The History of the CNB's Core FPAS Models

CNB Research Open Day 2023
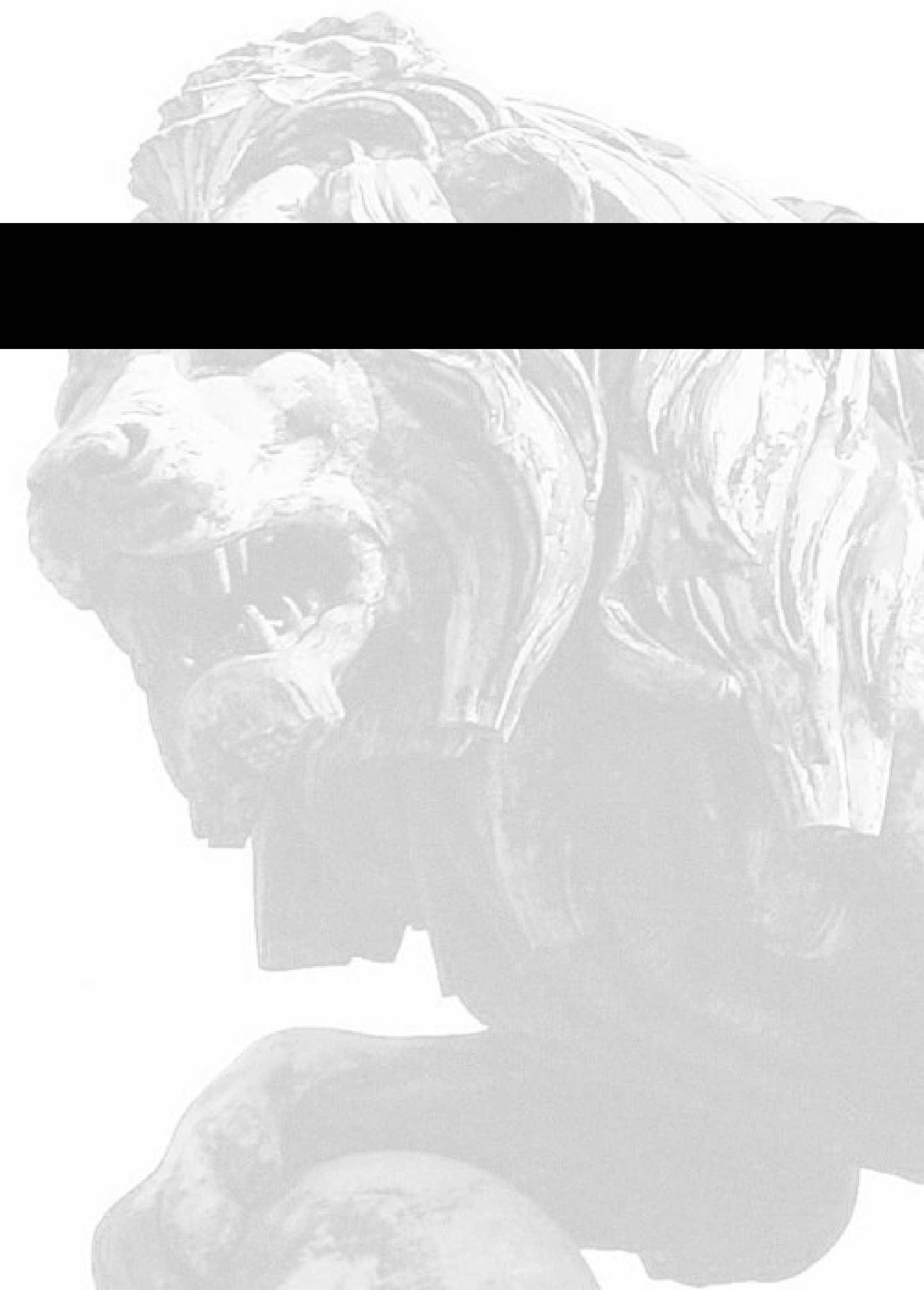
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The views expressed herein are those of the author and do not necessarily reflect the official positions of the Czech National Bank.
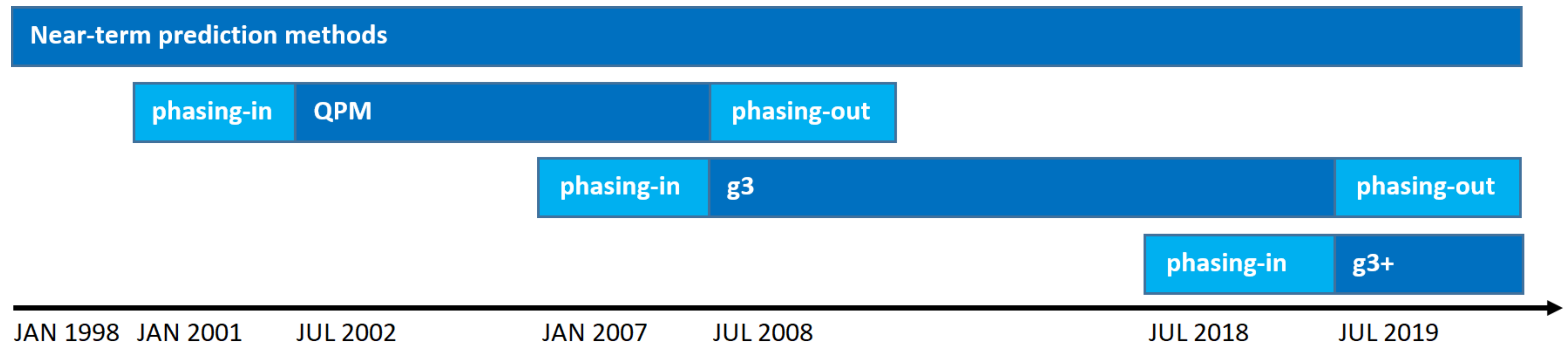
Presentation Outline

Inflation Targeting Framework

- Svensson's (2010) **definition of inflation targeting**:

  - "Inflation targeting is a monetary-policy strategy that is characterized by an announced numerical inflation target, an implementation of monetary policy that gives a major role to an inflation forecast and has been called forecast targeting, and a high degree of transparency and accountability."

- Main feature of IT framework is its **forward-lookingness**:

  - Monetary authorities must form views on future inflation developments and know characteristics of the monetary transmission mechanism.
  - There is a lag between monetary-policy actions and their impact on the central bank's target variables, therefore, monetary policy is more effective if it is guided by forecasts.

- **Principles of inflation-forecast targeting** (Svensson, 2010):

  - Real-world inflation targeting is not strict inflation targeting where policy rate responds only to current inflation
  - Policy rate responds to all information that affects the forecast of inflation and the real economy

- Announcing and explaining our forecasts enhances the impact on private sector expectations and the economy and supports the effective implementation of monetary policy.

Forecasting and Policy Analysis System

- Vickers's (1999) presentation:
  - Models are useful in forecasting.
  - Models help understanding of where the economy has been and how it has worked in the past.
  - Models try to explain the relationships between forecasts and policy (e.g. analyses of monetary policy reaction functions, sacrifice ratio, uncertainty).

Timeline of CNB's model-based forecasting practice

Near-term prediction methods			
phasing-in	QPM	phasing-out	
	phasing-in	g3	phasing-out
		phasing-in	g3+

JAN 1998   JAN 2001   JUL 2002   JAN 2007   JUL 2008   JUL 2018   JUL 2019

Before QPM

- **Prior to the introduction of QPM**:
    - Early stage CNB's models (Age of NTF): no simultaneous-equations, no active monetary policy and no forward-looking channels.
    - Lack of expertize in the real-time use of complex formal tools.
    - „Modeling" staff was challenged by lack of experience in developing a complex micro-founded DSGE model.
    - Insufficient experience of „Non-modeling" staff (communication specialists, editors) to communicate on the basis of a highly formalized and structural paradigm.

- **Forecast process/organizational challenges**:
    - Forecast integration:
        - Core and satellite models
    - New challengers: Integrating of the core model forecast with other short-term and expert information into a single staff projection.
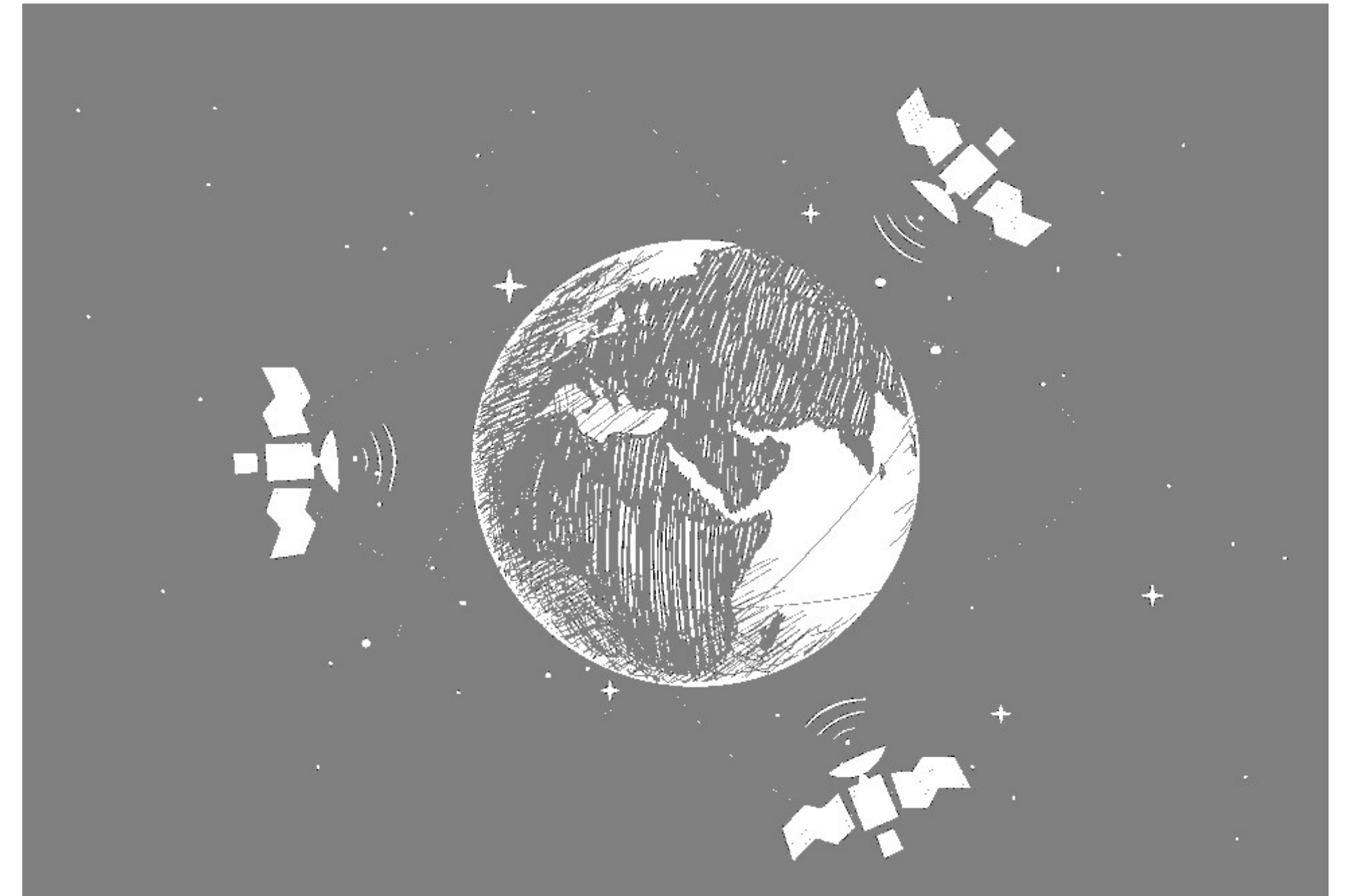
Presentation Outline

1. Inflation Targeting FPAS

2. **Quarterly Projection Model (QPM)**

3. g3 model

4. g3+ model

Quarterly Projection Model

- **Objective: Create simple model**

- **Reasons to start with rather small model included**:
  - Staff did not possess experience with operating complex models: Time to learn and develop their skills.
  - Insufficient data to calibrate more ambitious models.
  - Process of inflation forecast integration (i.e. combining core model forecast with other short-term and expert information into a single staff projection) is considerably smoother with a simpler model.
  - Less assumptions makes it easier to maintain consistency across tools.
  - CNB board has expressed desire to participate in discussion of modeling.

- **A small structural (calibrated) model built initially in 2001**:
  - Model captured essentials of general equilibrium nature of the system: mid- and long-run components
  - Used to produce inflation forecasts and for research on the monetary transmission mechanism.
  - Set up a framework for developing communication tools: GRIP, forecast update decomposition,…
  - Early version framework: Coats et al. (2003)

Components of QPM

- Block of **long-run trends**:
  - real output, real exchange rate, real interest rate – natural rate,
  - monetary decisions have a small impact on long term real trends,
  - history - satellite statistical model, forecast – QPM,
  - Allows for expert judgement.

- **Cyclical part**:
  - Agents' decisions influenced by expectations.
  - Basic blocks:
    - aggregate demand
    - Phillips curve – price and wage stickiness
    - exchange rate
    - monetary policy rule

Potential output and Real GDP
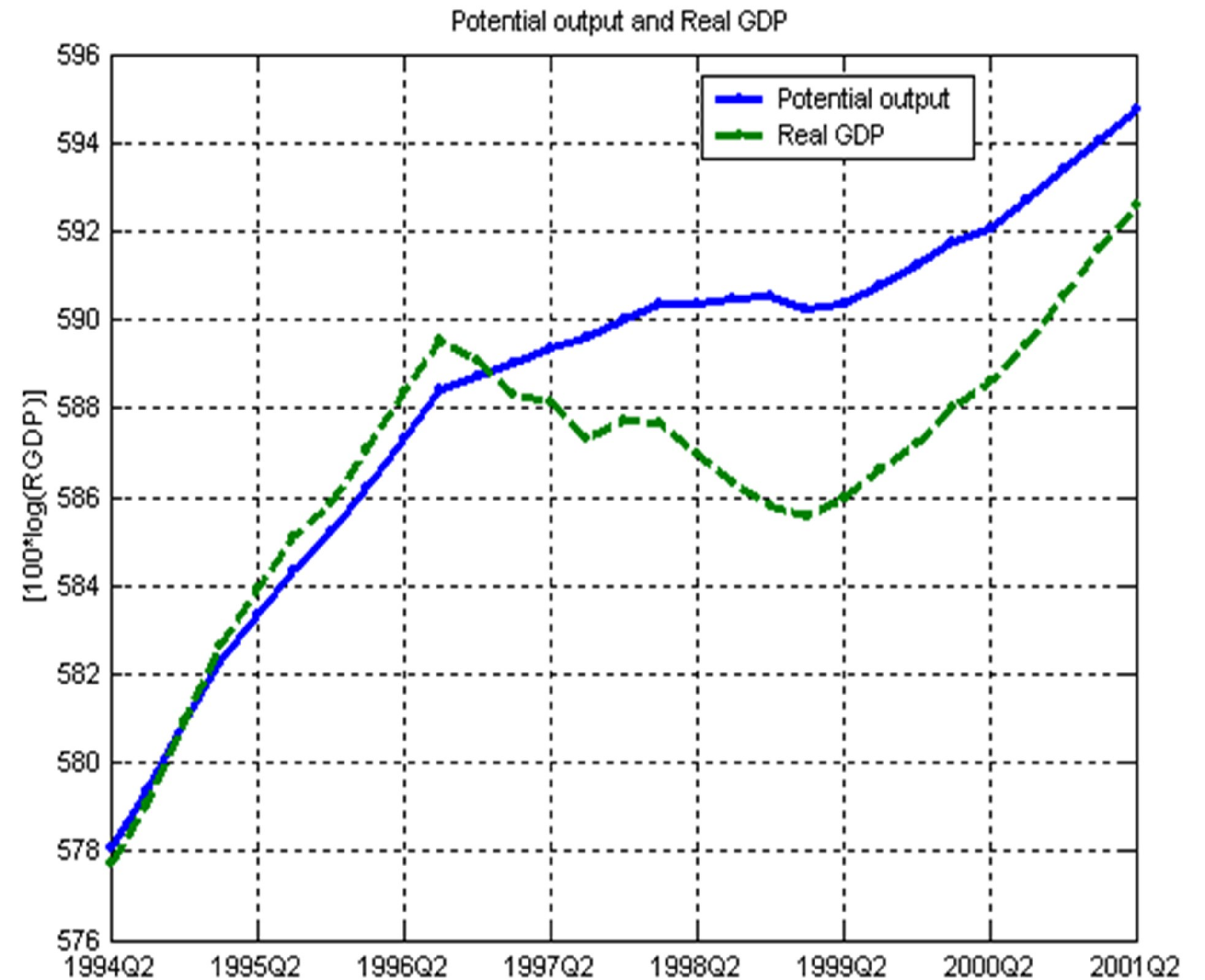
Core Components of QPM

Early version of essential equations

- **Aggregate demand:**

$$ygap_t = d_0 ygap_{t-1} - d_1 rr12gap_{t-1} - d_2 rr4gap_{t-1} - d_3 gr\_rrgap_{t-1} - d_4 lzgap_{t-1} + \varepsilon_t^{ygap}$$

- **Phillips curve:**

$$\pi core_t = a_0 \left[\pi 4_t^{MexE} + 100 * \Delta_4 lz_t^{eq} \right] + a_1 E_t \pi 4_t + (1 - a_0 - a_1) \pi core_{t-1} + a_2 ygap_{t-1} + \varepsilon_t^{\pi}$$

- **UIP:**

$$ls_t = g_0 E_t ls_{t+1} + (1 - g_0)(ls_{t-1} - 2E_t(\pi 1_t - gr\_\pi 1)/400 + 2\Delta lz_t^{eq})$$
$$+ (rs - gr\_rs - prem)/400 + \varepsilon_t^{LS}$$

- **Monetary policy rule:**

$$rs_t = m_0 rs_{t-1} + (1 - m_0)(rr_t^{eq} + E_t \pi 4_{t+4} + m_1(E_t \pi 4_{t+4} - \pi_t^{Tar}) + m_2 ygap_t) + \varepsilon_t^{rs}$$

QPM Forecasting

- **Forecast process flow**

  - Identify long run trends in foreign and domestic economy – initial state.

  - Run the cyclical part to compute forecast.

  - NTF forecast used as assumptions for conditioning the QPM forecast + expert judgement.

- **Integration of NTF and model forecasts**

  - Finalizing step: consistency

  - Take NTF tools and extra satellite models to create consistent projection of variables not included forecast model.
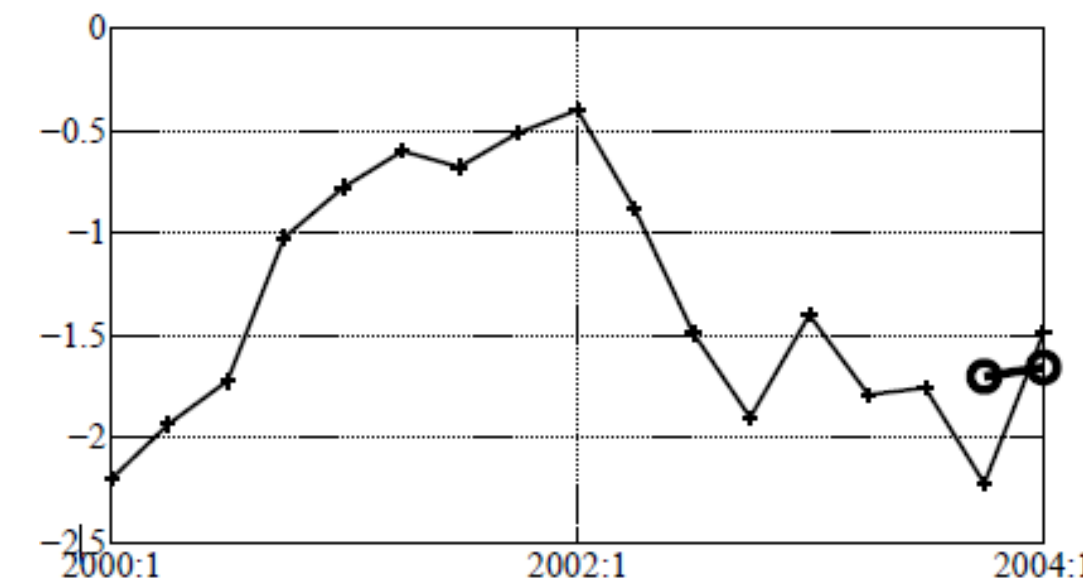
- **Communicate effects of factors forcing the update of forecast trajectories**

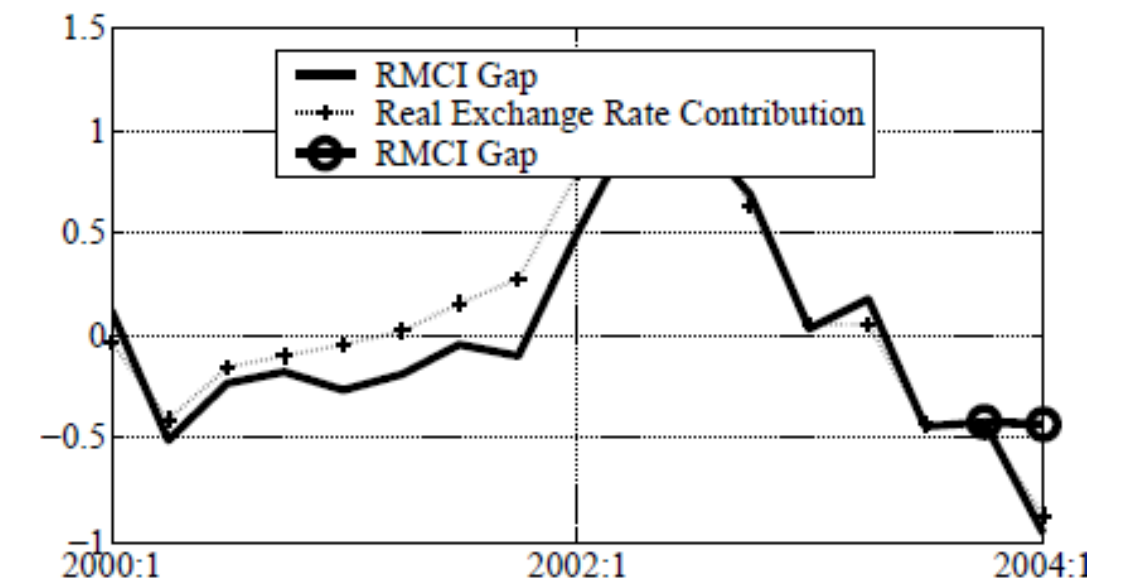 - Sequential forecast difference decomposition.
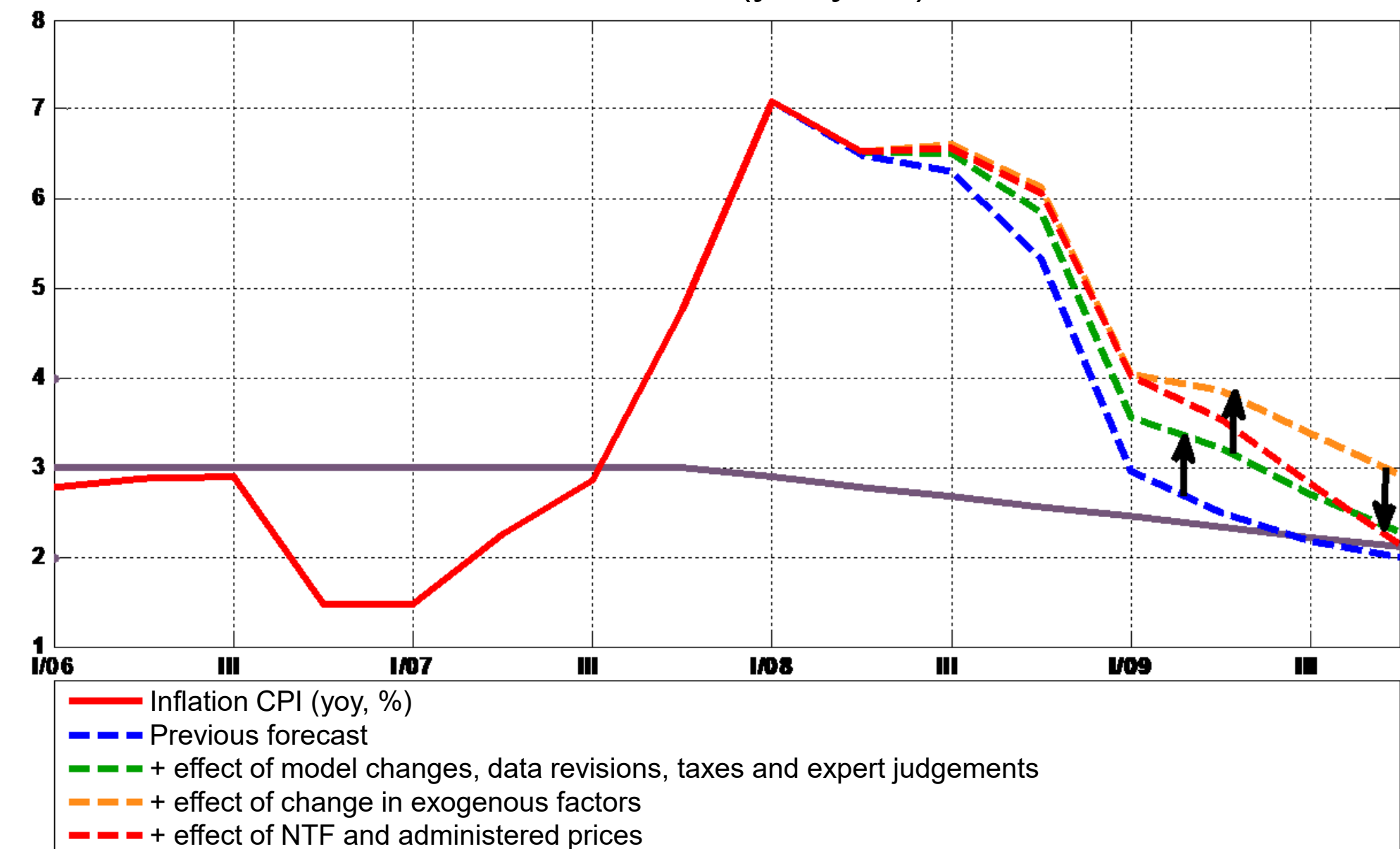

April 2004 Forecast Round

Initial State

Real GDP Gap

Real Monetary Conditions

- RMCI Gap
- Real Exchange Rate Contribution
- RMCI Gap

Inflation CPI (y-o-y, %)

- Inflation CPI (yoy, %)
- Previous forecast
- + effect of model changes, data revisions, taxes and expert judgements
- + effect of change in exogenous factors
- + effect of NTF and administered prices

QPM Modifications

Successful amendments in the model framework:

- 2004: primary and secondary tax effects,

- 2005: decomposing trend in real exchange rate follows inflation categories,

- 2006: wage Philips curve – real wage response to disinflationary and demand shocks, low wage persistency vs persistency of inflation,

- 2006: effective indicators for Eurozone, Germany replaced by new aggregate, systematic deviations,

- 2007: complex inflation expectations structure; strong influence of administered prices induced changes on all components of the inflation

  - $E0\_PIE4 = alpha*(0.5*PIE\{1\} + (1-0.5)*PIE\{-1\}) + (1-alpha)*(0.5*PIE\_NET\{1\} + (1-0.5)*PIE\_NET\{-1\}) + RES\_E0\_PIE4$

  - Expectations stickiness

- 2007: real exchange rate adjusted for domestic and foreign tax changes.

What did not work out very well:

- 2005: USD/EUR exchange rate in exchange rate part of monetary conditions,

- 2006: backward looking UIP condition.

QPM Scheme
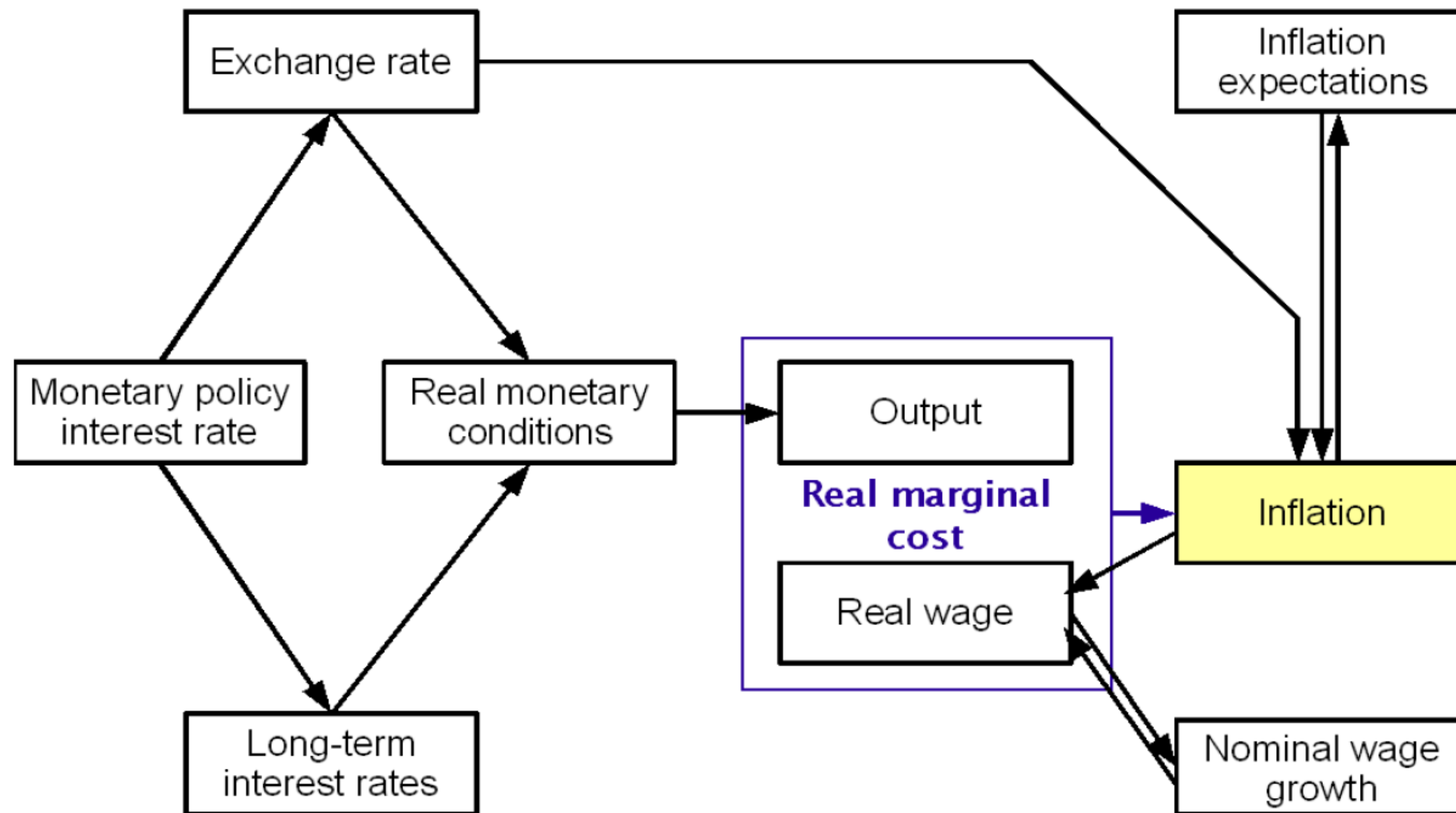
- General scheme of CNB QPM at the end of its service.

- Small open economy model: Also included foreign components.

Presentation Outline

1. Inflation Targeting FPAS

2. Quarterly Projection Model (QPM)

3. **g3 model**

4. g3+ model

g3 Model

- Benes et al. (2005): Desire to improve degree of theoretical coherence = development of new fully micro-funded model.

- First gig of g3: Analysis of wage response to disinflationary and demand shocks, motivated extension of our QPM.

- Introduced into service in Inflation Report III/2008: Used simultaneously with QPM already since January 2007, Andrle et al. (2009).

- **The CNB was one of the first central banks to use a DSGE** (Dynamic Stochastic General Equilibrium) **model as a core policy tool**: Sveriges Riksbank (RAMSES), Bank of Finland (Aino) or Bank of Canada (TOTEM)

- **g3 main features**:
  - small open economy model,
  - consistent with quarterly national accounts,
  - no use of ad-hoc detrending and/or pre-filtering,
  - trends and cycles are not separable,
  - technologies are introduced: labor-augmenting technology or export-specific technology,
  - measurement errors,
  - initially 17 observable variables.

Structure of g3 Model
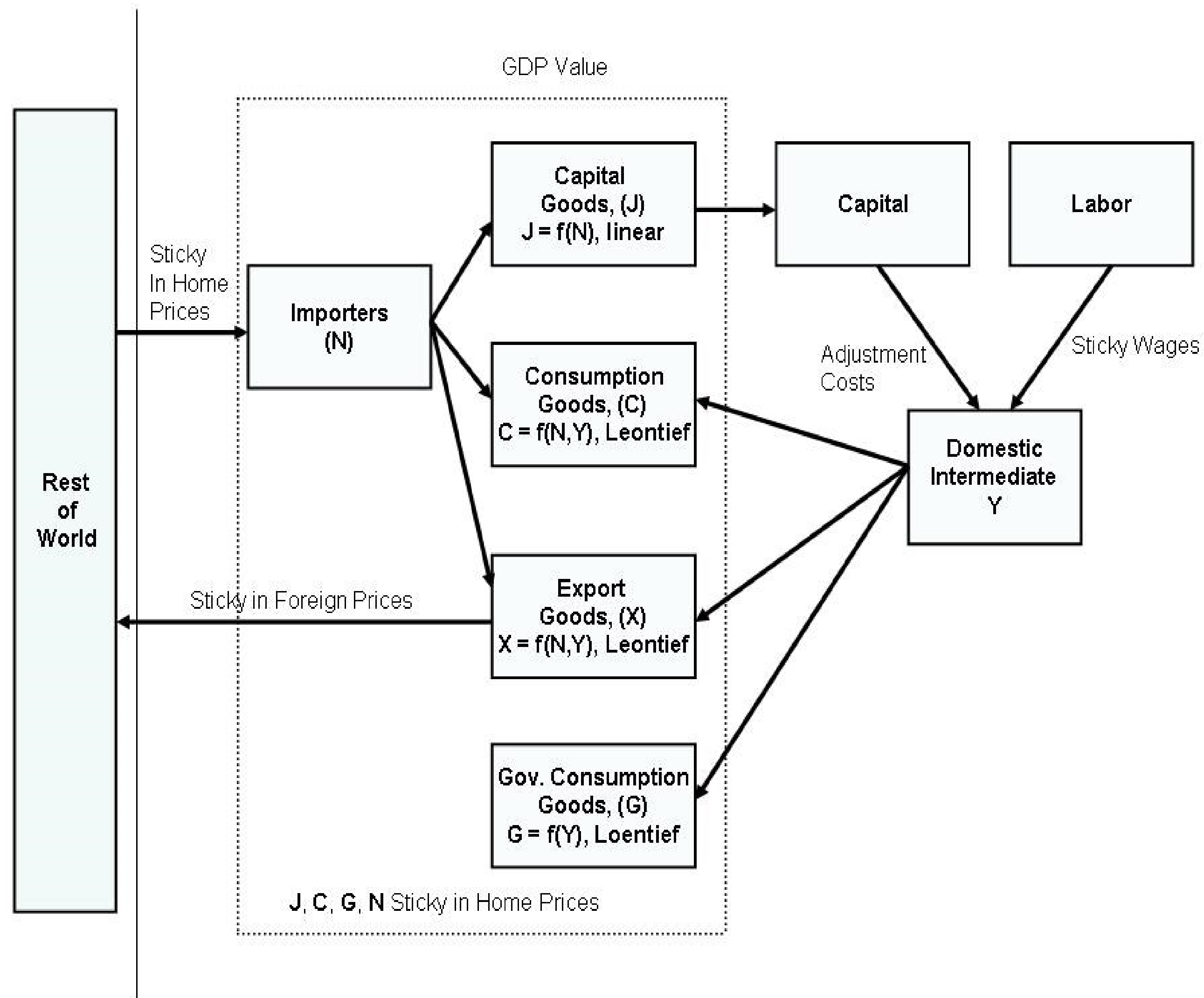
- **Model includes following sectors**:
  - Households: Decision on C and I, offers L in exchange for W,
  - Domestic intermediate good: L + K → Y,
  - Importers: N,
  - Final goods producers: N + Yd → C, I, G, X,
  - Government: fiscal rule,
  - Central Bank: MP policy rule,
  - Rest of the world: exogenous AR(1) Y*, P*, I* - demand, prices and policy.

Price Tree of g3 Model
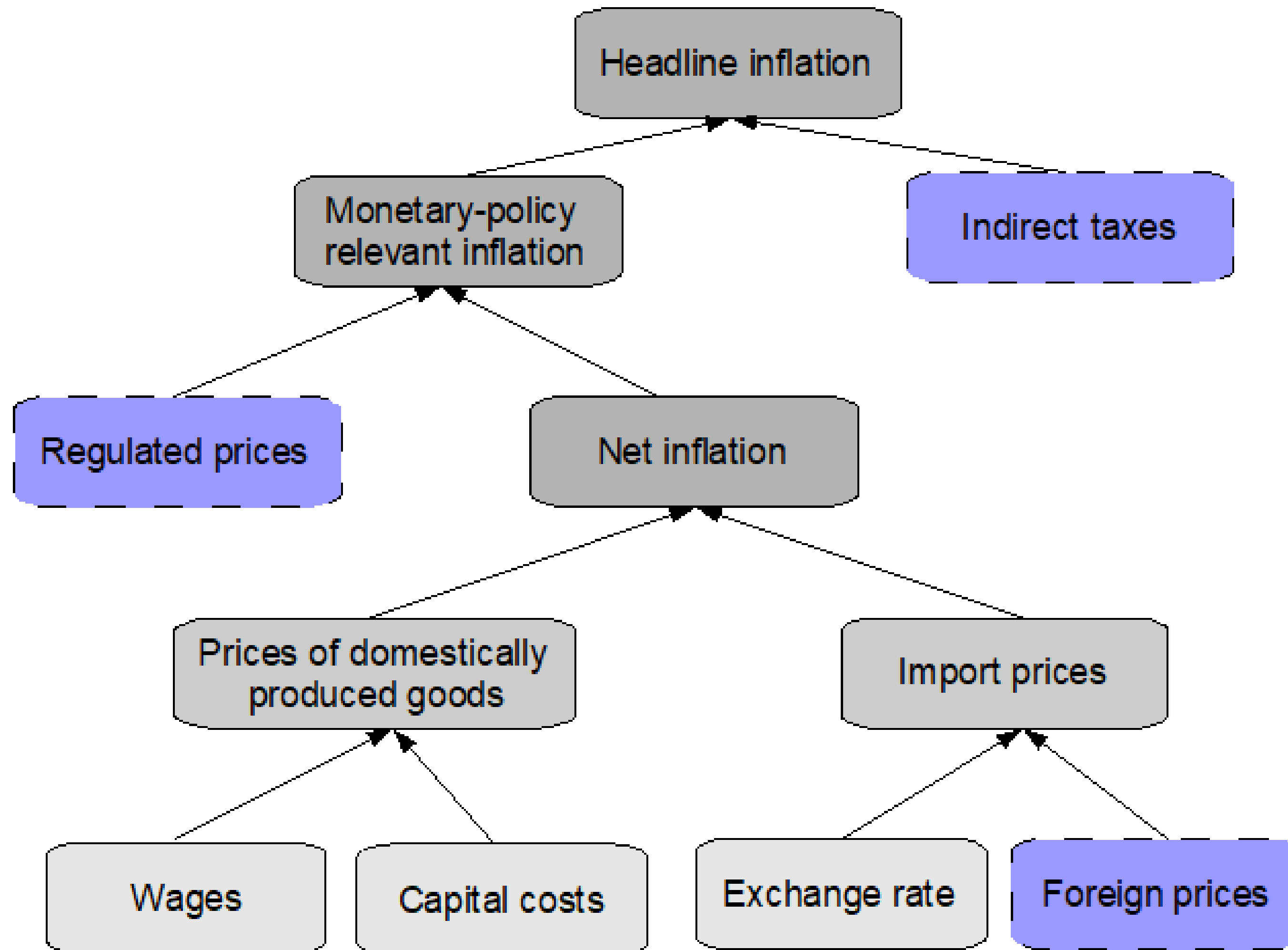
- Cascade of **wage and price rigidities**, **imperfect exchange rate pass-through**.

- Rich set of **real rigidities and frictions**

- Utilizes concepts developed while using the QPM: handling **primary and secondary effects of tax changes**.
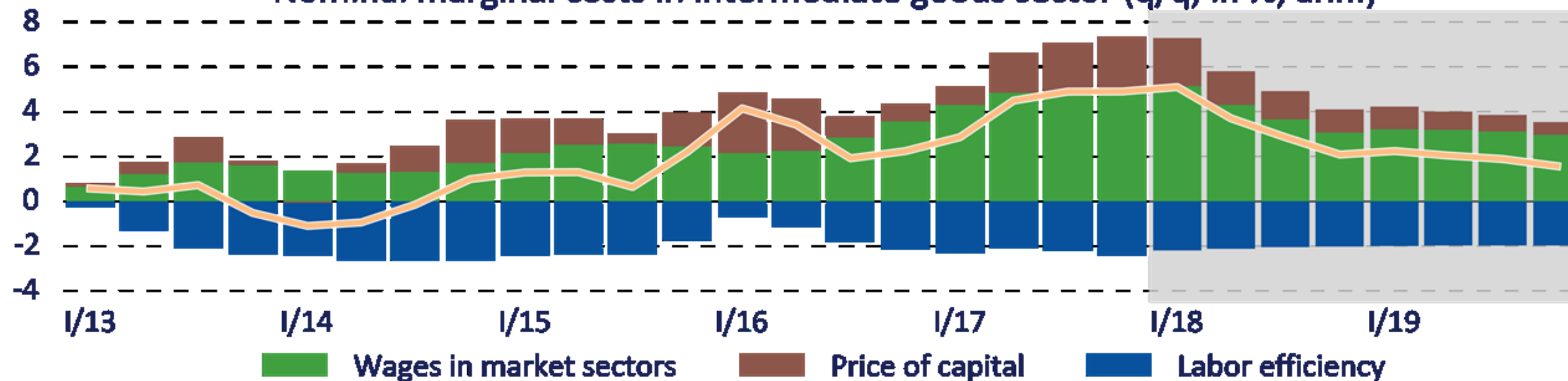
New Communication Features

- **Cyclical indicators**: Profit margins gaps and productivities
- **Marginal costs** are indicators of inflation pressures in given sectors.
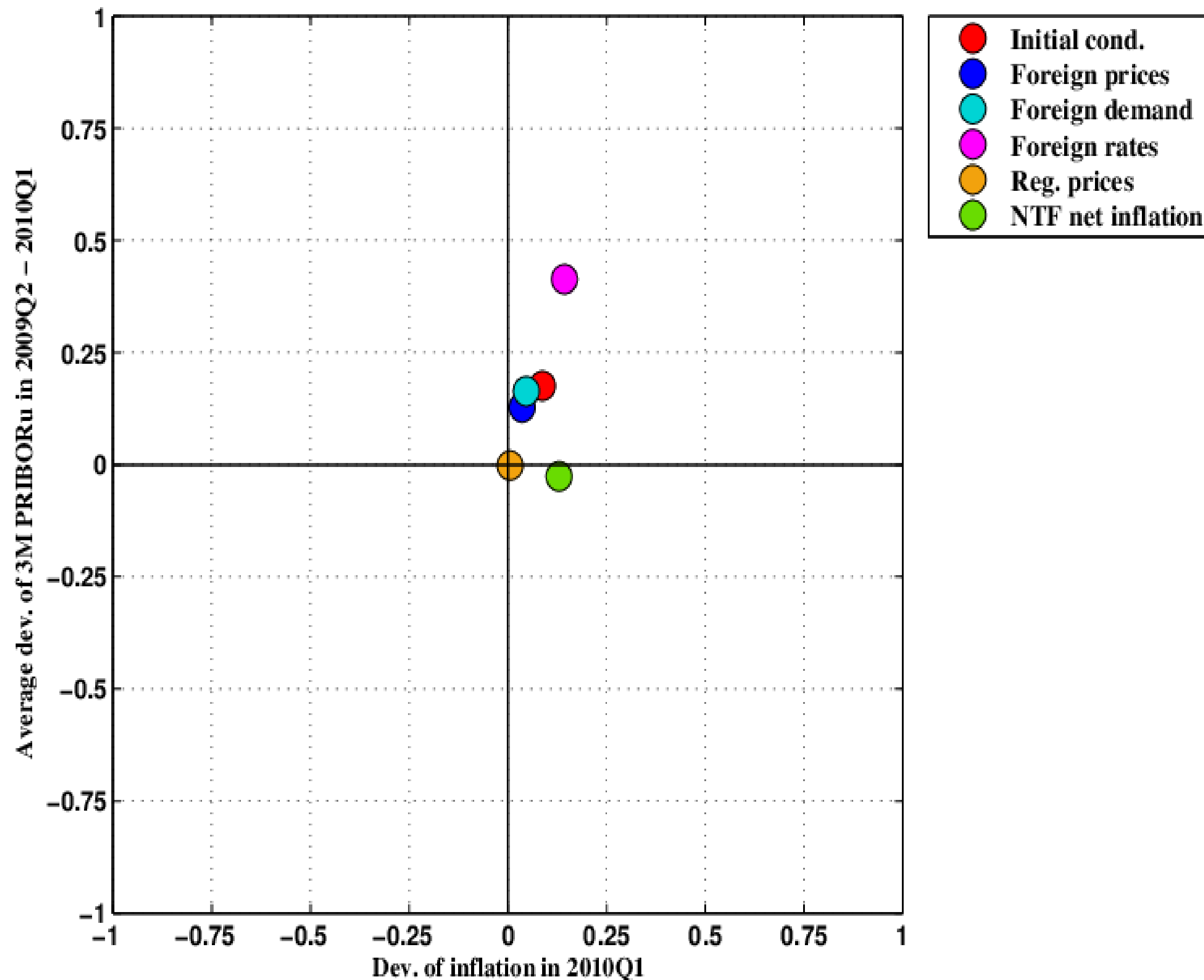

Nominal marginal costs in the consumer sector (q/q, in %, ann.)

Legend: Price convergence, Import prices, Intermediate goods prices
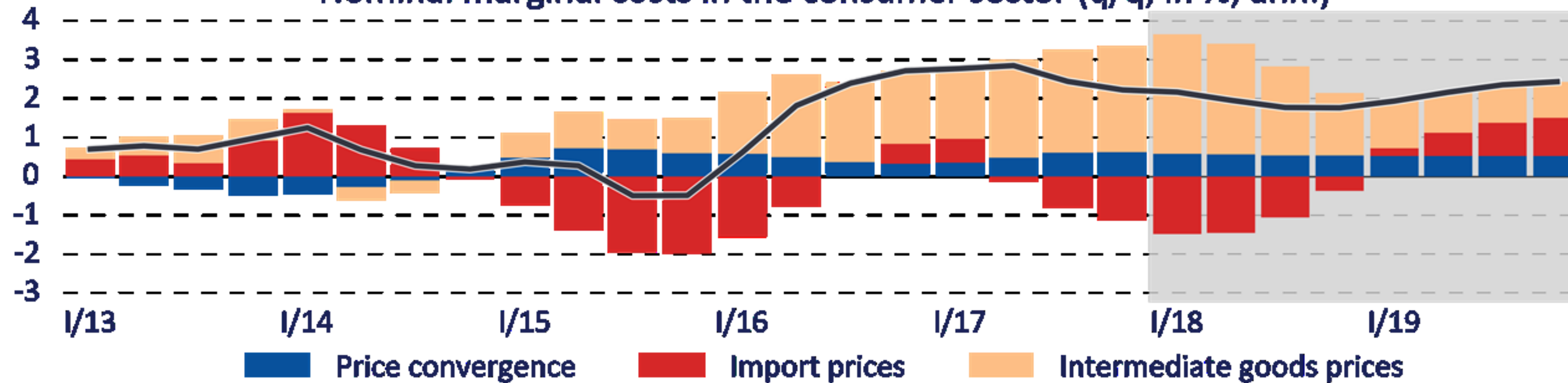
Nominal marginal costs in intermediate goods sector (q/q, in %, ann.)

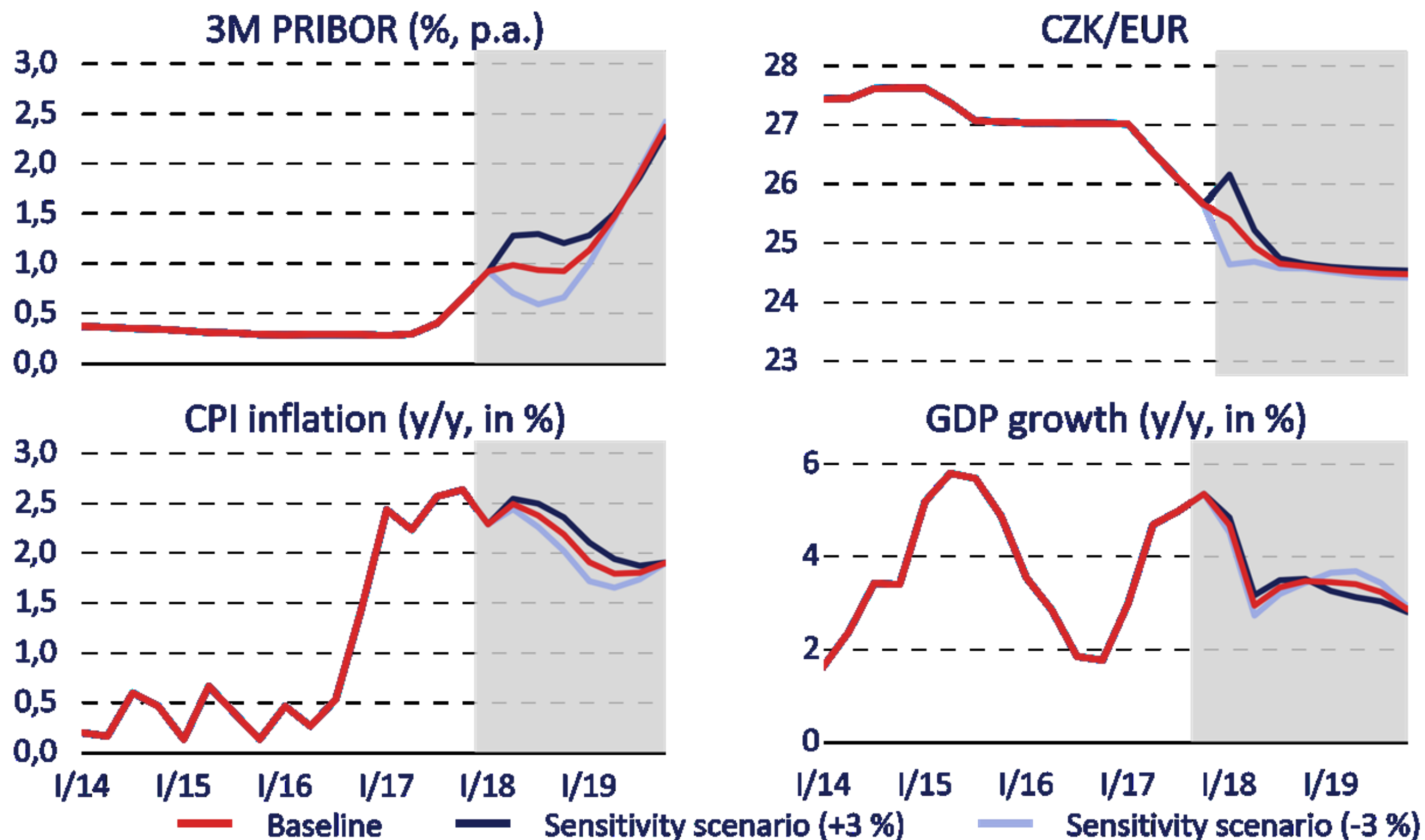Legend: Wages in market sectors, Price of capital, Labor efficiency

Graph of Risks to the Inflation Projection

- With the introduction of new simulating techniques, the elasticity of forecast trajectory with respect to new data can be evaluated.

- Partial contributions can be identified without conditioning on ordering – easy to follow.

- New support tool became available to the public.

Scenario Analysis

3M PRIBOR (%, p.a.)

CZK/EUR

CPI inflation (y/y, in %)

GDP growth (y/y, in %)

Baseline — Sensitivity scenario (+3 %) — Sensitivity scenario (-3 %)

- In Inflation Report I/2018 CNB resumed publication of the exchange rate forecast

- This is standard symmetric exchange rate sensitivity scenario.

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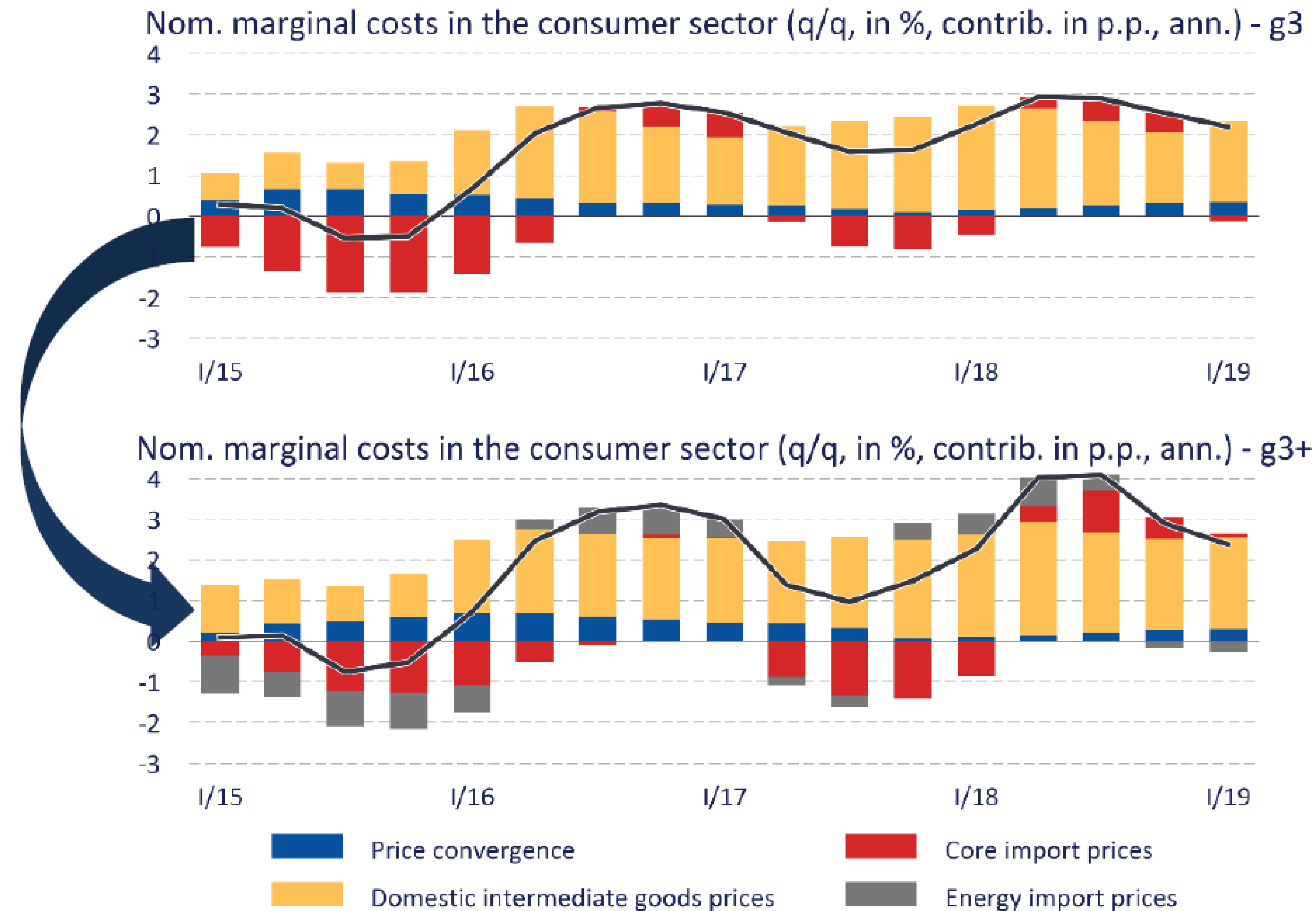
3. g3 model

4. **g3+ model**

g3+ Model

- g3+ model introduced in Inflation Report III/2019, Brázdik et al. (2020).
- **Redesigned external block**:
  - Reduced-form structural neo-Keynesian model.
- Introduction of **energy-core price decomposition of foreign prices**:
  - Oil is a new a production factor in the domestic economy.
- **Heterogeneous households sector**:
  - Two types of households:
    - Households with access to financial markets are able smooth their consumption.
    - Households without access to the financial market, always spend all of their income on consumption.
- **Limited information rational expectations**:
  - New simulation method introduced.
  - Assumes that agents are not able to process conditioning information over infinite horizon.
- **Model calibration:**
  - Changes include adjustments of steady-state levels and parameters of the model: e. g., a gradual decline in the EA of steady state nominal interest rate from 3.5% to 2.5%.
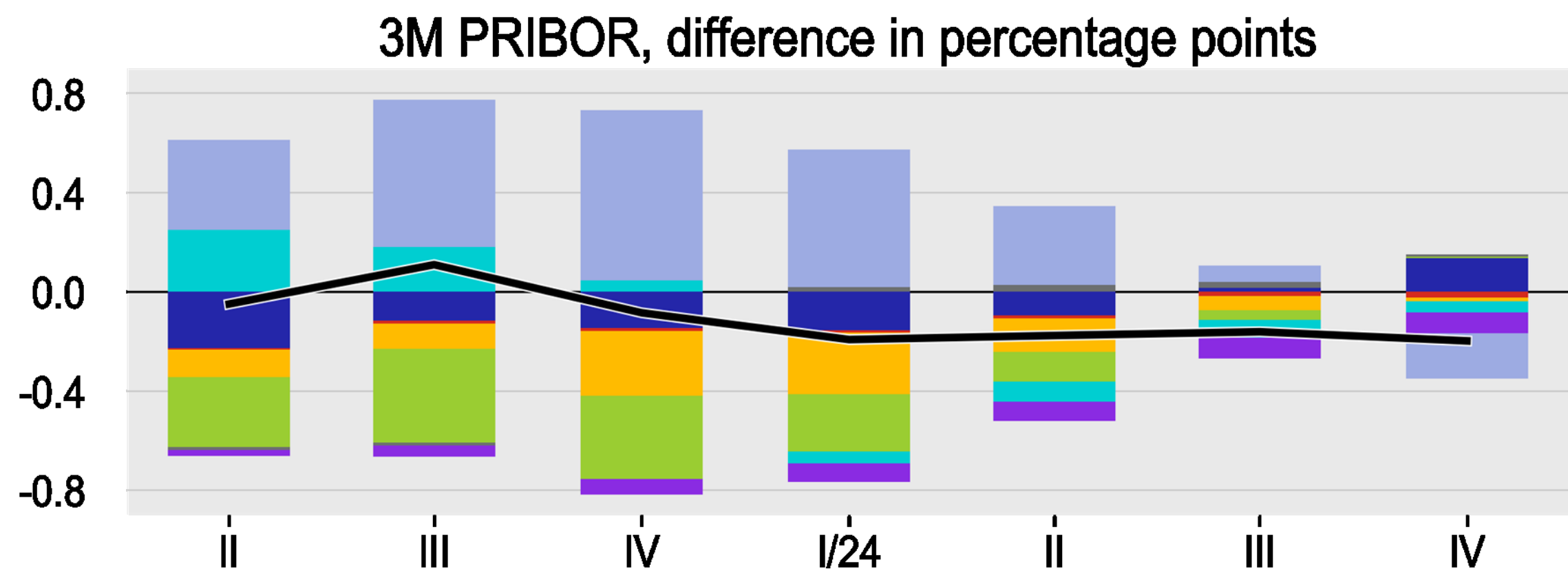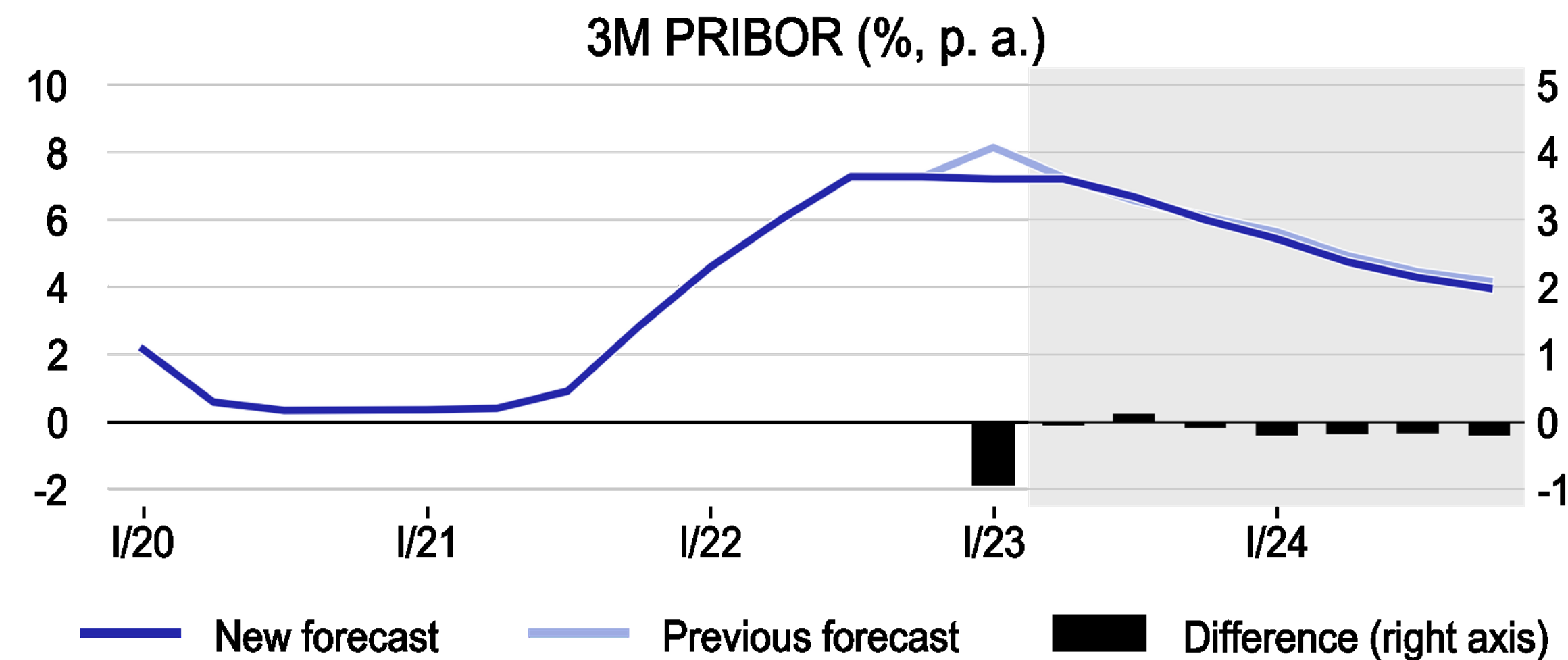
g3+ Production Scheme
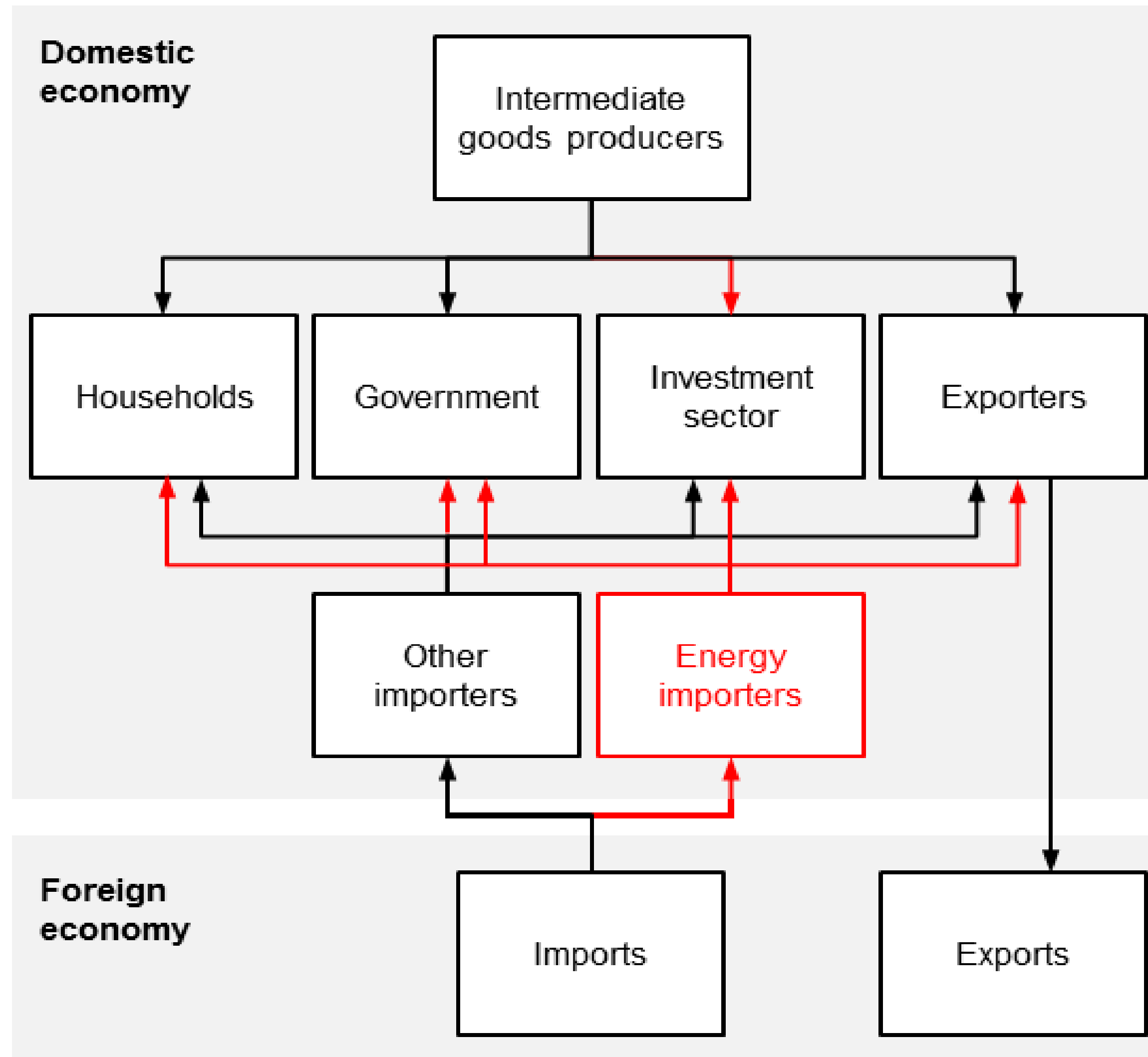
- Novelty is introduction of **energy (oil) as a production factor** for final goods:
  - Leontief production function

- Domestic component of investment.

- In this setup, price of oil does not affect price competitiveness of Czech exporters.

New Structure of Production Costs

Nom. marginal costs in the consumer sector (q/q, in %, contrib. in p.p., ann.) - g3

Nom. marginal costs in the consumer sector (q/q, in %, contrib. in p.p., ann.) - g3+

Legend:
- Price convergence (blue)
- Core import prices (red)
- Domestic intermediate goods prices (yellow)
- Energy import prices (grey)

- Energy as a **new production factor**: contribution of the energy cost in domestic marginal costs in consumption.

- In consumer sector, inflation pressures out of imported costs are originating from:
  - Core (non energy) foreign producer prices
 - Energy price (Oil)

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g3+ Forecast Tools

3M PRIBOR (%, p. a.)

New forecast — Previous forecast — Difference (right axis)

3M PRIBOR, difference in percentage points

- ■ Initial state
- ■ Government consumption
- ■ Administered prices
- ■ Exchange rate
- ■ Short-term inflation forecast
- ■ Foreign environment
- ■ Fiscal impulse
- ■ Expert judgement

- With the g3+, the **decomposition of forecast differences** is regularly explained.

- Easy to follow as the contributions are not conditional on ordering as in QPM.
  - Brazdik et al. (2014) more details on decomposing forecast differences
  - Used also for analysis of past forecast performance.

- Transparent handling of expert judgement of forecasting staff:
  - Expert judgement examples: Andrle et al. (2009), Bruha et al. (2013)

Conclusion

- Since introduction of an inflation targeting regime in 1998:
  - CNB introduced, formalized and constantly improves its Forecasting and Policy Analysis System, Al-Mashat et al. (2018) methodology.
  - CNB made a considerable progress in developing formal tools for supporting FPAS.
  - FPAS often reflects the feedback mechanisms for its validation.
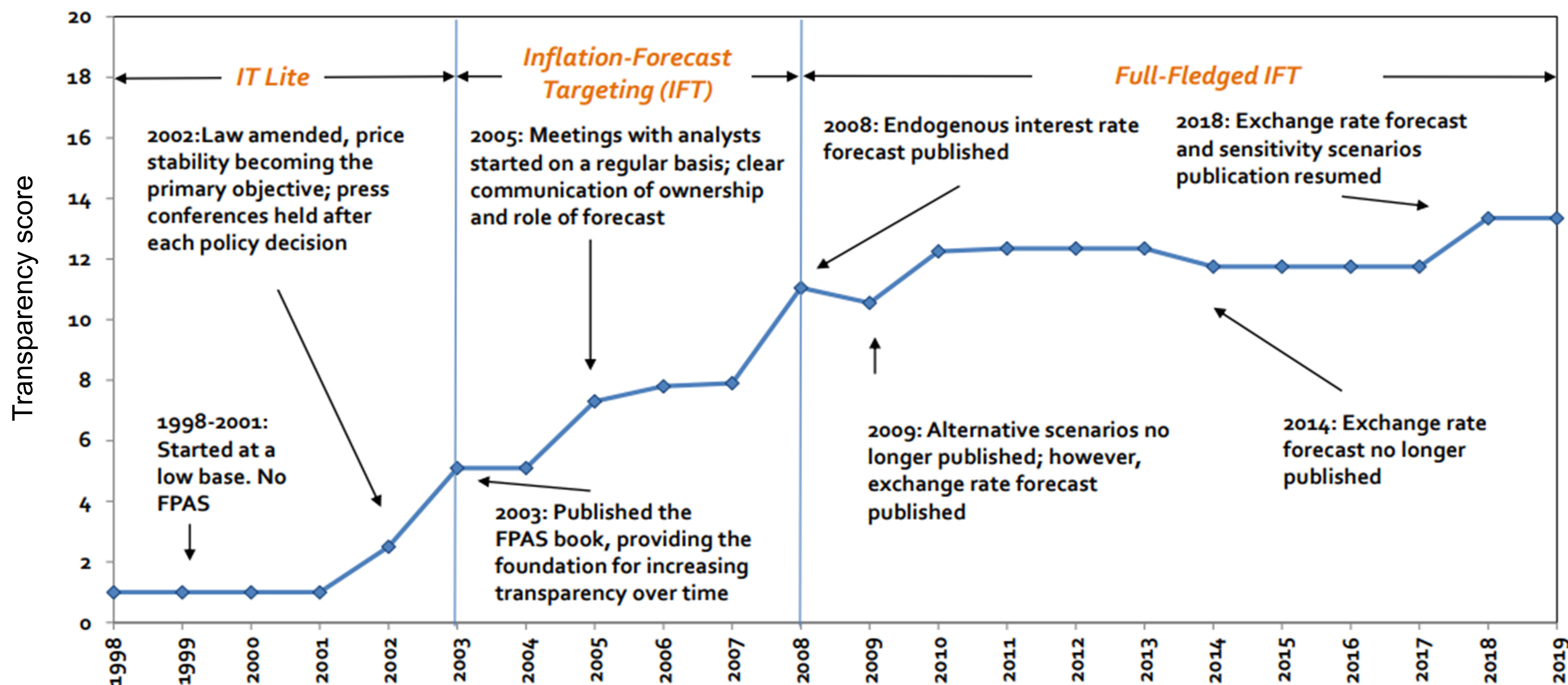
Thank you for your attention

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References I

- Al-Mashat, R. A., Bulir, A., Nergiz Dinçer, N., Hledik, T., Holub, T., Kostanyan, A., Laxton, D., Nurbekyan, A., Portillo, R. A. and Wang, H. (2018): "An Index for Transparency for Inflation-Targeting Central Banks: Application to the Czech National Bank," IMF Working Papers 2018/210, International Monetary Fund.

- Andrle, M., Hledik, T., Kamenik, O. and Vlcek, J. (2009): "Implementing the New Structural Model of the Czech National Bank", Working Papers 2009/2, Czech National Bank.

- Benes, J., Hledik, T., Kumhof, M. and Vavra, D. (2005): "An Economy in Transition and DSGE: What the Czech National Bank's New Projection Model Needs", Working Papers 2005/12, Czech National Bank.

- Jan Bruha & Tibor Hledik & Tomas Holub & Jiri Polansky & Jaromir Tonner, (2013). "Incorporating Judgments and Dealing with Data Uncertainty in Forecasting at the Czech National Bank," Research and Policy Notes 2013/02, Czech National Bank.

- Frantisek Brazdik & Zuzana Humplova & Frantisek Kopriva, (2015). "Evaluating a Structural Model Forecast: Decomposition Approach," Working Papers 2015/12, Czech National Bank.

- Bruha, J. and Tonner, J. (2018): "Independent Monetary Policy Versus a Common Currency: A Macroeconomic Analysis for the Czech Republic Through the Lens of an Applied DSGE Model", Working Papers 2018/19, Czech National Bank.

- Bruha, J. and Tonner, J. (2018): "An Exchange Rate Floor as an Instrument of Monetary Policy: An Ex-Post Assessment of the Czech Experience", Czech Journal of Economics and Finance (Finance a uver), Charles University Prague, Faculty of Social Sciences, vol. 68(6), pages 537-549.

References II

- Brazdik, F., Hledik, T., Humplova, Z., Martonosi, I., Musil, M., Rysanek, J., Sestorad, T., Tonner, J., Tvrz, S. and Zacek, J. (2020): "The g3+ Model: An Upgrade of the Czech National Bank's Core Forecasting Framework", Working Papers 2020/7, Czech National Bank.

- Coats, W., Laxton, D. M. and Rose, D. (2003): "The Czech National Bank's Forecasting and Policy Analysis System", Czech National Bank, Prague.

- Musil, K., Tvrz, S. and Vlcek, J. (2021): "News versus Surprise in Structural Forecasting Models: Central Bankers' Practical Perspective", Research and Policy Notes 2021/02, Czech National Bank.

- Pagan, A. (2003): "An Examination of Some Tools for Macro-Econometric Model Building", Research School of Social Sciences, The Australian National University, mimeo, July 2003.

- Svensson, Lars E. O. (2010): "Inflation Targeting", NBER Working Paper No. w16654, December 2010.

- Tonner, J. (2022): "Current trends in macroeconomic modelling in central banks in light of the turbulent nature of recent events", Occasional Publications - Chapters in Edited Volumes, in: CNB Global Economic Outlook - July 2022, pages 14-20, Czech National Bank.

- Vickers, J. (1999): "Inflation targeting in practice: The UK experience", CFS Working Paper Series 1999/02, Center for Financial Studies (CFS).

Backup Slides

Models Classification
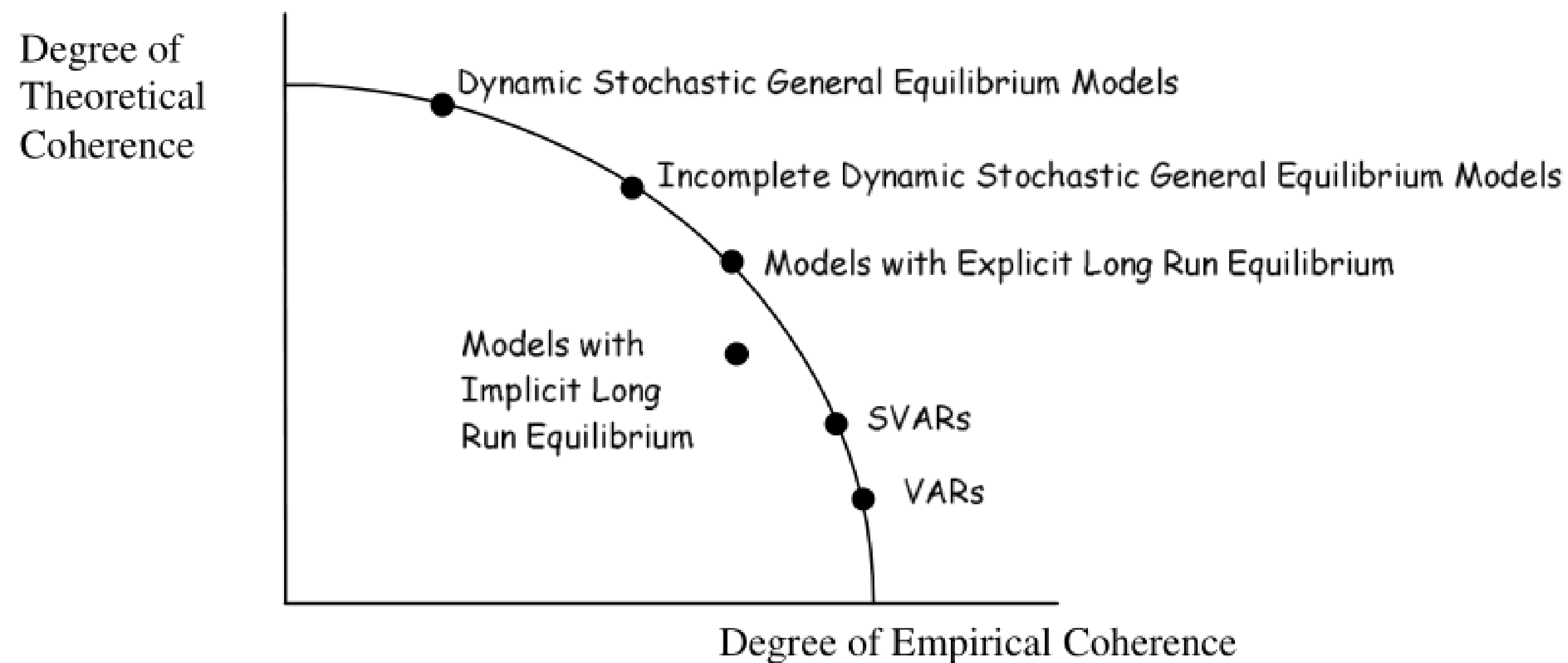
- Following Pagan (2003) reasoning:
  - DSGE models provide great theoretical coherence as they are build from well funded theoretical components.
  - Even in such models you can, with the use of expertise, model the empirical puzzles.

Real Time Forecasting

AKTUÁLNÍ - 8. SZ 2002

| veličina	predikce nebo CF	skutečnost	odchylka
Inflace (červenec, mzr.)	0.40	0.60	0.20
nezaměstnanost (červenec)	9.13	9.18	0.05
IPP (červen, mzr.)	6.00	1.30	-4.70
M2 (červen, mzr.)	6.50	4.40	-2.10
tržby v maloobchodě (červen, mrz.) Retail sales			
PPI (červenec, mrz.)	-0.60	-1.10	-0.50
CZV (červenec, mrz.)	-13.80	-18.90	-5.10
Kč/EUR (červenec, mrz.)	-11.40	-12.10	-0.70
Kč/USD (červenec, mrz.)	-22.90	-23.80	-0.90
cena ropy (červenec, mrz.)	-0.17	9.25	9.42
PPI SRN (červen, mrz.)	0.20	-1.10	-1.30
mzda v průmyslu (červen, mrz.)	5.10	3.70	-1.40

data za tržby nebyla kvůli povodním dodána

Data for sales was not available due to floods

- Real time forecasting comes with many process challenges:
  - 2002: Floods
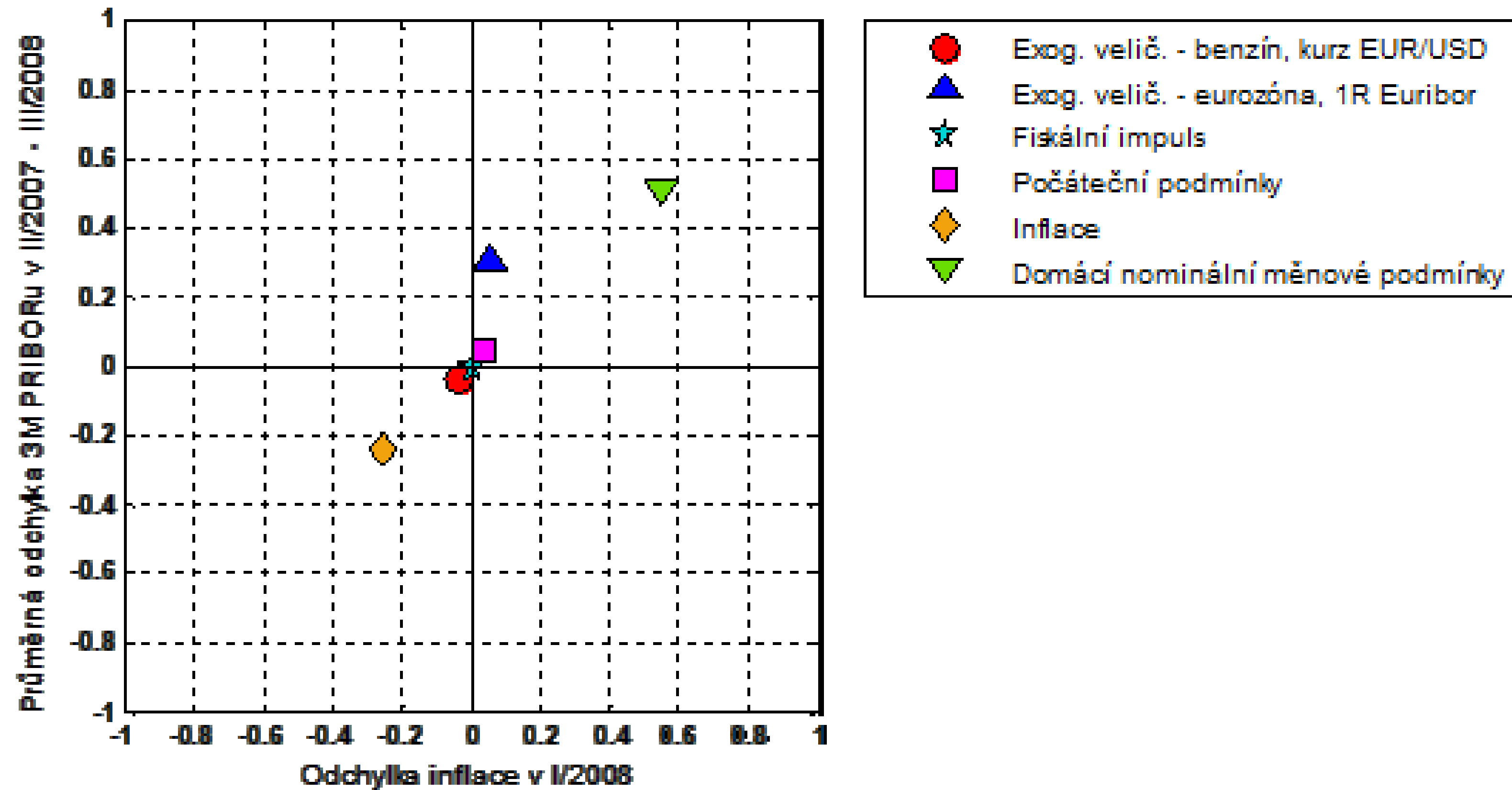 - Example – Evaluation of the forecast
  - Note the footnote

Early QPM Scheme

MODEL MTFM

Very First GRIP

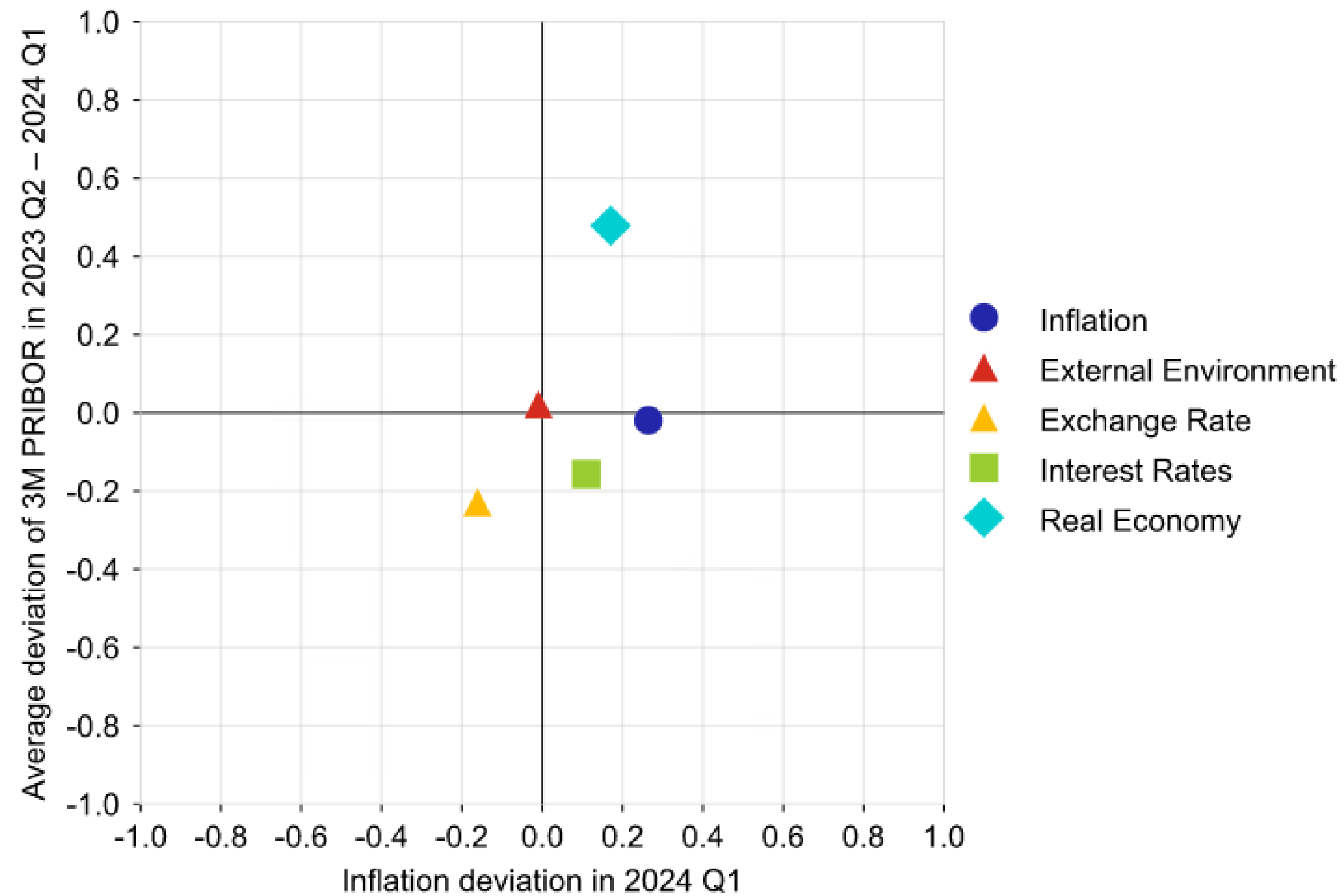- Graph of Risks of Inflation Projection:
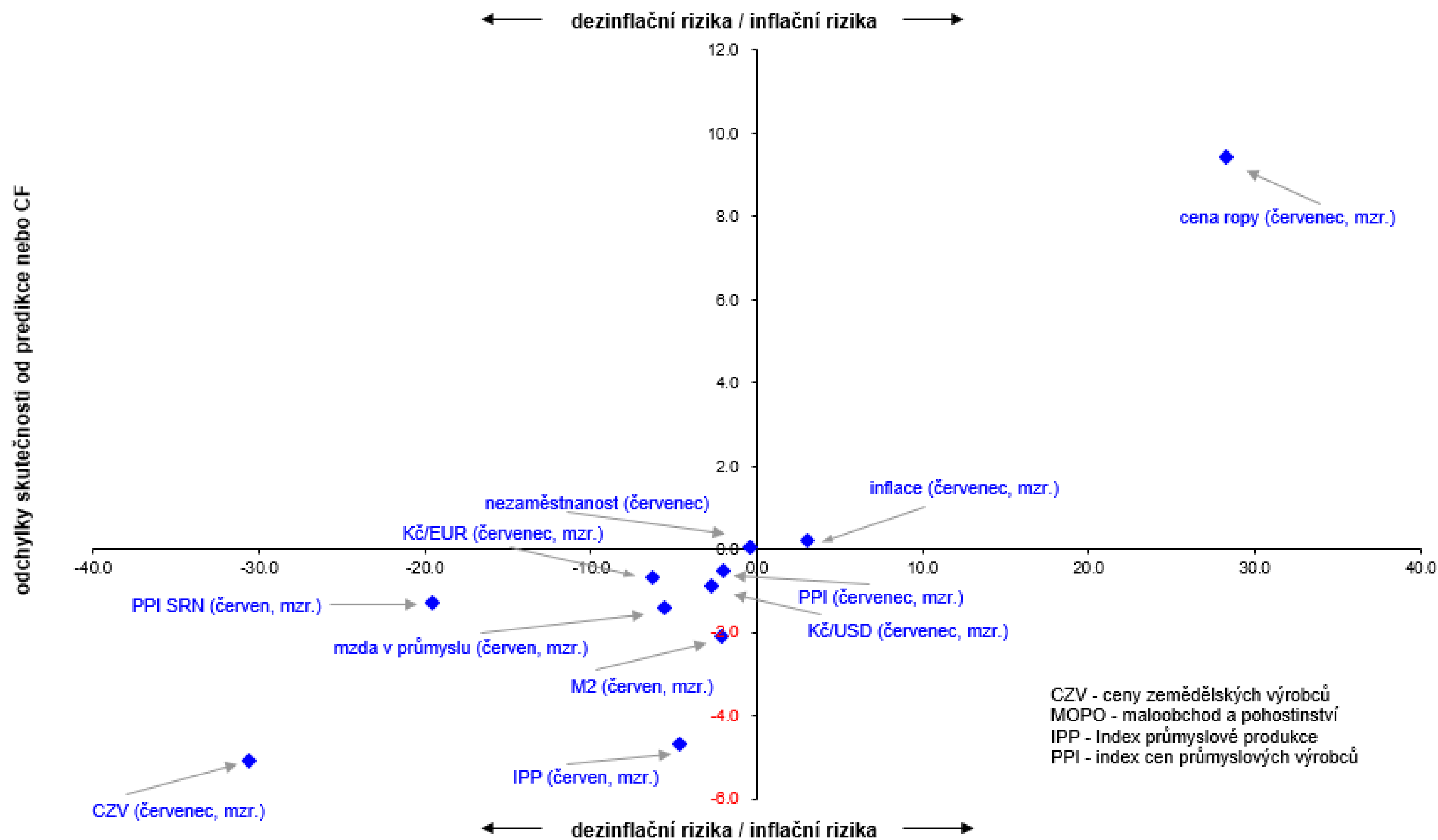
GRIP by QPM

- Graph of Risks of Inflation Projection:

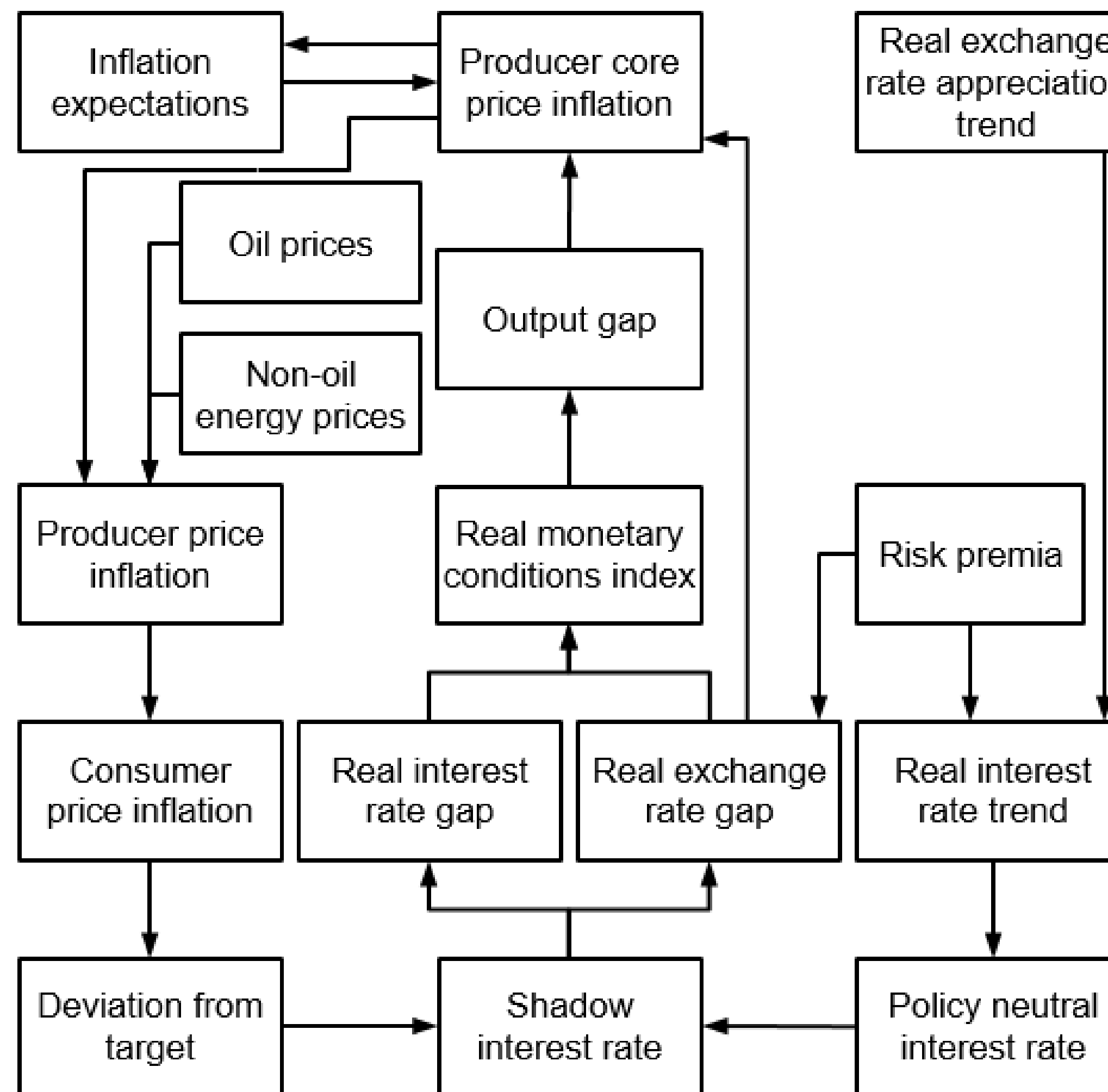- QPM GRIP produced points conditional ordering

GRIP by g3+

- Graph of Risks of Inflation Projection:

- g3 and g3+ GRIP points are not conditioned by ordering as in QPM framework

g3+ Foreign Block scheme

- Simple AR(1) processes were replaced by complex structure
  - Brazdik et al. (2020)

- Novelty: concept of shadow interest rate to handle asset purchasing programs of ECB.

Expert judgement

- Forecast are not just model trajectories.

- Story telling is important.

- Bruha et al. (2013) lists examples how the expert opinions help to shape forecast trajectories.
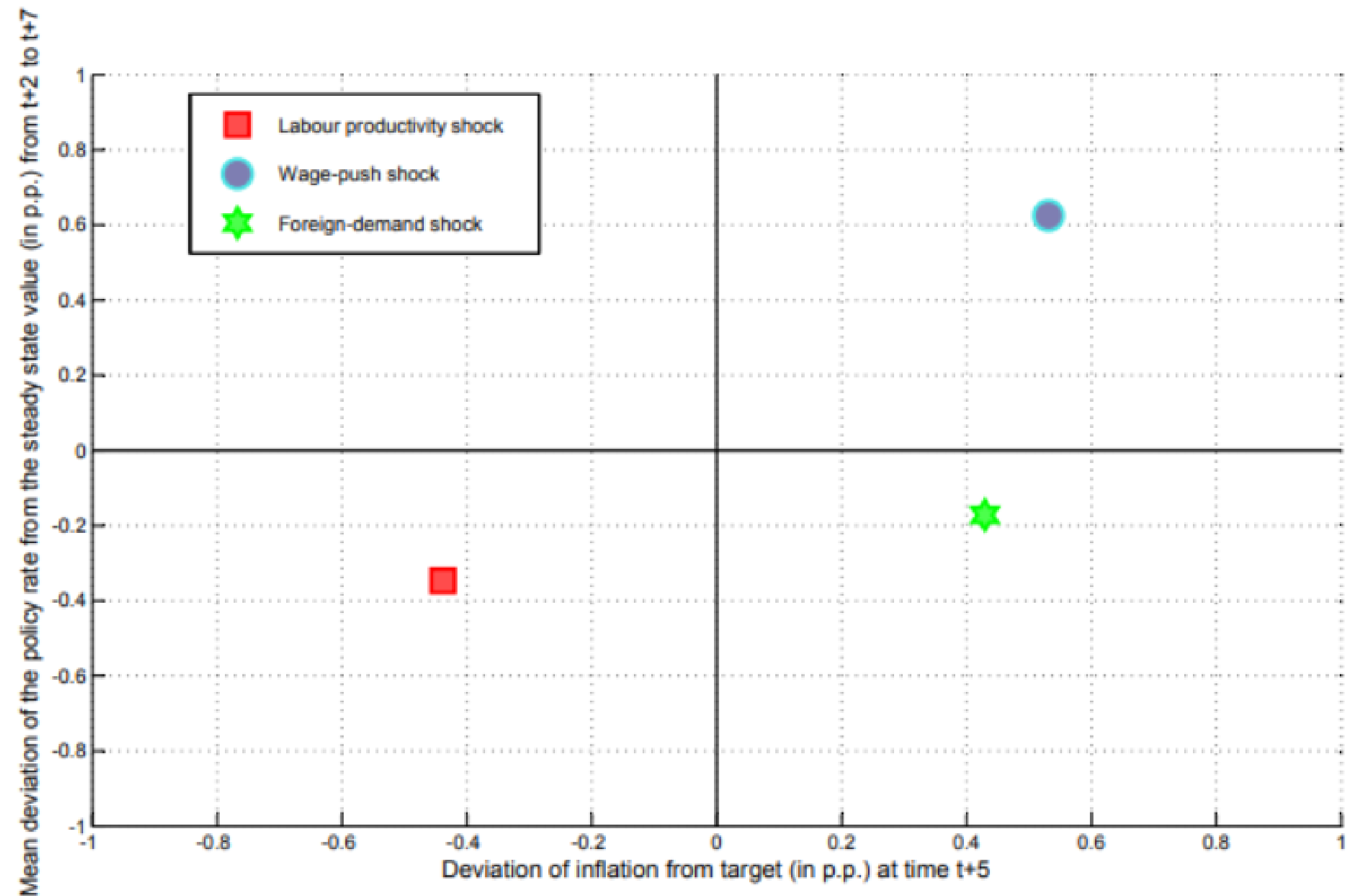
LIRE Scheme

- Detailed description Musil et al. (2021)
- Although the conditioning information spans 16 quarters ahead

- Economic agents in each quarter of the simulation fully believe the outlook for six quarters

- Additional six quarters are not utilized in first quarter of forecast

- At the beginning, decision making is mainly influenced by the close outlook, but later on information from a more distant outlook will become apparent

Rational Expectations with limited information - the current scheme for g3+

forecast horizon / forecast quarter	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
Information	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
present	1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0	0	0	0	0
quarter q+1		1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0	0	0	0
quarter q+2			1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0	0	0
quarter q+3				1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0	0
quarter q+4					1	1	1	1	1	1	0.8	0.6	0.4	0.2	0	0
quarter q+5						1	1	1	1	1	1	0.8	0.6	0.4	0.2	0
quarter q+6							1	1	1	1	1	1	0.8	0.6	0.4	0.2

Note: The new scheme reflects the inflation targeting regime and the effort to more accurately capture expectations in reality, ie:

1) Full coverage of monetary policy horizon (6 quarters ahead)

2) Fast decreasing confidence in the outlook after 1.5 years

3) The gradual use of the entire available outlook (4 years) in the later quarters of simulation

Features: g3 model vs QPM

g3 model	QPM
Explicit derivation based on "behavioral principles"	Reduced form
Model consistent expectations	Model consistent expectations
Consistence of stocks and flows	Flows only
Replicates national accounts	No GDP structure
Works with level variables	"gaps"
BGP, technology trends	Equilibrium trends
Simple fiscal block	Implicit treatment
Forward looking interest rate rule	Forward looking interest rate rule
Carefully considered "structural shocks"	Residuals in each equation