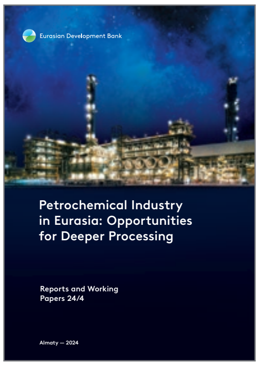
The report examines ten system elements of the Eurasian transport framework concept. Among them are the formation of a transport crossroads in Central Asia, priorities for intraregional transport connectivity, an impetus for realizing the agro-industrial potential of the countries of the region, and improvement of soft infrastructure.



Report 24/5
(RU/EN)

Drinking Wateer Supply and Sanitation in Central Asia

In Central Asia, 10 million people do not have access to safe drinking water. Given the priority importance of drinking water for public health and the scale of the challenges, a comprehensive approach is required in the region. A new EDB report presents a set of practical steps that shape such an approach.



Report 24/4
(RU/EN)

Petrochemical industry in Eurasia: Opportunities for Deeper Processing

The analytical report uses a balance approach to assess the production and export potential of the petrochemical complex of the Eurasian region (Armenia, Belarus, Kazakhstan, Kyrgyzstan, Russia, Tajikistan, Turkmenistan, Uzbekistan) in the perspective up to 2035.

Report 24/3
(RU/EN)

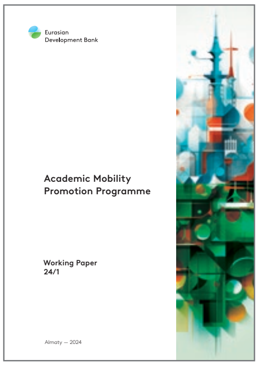
Infrastructure in Eurasia: short-term and medium-term trends

The EDB's report highlights ten important short- and medium-term investment and institutional trends in the region's energy, transportation, logistics, water supply and telecommunications sectors.

Report 24/2
(RU/EN)

Economic Cooperation in Eurasia: Practical Solutions

The EDB's report "Economic Cooperation in Eurasia: Practical Solutions" contains a "menu" of pragmatic applied solutions that can be enabled relatively fast and with flexible configurations among participating countries aimed at fostering mutually beneficial economic cooperation among Eurasian countries.



Report 24/1
(RU/EN)

EDB Monitoring of Mutual Investments — 2023

Eurasian countries' FDI stock reached $48.8 billion by mid-2023, following a 5.4% increase in 2022 and with continued growth in 2023.

Report 23/5
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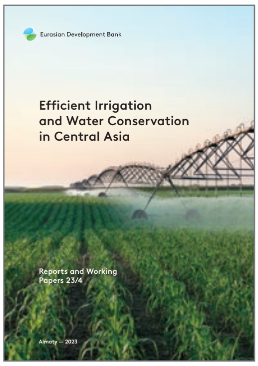

Report 23/4
(RU/EN)

Efficient Irrigation and Water Conservation in Central Asia

A new EDB study outlines ten practical steps for preserving irrigated land potential and promoting water conservation. The list includes four recommendations for adoption at the regional level and six at the national level.

Eurasian Development Bank

RESEARCH DEPARTMENT
EURASIAN DEVELOPMENT BANK

Your comments and suggestions
concerning this document
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