



EUROPEAN CENTRAL BANK

EUROSYSTEM

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# ECB models and forecasting tools

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*\* The views expressed in this presentation are those of the presenter and do not necessarily reflect those of the ECB or the Eurosystem.*

**A Modelling challenges in post crisis environment**

**B Addressing the modelling challenges**

**C ECB modelling portfolio for monetary policy preparation: a multi-pronged strategy**

**A** **Modelling challenges in post crisis environment**

**B** Addressing the modelling challenges

**C** ECB modelling portfolio for monetary policy preparation: a multi-pronged strategy

- The financial and sovereign debt crises have posed challenges to the economic and econometric models that had been predominantly used in the economics profession, with the ECB being no exception.
- All central banks have been affected by the near absence of financial markets in aggregate models of the economy and the separation between economic and financial econometric models, i.e. the neglect of macro-financial linkages.
- Over recent years, there have been substantial modelling efforts at the ECB to adapt or develop models by incorporating:
  - a variety of financial channels and frictions
  - fiscal sustainability analysis
  - more granularity in terms of sectors and agents
  - multi-country dimension
  - structural changes
  - interactions among a number of policy tools, accounting for model uncertainty

<h2>Forecasting</h2>	<h2>Policy Analysis</h2>
<ul style="list-style-type: none"><li>• Baseline construction: conditioning on a large information set</li></ul>	<ul style="list-style-type: none"><li>• Risk and sensitivity analysis (i.e. variants on baseline assumptions)</li></ul>
<ul style="list-style-type: none"><li>• Residual/shock analysis: Measuring and identifying contribution of judgement</li></ul>	<ul style="list-style-type: none"><li>• Monetary analysis and monetary policy</li></ul>
<ul style="list-style-type: none"><li>• Forecast interpretation: developing coherent economic “stories”</li></ul>	<ul style="list-style-type: none"><li>• Fiscal policy and structural policy</li></ul>
<ul style="list-style-type: none"><li>• Discipline and consistency over time</li></ul>	<ul style="list-style-type: none"><li>• Medium term scenarios</li></ul>

**A** Modelling challenges in post crisis environment

**B** **Addressing the modelling challenges**

**C** ECB modelling portfolio for monetary policy preparation: a multi-pronged strategy

## One or many models?

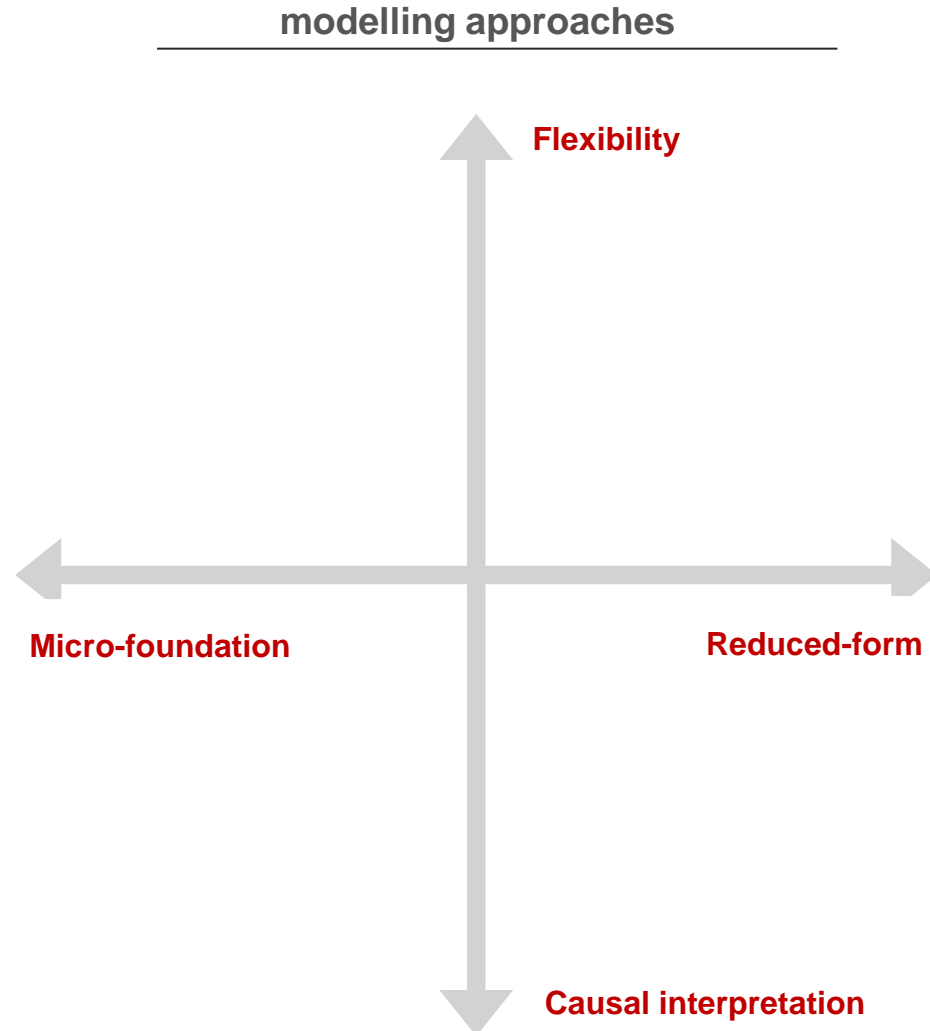
- No aspiration to build a model that includes everything
- Need for continuity in the assessment while keeping changing and including new channels and frictions
- Resonance or dissonance between academic research and modelling at policy institutions?

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 portfolio of **MAIN** model(s) interacting with a range of **SATELLITE** models

- **Modelling strategy: “suite of models”**

- no best single model: different models have their advantages and disadvantages
- different models may be best suited to respond to each specific question
- complementarity and robustness of results
- possibility of model combination



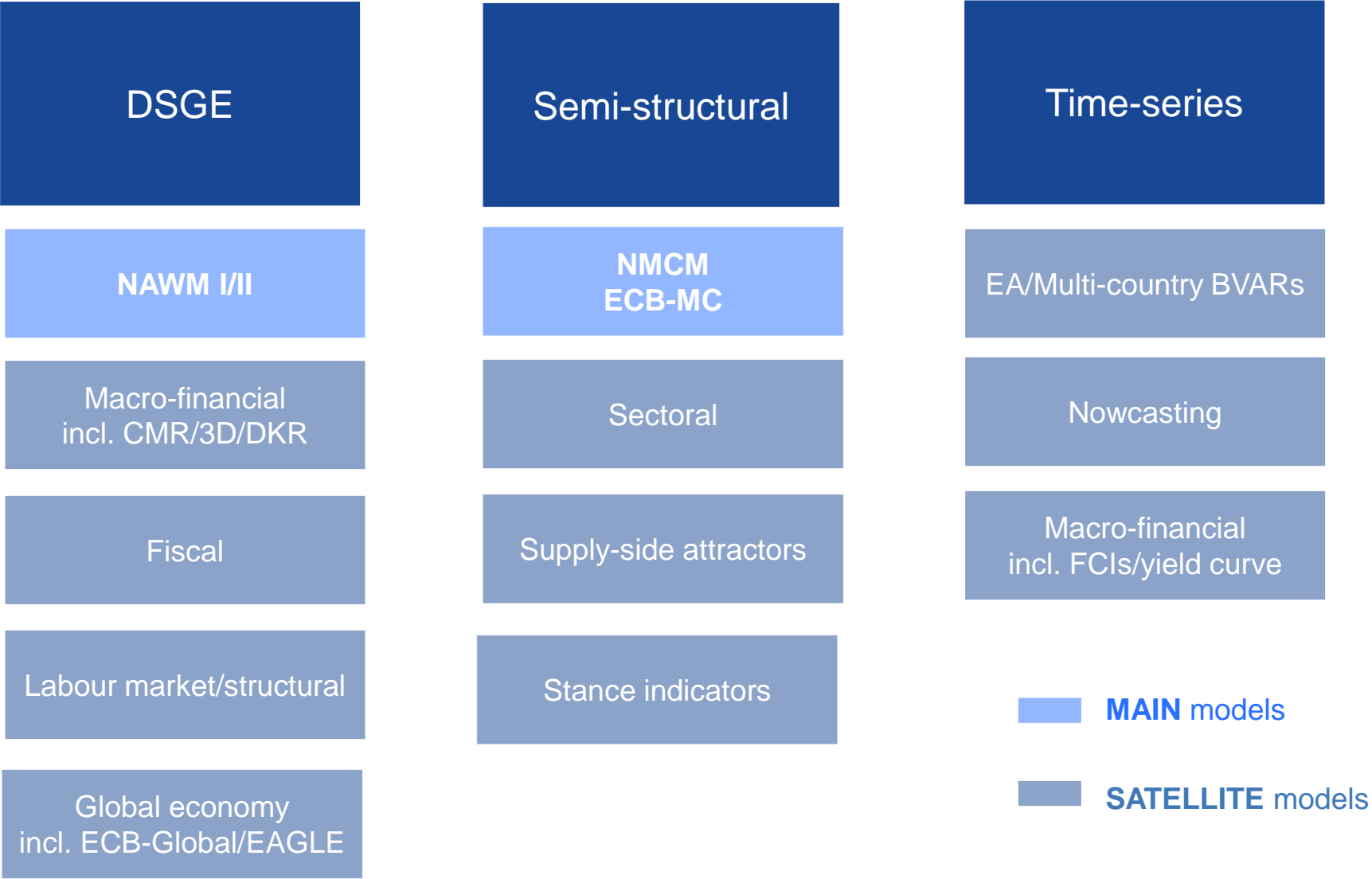


**A** Modelling challenges in post crisis environment

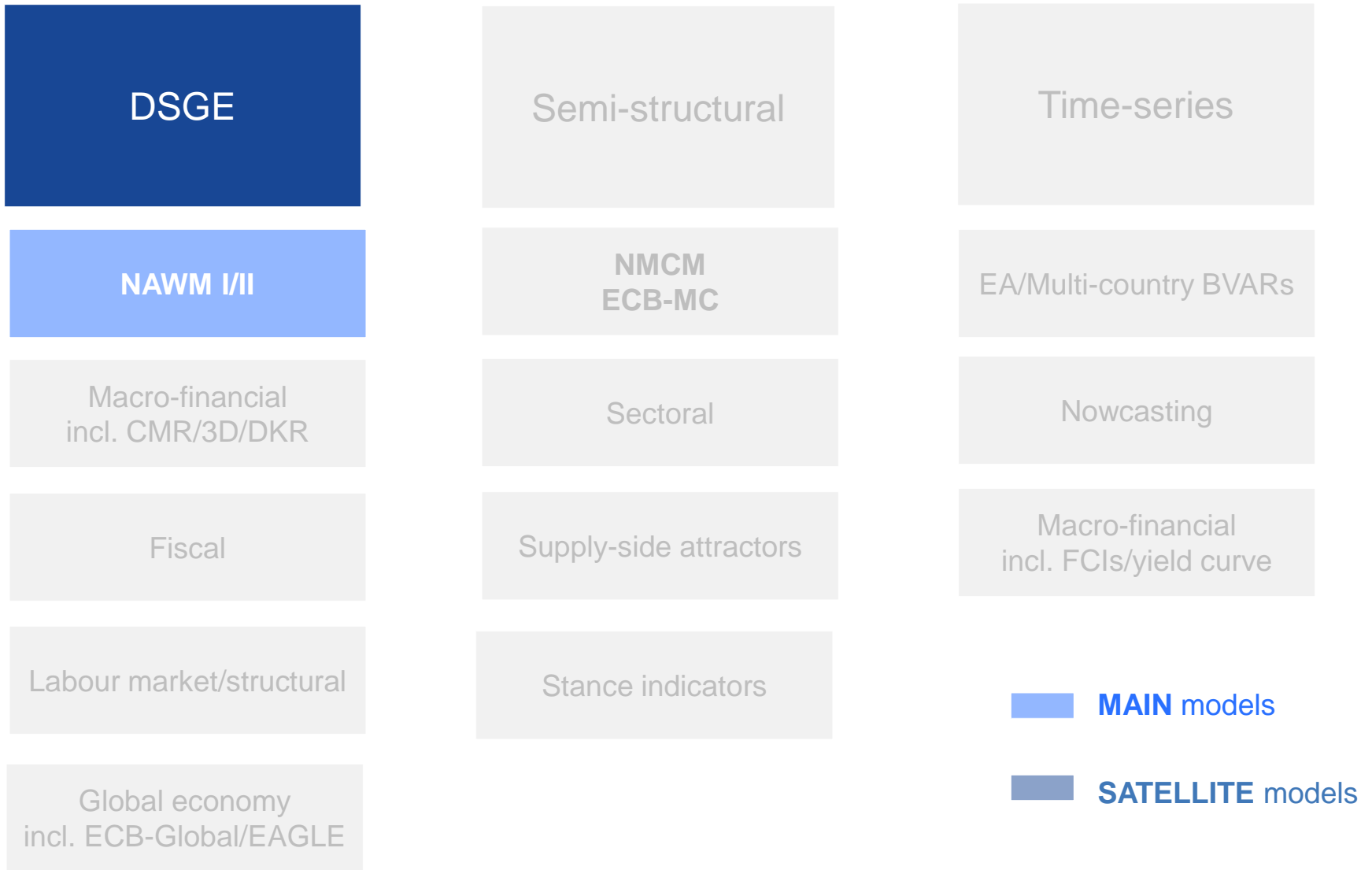
**B** Addressing the modelling challenges

**C** **ECB modelling portfolio for monetary policy preparation: a multi-pronged strategy**

# ECB modelling portfolio for monetary policy preparation



# ECB modelling portfolio for monetary policy preparation



- The **New Area-Wide Model (NAWM)** is an open-economy extension of the model by Christiano et al. (JPE, 2005) and Smets-Wouters (JEEA, 2003; AER, 2007) designed for forecasting and policy analysis (cf. ECB WP 944, 2008)
  - **Agents:** households, (intermediate and final-good) firms, monetary authority and fiscal authority
  - **Real and nominal frictions:** habit formation, adjustment costs, sticky prices and wages, limited exchange-rate pass-through
  - **Financial frictions:** domestic and external risk premium
  - Rest-of-World block (SVAR)
  - **Estimated** on time series for 18 key macro variables employing Bayesian inference methods
  - Builds on calibrated, two-country version of NAWM (cf. ECB WP 747, 2007)

- In recent years, the ECB's standard monetary policy operations have been complemented by several non-standard measures (NSMs).
- Asset price reactions suggest that these NSMs had expansionary effects but the quantitative impact on other macroeconomic variables remains uncertain.
- There is a pressing need to facilitate the analysis of the quantitative effects of NSMs by developing coherent structural macroeconomic modelling frameworks.
- Standard DSGE models are silent on the transmission channels of NSMs or, more generally, on the role of financial frictions and the propagation of financial disturbances.

# The financial extension of the NAWM: A bird's eye

- Households face a loan-in-advance (LIA) constraint:
  - households accumulate physical capital, the services of which they rent out to firms
  - capital investments have to be financed by new bank loans (Carlstrom- Fuerst- Paustian, 2014)
- Financial intermediaries (banks) engage in maturity transformation:
  - banks offer long-term loans to the private sector to finance capital investments and hold domestic and foreign long-term government bonds
  - banks' long-term assets are modelled as nominal consoles with geometrically decaying coupons à la Woodford (2001)
  - banks fund their assets with short-term household deposits and with their equity/net worth (accumulated through retained earnings)
- Firms' foreign trade is intermediated by banks.

## Imperfect financial markets:

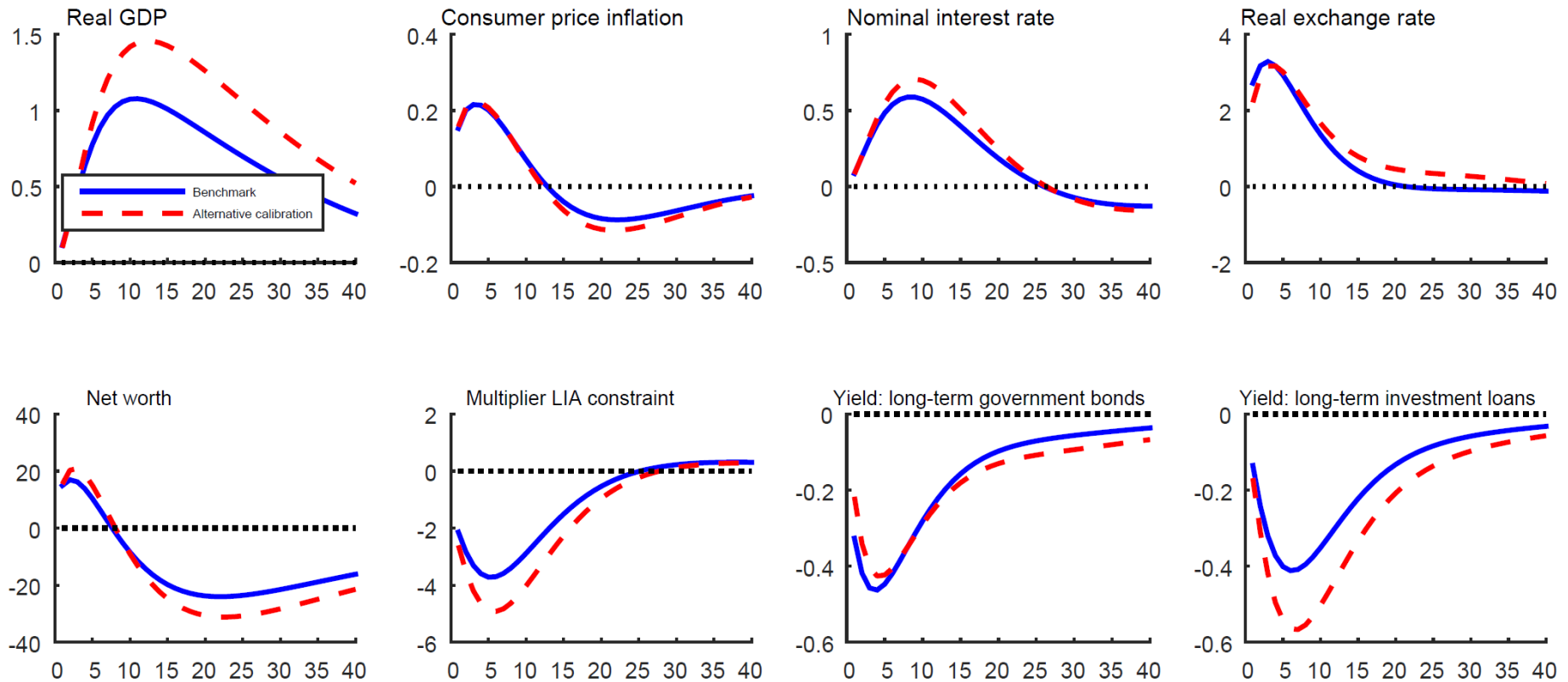
- the option to abscond (agency problem) limits the leverage of banks (Gertler-Karadi, 2011 and 2013)
- banks' capital position influences the transmission of shocks (financial accelerator mechanism)
- Delayed pass-through to lending rates:
  - loans are originated by funding-constraint wholesale banks
  - monopolistically competitive retail banks (Gerali-et-al., 2011) distribute loans and adjust loan rates sluggishly
- Exogenous financial disturbances:
  - shock to survival rate of wholesale banks (net worth)
  - shock to mark-down parameter of retail banks (market power)

- Central bank can purchase long-term private sector loans and/or government bonds:
  - relief of banks' balance sheets/leverage constraints (stealth recapitalisation) and improvement of lending conditions
  - banks' holdings of foreign currency-denominated bonds accounts for exchange-rate channel of asset purchases
- Households face portfolio adjustment costs w.r.t. their holdings of government bonds.
- Model is estimated on quarterly data (1985 to 2014)
  - 18 macro time series (NAWM I)
  - Financial: AAA ten year government bond for US and EA,
  - Survey data on long-term inflation expectations and long term growth expectations and measure of output gap



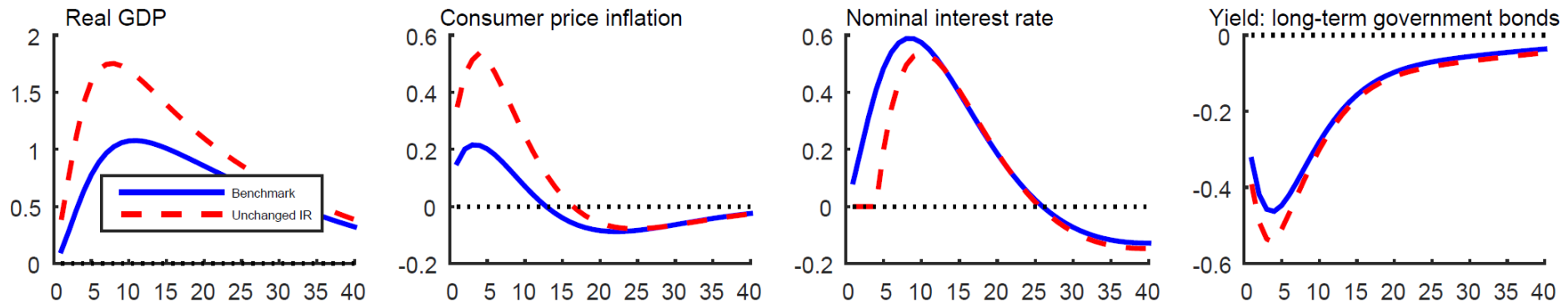
- Simulating the effects of asset purchases
  - Asset Purchase Programme (APP) as announced in January 2015:
  - 11% of GDP, 8-year maturity (9% in ten-year equivalents)
  - 20% AAA government bonds, 80% risky assets
  - hump-shaped, peaks in 2 years' time, exits as bonds mature
- Alternative calibration:
  - higher fraction of AAA government bonds: 70% (vs. 20%) Central bank can purchase long-term private sector loans and/or government bonds:

# NAWM II: Simulating the effects of asset purchases



Note: This slide depicts the impulse responses of selected domestic variables to an asset purchase shock for the benchmark and for the alternative calibration. All impulse responses are reported as percentage deviations from the model's non-stochastic balanced growth path, except for the impulse responses of the inflation and interest rates which are reported as annualised percentage-point deviations.

# NAWM II: Simulating the effects of asset purchases



- CB purchases assets and promises to keep interest rates unchanged by four quarters
  - the nominal and real effects of the central bank asset purchases get elevated under forward guidance
  - Forward guidance puzzle addressed via inattentiveness of a subset of households and firms.

# NAWM II: Summary of asset purchase

Simulation	Consumer					
	Real GDP growth (pp)			price inflation (pp)		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Benchmark	0.38	0.54	0.16	0.20	0.17	0.06
<u>Variants:</u>						
Higher riskiness	0.41	0.72	0.30	0.20	0.17	0.05
4-q interest-rate peg	0.92	0.78	-0.04	0.47	0.44	0.22
No exch.-rate channel	0.28	0.52	0.31	0.03	-0.01	-0.06

Note: This table reports the impulse responses of real GDP growth and consumption deflator inflation to a central bank asset purchase shock with a total size of 11% of GDP. The responses are expressed as average annual percentage-point (pp) deviations from the model's balanced-growth path.

- Estimated/calibrated models with both **demand and supply-side credit frictions**, based on “first principles” in macro but major deviations from pre-crisis paradigm:
  - bank capital channel, incentives for excessive credit and regulatory constraints
  - sovereign-banking nexus and funding access of banks
  - credit frictions for both households and firms
  - default as a credible characterization of financial instability, not only for banks but also non-financial corporations and households (“3D”)
  - both for euro area and multi-country settings
- Those models can provide a monetary policy perspective on **regulatory, supervisory and macroprudential** interventions
  - transitional costs of higher bank capital ratios through the euro area: Bank deleveraging process which adversely constrained the provision of credit
  - long-term cost and benefits of capital regulation:
    - risk-sensitivity of bank liabilities
    - fiscal consequences of bank fragility
  - strategic complementarities between MP and MaPru (capital versus asset based, untargeted versus targeted)

# ECB modelling portfolio for monetary policy preparation

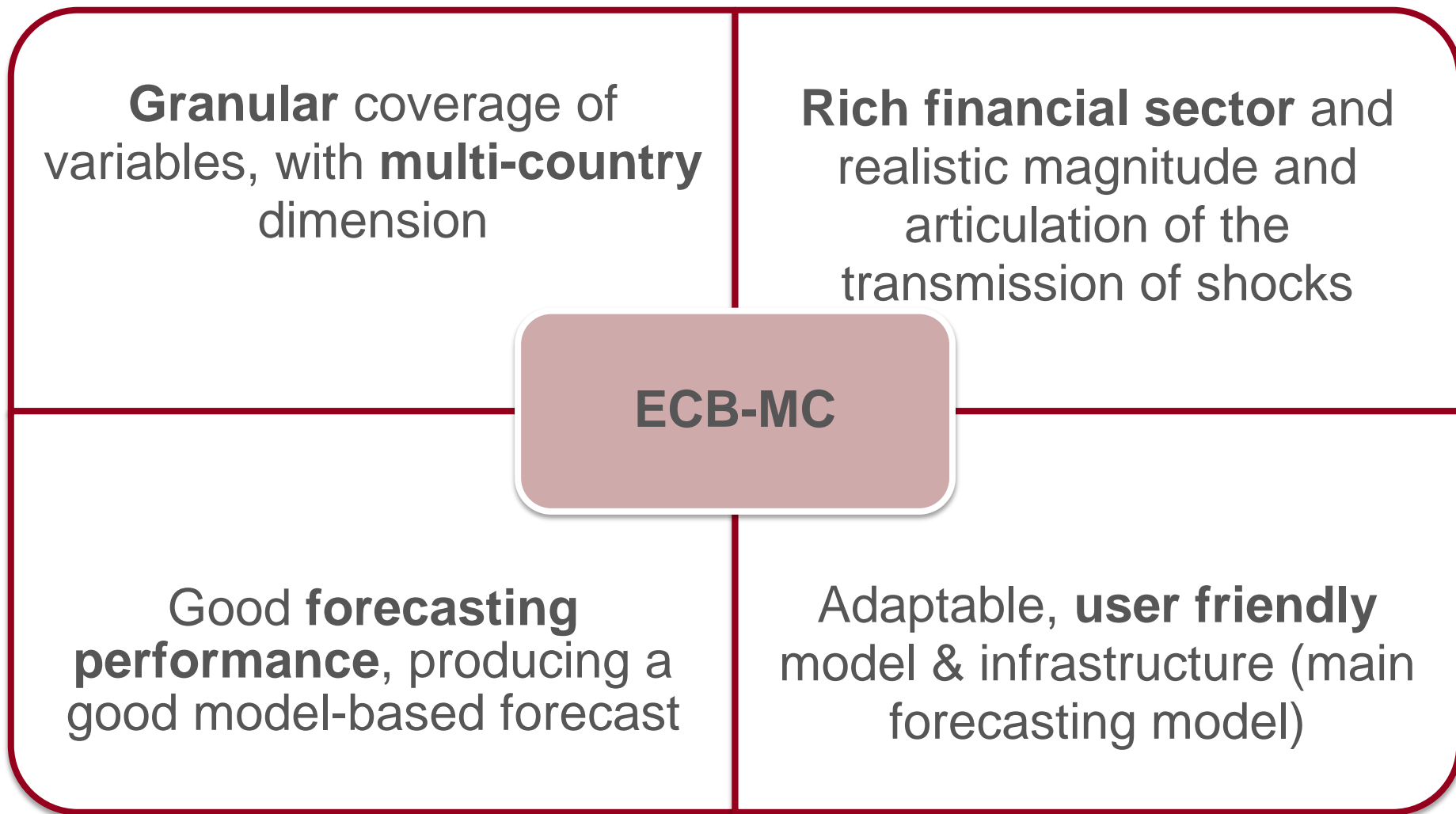


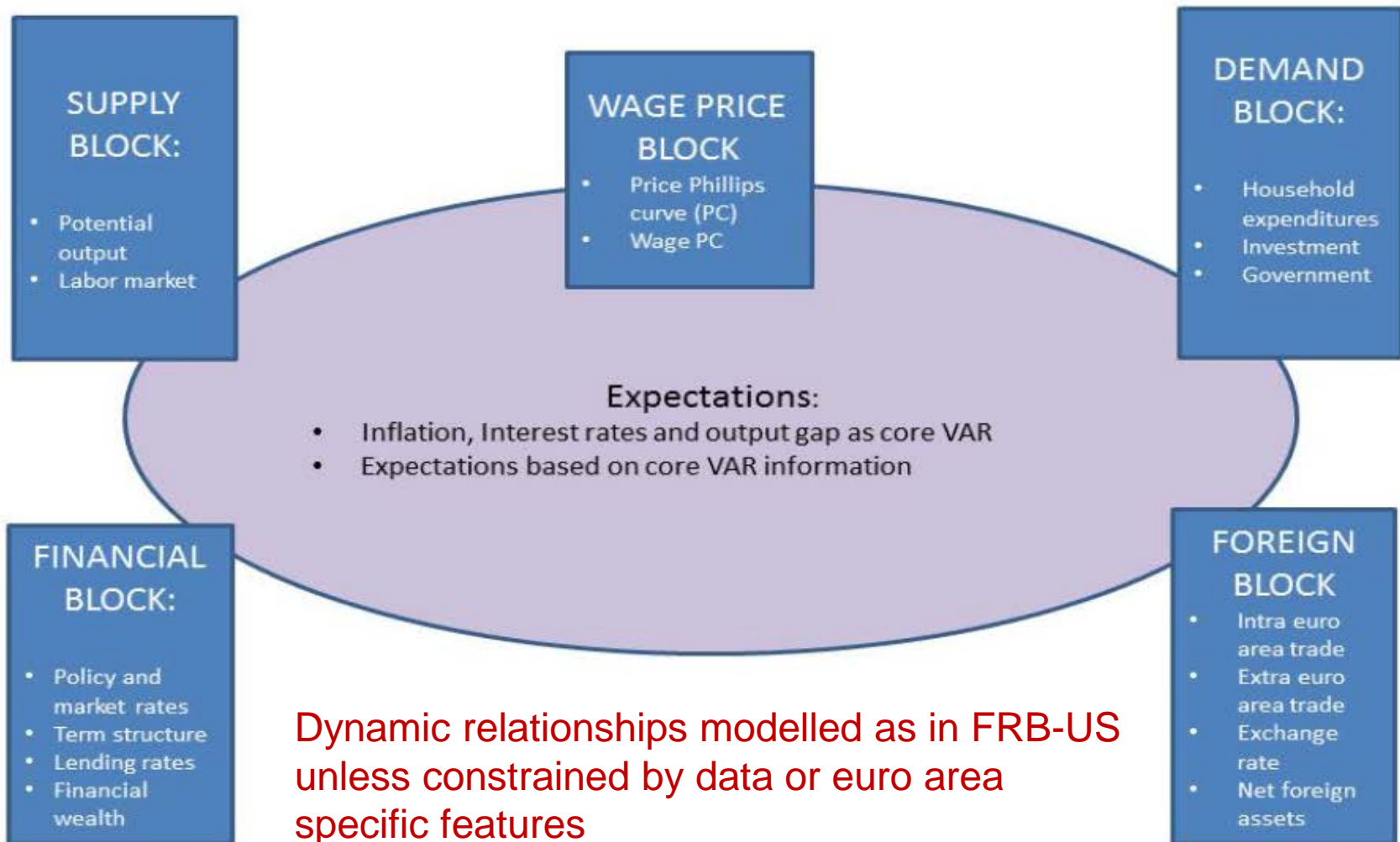
- The NMCM is a multi-country model, with five country blocks (DE, ES, FR, and NL as well as an euro area version ECB-BASE) linked via trade, common monetary policy and common exchange rate
- The institutional framework of the ECB's forecasting process:
  - bottom-up approach: **individual country forecasts**
  - ECB (Mar. and Sept.) and NCB staff (Jun. and Dec)
  - forecasts conditional on technical assumptions based on satellite models
  - judgmental forecasts
- The financial and sovereign debt crises further revealed the importance of the **country dimension** and the benefits of **flexible semi-structural models**.
- In response to the crises, the existing NMCM was re-estimated and partly adapted, before a decision was taken to more fundamentally revamp the ECB's multi-country modelling.

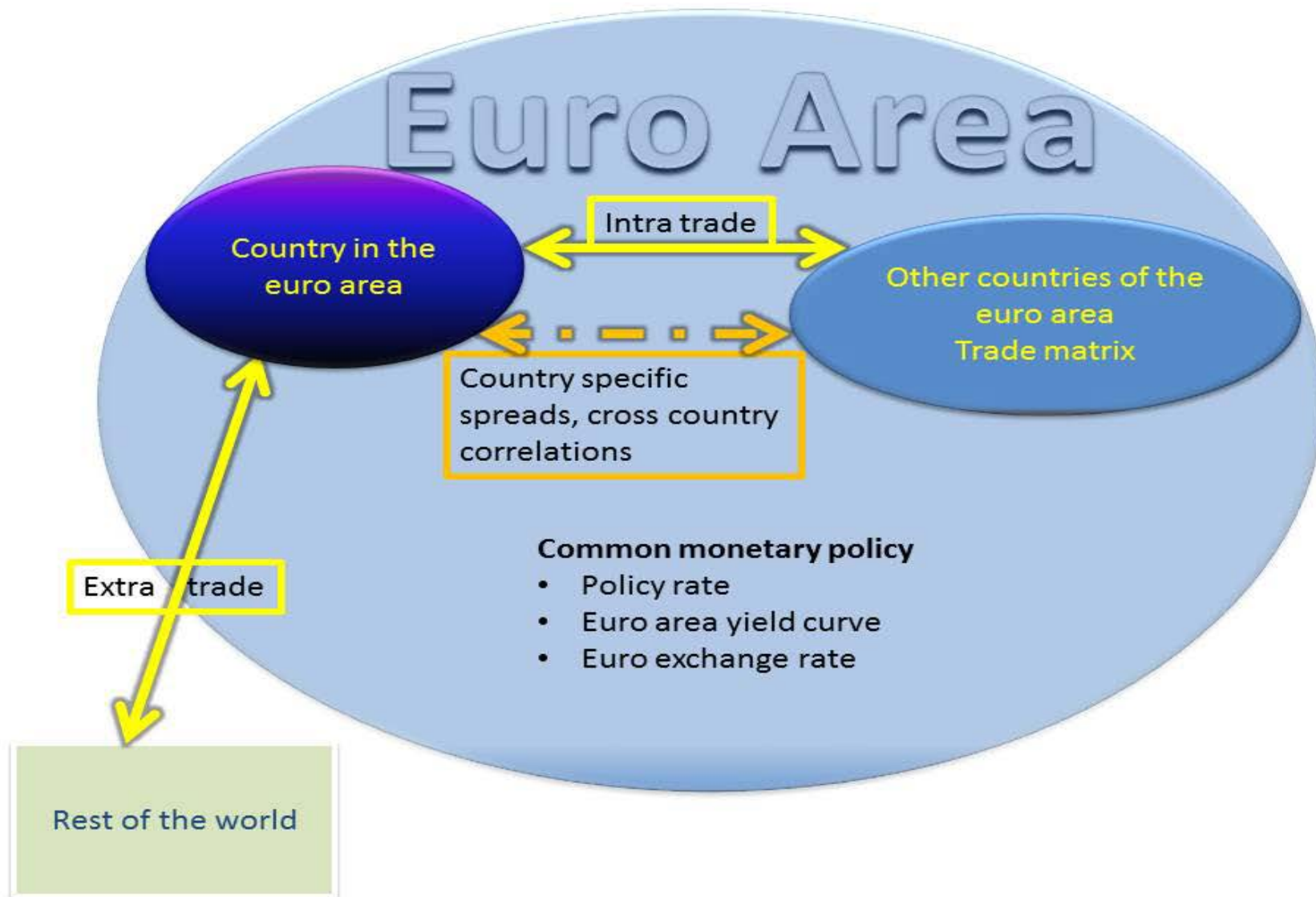
- The main goals in developing a new version of the multi-country model:
  - taking into account the **multi-country dimension**, also on the financial side
  - accounting for **multiple channels** of monetary policy transmission and featuring a realistic magnitude and articulation of the transmission of shocks
  - good **forecasting performance**
  - adaptable **user-friendly** model & infrastructure (main forecasting model)
- A semi-structural approach along the lines of FRB-US:
  - **theory-based** but **less stringent** than a DSGE model
  - **good empirical fit**, with empirical regularities matched in a reliable way
  - **flexible framework**: more granularity in the coverage of variables; more straightforward to include multi-country dimension; easier to link with other in-house tools, new mechanism can be introduced more swiftly



- ECB-MC has a flexible empirical orientation, inspired by the FRB-US model







- The Great Recession in Euro Area offered few lessons:
  - **Multi-country dimension** of Euro Area is important
  - Macroeconomic models have to include a **richer financial propagation** mechanism
  - Models should be **readily adaptable** in order to address newly emerging policy questions in a timely manner
  
- In response ECB decided for a revamp of its multi-country modelling
  - The main forecasting model redesigned along the lines of the Federal Reserve's **FRB/US model** that proved invaluable tool at FED during the crisis
  - Development of purely statistical Bayesian VAR model to validate more structural models and to cross-check projections

## ➤ **Financial frictions**

- Allows for a much richer set of financial variables, including a variety of spreads (risk, term, sovereign)
- Empirical approach without taking a stance on the exact theoretical mechanism. Financial frictions, like different pass-through to lending rates, captured empirically

## ➤ **Rational expectations**

- Baseline assumes bounded rationality by agents: VARs with market/survey based expectations.
- Allows for Model Consistent expectation or mix, and also other expectation formations, like learning

## ➤ **Heterogenous agents**

- Derivation of consumption function takes into account rule of thumb consumers and different consumption elasticities for different population cohorts

## ➤ **Microfoundations**

- “Targets” microfounded and constructed/estimated from the data – empirical check of the theory

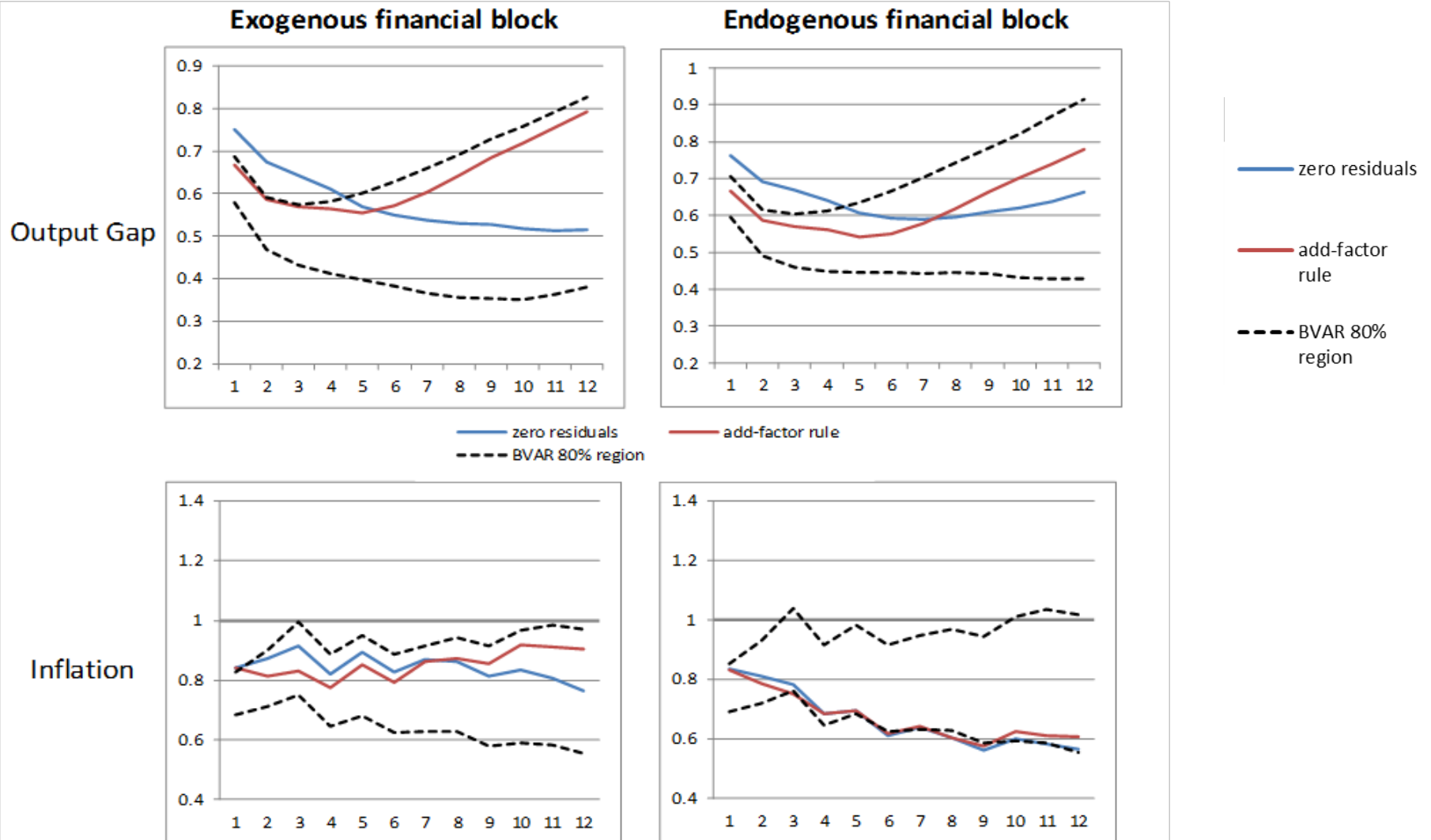
## ➤ **True forecasting with ‘traditional’ models is difficult:**

- Model is estimated equation by equation: general equilibrium version is ‘miss specified’
- Typically forecast is conditioned on a set of conditioning variables (international environment, financial side and fiscal )

## ➤ **Adding ‘Add-factors’ to account for misspecification**

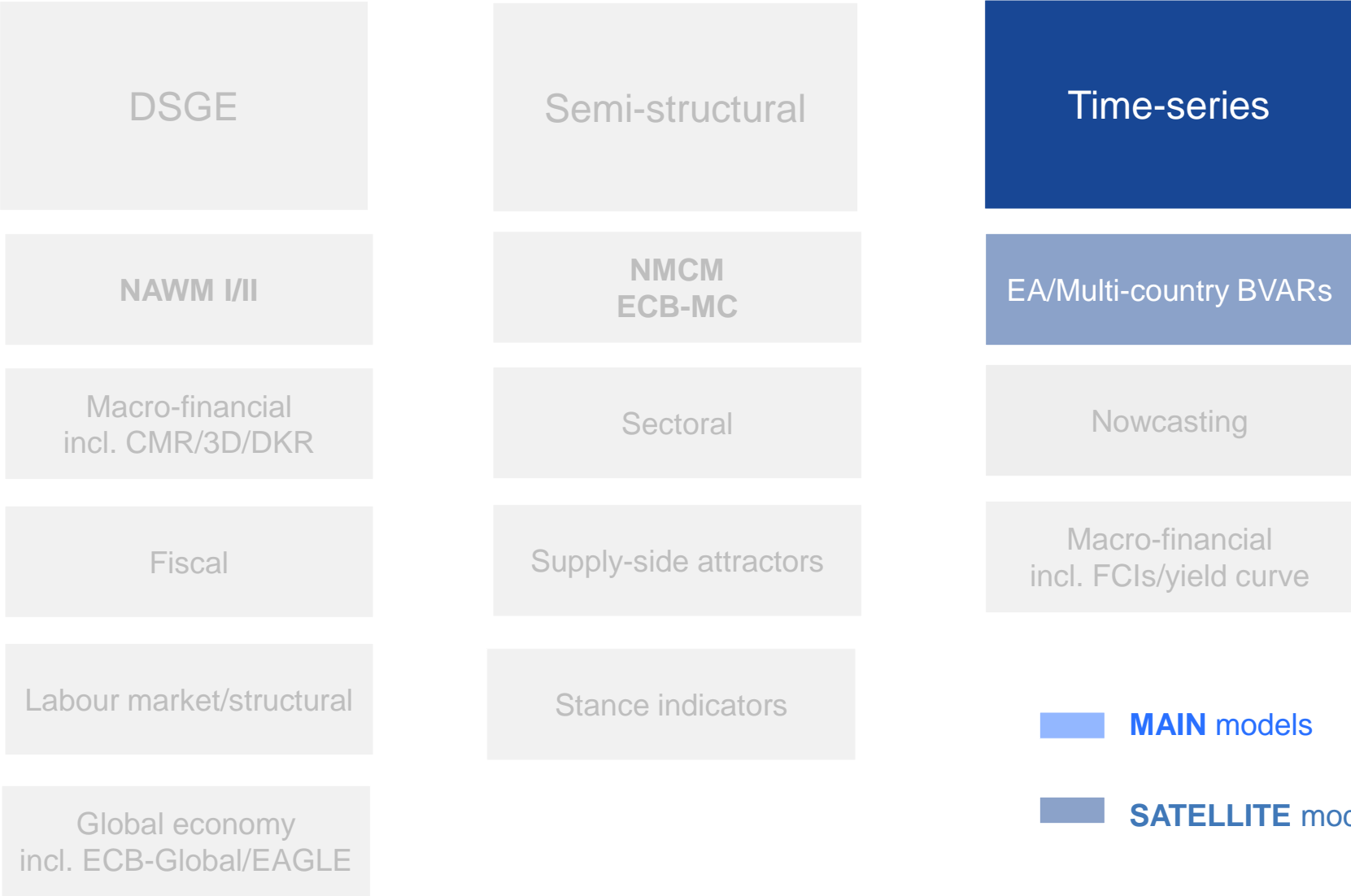
- Define mechanical rules to extrapolate residuals to correct for misspecification but avoid too much ‘judgment’
  - Zero-residual rule
  - Unobserved component model

# Forecasting with the ECB-BASE: RMSE relative to RMSE of Random Walk/AR(2)



Note: The charts report the RMSE of the ECB-BASE model projected for 12 horizons and evaluated over the sample 2004-2017 as a ratio of the RMSE obtained with a naive benchmark (Random Walk forecast for inflation and AR(2) for output gap). The bands are derived from the forecast over the same horizon and sample of a BVAR model. In the setup with exogenous financial variables, the BVAR has with four endogenous variables (output gap, GDP deflator inflation, consumption growth and wage inflation) and five exogenous variables (short term interest rate, government consumption growth, oil price inflation, exchange rate, and world demand growth). In the setup with endogenous financial variables, the short term interest rate becomes endogenous.

# ECB modelling portfolio for monetary policy preparation





## Advantages – it is easier to:

- Incorporate mixed/high frequency (timely) data  
E.g. daily financial data, weekly gasoline prices, monthly opinion surveys and sectoral indicators
- Deal with large systems  
E.g. including country and sectoral data, measures of expectations, sentiment and uncertainty indicators, financial data
- Allow for non-linear/time-varying features  
E.g. vector autoregressions with time varying coefficients or steady states, models with regime switching
- Account for model and parameter uncertainty and construct predictive distributions  
Bayesian estimation and simulation
- Use

## Examples of uses:

- (Updates of) short-term outlook
- Assessment of risks to the projections
- Forecasting auxiliary variables/assumptions
- Constructing scenarios and interpreting past developments
- Providing benchmarks on data regularities and forecast performance for the main models
- Refining and broadening the set of identification strategies for non-standard measures

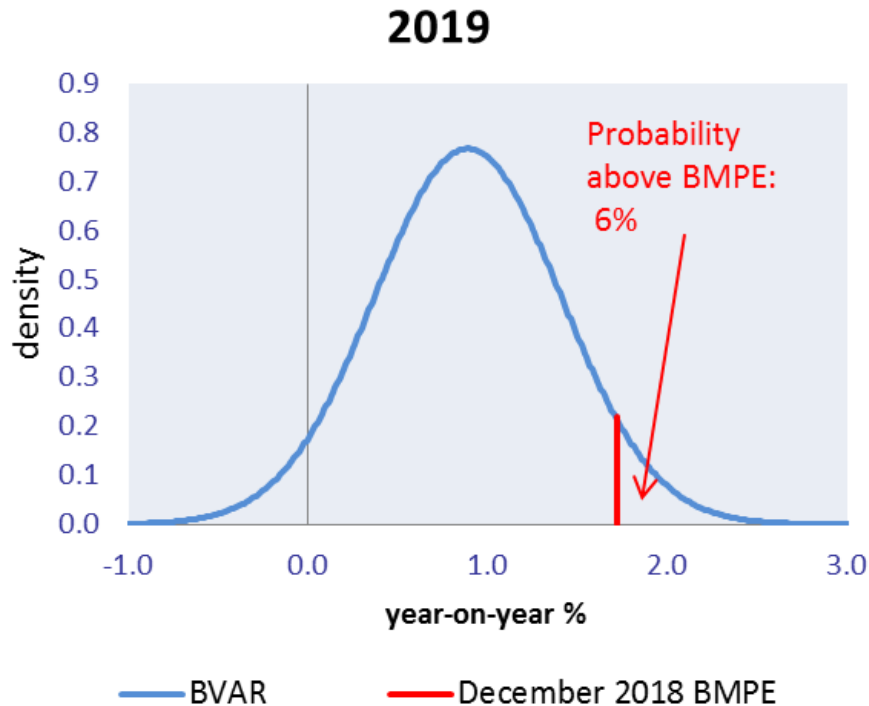
## Examples of models:

Nowcasting models for GDP and inflation, Phillips curves, **Bayesian VARs**, (structural) factor models, models for the yield curve or financial conditions indicators

$$y_t = c + B_1 y_{t-1} + \dots + B_p y_{t-p} + \varepsilon_t$$

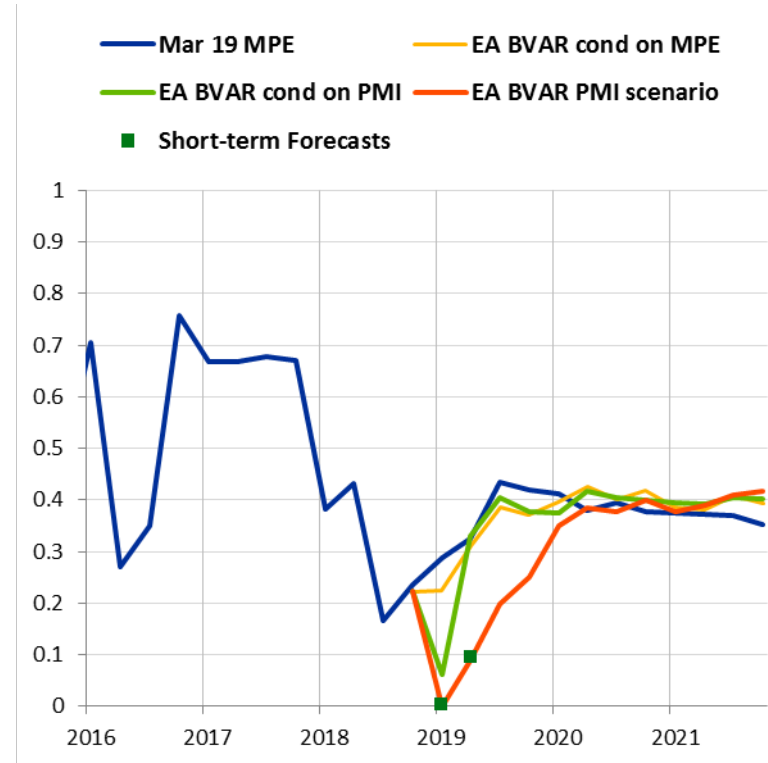
- Implementation with variety of priors
  - Minnesota type, priors on the steady states
- Versions with time-varying coefficients and stochastic volatility
- Versions for the euro area and for countries
- Simulations (of parameters and shocks) using Bayesian methods in order to construct predictive distributions (“fan charts”)
- Forecast combination
  - Linear opinion pools and non-linear methods to improve calibration
- Conditional forecasts
  - E.g. future paths of external developments as given; scenarios

## Risks to December 2018 BMPE assessed in February 2019



Notes: Predictive distribution (density) for 2019 is derived from a Bayesian VAR (BVAR) model via simulation of parameters and shocks. The risks to the projections are assessed as the probability mass of this distribution to the left and right of the projected outlook. For example, low probability mass to the right signals downside risks to the projection via the lens of the model.

## March 2019 MPE and scenarios



Notes: March 19 MPE: March 2019 ECB staff macroeconomic projection for GDP growth; EA BVAR cond on MPE: GDP forecast from a BVAR model conditional on external and technical assumptions underlying the March projection; EA BVAR cond on PMI: PMI reading for 2019 Q1 is further included as conditioning information; EA BVAR cond on PMI scenario: conditional forecast assuming a slow recovery path for PMI throughout 2019.

**Increased modelling activity to address the challenges to modelling since the great recession:**

**Suite of models to explore complementarities and avoid 'too large' models**

- NAWM II: DSGE model with financial sector is able to model the impact of main non-standard policy measures (Asset purchases and forward guidance), finalized and incorporated into policy process.
- ECB-MC: semi-structural multi-country model. Euro area version up and running and multi-country version still under construction
- Extension of time-series models suite: accounting for uncertainties and structural changes

## MAIN models:

- *Christoffel, K., G. Coenen, and A. Warne, 2008, “The New Area-Wide Model of the Euro Area: A Micro-Founded Open-Economy Model for Forecasting and Policy Analysis.” Working Paper No.944, European Central Bank.*
- *Coenen, G. and A. Warne, 2014, “Risks to Price Stability, the Zero Lower Bound, and Forward Guidance: A Real-Time Assessment”, International Journal of Central Banking.*
- *Coenen, G. and S. Schmidt, 2016, “The Role of the ECB's Asset Purchases in Preventing a Potential De-anchoring of Longer-term Inflation Expectations”, ECB Research Bulletin No. 25.*
- *Coenen, G., P. Karadi, S. Schmidt and A. Warne, 2018, “The New Area-Wide Model II: An extended version of the ECB's Micro-Founded Model for Forecasting and Policy Analysis with a Financial Sector”, ” Working Paper No.2200, European Central Bank.*

## SATELLITE models:

- *Darracq Pariès, M., C. Kok and D. Rodriguez (DKR), 2011, International Journal of Central Banking.*
- *ESCB Macropprudential Research Network, 2010-2014.*
- *Clerc, L. et al. 2015, (3D), International Journal of Central Banking.*
- *Darracq Pariès, M., P. Jacquinot and N. Papadopoulou (2016), Working Paper No. 1891, European Central Bank.*
- *Banbura, M., Giannone, D. and M. Lenza (2015), International Journal of Forecasting.*
- *Angelini, E., Lalik, M., Lenza, M. and J. Paredes (2019), International Journal of Forecasting.*