EUROPEAN CENTRAL BANK

EUROSYSTEM

ECB Macroeconometric Models for Forecasting and Policy Analysis

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ECB macroeconometric models for forecasting and policy analysis

Development, current practices and prospective challenges

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Box 1: Benchmarking our models against external models for a standard monetary policy shock (**Srečko Zimic**)

Box 2: Unconditional and conditional forecasting with NAWM II (**José Emilio Gumiel** and **Anders Warne**)

Box 3: A carbon tax transition scenario using our climate-augmented models (**Romanos Priftis**)

Annex I: How did we get there? A short history of model development at the ECB (**Matteo Ciccarelli** and **Gabriel Fagan**)

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Overview

1. Suite of model approach
2. Policy use cases: projection, scenarios, risks, monetary policy
3. Forecasting and policy analysis under *high* uncertainty
4. Investing in modelling infrastructure
5. Current agenda and the future of models

1

Suite-of-model approach

Rationale and flexibility

One or many models?

- No aspiration to build a model that includes everything
- Need for continuity in the assessment while keeping changing and including new channels and frictions
- Resonance or dissonance between academic research and modelling at policy institutions?

Academic research	Policy modelling
Simple and stylised	Realistic and granular
Deep theoretical foundations	Robust to structural uncertainty
Original and strong policy prescriptions	Continuity and consistency with policy paradigm

➢ **ECB approach: develop and maintain a suite of models and tools for complementary purposes**

ECB macro-modelling portfolio: guiding principles

Ensure robustness across modelling approaches

- Exploit the trade-off between strong structural features and empirical performance

Aggregate and multi-country modelling of the EMU

- Bottom up and top down approaches

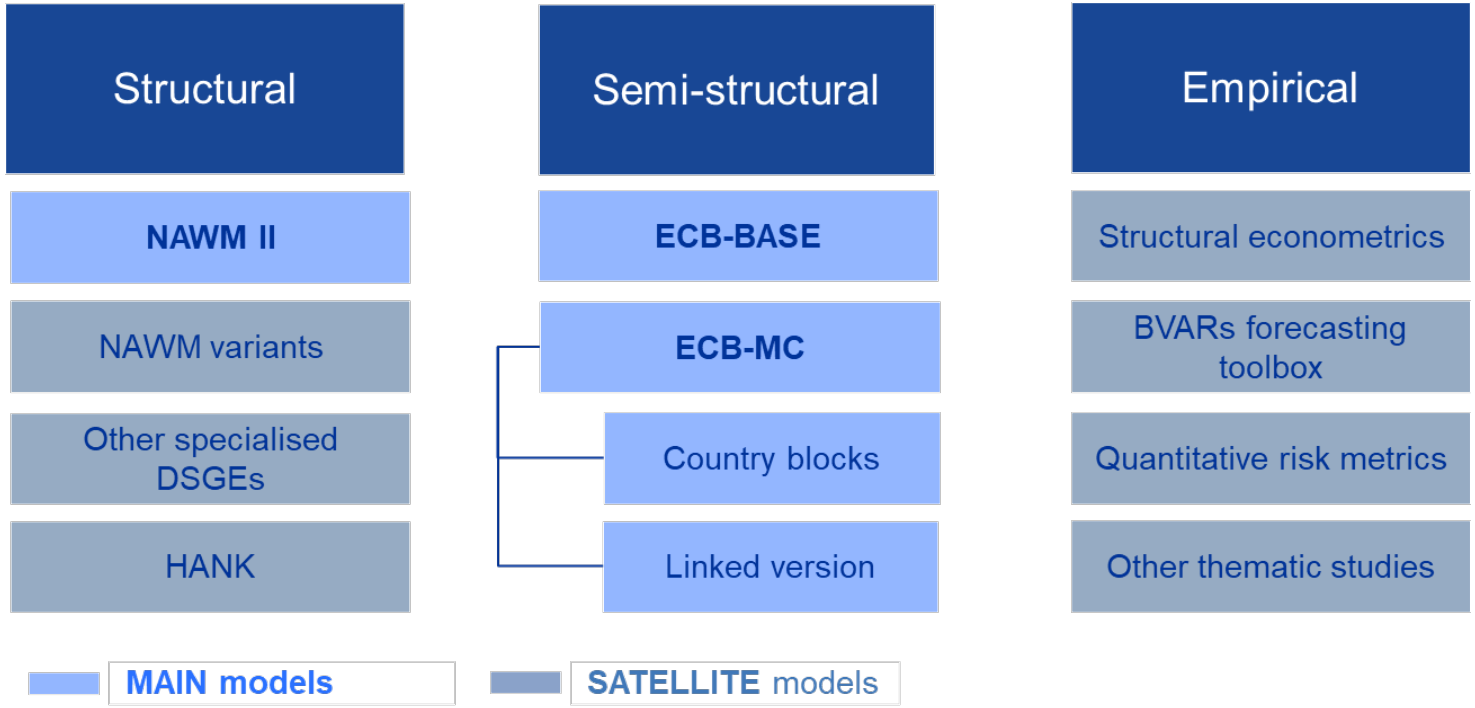
Interactions between MAIN and SATELLITE models

- Create a common institutional language through (few) MAIN models
- But articulate them with specialised SATELLITE tools

Evolutionary process

- Balance the need to learn from on-going research creativity while maintaining consistency in the model-based input to the policy process

Broad ECB macro-modelling portfolio



ECB staff rationale for investing in semi-structural models

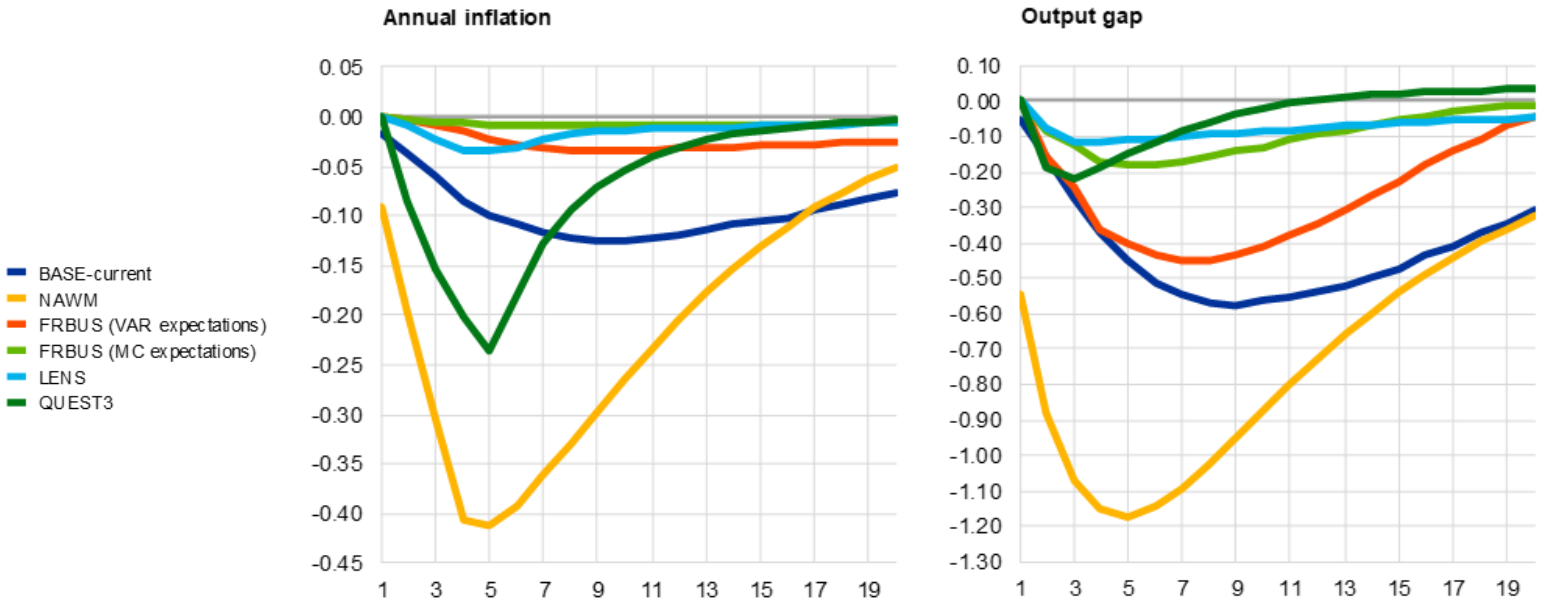
Need to account for country dimension	• Managing a multi-country/sector dimension is relatively easier (e.g. in terms of specification and estimation) than in a structural model
Need to account for *conceptual* flexibility regarding specification design	• Complementary to DSGE models also under different or hybrid expectations formation, and in combination with satellite financial models
Need to introduce *empirical* flexibility in a changing world for timely analyses	• Exploit a greater data flexibility and sectoral granularity within a consistent theoretical and accounting framework
Need to introduce *institutional* flexibility amenable to the policy process	• Forecasting with judgment, incorporating sectoral and/or country-specific expert views

- *See also Bernanke's Bank of England review*

Benchmarking our models against external models for a standard monetary policy shock

Annual inflation (left) and output gap (right)

(percentage point deviations from baseline; quarters)



Note: The responses of the models are based on publicly available material and may not reflect the most current version of each model. FRB/US: a large scale general equilibrium model of the US economy with flexible optimisation, developed by the Federal Reserve System; LENS: a large empirical and semi-structural model used by the Bank of Canada for forecasting and policy analysis; NAWM II: the New Area-Wide Model, a structural econometric model used by the ECB within a DSGE framework for the euro area; QUEST III: a macroeconomic model used by the European Commission for policy analysis and research in the EU; ECB-BASE: a semi-structural model used by the ECB for the euro area.

2

Policy use cases

Projections, policy scenarios, risks analysis, monetary policy

Policy use of the ECB macro-modelling portfolio

Economic projections

- Forecasting with judgment and model-based projection narratives for the euro area as well as for the largest euro area countries

Sensitivity, risk and scenario analysis

- Conditional predictive densities from forecasting models
- Sensitivity of baseline to key assumptions (Oil, FX, Fiscal, Financial)
- Risk balance for the (B)MPEs
- Scenario analysis of relevant macroeconomic contingencies

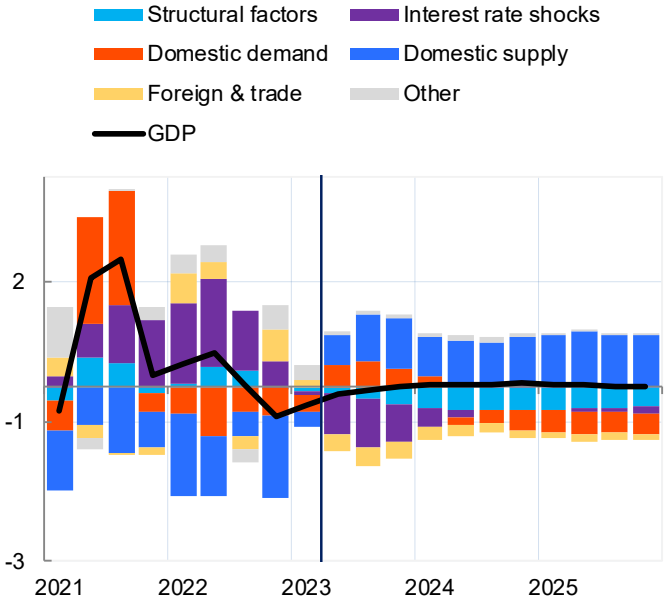
Policy analysis

- Impact study of monetary policy options
- Normative monetary policy analysis
- Strategic issues related to monetary-fiscal-financial policy mix in the euro area

NAWM: Structural shock decomposition of the June 2023 MPE baseline

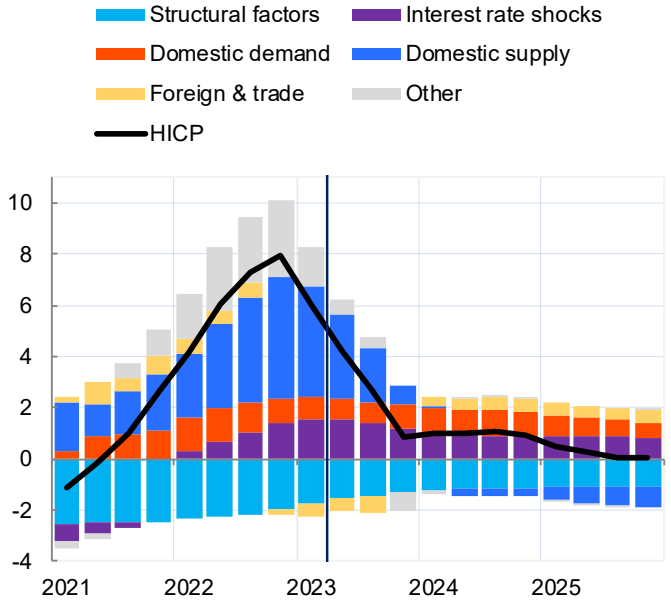
Real GDP

(q-o-q growth rates, in pp, in deviations from steady state)



HICP inflation

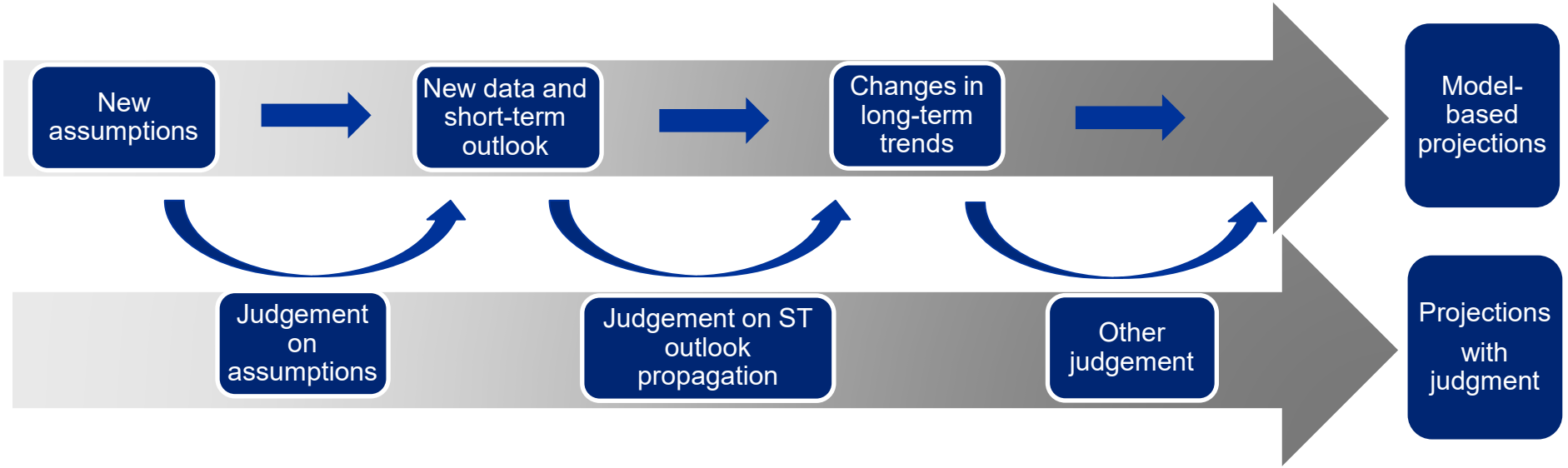
(y-o-y growth rates, in pp, in deviations from 2%)



Source: ECB staff calculations using the NAWM II.

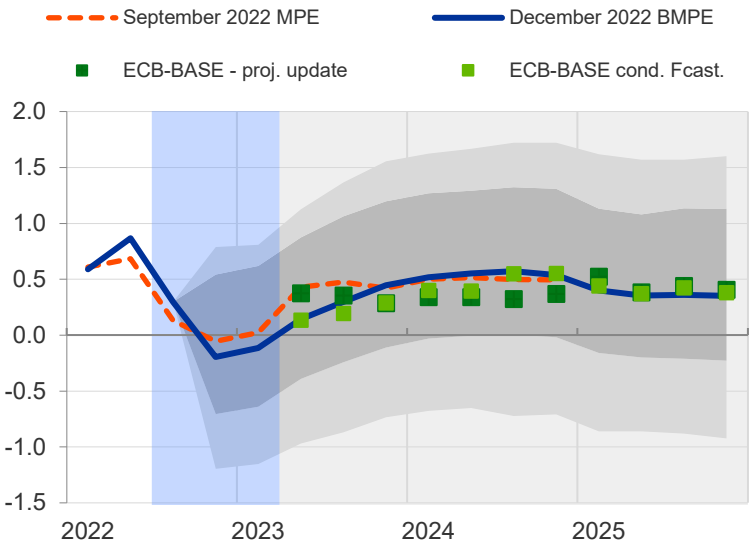
The category "**Structural factor**" includes the contributions of the initial state, the discount rate shock and the persistent component of the permanent technology shock. "**Interest rate shocks**" comprises the short-term interest rate shock and the shock to the retail bank's markdown. "**Domestic demand**" includes the domestic risk-premium shocks and shocks to government spending. The category "**Domestic supply**" captures supply-shocks, namely: the transitory component of the permanent technology shock and the transitory and investment specific technology shocks as well as wage and price mark-ups. The category "**Foreign and trade**" captures shocks to foreign demand, foreign prices, US 3-month and 10-year interest rates, competitor's export prices, oil prices, import demand , export preferences, mark-up shocks to export prices and import prices and a foreign risk-premium shock whereas "**Other**" includes measurement errors and residuals from bridge equations.

Forecasting with judgement: analytical roadmap

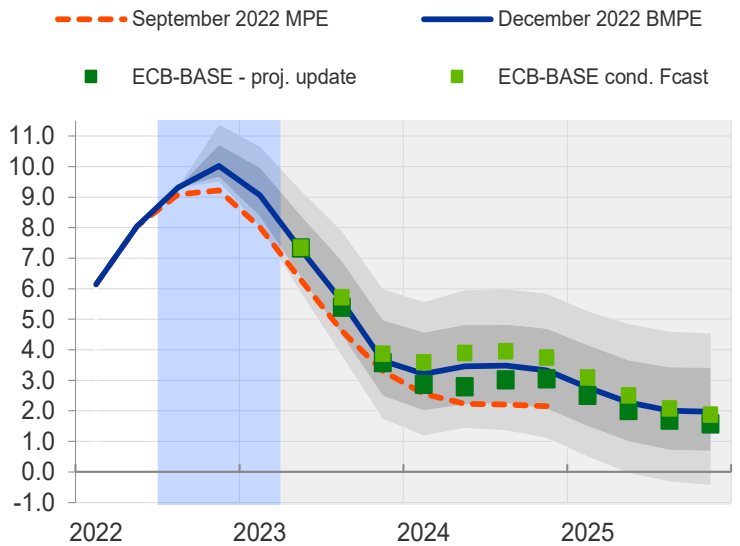


Model-based projections: December 22 BMPE

Real GDP – Euro area
(q-o-q growth rates, in %)



HICP– Euro area
(y-o-y growth rates, in %)



Source: ECB/NCB projections database and ECB/NCB staff calculations based on ECB-BASE December 2022 BMPE MPC assumptions and short-term outlook until 23Q1.
'Projection updates' correspond to model-based updates of the previous (B)MPE baseline on the basis of changes in assumptions as well as new data and changes in the short-term outlook up to 2023Q1. The dark grey areas represent the 90% confidence interval from the conditional ECB BASE forecast and light grey areas represent the 90% confidence interval from the unconditional ECB BASE forecast. They are both centred around the ECB BASE projection update. The conditional ECB-BASE forecast uses the values produced by the ECB staff for the Fiscal, Foreign, UIP, Transfers, Exchange rate, House prices, Financial, Wealth, Production, Inventories and Policy Rule blocks. In the ECB BASE model, the density forecast is computed using a bootstrap method that re-samples the in-sample residuals of the model. The forecasted value of an endogenous variable is calculated by adding the re-sampled residual to the value forecasted by the model and the distribution is obtained by repeating the process 500 times.

Risk analysis: Probabilities of high inflation under alternative scenarios

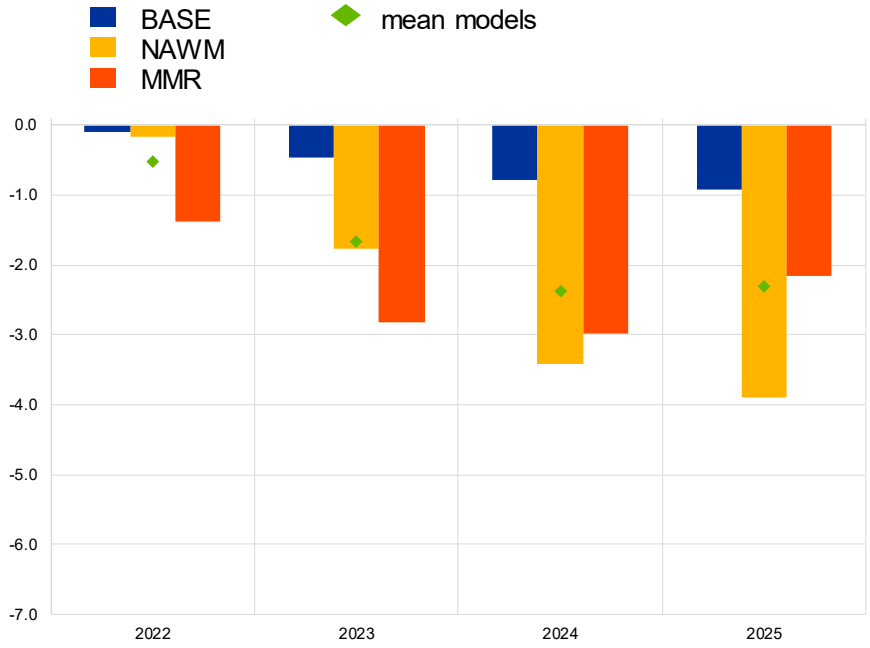
	2024		2025	
	HICP between 1.75% and 2.25%	HICP > 2.25%	HICP between 1.75% and 2.25%	HICP > 2.25%
ECB-BASE				
Baseline	**11%**	**85%**	**28%**	**42%**
Uncentred	0%	100%	23%	61%
Higher wage indexation	6%	92%	24%	56%
Unanchoring of long-term inflation	10%	86%	26%	50%
Higher wage indexation and unanchoring	6%	93%	20%	65%
NAWM II				
Baseline	**12%**	**69%**	**14%**	**48%**
With supply risks	9%	80%	11%	57%
Higher wage indexation	9%	73%	13%	55%
Unanchoring of long-term inflation	10%	73%	15%	51%
Higher wage indexation and unanchoring	8%	84%	12%	60%
BVARs				
Small VAR	**11%**	**56%**	**11%**	**50%**
Large VAR	10%	63%	9%	63%
Small VAR with time-varying coefficients	9%	60%	8%	54%

Sources: ECB calculations and June 2023 BMPE.

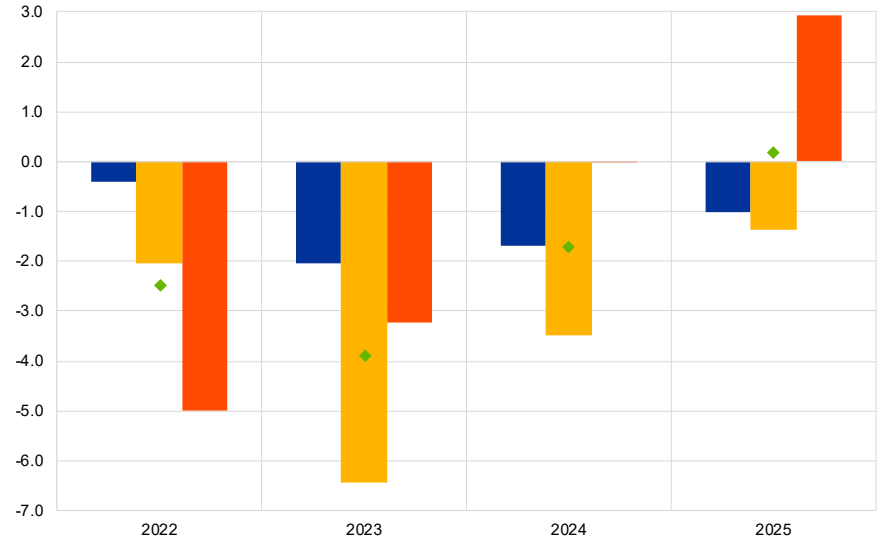
Notes: The table shows the probability of different inflation events under different risk scenarios. The probabilities are calculated using stochastic simulations around the baseline. For ECB-BASE, in the case of higher wage indexation the parameter capturing wage indexation in the wage Phillips curve of the model increases from 0.39 to 0.5. The case of unanchoring assumes that long-term inflation expectations are an autocorrelated process that depends on the ECB's inflation target and past inflation outcomes, with the weights for target inflation (72%) and past inflation (28%) calibrated so that long-term inflation expectations in the baseline reach 2.5% at some point during the forecast horizon. For NAWM II, the case of higher wage indexation assumes that the wage indexation parameter in the model increases from 0.37 to 0.5. In the case of unanchoring, long-term inflation expectations are assumed to react to past inflation, such that $\pi_t^* = 0.75\pi_{t-1}^* + 0.25\delta\pi_{t-1}$, with $\delta = 0.32$. "Small VAR" refers to a VAR with GDP growth, headline HICP inflation and the short-term interest rate; "large VAR" includes 14 variables; "small VAR with time-varying coefficients" includes the same variables as "small VAR".

Impact of monetary policy tightening from end-21 to spring-23 across models

Impact of monetary policy tightening on real GDP growth (year-on-year, percentage points)



Impact of monetary policy tightening on HICP inflation (year-on-year, percentage points)

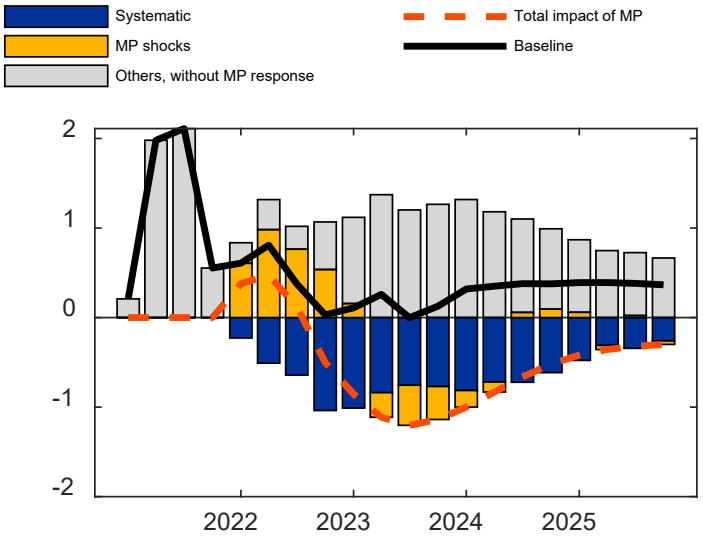


Sources: ECB calculations based on Darracq, Montes-Galdon, Motto, Ristiniemi, Satin-Guilhem and Zimic (2023), "A model-based assessment of the macroeconomic impact of the ECB's monetary policy tightening since December 2021," Economic Bulletin Boxes, European Central Bank, vol. 3.
Notes: This chart reports the results of a simulation involving changes to short-term rate expectations between December 2021 and March 2023 and changes to expectations regarding the ECB's balance sheet between October 2021 and May 2023. The reported values refer to year-on-year growth rates. "Mean" denotes the average across the three models.

NAWM: Monetary policy decomposition of the June 2023 MPE baseline

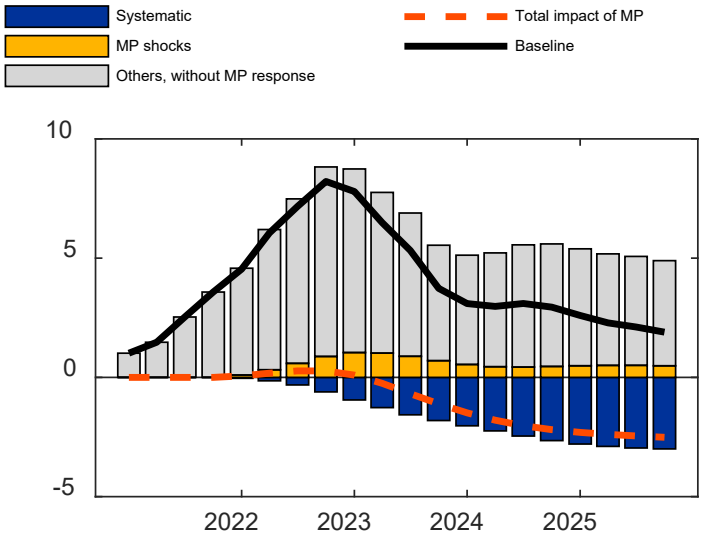
Real GDP

(q-o-q growth rates, in pp, in deviations from steady state)



Private consumption deflator

(annual level)



Source: ECB calculations using NAWM II and June 2023 BMPE.
Notes: The chart shows a historical decomposition of the June 2023 BMPE baseline based on NAWM II that identifies the impact of monetary policy (MP) shocks and the impact of the systematic component of monetary policy since December 2021. The latter refers to the historical response in the short-term nominal interest rate to changes in inflation and output according to a policy rule, while the shocks account for deviations from that rule. The grey bars capture the impact of all other shocks in the model, without any monetary policy response.

3
Forecasting and policy analysis under high uncertainty

The effect of large and unexpected crises on the approach

- Point or density forecast becomes ‘problematic’
- IRF and conditional forecasts of time series models with extreme values can explode
- The forecast uncertainty (typically based on past performance) is not meaningful any longer

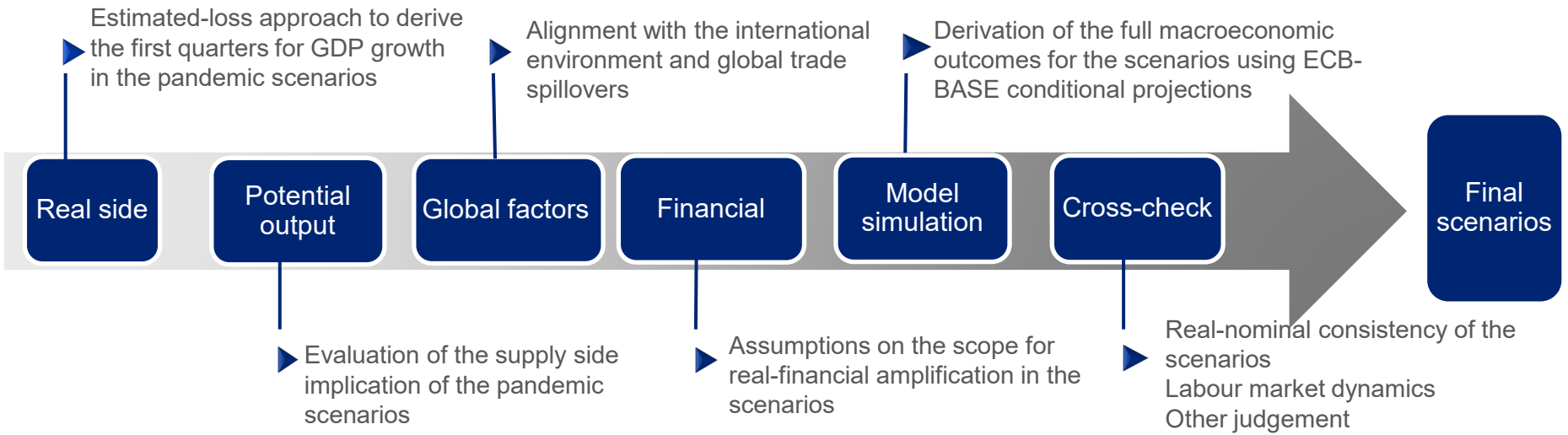
Solution: informed scenarios make more sense than a baseline forecast

For example:

- Alternative pandemic scenarios for the euro area economic outlook, September 2020.
- The impact of the conflict in Ukraine on the euro area economy in the baseline and two alternative scenarios, March 2022.
- Scenario analysis of a potential further slowdown and financial stresses in China and spillovers to the euro area, September 2023.
- Scenario analysis of a potential further escalation of the conflict in the Middle East, December 2023.

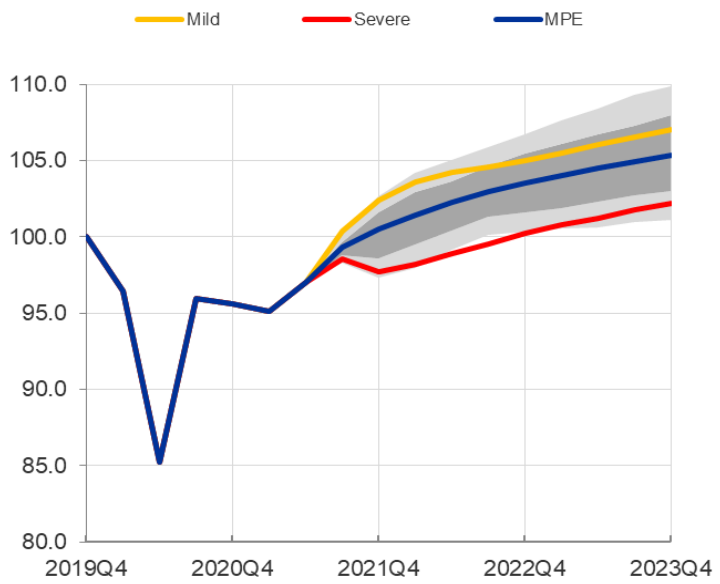
Alternative pandemic scenarios for the euro area: analytical roadmap

Unchanged technical assumptions across scenarios

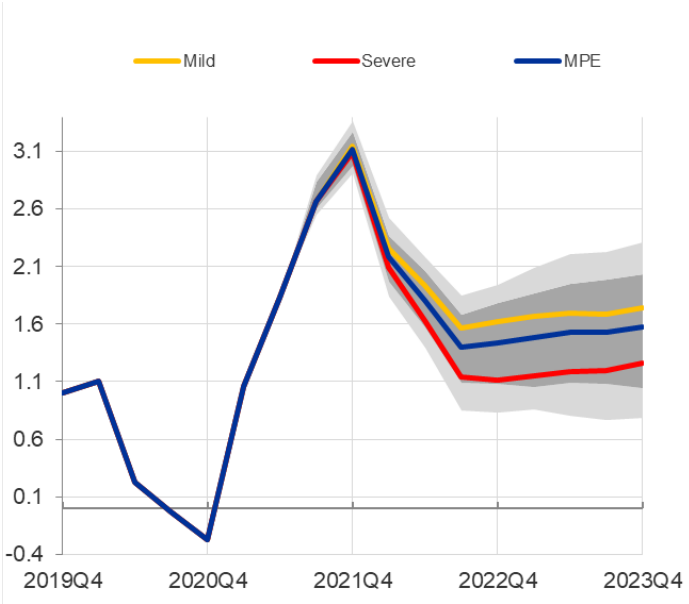


ECB-BASE: Simulating alternative pandemic developments in 2020Q3

Real GDP
(index =100 2019q4)



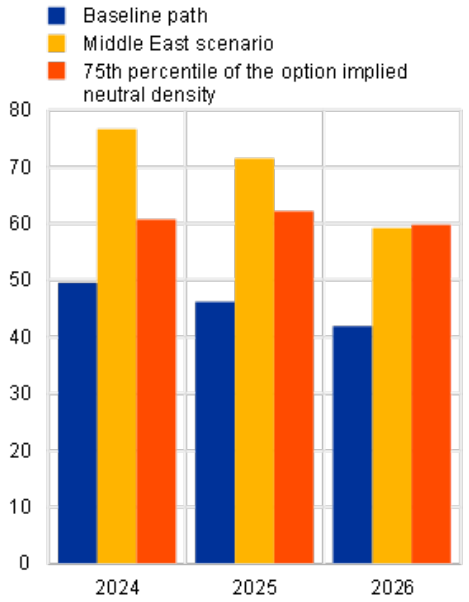
HICP inflation
(y-o-y growth rates, in %)



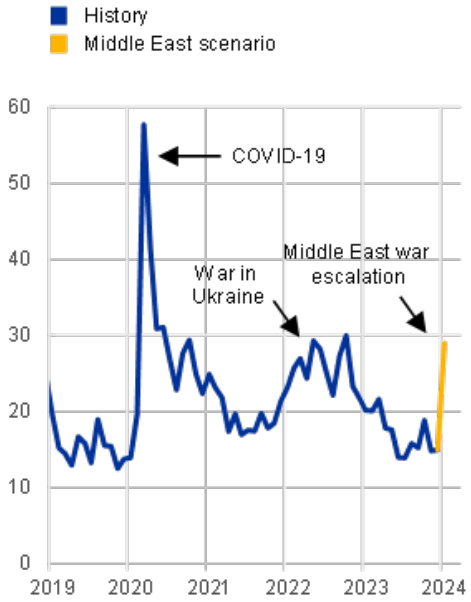
Sources: ECB projections database and ECB calculations based on ECB-BASE for the scenarios.
Notes: The grey areas represent the 90% and 68% confidence intervals from the ECB-BASIR forecast. They are centred around the September 2021 MPE. The density forecast is computed using a bootstrap method that re-samples the in-sample residuals of the model and considers the uncertainty related to pandemic developments, like vaccination efficiency and virus fundamentals.

Scenario of a potential escalation of the conflict in the Middle East

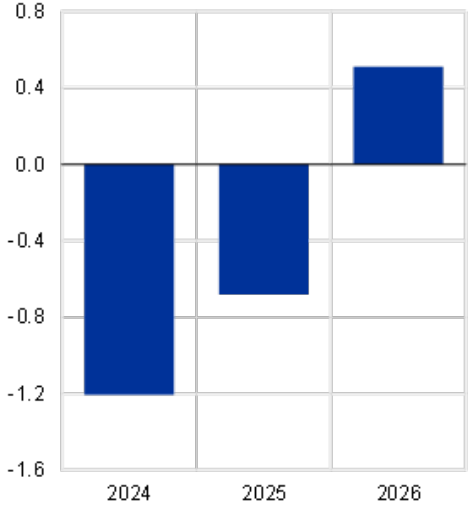
Synthetic energy price index
(USD/MWh)



US stock market volatility index (VIX)
(index)



Euro area foreign demand growth
(percentage point deviation from baseline)

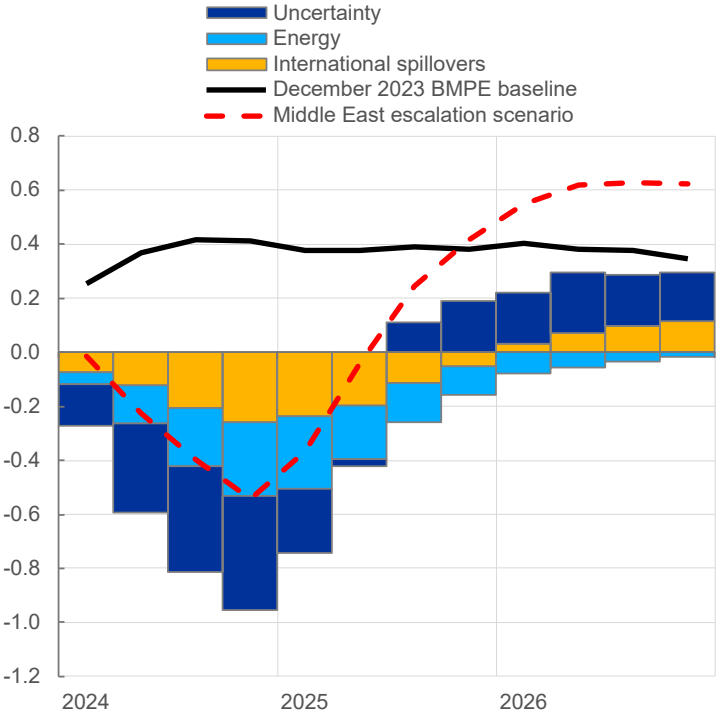


Notes: The Synthetic Energy Commodity Price Index is calculated as a weighted average of oil and gas prices. The oil price scenario is constructed based on the elasticity of the oil price to oil supply shocks as estimated in Caldara, D., Cavallo, M. and Iacoviello, M., "Oil price elasticities and oil price fluctuations", Journal of Monetary Economics, Vol. 103, 2019; while the gas price scenario is constructed based on the elasticity of the gas price to gas supply shocks as estimated in Albrizio, S., Bluedorn, J., Koch, C., Pescatori, A. and Stuermer, M., "Sectoral Shocks and the Role of Market Integration: The Case of Natural Gas", AEA Papers and Proceedings, American Economic Association, Vol. 113, pp. 43-46, May 2023. The volatility index is based on the VIX from the Chicago Board Options Exchange. The impact on euro area foreign demand is computed using the ECB-Global Model and covers energy prices, uncertainty and trade effects.

Simulating a Middle East war escalation scenario in 2023Q4

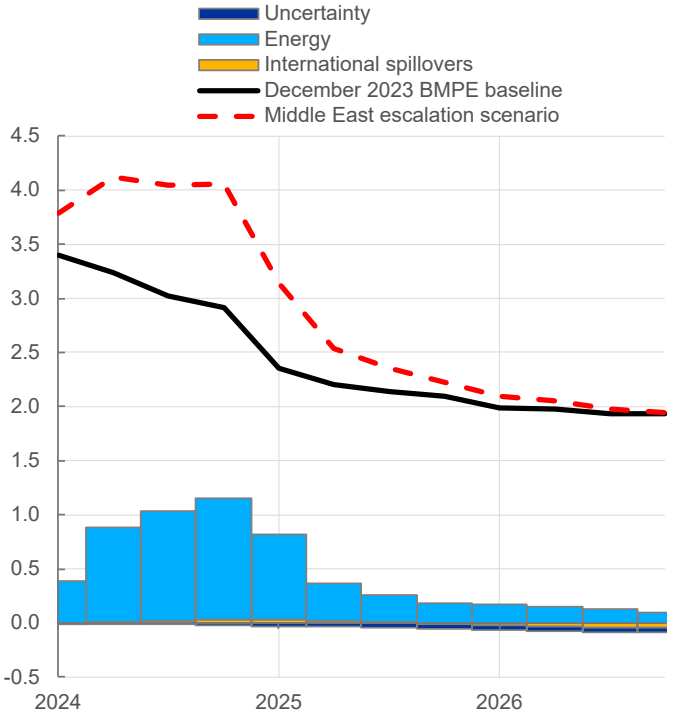
Real GDP

(quarter-on-quarter growth rates)



HICP inflation

(year-on-year growth rates)



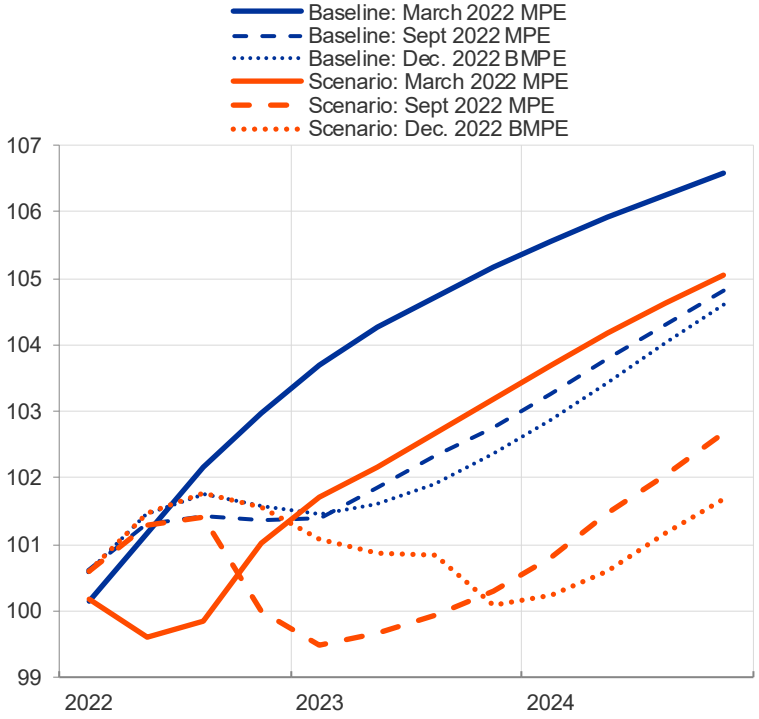
Source: ECB staff calculations.

EA macroeconomic results simulated with ECB-BASE. International spillovers effects consists of euro area foreign demand, competitor's export prices and exchange rate changes. Energy consists of oil and gas price assumptions. The effect of uncertainty on GDP is derived from a satellite VAR analysis featuring the VIX index. The real GDP, business investment and consumption effects are then imposed in ECB-BASE to extract other endogenous variables including HICP inflation.

Risk assessment through counterfactual scenarios during the energy crisis

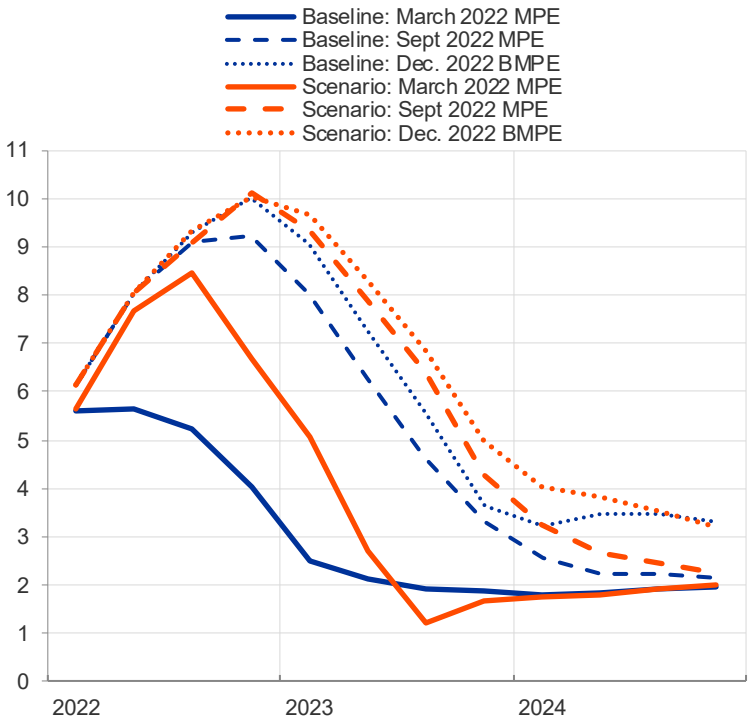
Real GDP

(index, 2021Q4 = 100)



HICP inflation

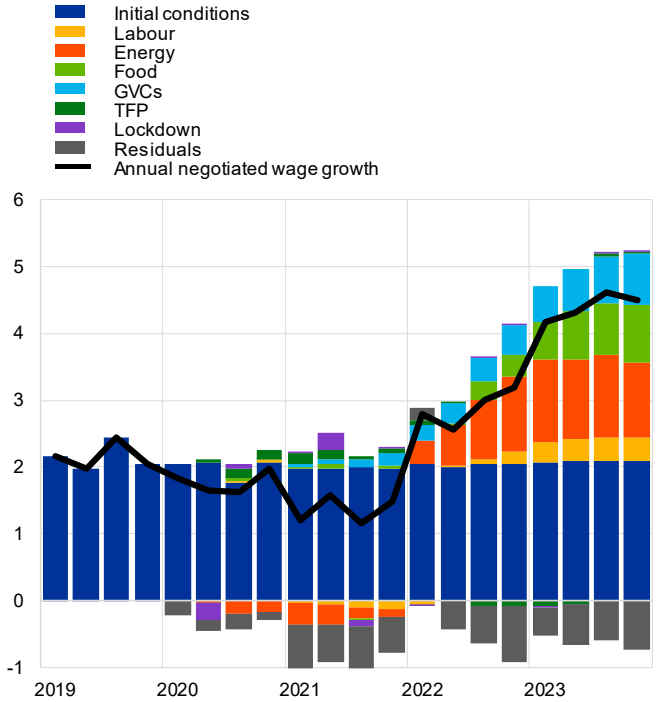
(year-on-year growth rates)



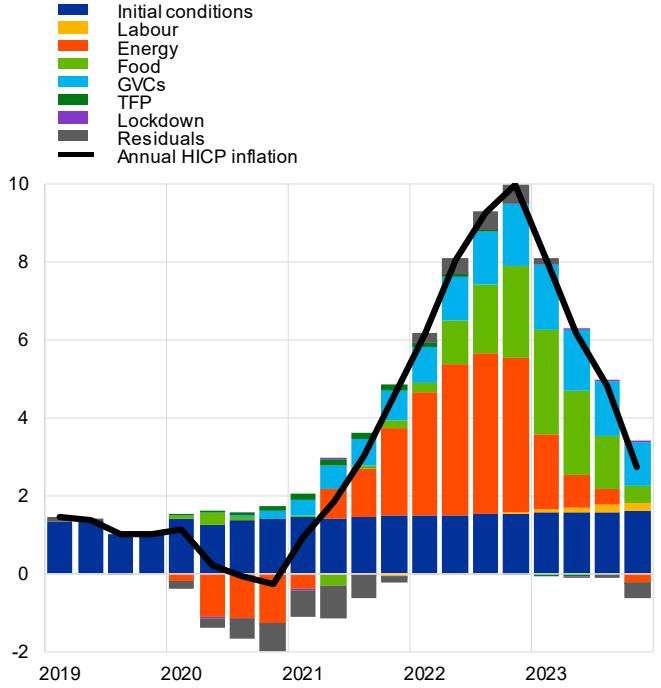
Source: ECB staff calculations.
Baseline refer to the respective baseline staff projections.
Scenario: March 2022 MPE: see box: 'The impact of the conflict in Ukraine on the euro area economy in the baseline and two alternative scenarios'
Scenario: Sept. 2022 MPE: see box: 'A downside scenario related to the war in Ukraine and energy supply cuts'
Scenario: Dec. 2022 BMPE: see box: 'A downside scenario related to the war in Ukraine and energy supply cuts'

The “inflation surge” through the lens of Bernanke-Blanchard model for the euro area

Negotiated wages
(annual percentage change)



HICP inflation
(annual percentage change)



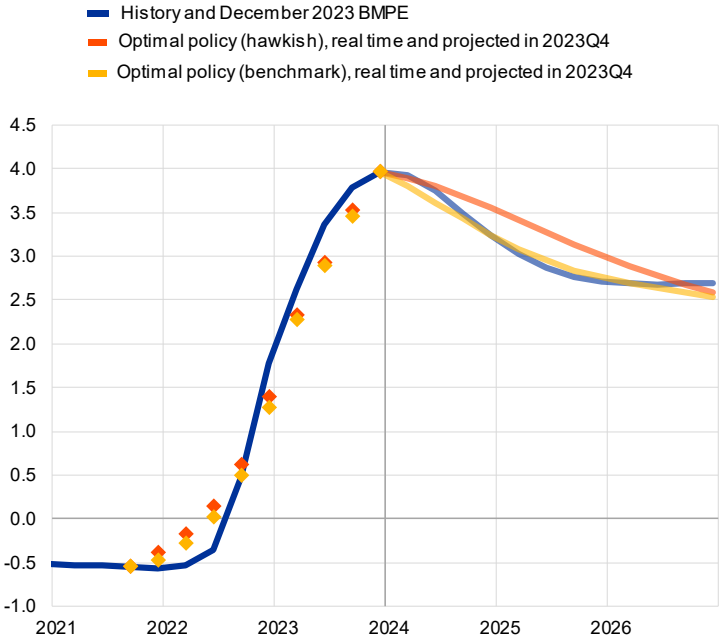
Source: ECB calculations based on Arce, A., Ciccarelli, M., Kornprobst, A. and Montes-Galdón, C. (2024), “What caused the euro area post-pandemic inflation?”, Occasional Paper Series, No 343, ECB.
Notes: The figure shows a decomposition of the sources of annual negotiated wage growth and HICP inflation between the first quarter of 2019 and the fourth quarter of 2023 based on the solution of the full model and the implied impulse response functions. The continuous line shows actual data, and the total net heights of the bars are the model’s forecast of inflation in each period, given initial conditions up to the fourth quarter of 2019. The contributions of the residuals are computed as the difference between actual and simulated data. The dark blue portion of each bar shows the contribution of pre-2020 data. The coloured segments of each bar show the general equilibrium, fully dynamic contribution of each exogenous variable to inflation in that period, as implied by the estimated model.

Monetary policy analysis

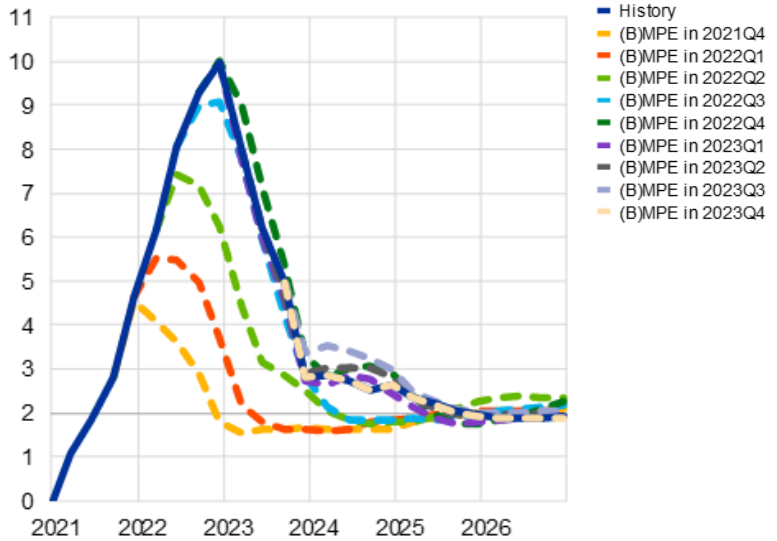
- Scenario analysis also considers the impact of monetary policy and its calibration
- Together with **counterfactual analysis** to evaluate its effectiveness
- Also, **normative** analysis: $\mathcal{L}_j = \frac{1}{2}\sum_{t}^{t+h} \beta^t \mathbb{E}_t(\lambda_\pi \hat{\pi}_{t,j}^2 + \lambda_y \hat{y}_{t,j}^2 + \lambda_{\Delta i} \Delta i_{t,j}^2)$
  - Monetary policy strategies to navigate post-pandemic inflation: an assessment using the ECB's New Area-Wide Model, *ECB Working Paper No 2935, 2024.*

Actual monetary policy conduct against real-time optimal policy benchmarks

Optimal short-term interest rate
(annualised, percentages)



HICP inflation
(year-on-year growth rate)



Source: ECB calculations based on Darracq Pariès, M., Kornprobst, A., and Priftis, R (2024) "*Monetary Policy Strategies to Navigate Post-Pandemic Inflation: An Assessment using the ECB's New Area-Wide Model*", ECB Working Paper, No. 2935

Note: This figure depicts policy under staggered real-time information about macroeconomic conditions between 2021Q4 and 2023Q4. Policy projections are updated every quarter with the vintage of the relevant projection baseline (December 2021, March 2022, June 2022, September 2022, December 2022, March 2023, June 2023, September 2023, December 2023). The optimal policy paths are computed by minimizing the central bank loss function. From 2023Q4 onwards, the optimal policy projections conditional on the December 2023 baseline are shown over the projection horizon.

Transparency on forecast errors

For forecast accuracy of BMPE projections and related material see these publications:

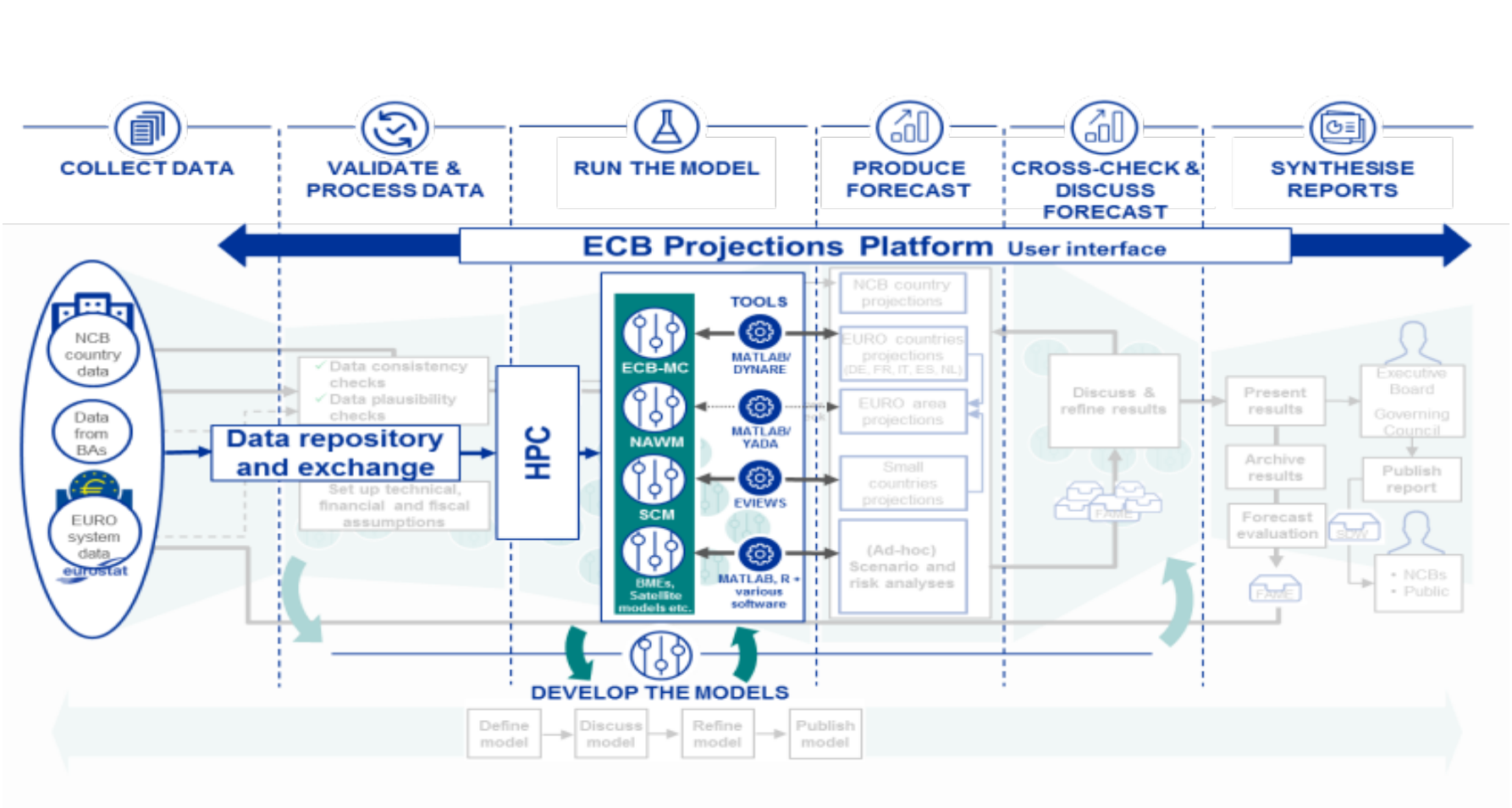
1. An update on the accuracy of recent Eurosystem/ECB staff projections for short-term inflation, ECB Economic Bulletin, Issue 2/2024.
2. What explains recent errors in the inflation projections of Eurosystem and ECB staff?", *Economic Bulletin*, Issue 3, ECB, 2022.
3. The performance of the Eurosystem/ECB staff macroeconomic projections since the financial crisis, *Economic Bulletin*, Issue 8, ECB, 2019.
4. A full database of past Eurosystem/ECB staff macroeconomic projections is available to the public via the ECB Data Portal, which allows researchers to easily assess the performance of these projections. The processes and tools used to produce staff projections are described in a guide available on the ECB's website.
5. An updated assessment of short-term inflation projections by Eurosystem and ECB staff", *Economic Bulletin*, Issue 1, ECB, 2023.

4

Modelling infrastructure

The importance of investment

The importance of a good infrastructure: A projection platform



The importance of a good infrastructure

Versioned and controlled

- Preserve institutional knowledge
- Ease model development
- Maximize synergies (internals and with NCBs)

Robust

- Sustainable
- Fully supported
- Long-term solution that reduces risks and increases consensus

Lean and efficient

- Efficient use of resources with maximum time for analysis

5

Agenda

Current modelling plans and future agenda

Main ingredients for soundness

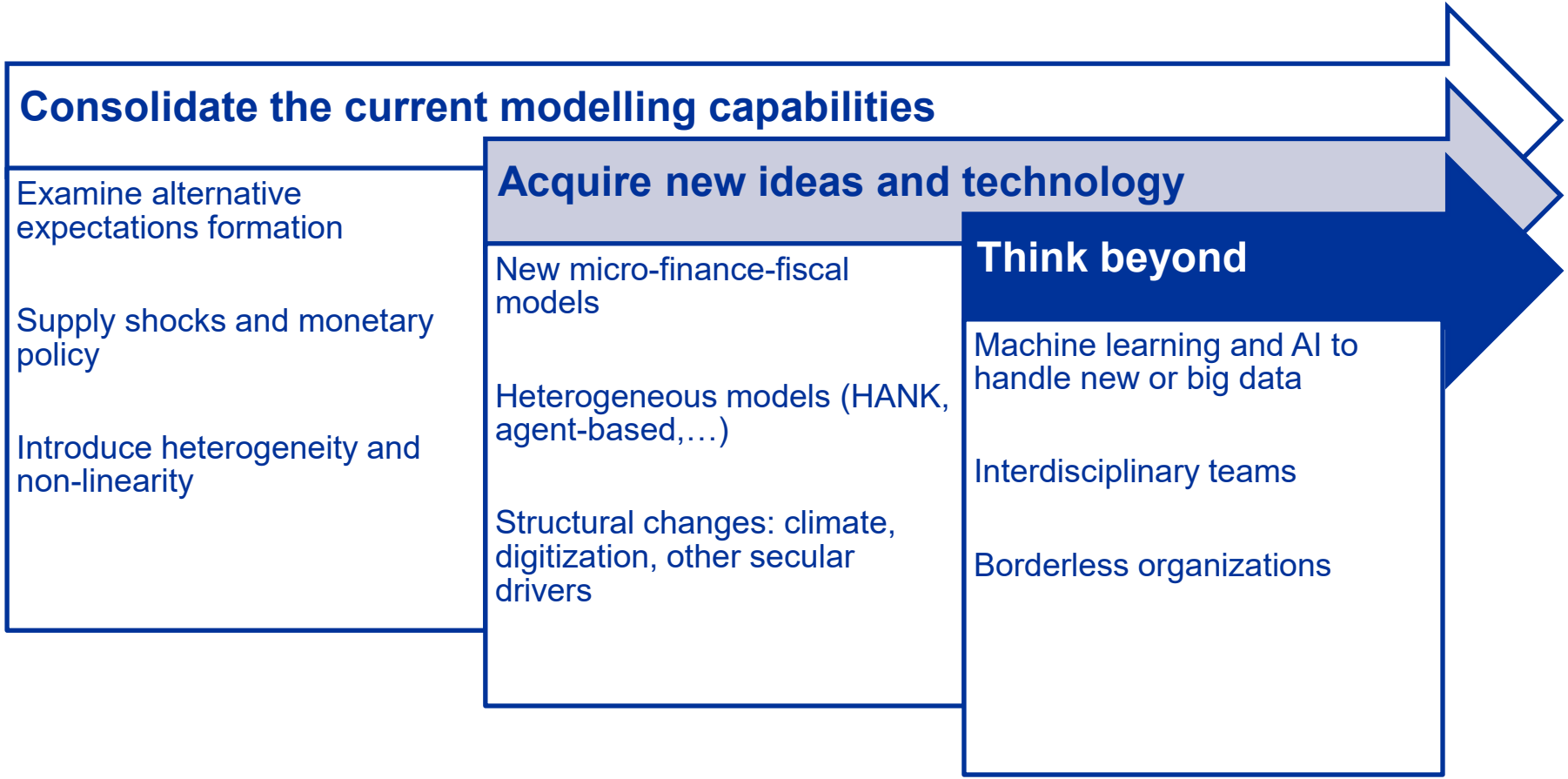
Humbleness

- Models fail and need to be constantly reviewed or complemented by judgment and other models
- Suite-of-model approach will continue to be a robust way of combining complementary alternative tools that can be flexibly adjusted to address unforeseen events and new challenges

Adaptability

- Inclusion of new economic theories and developments
- Keep abreast of technological advances for models and infrastructure
- Cooperate, cooperate, cooperate

The future of modelling




THANK YOU
Dziękuję
감사합니다
Děkuji
Mulțumesc
Спасибо
謝謝
Merci
Danke
Köszönöm
Gracias
Obrigado
ありがとう
Kiitos
Terima kasih
Teşekkür ederim
Takk
Dank U
Tack