CENTRAL BANK OF THE REPUBLIC OF UZBEKISTAN

Quarterly Projection Model of the Central Bank of the Republic of Uzbekistan

Monetary Policy Department

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Contents

Abbreviations

Abbreviation	Full name
QPM	Quarterly Projection Model
FPAS	Forecasting and Policy Analysis System
RMCI	Real Monetary Conditions Index
UIP	Uncovered Interest rate Parity
IRF	Impulse Response Function
FDI	Foreign Direct Investment
DSGE	Dynamic Stochastic General Equilibrium
CPI	Consumer Price Index
NPL	Non-Performing Loans

Abstract

This document[1] sets out the conceptual foundations, the core equations, and the macroeconomic blocks of the Quarterly Projection Model *(QPM)* that the Central Bank of the Republic of Uzbekistan uses in preparing the monetary policy decisions. It also describes how the model is applied within the Forecasting and Policy Analysis System *(FPAS)*.

The QPM is a forward-looking, semi-structural New Keynesian gap model calibrated to the conditions of a small open economy.

The model brings together blocks for aggregate demand, inflation, the monetary policy reaction, the exchange rate, the external sector, the fiscal stance, credit conditions, and foreign direct investment. Jointly, these blocks trace how demand pressure, import inflation, the exchange-rate channel, the credit channel, the fiscal impulse, and external shocks feed through to inflation and the output gap. The model's output is not a mechanical forecast: it is used alongside expert judgment, near-term forecasts, sectoral analysis, and alternative scenarios.

For monetary policy, the central value of the QPM is that it draws the individual projections together into a single, internally consistent macroeconomic framework. It allows the Bank to gauge the current cyclical position of the economy, identify the sources of inflationary pressure, judge how tight or loose monetary conditions are, and derive the policy-rate path needed to bring inflation back to target.

The model also indicates how monetary policy should respond as different risks materialize. In this sense the QPM is not simply a forecasting device but an instrument that structures the decision-making process, gives economic discussions a common frame of reference, and places monetary policy scenarios on a quantitative footing.

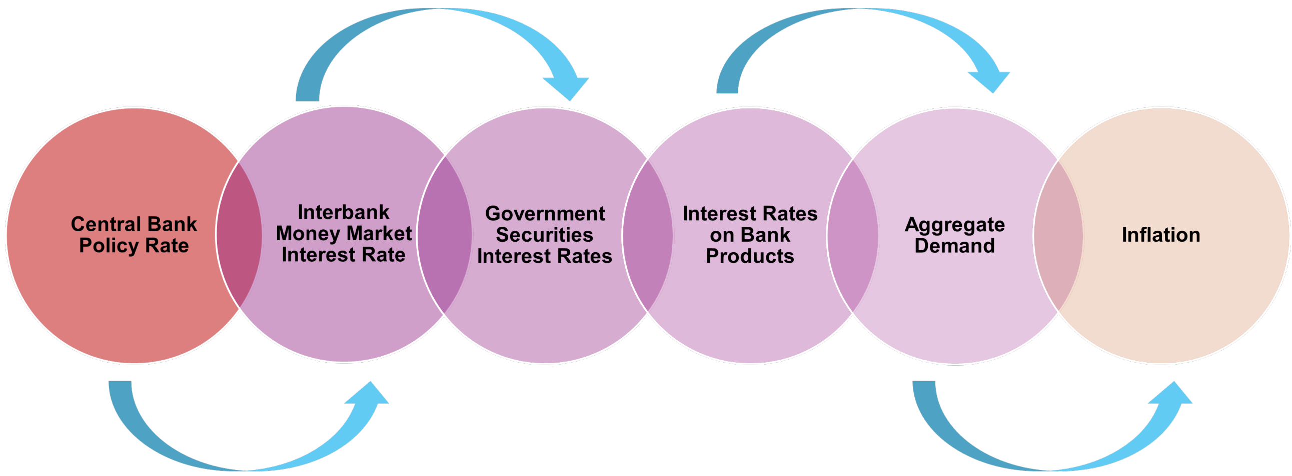
Keywords: quarterly projection model, QPM, semi-structural model, inflation targeting, monetary policy, FPAS, policy rate, output gap, inflation forecasts.

[1] Comments and suggestions on this document may be sent to the Monetary Policy Department of the Central Bank by email: i.inkhomiddinov@cbu.uz

1. Introduction

Monetary policy acts on the economy with a lag. A policy-rate decision taken today therefore affects not current inflation but aggregate demand, the exchange rate, credit activity, inflation expectations, and price formation in the quarters and years ahead *(Figure 1).*

Figure 1. Transmission of the Central Bank's policy-rate decisions to the economy



Source: Central Bank

Under an inflation-targeting regime, one of the central bank's principal tasks is thus to assess the likely path of the economy and to set the monetary policy stance in line with that assessment.

At the Central Bank of the Republic of Uzbekistan, the QPM has been developed as the principal tool for medium-term forecasting and monetary policy analysis in support of this task[2]. The model quantifies the interlinkages among inflation, output, the exchange rate, interest rates, external demand, credit conditions, and fiscal factors. It also allows expert judgment to be brought into the forecasting process, since in practice no model can capture every process and every piece of data in an economy.

International experience shows that models of the QPM type serve two main purposes at central banks: forming macroeconomic projections, and supporting monetary policy analysis and scenario simulation. This approach is well established in the practice of the central banks of Canada, the Czech Republic, Russia, Hungary, Croatia, Georgia, Ukraine, Vietnam, and others.

[2]The Central Bank of the Republic of Uzbekistan is grateful to the experts of the international consulting firm OGResearch, and to the EBRD and the IMF and their experts, for their assistance in developing and refining the QPM. The structure of the model draws on the experience of the IMF and of central banks that operate quarterly projection models under an inflation-targeting regime.

More broadly, such models help not only to generate the forecast numbers but also to help decision-makers understand the channels through which inflation is shaped, the choices open to monetary policy, and the principal risks.

This document is intended as an accessible account of the Central Bank's QPM for a wider audience. It retains the essential technical detail while keeping the emphasis on the economics of the model and on its use in monetary policy.

2. The monetary policy regime in Uzbekistan and the role of the QPM

In moving to an inflation-targeting regime, the Central Bank of the Republic of Uzbekistan has set price stability as the primary objective of monetary policy [3].

Within this framework, the policy rate is the main instrument for returning inflation to its target level over the medium term.

The effect of policy-rate decisions on the economy, however, runs through a number of channels. Real interest rates, credit conditions, the exchange rate, import prices, aggregate demand, and inflation expectations all play a part in this process.

Several features of the Uzbek economy call for particular treatment in the QPM. First, it is a small open economy, so external demand, inflation in partner countries, commodity prices, and the exchange rate exert a marked influence on the dynamics of inflation and output. Second, energy, utility, and other regulated prices are not fully driven by ordinary demand factors. Third, food and fruit-and-vegetable prices are highly sensitive to supply conditions and seasonal factors. Fourth, fiscal stimulus, the credit market, foreign direct investment, and remittances play an important role in shaping domestic demand.

The QPM draws these factors together on a single analytical platform. It allows in a systematic way to address questions such as:

whether there is demand pressure in the economy;

which part of inflation is fundamental and which part temporary;

how strongly external prices and the exchange rate are feeding into inflation;

and whether the prevailing policy-rate path is sufficient to bring inflation back to target.

The model is likewise a valuable tool for assessing how monetary policy should adjust when various risk scenarios materialize.

[3] Article 5, the Law "On the Central Bank of the Republic of Uzbekistan"

3. The forecasting and monetary policy analysis system at the Central Bank

The QPM is best seen not as a stand-alone model but as the core of the Forecasting and Policy Analysis System (FPAS). FPAS integrates the database, sectoral analysis, expert judgment, near-term forecasting models, the medium-term QPM, scenario analysis, policy recommendations, and communication materials into a single process.

Within FPAS, forecasting and the preparation of monetary policy decisions are organized in a stepwise manner. In the practice of the Central Bank of the Republic of Uzbekistan the process typically runs through seven stages, spanning everything from the assessment of current macroeconomic conditions to the communication of the policy-rate decision to the public *(Figure 2).*

In the first stage, current domestic and external macroeconomic conditions are analyzed, the statistical database is updated, near-term forecasts are prepared, and the QPM parameters are given a preliminary expert assessment. On this basis, a first version of the medium-term projection is prepared.

In the second stage, the preliminary forecasts and model results are discussed with management, and the principal risks and the assessment of monetary conditions are reconsidered.

In the third stage, the baseline and alternative scenarios are developed. A range of macroeconomic scenarios is constructed around the domestic and external risks, and the probable monetary policy response is assessed for each.

In the fourth stage, the consistency of the forecast results across the macroeconomic models is checked, and the final analytical conclusions on monetary conditions are drawn.

In the fifth stage, the macroeconomic analysis and forecasts are discussed by the Central Bank's Credit Committee, and proposals are prepared for the Board.

In the sixth stage, the Board takes the policy-rate decision on the basis of this analysis and these proposals.

In the seventh and final stage, the decision is communicated to the public through a press release, a press conference, the “Monetary Policy Report,” and other communication channels.

Figure 2. Stages of the forecasting and monetary policy analysis system at the Central Bank of the Republic of Uzbekistan

No.	Stage	Description
1	**Assessing the current state**	Analysis of current macroeconomic conditions; update of the data; near-term forecasts; preliminary assessment of the QPM parameters.
2	**Discussion with management**	Discussion of the preliminary forecasts and model results; reassessment of the risks and of monetary conditions.
3	**Developing scenarios**	Construction of the baseline and alternative scenarios; assessment of the monetary policy measures consistent with each.
4	**Consistency across the models**	Reconciliation of the forecast results across the macroeconomic models; final analytical conclusions.
5	**Credit Committee discussion**	Review of the macroeconomic analysis and forecasts by the Credit Committee; preparation of proposals for the Board.
6	**Board decision**	The Board takes the final policy-rate decision on the basis of the analysis and proposals.
7	**Communication to the public**	Communication of the decision through a press release, a press conference, the "Monetary Policy Review," and other channels.

Source: compiled by the author on the basis of Central Bank practice.

International experience shows that the effectiveness of the forecasting process depends not only on the quality of the model but also on how well the process itself is organized. At the Czech National Bank, for instance, the forecast round opens with a discussion of the initial conditions and the exogenous assumptions, after which the final recommendation is shaped through successive forecast rounds, alternative scenarios, and policy simulations. The experience of the Central Bank of Chile, for its part, underscores the importance of allowing sufficient time for risk assessment and for alternative scenarios.

As a matter of good practice, it is recommended that each forecast round prepare a baseline scenario, at least two alternative scenarios, and a range of policy-rate options. In each scenario, the mutual consistency of inflation, the output gap, the real interest rate, the real exchange rate, credit growth, the fiscal impulse, and the external assumptions should be checked in the round.

4. The conceptual foundation of the model

The QPM is a semi-structural New Keynesian model. "Semi-structural" means that each of its core equations is grounded in economic reasoning and intuition, but is not derived from the full optimization of all economic agents, as it would be in a fully micro-founded DSGE model. This design carries important practical advantages: the model is comparatively simple and fast to run, it accommodates expert judgment, and it is readily adapted to the features of the domestic economy.

Real variables are typically expressed in gap form. A gap is the difference between the current value of a variable and its trend, or equilibrium, level. The output gap, for example, is the deviation of real GDP from potential GDP. Over the long run such gaps close to zero. This reflects the principle that monetary policy does not set the economy's long-run growth rate, though in the short and medium run it can affect, and thereby stabilize, the dynamics of aggregate demand and inflation.

In the model, prices do not adjust fully in the short run (price rigidity)[4]. Changes in demand therefore affect output first and pass through to inflation later. When the policy rate is raised, for instance, the real interest rate rises, credit and consumption activity slow, demand pressure eases, and the disinflationary effect builds accordingly.

In an open economy, higher interest rates can also lower import inflation through the exchange rate, as they raise demand for assets denominated in domestic currency. For convenience, the model uses the following notation:

- a hat ($\widehat{x}$) denotes the gap of a variable; for example, $\widehat{y}_t$ is the output gap;
- a bar ($\overline{x}$) denotes the trend of a variable; for example, $\overline{y}_t$ is the output trend;
- for analytical convenience, all variables are expressed in logarithmic form (*100*log()*).

4.1. Capabilities and limitations of the QPM model

The QPM is a semi-structural model designed for medium-term macroeconomic forecasting and for the analytical support of monetary policy decisions. It allows the Bank to:

- decompose the main drivers of inflation, distinguishing the contributions of domestic demand, import prices, the exchange rate, and regulated prices;
- estimate the output gap as a measure of the economy's cyclical position;
- measure the degree of tightness of monetary conditions through the real monetary conditions index (RMCI);
- derive and assess the policy-rate path required to return inflation to its target;

[4] New Keynesian theory holds that short-run fluctuations in activity feed through to the price level only with a delay.

- develop alternative macroeconomic scenarios and compare their outcomes quantitatively.

The model also has a number of limitations. In particular:

- it produces not precise point forecasts but a probability distribution of the forecast variables and their central projection path, so its results should be read in terms of probable scenarios rather than certainties;
- by virtue of its semi-structural design, it does not fully capture the microeconomic effects of structural reforms;
- it captures financial crises, geopolitical shocks, and sharp or nonlinear changes in the economy only to a limited extent;
- it does not directly account for the effect of the informal (shadow) economy on the macroeconomic aggregates.

For these reasons, although the QPM is an important analytical input to monetary policy decisions, its results are best used alongside other models, expert judgment, and additional analysis.

4.2. Forecast uncertainty

Every macroeconomic forecast carries a degree of uncertainty. The QPM results are, accordingly, conditional forecasts: they rest on assumptions about the external environment, the path of regulated prices, the fiscal parameters, and other exogenous factors. If those assumptions change, the forecast is revised in turn.

The baseline scenario should therefore be read not as the single or guaranteed path for future outcomes but as the most likely trajectory given the available data and assumptions. To convey the uncertainty around the projection, the results are usually presented together with probability intervals, including in the form of a fan chart.

By the same token, the policy-rate path generated in the forecast round is not a pre-commitment to future decisions. It is a conditional, illustrative path, computed under a specific set of macroeconomic conditions for the purpose of returning inflation to target. The Central Bank's actual decisions are taken period by period, in light of the macroeconomic conditions prevailing at the time, the balance of risks, and the latest projections.

4.3. Dependence on assumptions and data

The quality and accuracy of the QPM results depend significantly on the external assumptions, the incoming data, and expert judgment. Factors such as the pace of activity in partner countries, world commodity prices, external financial conditions, and international interest rates weigh heavily on the projection. A change in the assumptions about these factors therefore calls for a corresponding revision of the forecast paths.

At the same time, the relatively short statistical series available for the Uzbek economy, together with the structural reforms and institutional changes that the economy undergoes on a continuing basis, introduce a degree of uncertainty into the estimation of the model parameters. For this reason, the model's calibration and estimation parameters are reviewed on a regular basis and updated as new data arrive.

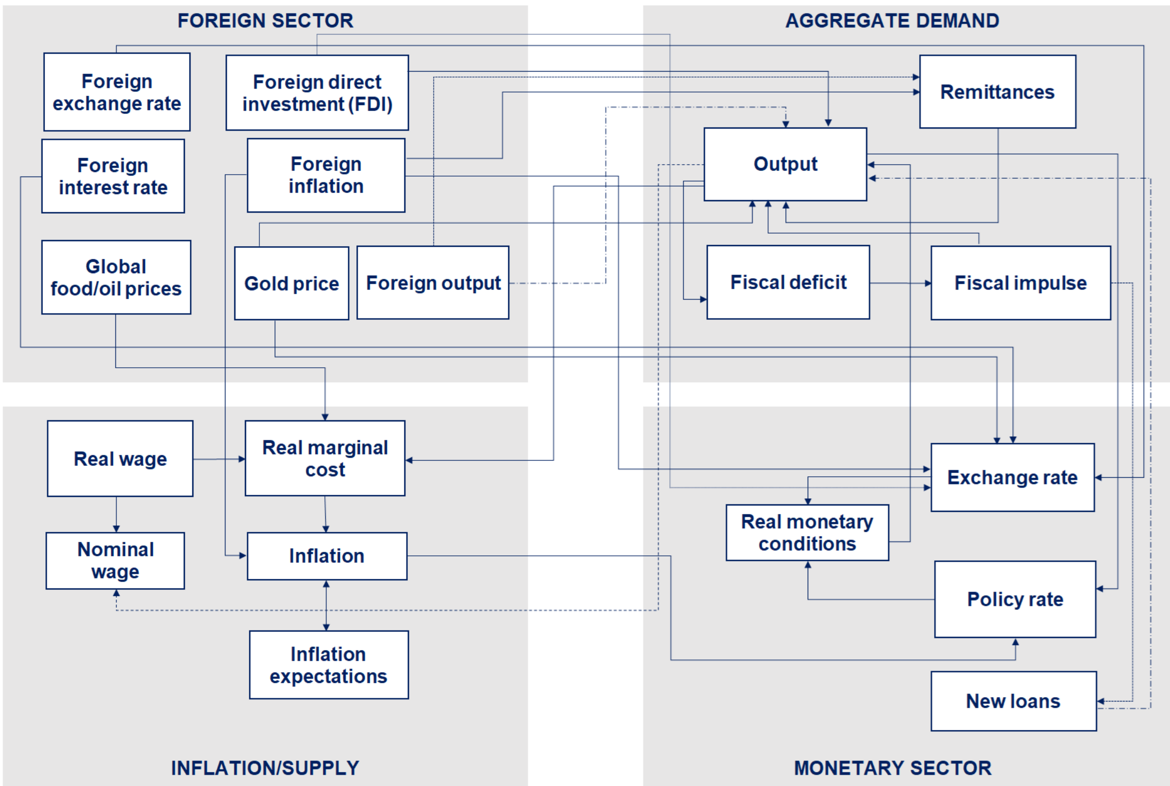
Expectations play an important role in the model. The balance between the adaptive (backward-looking) and the forward-looking components of inflation expectations is closely tied to the credibility of monetary policy. As that credibility and the predictability of policy increase, agents are expected to become more forward-looking, and this balance is expected to shift over time.

Expert judgment and analytical reasoning are, likewise, central to the QPM. The model does not automate the decision; rather, it is a platform for structuring macroeconomic analysis, testing alternative scenarios, and drawing economists' expert conclusions together onto a common analytical footing. On this understanding, the QPM results should always be interpreted together with expert analysis and other economic information. This principle - the basis on which the model results are used - is maintained consistently from the opening of this document through to its conclusion.

5. The main blocks of the model

The diagram below sets out the main linkages in the Central Bank's QPM.

Figure 3. Structure of the QPM model



5.1. Aggregate demand block

The aggregate demand block generates the output gap within the model. It captures the influence of the business cycle, domestic demand pressure, and external factors on economic activity.

In the Uzbek QPM, the demand equation is broader than the classic IS curve: it also brings in monetary conditions, external demand, remittances, the fiscal impulse, credit activity, and foreign direct investment:

$$\widehat{y}_t = a_1\widehat{y}_{t-1} + a_2\, E(\widehat{y}_{t+1}) - a_3\, \mathsf{rmci}_{t-1} + a_4\widehat{y}^f_t + a_5\left(\widehat{rem}_{t-1} + \widehat{z}_{t-1}\right) + a_6\, \mathsf{fisc}^{imp}_t + a_7\frac{\widehat{\mathsf{cr}^{new}_t}}{4y^{nom}_t} + a_8\frac{\widehat{\mathsf{fdi}_t}}{4y^{nom}_t} + \varepsilon^{\widehat{y}}_t$$

where $a_1 - a_8$ are parameters and:

$\widehat{y}_t$ is the output gap, the deviation of actual output from its potential level; equivalently, the difference between the actual and the potential growth rate of GDP ($\widehat{y}_t = y_t - \overline{y}_t$);

$\widehat{y}_{t-1}$ is the lagged output gap, which captures the inertia and persistence of the business cycle. It reflects the fact that agents - in particular households and firms - take past demand and consumption into account when making their own consumption and investment decisions;

$rmci_{t-1}$ *(real monetary condition index)* is the real monetary conditions index, built from the real interest rate gap and the real exchange rate gap. It enters with a negative sign, so a rise in the index signals a tightening of monetary conditions that dampens aggregate demand and activity;

$\widehat{y}_t^f$ is the output gap of partner countries, entering with a positive sign: stronger activity abroad raises external demand and supports domestic output;

$\widehat{rem}_{t-1}$ is the real remittances gap; higher remittances raise household incomes and consumption demand and so support aggregate demand;

$\widehat{z}_{t-1}$ is the real exchange rate gap, which acts on activity through external competitiveness and import prices;

$fisc_t^{imp}$ is the fiscal impulse; an increase in government spending or fiscal stimulus supports aggregate demand and raises output;

$\widehat{\frac{cr_t^{new}}{4y_t^{nom}}}$ is the gap of newly issued credit relative to GDP; a rise signals strong credit activity and supports output by underpinning investment and consumption;

$\widehat{\frac{fdi_t}{4y_t^{nom}}}$ *(fdi - foreign direct investment)* is the gap of foreign direct investment relative to GDP; higher investment raises production capacity and activity and supports growth;

$\varepsilon_t^{\widehat{y}}$ is the aggregate demand shock, capturing the influence on the output gap of factors other than those listed above.

Monetary conditions index

The monetary conditions index (RMCI) is defined from the real interest rate gap and the real exchange rate gap:

$$rmci_t = (1 - a_{rmc})\,\widehat{r}_t - a_{rmc}\widehat{z}_t$$

where $rmci_t$ is the monetary conditions index, a_{rmc} is a parameter, $\widehat{r}_t$ is the real interest rate gap, and $\widehat{z}_t$ is the real exchange rate gap.

The index gauges how stimulative or restrictive monetary conditions are for the economy. When the real interest rate and the real exchange rate stand at their equilibrium *(long-run trend)* levels, monetary conditions are neutral; accordingly, when both gaps are zero, the RMCI is zero as well.

A positive RMCI signals that monetary conditions have tightened; a negative value, that they have eased.

The coefficient on the real interest rate gap, $(1 - a_{rmc})$, is positive and usually lies between 0 and 1. A wider real interest rate gap means tighter monetary conditions: higher real rates raise the cost of financing investment and consumption and, by making it more attractive to postpone spending and save, weigh on demand. Aggregate demand and activity decline as a result.

The coefficient on the real exchange rate gap, a_{rmc}, enters with a negative sign. A depreciation of the domestic currency therefore lowers the RMCI and eases monetary conditions: it improves the competitiveness of local exporters and supports external demand and domestic production. A rise in the real exchange rate thus acts to stimulate activity.

Because a positive RMCI denotes tight conditions, the index enters the output gap equation with a negative sign. A higher index restrains demand more firmly, since in the short run output is governed largely by demand: as demand falls, producers cut capacity utilization, and activity and the output gap decline.

The RMCI coefficient in the output gap equation, (a_3), is typically small and lies between 0 and 1, reflecting the gradual, lagged pass-through of monetary conditions to the economy. When the Central Bank changes the policy rate, the change first passes to rates on new loans. Because part of the existing loan book is at fixed rates, not all agents feel the effect at once; and until firms and households take out new loans, the rate change does not bear directly on their decisions.

The RMCI is, for this reason, an important gauge in the policy discussion. Even where inflation remains high, if monetary conditions have already tightened sufficiently, any further tightening should be weighed with care.

5.2. Remittances block

Remittances are one of the key channels shaping household incomes and domestic demand in Uzbekistan, and the QPM treats them separately. In the model, remittances are first converted from nominal to real terms and then split into trend and gap. The remittances gap is closely tied to the Russian business cycle in particular, since migrant workers' incomes and employment prospects are highly sensitive to activity abroad.

Movements in the ruble exchange rate likewise bear directly on the remittances that migrants send home.

$$\widehat{rem}_t = c_1^{rem} * \widehat{rem}_{t-1} + c_2^{rem} * \widehat{y}_t^{ru} - c_4^{rem} * (\Delta s_t^{ru} - \Delta s_{ss}^{ru}) + \varepsilon_t^{\widehat{rem}_t}$$

where c_1^{rem}, c_2^{rem}, c_4^{rem} are parameters, $\widehat{rem}_t$ is the remittances gap, $\widehat{y}_t^{ru}$ is the output gap of the Russian economy, and $\Delta s_t^{ru} - \Delta s_{ss}^{ru}$ is the deviation of the change in the ruble exchange rate from its long-run equilibrium.

This block is central to explaining how the external assumptions in the baseline feed through to domestic demand. A slowdown in the main labor-migration destinations, for example, can lower domestic consumption and demand for services through weaker remittances.

5.3. Inflation block

Headline inflation is decomposed into three components: core inflation, fruit-and-vegetable inflation, and regulated-price inflation. This split matters for monetary policy, because the components respond to policy to very different degrees.

Core inflation is driven mainly by demand pressure and inflation expectations; fruit-and-vegetable inflation is shaped largely by supply and seasonal shocks; and regulated-price inflation is set chiefly by government decisions, tariff policy, and administrative reforms.

$$\pi_t = w_1^{\pi_t} * \pi_t^{fv} + w_2^{\pi_t} * \pi_t^{core} + (1 - w_1^{\pi_t} - w_2^{\pi_t}) * \pi_t^{reg}$$

where π_t is headline inflation, $w_1^{\pi_t}$ is a parameter *(the weight of fruit and vegetables in headline inflation)*, $w_2^{\pi_t}$ is a parameter *(the weight of core inflation in headline inflation),* π_t^{fv} is fruit-and-vegetable inflation, π_t^{core} is core inflation, and π_t^{reg} is the inflation of goods and services whose prices are set by the state.

By definition, the three weights sum to one:

$$w + w + w = 1.$$

The weight of regulated prices is therefore written not as a separate parameter but as

$$(1 - w_1^{\pi_t} - w_2^{\pi_t}).$$

The weights are revisited periodically as the composition of the CPI basket is updated.

Core inflation is generated from inflation expectations, past inflation, import inflation, and real marginal costs. It is the single most important component of inflation, as it captures the underlying price pressures in the economy - and the influence of monetary policy - most clearly.

$$\begin{aligned}\pi_t^{core} &= b_1^{core} E_t \pi_t^{core} \\ &\quad + (1 - b_1^{core} - b_2^{core}) \Big(b_{adapt} \pi_{t-1}^{core} + (1 - b_{adapt}) \big(\pi_{t-1} + \overline{\pi}_t^{rp_{core}} \big) \Big) \\ &\quad + b_2^{core} \pi_t^{imp} + b_3^{core} rmc_t^{core} + \varepsilon_t^{\pi_{core}}\end{aligned}$$

where b_1^{core}-b_3^{core} and b^{adapt} are parameters, π_t^{core} is core inflation (relative to the previous quarter, annualized), $E_t\pi_t^{core}$ is expected core inflation ($E_t\pi_t^{core} = \pi_{t+1}^{core}$), π_{t-1}^{core} is lagged core inflation, π_{t-1} is lagged headline inflation, $\overline{\pi}_t^{rp_{core}}$ is the trend in the ratio of core to headline inflation, π_t^{imp} is import inflation, rmc_t^{core} is real marginal cost[5], and $\varepsilon_t^{\pi_t^{core}}$ is the core inflation shock.

The equation takes the form of a hybrid Phillips curve. Its forward-looking term ($E_t\pi_t^{core}$) reflects the weight of expected future inflation in price setting, while the lagged term (π_{t-1}^{core}) reflects inflation inertia and the fact that expectations are not yet fully anchored. Import inflation and real marginal cost capture, respectively, the external and domestic cost pressures bearing on inflation.

The core equation embeds a mechanism whereby firms reset prices in line with their expected inflation *(b_1^{core} is the share of firms that set prices on the basis of expected inflation).*

[5]The cost of producing one additional unit of output.

The model also allows for second-round effects of the other components on core inflation (π_{t-1}), so that movements in fruit-and-vegetable and regulated prices feed indirectly into headline inflation.

Real marginal cost captures the costs faced by producers and importers. The output gap stands for the costs of domestic producers, while the real exchange rate and world food and oil prices stand for those of importers.

When output runs above potential, demand for labor and other inputs rises and firms' marginal costs increase. At the same time, a depreciation of the domestic currency adds to domestic price pressure by raising the cost of imported raw materials, intermediate goods, and consumer goods.

A further reason the output gap stands for domestic producers' real marginal cost lies in capacity: as a firm expands capacity, the depreciation of its technology accelerates and it must replace that technology sooner.

Doing so requires additional outlays, and this cost of replacing capital raises marginal cost and, in turn, inflation.

$$\begin{aligned} rmc_t^{core} &= b_1^{rmc_{core}} \widehat{y}_t + (1 - b_1^{rmc_{core}}) (\widehat{z}_t - \widehat{rp}_t^{rp_{core}}) \\ &\quad + b_2^{rmc_{core}} \widehat{rw}_t + b_3^{rmc_{core}} \widehat{oil}_t + b_4^{rmc_{core}} \widehat{food}_t + \varepsilon_t^{rmc_{core}} \end{aligned}$$

where rmc_t^{core} is real marginal cost, $b_1^{rmc_{core}} - b_4^{rmc_{core}}$ are parameters, and $\widehat{y}$ is the output gap, standing for demand-side inflationary pressure.

$\widehat{z}_t$ is the real exchange rate gap, which conveys marginal cost through import prices. A rise (depreciation) in the nominal exchange rate, for example, makes the real exchange rate gap more positive (or less negative), so that the domestic-currency cost of imported goods increases; the prices of goods and services then rise, adding to inflation.

$\widehat{rp}_t^{rp_{core}}$ is the relative core price gap; in the expression ($\widehat{z}_t - \widehat{rp}_t^{rp_{core}}$) it sets the external cost against core-sector relative prices. $\widehat{rw}_t$ is the real wage cost gap, $\widehat{oil}_t$ is the real oil price gap, and $\widehat{food}_t$ is the real food price gap.

In recent years, world food and oil prices have exerted a growing influence on domestic prices. To capture this, the real oil and food price gaps are included in the model.

For fruit-and-vegetable and regulated-price inflation, simpler equations are used, with the emphasis on inflation inertia, short-term shocks, and the return of relative prices to their long-run trend.

$$\pi_t^{fv} = b_1^{fv} \pi_{t-1}^{fv} + \left(1 - b_1^{fv}\right) \left(\pi_t^{yoy} + \overline{\pi}_t^{rp_{fv}} \right) - b_2^{fv} \widehat{\pi}_t^{rp_{fv}} + \varepsilon_t^{\pi_t^{fv}}$$

where b_1^{fv}, b_2^{fv} are parameters, π_{t-1}^{fv} is lagged fruit-and-vegetable inflation, π_t^{yoy} is year-on-year inflation, $\overline{\pi}_t^{rp_{fv}}$ is the trend in relative fruit-and-vegetable inflation, $\widehat{\pi}_t^{rp_{fv}}$ is the relative fruit-and-vegetable inflation gap, and $\varepsilon_t^{\pi_t^{fv}}$ is the fruit-and-vegetable inflation shock.

$$\pi_t^{reg} = b_1^{reg} \pi_{t-1}^{reg} + (1 - b_1^{reg}) \left(\pi_t^{yoy} + \overline{\pi}_t^{rp_{reg}} \right) - b_2^{reg} \widehat{\pi}_t^{rp_{reg}} + \varepsilon_t^{\pi_t^{reg}}$$

where b_1^{reg}, b_2^{reg} are parameters, π_{t-1}^{reg} is lagged regulated-price inflation, π_t^{yoy} is year-on-year inflation, $\overline{\pi}_t^{rp_{reg}}$ is the trend in relative regulated-price inflation, $\widehat{\pi}_t^{rp_{reg}}$ is the relative regulated-price inflation gap, and $\varepsilon_t^{\pi_t^{reg}}$ is the regulated-price inflation shock.

Expert judgment is important in forecasting regulated prices. Where tariff decisions have been taken or announced in advance, they should enter the model as a shock or a conditional path; otherwise, the model cannot fully account for these prices from cyclical factors alone.

Import inflation is determined as follows, consisting of the global inflation rate and the change in the exchange rate:

$$\pi_t^{imp} = 0.4{*}\pi_{t-1}^{imp} + 0.6 * (\pi_t^f + \Delta s_t - \Delta\overline{z}_t + \ \overline{\pi}_t^{rp_{core}})$$

where π_t^{imp} is import inflation, π_t^f is external inflation, Δs_t is the change in the nominal exchange rate, and $\Delta\overline{z}_t$ is the change in the real exchange rate trend.

The weights 0.4 and 0.6 are not econometric estimates but calibrated values: they reflect an empirical balance between the inertia and the speed of pass-through from import to domestic prices, and may be revisited in light of the diagnostics (IRFs, historical decompositions).

A relative price is the price of one good *(or service)* relative to another. Relative prices are an important part of the model because they shape the behavior of economic agents: if the price of one group of goods *(or services)* rises by less than another's, demand shifts toward it.

The model contains three relative prices: those of the core; of fruit and vegetables; and of regulated goods and services.

Relative core prices:

$$rp_t^{core} = cpi_t^{core} - cpi_t$$

where rp_t^{core} is relative core prices, cpi_t^{core} is core prices, and cpi_t is headline prices.

Relative fruit-and-vegetable prices:

$$rp_t^{fv} = cpi_t^{fv} - cpi_t$$

where rp_t^{fv} is relative fruit-and-vegetable prices and cpi_t^{fv} is fruit-and-vegetable prices.

Relative regulated prices:

$$rp_t^{reg} = cpi_t^{reg} - cpi_t$$

where rp_t^{reg} is relative regulated prices and cpi_t^{reg} is regulated prices.

Relative prices are split into trend and gap. Over the long run the relative price gap is zero - that is, relative prices grow at the rate of headline inflation - and at any point in time their weighted sum is likewise zero:

$$b_1^{cpi_t} * \widehat{rp}_t^{fv} + b_2^{cpi_t} * \widehat{rp}_t^{core} + \left(1 - b_1^{cpi_t} - b_2^{cpi_t}\right) * \widehat{rp}_t^{reg} = 0$$

Relative prices can be moved by both temporary and permanent factors.

Temporary factors govern the adjustment of individual prices to shifts in demand and supply:

- supply disruptions - a poor harvest owing to weather, disease, and the like;
- high or low demand, or inventory positions, in raw-material prices;
- shocks that affect the terms of trade, among others.

Permanent factors are changes in preferences, taxes, efficiency, and other fundamentals.

In most cases relative prices move not because of monetary policy but under the influence of market or fundamental factors.

A widening of **the real wage** gap raises producers' costs, and its effect on inflation runs through real marginal cost. The nominal wage is determined as follows:

$$\Delta w_t = c_1^w * \Delta w_t^e + (1 - c_1^w) * \Delta w_{t-1} + c_2^w * ((1 - c_3^w) * \widehat{y}_t - c_3^w * \widehat{rw}_t) + \varepsilon_t^w$$

where Δw_t is the change in the nominal wage and $c_1^w - c_3^w$ are parameters; c_1^w is the share of firms that adjust wages on the basis of expectations, and $(1 - c_1^w)$ the share that set wages on the basis of the previous period's wage change.

Δw_t^e is the expected change in the wage.

$\widehat{y}_t$, the output gap, also bears on wages. When demand rises, producers move to raise output.

Beyond a certain point, producing one more unit of output requires the firm to take on a new worker or to extend the hours of existing staff - additional wage cost per unit of output. As demand rises further, pressure on wage costs builds, and that pressure raises the cost of producing each additional unit of output and of providing services.

5.4. Monetary policy reaction function

The model features two interest rates: the rate implied by uncovered interest rate parity (UIP)[6] and the Central Bank's policy rate. The benchmark rate is computed as the average of the two.

[6] **Uncovered interest rate parity** (UIP) is one of the fundamental relationships in economics, linking domestic and external interest rates to exchange rates. In essence, interest rate parity requires that, in the global economy, the price of goods be the same everywhere once interest rates and exchange rates are taken into account (the law of one price).

UIP theory holds that, over a given horizon, the expected change in the exchange rate between two countries should equal the interest rate differential over that horizon.

UIP can be derived from a household's optimal choice between holding its assets in domestic or in foreign currency, and it expresses a no-arbitrage condition: in equilibrium, an optimizing household should be indifferent between the two. The UIP equation is:

$$i_t^{uip} = 4\left(E_t s_{t+1} - s_t\right) + i_t^f + prem_t - c_1^{uip}\widehat{rem}_t$$

where i_t^{uip} is the UIP-implied interest rate, $E_t s_{t+1}$ is the expected nominal exchange rate, s_t is the nominal exchange rate, i_t^f is the external nominal interest rate, and $prem_t$ is the long-run risk premium in UIP.

The Central Bank's policy-rate equation takes the form of a Taylor-type reaction function: the Bank responds to the deviation of inflation from target and to the output gap. In practice, rate changes are not abrupt but are made gradually.

$$i_t^p = c_1^{i_t^p} * i_{t-1}^p + \left(1 - c_1^{i_t^p}\right) * \left(\bar{i}_t^p + c_2^{i_t^p} * dev_t^{cpi} + c_3^{i_t^p} * \widehat{y}_t\right) + \varepsilon_t^{i_t^p}$$

where i_t^p is the Central Bank's policy rate, $c_1^{i_t^p}$, $c_2^{i_t^p}$, $c_3^{i_t^p}$ are parameters, i_{t-1}^p is the lagged policy rate, $\bar{i}_t^p$ is the nominal neutral rate *(the trend of the nominal interest rate),* dev_t^{cpi} is the deviation of expected inflation from target, $\widehat{y}_t$ is the output gap, and $\varepsilon_t^{i_t^p}$ is the interest rate shock.

The lagged policy rate (i_{t-1}^p) enters the equation to represent interest rate smoothing - the aim of avoiding abrupt changes - and the carry-over of the previous period's rate into the current one. It also reflects the Bank's conservatism in waiting for the economic picture to clarify before moving the rate, which brings the model closer to actual conduct.

The policy rate responds to the deviation of expected inflation from target, ($dev_t^{cpi} = \pi_{t+2}^{yoy} - \pi_{t+2}^{tar}$).

Its response to the output gap ($\widehat{y}_t$) reflects the twin aims of containing future inflation and supporting stable growth.

In the long run, absent shocks, the policy rate equals its neutral level ($\bar{i}_t^p$); a rate at neutral means that policy is neither tight nor loose. The nominal neutral rate is the sum of the real interest rate trend ($\overline{r}_t$) and expected inflation ($E_t\pi_{t+4}^{yoy}$):

$$\bar{i}_t^p = \overline{r}_t + E_t\pi_{t+4}^{yoy}$$

The benchmark rate is the average of the UIP-implied rate and the Central Bank's nominal rate:

$$i_t = c_1^{i_t} * i_t^p + (1 - c_1^{i_t}) * i_t^{uip}$$

where i_t is the nominal interest rate, $c_1^{i_t}$ is a parameter, i_t^p is the Central Bank's nominal rate, and i_t^{uip} is the UIP-implied rate.

The real interest rate is obtained via the Fisher relation, as the difference between the nominal rate and expected inflation:

$$r_t = i_t - E_t \pi_t^{yoy}$$

The real rate is split into trend ($\overline{r}_t$) and gap ($\widehat{r}_t$):

$$r_t = \overline{r}_t + \widehat{r}_t$$

The real rate trend depends on fundamentals such as the global price of capital, the sovereign risk premium, and the real depreciation of the exchange rate, all of which bear directly on the prevailing policy stance.

In emerging economies, faster productivity growth leads to real exchange rate appreciation and lowers the equilibrium real interest rate *(the Balassa–Samuelson effect).* For a small open economy, estimating the neutral real rate through UIP is the appropriate approach; estimating it from domestic determinants alone can lead to mistaken policy conclusions. In the model, the real rate trend follows an AR(1) process that takes UIP into account:

$$\overline{r}_t = c^{\overline{r}} \overline{r}_{t-1} + \left(1 - c^{\overline{r}_t}\right) * \overline{r}_t^f + \Delta \overline{z}_{t+1}^{us} + prem_t$$

where $\overline{r}_t$ is the neutral real rate, $\overline{r}_t^f$ is the global equilibrium real rate, $\Delta \overline{z}_{t+1}^{us}$ is the expected next-quarter change in the real effective exchange rate trend against the US dollar *(an increase denotes depreciation)*, and $prem_t$ *(risk premium)* is the country risk premium.

5.5. Exchange rate and UIP block

In an open economy the exchange rate is a key channel of monetary transmission. In the QPM the nominal exchange rate rests on a hybrid uncovered interest parity (UIP) relationship, under which the expected returns on domestic and foreign assets are linked through the risk premium and the expected change in the exchange rate.

In practice, however, UIP does not hold in fully rational form. Inertia in the foreign exchange market, incompletely formed expectations, restrictions on capital movement, and other frictions add to exchange rate dynamics.

$$s_t^{uip} = d_1^{s_t} * E_t\left(s_{t+1}\right) + \left(1 - d_1^{s_t}\right) * \left(s_{t-1} + \frac{2\left(\overline{z}_t + \pi_t - \pi_t^f\right)}{4}\right) + \left(i_t^f - i_t + prem_t\right)/4 + \varepsilon_t^{s_t^{uip}}$$

where $d_1^{s_t}$ is a parameter, s_t^{uip} is the UIP-based nominal exchange rate, $E_t\left(s_{t+1}\right)$ is the next-quarter expected nominal exchange rate, $\overline{z}_t$ is the change in the real exchange rate trend, π_t^f is external inflation, i_t^f is the external nominal rate, and i_t is the domestic nominal rate.

In emerging economies, and especially in highly dollarized ones, the exchange-rate channel is powerful, and the inflation expectations of households and firms are strongly correlated with movements in the exchange rate.

As the Central Bank achieves its inflation target, the role of the exchange-rate channel in the formation of expectations diminishes. In the model, the Bank's foreign exchange interventions - conducted on the principle of neutrality, so as to stabilize the exchange rate and thereby inflation - are represented through a rule-based exchange rate equation:

$$\begin{aligned}\Delta s_t^{pol} &= c_1^{\Delta s_t^{pol}} \Delta s_{t-1}^{pol} \\ &\quad + \left(1 - c_1^{\Delta s_t^{pol}}\right) \left(\Delta \overline{z}_t + \pi_t^{tar} - \pi_{t+4}^{f} - d_2^{s_t} \widehat{z}_t - d_3^{s_t} \widehat{rem}_t\right) \\ &\quad - d_4^{s_t} \left(\pi_t^4 - \pi_t^{tar}\right) + \varepsilon_t^{\Delta s_t^{pol}}\end{aligned}$$

where $c_1^{\Delta s_t^{pol}}$, $d_2^{s_t}$, $d_3^{s_t}$, $d_4^{s_t}$ are parameters, Δs_t^{pol} is the change in the rule-based exchange rate, $\Delta \overline{z}_t$ is the change in the real exchange rate trend, $\widehat{z}_t$ is the real exchange rate gap, $\widehat{rem}_t$ is the remittances gap, π_{t+4}^{f} is expected external inflation, and $\varepsilon_t^{\Delta s_t^{pol}}$ is the rule-based exchange rate shock.

The nominal exchange rate is the weighted average of the UIP-based and the rule-based rates:

$$s_t = \left(1 - c_1^{s_t}\right) s_t^{pol} + c_1^{s_t} * s_t^{uip}$$

The real exchange rate (z_t) is obtained from the nominal rate (s_t) adjusted for the differential between domestic and external inflation $(\pi_t - \pi_t^f)$:

$$z_t = s_t - \left(\pi_t - \pi_t^f\right)$$

The change in the real exchange rate trend is given by:

$$\Delta \overline{z}_t = c_1^{\Delta \overline{z}_t} \Delta \overline{z}_{t-1} + \left(1 - c_1^{\Delta \overline{z}_t}\right) * \Delta \overline{z}_{ss} - c2^{\Delta \overline{z}_t} * \left(\frac{\overline{fdi}_t}{4 y_t^{nom}} - \frac{fdi_{ss}}{4 y_t^{nom}}\right) - c3^{\Delta \overline{z}_t} * \left(\Delta \overline{gold}_t - \Delta \overline{gold}_{ss}\right) + \varepsilon_t^{\Delta \overline{z}_t}$$

where $c_1^{\Delta \overline{z}_t}$, $c2^{\Delta \overline{z}_t}$, $c3^{\Delta \overline{z}_t}$ are parameters and $\Delta \overline{z}_{ss}$ is the equilibrium change in the real exchange rate trend. The term $\left(\frac{\overline{fdi}_t}{4 y_t^{nom}} - \frac{fdi_{ss}}{4 y_t^{nom}}\right)$ is the deviation of the FDI-to-GDP trend from its long-run equilibrium - a higher inflow implying an appreciating trend - while $\left(\Delta \overline{gold}_t - \Delta \overline{gold}_{ss}\right)$ captures the effect of the change in the gold-price trend on the exchange rate trend, and $\varepsilon_t^{\Delta \overline{z}_t}$ is the exchange rate trend shock.

The exchange rate acts on inflation through two channels. The first is the import-price channel: a depreciation raises the prices of imported goods and inputs. The second is the demand channel: a real depreciation can improve export competitiveness and strengthen import-substituting demand.

The exchange-rate channel thus plays an important part in the paths of both inflation and output.

5.6. External sector block

In the external sector, the output gaps, inflation rates, interest rates, exchange rates, and global commodity prices of the main trading partners are treated as exogenous or AR(1) processes. The external output gap is built from the trade-weighted gaps of the main partners - Russia, Kazakhstan, and China - and foreign inflation is likewise weighted by partner shares.

$$\widehat{y}_t^{ru} = c^{ru} * \widehat{y}_{t-1}^{ru} + \varepsilon_t^{\widehat{y}_t^{ru}},$$

$$\widehat{y}_t^{cn} = c^{cn} * \widehat{y}_{t-1}^{cn} + \varepsilon_t^{\widehat{y}_t^{cn}},$$

$$\widehat{y}_t^{kz} = c^{kz} * \widehat{y}_{t-1}^{kz} + \varepsilon_t^{\widehat{y}_t^{kz}}$$

where c^{ru} , c^{cn}, c^{kz} are parameters, $\widehat{y}_t^{ru}$ is the output gap of the Russian economy, $\widehat{y}_t^{cn}$ that of the Chinese economy, $\widehat{y}_t^{kz}$ that of the Kazakh economy, and $\varepsilon_t^{\widehat{y}_t^{ru}}$, $\varepsilon_t^{\widehat{y}_t^{cn}}$, $\varepsilon_t^{\widehat{y}_t^{kz}}$ are the respective output gap shocks.

The external output gap is the trade-weighted average of these gaps:

$$\widehat{y}_t^{f} = w^{ru} * \widehat{y}_t^{ru} + w^{cn} * \widehat{y}_t^{cn} + w^{kz} * \widehat{y}_t^{kz}$$

where $w^{ru},\ w^{cn},\ w^{kz}$ are parameters set from the volume of foreign trade, with $w^{ru} + w^{cn} + w^{kz} = 1$.

Foreign inflation is likewise given in autoregressive form:

$$\pi_t^{us} = c^{cpi_{us}} * \ \pi_{t-1}^{us} + \left(1 - c^{cpi_{us}}\right) * \pi_{ss}^{us} + \varepsilon_t^{\pi_{us}}$$

,

$$\pi_t^{ru} = c^{cpi_{ru}} * \ \pi_{t-1}^{ru} + \left(1 - c^{cpi_{ru}}\right) * \pi_{ss}^{ru} + \varepsilon_t^{\pi_{ru}}$$

$$\pi_t^{cn} = c^{cpi_{cn}} * \ \pi_{t-1}^{cn} + \left(1 - c^{cpi_{cn}}\right) * \pi_{ss}^{cn} + \varepsilon_t^{\pi_{cn}}$$

External consumer prices are determined in the model as:

$$cpi_t^{f} = w^{cpi_{us}} * \ cpi_t^{us} + w^{cpi_{ru}} * (cpi_t^{ru} - s_t^{ru}) + w^{cpi_{cn}} * (cpi_t^{cn} - s_t^{cn})$$

where $w^{cpi_{us}}$, $w^{cpi_{ru}}$, $w^{cpi_{cn}}$ are parameters, cpi_t^{us} is the US consumer price index, cpi_t^{ru} the Russian, s_t^{ru} the dollar/ruble exchange rate, cpi_t^{cn} the Chinese consumer price index, and s_t^{cn} the dollar/yuan exchange rate.

The external interest rate (i_t^f) is determined as:

$$i_t^f = c_1^{i_t^f} * i_{t-1}^f + \left(1 - c_1^{i_t^f}\right) * \left(\overline{r}_t^f + \pi_t^{us_{ss}}\right) + \varepsilon_t^{i_t^f}$$

where $c_1^{i_t^f}$ is a parameter, i_{t-1}^f is the previous quarter's external nominal rate, $\overline{r}_t^f$ is the external real rate trend, and $\pi_t^{us_{ss}}$ is the US steady-state inflation rate.

In a small open economy the external sector transmits through two main channels. First, external demand acts on domestic output and activity via exports and remittances. Second, external inflation and world prices for oil, food, and other commodities feed through to domestic inflation via import inflation.

Changes in the external block are therefore treated in most cases not as systematic shocks but as exogenous assumptions, since the model does not fully capture the internal interlinkages of the global economy and takes the external environment largely as given.

Global food prices, once converted to real terms using external inflation, are split into trend and gap:

$$food_t = \overline{food}_t + \widehat{food}_t$$

The change in the global real food-price trend is given in autoregressive form:

$$\Delta\overline{food}_t = c^{\Delta\overline{food}_t} * \Delta\overline{food}_{t-1} + \left(1 - c^{\Delta\overline{food}_t}\right) * \Delta\overline{food}^{ss} + \varepsilon_t^{\Delta\overline{food}_t}$$

The oil price is likewise converted to real terms using external inflation and split into trend and gap:

$$oil_t = \overline{oil}_t + \widehat{oil}_t$$

The change in the real oil-price trend is given in autoregressive form:

$$\Delta\overline{oil}_t = c^{\Delta\overline{oil}_t} * \Delta\overline{oil}_{t-1} + \left(1 - c^{\Delta\overline{oil}_t}\right) * \Delta\overline{oil}^{ss} + \varepsilon_t^{\Delta\overline{oil}_t}$$

The gold price is treated the same way - converted to real terms using external inflation, split into trend and gap, with the change in its trend given in autoregressive form:

$$gold_t = \overline{gold}_t + \widehat{gold}_t$$

$$\Delta\overline{gold}_t = c^{\Delta\overline{gold}_t} * \Delta\overline{gold}_{t-1} + \left(1 - c^{\Delta\overline{gold}_t}\right) * \Delta\overline{gold}^{ss} + \varepsilon_t^{\Delta\overline{gold}_t}$$

5.7. Fiscal block

The fiscal block captures the influence of the budget position on economic activity. The main fiscal aggregates are expressed relative to GDP, which allows their macroeconomic effect to be gauged more precisely. The overall budget deficit is split into the primary deficit and the cost of servicing government debt, and the primary deficit is further divided into structural, cyclical, and temporary components.

From the model's standpoint, one of the most important indicators is the fiscal impulse, which measures the additional stimulus or restraint that changes in government spending and budget policy impart to aggregate demand and activity.

$$fisc_t^{imp} = c_1^{fisc} * \left(4 * \left(str_t^{def} - str_{t-1}^{def}\right)\right) + c_2^{fisc} * \left(4 * \left(def_t^{tmp} - def_{t-1}^{tmp}\right)\right) + c_3^{fisc} * \varepsilon_t^{def^{tar}}$$

where c_1^{fisc}, c_2^{fisc}, c_3^{fisc} are parameters, $fisc_t^{imp}$ is the fiscal impulse, def_t^{str} is the structural deficit, and def_t^{tmp} is the temporary deficit.

A positive fiscal impulse indicates that fiscal policy is supporting aggregate demand, which can widen the output gap and add to inflationary pressure. The consistency of monetary and fiscal policy therefore matters in the QPM: if budget policy strengthens demand, monetary policy may need to be tighter to return inflation to target.

The overall deficit is split into the primary deficit and interest payments:

$$def_t = def_t^{prim} + intcost_t$$

where def_t is the fiscal deficit, def_t^{prim} is the primary deficit, and $intcost_t$ is the cost of servicing government debt *(interest payments).*

The primary deficit is the current-year fiscal deficit net of interest payments on government debt, and is divided into structural, cyclical, and temporary components:

$$def_t^{prim} = def_t^{str} + def_t^{cyc} - c2\_def * edebt_t^{dev} + def_t^{tmp}$$

where def_t^{str} is the structural deficit, def_t^{cyc} the cyclical deficit, def_t^{tmp} the temporary deficit, and $edebt_t^{dev}$ the deviation of debt from its target.

The structural deficit is the deficit that would arise even with the economy operating at full potential:

$$def_t^{str} = rho_{FP} * \left(def_{t-1}^{str} + c1_{def_{str}} * \widehat{cycle}_t\right) + (1 - rho_{FP}) * def_{tar}^{str} + \varepsilon_t^{def_{str}}$$

where $\widehat{cycle}_t$ is the cyclical gap and def_{tar}^{str} is the structural deficit target.

The structural deficit target is determined as:

$$def_{tar}^{str} = 4 * a * \frac{debt_{tar}}{debt_{shr}^{d}} * (1 - 1/exp(\frac{\Delta ey_t^{nom}}{400}))$$

where $debt_{tar}$ is the government debt target, $debt_{shr}^{d}$ is the share of domestic debt in total government debt, and Δey_t^{nom} is the expected change in GDP.

The cyclical gap is determined as:

$$\widehat{cycle}_t = y_t^{nom} - \frac{y_{t-4}^{nom} + y_{t-3}^{nom} + y_{t-2}^{nom} + y_{t-1}^{nom} + y_t^{nom} + y_{t+1}^{nom} + y_{t+2}^{nom} + y_{t+3}^{nom} + y_{t+4}^{nom}}{9}$$

where y_t^{nom} is nominal GDP.

When a recession sets in, government revenue falls just as the more vulnerable parts of the population come to need greater support. To stabilize activity, the government runs a larger deficit, and this additional deficit is treated as cyclical. The cyclical deficit is inversely related to the cycle:

$$def_t^{cyc} = -c1_{def_{cyc}} * \widehat{y}_t$$

The temporary deficit is the deficit incurred to cushion the effect of temporary shocks:

$$def_t^{temp} = c1_{def_{temp}} * def_t^{temp} + \varepsilon_t^{def_{temp}}$$

Government debt comprises domestic and external debt:

$$debt_t = debt_t^d + debt_t^f$$

where $debt_t$ is total government debt, $debt_t^d$ is domestic debt, and $debt_t^f$ is external debt.

Domestic debt comprises borrowing raised in the current period and outstanding earlier debt:

$$debt_t^d = debt_t^{d^{new}} + \left(1 - invmat^d\right) * \frac{debt_{t-1}^d}{\text{exp}\left(\frac{\Delta y_t^{nom}}{400}\right)} + \varepsilon_t^{debt^d}$$

where $debt_t^{d^{new}}$ is domestic debt raised in the current period and $invmat^d$ is the average maturity of total domestic debt.

$$debt_t^{d^{new}} = debt_{shr}^d * \left(\frac{def_t^{prim}}{4}\right) + \frac{intcost_t^d}{4} + invmat^d * \frac{debt_{t-1}^d}{\text{exp}\left(\frac{\Delta y_t^{nom}}{400}\right)}$$

where $debt_{shr}^d$ is the share of domestic debt in total government debt and $intcost_t^d$ is the interest cost on domestic debt in the current period, given by:

$intcost_t^d = \frac{idebt_t^d}{100} * \frac{debt_{t-1}^d}{\text{exp}\left(\frac{\Delta y_t^{nom}}{400}\right)} + \varepsilon_t^{intcost^d};$

with $invmat^d * \frac{debt_{t-1}^d}{\text{exp}\left(\frac{\Delta y_t^{nom}}{400}\right)}$ the principal repayments on domestic debt in the current period; and

$idebt_t^d$ the average interest rate on domestic debt, given by:

$$idebt_t^d = \frac{i_t + i_{t+1} + i_{t+2} + i_{t+3}}{4} + t_t^{prem}$$

where t_t^{prem} is the term premium, given in the model by:

$$t_t^{prem} = c1_{t_{prem}} * t_{t-1}^{prem} + \left(1 - c1_{t_{prem}}\right) * t_{ss}^{prem} + c2_{t_{prem}} * (debt_t - debt_{tar}) + \varepsilon_t^{t_{prem}}$$

External debt comprises borrowing raised in the current period and outstanding earlier debt:

$$debt_t^f = debt_t^{f^{new}} + \left(1 - invmat^f\right) * \frac{debt_{t-1}^f * exp(\frac{\Delta s_t}{400})}{\text{exp}\left(\frac{\Delta y_t^{nom}}{400}\right)} + \varepsilon_t^{debt^f}$$

where $debt_t^{f^{new}}$ is external debt raised in the current period, Δs_t is the change in the nominal exchange rate, and $invmat^f$ is the average maturity of total external debt.

$$debt_t^{f^{new}} = (1 - debt_{shr}^d) * \left(\frac{def_t^{prim}}{4}\right) + \frac{intcost_t^f}{4} + \frac{debt_{t-1}^f * exp(\frac{\Delta s_t}{400})}{\text{exp}\left(\frac{\Delta y_t^{nom}}{400}\right)}$$

where $intcost_t^f$ is the interest cost on external debt in the current period, and $\frac{debt_{t-1}^f * exp(\frac{\Delta s_t}{400})}{\text{exp}\left(\frac{\Delta y_t^{nom}}{400}\right)}$ the principal repayments on external debt in the current period.

$$intcost_t^f = \frac{idebt_t^f}{100} * \frac{debt_{t-1}^f * exp(\frac{\Delta s_t}{400})}{\text{exp}\left(\frac{\Delta y_t^{nom}}{400}\right)} + \varepsilon_t^{intcost^f}$$

where $idebt_t^f$ is the average interest rate on external debt.

5.8. Credit block

Bank lending is one of the main sources of financing in the Uzbek economy. With a relatively shallow capital market and a large role for the banking system, credit activity bears heavily on aggregate demand, investment, consumption, and activity. For this reason the credit channel is set up as a separate block in the QPM - one of the model's important institutional and structural strengths.

The credit block is designed to capture credit activity, changes in credit quality, the revaluation of the loan portfolio through the exchange rate, and the influence of the credit cycle on demand and inflation. Through it, the link between the banking and real sectors is modeled endogenously.

The total loan stock is split into two parts: performing (working) loans and non-performing loans. This allows the model to reflect the fact that not only the volume of credit but also its quality bears on the macroeconomy.

$$cr_t = cr_t^p + cr_t^{np}$$

where cr_t is the total loan stock, cr_t^p the stock of performing loans, and cr_t^{np} the stock of non-performing loans.

The stock of performing loans evolves through the carry-over of the existing portfolio, new lending, and random shocks. A share of loans is repaid each period, and the remainder rolls forward.

$$cr_t^p = (1 - c_2^{cr}) * cr_t^{p^o} + cr_t^{new} + \frac{\varepsilon_t^{cr_t^p}}{100} * cr_t^{p^o}$$

where c_2^{cr} is the inverse of the average loan maturity, $cr_t^{p^o}$ is the opening stock of performing loans, and cr_t^{new} is lending in the current period.

The opening stock of performing loans depends on two factors:

(1) a share of loans falling into default; and

(2) the revaluation of foreign-currency loans as the exchange rate moves.

$$cr_t^{p^o} = j_t * \left(1 - \frac{q_t}{100}\right) * cr_{t-1}^p$$

where j_t is the exchange-rate revaluation effect and q_t is the share of loans in default.

Because a sizable share of loans in Uzbekistan is denominated in foreign currency, exchange rate movements weigh heavily on the size of the loan portfolio: a depreciation raises the domestic-currency value of foreign-currency loans. The model represents this revaluation as:

$$j_t = 1 + c1^{cr} * \left(\text{exp}\left(\frac{\Delta s_t}{400}\right) - 1\right)$$

where $c1^{cr}$ is the share of foreign-currency loans in the total loan stock and Δs_t is the change in the exchange rate.

Through this mechanism, the effect of exchange rate shocks on the bank balance sheet and on credit dynamics is captured directly.

Non-performing loans are modeled separately. Their stock is built from the previous period's non-performing loans, newly defaulted loans, and write-offs.

$$cr_t^{np} = cr_t^{np0} - c_3^{cr} * cr_t^{np0} + \frac{\varepsilon_t^{cr_t^{np}}}{100} * cr_t^{np0}$$

where c_3^{cr} is the share of non-performing loans written off and $cr_t^{np^o}$ is the opening stock of non-performing loans.

The opening stock of non-performing loans is given by:

$$cr_t^{np^0} = j_t * \left(cr_{t-1}^{np} + \frac{q_t}{100} * cr_{t-1}^p\right)$$

This says that a higher default rate raises the stock of non-performing loans; the exchange-rate revaluation applies to non-performing loans as well.

The share of non-performing loans in total loans, an important gauge of financial stability, is:

$$npl_t = \frac{cr_t^{np}}{cr_t} * 100 + \varepsilon_t^{npl}$$

The default rate is determined endogenously over the cycle: as activity slows, the capacity of firms and households to service their debt weakens and the default rate rises.

$$q_t = q_{ss} - c_1^q * \widehat{y}_t + \varepsilon_t^{q_t}$$

where q_{ss} is the long-run equilibrium default rate and c_1^q is the elasticity of the default rate to activity.

The equation implies that the default rate falls when activity is strong and rises in a downturn - the countercyclical character of the credit cycle.

Lending is gauged, as an indicator of financial deepening, by the ratio of loans to GDP.

$$\frac{cr_t}{4y_t^{nom}} = 100 * \frac{cr_t}{4 * \text{exp}\left(\frac{y_t^{nom}}{100}\right)} + \varepsilon_t^{\frac{cr_t}{4y_t^{nom}}}$$

The loans-to-GDP ratio $\frac{cr_t}{4y_t^{nom}}$ is split into trend and gap:

$$\frac{cr_t}{4y_t^{nom}} = \frac{\overline{cr}_t}{4y_t^{nom}} + \frac{\widehat{cr}_t}{4y_t^{nom}}$$

where $\frac{\overline{cr}_t}{4y_t^{nom}}$ is the trend and $\frac{\widehat{cr}_t}{4y_t^{nom}}$ the gap of the loans-to-GDP ratio.

One of the most important elements of the block is new lending, since it is new loans that add most directly to demand. The ratio of new lending to GDP is therefore tied to the real interest rate, fiscal conditions, and the credit cycle.

$$\frac{cr_t^{new}}{4y_t^{nom}} = c1^{\frac{cr_t^{new}}{4y_t^{nom}}} - c2^{\frac{cr_t^{new}}{4y_t^{nom}}} * \widehat{r}_t + c3^{\frac{cr_t^{new}}{4y_t^{nom}}} * fisc_t^{imp} + c4^{\frac{cr_t^{new}}{4y_t^{nom}}} * \frac{\widehat{cr}_t}{4y_t^{nom}} + \varepsilon_t^{\frac{cr_t^{new}}{4y_t^{nom}}}$$

where $\frac{cr_t^{new}}{4y_t^{nom}}$ is new lending relative to GDP, $c1^{\frac{cr_t^{new}}{4y_t^{nom}}}$ is its long-run average, $\widehat{r}_t$ is the real interest rate gap, and $fisc_t^{imp}$ is the fiscal impulse.

The equation implies that:

- higher real interest rates restrain credit demand;
- fiscal stimulus strengthens lending;
- the upswing of the credit cycle stimulates lending further.

The new-lending gap enters the aggregate demand equation directly, which is how the model captures monetary transmission through the credit channel.

When rates fall, lending strengthens and, via higher investment and domestic demand, pushes the output gap into positive territory; conversely, tight policy slows credit growth and eases demand and inflationary pressure.

The credit block thus lets the QPM capture the interplay between the financial and real sectors in depth. Through it, the model assesses endogenously:

- the effect of the credit cycle on activity;
- the transmission of changes in financial conditions;
- the revaluation of the bank balance sheet as the exchange rate moves;
- the effect of deteriorating credit quality on financial stability;
- the inflationary risks of credit expansion.

Given the prominence of bank lending in the Uzbek economy, the substantial degree of state participation, and the share of foreign-currency loans, the inclusion of the credit block materially enhances the practical relevance and analytical reach of the model.

5.9. Foreign direct investment block

Foreign direct investment (FDI) is an important factor in investment activity, in the expansion of production capacity, and in the support of growth. In emerging economies especially, FDI - as a stable source of external financing - supports activity by raising capital investment, creating new production facilities, expanding export potential, and encouraging technology transfer.

In Uzbekistan, FDI is important in financing large projects in industry, energy, infrastructure, and services. The QPM therefore includes FDI flows as one of the factors bearing on activity.

FDI is measured relative to GDP, which allows the intensity of investment to be judged against the size of the economy.

$$\frac{fdi_t}{4y_t^{nom}} = \frac{\overline{fdi}_t}{4y_t^{nom}} + \frac{\widehat{fdi}_t}{4y_t^{nom}}$$

where $\frac{fdi_t}{4y_t^{nom}}$ is the FDI-to-GDP ratio, $\frac{\overline{fdi}_t}{4y_t^{nom}}$ its trend, and $\frac{\widehat{fdi}_t}{4y_t^{nom}}$ its gap.

The FDI-to-GDP ratio is computed as:

$$\frac{fdi_t}{4y_t^{nom}} = 100 * \frac{fdi_t * s_t}{ny_t}$$

where $\frac{fdi_t}{4y_t^{nom}}$ is the volume of foreign direct investment, s_t is the exchange rate, and ny_t is nominal GDP.

Splitting this ratio into trend and cyclical components allows short-term investment swings to be distinguished from long-term investment trends.

The FDI gap is modeled as an autoregressive process, reflecting the persistence of investment flows: current investment depends in part on the previous period's.

$$\frac{\widehat{fdi}_t}{4y_t^{nom}} = c1_{fdi} * \frac{\widehat{fdi}_{t-1}}{4y_t^{nom}} + \varepsilon_t^{\frac{\widehat{fdi}_t}{4y_t^{nom}}}$$

where $c1_{fdi}$ is the persistence coefficient of the FDI gap and $\varepsilon_t^{\frac{\widehat{fdi}_t}{4y_t^{nom}}}$ is the exogenous shock to FDI flows.

Short-term swings in FDI thus have a degree of persistence: large projects or a pickup in external investors' activity, for example, can persist over several periods.

The FDI trend is likewise autoregressive, reflecting the convergence of the investment share to its long-run equilibrium.

$$\frac{\overline{fdi}_t}{4y_t^{nom}} = c2_{fdi} * \frac{\overline{fdi}_{t-1}}{4y_t^{nom}} + (1 - c2_{fdi}) * \frac{fdi_{ss}}{4y_t^{nom}} + \varepsilon_t^{\frac{\overline{fdi}_t}{4y_t^{nom}}}$$

where $c2_{fdi}$ is the persistence coefficient of the trend and $\frac{fdi_{ss}}{4y_t^{nom}}$ is the long-run equilibrium FDI-to-GDP ratio.

This says that the long-run path of FDI forms gradually and shifts with external and domestic macroeconomic conditions.

In the QPM the FDI-to-GDP gap enters the output gap equation with a positive sign: FDI stimulates growth by adding to demand and investment activity. Higher FDI raises investment demand, expands output, supports construction and industry, and lifts domestic demand.

The output gap may, as a result, move positive in the short to medium run.

The block is aimed chiefly at the effect of FDI on demand. In principle, FDI can also raise the economy's productive capacity and potential growth - through technology transfer, higher labor productivity, and new capacity - and so strengthen long-run supply. In the present specification, the FDI term that also appears in the potential-growth equation is modeled mainly as a cyclical demand factor.

6. Calibration of the model parameters

The QPM parameters are set largely by calibration[7]. This is standard practice at central banks, and it is particularly suited to economies where the data series are short, structural change is frequent, and the inflation-targeting regime is still taking shape.

Calibration does not mean abandoning econometric estimation. Rather, it harmonizes historical data, empirical research, international experience, impulse response function (IRF) analysis, and expert judgment.

Calibration of the QPM parameters can be divided into four stages:

1. setting the steady-state parameters;
2. determining the trend dynamics;
3. calibrating the coefficients of the main equations;
4. setting the standard deviations of the shocks.

The steady-state parameters must be mutually consistent with the inflation target, the long-run potential growth rate, the neutral real interest rate, the risk premium, the real exchange rate trend, and the main external-sector assumptions.

Four diagnostics are normally used to check the calibration:

- impulse response functions (IRFs);

- historical decomposition;

- how well the model explains the historical data (in-sample forecast performance);

- and variance decomposition - that is, the attribution of the variation in each variable to the various shocks and factors.

If, for instance, the model does not respond to a positive demand shock with higher inflation, a higher policy rate, and a gradual normalization of demand, or if the variables show excessive volatility after shocks, the parameters should be revisited and the calibration refined.

Expert conclusion

In the forecasting process the QPM serves not as an “automatic forecasting machine” but as a platform for structuring and reconciling the analytical judgment of economists. A forecast round typically opens with updating the database and carrying out seasonal adjustment and recalculation. Near-term forecasts are then prepared, and on their basis a medium-term baseline scenario is built with the QPM.

Expert judgment carries particular weight in certain situations: one-off changes in the data; tariff or tax decisions known in advance; weather, agricultural, geopolitical, or logistics

[7] Calibration is the process of assigning the model parameters appropriate values on the basis of economic theory, historical data, empirical research, and expert judgment. Its aim is to bring the model’s dynamics and results into line with the processes observed in the economy.

shocks not fully captured by the statistical model; additional information on the external assumptions; and planned changes in credit or fiscal policy.

An effective forecast round should produce, at a minimum, the baseline forecast, an inflation decomposition, an output-gap decomposition, the path of the RMCI, the policy-rate path and its consistency with the inflation target, at least two main risk scenarios, policy options together with their effect on inflation and output, and an analysis of forecast errors.

7. Model properties and impulse responses

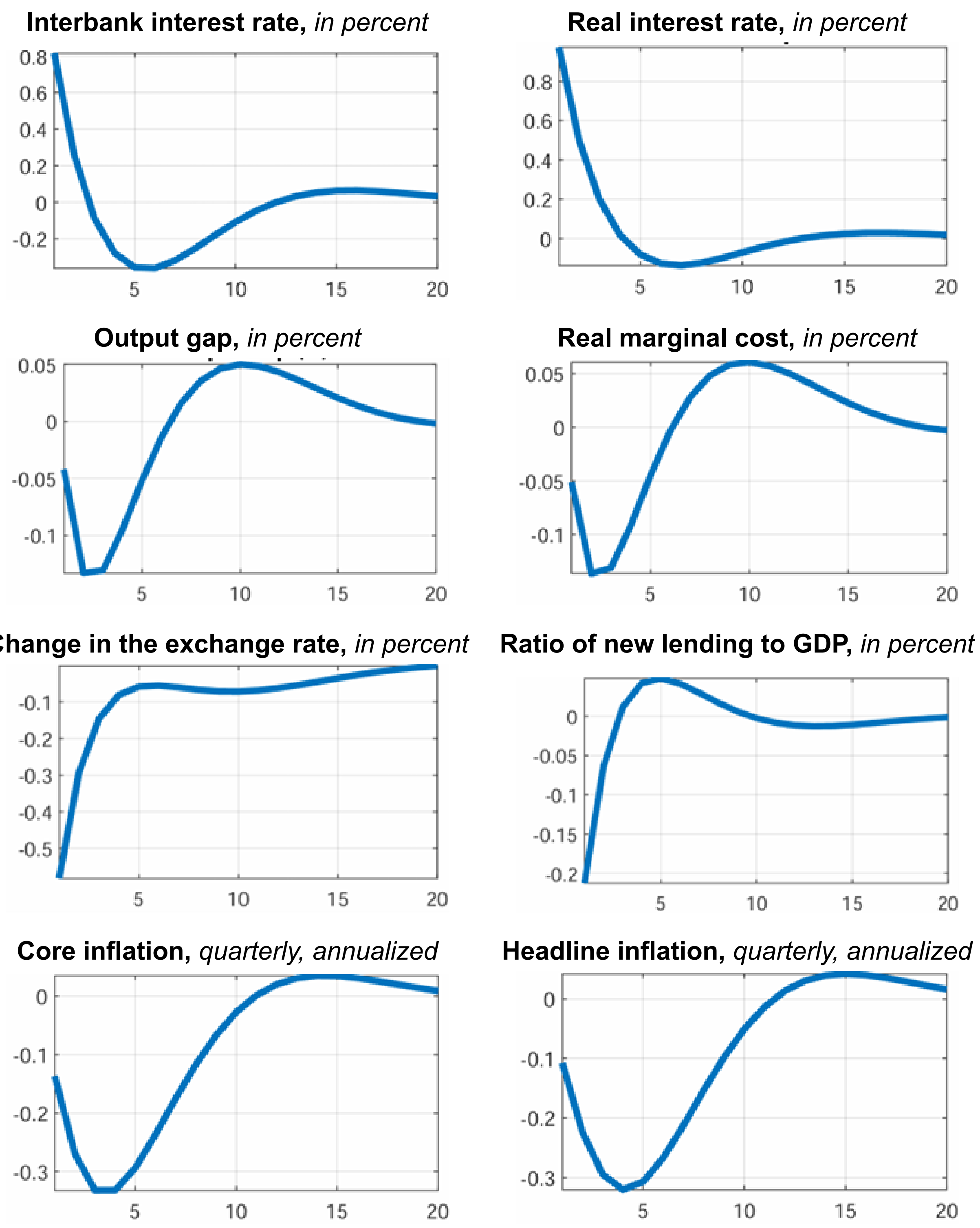
Impulse response functions (IRFs) are used to verify that the model behaves in line with economic reasoning and to assess its dynamic properties. They are not forecasts; they answer the question of how the model responds when a particular shock hits the economy. As such, they are an important part of calibrating and diagnosing the QPM.

Following a positive demand shock, the output gap turns positive, real marginal cost rises, and pressure on core inflation builds. The reaction function addresses this pressure by raising the policy rate. Monetary conditions tighten, demand slows over time, and inflation returns to its target path.

Under a monetary policy shock, the policy rate is set above the level the reaction function would call for. The real interest rate rises, credit and consumption activity slow, the output gap narrows, and inflation falls *(Figure 4).* In a small open economy, higher rates also lower import inflation as the domestic currency strengthens.

An exchange rate shock acts on inflation mainly through import prices. A depreciation first raises import inflation and adds to overall price pressure; thereafter, the policy response and slowing demand bring the pressure down gradually. This shock calls for care in interpretation, since in practice exchange rate movements often coincide with external shocks, changes in the risk premium, or shifts in inflation expectations.

Figure 4. Impulse responses of key indicators to an interest-rate shock



Based on the results of the QPM model

8. Conclusion

The QPM of the Central Bank of the Republic of Uzbekistan has been built as the central analytical tool for preparing monetary policy decisions under an inflation-targeting regime. Grounded in a semi-structural New Keynesian approach, it combines the coherence of economic theory, the capacity to incorporate expert judgment, and the ability to reflect the specific features of the Uzbek economy.

The model's principal contributions are threefold. First, it draws the main macroeconomic blocks - aggregate demand, inflation, the monetary policy reaction, the exchange rate, the external sector, fiscal policy, credit activity, and foreign direct investment - into a single analytical system, ensuring the internal consistency of the forecasts and allowing the interaction of the various channels to be assessed quantitatively. Second, it represents the transmission channels of monetary policy - interest rate, exchange rate, credit, and expectations - endogenously. Third, it structures the decision-making process by comparing alternative scenarios and policy options on a quantitative basis.

The tailoring of the model to the Uzbek economy is one of its important features. A small open economy, the degree of dollarization, the large weight of remittances in domestic demand, the primacy of bank lending in financing, and the distinctive dynamics of regulated and fruit-and-vegetable prices are all built in through dedicated blocks. The revaluation of foreign-currency loans in the credit block and the dependence of the default rate on the cycle, in particular, reflect the structural features of the Uzbek banking system.

The model is not without limitations. First, the semi-structural approach does not provide full microeconomic foundations, so its scope for assessing the effects of structural reforms is limited. Second, the short data series and the rapid pace of structural change leave the calibrated parameters subject to some uncertainty and in need of regular re-estimation. Third, the balance between the adaptive and forward-looking shares in the expectations mechanism depends on the credibility of policy and the effectiveness of communication, and is expected to shift over time. Fourth, the influence of the shadow economy is not directly captured.

In practical terms, the QPM is not merely a device for generating forecast numbers but a platform that shapes the Bank's analytical culture, gives economic reasoning a common language, and lends objectivity to decision-making. In medium-term forecast rounds it supports the systematic analysis of alternative scenarios alongside the baseline, the assessment of the path back to the inflation target, and the quantitative comparison of the economic consequences of different policy-rate options.

The model's usefulness, however, rests not on technical sophistication but on its proper use within the Forecasting and Policy Analysis System (FPAS), where expert judgment, sectoral analysis, near-term forecasts, and communication policy must work alongside the model results. It is in precisely this sense that the QPM is not the decision itself but the analytical basis for systematic decision-making.

In sum, the QPM is an important institutional and methodological tool in the Central Bank's steady transition to inflation targeting and in strengthening the transparency and communication of monetary policy. Keeping the model up to date, adapting its parameters to new data and changing conditions, and drawing on international best practice are all of strategic importance in meeting the objective of price stability.

Appendix 1. QPM model parameters

Parameter	Value	Name
a_1	0.6	Output gap lag coefficient
a_2	0.01	Coefficient on the expected future output gap
a_3	0.15	RMCI coefficient
a_4	0.18	Partner-country (external) output gap coefficient
a_5	0.03	Remittances gap coefficient
a_6	0.2	Fiscal impulse coefficient
a_7	0.2	Credit activity coefficient
a_8	0.05	FDI (FDI/GDP) coefficient
a_{rmc}	0.45	Weight of the real exchange rate in the RMCI
b_1^{core}	0.25	Inflation expectations coefficient
b_2^{core}	0.15	Import inflation coefficient
b_3^{core}	0.5	Real marginal cost coefficient
b_{adapt}	0.6	Inflation inertia
b_1^{fv}	0.2	Fruit-and-vegetable inflation inertia
b_2^{fv}	1	Coefficient of return to the relative price
b_1^{reg}	0.01	Regulated-price inertia
b_2^{reg}	0.5	Regulated-price coefficient
$c_1^{i_t^p}$	0.6	Interest rate smoothing in the Taylor rule
$c_2^{i_t^p}$	1	Response coefficient to inflation
$c_3^{i_t^p}$	0.35	Response to the output gap
$d_1^{s_t}$	0.2	Exchange rate expectations
$d_2^{s_t}$	1	Real exchange rate coefficient
$d_3^{s_t}$	0.1	Remittances coefficient
c_1^{rem}	0.8	Remittances inertia
c_2^{rem}	0.65	Russian cycle coefficient
c_3^{rem}	0.9	Remittances trend
c_4^{rem}	0.1	Ruble exchange rate coefficient
c_1^w	0.5	Wage expectations
c_2^w	3	Output gap coefficient
c_3^w	0.7	Real wage gap

Source: Central Bank QPM model, as of May 2026

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