CNB's Forecasting and Policy Analyses System: Forecasting Tools

Czech National Bank, Monetary Department

October 2024

Contents

1 Forecasting and Policy Analyses System

Monetary policy of the Czech National Bank (CNB) operates in an inflation-targeting framework. Inflation forecast targeting requires that the central bank provides a coherent and transparent forecast narrative to the public. This forecast narrative explains how current policy decisions align with the expected evolution of economic activity and inflation over the horizon relevant for monetary policy decisions. In this document we outline the forecasting tools and models employed at CNB to construct and communicate this narrative. The whole ecosystem of tools and processes is commonly referred "Forecasting and Policy Analysis System" (FPAS).

The FPAS at the CNB centers around the structural core forecasting model of a New Keynesian DSGE type, called g3+ (denoting the third generation of models[1], with "+" indicating further updates). In addition, there is a wide array of other modelling tools used at the CNB. Econometric and data-driven methods are used for the nowcast and short-term forecast and generally serve for assembling majority of data inputs for the core model. Some of the trajectories are used to condition core model forecast; many of these are utilized only in the first forecasted quarter. However, for some variables (such as administered prices, fiscal policy or the outlook of foreign variables), the econometric methods or market outlooks provide trajectories for the whole forecasting horizon.

Although the core model provides a comprehensive framework, it does not encompass forecasts for all variables essential for a full understanding of the economy and for policy debate and decision. To cover additional topics of interest, we employ satellite models that condition their outputs on trajectories produced by the core model to ensure consistency. The example of this approach is the forecasting of credit and monetary aggregates, which relies on a satellite model and utilizes inputs from the core macroeconomic forecast. Numerous other satellite models are employed, including tools for estimating the Non-Accelerating Inflation Rate of Unemployment (NAIRU), decomposing inflation in to its subcomponents, forecasting house prices, generating fiscal forecasts, and modeling the balance of payments trajectories. Some of these satellite tools also serve for consistency checks and/or detailed scenario analyses.

CNB's FPAS based on the core model is flexible and capable of producing a variety of sensitivity and policy scenarios while keeping consistency. These scenarios range from relatively simple policy simulations such as "what if the central bank keeps rates unchanged for next few quarters", to complex ones involving changes in deep model parameters, such as the extended horizon of monetary policy reaction function (as employed in 2022) or temporarily elevated inflation expectations (used during 2023). The complex scenarios, which we typically refer to as "alternatives", involve preparing a full parallel forecast with all the satellite computations.

Scenarios often emerge from discussions within the CNB board, where specific risks or concerns are raised during preparatory meetings held with the Monetary Department. Further, scenarios are also prompted by risks to central forecast trajectory identified by the Monetary Department or operational events, such as the switch to a new core projection model (where a shadow forecast prepared using the new/old version of the model is often presented as a scenario). Additionally, the CNB board regularly provides feedback and poses questions about the baseline forecast during two preparatory meetings. The final outcome is presented as the official staff forecast, but the board retains the discretion to communicate alternative views or to adopt one of the prepared scenarios.

The CNB continuously updates the tools within its FPAS to reflect the recent analytical and forecasting needs and challenges. The most recent update to the core model was introduced in the Monetary Policy Report–Spring 2024, which featured substantial revisions to the foreign economy block. Other tools are also being continually refined. For example, a new suite of wage nowcasting

[1] The CNB's macroeconomic modeling evolved through three generations: first-generation partial equilibrium models, followed by the second-generation Quarterly Prediction Model (QPM), and culminating in the third-generation DSGE model..

models was introduced in autumn 2024, and a new set of high-frequency indicators derived from web-scraped data have been integrated into the analysis of price developments.

In parallel with these model improvements, the CNB has enhanced the way it communicates its economic narrative. Reflecting on the lessons learned from the recent period of double-digit inflation—where certain inflationary pressures were not fully captured by existing tools—the CNB has initiated systematic monitoring of slow-moving inflationary risks and underlying macroeconomic imbalances. These risks are now visually summarized in the Scoreboard of Inflationary and Monetary Policy Risks, allowing for clear communication of risks that may not be fully reflected in the baseline forecast or scenarios.

2 Medium-Term Forecast – g3+ model

The medium-term forecast preparation is based on the core projection model g3+.[2] The core model serves several key functions. First, it forms the center of the FPAS, serving as the unifying framework for constructing staff forecasts at the CNB. Second, g3+ works as a narrative tool, supporting the explanation of forecast story by analyzing the driving forces behind the development of key macroeconomic variables. Third, the model facilitates the preparation of various sensitivity and alternative scenarios, including those based on alternative sets of forecast assumptions or monetary policy responses.

To ensure the operational efficiency of g3+ and to streamline forecast processes, the model prioritizes the key features and stylized facts of the Czech economy, while abstracting from less relevant economic features. These features are integrated into the forecast by other auxiliary (satellite) tools supporting the creation of the forecast. The core model has been updated and enlarged multiple times since its introduction in 2008. First, model parameters, steady-state values, and trends are periodically re-evaluated, recognizing that an economy is a dynamic and evolving entity. Second, the model's structure undergoes periodic reassessment, as economic events and operational experience prompt the introduction of innovations or adjustments to existing linkages.[3]

2.1 The Modelling Approach

The Czech economy is described by a structural two-agent New Keynesian (TANK) small open economy (SOE) dynamic stochastic general equilibrium (DSGE) model, which constitutes a domestic economy block. Additionally, a small semi-structural gap model represents a foreign economy block. Drawing from the New Keynesian (NK) tradition, model g3+ incorporates various nominal rigidities and real frictions. The SOE component establishes the connection between the Czech economy and its primary trading partner, the trade-weighted (effective) euro area. The model design is in line with the standard practice of leading central banks and keeps pace with modelling approaches applied for regular forecasting practice.[4]

The set of first order conditions derived from the optimization of economic agents, supplemented by budget constraints and market-clearing conditions defines the domestic block. The foreign block is characterized as semi-structural, and consists of behavioral equations. The dynamics of the model are governed by a series of underlying processes, collectively referred as technologies.[5] The decision problems of economic agents have intertemporal nature, meaning that decisions of agents have consequences over multiple time periods and also involve expectations. Model g3+ relies on forward-looking model-consistent expectations in the vein of limited rational expectations. The model-consistent expectations framework also has a useful feature of avoiding the Lucas critique, in that the model structure and dynamic behavior is invariant to typical policy changes, such as monetary policy decisions.

We solve the model by applying linear approximation to the set of micro-founded equations. As Andrle (2008) explains the need for the presence of trends in a model of a converging economy, g3+ incorporates endogenous model-consistent identification of trends in observed variables, facilitating a coherent interpretation of cyclical development along the balanced growth path (BGP). The model is set

[2] The g3+ model was first presented to the public in a summarized manner through an Annex to the Inflation Report III/2019, alongside a video blog (in Czech only) and a blog post on the CNB website. A more comprehensive explanation followed in CNB WP 7/2020. Its predecessor, the g3 model, was implemented in 2008 and detailed in CNB WP 2/2009. The latest version of the g3+ model, along with a shadow forecast, was unveiled in an Annex to the Monetary Policy Report – Winter 2024.

[3] For example, explore a thematic article in the Global Economic Outlook – July 2022. Other avenues of potential model development were explored in CNB WP 12/2011 (financial frictions modelling), CNB WP 6/2015 (labor market modelling), and CNB WP 8/2023 (unconventional monetary policy).

[4] For example, see core projections models of the FRBNY (Del Negro et al. (2013)), the Bank of Canada (Corrigan et al. (2021)), the Bank of England (Burgess et al. (2013)), or the ECB (Coenen et al. (2019)).

[5] Technologies are persistent exogenous processes that also define trends in observables and define the balanced growth path.

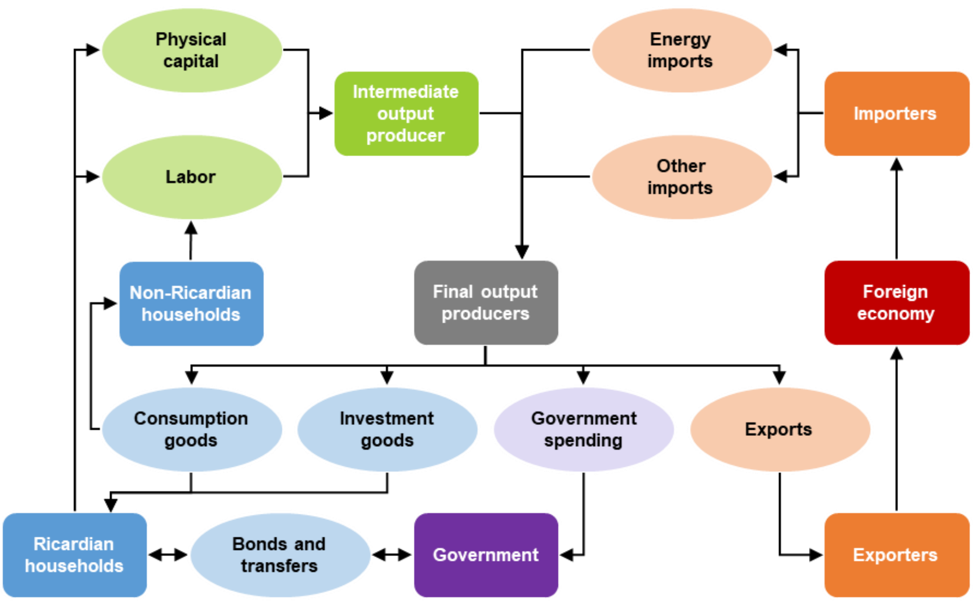
to be stationary around its BGP. When fitting the model to observed data, we refrain from using external pre-filtering or de-trending methods and prefer to use the model structure to estimate the trends endogenously.

2.2 The Core Model

g3+ consists of several types of economic agents: two types of households, four producers, government, foreign exchange dealers, central bank and foreign economy. Figure 2.1 offers a stylized scheme of economic agents and interactions among them, where rounded boxes depict sectors.

- *Households* consist of two types: Ricardians and non-Ricardians. The *Ricardians* engage in the consumption of final goods, featuring an internal habit formation. They rent capital, supply labor to intermediate producers, and earn wages based on Calvo-type contracts. Additionally, they trade in domestic nominal government bonds, but lack direct access to foreign financial markets. The *Non-Ricardians* entirely consume their labor income every period without any access to domestic financial markets.
- The *intermediate production sector* consists of three types of firms. The first one produces *domestic intermediate goods* using physical capital and labor inputs. *Importing firms* comprise two types: *energy* and *core* (non-energy) *importers*. Imported intermediate production does not utilize any domestic inputs. Importers operate under the stickiness of imported goods in the domestic currency. All firms utilize Calvo pricing.
- *Final goods producers* bundle consumption, public spending, investment, and export goods. All goods and services are produced using imported and domestically produced intermediate goods, each with specific technologies. Similar to the intermediate production sector, each final goods sector adopts Calvo price setting. Price stickiness of export goods is modeled under the foreign-currency assumption.
- *The government* is characterized by a period budget constraint and collects taxes, distributes lump-sum transfers, and consumes public spending goods.
- *Foreign exchange dealers*, who have access to international financial markets and trade international currency bonds, collect payments from households and invest in international markets. They transfer net cash-flow back to households.
- *The central bank* implements regime of inflation targeting and sets its policy rate in line with a Taylor-type policy rule.
- *The foreign economy* creates demand for domestic export goods and serves as a source of imported goods (and therefore imported inflation pressures), among other factors.

Figure 2.1: Overview of g3+



2.2.1 Domestic Block

Demand

The model economy is populated by two types of households, of which a fraction $(1 - w^{liq})$ is represented by optimizing Ricardian households (with an access to capital markets and ability to borrow and save to smooth consumption), while the remaining fraction w^{liq} is represented by liquidity constrained non-Ricardian households (without an access to the financial markets), consuming their entire labor income in each period. The aggregated household consumption is then given by:

$$C_t = C_t^{liq} + C_t^{ric}\,, \tag{1}$$

where C_t is aggregate consumption and C_t^{liq} and C_t^{ric} are consumption of respective household types. The fraction of the non-Ricardian households w^{liq} is set to 0.3. The non-Ricardian household consumption choice follow a simple rule stating that the entire labor income is consumed at each period. Therefore, their budget constraint is given by:

$$C_t^{liq} = w^{liq} \frac{W_t L_t}{P_t^C}, \tag{2}$$

where $W_t L_t$ is the labor income and P_t^C is the consumption price level.

The Ricardian households on the other hand face the following optimization problem reflecting habit persistence of consumption and utility from leisure. Households choose their optimal consumption path C_s^{ric}, domestic government bond holdings B_s, investment path J_s and hours worked L_s to maximize their life-time utility function:

$$\max_{\{C_s^{ric}, B_s, J_s, L_s\}} E_0 \sum_{s=t}^{\infty} \beta^{s-t} \left[log\left(\frac{C_s^{ric}(h) - \chi C_{s-1}^{ric}(h)}{1-\chi}\right) \kappa_s^H + \kappa a_t^L (1 - L_s(h)) \right], \tag{3}$$

where parameter χ captures the strength of habit formation behavior. The optimal choice of Ricardian households' is subject to a budget constraint:

$$B_t(h) + P_t^C C_t(h) + P_t^J J_t(h) = i_{t-1} B_{t-1}(h) + P_t^K K_{t-1}(h) + P_t^C F_t(h) + \Psi_t(h) + \Phi_t(h), \tag{4}$$

where expenditures on investment contribute to physical capital accumulation:

$$K_t(h) = [K_{t-1}(h)]^{1-\delta} [J_t(h)/\delta]^{\delta} - \frac{\eta}{2} \left(\frac{J_t(h)}{J_{t-1}(h)} \frac{1}{\alpha\alpha^J} \right)^2 K_{t-1}(h), \tag{5}$$

and labor demand function that is downward sloping with given household's wage $W_t(h)$:

$$L_t = L_t^d \int_0^1 (W_t(h)/W_t)^{-\epsilon} dh. \tag{6}$$

The budget constraint stipulates that households can finance their purchases of government bonds $B_t(h)$, nominal consumption expenditures $P_t^C C_t(h)$, and nominal investment expenditures $P_t^J J_t(h)$, using their income sources, which include the returns from government bonds held from the previous period $i_{t-1} B_{t-1}(h)$, return on their capital stock $P_t^K K_{t-1}(h)$, government lump-sum transfers $P_t^C F_t(h)$, labor income $\Phi_t(h)$ and dividend income from firms $\Psi_t(h)$.

The capital accumulation rule describes how the capital stock evolves over time. The current period's capital stock is determined by combining the depreciated capital from the previous period, represented as $[K_{t-1}(h)]^{1-\delta}$ with new investment adjusted by efficiency, expressed as $[J_t(h)/\delta]^{\delta}$. This is then reduced by the investment adjustment costs, which account for the friction in adjusting the capital stock. In this formulation, parameter δ represents the quarterly depreciation rate of capital, $\alpha\alpha^J$ denotes the steady-state investment growth and η represents the parameter governing investment adjustment costs.

Solving the optimization problem outlined above results a set of first-order conditions that govern the optimal behavior of Ricardian households. The central equation describing the consumption path of household has the following form:

$$\lambda_t P_t^C = (1-\chi)\left(\frac{1}{C_t^{ric}-\chi C_{t-1}^{ric}} - \beta \frac{\chi}{C_{t+1}^{ric}-\chi C_t^{ric}}\right)\kappa_t^C, \tag{7}$$

where shadow price of nominal household wealth λ_t reflects the value of an additional unit of wealth. The habit formation parameter χ represents the degree how past consumption influences utility derived from the current consumption. The discount factor β is captures the household's time preference for current versus future consumption and stochastic process κ_t^C introduces persistent deviations in household preferences, adjusting the relative desire for consumption versus time spent working. Furthermore, the solution of the optimization problem with respect to capital accumulation constraint yields a rule for the path of investment J_t.

Supply

The model domestic economy consists of three intermediate goods sectors (domestic intermediate and energy and non-energy importing sectors) and four final goods producers (consumption, investment, government spending and export goods). Producers operate under monopolistic competition, meaning each firm has some market power to set prices above marginal cost. The pricing behavior of producers follows Calvo-pricing schemes, where only a fraction of firms can adjust their prices in each period. This mechanism creates price rigidities, as many firms are unable to immediately adjust their prices in response to economic shocks.

Domestic producers of intermediate goods combine capital stock and labor acquired from the household sector through competitive markets to manufacture intermediate goods. They employ *Cobb-Douglas production technology*:

$$Y_t = a_t K_t^{1-\gamma}(A_t L_t)^{\gamma} \tag{8}$$

where Y_t represents intermediate goods, K_t and L_t denote production inputs (capital and labor) with respective shares determined by γ, and a_t and A_t are the stationary total factor productivity shock and the nonstationary labor-augmenting technology process, respectively. As exogenous shocks are present, the efficiency of production can vary over time. Importers produce a variety of differentiated import intermediate goods using a common constant elasticity of substitution (CES) technology while they face foreign prices and exchange rate movements, but their prices are sticky in domestic currency.

Final goods producers utilize both imported bundles of goods and domestic intermediate goods to manufacture goods for final consumption. First two types of final goods producers, those producing for government spending G_t and investment goods I_t , employ Leontief production functions. [6] This means that the factors of production are utilized in fixed, predetermined proportions, with no possibility for substitution between them. For $M \in \{G, J\}$, *the production function under Leontief technology* is expressed as:

$$M_t = \min\left\{\frac{N_t^{ener,M}}{\phi^M \omega^M}, \frac{N_t^{other,M}}{(1-\phi^M)\omega^M}, \frac{Y_t^M}{1-\omega^M}\right\}, \tag{9}$$

where $N_t^{ener,M}$, $N_t^{other,M}$ and Y_t^M are imported energy and other components, and domestic intermediate input, respectively. Parameter ϕ^M is the share of energy imports on the production of final good and ω^M stands for the import intensity of the production.

The two remaining final goods producers, responsible for household consumption (C) and export goods (X), utilize a CES production function. This production function allows for some degree of substitution between various production inputs, offering flexibility in the face of changing economic conditions. This

[6] The choice of these two sectors is motivated by the considerable rigidity observed in the government sector, which is constrained by numerous processes and regulations. Furthermore, the investment sector has been chosen due to its specific features and distinct challenges associated with substituting imported investment goods.

substitutability becomes particularly important during extraordinary events, such as the recent significant surge in energy prices, where producers can partially replace expensive energy inputs with other, less costly factors of production, albeit to a limited degree. For producers of goods $O, O \in \{C, X\}$, *the production function* is expressed as follows:

$$O_t = \left[(\phi^O \omega^O)^{\frac{1}{\eta^O}} \left(N_t^{ener,O}\right)^{\frac{\eta^O - 1}{\eta^O}} + ((1-\phi^O)\omega^O)^{\frac{1}{\eta^O}} \left(N_t^{other,O}\right)^{\frac{\eta^O - 1}{\eta^O}} + (1-\omega^O)^{\frac{1}{\eta^O}} (Y_t^O)^{\frac{\eta^O - 1}{\eta^O}} \right]^{\frac{\eta^O}{\eta^O - 1}}, \quad (10)$$

where elasticity of substitution parameter η^O rules the substitution among production factors.

Price and Wage Setting

As mentioned earlier, all firms operate under monopolistic competition and the assumption of Calvo pricing, implying the existence of price rigidities. Firms set their prices as a mark-up over the marginal costs, while taking into account past and expected future changes in inflation. The pricing gives rise to *New-Keynesian Phillips Curves in all production sectors* (ι) of the following form:

$$\pi_t^\iota = \frac{1}{1+\beta}\pi_{t-1}^\iota + \frac{\beta}{1+\beta}\mathrm{E_t}(\pi_{t+1}^\iota) + \frac{(1-\beta\xi_\iota)(1-\xi_\iota)}{\xi_\iota(1+\beta)}\mu_\iota mc_{\iota,t}^r + \epsilon_t^\iota, \quad (11)$$

where π_t^ι is inflation in a respective sector, $mc_{\iota,t}^r$ represent real marginal costs, β is the discount factor, ξ_ι stands for Calvo parameter, μ_ι is a markup and ϵ_t^ι is a price cost-push shock.[7]

The wage-setting process follows a staggered fashion, adhering to the pricing mechanism introduced by Calvo (1983) and Yun (1996). In this framework, households select their preferred wage dynamics under constraints, aiming to maximize their lifetime utility while considering individual labor demand and an indexing scheme during periods when re-optimization is not permitted. Consequently, wage inflation follows a *Hybrid Dynamic New-Keynesian Wage Phillips Curve*, which suggests that wage dynamics comprise a combination of backward- and forward-looking component, influenced by real marginal costs. The wage PC takes the following form:

$$\pi_t^w = \frac{1}{1+\beta}\pi_{t-1}^w + \frac{\beta}{1+\beta}\mathrm{E_t}(\pi_{t+1}^w) + \frac{(1-\beta\xi_w)(1-\xi_w)}{\xi_w(1+\beta)}\mu_w mc_{w,t}^r + \epsilon_t^w, \quad (12)$$

where π_t^w is wage inflation, $mc_{w,t}^r$ represent real marginal costs and ϵ_t^w is a wage cost-push shock.

Model Price Vertical

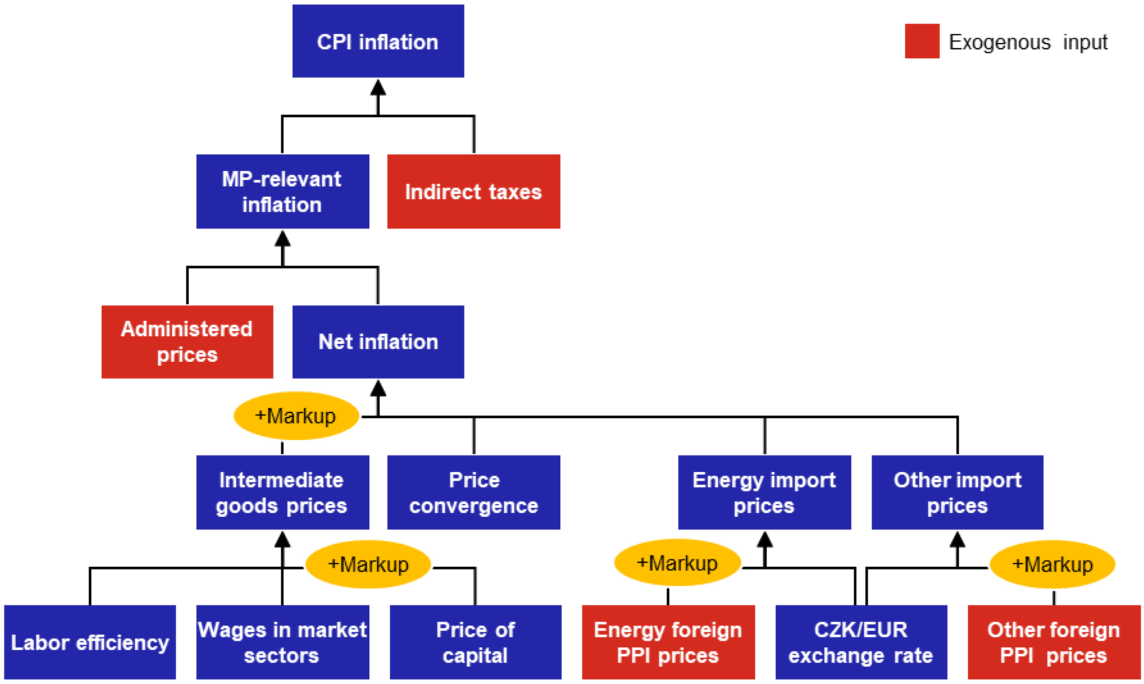
Inflation and its determinants within the g3+ model is captured by a "price vertical" (see Figure 2.3) that follows the layered structure of demand and costs factors in the Czech economy.[8] Overall consumer price inflation is determined by net inflation, administered prices and indirect taxes changes. In g3+ model, the central bank sets interest rates by rule focused on targeting forecast of monetary policy-relevant inflation (MP-relevant inflation), i.e., consumer price inflation adjusted for the first-round effects of changes to indirect taxes. Such adjustment originates from the fact that the first-round effects are beyond the central bank's control (as they result from decisions of government and regulatory authorities) and have only short-term impacts on inflation.

The key variable in the g3+ model is the net inflation, which reflects cost pressures both from the domestic and foreign economy. Besides costs, net inflation includes producers' margins, which reflects demand pressures in the economy. If production factors costs increase, producers can choose whether to respond by increasing output prices or to absorb such increase by cutting theirs margins, depending on a their evaluation of demand environment.

[7] The connection between mark-ups and observed economic data regarding profitability was investigated in a blog post on the CNB website (in Czech only) and in in the Monetary Policy Report – Autumn 2022 (Box 1).
[8]The recent comprehensive description and discussion is presented in the Monetary Policy Report – Summer 2021 (Box 3).

Net inflation depends predominantly on growth in prices of domestic inputs, which is driven mainly by domestic cost factors – wages in market sectors and the price of capital, reflecting the performance of the domestic economy. By contrast, technological progress – captured in the model as increasing labor efficiency – mitigates growth in costs and prices, as rising labor efficiency enables firms to make products using less labor and capital. Domestic inflation is also significantly affected by import prices, which we divide into two components – energy-related and other (core) goods.

Figure 2.3: g3+ Price Vertical



Final Domestic Demand

Interactions with the Foreign Economy

Optimization problem of foreign importers of domestic good (which is assumed to be symmetric to that of domestic importers) leads in *demand function for domestic exports*, expressed as:

$$X_t = \left(\frac{P_t^x}{P_t^{*core}}\right)^{-\theta_x} (\hat{y}_t^*)^{\eta_t^{n*}} \frac{\left(Y_t^{*trend}\right)^{\eta_t^{n*}}}{tech_t^x}, \tag{13}$$

where X_t represents real exports, P_t^x is the export deflator, P_t^{*core} denotes the core foreign producer price index (PPI), which reflects the prices of core goods abroad. The price elasticity of demand θ_x is indicating how sensitive the demand for exports is to changes in relative prices. Further, Y_t^{*trend} is the trend component of foreign GDP representing the long-term growth path of foreign economic activity, $tech_t^x$ is export-stationarizing technology and $\hat{y}_t^*$ is the gap component of foreign GDP representing current position in demand cycle and η_t^{n*} is the time-varying foreign demand elasticity. Demand for domestic exports is decreasing in the relative price of domestic exports with respect to foreign PPI core prices and is increasing in foreign (both potential and cyclical) economic activity.

A representative foreign exchange dealer manages collection of payments from households and invests these funds in international financial markets. The dealer transfers net cash-flows back to households. The dealer also chooses the stock of international currency bonds to maximize the expected net cash-flow evaluated using the households' nominal domestic currency pricing kernel, facing the quadratic adjustment costs that need to be paid to government. The solution of this optimization problem results in *an extended version of the uncovered interest rate parity condition (UIP)*:

$$\frac{i_t}{i_t^*} = \mathrm{E_t}(\Delta\, s_{t+1})^{\rho_S}(\Delta s_t)^{-(1-\rho_S)}(\Delta s_{ss})^{2(1-\rho_S)}\ prem_t^{nfa} prem_t\ \ \exp(\epsilon_t^{UIP}), \tag{14}$$

where i_t and i_t^* represent domestic and foreign nominal interest rates, respectively. The term $prem_t^{nfa}$ represents risk premium associated with the net foreign asset position, while $prem_t$ represents risk country premium composed of long-term and short-term volatile components[9]. The change in the exchange rate Δs_t represents CZK/EUR changes with its steady-state rate Δs^{ss} and ϵ_t^{UIP} is a one-off UIP shock. This relationship states that the weighted average change in the nominal CZK/EUR exchange rate (comprising current, expected, and steady-state values) equals the interest rate differential between domestic and foreign nominal interest rates, adjusted for the effects of the debt-elastic premium and the general risk premium (up to the UIP shock).

The debt-elastic premium is linked to the net asset position (also known as Net Foreign Assets or Net Foreign Debt position), which is defined as the current account and net foreign debt motion of the domestic economy. It is driven by debt repayment, the need for additional financing, and nominal net exports as a representation of the trade balance. Over the long-term, we assume zero contribution from this premium, and ensuring model stationarity in line with the approach of Schmitt-Grohé and Uribe (2003).

Government

The government collects taxes (such as value-added and labor income taxes) and fees (including transaction costs), distributes lump-sum transfers, and consumes public-spending goods. Additionally, we allow for the accumulation of public debt; hence, the government faces *a period budget constraint*, which is given by:

$$B_t^G = i_{t-1}B_{t-1}^G + P_t^G G_t + P_t^C F_t - \frac{\zeta_B}{2} S_t \tilde{B}_{t-1} - (\tau^W + \tau^S)W_t L_t - \tau^C P_t^C C_t, \tag{15}$$

where B_t^G is a public debt, P_t^G is a government price deflator, G_t stands for a public sector goods consumption (nonproductive enhancing spending), F_t are lump-sum transfers, τ^S social contribution rate of employed (intermediate good production), τ^W represents a labor income tax and τ^C is value-added tax. As explained in Schmitt-Grohé and Uribe (2003), government also bears the costs $\frac{\zeta_B}{2} S_t \tilde{B}_{t-1}$ of trading bonds by foreign exchange dealers on international markets.

The fiscal rule in the model states that the nominal government spending develops proportionately to the nominal spending of households, thus maintaining the steady-state ratio of these two aggregates in nominal terms. The presence of fiscal shocks results in deviation from this proportion. The fiscal rule, therefore, supports the assumption of model agents that the government spending will not follow an explosive path. The fiscal authority guarantees its intertemporal solvency via adjustment of public transfers. At the same time, the domestic Ricardian households absorb the government debt by purchasing government bonds.

Monetary Policy

The central bank implements a regime of inflation (forecast) targeting and follows an interest rule with an interest rate smoothing feature. The monetary authority in the model targets the deviation of year-over-year MP-relevant inflation[10] from its target four quarters ahead. The rule takes the form:

[9] The long-term and short-term risk premiums are modelled as autoregressive processes of order one (AR(1)). The estimation of these premiums over a historical period is an integral part of the initial state identification. Throughout the forecast horizon, the risk premiums are typically expected to converge toward their steady-state levels, reflecting long-term equilibrium. However, experts may adjust the premium process to capture our views related to the regional sentiment and risk position of the Czech economy. A more detailed discussion on initial state identification and forecasting is presented in Section 2.5.

[10] MP-relevant inflation is defined as headline inflation adjusted for first-round effects of changes to indirect taxes.

$$i_t = (i_{t-1})^{\rho_i} \left(i_{ss} \mathrm{E}_t \left(\frac{E_t \pi_{t+4}^4}{\pi_{t+4}^{tar4}} \right)^{\psi} \right)^{(1-\rho_i)} exp\{\epsilon_t^i\}, \quad (16)$$

where i_{ss} is the steady state of nominal interest rates, $E_t\pi_{t+4}^4$ is year-over-year expected MP inflation, π_{t+4}^{tar4} is the one-year-ahead inflation target, ρ_i is an interest rate smoothing parameter, ψ is a strength of the policy response to inflation developments and ϵ_t^i is a monetary policy shock.

2.2.2 Foreign Block

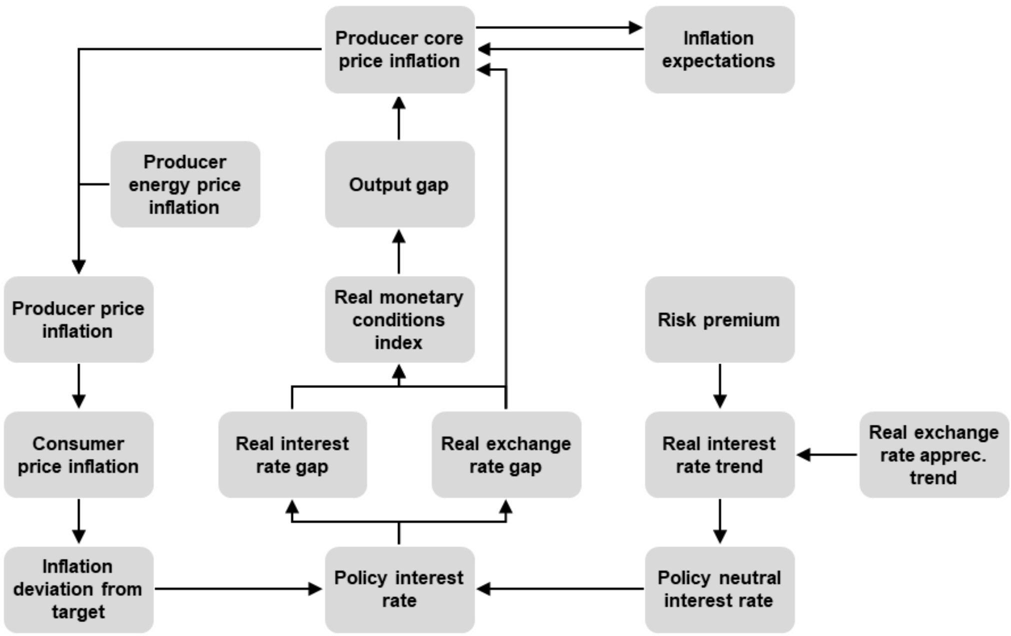
The foreign economy block of g3+ is represented by a small semi-structural gap model based on New-Keynesian principles of effective euro area (EA), in which the foreign economy variables are mutually connected. Unlike simple, mutually independent autoregressive models, this approach significantly enhances the identification of the foreign economy's position within the business cycle, offering a coherent and detailed framework for interpreting foreign economic dynamics.

This model allows for a more nuanced analysis of key foreign factors. For instance, it enables the decomposition of producer price inflation to assess the specific contributions of different drivers, such as the European Central Bank's (ECB) monetary policy actions or the sharp increase in energy prices during 2021–2022. Its structure facilitates a deeper understanding of how international economic developments influence the Czech economy.

Additionally, the euro area economy block is designed as a closed system that operates independently of the Czech economy, allowing for clear analysis without feedback effects from domestic conditions. Its relatively small size makes the model practical and efficient for operational use, enhancing its applicability for policy analysis and forecasting.

The effective EA describes the aggregate behavior of main trading partners of Czech economy and considers the rest of the world represented by the United States. The effective euro area comprises an EA6 aggregate (Germany, Slovakia, France, Italy, Spain, and Austria), which accounts for approximately 57% of Czech exports. Figure 2.2 outlines the scheme of the foreign block.

Figure 2.2: Foreign Block of g3+



The equations of the foreign block comprise semi-structural behavioral equations, definitions and identities, and autoregressive processes. The core behavioral equations include *the IS curve* describing the EA output gap, the *open economy version of the Phillips curve* depicting EA core producer prices inflation, *the inflation-targeting monetary policy rule* setting foreign nominal interest rates, and *the nominal US dollar-euro exchange rate equation*.

From a practical standpoint, the foreign economy block serves as a consistency check for narrative based on assumptions given by foreign outlook variables trajectories, which are gross domestic product, the harmonized index of consumer inflation, producer prices (and their sub-indices), 3M EURIBOR, and EUR/USD. The outlooks for foreign effective GDP, HICP and PPI are results from computation outside of the foreign economy block via various econometric methods and expert judgment. 3M EURIBOR and EUR/USD are derived from financial instruments and the Consensus Forecast publication, respectively.[11] Given these trajectories, the foreign economy block is able to endogenously provide estimate of the output gap and potential output, and also apply expert judgment if needed. Foreign block is also able to support narrative of effective EA economy outlook with identification of foreign structural shocks.

Overall, the effective EA economy block in g3+ represents a significant advancement in the CNB's capability to analyze and predict the effects of foreign economic conditions on the Czech economy, ultimately aiding in more informed policy-making decisions.

Economic Activity

The foreign output gap, $\hat{y}_t^*$, is characterized by *the dynamic IS* curve that captures the relationship between demand and monetary conditions. The equation takes the following form:

$$\hat{y}_t^* = a_{y^*}\,\hat{y}_{t-1}^* - a_{y^*}^{r^*}\,\hat{r}_{t-1}^* + a_{y^*}^{z}\,\hat{z}_t + \epsilon_t^{\hat{y}^*}, \tag{17}$$

where $\hat{y}_{t-1}^*$ is the lagged output gap, representing persistence and resembling to habit formation, $\hat{r}_{t-1}^*$ is the lagged real interest rate gap, approximating the effects of foreign monetary policy conditions, $\hat{z}_t$ represents the USD/EUR real exchange rate gap, which accounts for the exchange rate channel in an open economy, and $\epsilon_t^{\hat{y}^*}$ is a demand shock.

Producer Price Inflation

The foreign produced prices index, $\tilde{P}_t^*$, is composed of two parts: core and energy components. Formally, the PPI equation is given by

$$\tilde{P}_t^* = \left(\tilde{P}_t^{*energy}\right)^{\rho_{*\frac{ener}{ppi}}} \left(\tilde{P}_t^{*core}\right)^{1-\rho_{*\frac{ener}{ppi}}}, \tag{18}$$

where $\tilde{P}_t^{*energy}$ and $\tilde{P}_t^{*core}$ are the energy and core components, weighted by the energy share $\rho_{*\frac{ener}{ppi}}$ The weight assigned to the energy component is 28%, leaving the remaining portion of 72% to the core component. The structure of the PPI gives rise to both energy and core PPI inflations. The energy PPI inflation is represented by a simple autoregressive process of order one, whereas the core PPI inflation is structurally interpreted through *the forward-looking Phillips curve* (PC):

$$\tilde{\pi}_t^{*core} = a_{\pi^{*core}}\,\tilde{\pi}_{t-1}^{*core} + (1 - a_{\pi^{*core}})\,E_t\tilde{\pi}_{t+1}^{*core} + a_{\pi^{*core}}^{y^*}\hat{y}_t^* + a_{\pi^{*core}}^{z}\,\hat{z}_t + \epsilon_t^{\tilde{\pi}^{*core}}, \tag{19}$$

where $\tilde{\pi}_t^{*core}$ is core PPI inflation and $\epsilon_t^{\tilde{\pi}^{*core}}$ is a cost-push shock. The PC links the output gap $\hat{y}_t^*$, as a proxy for demand, along with the real exchange rate $\hat{z}_t$, to core inflation $\tilde{\pi}_t^{*core}$. Both the output gap and the real exchange rate gap serves as proxies for real marginal costs.

Monetary Policy Rule

Monetary policy of the ECB is described by *a simple inflation forecast-targeting rule* with an element of interest rate smoothing. The rule accounts for developments in demand, represented by output gap, and

[11] For more details on foreign economic environment forecast tools, see Section 5.1.

the deviation of expected year-over-year HICP inflation from the target in a four-quarter horizon. The rule is given by:

$$i_t^* = a_{i^*} i_{t-1}^* + (1 - a_{i^*}) \left(i_t^{*eq} + a_{i^*}^{y^*} \hat{y}_t^* + a_{i^*}^{\pi^*} \left(E_t \tilde{\pi}_{t+4}^{*cpi4} - \tilde{\pi}^{*cpi4} \right) \right) + \epsilon_t^{i^*}, \tag{20}$$

where i_t^* stands for the euro area policy interest rate, i_t^{*eq} represents its equilibrium, $\hat{y}_t^*$ is the EA6 output gap, $E_t \tilde{\pi}_{t+4}^{*cpi4}$ is year-over-year HICP inflation (four quarters ahead expectation), $\tilde{\pi}^{*cpi4}$ captures the inflation target and $\epsilon_t^{i^*}$represents a foreign monetary policy shock.

USD/EUR Exchange Rate

The effective euro area is assumed to be an open economy. Its counterpart, the rest of the world, is represented by the United States. A modified version of an uncovered interest rate parity condition establishes the dynamics of the nominal US dollar-euro exchange rate. It is expressed as follows:

$$0 = \rho_{usdeur}\, \Delta usdeur_{t+1} - (1 - \rho_{usdeur}) \Delta usdeur_t + \left(i_t^* - i_t^{*eq} - prem_t^{usdeur} \right) + \epsilon_t^{\Delta usdeur}, \tag{21}$$

where $\Delta usdeur_t$ is a nominal USD/EUR pair depreciation, $prem_t^{usdeur}$ represents a risk premium, and $\epsilon_t^{\Delta usdeur}$ is the foreign UIP shock.

2.2.3 Balanced Growth Path

The balanced growth path is a key concept in dynamic macroeconomic models like g3+, which deals with economies with non-stationary variables, those that either do not exhibit a steady state or possess multiple steady state rather remaining static. Essentially, a balanced growth path is the long-term trajectory along which all relevant economic variables either grow at a constant rate or remain constant relative to one another. This ensures a kind of equilibrium in which the economy grows consistently without internal imbalances over time.

The real stochastic growth trends of BGP are driven by a set of technological processes, each modeled as AR(1) processes. These include:

- *Labor augmenting technology,* A_t, governing the underlying growth of economy,
- *Investment-specific technology*, A_t^J, capturing medium-term deviations from domestic investment,
- *Trade productivity technology*, A_t^X, accounting for Baumol-Bowen and Balassa-Samuelson effects, which allow for productivity differences across sectors,
- *Willingness to work technology,* A_t^L, introducing non-stationarity in the hours worked,
- *Public goods sector-specific technology*, A_t^G,reflecting productivity trends in the provision of public goods,
- *Trade openness technology*, A_t^O, representing the increasing trade openness of the domestic economy to international trade.

The *implied aggregate rate of growth,* ΔZ_t, is derived from the growth rates of these technologies, particularly, investment-specific A_t^J, labor-augmenting A_t, and willingness-to-work A_t^L, according to the following equation:

$$\Delta Z_t = \frac{1-\gamma}{\gamma} \Delta A_t^J + \Delta A_t - \Delta A_t^L \tag{21}$$

where γ is the labor share in the Cobb-Douglas production function for domestic intermediate goods, as given by Equation (6). Sector-specific trends lead to the emergence of trends in relative sector prices, and the model's structure results in interactions among these technological processes. Table 2.1 summarizes the steady-state growth rates of all technologies.[12]

On top of the real trends, the model also incorporates two nominal trends:

- *Administered price goods and services technology,* A_t^R, introducing a trend in the relative price between net and headline consumer price index baskets,
- *Consumer price index*, π_t^{tar4}, reflecting the CNB's inflation targeting framework, which is assumed to follow a predetermined rate, underscoring the central bank's commitment to maintaining price stability.

In sum, the BGP is a theoretical construct that provides a stable framework for modeling economic growth in a way that accounts for both real and nominal trends over the long term. This framework enables g3+ to incorporate sector-specific growth differentials while remaining consistent with CNB's broader inflation-targeting monetary policy. Importantly, the BGP allows for non-stationary variables, meaning variables that do not revert to a fixed steady state but instead follow growth trends driven by technological progress and other factors, which is necessary for model consistent identification of trends.

Table 2.1: Steady-state Growth Rates of Technologies (QoQ annualized, %)

	Notation	**Value**
Labor augmenting	ΔA	2.5
Public goods sector-specific	ΔA^G	0
Investment-specific	ΔA^J	0
Willingness to work	ΔA^L	0
Trade openness	ΔA^O	1.4
Trade productivity	ΔA^X	1.3
Implied aggregate rate of growth	ΔZ	2.5
Administered price goods	ΔA^R	0

2.2.4 Model-Consistent Expectations

The dynamics of DSGE models, which involve both backward- and forward-looking elements, hinge on the assumptions regarding how individuals form expectations. Typically, DSGE-type models operate on the premise of 'rational expectations', first introduced by Muth (1961) and further refined by Sargent (1986). The concept suggests that expectations can be considered rational if the current values of variables, on average, align with the expected values. This means that individuals do not make systematic errors in their predictions and that their predictions are not biased by past errors. The key implication of rational expectations is that government policies, such as changes in monetary or fiscal policy may not be as effective if individuals' expectations are not considered.

The core model framework adheres to this principle[13], but we adjust how conditioning information from our forecast outlooks are treated by agents.[14] In general, forecasts must integrate all relevant information about future developments. These developments are captured in the modelling framework through anticipated future events or unexpected shocks.[15]

[12] The implied aggregate rate of growth have been adjusted several times since the introduction of the g3 model: 5.0 (2008Q3–2010Q1), 4.0 (2010Q2–2013Q3), 3.0 (since 2013Q3), 2.5 (since 2024Q3). To account for these past changes in growth, the model features convergence add-on technology.

[13] There are several model equations that explicitly contain expectations of decision variables (e.g. inflation, deflators, wages, or the nominal exchange rate). The laws of motion for expected values are obtained as part of the solution of the model under the assumption of rational expectations. In general, their numerical values are not a result of a simple formula as they in fact depend on all the remaining variables in the model. This part of core model expectations is not directly affected by the LIRE approach (as discussed later).

[14] Conditioning assumptions and their treatment is described in Section 2.5.

[15] In central banks' forecasts, future events are classified as anticipated or surprise shocks. Surprises occur unexpectedly, catching economic agents off guard, while anticipated events are predicted in advance, allowing agents to prepare and react beforehand and mitigate their impact. The LIRE approach affects how the conditioning assumptions on the forecast are translated into anticipated and unanticipated shocks.

Treating forecast conditioning information as anticipated information should be the natural choice for central bank forecasts for two key reasons. First, central banks aim to incorporate all available information into their forecasts, thereby prompting economic agents to anticipate future events. Treating these events as surprises could lead to policy errors, as it contradicts the proactive nature of central bank communication. Second, without anticipating future developments, inflation forecasts may fail to reach the target within the policy horizon, risking the anchoring of inflation expectations.[16] Reacting to an event only when it occurs, including the central bank's response, may be too late to effectively bring inflation back to the target due to transmission lags.

While utilizing anticipated events offers several advantages, they also come with drawbacks. The assumption of having complete information about future events is often deemed unrealistic, leading to what's known as the 'forward guidance puzzle'.[17] Moreover, agents' reactions to expected news differ depending on the time horizon – both the magnitude of the shock and the duration of the horizon play crucial roles.

In our core projection framework, we rely on an approach grounded in the Limited Information Rational Expectations (LIRE) concept[18] to address or mitigate potential drawbacks. Within this framework, information regarding expected future events is integrated into agents' information sets in a controlled manner. Full forward-looking behavior is restricted to only several quarters ahead, with less weight given to information about more distant events. Near-term events receive full consideration in agents' decision-making, while very distant ones are disregarded. As the forecast trajectory progresses, each quarter corresponds to a shift in the foreseen window, gradually incorporating distant events. An example of a LIRE scheme definition for a given exogenous shock is illustrated in Figure 2.4.

Figure 2.4: An Example of a LIRE Scheme

Horizon / Period	year $y+1$				year $y+2$				year $y+3$				year $y+4$			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
current period	1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0	0	0	0	0
quarter $q+1$	P	1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0	0	0	0
quarter $q+2$	P	P	1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0	0	0
quarter $q+3$	P	P	P	1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0	0

Note: Historical data are assumed available until Q4 of year y. Therefore, the forecast in the current round begins in Q1 of year y+1. Columns represent periods of the forecast horizon, while rows represent forecasted periods in the current round (and subsequent rounds starting from the given period). The values indicate the proportion of the shock considered anticipated. "P" denotes the predicted value from the previous period.

The LIRE approach proves particularly valuable amidst extraordinary events and times of high macroeconomic uncertainties, where the distant future remains highly unclear. The prime example is the euro area outlook – although being very uncertain and also volatile on longer forecast horizons, these distant events would otherwise lead to substantial forward-looking reactions of domestic agents (and monetary policy). This method effectively addresses challenges such as the limited impact of future events on current decisions, the low availability and reliability of distant outlooks, and the high dispersion of long-run projections regarding future events. Essentially, it means that highly uncertain news about the distant future has little to no immediate effect on current macroeconomic behavior or monetary policy responses. However, as these events draw nearer, their relevance increases, prompting corresponding reactions.

[16] Much attention was recently given to the inflation expectations, the main findings were summarized in CNB WP 3/2024.

[17] The forward guidance puzzle describes a scenario where monetary policy responses to anticipated future events intensify as those events are expected further into the future. In some cases, the initial reaction to the expected event may even differ from that of the unanticipated version, or it may indicate considerable volatility in optimal behavior. These phenomena are often difficult to explain and understand.

[18] The CNB's approach as described in a form of a blog post on the CNB website and also in CNB RPN 2/2021 is in principle similar for example to De Droot and Mazelis (2020).

2.3 Parametrization and Data

2.3.1 Parametrization

The Foreign Block

In the semi-structural framework of the foreign block (focused on cyclical fluctuations), each behavioral equation holds an economic interpretation, although the coefficients are reduced forms rather than deep parameters. The long-term characteristics of trends represent enduring properties of the effective euro area economy.

Table 2.2 outlines these long-term properties of trending variables. With the latest release of the updated version of g3+, the potential effective EA GDP growth has been revised downwards to reflect recent trends. The setup of effective EA HICP inflation aligns with the ECB target. Additionally, the current setup assumes a 2% growth rate for the energy component of effective EA PPI, consistent with the growth rates of both the core component and the overall PPI. Furthermore, there is no long-term assumption of Euro appreciation against USD, which corresponds with the properties of USD/EUR outlooks. The level of nominal interest rate and implied natural values reflect the communication of the ECB regarding its monetary policy.

Table 2.2: Long-term Characteristics (Steady States Values) of the Effective Euro Area Block

QoQ (annualized), %	Notation	Value	Level, %	Notation	Value
GDP	Δy^*	1.6	Nominal Interest Rate	i^*	2.5
Potential GDP	Δy^{*trend}	1.6	Real Nat. Rate of Interest	i^{*eq}	0.5
HICP	$\tilde{\pi}^{*cpi}$	2.0	Risk Premium	$prem^{usdeur}$	0.0
PPI	$\tilde{\pi}$	2.0			
Core PPI	$\tilde{\pi}^{*core}$	2.0			
Energy PPI	$\tilde{\pi}^{*ener}$	2.0			
USD/EUR	$\Delta usdeur$	0.0			
RoW Infl. Target Wedge	Δz^{eq}	-2.0			

The majority of dynamic parameters in the foreign block are estimated. Exceptions include the parameter of the policy response to expected inflation, the persistence in the IS curve, and the standard deviations of measurement errors. Table 2.3 offers a concise overview of the main dynamic parameters.

Table 2.3: Reduced Form Parameters of Foreign Economy Block

Parameter	Notation	Value	Parameter	Notation	Value
IS Curve			**Phillips Curve (Core PPI)**		
Lag	a_{y^*}	0.750	Lag	$a_{\pi^{*core}}$	0.187
Real Interest Rate Gap	$a_{y^*}^{r^*}$	0.113	Output Gap	$a_{\pi^{*core}}^{y^*}$	0.108
Real ER Gap	$a_{y^*}^{z}$	0.017	Real ER Gap	$a_{\pi^{*core}}^{z}$	0.010
Monetary Policy Rule			**USD/EUR UIP**		
Interest rate smoothing	a_{i^*}	0.791	Lead	ρ_{usdeur}	0.334
Expected Inflation	$a_{i^*}^{\pi^*}$	2.000	**Foreign PPI**		
Output gap	$a_{i^*}^{y^*}$	0.198	Energy Share in PPI	$\rho_{*\frac{ener}{ppi}}$	0.280

The Domestic Block

In the micro-founded domestic block of g3+ model, each behavioral equation carries an economic interpretation, with coefficients serving as deep parameters, as is standard in the DSGE framework.

Table 2.4 provides an overview of the long-term properties of domestic trending variables. With one of the recent release of the updated version of g3+, the growth of imports and exports has been revised downwards to reflect economic trends observed in recent years. The assumed long-term appreciation of the CZK exchange rate is determined by long-run interest rate differential and real economic convergence.

Table 2.4: Long-term Characteristics (Steady State Values) of the Domestic Economy Block

Growth, %	Notation	Value	Level, %	Notation	Value
GDP	Δy	2.5	Nominal Interest Rate	i	3.0
Household Consumption	Δc	2.5	Inflation Target	π^{tar}	2.0
Investment	Δj	2.5			
Government Consumption	Δg	2.5			
Imports	Δn	4.8			
Exports	Δx	4.8			
CZK/EUR	Δs	-1.0			

Deep parameters in the domestic block are calibrated and reviewed by separate estimations. These parameter values are derived from long-term characteristics and refined through a combination of literature review, data observation, and fine-tuning of model properties. The most distinctive parameters of the domestic economy are outlined in Table 2.5.

Table 2.5: Deep Parameters of Domestic Economy Block

Parameter	Notation	Value	Parameter	Notation	Value
Habit Formation	χ	0.80	Elasticity of Subst. Consumption	η^c	0.05
Discount Factor	β	0.9975	Elasticity of Subst. Exports	η^x	0.05
Forward-lookingness of UIP	ρ_s	0.65	Foreign Demand Elasticity	η^{n*}	3.00
Calvo Imports Energy	$\xi_{Nenergy}$	0.25	Government Cons. Rule	ρ_g	0.85
Calvo Wages	ξ_L	0.85	Price Elasticity of Exports	θ	1.00
Calvo Exports	ξ_X	0.70	Elasticity of Subst. Consumption	η^c	0.05
Calvo Consumption goods	ξ_ι	0.65			

The last set of parameters comprises the standard deviations of structural shocks. These determine the stochastic properties of the model and are both estimated and calibrated, taking into consideration the observed variance in the data and model properties. Given their significance, we provide a visualization of their resultant properties through forecast error variance decompositions in Section 2.4.

Parameter Revisions

The parameters of the model undergo regular reassessments over the time. The steady-state values of the model are adjusted when data indicate structural changes in the economy or there are clear signals regarding the expected evolution of the Czech economy that differs from the implemented settings. Additionally, each upgrade of the model prompts us to either change or at least review the reduced-form and deep parameters of the model to align with its new structure. In these instances, the parameters are either estimated or calibrated based on existing literature or out-of-model estimations to ensure the model behavior remains consistent with the stylized facts of the Czech economy.

2.3.2 Observed Data

The core model is linked to observed data through an observation block. Model g3+ includes distinct observation blocks for foreign and domestic parts, reflecting the organization of the forecasting process. A complex and detailed description of data inputs offers Figure 2C.1 in Appendix.

The foreign economy block draws upon effective EA data, which is defined by trade-weighted variables of the six most significant euro area countries, based on Czech export weights. These are Germany, Slovakia, France, Italy, Spain and Austria, which account approximately for 60% of Czech exports. Our decision to monitor a narrow group of countries is based on the observation that overall PPI and GDP dynamics exhibit quite similar trajectories in effective terms for both the EA6 and the full composition.[19]

[19] We have been using effective euro area indicators since 2006 (see Box 1 in the Inflation Report III/2006). However, their definitions have changed over time. We started with eleven member states (excluding Luxembourg due to limited data availability) and gradually expanded to seventeen member states (also excluding Malta due to the same reasons) in 2018. We have been using the EA6 aggregate since the latest update of g3+ in 2024.

The effective EA GDP and its decomposition into trend and gap is identified endogenously. Effective EA PPI inflation is composed by its energy and core component. The effective EA PPI and CPI indicators are a result of CNB's calculations based on country data from the Eurostat database. The decomposition into their energy and core components follows the Statistical Classification of Economic Activities in the European Community (NACE). Nominal dollar-euro exchange rate comes from Bloomberg. Monetary policy in the euro area is described by the shadow interest rate and its equilibrium level. The shadow rate series is a 3M EURIBOR rate adjusted for the effects of ECB's balance sheet policies. This relies on the estimation of the effects of the ECB's unconventional monetary policies according to CNB calculations based on the data sourced from Bloomberg. The observed data sample for the foreign block starts from the 1998Q1.

The domestic economy observed data originate mainly from the Czech Statistical Office and CNB's calculations. The real economic activity is represented by real consumption, investment, imports and exports, while the government consumption is observed in nominal terms. In addition, the respective deflators for the individual components of GDP are also in the set of the observed variables. Further, the nominal side of model is represented by price observations, which include net prices, administered prices and overall consumer price index level. The inflation target has evolved over time and model structure covers also past values of target. Observed labor market data include evolution of worked hours and nominal wage level. Domestic monetary conditions are represented by 3M PRIBOR interest rate and CZK/EUR exchange rate, which originate from ARAD system.

2.4 Model Properties

The evaluation of model performance and the determination of opportunities for further model improvements includes examining both stochastic and deterministic properties of g3+. Commonly, we perform the following set of analyses to check model properties and model's alignment with observed reality.

- **Recursive filtering and forecasting**: Recursive simulations with updated exogenous assumptions allow for a dynamic assessment of how well the model predicts future outcomes.
- **Variance decomposition**: The decomposition indicates the amount of information that each variable contributes to the other variables, thus shedding light on the relative importance of different factors in forecasting.
- **Impulse response functions** (IRFs): The IRFs provide a dynamic illustration on how the model responds to various shocks and highlights their propagation and implications on the economy.
- **Historical decomposition:** Analyzing how the model attributes observed changes to structural shocks offers insights into the understanding of business cycles and economic dynamics.
- **Comparison of model moments with data moments**: This comparison helps ensure that the model accurately reflects the data and relationships observed in the real world.

Here, we briefly present selected analyses from this area.

2.4.1 Recursive Filtering and Forecasting (In-Sample Simulations)

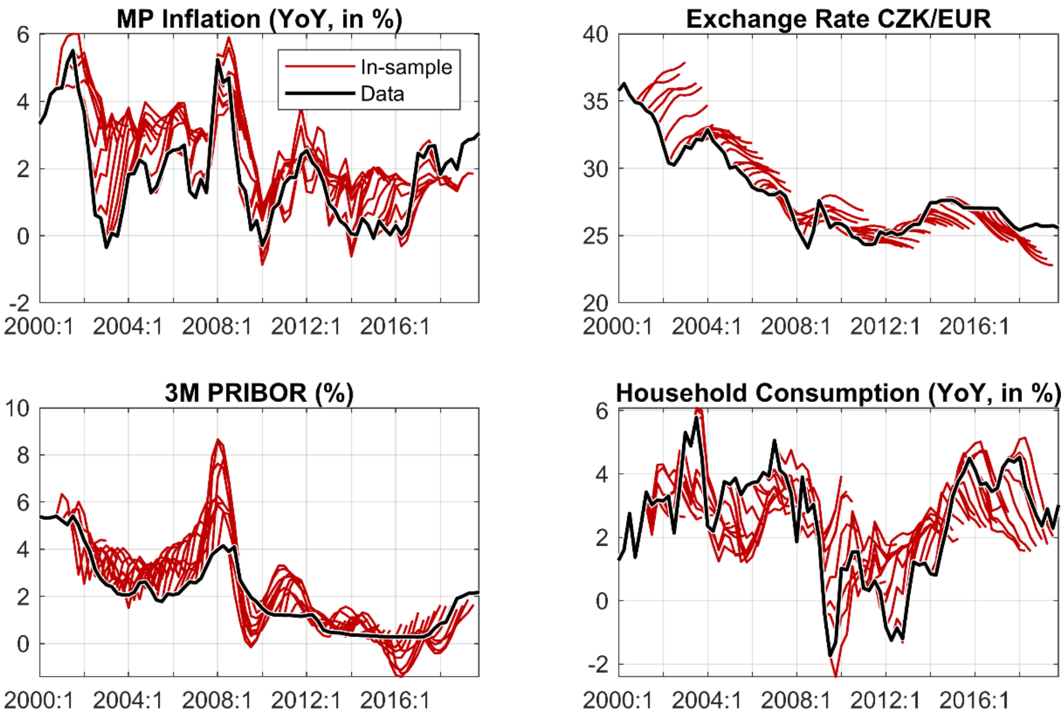
This analysis utilizes a recursive approach that involves identification of forecast initial state and then producing projections while using conditioning assumptions in a mechanical manner without any expert judgments. Simulations are generated recursively, with the sample window expanding by a quarter in each new iteration. These projections are then evaluated against observed data.[20]

The simulations presented in Figure 2.5 demonstrate that, given the complexity of real-world mechanisms, model forecasts align well with observed trajectories, and there is no systematic bias. This supports the general validity of the model's structural relationships and calibration in describing the Czech economy properly. However, certain non-standard events (such as the binding zero-lower bound on nominal rates situation combined with the exchange rate interventions by the CNB during 2013–2017), which are not accounted for in the model design, adversely affect the fit of in-sample simulations.

[20] A detailed discussion of in-sample simulations is presented in CNB WP 7/2020.

This indicates that the model relying only on forecast conditioning assumptions cannot fully capture all real-world dynamics, emphasizing the importance of expert judgments and continual model updates. Notably, a recent model update significantly improved in-sample forecasts accuracy, as evidenced by a reduction in the root mean square errors.[21]

Figure 2.5: Recursive Filtering and Forecasting



Note: The presented In-sample simulations cover the time period or 2001Q1–2019Q4 and exclude the extraordinary years of the Covid pandemic and the Russian aggression against Ukraine.

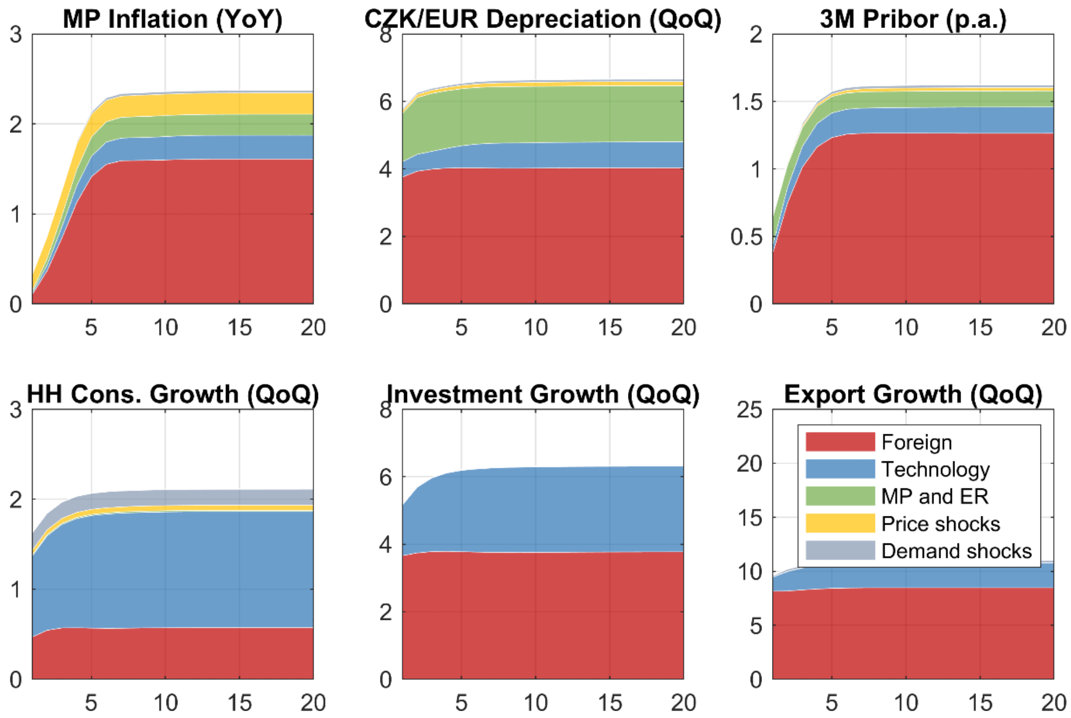
2.4.2 Variance Decomposition

The forecast error variance decomposition brings insights into the relative importance of different factors driving model-based forecasts. This decomposition allows to identify which shocks have the significant impact on forecast uncertainty. Additionally, it facilitates the identification of potential areas for model improvement by pinpointing sources of forecast error variance that may be addressed through model refinement or data enhancement.

As depicted in Figure 2.6, foreign shocks emerge as the primary source of the variance decomposition, reflecting the status of the Czech economy as a small, export-oriented economy. In the latest model update, substantial amendments have been implemented, primarily through refining the structural representation of the foreign economy. At the same time, some of the domestic variables have been amended recently as well. For example, the variance decomposition of investments reflects a revised understanding of the relationship between domestic investment activity and foreign demand.

Figure 2.6: Forecast Error Variance Decomposition

[21] See Table 2B in an Appendix to the Monetary Policy Report – Winter 2024.



Note: The horizontal axis displays quarters.

2.4.3 Impulse Response Functions

Appendix 2E presents a collection of impulse responses to selected structural shocks for reference. Below, we delve into the propagation of four commonly used unexpected unit shocks: foreign monetary policy, wage-push, domestic monetary policy and one-off UIP shock. We refer the reader to Brázdik et al. (2020) for a detailed discussion on other IRFs.

A *foreign monetary policy shock* (shown in Figure 2E.1) results in an uptick in foreign interest rates. Higher foreign interest rates dampen foreign demand and also foreign inflation. At the same time, the koruna depreciates via the interest rate differential. The decrease in foreign core prices worsens Czech exporters' price competitiveness. Domestic consumption and investment also decrease in response to the lower foreign demand and tight domestic monetary conditions. Overall, domestic GDP declines. Weaker koruna sparks higher import costs, causing domestic inflation to increase. In response, the domestic monetary authority raises interest rates.

The wage-push shock (illustrated in Figure 2E.4) directly boosts domestic nominal wages. The increase in wages enhances households' purchasing power, as reflected in heightened consumption, leading to higher overall inflation pressures. The central bank adjusts its stance by raising interest rates. The resulting wider interest rate differential vis-à-vis the euro pushes the koruna to appreciate, leading to lower price competitiveness of Czech exporters, thereby leading to a notable decline in export activity, overweighting the upward move in consumption. Consequently, there is a slight drop in real GDP.

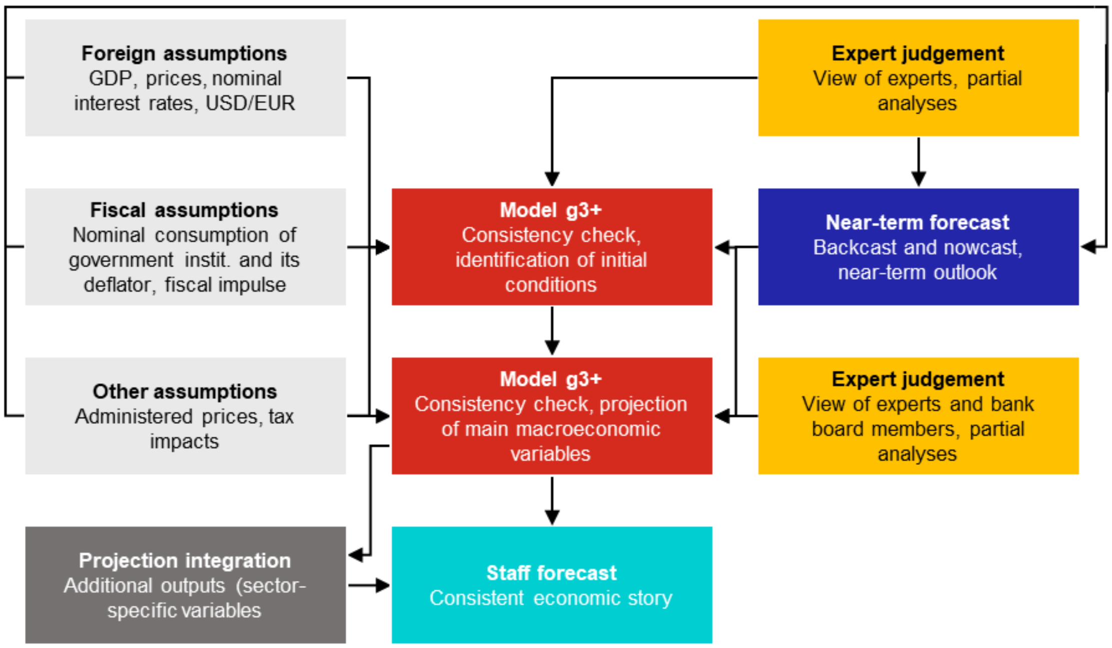
The domestic monetary policy shock (illustrated in Figure 2E.6) directly triggers an increase in domestic interest rates, consequently appreciating the koruna due to a wider interest rate differential. The ensuing tighter monetary policy conditions result in lower current consumption due to an intertemporal substitution, leading to a reduced economic activity. This in turn translates into decreased production, a decline in nominal wages, and a decrease in inflation. The depreciation of the koruna also reduces the competitiveness of domestic exporters, causing their lower activity and contributing to the overall contraction and lower inflation.

The one-off exchange rate shock (depicted in Figure 2E.7) leads to a depreciation of the koruna, which sparks inflation pressures via import prices. In response, the central bank reacts by raising the interest rates. At the same time, weaker domestic currency stimulates exports as domestic goods become more affordable for foreign entities. Higher demand for domestic production results in labor demand pressure, causing wages go up. Despite the increase in wages, real consumption falls due to the higher costs of imported goods and tighter monetary policy. The overall impact on domestic GDP is positive, since the contribution of export growth outweighs the negative contribution of the remaining components of the domestic demand.

2.5 How Is the Medium-Term Forecast Prepared

The development of the medium-term forecast using the core projection model involves several stages and integrates information from various sources. The preparation of the forecast is summarized in the scheme presented in Figure 2.7.

Figure 2.7: Medium-Term Forecast Preparation



2.5.1 Conditioning Assumptions

Each forecast is conditioned on a set of assumptions (trajectories) related to foreign and domestic factors that are beyond the scope of monetary policy actions or endogenous mechanisms.[22] These conditioning assumptions consist of:

g3+ related exogenous outlooks for the effective EA:

- Effective EA real GDP and its decomposition into trend and gap,
- Eff. EA producer prices inflation and its components (energy-related and other),
- Eff. EA HICP inflation,
- Nominal EURIBOR 3M interest rates and their shadow unconventional counterpart,
- USD/EUR exchange rate.

g3+ related exogenous outlooks for the Czech economy[23]:

- Nominal consumption of government institutions and its deflator,
- Fiscal impulse contributions to real household consumption and private investment,
- Administered prices inflation and tax impacts.

The outlooks for model exogenous variables (except for the effective EA GDP foreign-block-based decomposition) are generated outside of the core projection model using a variety of econometric

[22] A high-level description of conditioning outlooks offers Figure 2C.1 in Appendix C.
[23] Section 4 offers a detailed discussion related to fiscal assumptions.

approaches (described below in a dedicated Sections 3 and 4). Once they enter the projection, they are treated as given and interpreted in a model consistent manner. Additionally, the developments given by all these exogenous outlooks are to some extent anticipated by model agents, as outlined in the LIRE approach in Section 2.2.

2.5.2 Near Term Forecast (NTF) Assumptions

From a medium-term projection standpoint, we also incorporate additional assumptions about near-term outlook, specifically for the first quarter of the forecast, concerning the CZK/EUR exchange rate and domestic consumer price index (CPI) inflation. This approach is driven by the availability of exchange rate and inflation (or inflation-related) data on a frequency higher than quarterly. When preparing a regular forecast, the most recent data from the ongoing quarter are already known and utilized by nowcasting techniques. This provides the most precise estimates through empirical data-driven methods accompanied by expert judgment available at that time. These are implemented as mechanical 'hard assumptions'.

In contrast, NTF outlooks related to the real economic activity and the labor market are implemented using a combination of structural shocks interpreted through the structure of g3+. These near-term outlooks are integrated into the model using expert judgments via a combination of relevant structural shocks.

2.5.3 Initial Conditions Identification

The initial phase of forecast production entails the identification of initial conditions, specifically the most recent observed quarter. During this stage, the historical input database—including nowcasts and newly available historical revisions—is utilized. A Kalman filter (in the form of smoother, to be precise) approach is employed to identify unobserved model variables, including structural shocks that correspond to observed data and reflect the underlying model structure.

Expert judgments, informed by supplementary evidence such as time-series data that do not directly enter the model but serve as proxies for unobserved variables (e.g., model-based profit margins compared to unit profit data from national accounts), are also incorporated. In certain instances, observed data may be affected by non-fundamental developments, such as inventory fluctuations impacting gross capital formation or one-off wage compensations, which are considered temporary with no lasting effects. In such cases, we mitigate their impact by integrating expert judgments to limit the propagation of such information throughout the forecast horizon. This process enhances the understanding of the current macroeconomic situation regarding model variables and sets the initial conditions for the forecasting step.

2.5.4 Forecasting

The second step involves the forecasting process itself, starting from the initial conditions and constructing a conditional forecast simulation that considers the assumptions described above. A group of corresponding structural shocks is found to align with the conditioning trajectories.[24] Additional structural shocks are utilized to integrate expert judgments into the resulting forecast simulation. Throughout the forecast horizon, the judgments primarily serve to incorporate available information about future events in the domestic economy into the simulation. Generally, NTF and nowcast estimates are regularly incorporated into the simulation, as mentioned above. Additionally, anticipated one-off events such as increases in the minimum wage, secondary impacts of tax changes, or large private investment projects announced to the public are integrated as well.

[24] Specifically, we task the model toolbox to solve for suitable combination of given structural shocks that delivers the conditioned trajectories of required variables.

2.5.5 Expert Judgements

The important and irreplaceable role of expert judgments during the forecast[25] preparation is illustrated in Table 2.6. The table displays the relative difference of Root Mean Square Errors (RMSEs) in percent between real-time forecasts compared to pure model-based, no-judgment in-sample simulations at selected forecast horizons. The evaluation of the forecast errors is conducted on the pre-pandemic sample spanning from 2010Q1 to 2019Q4. Since the time series of GDP growth is subject to historical revisions, real-time forecast errors were calculated with respect to the first data releases.

Table 2.6: The Role of Expert Judgements (Relative Difference in RMSEs in %)

	Forecast horizon	
	t+1	t+4
CPI Inflation (YoY)	-66	-18
Real GDP growth (QoQ)	-41	-28
PRIBOR 3M	-73	-71
CZK/EUR	-45	-8

As indicated by the table, which displays the main forecasted variables, the integration of expert judgments into projections leads to more accurate simulations for all main variables, compared to purely model-based ones (negative numbers in the table denote an improvement in projections when expert judgments are incorporated). This illustrates the essential role of judgement in the forecasting process.

2.5.6 Integration

The final step leading to the staff forecast presented in our Monetary Policy Reports (MPR) is the integration. The integration step involves forecasting other macroeconomic variables or computing additional and satellite outputs that are not directly produced by the core projection model, while conditioning on the outputs from the core model projection.

2.5.7 Complementary Scenarios

In addition to the baseline scenario, regular forecasting exercises also involve the construction of additional scenarios, each serving a specific purpose.[26]

Alternative Scenarios

These scenarios illustrate alternative economic developments that could occur with a certain degree of certainty. They are based on different sets of assumptions and result in comprehensive forecasts, including integration steps. Examples of such scenarios are typically motivated by major events leading to an alternative development abroad like Brexit or a halt in energy commodity supplies from Russia to the EU[27].

Sensitivity Scenarios

These are designed to capture a sensitivity of the baseline scenario to a particular macroeconomic aspect. First, such scenario may originate from certain assumptions different from the baseline (for example, a different setting of the NTF exchange rate[28]). Second, sensitivity scenarios might focus on a certain macroeconomic feature that is not present in the baseline version of the core projection model. In this case, the alternative version of core model may be used to deliver scenario simulation. In this

[25] The role of expert judgements during forecast is discussed, e.g., in this blog post (in Czech only) on the CNB website.
[26] An extensive list of scenarios and simulations is included in Appendix 2F.
[27] For the scenario of a complete and permanent halt in energy commodity supplies from Russia to the EU see an Annex to the Monetary Policy Report – Summer 2022 (Appendix).
[28] See, e.g., Monetary Policy Report – Spring 2024.

case, an alternatively calibrated or even a structurally adjusted version of the core projection model can be used to produce such a scenario.[29]

Monetary Policy Simulations

These simulations are based on the baseline scenario, but incorporate an additional assumption about domestic monetary conditions, typically concerning the path of domestic nominal interest rates. Unlike in the baseline scenario, where the domestic interest rate path is determined endogenously, for the purpose of policy experiment the interest rate is conditioned on exogenously given trajectory. During 2022, monetary policy simulations with different setting of the monetary policy horizon were conducted, later even becoming a baseline scenario.[30]

2.6 Forecast Evaluation

The FPAS also includes elements aimed at evaluating forecasting tools or forecasts themselves. Here, we present some of the approaches, which are conducted on a quarterly or yearly frequency and their results are presented to public.[31]

2.6.1 Comparison with the Previous Forecast

The most common method of forecast evaluation involves the comparison of the current forecast with the previous one. The forecast team analyses changes in the underlying unobserved model variables related to the updated input database of observables and external assumptions. This analysis yields a decomposition of factors leading to changes in the projected trajectories.[32] Specifically, the change in the domestic nominal interest rate between two consecutive forecasts is regularly presented in CNB's Monetary Policy Report. This decomposition reveals what is the impact of newly available data, how have the external assumptions changed and/or how have the expert judgments been revised and what the corresponding monetary policy-relevant impacts are.

2.6.2 Assessment of the Fulfilment of the Inflation Target

Another tool used in every forecast round is the decomposition of the deviation of domestic CPI inflation from its inflation target.[33] This tool is constructed by decomposing the deviation of year-on-year inflation from its steady state (2% inflation target) into structural shocks. Contributions of the specific structural shocks are then grouped into factors with economic interpretations. This process examines the broad macroeconomic story behind the drivers of the deviation of inflation from target, thus shedding light on the sources of forecast errors. Results of this analysis are included in the supplement of every Monetary Policy Report – Chartbook (Chapter D). Additionally, a thematic box providing an in-depth assessment is prepared regularly once a year.

2.6.3 Annual Forecasts Evaluation

Each year, the CNB undertakes a thorough *evaluation of past projections*.[34] Typically, two-year-old forecasts are considered, as this timeframe corresponds to the usual lag in the transmission of monetary policy and also aligns with the policy horizon. The evaluation assesses the accuracy of external assumptions and forecasts of key macroeconomic variables, with particular attention to the sources of forecast errors.

[29] See, for example, Monetary Policy Report – Winter 2024.
[30] See a related discussion in this blog post (in Czech only) on the CNB website.
[31] The first informal public evaluation of g3+ model was done at its one-year anniversary in the form of a blog post (in Czech only) on the CNB website. The experience gained from the forecast rounds during the pandemic was described in this blog post (in Czech only). The evaluation of monetary policy in 2021 and 2022 was done using counterfactual scenarios and presented in this blog post.
[32] See CNB WP 12/2015 for details.
[33] See Box 1 in the Monetary Policy Report – Winter 2024 (Box 1).
[34] See an Annex to the Monetary Policy Report – Spring 2024 (Appendix).

As part of this process, *a synthetic simulation with the knowledge of assumptions (factors)* is constructed for selected past projection as a counterfactual scenario, demonstrating what the prediction would have been if the current vintage of assumptions (foreign and domestic) had been used.[35] This counterfactual scenario helps to determine to what extent the forecast errors can be attributed to factors such as historical data revisions or inaccuracies in external assumptions. The remaining forecast errors are attributed to structural shocks. These, if systematic, could indicate potential model misspecification or omission of important factors.

In the following part, we provide a discussion on the fulfilment of the CNB's forecasts for key macroeconomic variables since 2008. Figure 2.8 depicts the historical projections and their alignment with actual values[36]:

CPI Inflation

- Before Covid, the accuracy of forecasts was roughly stable, although larger errors were observed at the outset of foreign exchange interventions, driven by expectations of a more rapid increase of inflation than materialized.
- Forecasts from 2021 are the least accurate. The CNB forecast has anticipated a swift emergence of disinflationary pressures, whether from external factors or shifts in domestic demand, which would steer inflation back toward its target.
- As we approached the peak of the inflationary wave in 2020, forecasts began to align again – the disinflationary process was fairly well predicted.

GDP Growth

- GDP forecasts exhibit some of the largest discrepancies, partly due to data revisions.
- Our forecasts deviated the most (particularly on the longer end of the forecast horizon) in the period before Covid, as we did not fully anticipate the sharp downturn of the Czech economy.
- Nevertheless, following the downturn, our forecasts generally regained their accuracy from previous years.

3M PRIBOR

- Interest rates rank among the most accurately predicted variables, largely because they serve as a policy tool and the Bank Board uses the trajectory as a benchmark and guidance for the decisions.
- Nevertheless, over time, the disparity between forecasted and actual outcomes has been high since 2020; higher variance emerged during the Covid period and the energy price crisis.

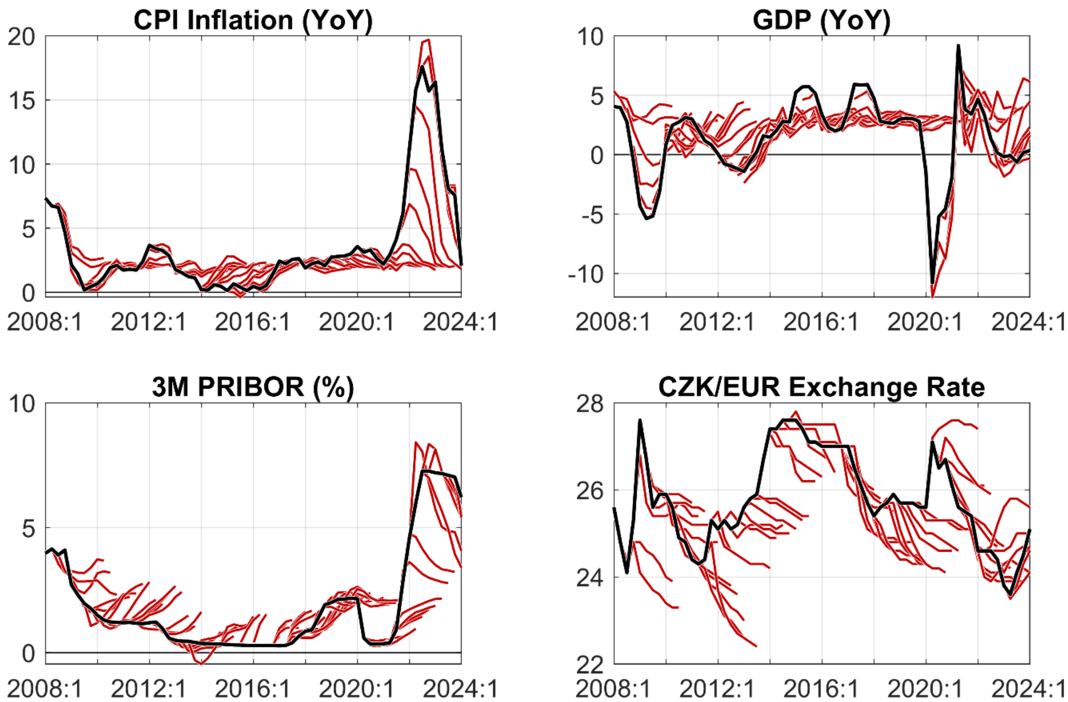
The CZK/EUR Exchange Rate

- Since 2014, the predictive accuracy of the Czech koruna exchange rate forecasts has significantly improved.
- Unsurprisingly, the highest predictive accuracy was achieved during the exchange rate intervention period.
- Interestingly, in the years following 2020, marked by substantial fluctuations in the koruna, predictive accuracy remained high. Our forecast evaluation analysis suggests that this can be partially attributed to the applied expert judgments regarding CZK/EUR developments, reflecting regional sentiment.

[35] In fact, the counterfactual scenarios are constructed and evaluated internally on a quarterly basis for all historical forecasts. Each year, one selected historical forecast is then evaluated and included as part of the publicly available publication.

[36] Figure 2C.2 in Appendix 2C offers a more detailed look on the inflation forecasts.

Figure 2.8: Accuracy of the CNB's Forecasts for Key Macroeconomic Variables since 2008



Note: Each red line represents a single macroeconomic projection; the black lines depict data.

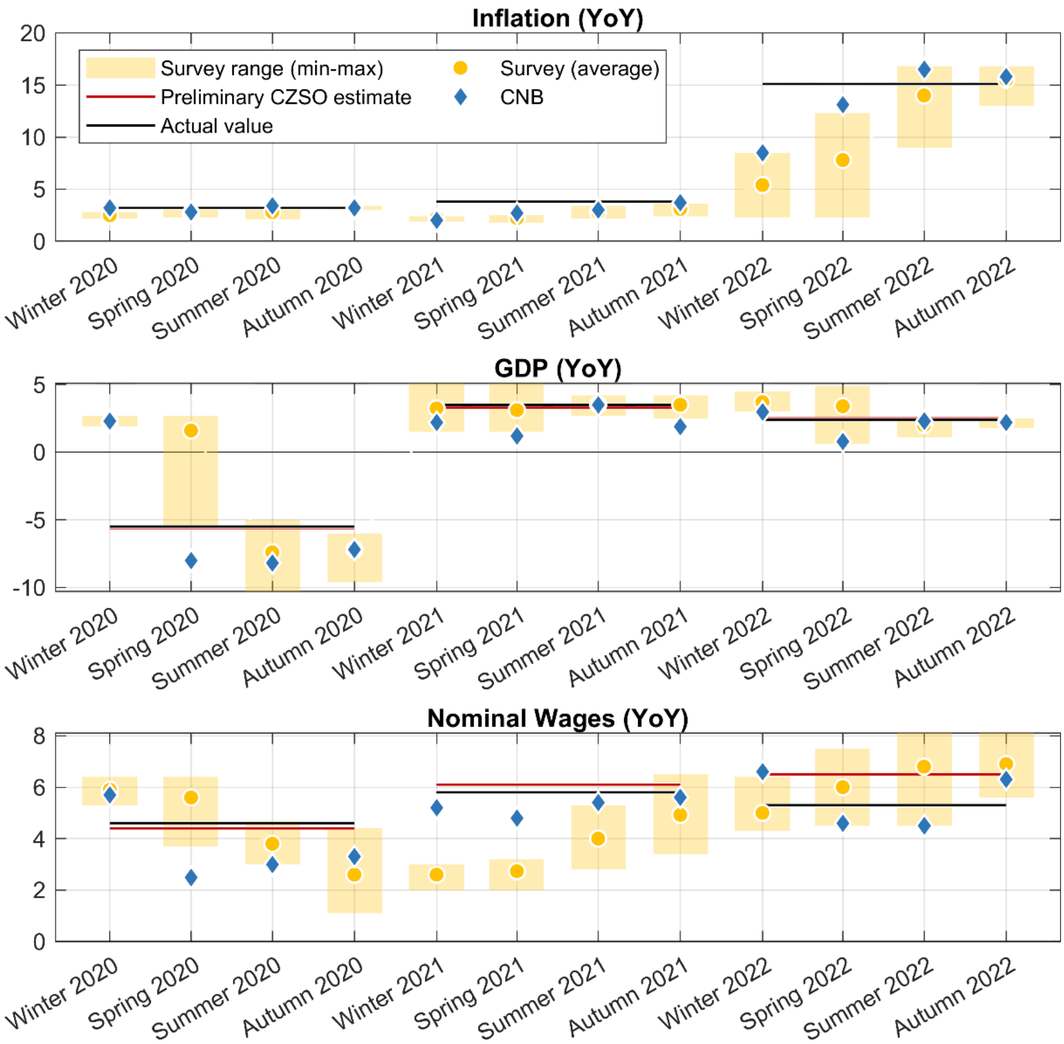
Finally, the last part of the annual forecast evaluation compares *the forecasting accuracy of the CNB to its peers*, such as Czech commercial banks and the Ministry of Finance. To offer a view on how the CNB performed with respect to other institutions in 2020 to 2022, i.e. in extraordinary years, we present the data in Figures 2.9 and 2.10.[37]

The regular evaluation process ensures ongoing improvement in the CNB’s forecasting tools and helps to refine the models by identifying areas where external shocks, data revisions, or structural changes might have caused forecast errors.

[37] In 2020, the Ministry of Finance decided not to produce its summer forecast due to the turbulent economic conditions caused by the Covid pandemic. As a result, the comparison lacks this input for that point.

Figure 2.9: Comparison of Forecasting Accuracy (current year)

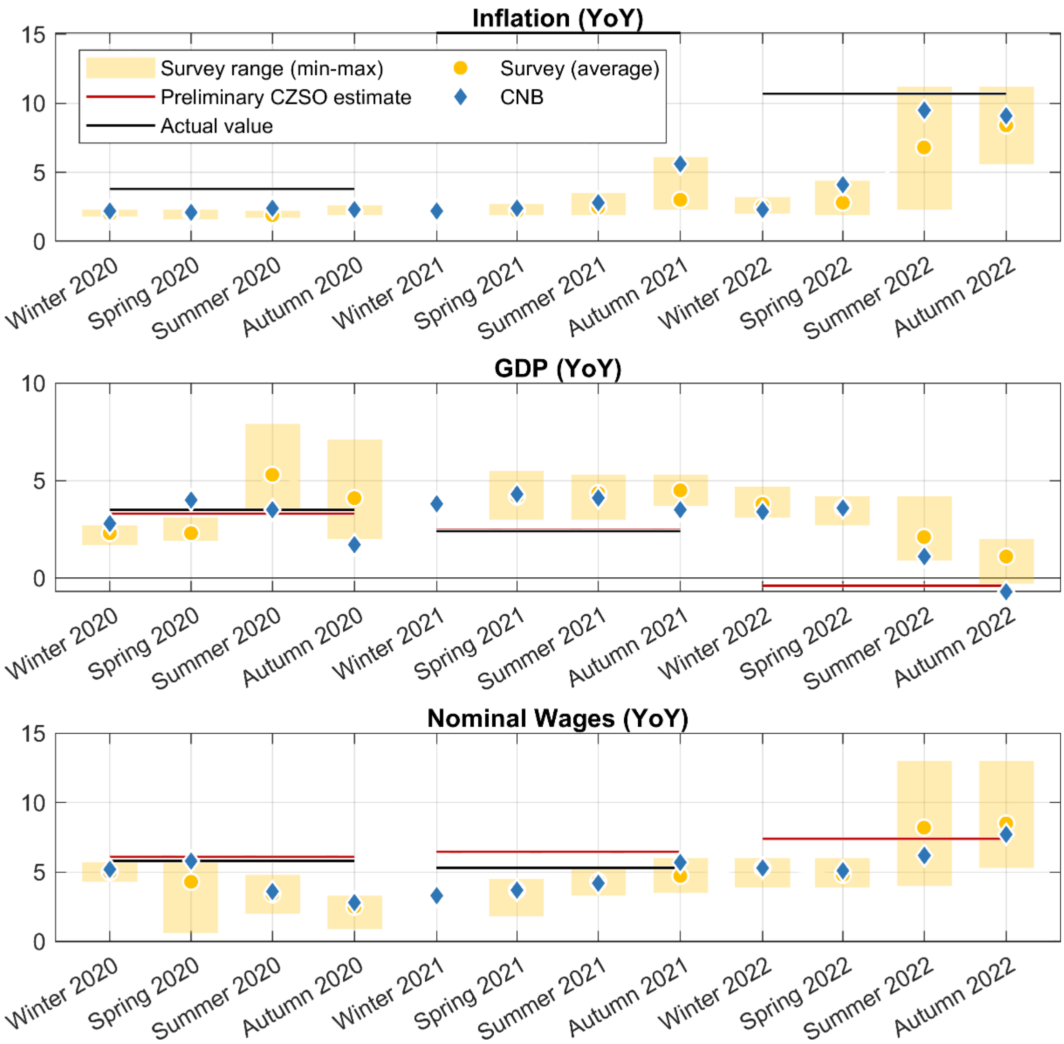
Example: The blue CNB diamond corresponding to "Spring 22" in the "GDP" chart shows the full-year GDP growth estimate for 2022 from the central bank forecast published in spring 2022 (i.e. the Spring 2022 MPR).



Note: The data sources for this analysis include forecasts from the Czech National Bank (CNB) and the Ministry of Finance (MoF), as well as the MoF surveys published in the 2020-2022 Macroeconomic Forecasts of the Czech Republic. These surveys incorporate publicly available forecasts from 13 institutions: eight domestic entities (including the CNB, Czech Banking Association, Ministry of Labor and Social Affairs (MLSA), and various domestic commercial banks) and five foreign institutions (such as the European Commission, Organization for Economic Co-operation and Development (OECD), and International Monetary Fund (IMF)). For the purposes of this document, CNB forecasts are excluded from the survey and presented separately.

Figure 2.10: Comparison of Forecasting Accuracy (one year ahead T+1)

Example: The blue CNB diamond corresponding to "Spring 22" in the "GDP" chart shows the full-year GDP growth estimate for 2023 from the central bank forecast published in spring 2022 (i.e. the Spring 2022 MPR).



Note: The data sources are the CNB and Ministry of Finance (MoF) forecasts and the MoF surveys published in the 2020-2022 Macroeconomic Forecasts of the Czech Republic. The MoF surveys are based on the publicly available forecasts of 13 institutions, eight of them domestic (CNB, Czech Banking Association, MLSA and domestic commercial banks) and the others foreign (e.g. European Commission, OECD, IMF). For the purposes of this document, the CNB's forecasts are excluded from the survey and displayed separately. In its winter 2021 forecast (and in the survey), the MoF did not publish data for 2022 in whole-year terms and hence the data are missing.

3 Near-Term Forecast

The Near-Term Forecast (NTF) unit is a vital part of the CNB's FPAS. In addition to production of nowcasts and short-term forecasts for the key sectors of the Czech economy, the NTF team also prepares and integrates projections for sector-specific variables not included in the core projection model g3+. Similar to the medium-term forecast, the NTF is based on conditioning assumptions regarding both foreign and domestic developments. Beyond its forecasting role, the NTF team also provides in-depth analyses of current economic issues and developments within the Czech economy. NTF experts are responsible for interpreting real-time data releases, analyzing forecast deviations, and explaining recent economic trends.

The NTF focuses on three primary areas: price developments, labor market, and economic activity. A set of models is used for each area (see sections below for further discussion). The consistency of forecasts across these areas is achieved through multiple iterations during each forecast round. The final iteration at the end of every forecast round, known as the integration step, ensures consistency across the macroeconomic projection and provides detailed sectoral computations in the form of satellite models.

In relation to core projection model g3+, the NTF team provides the following set of inputs/outputs:

- *Estimation of initial conditions* (backcast and nowcast) and *the near-term outlook* for the first quarter of the forecast[38],
- *Medium-term conditional forecast* and *satellite computations*, particularly for labor market, inflation analysis, output gap assessment, potential product estimations, and some *external assumptions entering* the core projection model, such as administered prices and tax impacts on prices.
- *Expert judgments* drawn from microdata, sectoral analyses*, and identification and quantification of specific economic factors/effects* not inherently included in our models.

The near-term forecast, analyses of topical issues, and current domestic economy developments are presented to the Board members during the first preparation meeting of the Monetary Department. The presented material also includes a comparison between the previous near-term outlook and the newly observed numbers.

An integral part of the NTF's work involves gathering and processing new types of data, including mixed-frequency, granular, and rich datasets obtained through web-scraping technologies. The NTF team's tasks during the forecasting process are divided into two main groups: one focuses on preparing the forecast itself, while the other concentrates on refining forecasting methods, enhancing data visualization, data visualization, conducting sector-specific analyses[39], or applied research[40].

3.1 Price Developments

The NTF of inflation developments provides in-depth analysis of the inflationary processes in the economy[41] and support the core projection model with relevant details. Besides the projections for key price aggregates variables, the NTF provides monitoring, analytical handling and quantitative assessment of information with potential impact on inflation (e.g. news, changes in VAT taxes, excise duties etc.), shaping the expert judgement and incorporating real-time data (e.g. web scraping).

---

[38] An illustrative example was the outbreak of the Covid pandemic, during which the core projection model primarily served as a consistency check, while the NTF unit prepared outlooks encompassing the entire forecast horizon. For further details, refer to the Annex of the Monetary Policy Report – Spring 2022.

[39] Recent analyses include, e.g., investigating the reasons for households' increased propensity to save (see Box 1 in the Monetary Policy Report – Summer 2023), analyzing wage growth (refer to Box 1 in the Monetary Policy Report – Spring 2023), and assessing the impact of elevated energy prices on households and businesses (see Box 2 in the Monetary Policy Report – Winter 2023).

[40] Recently, e.g., CNB WP 3/2024.

[41] For additional examples of recent analyses dedicated to the Czech economy refer to Appendix 3A.

3.1.1 Main Inflation Subcomponents

The NTF of inflation is based on bottom-up aggregation. The main inflation subcomponents are analyzed, and their projections are aggregated to deliver headline inflation projection. All the subcomponent series (except for administered prices) are adjusted for the effects of indirect taxes that are modelled separately.

The *core inflation* is modelled according to two different approaches: (i) the weighting of four (single-equation) models including different set of explanatory variables (foreign CPI, domestic PPI, domestic unit labor costs, import prices and others) and (ii) disaggregated approach based on the identification of key subcomponents of core inflation and their respective forecasts. The final forecast is the synthesis of these two approaches.

The forecast of *food price inflation* is guided by the development of agricultural prices. Additionally, the nowcast also incorporates information through web scraping, which involves the daily collection of prices from several Czech online retailers. *Fuel prices* are modeled based on the dynamics of Brent crude oil prices and fluctuations in the exchange rate. Web scraping is also employed to gather current-month fuel price data from petrol stations. Core, food and fuel inflations together constitute *net inflation* (or market-based inflation), which is also forecasted using the core forecasting model.

The last subcomponent are the *administered prices* that are forecasted in a disaggregated framework. With the exemption of natural gas prices (which is linked to the commodity futures), the forecasts benefit from expert judgements based on incorporating information provided by regulatory authorities, key players in the particular market etc. The NTF projection of administered prices is treated as an exogenous outlook by the core model over its forecast horizon for conditioning. Contrary, the above-mentioned net inflation (market prices) is fixed in the core projection model only for the first quarter of the projection.[42]

3.1.2 Other Inflation-Related Tools

The integration process delivers the consistency of the core-model forecast and the short-term modelling at the final stages of every quarterly forecast round. As the core-forecasting model does not feature net inflation subcomponents (core, food and fuel price inflation), the top-down approach is applied to secure overall consistency. Within the integration process, the net inflation trajectory from g3+ model is used to create integrated and consistent trajectories of core inflation π_t^{core}, the fuel price inflation π_t^{fuel} and the food price inflation π_t^{food}. A state space model is used for this decomposition.

The top-down approach is based on the aggregating equation for net inflation π_t^{net}:

$$\pi_t^{net} = \frac{w_t^{core}\pi_t^{core} + w_t^{fuel}\pi_t^{fuel} + w_t^{food}\pi_t^{food}}{w_t^{core} + w_t^{fuel} + w_t^{food}}, \tag{18}$$

where w_t^{core}, w_t^{fuel} and w_t^{food} are time varying weights of components in net inflation. The processes for the inflation components are defined as open economy versions of backward-looking Philips curves that include additional factors. These factors account for import prices, labor market pressures, oil price, USD/CZK exchange rate and secondary tax effects. Parameters of the Philips curves and remaining processes are re-estimated within each forecast round by the use of all available data.

Taking the outlooks for the factors and net inflation π_t^{net}, the trajectories for inflation subcomponents are estimated by maximum-likelihood approach build on the Kalman smoother. This technique allows including expert judgments into the estimation

We also forecast *house prices* using conditional BVAR and VECM models employing disposable income, mortgage interest rate, supply of new flats and expected exchange rate appreciation as data inputs. In addition, data from the State Administration of Land Surveying and Cadaster (available one-quarter earlier than the house price index (HPI) published by the Czech Statistical Office, CZSO) are utilized for a nowcast. The forecast of house prices is used for prediction of *imputed rent*, which has

[42] For additional details on utilizing near-term forecast, see Section 2.5.

non-negligible weight (around 10%) in the consumer basket for the computation of headline CPI. The projection of the imputed rent is a combination of results from two models. Besides the aforementioned house prices forecast, a prediction of prices of construction works is based on construction materials prices and Labor Utilization Composite Index (LUCI).

In addition, the NTF inflation team is also responsible for analyzing and forecasting *producer prices*, as well as *import and export prices*.

3.2 Labor Market

When analyzing and forecasting the labor market development, we divide our focus between the nominal (wage) and real aspects of the labor market. Due to data release delays (often as long as six months and subject to sizeable revisions), the NTF pays close attention to backcast and nowcast.

3.2.1 Nominal Variables

The official wage statistic, released by the CZSO, represents the main wage variable of interest in predicting the nominal part of the Czech labor market. In our framework, we further divide overall wages into the (officially unpublished) *wages in market sector* and *wages in non-market sector* based on the NACE sector methodology.[43] We forecast these separately, since only the market sector wages can be considered endogenous, are used in the g3+ model and form market-driven inflationary pressures. During the forecast process, we typically work with four variables available on monthly basis (survey of wages in industry, wages in construction, social-security contributions in the national budget data and the data from the Czech Social Security Administration) that are highly correlated with the official quarterly wage statistic published much later. Moreover, we employ information obtained by web scraping of the job advertisements from Czech web portals to adjust our forecast further.[44]

Since the forecast in spring 2024, a new set of nowcasting models, including machine learning, has been implemented.[45] These models rely on a range of explanatory variables, both nominal and real. These tools govern expert judgements implemented in wage forecasts.

Within the nominal aspect of the labor market, forecasts of two main variables, wages, and the *full-time equivalent number of employees*, are computed. Additionally, other variables such as the *total wage bill*, which further enter the NTF framework of GDP, or *nominal unit labor costs*, are computed for the full forecast horizon, following the statistical methodology of each variable.[46]

3.2.2 Real Variables

Employment and unemployment variables, which are key components of the real part of the labor market, are primarily derived from time-series data collected through the quarterly labor force survey (LFS) published by the CZSO. In addition to the quarterly data, the forecasting models integrate monthly data, such as the monthly LFS and the share of unemployed persons published by the Ministry of Labor and Social Affairs (MLSA). These variables are incorporated into the forecast to support expert judgments, along with indicators such as the number of newly created vacant job positions, the number of jobseekers, and results from questionnaire surveys (e.g., Manpower agency, Business and Consumer Survey by the European Commission, or the Labor Hoarding Indicator).

[43] NACE sectors belonging to the non-market sector are O (Public administration and defence; compulsory social security), P (Education), R (Arts, entertainment and recreation) and S (Other services activities). Other sectors are considered as market sectors.
[44] Wage growth for the whole year is cross-checked with data on wage rates from the consulting agency Business Development Advisory (BDA) and conjectural survey of the CNB and the Confederation of Industry of the Czech Republic.
[45] These methods are Bridge equations, MIDAS, Elastic net, Lasso, Supporting Vector Machines, Random Forest, ARIMA, Ridge and Dynamic Factor Models.
[46] A complete list of variables that outcome the forecasting models contains: nominal unit labor costs, the index of real wages, nominal volume of wages and salaries and real volume of wages and salaries.

Beyond these variables, forecasts are also made for key labor market metrics, such as the *number of employees* and the *share of unemployed persons*.

To provide a comprehensive evaluation of labor market conditions, we utilize the *Labor Utilization Composite Index* (LUCI), which captures the aggregate cyclical position of the labor market and also hints at the resulting price pressures. The LUCI is constructed using 28 nominal and real variables from the Czech labor market. The cyclical positions of these variables are determined using a trend-cycle model, with the Kalman smoother applied to ensure accurate identification of cyclical components.[47]

3.3 Economic Activity

3.3.1 Backcast and Nowcast

The backcast and nowcast of aggregate real economic activity consists of eight models, from which the weighted average estimate is derived based on the historical accuracy of the methods.[48] The framework integrates conventional econometric methods (Dynamic Factor Models, DFMs), PCA application (Index Rushin[49], primarily tailored for the Covid period), and a couple of machine learning techniques (Ridge, LASSO, Elastic Net, Support Vector Machine, and Random Forest), utilizing large datasets to their full potential. The nowcasting apparatus draws on approximately 30 time series from diverse sources, sectors, and frequencies. Through out-of-sample forecast testing, it has been shown to reduce forecast errors of the GDP nowcast by almost 20% in the relatively turbulent period after 2021, illustrating the value added in highly uncertain times. Additionally, since the spring 2024 we are testing this framework for applications in household consumption forecasts.

3.3.2 GDP and its Subcomponents

Each expenditure component is forecasted individually based on econometric model working with time series data from other agendas (labor market, price indices, foreign and fiscal prediction).

Household consumption forecasts are formulated based on wage dynamics and incorporate various fiscal metrics, reflecting a fiscal impulse. The nominal government consumption projection, is handled by the fiscal team. The NTF team enhances this input with a deflator projection based on non-business wages and CPI to derive the real component. *Fixed investment* is forecasted with the assistance of foreign demand projections and the fiscal impulse. In the final integration phase, investment forecast from the core model is decomposed into *private and public components* using the Kalman smoother technique. Given the absence of robust observed variables able to support projection, *changes in inventories* rely mainly on expert judgments.

Export projections depend on foreign demand outlooks and the real exchange rate, adjusted by the PPI. *Import projections* encompass both export (as the import content of exports is large in Czech economy) and domestic demand predictions, covering household consumption and investment. Ultimately, *net export* emerge as the difference between export and import forecasts.

3.3.3 Output Gap and Potential Output

To estimate the Czech economy's position in the business cycle, particularly given that the output gap is not an integral part of the core projection model, we employ two satellite estimations as part of the forecast integration process. This dual approach—production function and semi-structural modeling—provides a comprehensive evaluation of the Czech economy's cyclical position, with each method complementing the other in the overall forecasting process.

[47] Detailed descriptions of the LUCI and its methodology can be found in Inflation Report IV/2017, Inflation Report IV/2019, or Monetary Policy Report – Autumn 2023.
[48] For more detail see this blog post (in Czech only) on the CNB website.
[49] A detailed description offers CNB WP 4/2021.

Production Function Method

This method decomposes GDP using a standard Cobb-Douglas production function::

$$Y_t = A_t {L_t}^{\alpha} {K_t}^{1-\alpha} \tag{19}$$

where Y_t represents total output (GDP), K_t represents capital (stock of fixed capital), L_t represents labor (total employment), A_t is the total factor productivity (residual) and α is the output elasticity of labor. This elasticity indicates the share of compensation of employees in the sum of compensation of employees and fixed capital consumption.

Labor input and the identified total factor productivity are decomposed using the Hodrick-Prescott filter, to extract trend and cycle components. Further, noise from the data is removed by additional layer of smoothing, and trend components are then aggregated by the production function to obtain potential output estimate. Expert judgments play a crucial role in the decomposition process, especially to account for factors that the production function alone cannot address. A notable example of such application includes the closures during the first wave of the Covid pandemic, which is now interpreted as a break in potential output, rather than output gap. During this period, GDP experienced a significant drop, which is now attributed to a decrease in the economy's potential as many businesses were closed and producing minimal scale.

Semi-Structural Model Approach

An alternative approach to estimating potential output (and also the NAIRU) is based on the semi-structural model that links the output gap and inflation by open economy version of the Phillips curve. This approach utilizes portions of the CNB Quarterly Prediction Model (p. 63–97)[50] framework, which was previously serving as a core projection model.

The core equation of the model, the Phillips curve, maps the relation between economic activity and core inflation π_t^{CORE}:

$$\pi_t^{CORE} = \alpha\left(\pi_t^{En} + \Delta LZ_t^{eq}\right) + \beta\left(\gamma\pi_{t+4}^{CORE} + (1-\gamma)\pi_{t+4}\right) + (1-\alpha-\beta)\pi_{t-1}^{CORE} + \delta OG_t + \theta WG_t + \varepsilon^{\pi CORE}, \tag{20}$$

where π_t^{En} represents imported energy price inflation, ΔLZ_t^{eq4} is a trend real exchange rate appreciation in core inflation, π_{t+4}^{CORE} and π_{t+4} are one year ahead expectations of core and headline inflations, OG_t is the output gap and WG_t stands for the real wage gap.

In this open economy model, the domestic output gap responds to both domestic and foreign real monetary conditions, as well as to the foreign demand gap. To ensure consistency with the foreign business cycle, the foreign output gap is determined following the approach utilized in model g3+.

The model is used to estimate the domestic output gap OG_t using the Kalman smoother technique based on observed variables. This semi-structural tool allows for the incorporation of expert judgement to address the topical issues identified for the given prediction round.

[50] A brief introduction is also available in the presentation titled "The History of the CNB's Core FPAS Models Summary".

4 Fiscal Forecast

Identifying the impacts of fiscal measures on economic activity is an important part of our analytical and forecasting work. The fiscal forecast is done by a separate unit, which stays in close contact with the core forecast team.

The effect of discretionary fiscal policy measures is incorporated into the CNB's forecast through two channels. The first is the path of government consumption itself, which – as a direct component of domestic demand and GDP – is included in the fiscal block of the g3+ model.[51] In addition, the contributions of other discretionary fiscal measures are taken into account through an estimate of the size and structure of the fiscal impulse using the bottom-up method.[52] The contributions of individual fiscal measures to real GDP growth i.e. the fiscal impulse, are subsequently calculated as the product of the fiscal discretion[53] identified within specific categories and corresponding partial fiscal multipliers.

We configured the partial fiscal multipliers for the individual government revenue and expenditure categories using values (see the table below) based on available empirical estimates for the Czech Republic.[54] The calibration of partial fiscal multipliers aligns with the prevailing consensus in the literature, which holds that expenditure multipliers are greater than revenue multipliers. It is assumed that the highest multiplier effect on government expenditure is generated by additional public investment, while the lowest multiplier effect on the revenue side arises from changes in capital taxation.

Table 4.1: Values of partial fiscal multipliers for the main government revenue and expenditure categories

Revenues	**Multiplier**
Social contributions paid by the employer	0.4
Excise duties	0.3
Labor taxation	0.3
Capital taxation	0.1
Expenditures	**Multiplier**
Government investment	0.7
Government consumption	0.6
Other expenditures	0.5

For forecasting purposes, the total fiscal impulse is divided into the individual components of domestic demand: private consumption, private investment and government investment, which we subdivide into a domestic component and a component stemming from the drawdown of EU funds.

In the forecast integration stage, following the completion of the macroeconomic forecast and the incorporation of all relevant fiscal inputs, the fiscal forecast is computed in a satellite manner, based on the macroeconomic projections. On the revenue side, direct and indirect tax revenues and social contributions are linked by simple regressions to relevant macroeconomic bases (wage bill, operating surplus, or private consumption). The tax revenue forecast also accounts for discretionary changes in

[51] Besides government consumption, the fiscal unit provides the forecasting team with its outlook for several items of government expenditures such as social benefits, public sector wage bill and government investment. These items are used in the forecasting process in shaping final disaggregated macroeconomic story, which contains details beyond what the core model structure makes available (disposable income of households, average wage and wage bill in the non-profit sphere etc.).

[52] The fiscal impulse and its role within the forecasting system are comprehensively detailed in boxes of Monetary Policy Reports of 2021 (Winter Box 2 and Spring Box 2).

[53] Fiscal discretion refers to year-on-year changes in government revenue and expenditure (made by the government and/or due to legislative amendments) that are derived from specific fiscal measures and affect government finances beyond the impacts of the business cycle (i.e. beyond automatic fiscal stabilizers).

[54] See, e.g., *OECD Economic Outlook*, Interim Report March 2009: The effectiveness and scope of fiscal stimulus, Ambriško, R. (2017): Growth-friendly fiscal strategies for the Czech economy and Pikhart, Z. (2019): Metodika predikce tvorby hrubého fixního kapitálu v ČR (in Czech only).

tax legislation, whether already adopted or highly likely to be implemented, with estimates of their impact largely derived from official government sources (e.g., laws, Ministry of Finance Fiscal Outlook).

The forecast for main expenditure items – nominal government consumption, government investment and social benefits – is based on trends, or on the application of average growth rates over the past few years. Similarly to the tax revenue forecast, the effects of measures adopted that may significantly affect the outlook are taken into account (e.g. changes to social laws, wage adjustments, extraordinary pension indexation).

The resulting forecast for the general government balance is determined as the difference between total tax revenue and government expenditure. Moreover, the cyclical component of government budget balance is calculated according to the aggregated method, based on an estimate of the output gap and budget balance sensitivity parameter. The projection for general government debt reflects the underlying primary balance and the assumed yields on government bonds, which are aligned with the macroeconomic forecast.

Finally, the cyclically adjusted general government budget balance and government debt serve as two key fiscal indicators in the Scoreboard of Inflation Risks.

5 Foreign Economy and Balance of Payments

5.1 Assembling Foreign Economy Forecasts

Foreign Demand – the GDP Outlook for Effective Euro Area

The GDP outlook for the effective euro area aggregates forecasts from individual EA6 economies (Germany, Slovakia, France, Italy, Spain, Austria), weighted according to each country's share in foreign trade with the Czech Republic. For each country, short-term forecasts for the first and second quarters of the horizon employ nowcasting tools such as bridge equations (Adam and Novotný, 2018) and Bayesian additive vector autoregressive tree (BAVART) model (Huber et al., 2023). Additionally, a project on machine learning-based nowcasts is under way to enhance this toolkit. During the pandemic, the national accounts-based sectoral approach was effective, recently supplemented with targeted satellite models, such as the household consumption model in Germany. The goal is to integrate these domestic models with Oxford Economics' forecasts, utilizing key GDP components to refine activity projections abroad, which is achievable only with a narrower aggregation of countries.

Foreign Trade Price – the Producer Price Index Outlook

International trade price pressures are represented by the foreign producer prices, which serve as a measure of import goods prices and foreign competitors' price and thus provide a more accurate measure of international price pressures than foreign consumer prices. The Producer Price Index (PPI) outlook for the effective Euro Area constructed from forecasts for the individual EA6 economies: Germany, Slovakia, France, Austria, Italy, and Spain. These forecasts are weighted according to each country's share in foreign trade with the Czech Republic. The current weights are 59% for Germany, 14% for Slovakia, 8% for France, 7% for both Austria and Italy, and 5% for Spain. Forecasts for both the core and energy components of total producer prices are generated separately for each country. The core component corresponds to Eurostat's definition of total producer prices less energy, while the energy component corresponds to the Main Industrial Groupings (MIG) energy. Additionally, the outlook is prepared for the Euro Area in its standard meaning (EA20) as well.

We employ simple time-series models incorporation selected explanatory variables, which differ by country. These variables include lagged dependent variables, real GDP, commodity prices (such as Brent crude oil, electricity, coal, industrial metals, and food commodities), and the EUR/USD exchange rate. The outlook for total PPI at the individual country level is derived from the aggregation of its core and energy components, given the respective core and energy weights for each country. On the effective Euro Area level, the core weight is 71%, and the energy weight is 29%.

Foreign Consumer Price - Harmonized Index of Consumer Prices (HICP) Outlook

The Harmonized Index of Consumer Prices (HICP) outlook for the effective Euro Area aggregates forecasts from individual EA6 economies: Germany, Slovakia, France, Austria, Italy, and Spain. These forecasts are weighted according to each country's share in foreign trade with the Czech Republic. Forecasts are prepared separately at the individual country level. Furthermore, the outlook is prepared for the Euro Area in its standard meaning (EA20) as well.

Similar to the PPI outlook, we employ simple time-series models that comprise selected explanatory variables, which differ for each country. These variables include lagged dependent variables, real GDP, nominal wages, commodity prices, and the EUR/USD exchange rate. The outlook for total HICP at the individual country level arises from the aggregation of its core, food, and energy components, given the corresponding weights for each country. On the effective Euro Area level, the core weight is 70%, food is 19%, and the energy weight is 11%.

Forecast Sources

In addition to our internal forecasts, we cross-check them with alternative forecasts by Consensus Economics and Oxford Economics. Wage forecasts, along with EUR/USD forecasts, are sourced from Consensus Forecasts. Forecasts for commodity prices are derived from market futures prices. Futures prices reflect market expectations of future supply and demand conditions, as well as factors such as geopolitical events, weather patterns, and economic indicators. While futures markets do not perfectly predict future prices, they provide valuable information for forecasting purposes due to their role in price discovery and the participation of a wide range of market participants.

5.2 Alternative and Other Scenarios

Alternative and stress scenarios within the prediction process are modeled through the National Institute Global Econometric Model (NiGEM) semi-structural global model. It consists of individual country models for almost all economies in the OECD. International linkages come from patterns of trade, the influence of trade prices on domestic prices, the impacts of exchange rates and patterns of asset holding and associated income flows. The structure for the trade block ensures overall global consistency of trade volumes by imposing that the growth of import volumes is equal to the growth of export volumes at the global level.

The individual country models within NiGEM are comprehensive systems of dynamic equations based on the internationally accepted national accounting framework. The parameters of these models are estimated from aggregate time-series data, ensuring a robust empirical foundation. All country models share a broadly consistent New Keynesian structure, which assumes rational expectations for economic agents—though this assumption can be modified if necessary—and includes nominal rigidities that delay adjustments to external shocks or changes in economic conditions. Importantly, the individual country models incorporate well-specified supply-side behavior that underpins the sustainable growth rate of each economy in the medium-term. The NiGEM extended by a climate block, is also used at the CNB for modeling climate scenarios.

5.3 Equilibrium Exchange Rates and Additional External Environment Indices

Equilibrium Exchange Rates

The modeling of the equilibrium real exchange rate employs the BEER (Behavioral Equilibrium Exchange Rate) and FEER (Fundamental Equilibrium Exchange Rate). *The BEER model* accounts for the key economic fundamentals that influence the long-term trajectory of the real exchange rate. These fundamentals, include factors such as the differential in labor productivity relative to global economy, the foreign trade balance and investments that support expansion of the economy's production capacity.

The FEER model is predicated of the simultaneous achievement of internal and external equilibrium of the economy. Internal equilibrium is attained when the actual gross domestic product aligns with the potential GDP. The external equilibrium corresponds to the sustainable development of the current account of the balance of payments, which primarily reflects the export and import of goods and services.

The resulting equilibrium real exchange rate serves as a critical input in discussions concerning the short-term exchange rate assumption within the core prediction model forecast. Additionally, the implied real exchange rate gap, which approximates the degree of exchange rate misalignment is subsequently utilized for the estimation of the Real Monetary Conditions RMCI).

Additional Foreign Environment Indices

As complementary tool we produce an alternative index of real monetary conditions, as detailed in the Annex of the Inflation Report II/2015. Moreover, we construct an indicator of regional sentiment for exchange rates, as outlined in the report 'Regional Sentiment of Central European Currencies in a Global Context, Global Economic Outlook – March 2023'. This indicator serves as a foundational tool for discussions on the near-term forecast of the koruna exchange rate within the forecasting framework. An enhanced version of this regional sentiment estimate is also under preparation as part of the 'Global and Regional Factors in CEE Exchange Rate Dynamics' project. Additionally, we decompose the shocks to oil prices into demand and supply factors based on the methodology proposed by Venditti and Veronese (2024).

Further econometric models are being developed on an ad-hoc basis, including:

- the probability of a recession in Germany and the euro area,
- the intensity of the January re-pricing in the euro area countries,
- estimates of the re-pricing intensity in the euro area production sector (pipeline pressures),
- econometric methods for decomposing GDP into trend and cycle,
- Taylor rule estimates for the euro area.

5.4 Model-Based Forecasting System for the Current Account and BoP

The Balance of Payments (BoP)

To forecast key BoP items, we start with a system of semi-structural and empirical models, supplemented by satellite tools to construct disaggregated current account (CA) prediction. For the capital account predictions, we utilize the projections of the EU funds flows developed by the fiscal experts. In the final step, the aggregated balance series are constructed by use of BoP identities.

The development of a disaggregated approach to current account forecasting began with a research project in 2016 (Babecká Kucharčuková and Brůha, 2016). Following its successful completion and subsequent expansions, this system became fully operational in 2020, replacing the previous expert-based framework. In 2024, it provides forecasts for almost 60 time series (key time series and their trends) related to Czech Republic's current account and international trade at the disaggregated level for credit and debit sides.

The BoP input complements core model forecasting process in the area of external balances, and the primary findings are communicated both internally and externally of the CNB. In addition to deliver consistency check for core model net exports projection, the model outputs are used as inputs for satellite BoP models, particularly to expert-based forecast of selected financial account items and for assessing BoP-related exchange rate pressures arising from major BoP aggregates.

Beyond the regular forecasting cycle, BoP tools are employed to assess external vulnerabilities and adequacy of foreign exchange reserves. Additionally, these tools are providing estimates of the impact of adverse scenarios on current account are provided for the CNB's Financial Stability Department. Moreover, the current account model serve as an input to the risk-monitoring tool within Scoreboard of inflation and monetary policy risks.

The Current Account Forecasting

The current account forecasting system comprise two layers: empirical models for nowcasting and a quarterly model formulated within a structural time-series framework.

The first layer consists of a set of empirical nowcasting models. These models operate on the monthly frequency and are applied to nowcast export and import in the BoP methodology, separately for goods and services. Goods aggregates are also nowcasted and forecasted following the highest level of Standard International Trade Classification (SITC). These models leverage higher-frequency data, incorporating a set of leading and coincidence indicators. The results are validated using additional model known as Real-time Indicator of trade Development (RICARDO), which nowcasts exports and imports of goods and services for each EU country. This complementary approach allows for construction of an alternative estimate of "effective demand" over the short-run horizon. Additionally, a text-mining model for nowcasting travel services based on the number of Google reviews of tourist attractions in the Czech Republic posted by non-residents (for the credit side) and on the number of reviews of foreign locations posted in the Czech language (debit side).

The second layer consists of a structural time-series framework operating at quarterly frequency. Inputs to this model include the same set of exogenous assumptions regarding external developments and fiscal policy as those used in the core g3+ model. Additionally, the g3+ forecasts of sub-components of domestic demand, exchange rates, interest rates, and mark-up gaps are incorporated, ensuring full consistency with the core CNB model assumptions. This quarterly current account model is employed to forecast exports and imports of goods and services separately, primary income (broken down into compensation of employees, investment income and other components) and secondary income. For all items, the credit and debit sides are forecasted separately. Moreover, the forecast of aggregate exports and imports of services is further disaggregated into main service categories using a separate, smaller model.

The quarterly current account model is set within a trend-cyclical framework, which is based on the premise that different drivers of business cycles operate at different frequencies, as argued by Andrle and Brůha (2014). Trend components are treated as exogenous processes capturing long-run drivers, such as the pace of globalization, the change in the openness of the economy, or abrupt changes in methodology in the officially reported time series. Cyclical components are linked through a set of empirical relationships estimated using elastic nets, which in our case have been demonstrating to provide the most accurate linkage among cycles when compared to alternatives such as bridge equations, dynamic factor models, or partial least squares and their sparse variants. Expert judgment can be applied to the trend-cyclical decomposition or individual series when necessary. The structural time-series framework facilitates transparency and ease of interpretation for these judgments.

6 Other Satellite Computations – Money and Credit

Credit

The forecast for credit financing in economic activity serves not only to enhance our understanding of the relationship between the credit cycle and corporate investment but also to quantify the risks associated with household debt.

The methodology for credit forecasting was chosen with two primary objectives: first, to maximize its predictive capability, and second, to ensure that the prediction is delivered by model in line with standard theory to any puzzles. To achieve these goals, we employ a simple Bayesian VAR model, as described in Dieppe, Legrand and van Roye, 2018.

Forecasted variables in the model are loans to the non-financial sector following the basic breakdown, i.e. loans to non-financial corporations and loans to households for house purchase and consumption. Changes in the stocks of loans are linked to the output gap, the deviation of inflation from the target, financial market interest rates and exogenous factors such as drawdown of EU funds. For the sake of consistency projections of these input variables are obtained from the core g3+ model forecast supplemented by additional satellite models (for example, the ten-year government bond yield).

Monetary Aggregates Forecast and Three Monetary Indicators

In general, vector error correction model (VECM) methodology is employed to forecast money demand in terms of M1 and M3 aggregates. Also, this methodology is used to construct additional indicators of monetary cycle position: monetary overhang, nominal money gap and real money gap.

The monetary overhang represents the percentage difference between the actual nominal money aggregate M3 and its estimated value, corresponding to the current phase of the economic cycle. The nominal money gap is the percentage deviation of the actual M3 from the value it would have attained if it had grown at a reference rate since the reference period, which accounts for the inflation target, potential output, and the choice of the reference period. The real money gap reflects the deviation of the real M3 aggregate from its equilibrium value, considering the inflation target, potential output, and the equilibrium interest rate.

Money demand predictions is combination of prediction methods. For the first quarter of the monetary aggregates forecast, a seasonal autoregressive integrated moving average (SARIMA) model is employed due to its superior predictive accuracy, while VECM forecasts are employed for all subsequent quarters. Inputs for the money demand models, like observed data and projections for GDP, CPI and short term interest rate, are sourced from the core g3+ model projection.

The estimates of the aforementioned monetary indicators are produced based on the estimated coefficients of the money demand model to ensure consistency in the tools used for analyzing monetary aggregates.

Bank Lending Survey

The Bank Lending Survey[55] offers insights into the Czech bank credit market, as gathered by the CNB through a survey conducted quarterly. It summarizes trends in credit standards and the terms and conditions for loan approvals, as well as changes in loan demand among households and corporations. The survey also includes expectations for credit market developments of commercial banks in the upcoming months. In each round, CNB staff meet and interviews representatives from selected commercial banks to discuss the key factors influencing the credit markets.

[55] The results of survey are regularly published at the CNB webpage here.

7 Scoreboard of Inflationary and Monetary Policy Risks

The recent inflation surge episode has highlighted potential gaps in our understanding of how unforeseen inflationary risks develop and accumulate within the economy, particularly in terms of their incorporation into conventional analytical and forecasting practices. Beyond the scope of standard cyclical analyses, there might be long-term underlying inflation risks that are difficult to quantify. Such risks may only materialize if they accumulate over an extended period and/or if multiple critical events coincide. A recent example is the COVID-19 pandemic, which triggered widespread production shutdowns in both the Czech and global economies, causing significant supply chain disruptions and shortages.

Meanwhile, expansionary fiscal and monetary policies supported demand at levels misaligned with these supply-side constraints. Indicators of the quantity of money in the economy surged at double-digit rates. Simultaneously, for the Czech economy, there was still potential for nominal convergence of the price level towards the countries of the Western Europe. Furthermore, the Czech economy, particularly its labor market, had been overheated prior to the pandemic. Property prices also rose sharply, potentially reflecting households' concerns about future inflation risks. This already precarious situation was exacerbated by a significant energy shock, leading to coordinated price increases throughout the whole economy.

Moreover, Central and Eastern European countries were exposed to the energy crisis to higher degree in comparison with their western peers. The higher degree of exposure to energy prices originate from larger role in the economy due to the higher weight of energy-intensive industries in the economic structure and the greater representation of energy costs in the consumer basket. he adverse developments in terms of trade and the widening current account deficit would likely have further depreciated the koruna, worsening the inflationary pressures, had it not been for central bank interventions (both verbal and physical), which ensured that the exchange rate did not exacerbate the already escalating inflation situation.

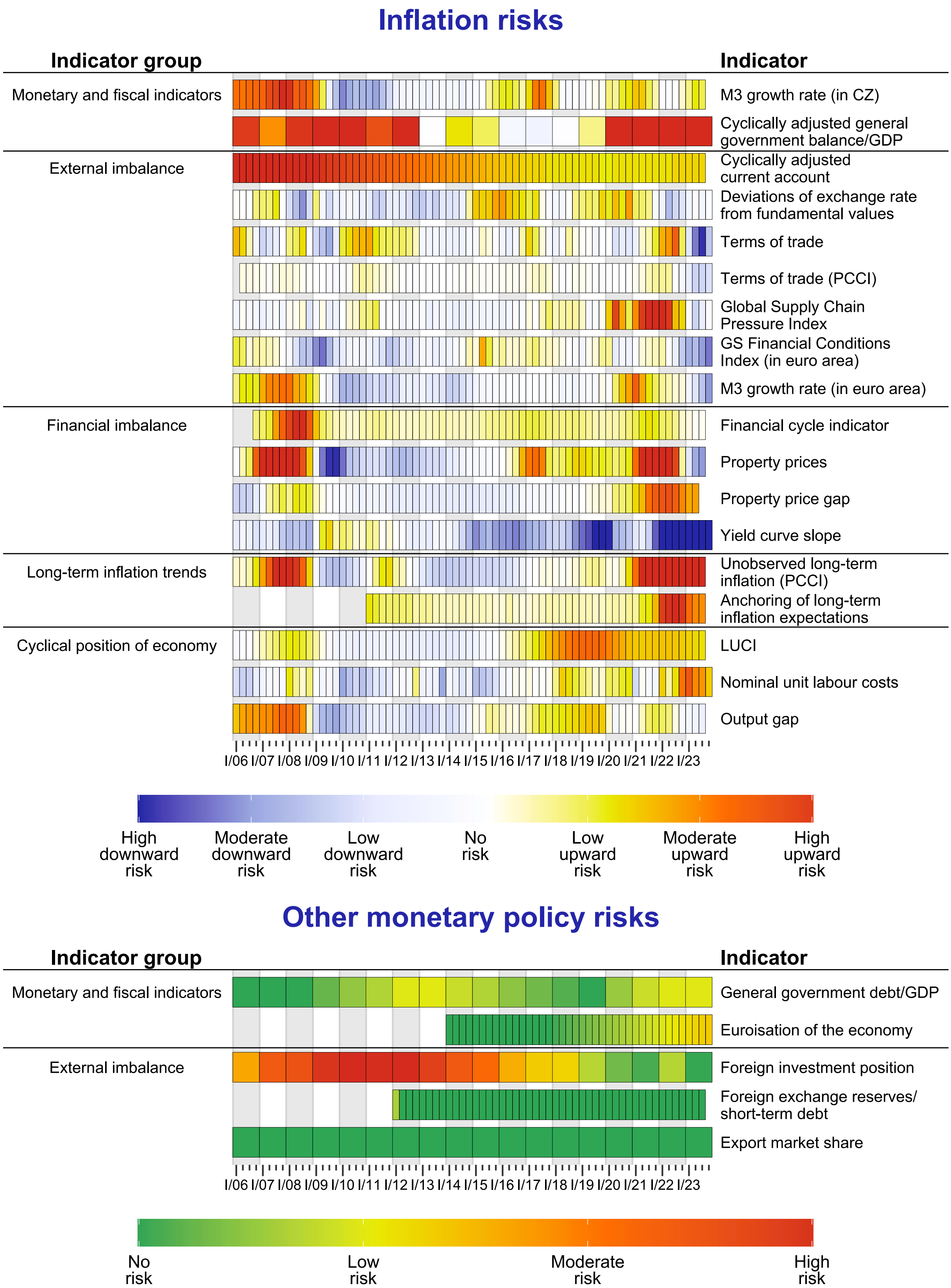
The aforementioned factors represent one-off, non-systematic, "once-a-century" events. Clearly, none of these factors alone would have caused such significant price growth, but together they pushed inflation to the highest levels since the economic transformation of the 1990s. As a result, it may be inadvisable to attempt to systematically incorporate such events into forecasting models, as their inclusion in typical linear frameworks would likely not improve forecast accuracy under normal conditions. The impact of these factors on inflation is difficult to quantify. They are often based on a cumulative effects hitting unknown thresholds, making them unpredictable in terms of timing. Moreover, the severity and likelihood of these risks materializing are substantially higher when two or more such factors coincide.

In light of these characteristics of the long-term underlying inflation risks, the Monetary Department, in line of consultations with the Bank Board, has developed an indicator-based approach – the Scoreboard of Inflationary and Monetary Policy Risks. In cases where the channels of effect on inflation are not precisely mapped, or are openly acknowledged to be are overwhelmingly complex, challenging to describe, a visual indicators serve as viable means of getting a handle on these risks, drawing attention to them and introducing them as a potential additional consideration in the monetary policy decision-making process.

For the Scoreboard, we have carefully selected critical thresholds for each indicator, considered appropriate transformations, and justified their inclusion. These issues are addressed in the accompanying documentation.[56] As our analysis of a particular area progresses we may make further adjustments of the forecast trajectory, forecasting process or even modification of core model to systematically include some of the risks. The Scoreboard's simple visualization represents an initial step in this process and serves as a tool to ensure that these risks are not underestimated.

[56] Published recently alongside Monetary Policy Report – Spring 2024 here.

Figure 7.1: Scoreboard of Inflationary and Monetary Policy Risks



8 Conclusion

In this document, we detail the components of the Czech National Bank's forecasting and monetary policy analysis system. We provide specific examples of how our core forecasting model functions as the central pillar of the integrated forecast produced by CNB staff. While we primarily focus on the role and features of the core forecasting model, we also summarize our overall forecasting process by offering an overview of our output across various channels.

Additionally, we illustrate the connection between the core and satellite models, and describe our workflow for integrating these models to support the production of the monetary policy report. Furthermore, we present recent enhancements to our monetary policy analysis toolbox, including the newest addition of macroeconomic scoreboard. Finally, we include results from our regular model evaluation processes, which serve as automatic feedback mechanisms for monitoring the quality of our forecasts.

References

Adam, T. and Novotný, F. (2018): "Assessing the External Demand of the Czech Economy: Nowcasting Foreign GDP Using Bridge Equations." CNB Working Paper Series, 18/2018.

Andrle, M. (2008): "The Role of Trends and Detrending in DSGE Models," MPRA Paper 13289, University Library of Munich, Germany.

Andrle M. and Brůha J. (2018): "Forecasting and Policy Analysis with Trend-Cycle Bayesian VARs." IMF mimeo.

Babecká Kucharčuková, O. and Brůha J. (2016): "Nowcasting the Czech Trade Balance." CNB Working Paper Series, 11/2016.

Brázdik, F., Hlédik, T., Humplová, Z., Martonosi, I., Musil, K., Ryšánek, J., Šestořád, T., Tonner, J., Tvrz, S. and J. Žáček (2020): "The g3+ Model: An Upgrade of the Czech National Bank's Core Forecasting Framework." CNB Working Paper Series, 7/2020.

Calvo, G. A. (1983): "Staggered Prices in a Utility-Maximizing Framework", Journal of Monetary Economics, 12, pages 383–398.

A. Dieppe, R. Legrand, B. van Roye (2018): Bayesian Estimation, Analysis and Regression Toolbox.

Gazzani, A., Venditti, F. and Veronese, G. (2024): "Oil Price Shocks in Real Time." Journal of Monetary Economics 144.

De Groot, O. and F. Mazelis (2020): "Mitigating the Forward Guidance Puzzle: Inattention, Credibility, Finite Planning Horizons and Learning." ECB Working Paper Series, No.2426/June 2020.

Huber, F., Koop, G., Onorante, L., Pfarrhofer, M. and Schreiner, J. (2023): "Nowcasting in a pandemic using non-parametric mixed frequency VARs." Journal of Econometrics, 232(1), 52-69.

Hantzsche, A., Lopresto, M. and Young, G. (2020): "Using NiGEM in Uncertain Times: Introduction and Overview of NiGEM." National Institute Economic Review, 244(1), R1–R14.

Komárek, L. and Motl, M. (2024): "Behavioural and Fundamental Equilibrium Exchange Rate of the Czech Koruna." Presentation at the European Central Bank.

Muth, J. A. (1961): "Rational Expectations and the Theory of Price Movements." Econometrica 29(6): 315–335.

Sargent, T. J. (1986): "Rational Expectations and Inflation." New York: Harper and Row.

Schmitt-Grohé, S. & Uribe, M., (2003). "Closing small open economy models," Journal of International Economics, Elsevier, vol. 61(1), pages 163-185.

Yun, T. (1996): "Nominal price rigidity, money supply endogeneity and business cycles", Journal of Monetary Economics, 37, pages 345–370.

Appendices

Appendix 2A: Publications Related to g3+

Blog Posts and Videoblogs

- Česká ekonomika po třiceti měsících kurzového závazku, M. Singer, 2. 6. 2016 (in Czech only)
- Letní prognóza ČNB poprvé na novém predikčním modelu, J. Tonner, 25. 7. 2019 (in Czech only)
- The CNB's projection model gets a new plus, P. Král, K. Musil, 25. 7. 2019
- Model g3+ boduje, P. Král, K. Musil, 14. 9. 2020 (in Czech only)
- Anticipated events versus surprise shocks in structural forecasting models: Czech National Bank's practical perspective, K. Musil, S. Tvrz, J. Vlček, 19. 1. 2022
- Proč jsou strukturální makroekonomické modely důležité pro prognózu a měnovou politiku?, J. Brůha, P. Král, J. Tonner, 29. 6. 2022 (in Czech only)
- Covidová stopa v prognózách ČNB, K. Musil, S. Tvrz, 4. 7. 2022 (in Czech only)
- Monetary policy of the last two years in the rear-view mirror, or what we managed to prevent, P. Král, K. Musil, S. Tvrz, 13. 7. 2022
- Současné trendy makroekonomického modelování v centrálních bankách, J. Tonner, 3. 8. 2022 (in Czech only)
- Rok 2022: zkouška flexibility reakce ČNB a jejího prognostického aparátu, P. Král, K. Musil, S. Tvrz, J. Žáček, 22. 5. 2023 (in Czech only)
- Zisky, ziskovost, míra zisku, marže.. Kdo se v tom má vyznat?!, P. Král, O. Michálek, K. Musil, M. Šarboch, 18. 4. 2024 (in Czech only)

Boxes and Annexes to Inflation/Monetary Policy Reports

- Assessment of fulfilment of the CNB's net inflation target in December 2001, Inflation Report I/2002 (Attachment)
- Fiscal policy in the CNB's modelling system, Inflation Report I/2006 (Attachment)
- The extension of the core prediction model to include the effect of real wages, Inflation Report I/2007 (Attachment)
- Changes to the CNB's core prediction model, Inflation Report I/2008 (Attachment)
- The new g3 structural model, Inflation Report II/2008 (Attachment)
- Pricing in the g3 model, Inflation Report IV/2008 (Attachment)
- The exchange rate path in the g3 model, Inflation Report I/2009 (Attachment)
- Monetary policy in the g3 model, Inflation Report II/2009 (Attachment)
- Publication of the graph of risks to the inflation projection (GRIP), Inflation Report III/2011 (Attachment)
- New steady-state settings in the g3 model, Inflation Report IV/2013 (Attachment)
- Using the exchange rate as an instrument to ease the monetary conditions, Inflation Report IV/2013 (Attachment)
- The impact of the Balassa-Samuelson effect on prices in the domestic economy, Inflation Report III/2016 (Attachment)
- A look back at the discontinued exchange rate commitment, Inflation Report II/2017 (Attachment), J. Filáček. P. Král
- Sources of the deviations of inflation from the CNB's 2% target, Inflation Report II/2018 (Attachment), Z. Humplová
- Margins and the price elasticity of aggregate supply, Inflation Report III/2018 (Attachment), J. Brůha, M. Gürtler
- Introducing the g3+ extended projection model, Inflation Report III/2019 (Annex), F. Brázdik, I. Martonosi, K. Musil, T. Šestořád, J. Tonner, S. Tvrz, J. Žáček
- Assessment of the fulfilment of the 2020 forecasts, Monetary Policy Report – Spring 2020 (Box 3), T. Keseliová, K. Musil, T. Šestořád, S. Tvrz, J. Žáček

- The fiscal impulse in CNB forecasts, Monetary Policy Report – Winter 2021 (Box 2), R. Ambriško, D. Hájková, P. Král, S. Tvrz
- Assessment of the fulfilment of the inflation target over the last two years, Monetary Policy Report – Spring 2021 (Box 4), J. Bechný, J. Syrovátka, T. Šestořád, J. Žáček
- Pricing and its importance for monetary policy from the perspective of the g3+ model, Monetary Policy Report – Summer 2021 (Box 3), T. Šestořád
- Monetary policy transmission in the Czech economy, Monetary Policy Report – Autumn 2021 (Box 3), F. Brázdik, J. Grossmann, D. Hájková, E. Hromádková, P. Král, B. Saxa
- Business performance and pricing amid the continuing energy shock, Monetary Policy Report – Autumn 2022 (Box 1), O. Michálek, M. Šarboch, J. Žáček
- Assessment of the fulfilment of the inflation target over the last two years, Monetary Policy Report – Winter 2023 (Box 3), T. Keseliová, T. Pokorný, J. Syrovátka, S. Tvrz, J. Žáček
- Assessment of the fulfilment of the 2021 forecasts, Monetary Policy Report – Spring 2023 (Appendix 1), T. Keseliová, K. Musil, T. Pokorný, T. Šestořád, S. Tvrz, J. Žáček
- Assessment of the fulfilment of the inflation target over the last two years, Monetary Policy Report – Winter 2024 (Box 1), T. Keseliová, T. Pokorný, J. Syrovátka, T. Šestořád, S. Tvrz
- The updated g3+ core forecasting model and the shadow forecast, Monetary Policy Report – Winter 2024 (Annex), F. Brázdik, M. Frydrych, T. Pokorný, T. Šestořád, J. Žáček

Working Papers and Research Policy Notes

- Issues in Adopting DSGE Models for Use in the Policy Process, CNB WP 6/2006
- Implementing the New Structural Model of the Czech National Bank, CNB WP 2/2009
- Monetary Policy Implications of Financial Frictions in the Czech Republic, CNB WP 12/2011
- Incorporating Judgments and Dealing With Data Uncertainty in Forecasting at the Czech National Bank, CNB RPN 2/2013
- Evaluating a Structural Model Forecast: Decomposition Approach, CNB RPN 2/2014
- Labor Market Modelling within a DSGE Approach, CNB WP 6/2015
- Evaluating a Structural Model Forecast: Decomposition Approach, CNB WP 12/2015
- An Exchange Rate Floor as an Instrument of Monetary Policy: An Ex-post Assessment of the Czech Experience, CNB WP 4/2017
- Independent Monetary Policy Versus a Common Currency: A Macroeconomic Analysis for the Czech Republic Through the Lens of an Applied DSGE Model, CNB WP 19/2018
- The g3+ Model: An Upgrade of the Czech National Bank's Core Forecasting Framework, CNB WP 7/2020
- News versus Surprise in Structural Forecasting Models: Central Bankers' Practical Perspective, CNB RPN 2/2021
- Implementing Yield Curve Control Measures into the CNB Core Forecasting Model, CNB WP 8/2023
- Understanding Inflation Expectations: Data, Drivers and Policy Implications, CNB WP 3/2024

Other Publications

- Current trends in macroeconomic modelling in central banks in light of the turbulent nature of recent events, Global Economic Outlook – July 2022, J. Tonner

Appendix 2B: Additional Tables

Table 2B.1: Observed Data and Model Units in the Foreign Block

	Transform		Transform
Real Economic Activity		**Prices**	
Real GDP	$100 * log$	Energy Price Level (EUR)	$100 * log$
Monetary Policy		Non-Energy Price Level (EUR)	$100 * log$
3M EURIBOR Interest Rate	-	Foreign Price Level (EUR)	$100 * log$
3M EURIBOR Eq. Interest Rate	-	Consumer Price Index	$100 * log$
Financial Markets			
Exchange Rate EUR/USD	$100 * log$		

Table 2B.2: Observed Data and Model Units in the Domestic Block

	Transform		Transform
Prices/Deflators		**Real Economic Activity**	
Net Price Level	$100 * log$	Real Consumption	$100 * log$
Administered Prices	$100 * log$	Real Investment	$100 * log$
Consumer Price Index	$100 * log$	Real Imports	$100 * log$
Consumer Price Index Infl. Target	$100 * log$	Real Exports	$100 * log$
Consumption Deflator	$100 * log$	**Nominal Economic Activity**	
Government Deflator	$100 * log$	Nom. Government Consumption	$100 * log$
Investment Deflator	$100 * log$	**Labor Market**	
Imports Deflator	$100 * log$	Worked hours	$100 * log$
Energy Imports Deflator	$100 * log$	Nominal Wage	$100 * log$
Exports Deflator	$100 * log$	**Monetary Policy**	
		3M PRIBOR Interest Rate	-
		Financial Markets	
		Exchange Rate CZK/EUR	$100 * log$

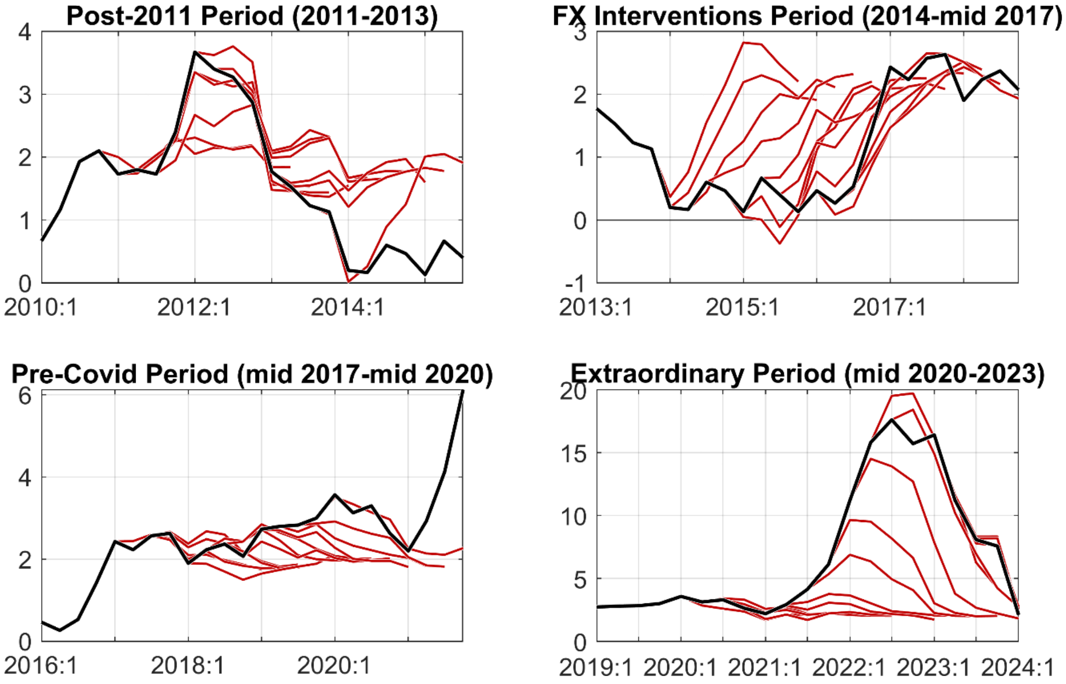
Appendix 2C: Additional Figures

Figure 2C.1: Data Inputs and Assumptions Handling

		Filter (history)				Forecast (outlook)			
		…	-3Q	-2Q	-1Q	1Q	2Q	3Q	…
Foreign data	USD/EUR Exchange Rate Depreciation (QoQ)	D	D	D	D	A	A	A	A
	EA HICP Inflation (QoQ)	D	D	D	D	A	A	A	A
	EA PPI Inflation (QoQ)	D	D	D	B	A	A	A	A
	EA Energy PPI Inflation (QoQ)	D	D	D	B	A	A	A	A
	EA Core PPI Inflation (QoQ)	D	D	D	B	A	A	A	A
	EA GDP (QoQ)	D	D	D	B	A	A	A	A
	3M EURIBOR (lev)	D	D	D	D	A	A	A	A
	3M EURIBOR Shadow (lev)	D	D	D	D	A	A	A	A
	EA Equilibrium Interest Rates (lev)	D	D	D	D	A	A	A	A
	EA GDP Potential (QoQ)	D	D	D	B	A	A	A	A
	EA GDP Potential One-Off Shock (QoQ)	D	D	D	B	A	A	A	A
	EA Output Gap (% of potential)	D	D	D	B	A	A	A	A
Domestic data	CPI Inflation (QoQ)	D	D	D	D	N			
	Net Inflation (QoQ)	D	D	D	D	N			
	Administered Prices Inflation (QoQ)	D	D	D	D	A	A	A	A
	CPI Inflation Target (QoQ)	D	D	D	D	A	A	A	A
	Consumption Deflator (QoQ)	D	D	D	B				
	Government Deflator (QoQ)	D	D	D	B	A	A	A	A
	Investment Deflator (QoQ)	D	D	D	B				
	Imports Deflator (QoQ)	D	D	D	B				
	Energy Imports Deflator (QoQ)	D	D	D	B				
	Other Imports Deflator (QoQ)	D	D	D	B				
	Exports Deflator (QoQ)	D	D	D	B				
	Real Consumption (QoQ)	D	D	D	B				
	Real Investment (QoQ)	D	D	D	B				
	Real Imports (QoQ)	D	D	D	B				
	Real Exports (QoQ)	D	D	D	B				
	Nominal Government Consumption (QoQ)	D	D	D	B	A	A	A	A
	Nominal Wages in Market Sectors (QoQ)	D	D	D	B				
	Hours Worked (hours)	D	D	D	D				
	3M PRIBOR (lev)	D	D	D	D				
	CZK/EUR Exchange Rate Depreciation (QoQ)	D	D	D	D	N			

Note: A – assumption, B – backcast prepared by the External Economic Relations Division or the NTF team, D – data, N – nowcast. The identification of gap and trend components of EA GDP originates from the standalone model of the foreign economy block extracted from core model. When using the core model, we treat the EA GDP components as exogenous inputs (observed variables, assumptions).

Figure 2C.2: Accuracy of the CNB's Forecasts for Inflation (YoY) since 2008 – a Detailed Look



Note: Each red line represents a single macroeconomic projection; the black lines depict data.

Appendix 2D: g3+ Foreign Block Equations

The IS curve:

$$\hat{y}_t^* = a_{y^*}\,\hat{y}_{t-1}^* - a_{y^*}^{r^*}\,\hat{r}_{t-1}^* + a_{y^*}^{z}\,\hat{z}_t + \epsilon_t^{\hat{y}^*}.$$

Producer Price Index:

$$\tilde{P}_t^* = \left(\tilde{P}_t^{*energy}\right)^{\rho_{*\frac{ener}{ppi}}}\left(\tilde{P}_t^{*core}\right)^{1-\rho_{*\frac{ener}{ppi}}}.$$

New Keynesian Phillips Curve:

$$\tilde{\pi}_t^{*core} = a_{\pi^{*core}}\,\tilde{\pi}_{t-1}^{*core} + (1 - a_{\pi^{*core}})\,\tilde{\pi}_{t+1}^{*core} + a_{\pi^{*core}}^{y^*}\hat{y}_t^* + a_{\pi^{*core}}^{z}\,\hat{z}_t + \epsilon_t^{\tilde{\pi}^{*core}}.$$

Monetary policy rule:

$$i_t^* = a_{i^*} i_{t-1}^* + (1 - a_{i^*})\left(i_t^{*eq} + a_{i^*}^{y^*}\,\hat{y}_t^* + a_{i^*}^{\pi^*}\left(\frac{\tilde{\pi}_{t+4}^{*cpi4}}{4} - \tilde{\pi}^{*cpi}\right)\right) + \epsilon_t^{i^*}.$$

USD/EUR Exchange Rate:

$$0 = \rho_{usdeur}\,\Delta usdeur_{t+1} - (1 - \rho_{usdeur})\Delta usdeur_t + \left(i_t^* - i_t^{*eq} - prem_t^{usdeur}\right) + \epsilon_t^{\Delta usdeur}.$$

The link between CPI and PPI price inflations:

$$\tilde{\pi}_t^{*cpi} - \tilde{\pi}^{*cpi} = \rho_{\pi^{*cpi}}\left(\tilde{\pi}_{t-1}^{*cpi} - \tilde{\pi}^{*cpi}\right) + \left(1 - \rho_{\pi^{*cpi}}\right)a_{\pi^{*cpi-ppi}}(\tilde{\pi}_t^* - \tilde{\pi}^*) + \epsilon_t^{\tilde{\pi}^{*cpi}}.$$

Definitions:

$$\tilde{\pi}_t^* = \rho_t^{*\frac{ener}{ppi}}\left(\tilde{\pi}_t^{*ener} - \tilde{\pi}_t^{*rp}\right) + \left(1 - \rho_t^{*\frac{ener}{ppi}}\right)\tilde{\pi}_t^{*core} + \epsilon_t^{\tilde{\pi}^*},$$

$$\hat{\rho}_t^{*\frac{ener}{ppi}} = \frac{\tilde{\pi}_t^{*ener}}{\tilde{\pi}_t^{*core}}\,\epsilon_t^{\hat{\rho}^{*\frac{ener}{ppi}}},$$

$$\hat{z}_t - \hat{z}_{t-1} = -\Delta z_t^{eq} - \Delta usdeur_t - \tilde{\pi}_t^*,$$

$$\hat{r}_t^* = i_t^* - \tilde{\pi}_{t+1}^{*cpi} - \left(i_t^{*eq} - \tilde{\pi}^{*cpi}\right),$$

$$prem_t^{*shadow} = i_t^* - i_t^{*shadow},$$

$$\Delta y_t^* = (\hat{y}_t^* - \hat{y}_{t-1}^*) + \Delta y_t^{*trend},$$

$$\Delta y_t^{*trend} = \Delta y_t^{*ftrend} + \Delta y_t^{*trendshift}.$$

Unobserved variables and non-structural relations:

$$\Delta z_t^{eq} = \rho_z^{eq}\Delta z_{t-1}^{eq} + \left(1 - \rho_z^{eq}\right)\Delta z^{eq} + \epsilon_t^{z^{eq}},$$

$$i_t^{*eq} = \rho_{i^{*eq}} i_{t-1}^{*eq} + (1 - \rho_{i^{*eq}})i^{*eq} + \epsilon_t^{i^{*eq}},$$

$$prem_t^{*shadow} = \rho_{prem^{*shadow}} prem_{t-1}^{*shadow} + \epsilon_t^{prem^{*shadow}},$$

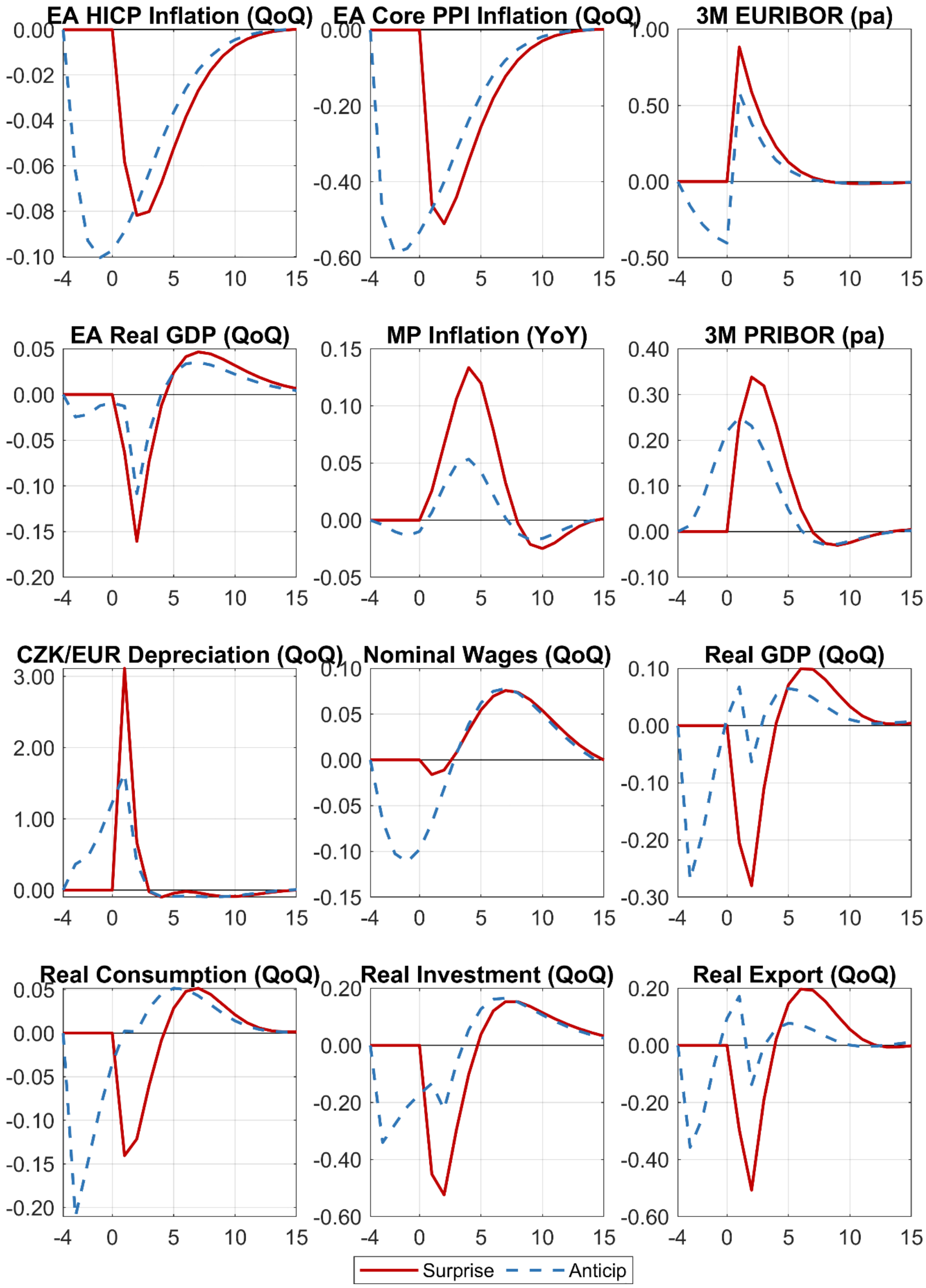
$$prem_t^{usdeur} = \rho_{prem^{usdeur}} prem_{t-1}^{usdeur} + \epsilon_t^{prem^{usdeur}},$$

$$\tilde{\pi}_t^{*ener} = \rho_{\pi^{*ener}}\,\tilde{\pi}_{t-1}^{*ener} + (1 - \rho_{\pi^{*ener}})\,\tilde{\pi}^{*ener} + \epsilon_t^{\tilde{\pi}^{*ener}},$$

$$\Delta y_t^{*ftrend} = \rho_{y^{*ftrend}}\Delta y_{t-1}^{*ftrend} + \left(1 - \rho_{y^{*ftrend}}\right)\Delta y^* + \epsilon_t^{y^{*ftrend}}.$$

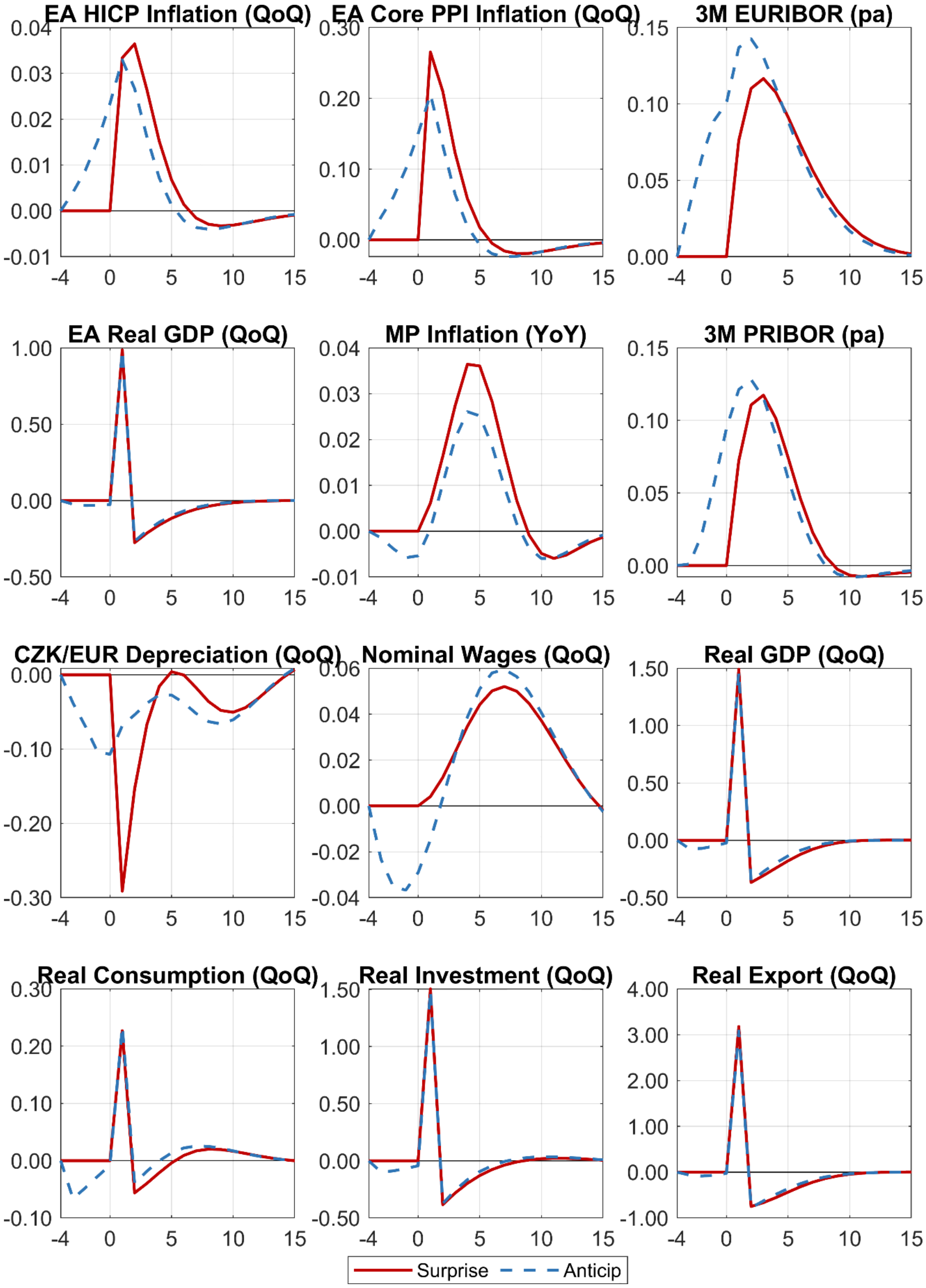
Appendix 2E: g3+ Impulse Responses

Figure 2E.1: Foreign Monetary Policy Shock (deviation, %)



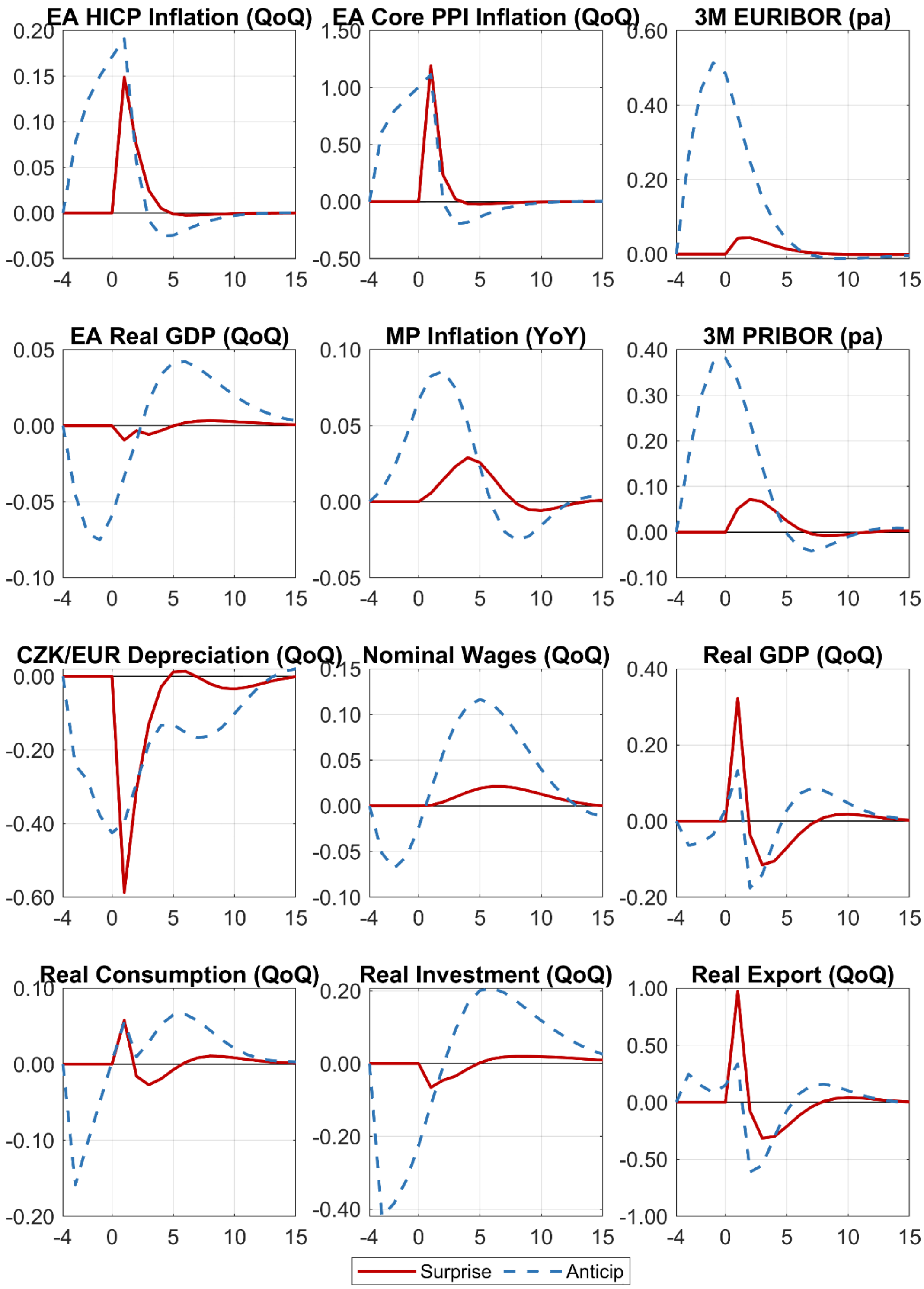
Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Figure 2E.2: Foreign Demand Shock (deviation, %)



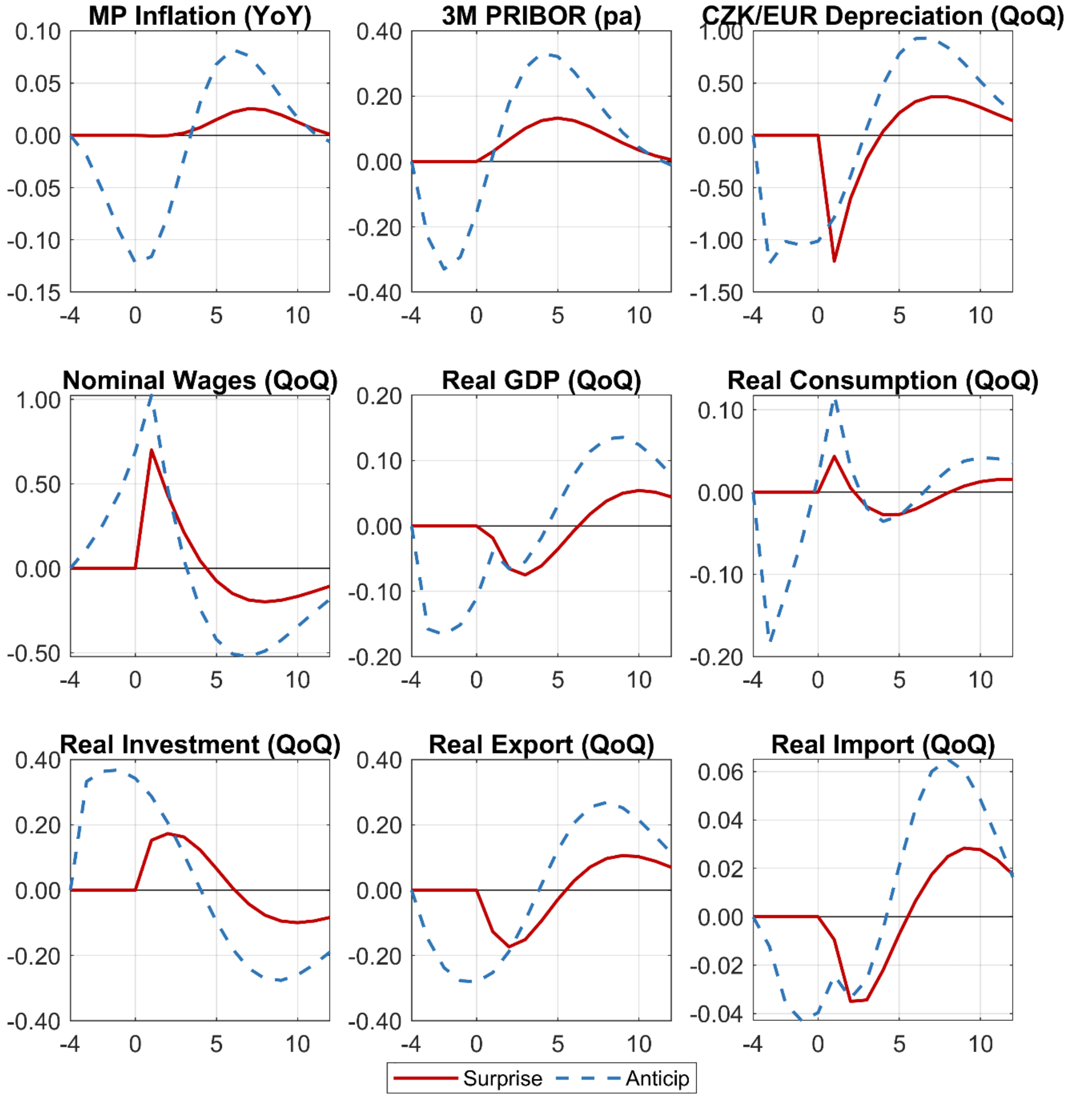
Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Figure 2E.3: Foreign Core Producer Price Inflation Shock (deviation, %)



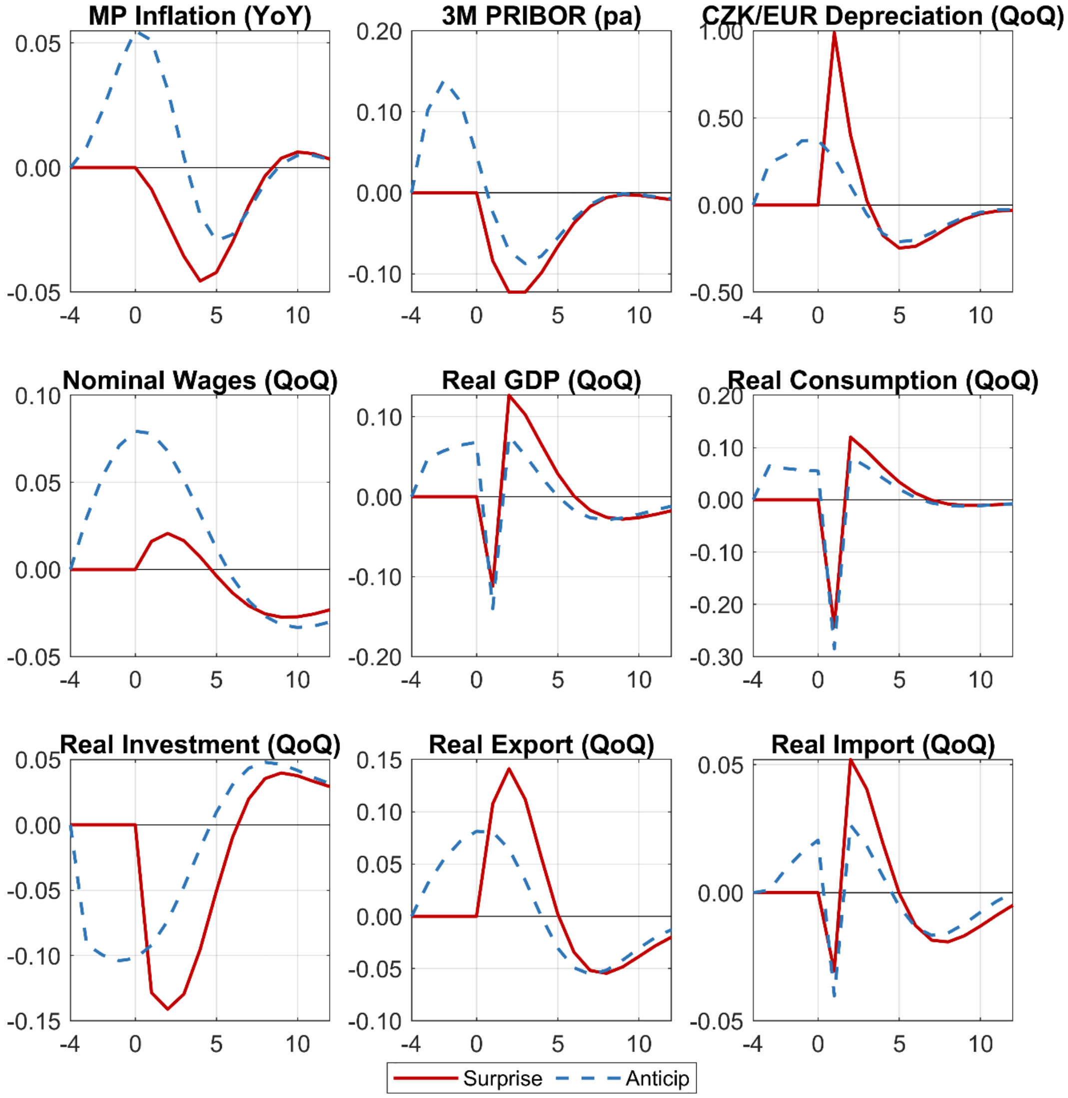
Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Figure 2E.4: Domestic Wage Push Shock (deviation, %)



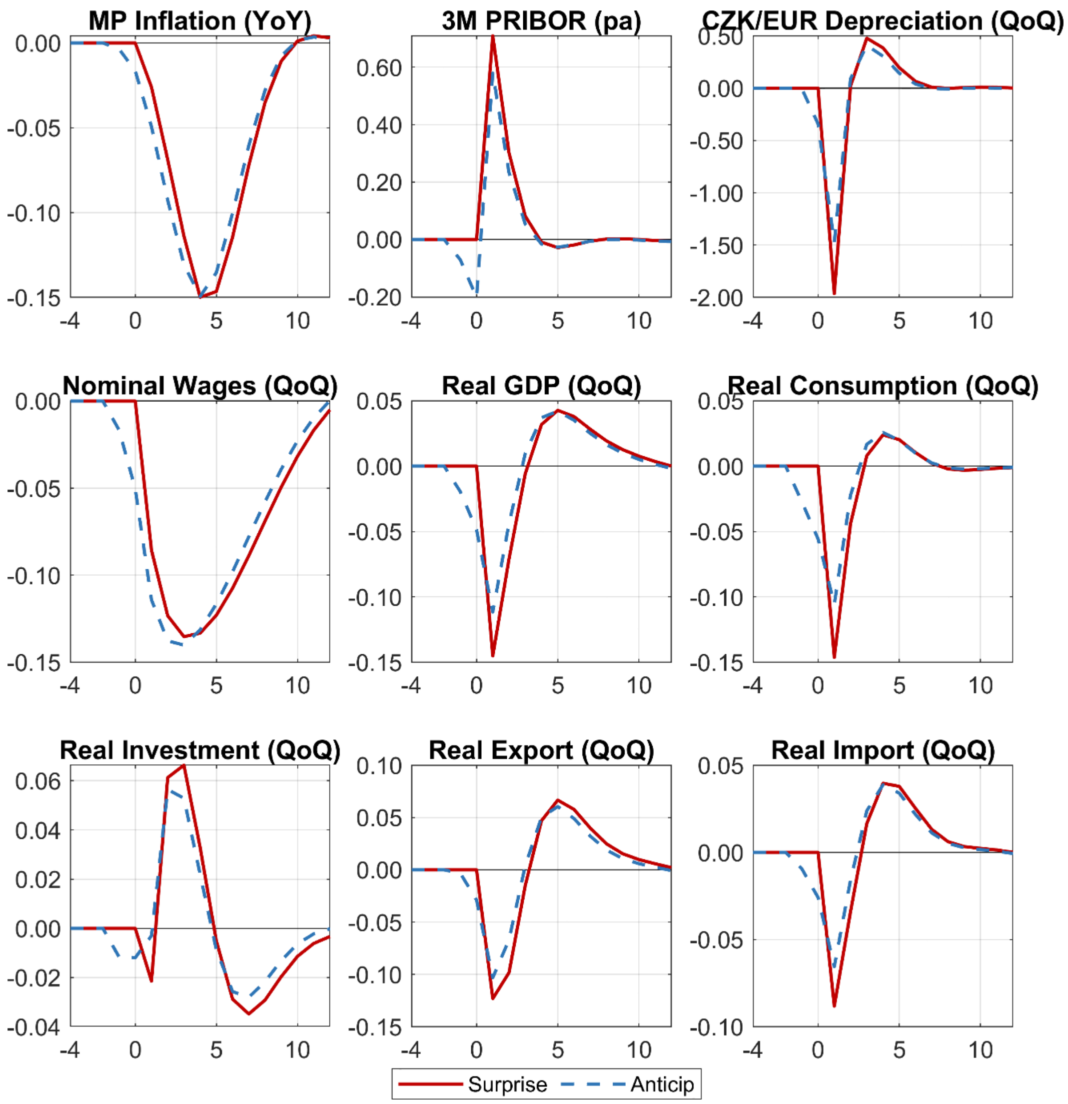
Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Figure 2E.5: Transient TFP Shock (deviation, %)



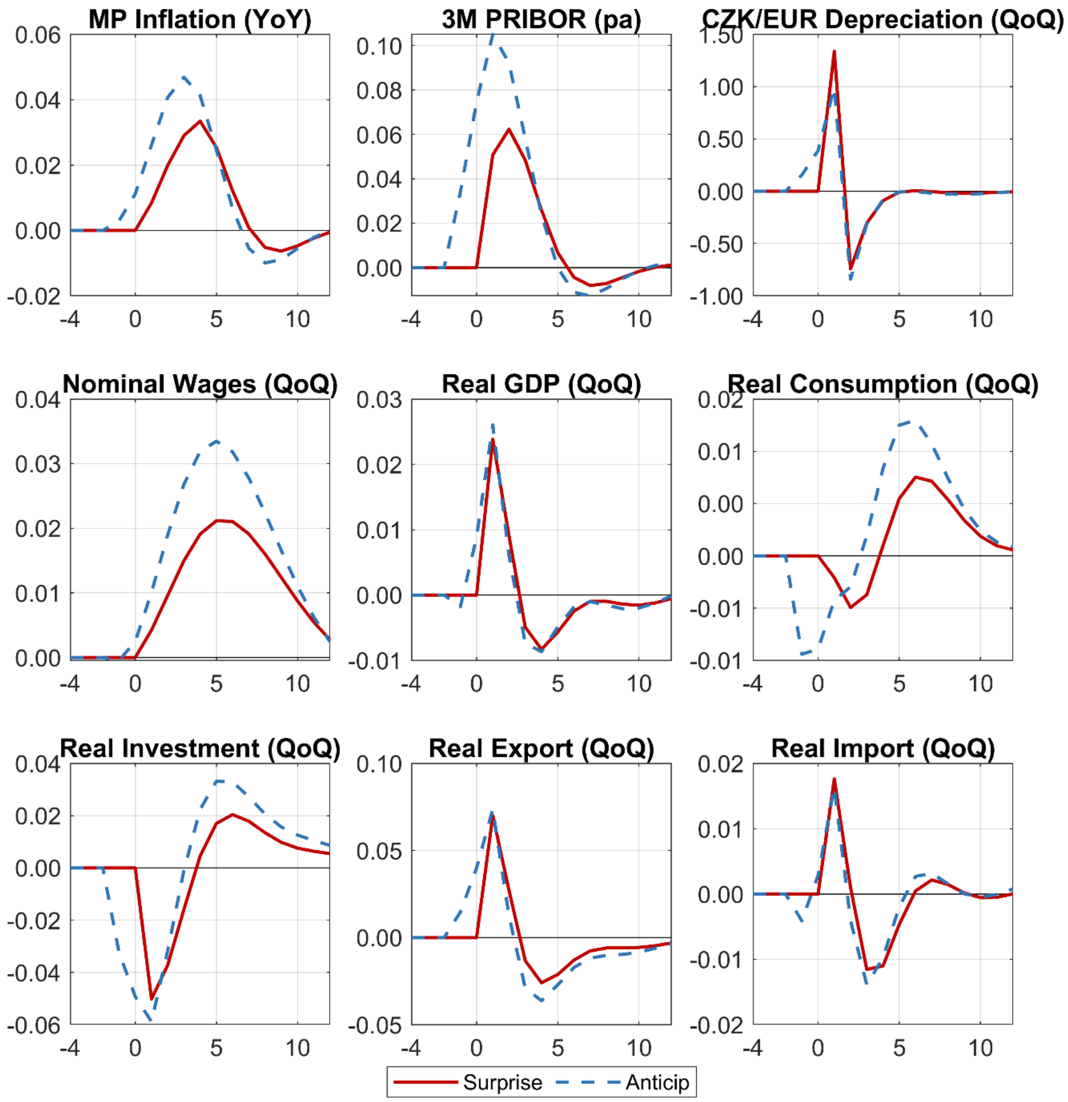
Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Figure 2E.6: Domestic Monetary Policy Shock (deviation, %)



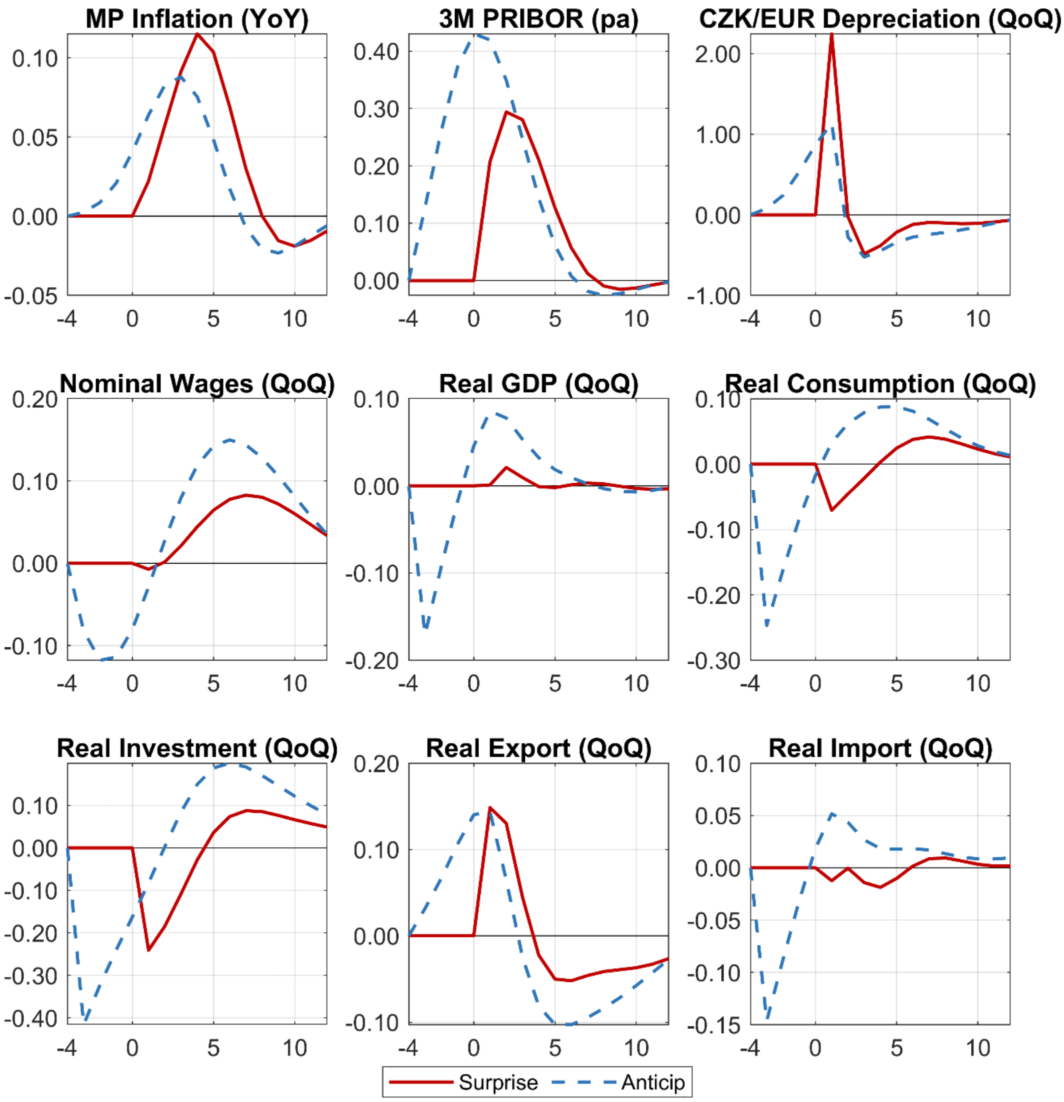
Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Figure 2E.7: Domestic One-Off UIP Shock (deviation, %)



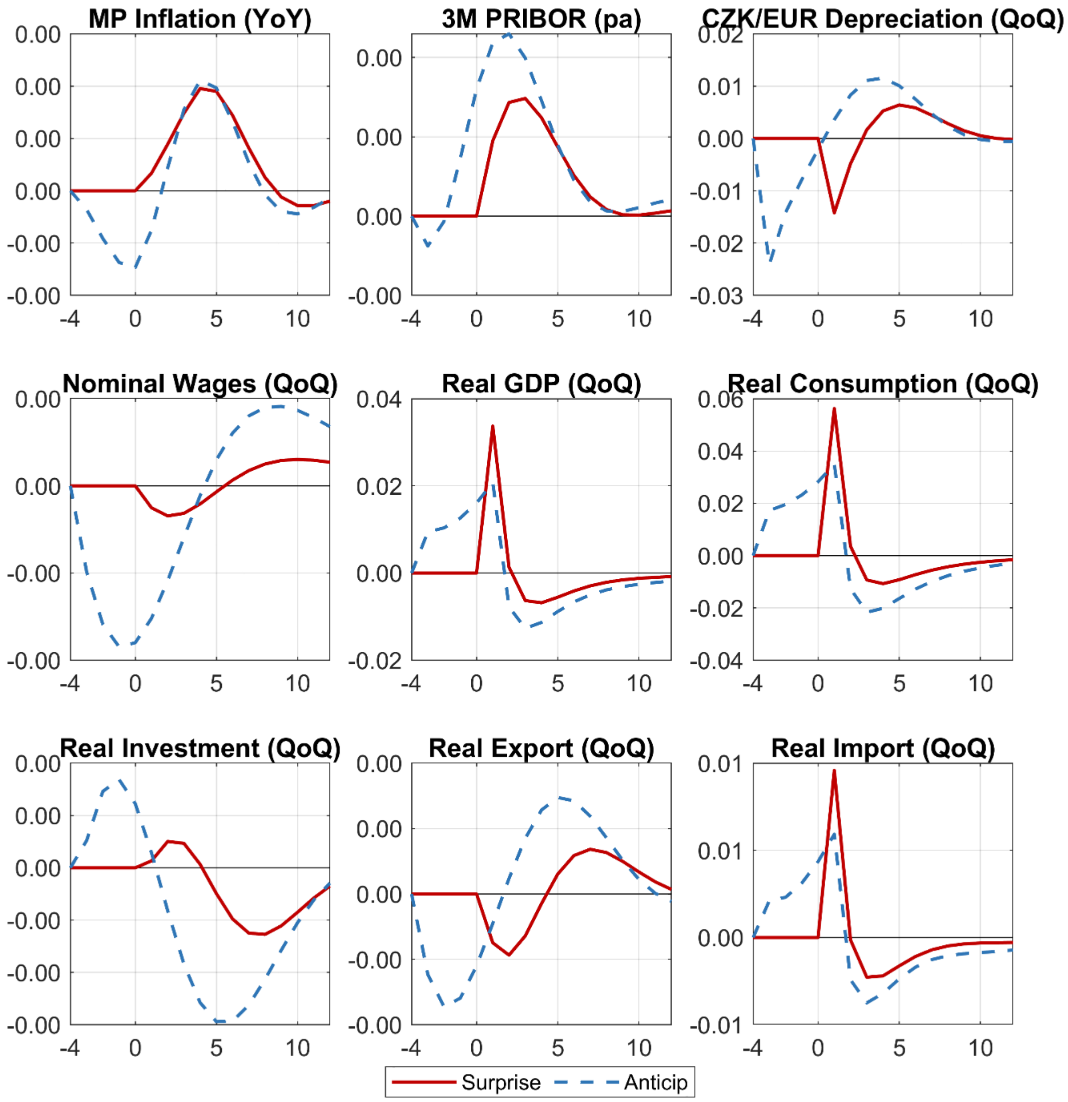
Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Figure 2E.8: Domestic Persistent UIP Shock (deviation, %)



Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Figure 2E.9: Domestic Consumption Preference Shock (deviation, %)



Note: The figure shows impulse responses of the variables to a one percent deviation surprise shock. Quarter-over-quarter dynamics are depicted in annualized rates.

Appendix 2F: Scenarios and Various Simulations

The Monetary Department produces four macroeconomic projections per year accompanied by four updates, resulting in a total of eight *reports* annually. The projections are published in our flagship publication, Monetary Policy Report (or Inflation Report prior to 2021), while the updates remain internal. The *reports* containing full projections are labelled with odd numbers 1, 3, 5, and 7, while the updates follow even numbers 2, 4, 6, and 8. For example, the report no. 3 in 2008 corresponds to the Inflation Report II/2008, or the Report no. 1 in 2024 corresponds to the Monetary Policy Report – Winter 2024. Unpublished internal scenarios are highlighted in red.

Table 2F.1: List of Scenarios and Simulations

Year	Report no.	Scenario type	Scenario description
2008	3	alternative	Model g3 (shadow forecast)
2008	5	sensitivity	Exchange rate
2008	7	alternative	Significant slowdown in the foreign and domestic economy
2008	7	sensitivity	Exchange rate
2008	7	sensitivity	Oil price
2009	1	alternative	Effects of a more pronounced slowdown in foreign economies
2009	1	sensitivity	Exchange rate
2009	3	sensitivity	Nominal wage
2009	3	sensitivity	Exchange rate
2009	5	sensitivity	Exchange rate
2009	5	sensitivity	Energy price development
2009	7	sensitivity	Exchange rate
2009	7	sensitivity	Nominal wage
2009	7	sensitivity	Development of aggregate technology
2010	1	sensitivity	Exchange rate
2010	1	sensitivity	Development of nominal wages and productivity
2010	3	sensitivity	Exchange rate
2010	5	sensitivity	Exchange rate
2010	5	sensitivity	Foreign interest rates
2010	5	sensitivity	Fiscal policy
2010	7	sensitivity	Exchange rate
2010	7	sensitivity	Commodity prices
2010	7	sensitivity	VAT
2011	1	alternative	Higher commodity price growth
2011	1	alternative	Higher external economic growth ("the German engine")
2011	1	alternative	Lower external economic growth ("escalation of the euro area debt crisis")
2011	1	sensitivity	Exchange rate
2011	3	alternative	VAT rate increase
2011	3	sensitivity	Exchange rate
2011	5	sensitivity	Exchange rate
2011	5	sensitivity	Foreign interest rate
2011	7	alternative	Euro area stagnation
2011	7	sensitivity	Exchange rate
2012	1	sensitivity	Exchange rate
2012	3	alternative	Additional budgetary measures

2012	3	sensitivity	Exchange rate
2012	5	sensitivity	Lower external demand
2012	5	sensitivity	Exchange rate
2012	7	alternative	Zero lower bound (ZLB)
2012	7	sensitivity	Higher fiscal multiplier
2012	7	sensitivity	Exchange rate
2013	1	sensitivity	Household consumption data uncertainty
2013	1	sensitivity	Longer-term consumption deferral
2013	1	sensitivity	Exchange rate
2013	3	sensitivity	Exchange rate
2013	5	alternative	Zero lower bound (ZLB)
2013	5	sensitivity	Exchange rate
2013	7	alternative	Use of the exchange rate as a monetary policy instrument
2013	7	mon. policy	Fully expected monetary policy passivity
2013	7	sensitivity	Exchange rate
2013	7	sensitivity	Lower natural domestic interest rate
2014	3	sensitivity	Exchange rate maintained at 27.4 CZK/EUR
2014	3	sensitivity	Fiscal policy
2015	1	alternative	Assessing the impacts of continuing low oil prices
2015	3	alternative	Lower inflation expectations
2015	7	sensitivity	Subdued price developments in the euro area
2016	1	sensitivity	Oil price (lower variant)
2016	1	sensitivity	Oil price (upper variant)
2016	3	sensitivity	Lower external PPI and insufficiently anchored inflation expectations
2016	7	sensitivity	Extension of ECB QE
2017	3	sensitivity	Gradual appreciation of the koruna after the end of the exchange rate commitment
2017	5	sensitivity	Gradual appreciation of the koruna after the end of the exchange rate commitment
2017	7	sensitivity	Gradual appreciation of the koruna after the end of the exchange rate commitment
2018	1	sensitivity	Exchange rate
2018	3	sensitivity	Labor efficiency
2018	3	sensitivity	Exchange rate
2018	5	sensitivity	Exchange rate
2018	5	sensitivity	Lower inflation
2018	7	sensitivity	Exchange rate
2019	1	sensitivity	Exchange rate
2019	1	sensitivity	Disorderly Brexit
2019	3	alternative	Model g3+ (shadow)
2019	5	sensitivity	Lower GDP growth in the euro area
2019	5	sensitivity	GDP stagnation in the euro area
2019	5	alternative	Model g3 (shadow)
2019	7	sensitivity	Disorderly Brexit
2020	1	sensitivity	Exchange rate
2020	2	alternative	Pessimistic scenario
2020	2	alternative	Counterfactual scenario without pandemic

2020	3	alternative	Longer-lasting pandemic
2020	3	alternative	Pandemic resurgence
2020	5	alternative	Lower global productivity
2020	5	sensitivity	Exchange rate
2020	7	alternative	Worse pandemic
2020	7	alternative	Fiscal policy
2021	1	alternative	The longer-lasting pandemic-induced downturn
2021	1	mon. policy	The unchanged rates scenario
2021	3	alternative	Longer-lasting pandemic scenario
2021	3	MP simulation	Rate stability – baseline assumptions materialise
2021	3	MP simulation	Growth rate with a longer-lasting pandemic scenario
2021	5	MP simulation /sensitivity	Slower rate growth with inflation expectations remaining anchored
2021	5	MP simulation /sensitivity	Slower rate growth with inflation expectations becoming unanchored
2021	5	sensitivity	Exchange rate
2021	7	alternative	Longer-lasting supply chain disruption
2021	7	MP simulation /sensitivity	Slower rate growth with inflation expectations remaining anchored
2021	7	MP simulation /sensitivity	Slower rate growth with inflation expectations becoming unanchored
2021	7	sensitivity	Fiscal restriction in 2023
2021	8	MP simulation	Loss of anchoring of inflation expectations
2022	2	MP simulation	Exempting the primary price effects of war
2022	2	MP simulation	Extended monetary policy horizon by 2 quarters (MPH shift)
2022	3	sensitivity	Temporarily elevated inflation expectations
2022	3	MP simulation	More distant monetary policy horizon than the standard one
2022	3	sensitivity	More distant monetary policy horizon and the use of foreign exchange interventions
2022	4	MP simulation	Temporarily elevated inflation expectations
2022	4	MP simulation	More distant monetary policy horizon
2022	5	MP simulation	Standard monetary policy horizon
2022	5	sensitivity	Increased inflation expectations
2022	5	alternative	Complete and permanent halt in energy commodity supplies from Russia to the EU
2022	6	MP simulation	Increased inflation expectations
2022	6	MP simulation	Unchanged rates
2022	6	MP simulation	More distant monetary policy horizon
2022	7	sensitivity	Unanchored inflation expectations (FMIE survey data)
2022	7	MP simulation	Monetary policy horizon 12–18 months ahead
2022	7	MP simulation	Monetary policy horizon 18–24 months ahead
2023	1	MP simulation	Unchanged rates
2023	3	MP simulation	Keeping interest rates unchanged for longer
2023	3	MP simulation /sensitivity	Keeping rates unchanged for longer amid elevated inflation expectations
2023	5	MP simulation /sensitivity	Elevated inflation expectations with rates kept unchanged for longer
2023	5	sensitivity	Faster decline in the saving rate
2023	7	MP simulation /sensitivity	Stronger January repricing with rates kept unchanged for longer

2023	7	MP simulation	Keeping interest rates unchanged for longer
2023	7	MP simulation	Keeping interest rates unchanged for longer followed by a gradual decline
2023	7	MP simulation	Gradual decline in interest rates
2023	8	MP simulation	Gradual decline in interest rates
2024	1	sensitivity	Elevated inflation expectations scenario
2024	1	MP simulation	More even reduction in interest rates
2024	1	alternative	Updated g3+ model (shadow)
2024	3	sensitivity	Higher natural rate of interest (r*)
2024	3	sensitivity	Exchange rate

Appendix 3A: The Latest Analyses of the Czech Economy

- Two phenomena of the current high inflation – intense and broad-based price growth, Monetary Policy Report – Winter 2022 (Box 4), K. Musil, J. Šolc, N. Tomanová
- The financial situation of domestic firms in an environment of high growth in energy prices, Monetary Policy Report – Winter 2022 (Box 3), O. Michálek
- How will the high energy prices affect household consumption?, Monetary Policy Report – Winter 2022 (Box 2), O. Michálek
- Ukrainian nationals on the Czech labor market, Monetary Policy Report – Spring 2022 (Box 2), A. Ruschka
- Inflation through the lens of demand factors, Monetary Policy Report – Autumn 2022 (Box 2), J. Brůha, J. Šolc, N. Tomanová
- Business performance and pricing amid the continuing energy shock, Monetary Policy Report – Autumn 2022 (Box 1), O. Michálek, M. Šarboch, J. Žáček
- The impact of elevated energy prices on households and businesses, Monetary Policy Report – Winter 2023 (Box 2), J. Šolc, N. Tomanová, A. Ruschka
- Analysis of wage growth in the Czech Republic, Monetary Policy Report – Spring 2023 (Box 1), K. Galuščák, B. Livorová, A. Ruschka
- Reasons for households' current increased propensity to save, Monetary Policy Report – Summer 2023 (Box 1), O. Michálek, M. Šarboch
- An updated LUCI computation method, Monetary Policy Report – Autumn 2023 (Box 3), A. Ruschka
- Several perspectives on the different development of goods and services prices, Monetary Policy Report – Spring 2024 (Box 2), J. Šolc, N. Tomanová

Appendix 3B: Working Papers Related to NTF Techniques

- The Rushin Index: A Weekly Indicator of Czech Economic Activity, CNB WP 4/2021
- Nowcasting Macroeconomic Variables Using High-Frequency Fiscal Data, CNB WP 5/2022
- Ace in Hand: The Value of Card Data in the Game of Nowcasting, CNB WP 14/2023