The Use of DSGE Models for Monetary Policy Analysis at Sveriges Riksbank with a discussion of Optimal Policy Projections

BANK INDONESIA and BANK FOR INTERNATIONAL SETTLEMENTS WORKSHOP
"STRUCTURAL DYNAMIC MACROECONOMIC MODELS IN ASIA-PACIFIC ECONOMIES"
Bali, Indonesia, June 3 - 4, 2008

Stefan Laséen

Purpose of Presentation

- Brief description of the DSGE model that has been developed at the Riksbank during the last years
- Describe how the model is used in the forecasting process and for policy analysis
- Ramses = **R**iksbank **A**ggregate **M**acromodel for **S**tudies of the **E**conomy in **S**weden

Agenda

- Models used for forecasting at the Riksbank
- 1. Ramses: model overview
- 2. Forecasting
  - Forecasting performance
  - Ramses role in the forecasting process
  - Ramses forecasting impact
- 3. Policy analysis with Ramses
  - Optimal Policy Projections

Models used at the Riksbank

- DSGE = Ramses
- BVARs & DSGE-VAR
- Large data set models (nowcasting)
    - Forecast combinations (classic + Bayesian model averaging)
    - Static factor (principal components) routines
    - Early information/forward looking information models
- Other partial information models and judgements (sector experts)

Ramses Model Overview I

- Small open economy version of the CEE (JPE 2005)-model
- Adding more shocks (Smets & Wouters)
- Model estimated on Swedish data 1986Q1-2007Q4
  - Allow for break in policy to account for monetary policy regime shift

Ramses Model Overview II

- Model we use in practice is very similar to the one presented in Adolfson et al. (*JEDC 2008*, forthcoming)
- Modified version of the UIP condition to improve on fitting exchange rate dynamics
- Monetary policy described by simple rule
  - Not loss function based approach for the moment – work in progress

Closed Economy Aspects

- Households
  - Utility from consumption, leisure
  - Capital accumulation
- Domestic intermediate goods firms
  - Cobb-Douglas (capital and labour)
  - Imperfect competition
- Competitive final goods firms
- Central bank
  - Taylor-type rule, interest rate ‘smoothing’
- Government: distortionary fiscal policy
  - exogenous VAR for taxes and government expenditures

Open Economy Aspects

- Consumption and investment baskets of foreign and domestic goods
- Importing (consumption, investment) firms and exporting firms
  - Imperfect competition
  - Brand naming technology
  - Local currency price setting

  $\Rightarrow$ Incomplete exchange rate pass-through (sticky prices)
- Trade in foreign bonds with endogenous risk-premium
- Foreign economy exogenous
  - (SVAR for inflation, GDP, nominal interest rate)

Frictions

- Nominal
  - Domestic prices, import and export prices (Calvo)
  - Wage stickiness (Calvo)
  - Working capital channel
- Real
  - Capital adjustment costs (investment)
  - Habit persistence in consumption
  - Imperfect competition
  - Distortionary taxes

Estimated Shocks

- Technology (stationary and permanent), investment specific, asymmetric (domestic vs foreign)
- Markup shocks (4)
- Preference shocks (2)
- Risk premium shock
- Monetary policy shocks (2)

Forecasting Performance I

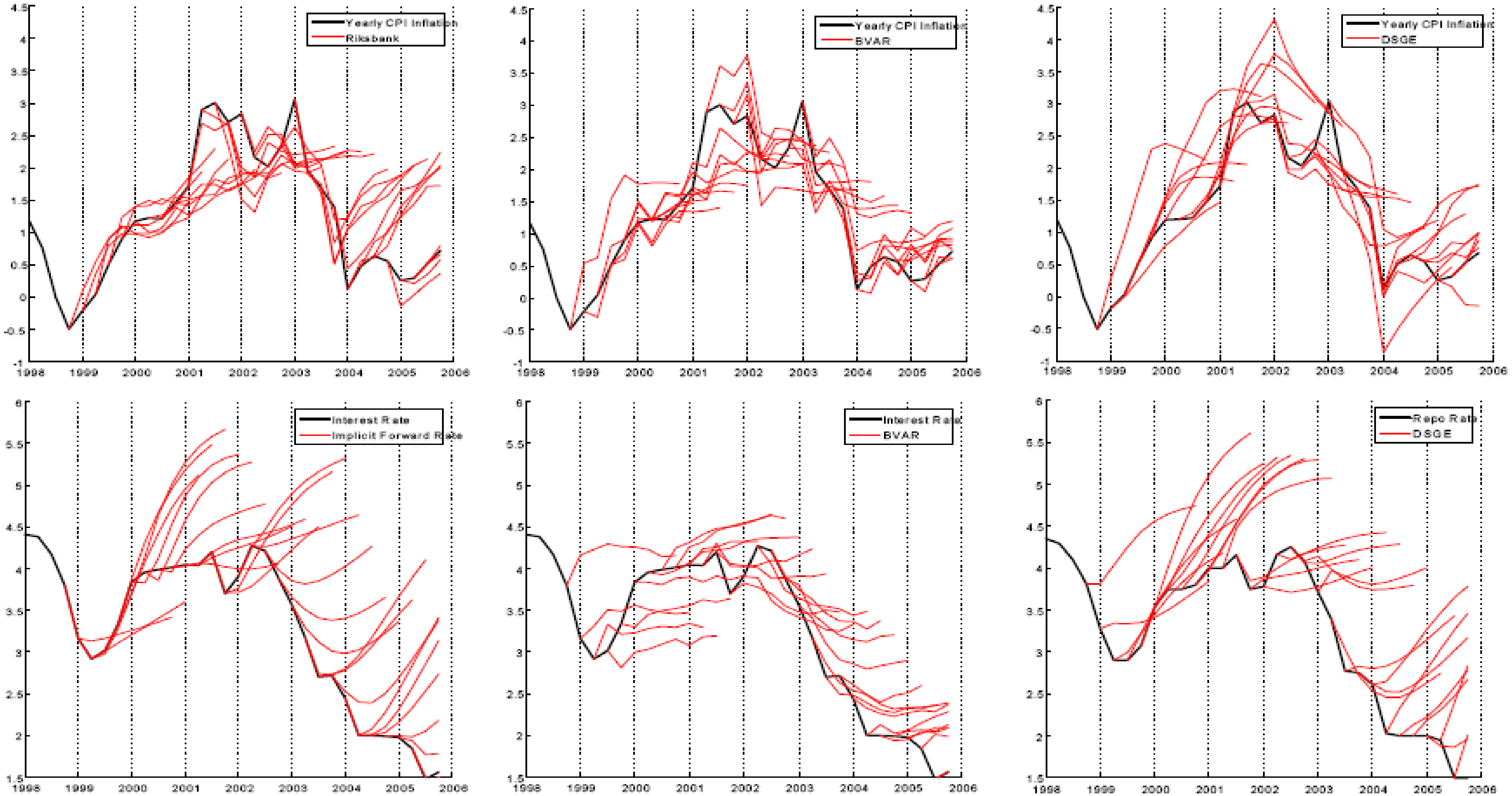
- Bayesian estimation of key model parameters (pertaining to dynamics)
  - Steady state parameters typically calibrated
- Forecasting properties in line with BVARs
- Forecasting properties in line with Riksbank's own forecasts
  - Pseudo out-of-sample comparison (no real time data)
  - Riksbank forecasts conditional on constant interest rate assumption

Forecasting Performance II

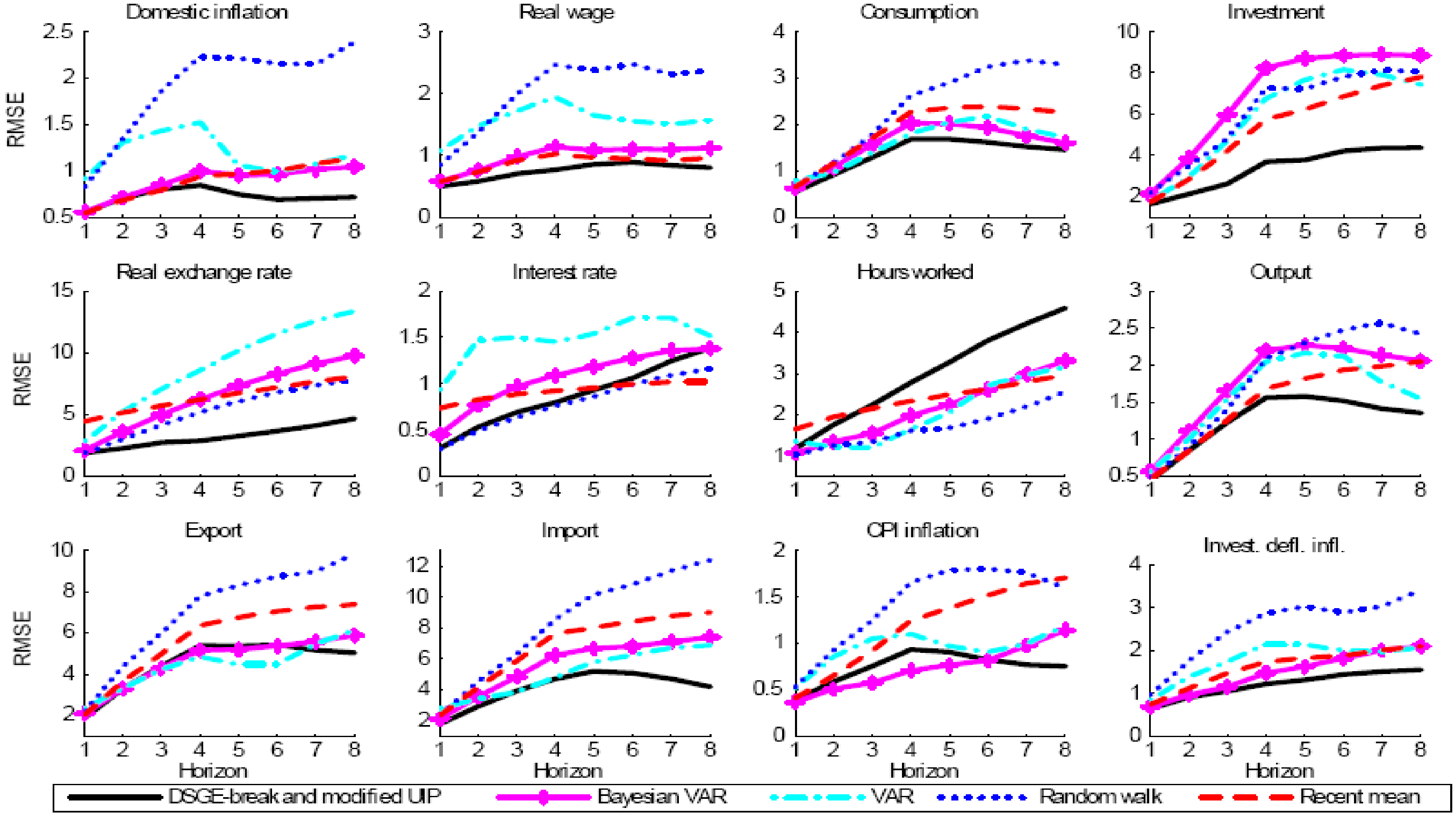
Riksbank BVAR DSGE

Inflation

Interest Rate



Forecasting Performance III



Forecasting and Communication

SVERIGES RIKSBANK

- 6 forecast rounds and interest rate decisions per year
  - 3 forecasts published in "*Monetary Policy Report*" (February, June, October)
  - 3 internal forecasts
  - Press conference after every interest rate decision (previously only when interest rate had been changed)
  - Names of Executive Board Members appear in the minutes

Ramses' Role in the Forecasting Process I

- **Meeting 1** : International developments & world economy forecast (TCW)
- **Meeting 2** : Financial markets (repo rate expectations, exchange rate…)
- **Meeting 3**: Assessment of initial conditions
- **Alternative Macro Scenarios Meeting**
- **Meeting 4**: Macro forecast

Ramses' Role in the Forecasting Process II

- **Meeting 5**: Disaggregated macro forecast
- **Monetary Policy Meeting** (Executive Board & Monetary Policy Dep. (MPD), Financial Stability Dep.)
- **Meeting 6**: The Executive Board Main Scenario

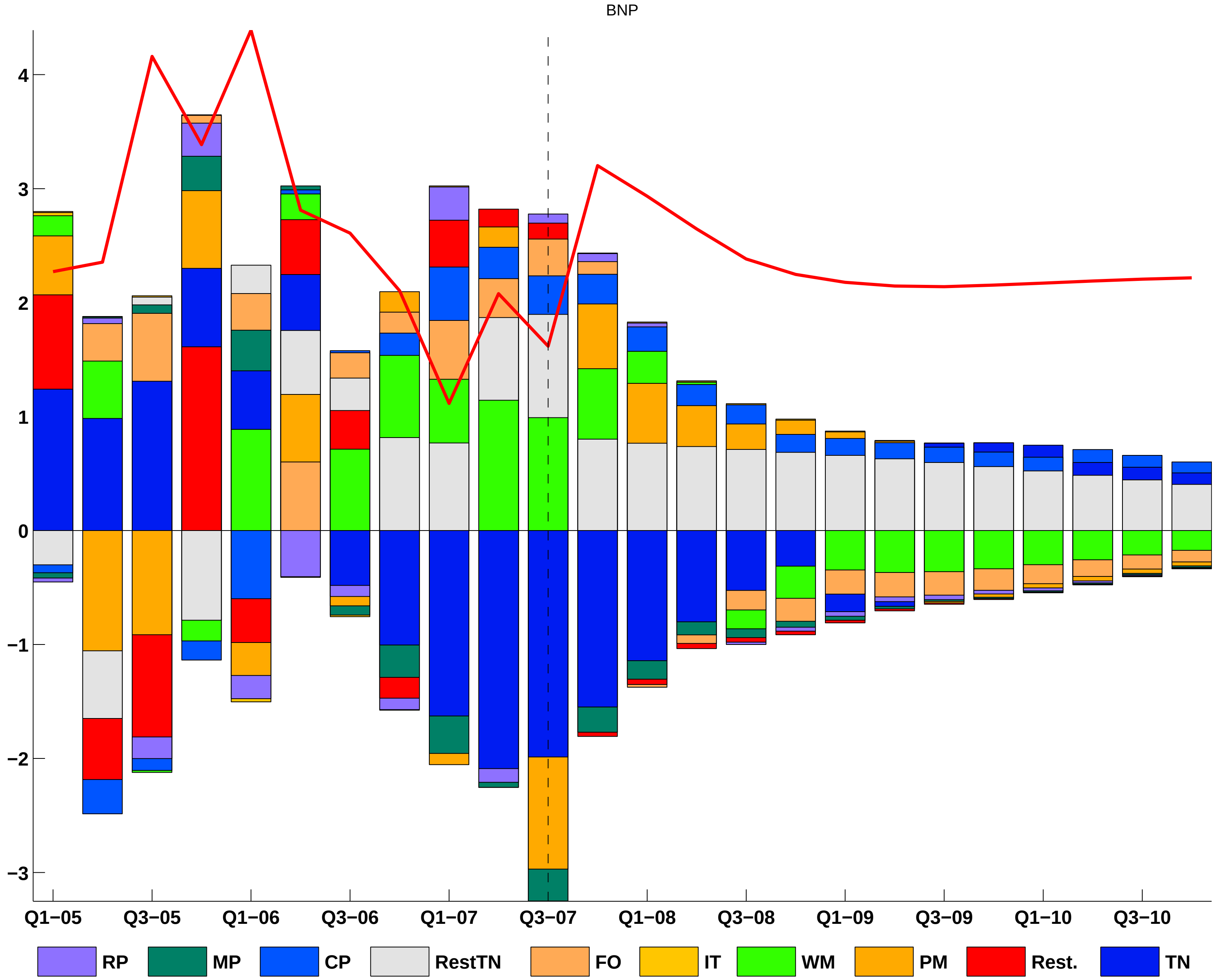
Ramses' Role in the Forecasting Process III

- **Initial conditions (Meeting 3)**
  - Unconditional forecasts
    - Focus on starting conditions e.g. what shocks have hit the economy?
    - Implications for the unconditional forecast (e.g. interest rate setting according to Ramses estimated policy rule)

Ramses' Role in the Forecasting Process III

Example: How Ramses is used to analyze initial conditions

- GDP forecast high initially?
  - Why?
- Positive imported consumption markup shock
  - Higher prices on imported goods
  - Relatively cheap domestic goods
  - Net-export and production increase


BNP
4
3
2
1
0
−1
−2
−3
Q1−05
Q3−05
Q1−06
Q3−06
Q1−07
Q3−07
Q1−08
Q3−08
Q1−09
Q3−09
Q1−10
Q3−10
RP
MP
CP
RestTN
FO
IT
WM
PM
Rest.
TN

Ramses' Role in the Forecasting Process IV

- **Macro forecast (Meeting 4)**
  - Conditional forecast, conditioned on
    - MPD assessment of initial conditions (current quarter) - monitoring rather than conditioning
    - MPD view on world (TCW) economy forecast
    - MPD initial repo rate assessment
  - Conditional forecasts using Waggoner-Zha (mix of shocks, historically relevant)
  - Ramses & BVAR forecasts used to update previous forecast (e.g. in MPR or Update)
  - DSGE-VAR (Del Negro & Schorfheide)
  - Optimal Policy Projections

Ramses' Role in the Forecasting Process V

- **Disaggregated macro forecast (Meeting 5)**
  - "Consistency check" of forecast
    - Ramses forecast conditioned on major domestic real variables (Y, C, I, X, M, H) and ROW (Y*, PI*, R*) in forecast
    - Implications for inflation, repo rate?
    - WZ – what are the driving forces (shocks)?

Ramses' Forecasting Impact I

- Ramses has been used as a forecasting and policy tool since 2005.
- One way to assess Ramses forecasting impact is to examine how the final forecasts for key variables relate to Ramses conditional forecasts
  - Ramses forecasts are conditional on sector experts' assessment of the current stance in the economy (current quarter)

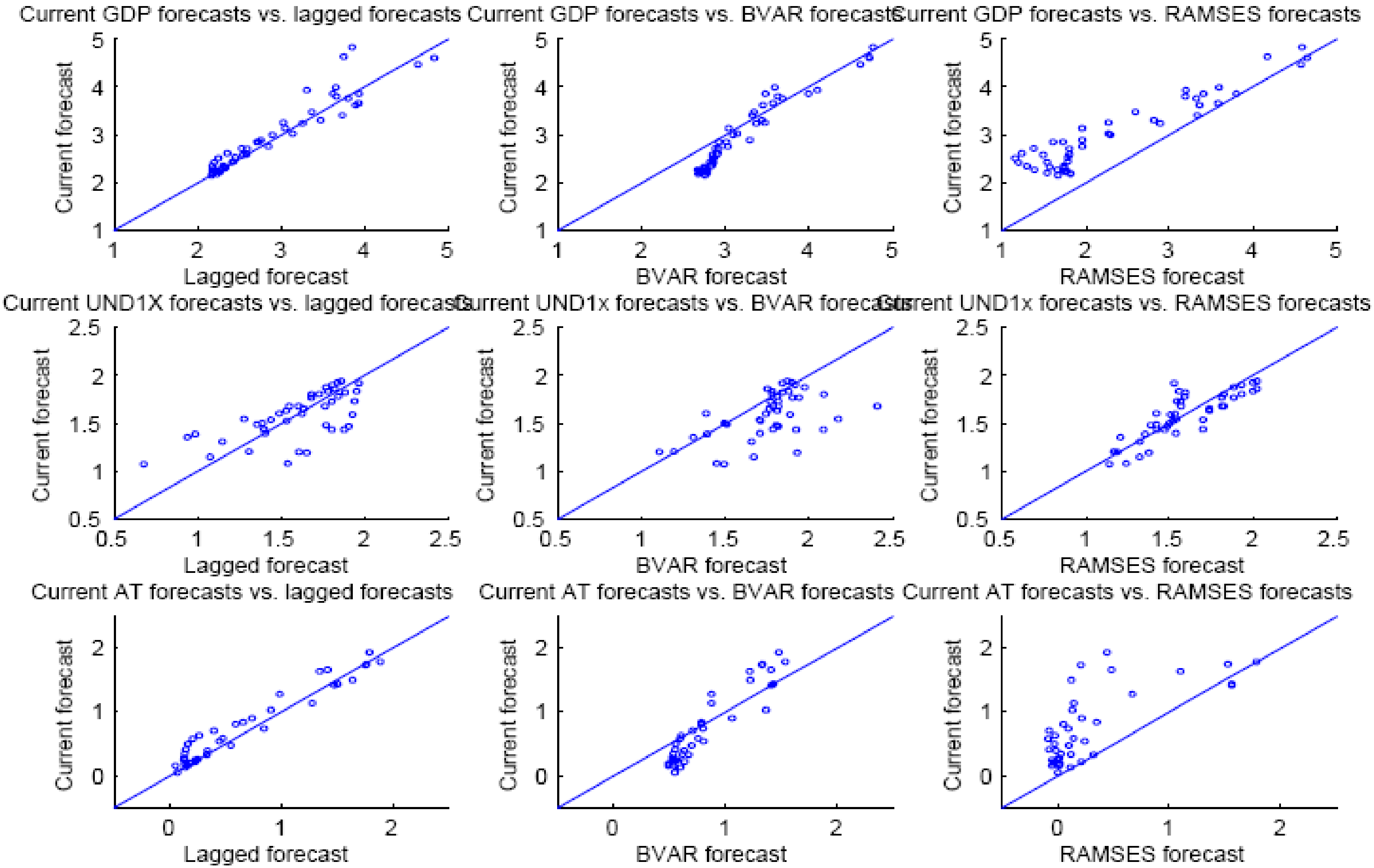
Ramses' Forecasting Impact II

- Can assess this by running the following regression:

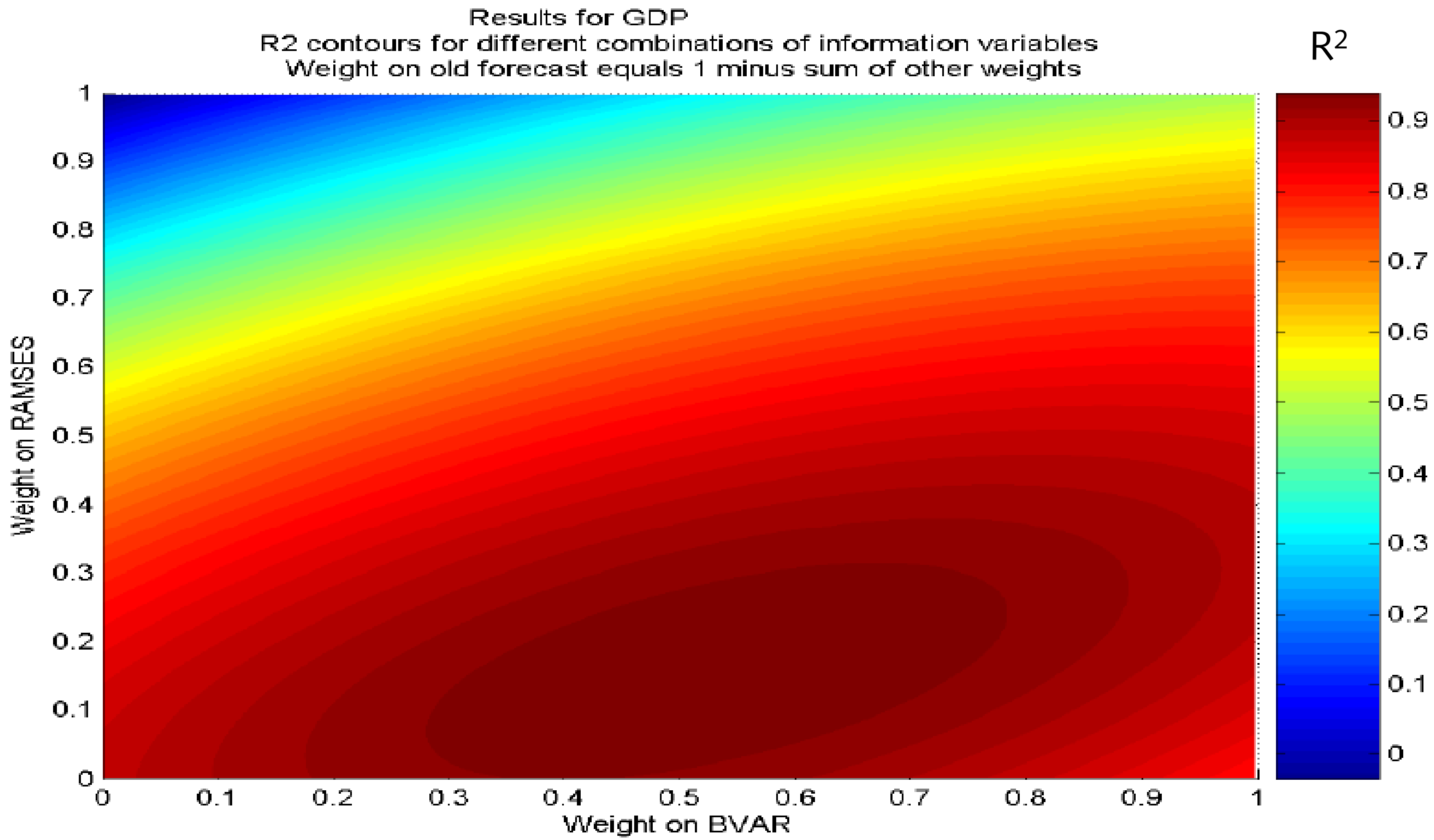
$$F_{t+h}^{New} = \omega_R F_{t+h}^{R} + \omega_B F_{t+h}^{B} + (1 - \omega_R - \omega_B) F_{t+h}^{old} + e_{t+h}$$

- In the equation above
  - ω_R is the weight on Ramses forecast h periods ahead
  - ω_B is the weight on BVAR forecast h periods ahead
  - $1 - \omega_R - \omega_B$ is the weight on the old forecast
  - e_t is a measure of judgement
- $1 - R^2$ is a measure of the degree of new judgements added to the forecast
- Plot R^2 contours for different variables and jointly using data for 6 forecast occasions 2005-
  - All horizons h are considered together

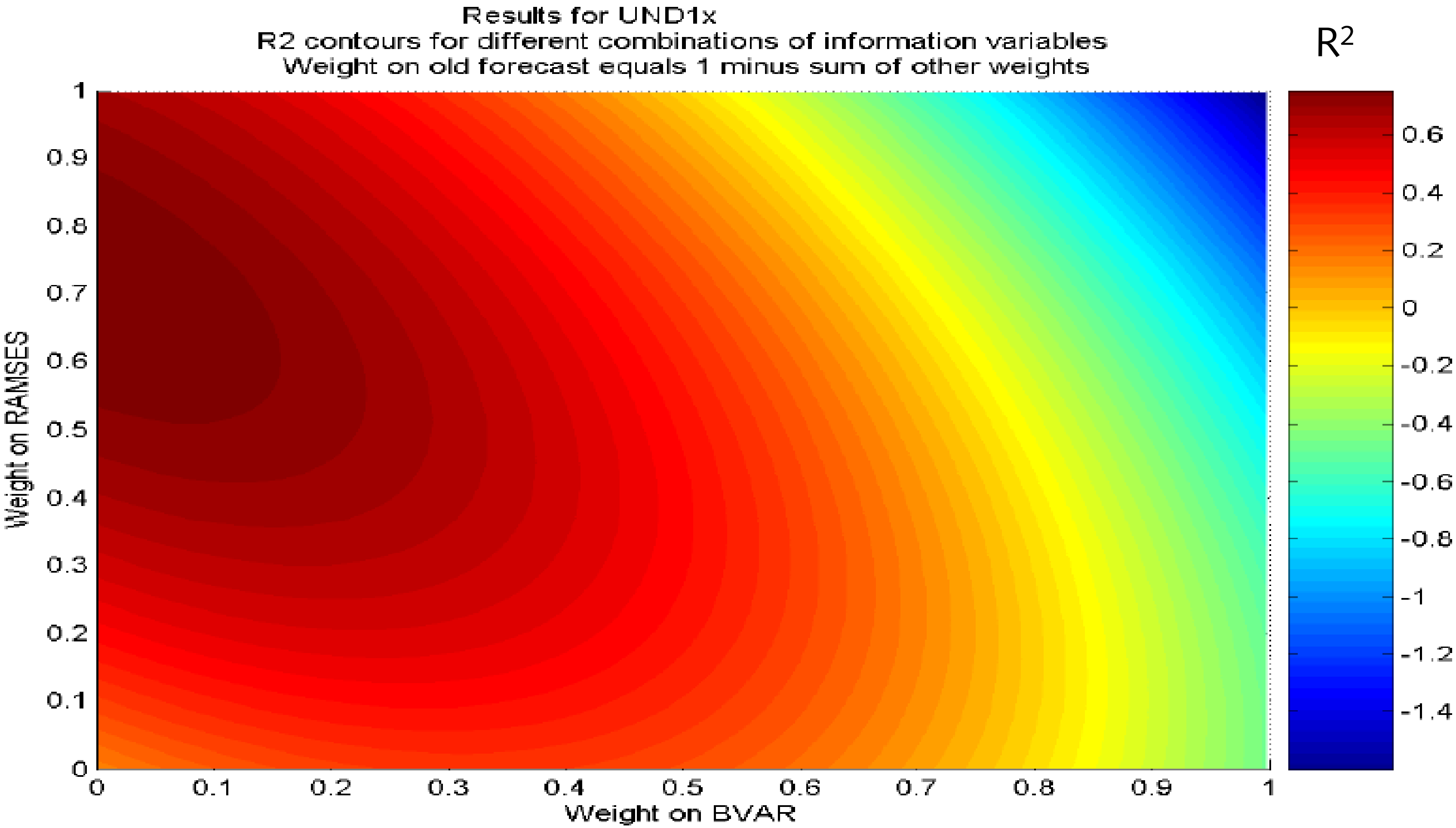
Ramses' Forecasting Impact III



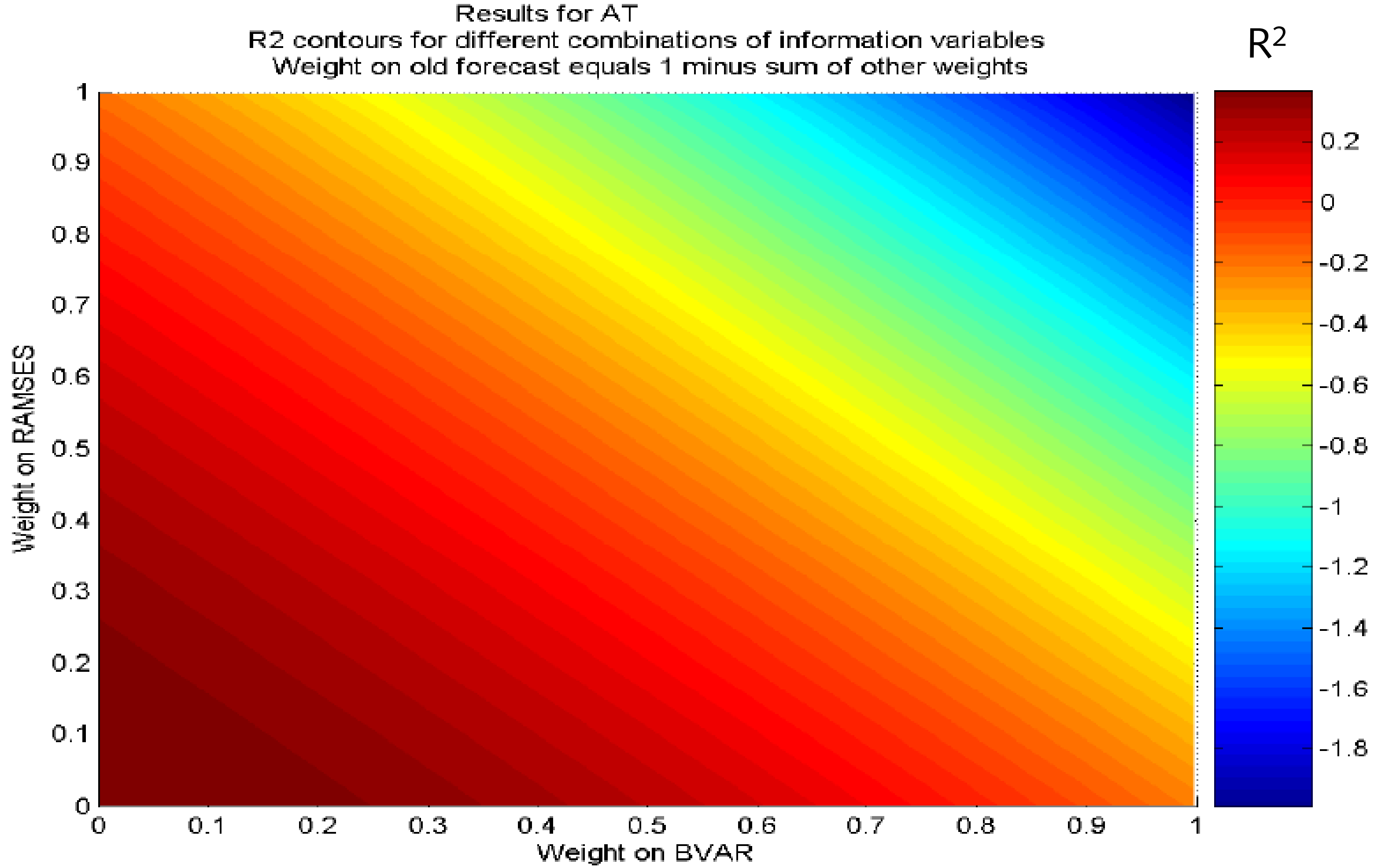
Ramses' Forecasting Impact IV: GDP



Ramses' Forecasting Impact V: Inflation



Ramses' Forecasting Impact VI: Worked Hours



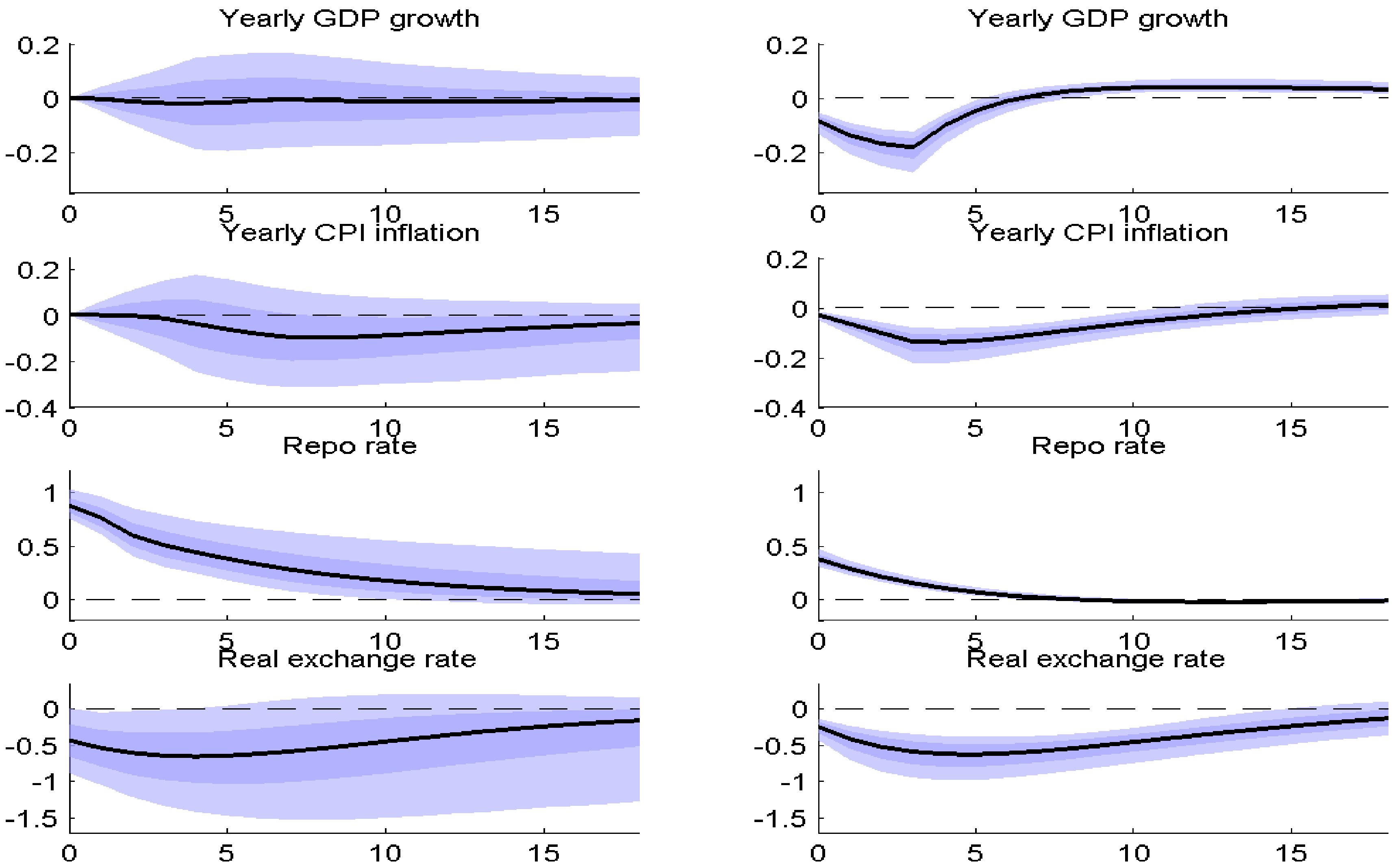
Policy Analysis with Ramses I

Effects of monetary policy I

- Impulse response functions in the DSGE and the BVAR (Minnesota prior, recursiveness assumption)
- BVAR with Minnesota prior not a very useful tool to get precise effects of policy shocks => use DSGE model when assessing the effects of alternative interest rate paths
  - Choice supported by DSGE-VAR analysis
  - DSGE-VAR an interesting alternative to Minnesota BVAR and DSGE in forecasting

Policy Analysis with Ramses I

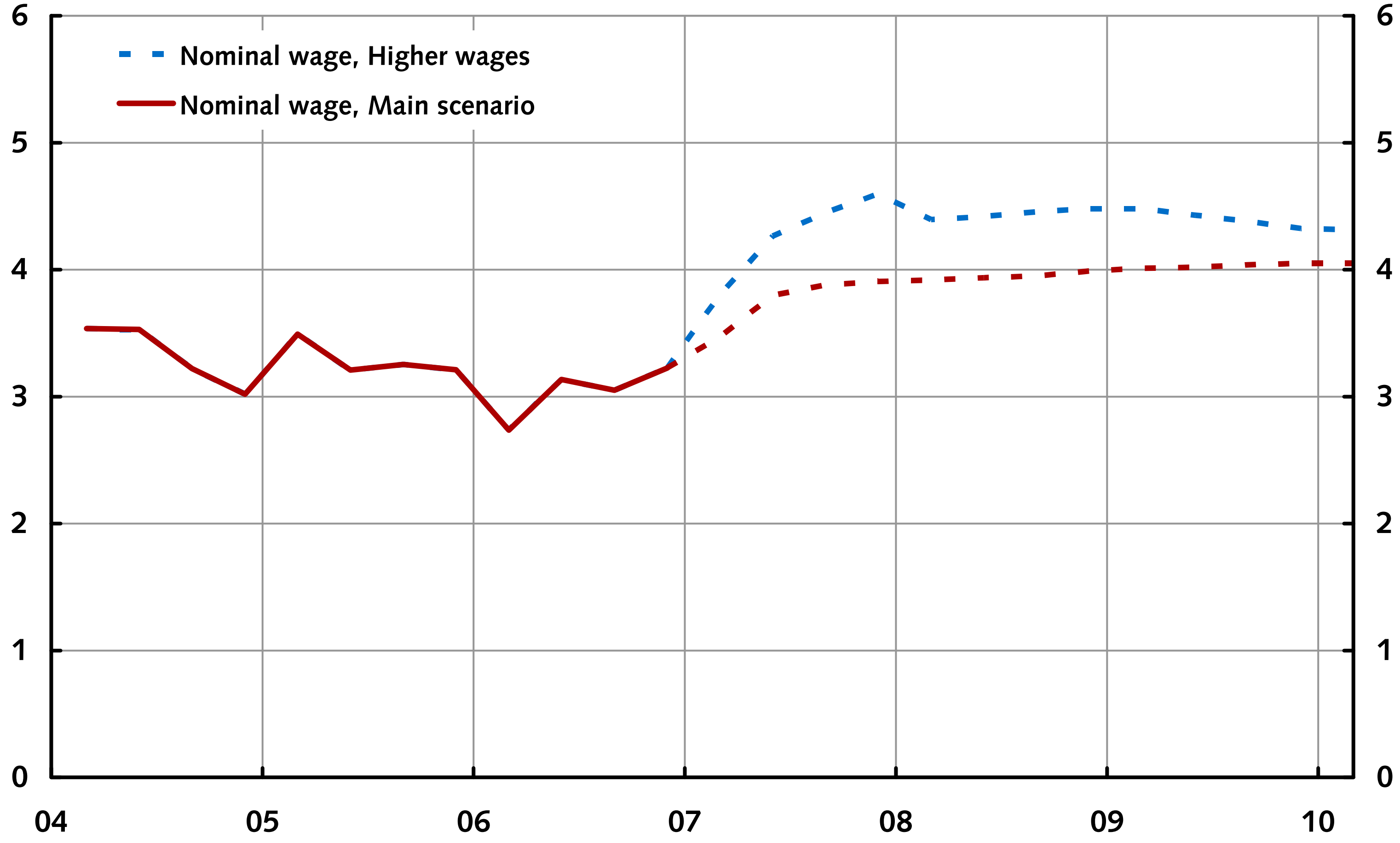
Effects of monetary policy II



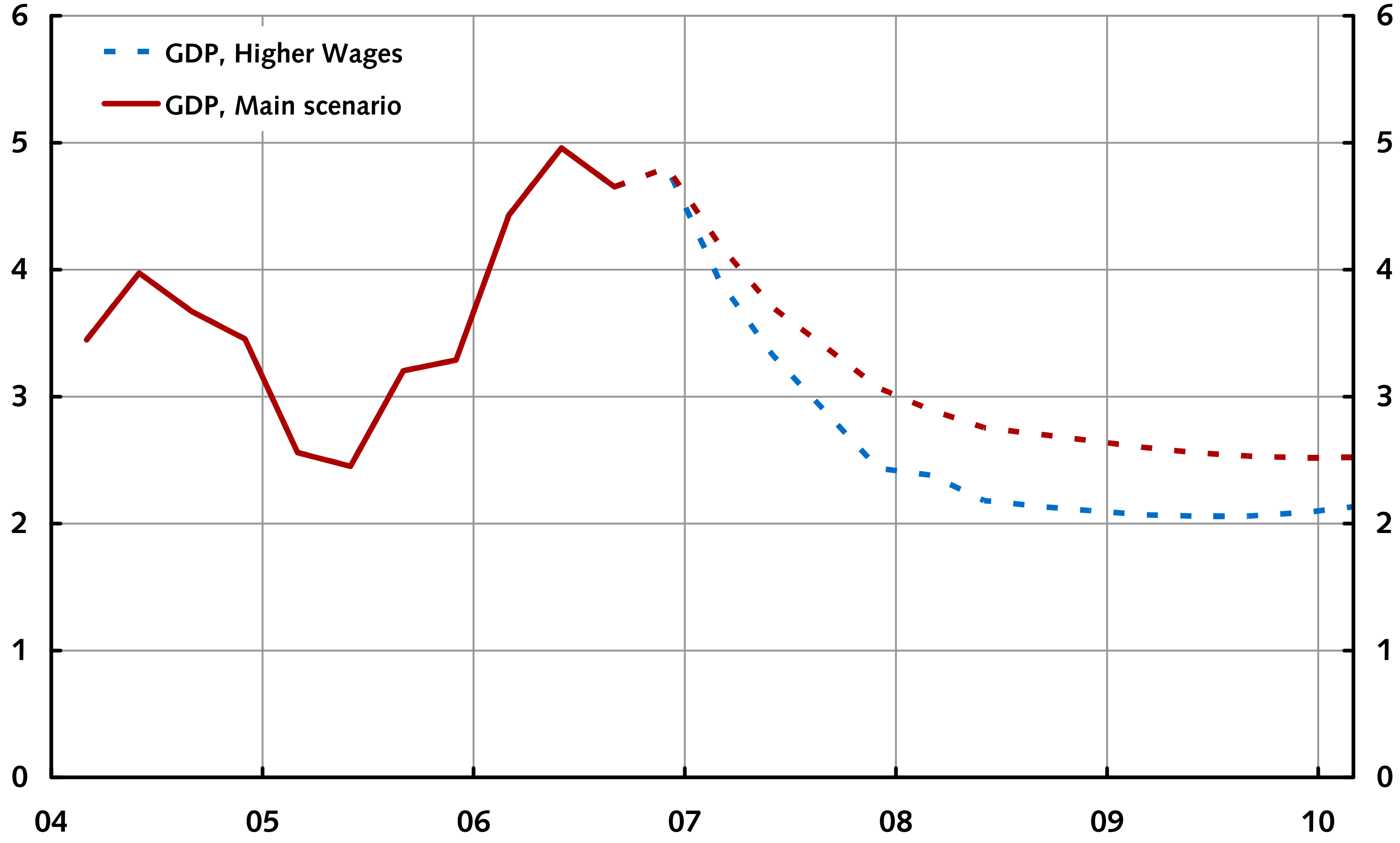
Policy Analysis with Ramses II

- Macro risks (Alternative macro scenarios meeting)
  - Alternative macro development (risks to world economy forecast, domestic risks – higher wages scenario, effects of labour market reforms, productivity)
- Example from *Monetary Policy Report 2007:1*: Higher nominal wage growth
  - Study effects on GDP, inflation, nominal interest rate

Policy Analysis with Ramses II
Scenario: Higher Wages y/y

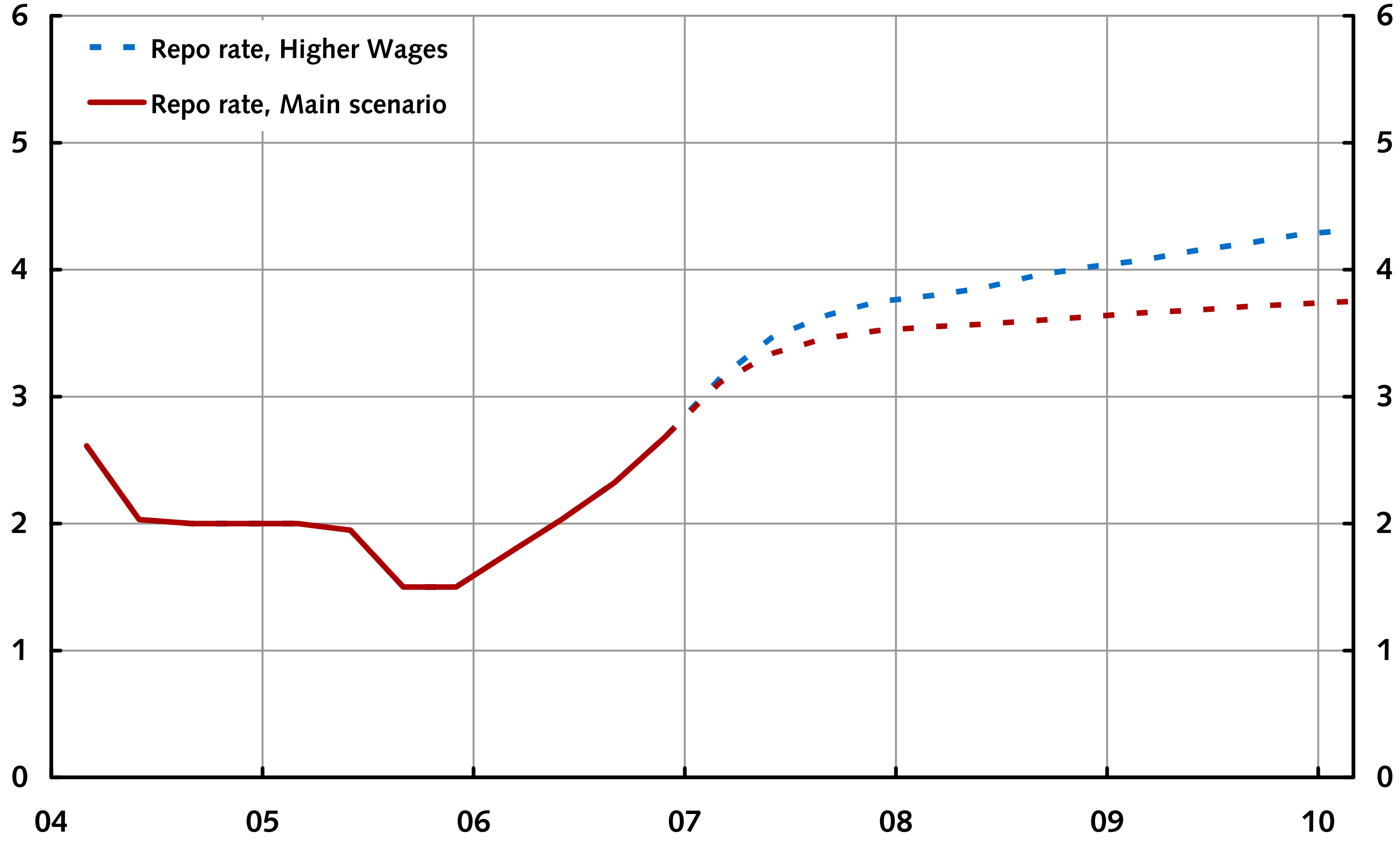


Policy Analysis with Ramses II
Scenario: Higher Wages -> GDP y/y



Policy Analysis with Ramses II
Scen.: Higher Wages -> Inflation y/y

Policy Analysis with Ramses II
Scen.: Higher Wages -> Interest Rate

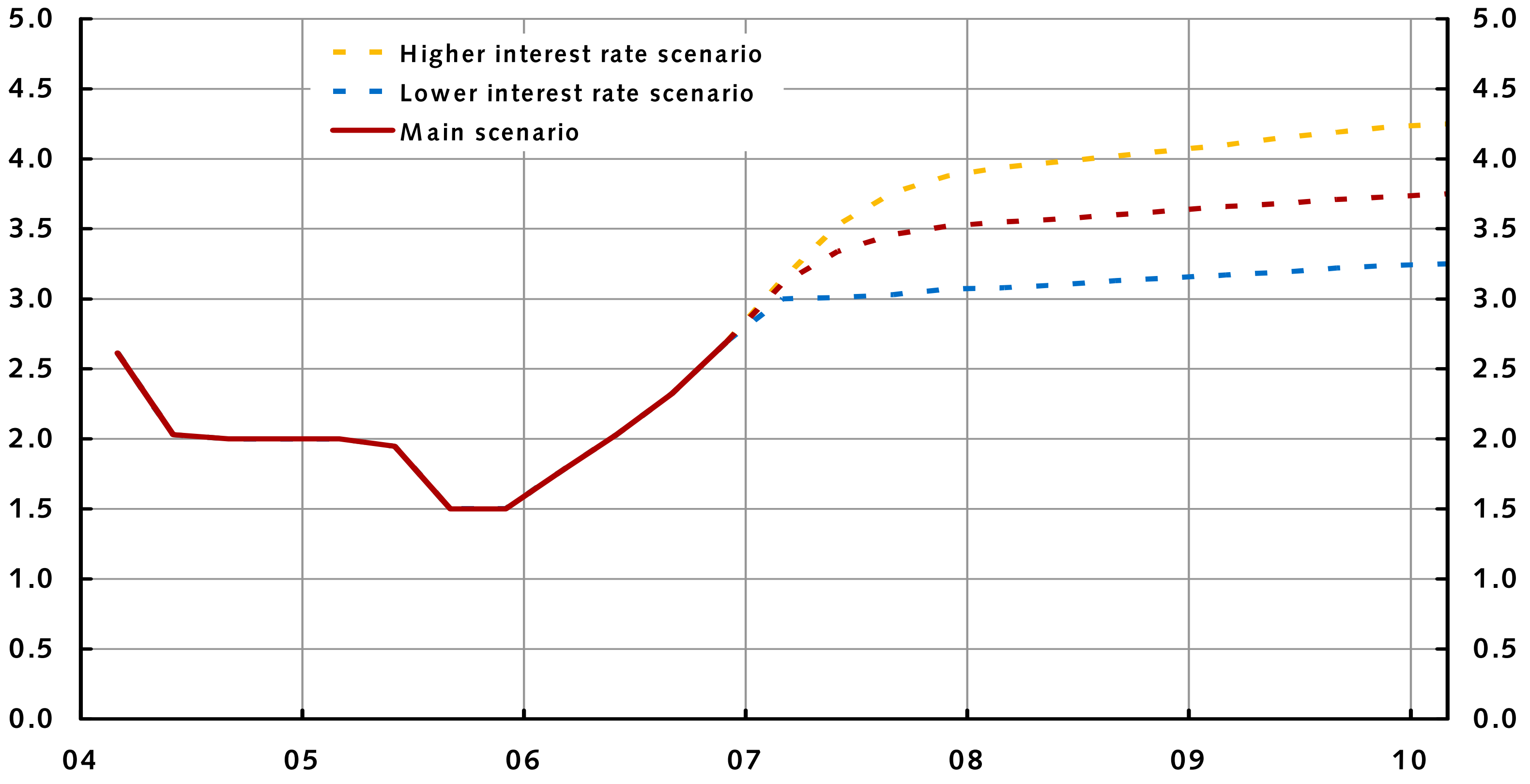


Policy Analysis with Ramses III

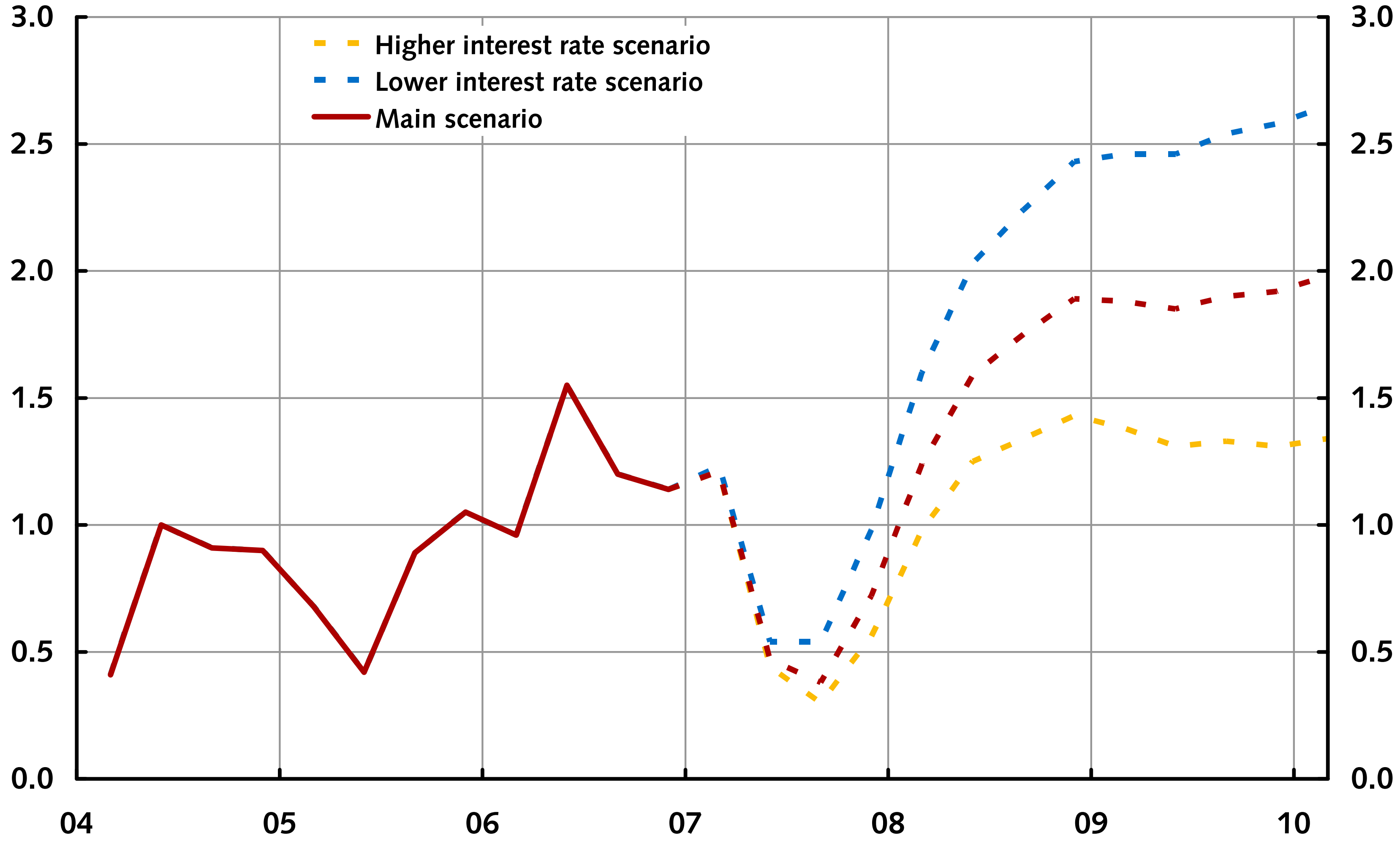
- **Monetary Policy Meeting**
  - How should the repo rate path change relative to initial assumption to achieve inflation projections in line with target while taking real considerations
  - Alternative repo rate projections generated with monetary policy shocks

Policy Analysis with Ramses IV Interest Rate Scenarios

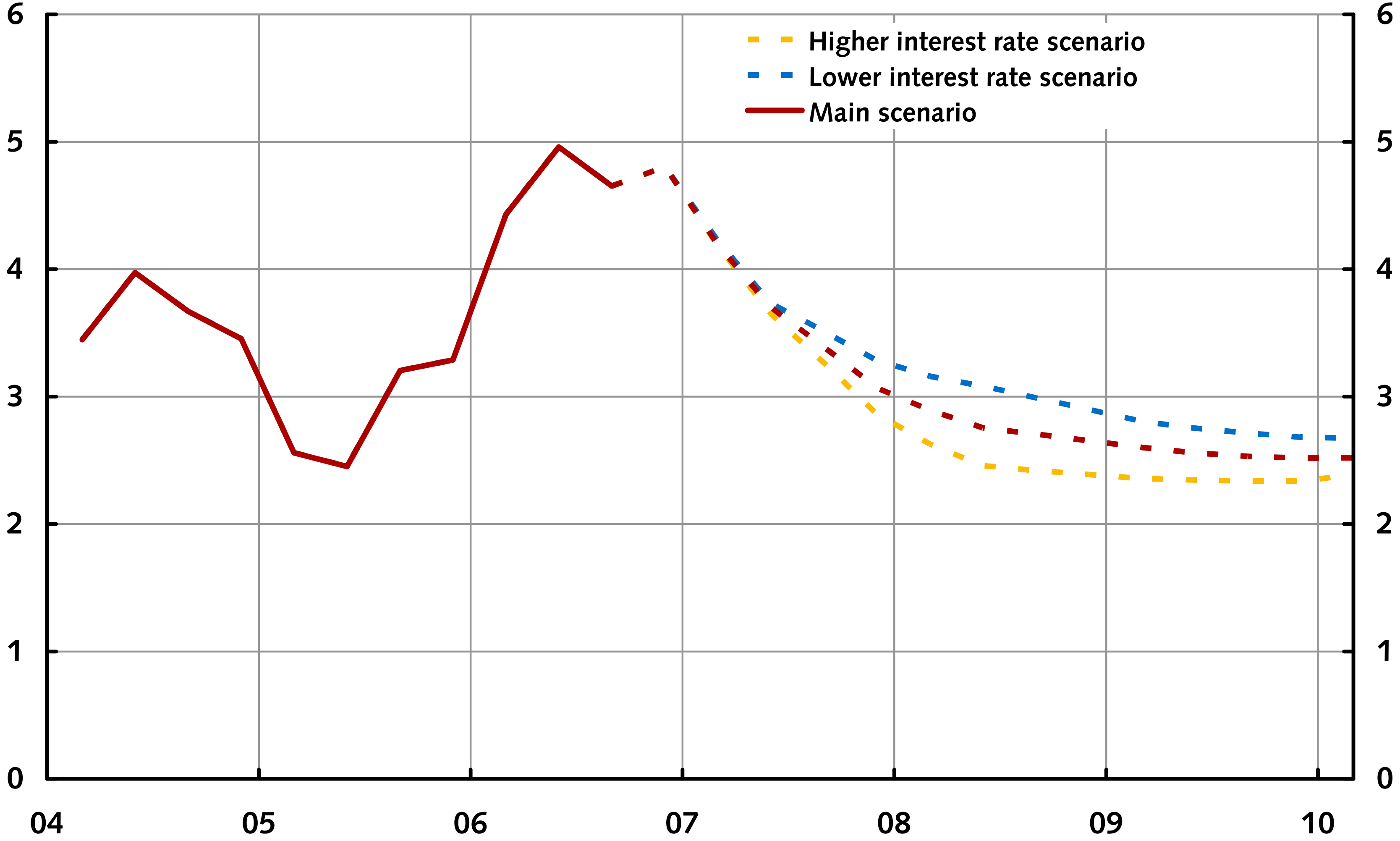
- Repo rate meeting – MPR 07:1



Policy Analysis with Ramses IV
Interest Rate Scenarios: Inflation y/y



Policy Analysis with Ramses IV
Interest Rate Scenarios: GDP y/y



Positive Vs. Normative aspects

- The analysis described above has stong positive flavor
  - Policy response to various shocks according to historical behavior (Instrument rule)
- Ongoing work: More normative analysis (ALLS)
  - Operational loss function: Stabilize yearly CPI inflation rate, some gap measure + policy interest rate
- This is a difficult issue:
  - Theory: Central bank "loss function" n.e. to household welfare, how handle model misspecification, RE-ass.
  - Practical: How agree on a gap variable (used in internal and external communication)
- Optimal Policy Projections at the Riksbank

1.Introduction

- Flexible inflation targeting: “Stabilize inflation around the inflation target, with some weight on stabilility of the real economy (output gap)”
- Construct optimal policy projections (OPPs) for Ramses, the Riksbank’s open-economy medium-sized DSGE model for forecasting and policy analysis
- The Riksbank Aggregate Model for Studies of the Economy of Sweden (Adolfson, Laséen, Lindé, and Villani) (ALLV)
- OPP: Find instrument-rate path that minimizes quadratic loss function under commitment in a timeless perspective: Alternative to historical empirical or ad hoc instrument rule (Taylor-type rule)

1.Introduction

- Flexible inflation targeting: “Stabilize inflation around the inflation target, with some weight on stabilility of the real economy (output gap)”
- Construct optimal policy projections (OPPs) for Ramses, the Riksbank’s open-economy medium-sized DSGE model for forecasting and policy analysis
- The Riksbank Aggregate Model for Studies of the Economy of Sweden (Adolfson, Laséen, Lindé, and Villani) (ALLV)
- OPP: Find instrument-rate path that minimizes quadratic loss function under commitment in a timeless perspective: Alternative to historical empirical or ad hoc instrument rule (Taylor-type rule)

1.Introduction

- Flexible inflation targeting: “Stabilize inflation around the inflation target, with some weight on stabilility of the real economy (output gap)”
- Construct optimal policy projections (OPPs) for Ramses, the Riksbank’s open-economy medium-sized DSGE model for forecasting and policy analysis
- The Riksbank Aggregate Model for Studies of the Economy of Sweden (Adolfson, Laséen, Lindé, and Villani) (ALLV)
- OPP: Find instrument-rate path that minimizes quadratic loss function under commitment in a timeless perspective: Alternative to historical empirical or ad hoc instrument rule (Taylor-type rule)

1.Introduction

- Flexible inflation targeting: "Stabilize inflation around the inflation target, with some weight on stabilility of the real economy (output gap)"
- Construct optimal policy projections (OPPs) for Ramses, the Riksbank's open-economy medium-sized DSGE model for forecasting and policy analysis
- The Riksbank Aggregate Model for Studies of the Economy of Sweden (Adolfson, Laséen, Lindé, and Villani) (ALLV)
- OPP: Find instrument-rate path that minimizes quadratic loss function under commitment in a timeless perspective: Alternative to historical empirical or ad hoc instrument rule (Taylor-type rule)

1. Introduction: New

- OPPs in DSGE model of this size
- Estimation requires combination of Klein and AIM algorithms for speed
- Test of whether past policy was optimal or not
- Alternative definitions of the output gap (potential output: trend output, conditional flexprice output, or unconditional flexprice output)
- Commitment in a timeless perspective: Alternative ways of computing initial Lagrange multipliers (past policy: optimal or just systematic)

1. Introduction: New

- OPPs in DSGE model of this size
- Estimation requires combination of Klein and AIM algorithms for speed
- Test of whether past policy was optimal or not
- Alternative definitions of the output gap (potential output: trend output, conditional flexprice output, or unconditional flexprice output)
- Commitment in a timeless perspective: Alternative ways of computing initial Lagrange multipliers (past policy: optimal or just systematic)

1. Introduction: New

- OPPs in DSGE model of this size
- Estimation requires combination of Klein and AIM algorithms for speed
- Test of whether past policy was optimal or not
- Alternative definitions of the output gap (potential output: trend output, conditional flexprice output, or unconditional flexprice output)
- Commitment in a timeless perspective: Alternative ways of computing initial Lagrange multipliers (past policy: optimal or just systematic)

1. Introduction: New

- OPPs in DSGE model of this size
- Estimation requires combination of Klein and AIM algorithms for speed
- Test of whether past policy was optimal or not
- Alternative definitions of the output gap (potential output: trend output, conditional flexprice output, or unconditional flexprice output)
- Commitment in a timeless perspective: Alternative ways of computing initial Lagrange multipliers (past policy: optimal or just systematic)

1. Introduction: New

- OPPs in DSGE model of this size
- Estimation requires combination of Klein and AIM algorithms for speed
- Test of whether past policy was optimal or not
- Alternative definitions of the output gap (potential output: trend output, conditional flexprice output, or unconditional flexprice output)
- Commitment in a timeless perspective: Alternative ways of computing initial Lagrange multipliers (past policy: optimal or just systematic)

1. Introduction: Conclusions

- OPPs feasible in Ramses
- Parameter estimates relatively stable
- Past policy not optimal
- Estimated loss-function paramaters: $\lambda_y = 1.1$, $\lambda_{\Delta i} = 0.39$
- Output-gap (potential-output) definition matters
- Initial Lagrange multipliers matter (somewhat)

1. Introduction: Conclusions

- OPPs feasible in Ramses
- Parameter estimates relatively stable
- Past policy not optimal
- Estimated loss-function paramaters: $\lambda_y = 1.1$, $\lambda_{\Delta i} = 0.39$
- Output-gap (potential-output) definition matters
- Initial Lagrange multipliers matter (somewhat)

1. Introduction: Conclusions

- OPPs feasible in Ramses
- Parameter estimates relatively stable
- Past policy not optimal
- Estimated loss-function paramaters: $\lambda_y = 1.1$, $\lambda_{\Delta i} = 0.39$
- Output-gap (potential-output) definition matters
- Initial Lagrange multipliers matter (somewhat)

1. Introduction: Conclusions

- OPPs feasible in Ramses
- Parameter estimates relatively stable
- Past policy not optimal
- Estimated loss-function paramaters: $\lambda_y = 1.1$, $\lambda_{\Delta i} = 0.39$
- Output-gap (potential-output) definition matters
- Initial Lagrange multipliers matter (somewhat)

1. Introduction: Conclusions

- OPPs feasible in Ramses
- Parameter estimates relatively stable
- Past policy not optimal
- Estimated loss-function paramaters: $\lambda_y = 1.1$, $\lambda_{\Delta i} = 0.39$
- Output-gap (potential-output) definition matters
- Initial Lagrange multipliers matter (somewhat)

1. Introduction: Conclusions

- OPPs feasible in Ramses
- Parameter estimates relatively stable
- Past policy not optimal
- Estimated loss-function paramaters: $\lambda_y = 1.1$, $\lambda_{\Delta i} = 0.39$
- Output-gap (potential-output) definition matters
- Initial Lagrange multipliers matter (somewhat)

2. The model

- State space form:

$$\begin{bmatrix} X_{t+1} \\ Hx_{t+1|t} \end{bmatrix} = A \begin{bmatrix} X_t \\ x_t \end{bmatrix} + Bi_t + \begin{bmatrix} C \\ 0 \end{bmatrix} \varepsilon_{t+1}$$

- X_t predetermined variables in quarter t ($n_X = 71$),
  x_t forward-looking variables ($n_x = 23$),
  i_t instrument rate, ε_{t+1} i.i.d. shock ($n_\varepsilon = 23$),
  $x_{t+1|t} \equiv \mathrm{E}_t x_{t+1}$
- A, B, C, H estimated with Bayesian methods, considered fixed and known for the optimal projections (certainty equivalence)

2. The model

- Target variables

$$Y_t = D \begin{bmatrix} X_t \\ x_t \\ i_t \end{bmatrix},$$

- Period loss function

$$L_t \equiv Y_t' W Y_t = (p_t^c - p_{t-4}^c - \pi^*)^2 + \lambda_y (y_t - \bar{y}_t)^2 + \lambda_{\Delta i}(i_t - i_{t-1})^2,$$

$$Y_t \equiv (p_t^c - p_{t-4}^c - \pi^*, y_t - \bar{y}_t, i_t - i_{t-1})'$$

Flexible inflation targeting: 4-qtr CPIX inflation, alternative definitions of potential output $\bar{y}_t$

- Intertemporal loss function ($0 < \delta < 1$)

$$\mathrm{E}_t \sum_{\tau=0}^{\infty} \delta^\tau L_{t+\tau}.$$

2. The model: Optimal policy

- Minimize intertemporaral loss function under commitment in a timeless perspective. Solution:

$$\begin{bmatrix} x_t \\ i_t \end{bmatrix} = \begin{bmatrix} F_x \\ F_i \end{bmatrix} \begin{bmatrix} X_t \\ \Xi_{t-1} \end{bmatrix},$$
$$\begin{bmatrix} X_{t+1} \\ \Xi_t \end{bmatrix} = M \begin{bmatrix} X_t \\ \Xi_{t-1} \end{bmatrix} + \begin{bmatrix} C \\ 0 \end{bmatrix} \varepsilon_{t+1}.$$

  F_i policy function: depends on A, B, C, H, D, W, δ, but not on $\Sigma_{\varepsilon\varepsilon}$ (certainty equivalence)
  Ξ_{t-1} Lagrange multipliers for equations for forward-looking variables in period $t-1$ ($n_\Xi \equiv n_x = 23$)
- Klein (2000) algorithm returns F_x, F_i, M

2. The model: Simple instrument rule

$$\begin{aligned} i_t &= \rho_R i_{t-1} + (1-\rho_R)\left[\widehat{\bar{\pi}}_t^c + r_\pi(\hat{\pi}_{t-1}^c - \widehat{\bar{\pi}}_t^c) + r_y \hat{y}_{t-1} + r_x \widehat{\tilde{x}}_{t-1}\right. \\ &\quad + r_{\Delta\pi}(\hat{\pi}_t^c - \hat{\pi}_{t-1}^c) + r_{\Delta y}(\hat{y}_t - \hat{y}_{t-1}) + \varepsilon_{Rt} \end{aligned}$$

- "Implicit" instrument rule

$$i_t = f_X X_t + f_x x_t$$

- Klein algorithm returns F_x, F_i, M

4. Optimal policy projections

- $y^t \equiv \{y_{t+\tau,t}\}_{\tau=0}^{\infty}$ projection in period t for any variable y_t: mean forecast conditional on information in period t
- Projection model for projections (X^t, x^t, i^t, Y^t) in quarter t is

$$\begin{bmatrix} X_{t+\tau+1,t} \\ Hx_{t+\tau+1,t} \end{bmatrix} = A \begin{bmatrix} X_{t+\tau,t} \\ x_{t+\tau,t} \end{bmatrix} + Bi_{t+\tau,t}, \quad Y_{t+\tau,t} = D \begin{bmatrix} X_{t+\tau,t} \\ x_{t+\tau,t} \\ i_{t+\tau,t} \end{bmatrix}$$

for $\tau \geq 0$.

4. Optimal policy projections

- Optimal projection $(\check{X}^t, \check{x}^t, \check{i}^t, \check{Y}^t)$, minimizes the intertemporal loss function under commitment in a timeless perspective

$$\sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau,t},$$

$$L_{t+\tau,t} = Y_{t+\tau,t}{}' W Y_{t+\tau,t}.$$

- $0 < \delta \leq 1$ OK

4. Optimal policy projections

- Solve with Klein or AIM (Anderson-Moore) algorithms: Solution

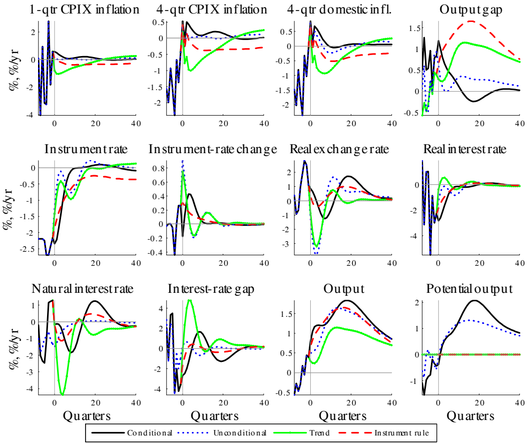
$$\begin{bmatrix} \check{x}_{t+\tau,t} \\ \check{i}_{t+\tau,t} \end{bmatrix} = F \begin{bmatrix} \check{X}_{t+\tau,t} \\ \Xi_{t+\tau-1,t} \end{bmatrix},$$

$$\begin{bmatrix} \check{X}_{t+\tau+1,t} \\ \Xi_{t+\tau,t} \end{bmatrix} = M \begin{bmatrix} \check{X}_{t+\tau,t} \\ \Xi_{t+\tau-1,t} \end{bmatrix},$$

  for $\tau \geq 0$, where $\check{X}_{t,t} = X_{t|t}$, $\Xi_{t-1,t}$ given
- Decision in quarter t
- Information in quarter t includes data up to $t-1$, $X_{t|t}$ estimated from $X_{t-1|t}$ under the assumption of simple instrument rule in quarter $t-1$

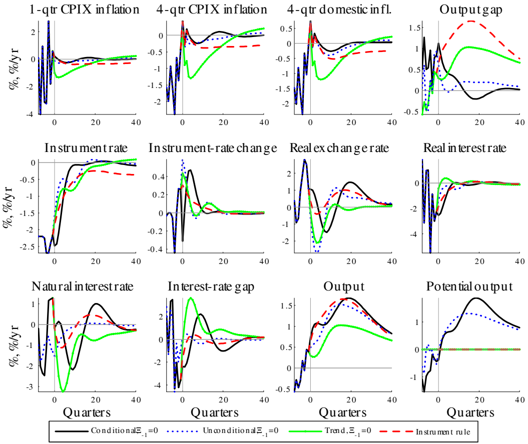
5. Results: Projections in 2006:3

Optimal policy for different output gaps, instrument rule



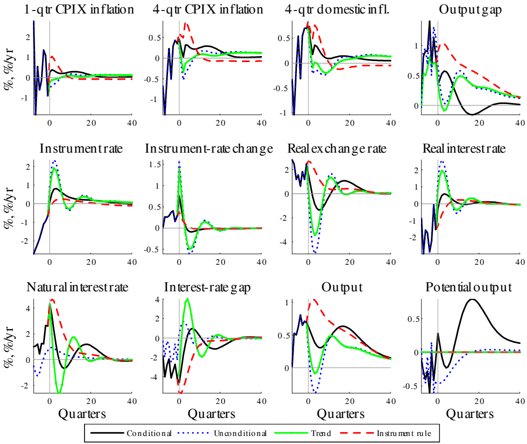
5. Results: Projections in 2006:3

Optimal policy for different output gaps, $\Xi_{t-1,t} = 0$



5. Results: Projections in 2007:4

Optimal policy for different output gaps, instrument rule



5. Results: Projections in 2006:3

Optimal policy, different loss functions (cond. output gap)