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

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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 = Riksbank Aggregate Macromodel for Studies of the Economy in Sweden
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
    \[ \Rightarrow \text{Incomplete exchange rate pass-through (sticky prices)} \]
- 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

[Graphs showing RMSE for various economic indicators such as Domestic inflation, Real wage, Consumption, Investment, Real exchange rate, Interest rate, Hours worked, Output, Export, Import, CPI inflation, Invest. defl. infl., with different models indicated by lines of different colors and styles.]
Forecasting and Communication

- 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
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:

\[ F_{t+h}^{\text{New}} = \omega_R F_{t+h}^R + \omega_B F_{t+h}^B + (1 - \omega_R - \omega_B) F_{t+h}^{\text{Old}} + e_{t+h} \]

- In the equation above
  - \( \omega_R \) is the weight on Ramses forecast \( h \) periods ahead
  - \( \omega_B \) 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

Current GDP forecasts vs. lagged forecasts
Current GDP forecasts vs. BVAR forecasts
Current GDP forecasts vs. RAMSES forecasts

Current UND1X forecasts vs. lagged forecasts
Current UND1x forecasts vs. BVAR forecasts
Current UND1x forecasts vs. RAMSES forecasts

Current AT forecasts vs. lagged forecasts
Current AT forecasts vs. BVAR forecasts
Current AT forecasts vs. RAMSES forecasts
Ramses’ Forecasting Impact IV: GDP

Results for GDP
R2 contours for different combinations of information variables
Weight on old forecast equals 1 minus sum of other weights
Ramses' Forecasting Impact V: Inflation

Results for UND1x
R2 contours for different combinations of information variables
Weight on old forecast equals 1 minus sum of other weights

Weight on RAMSES

Weight on BVAR

R^2
Ramses’ Forecasting Impact VI: Worked Hours

Results for AT
R2 contours for different combinations of information variables
Weight on old forecast equals 1 minus sum of other weights
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)
  - 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

Inflation, Higher Wages
Inflation, Main scenario
Policy Analysis with Ramses II
Scen.: Higher Wages -> Interest Rate

Repo rate, Higher Wages
Repo rate, Main scenario
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

Higher interest rate scenario
Lower interest rate scenario
Main scenario
Policy Analysis with Ramses IV
Interest Rate Scenarios: GDP y/y

- Higher interest rate scenario
- Lower interest rate scenario
- Main scenario
Positive Vs. Normative aspects

- The analysis described above has strong 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 stability 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)
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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)
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- OPPs feasible in Ramses
- Parameter estimates relatively stable
- Past policy not optimal
- Estimated loss-function parameters: $\lambda_y = 1.1, \lambda_{\Delta i} = 0.39$
- Output-gap (potential-output) definition matters
- Initial Lagrange multipliers matter (somewhat)
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2. The model

- State space form:

\[
\begin{bmatrix}
X_{t+1} \\
Hx_{t+1|t}
\end{bmatrix} = A \begin{bmatrix}
X_t \\
x_t
\end{bmatrix} + B_i + \begin{bmatrix}
C \\
0
\end{bmatrix} \varepsilon_{t+1}
\]

- \(X_t\) predetermined variables in quarter \(t\) \((n_X = 71)\),
- \(x_t\) forward-looking variables \((n_x = 23)\),
- \(i_t\) instrument rate, \(\varepsilon_{t+1}\) i.i.d. shock \((n_\varepsilon = 23)\),
- \(x_{t+1|t} \equiv E_t x_{t+1}\)

- \(A, B, C, H\) 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)

\[ E_t \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau}. \]
2. The model: Optimal policy

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

\[
\begin{bmatrix}
  x_t \\
  i_t \\
\end{bmatrix} = \begin{bmatrix}
  F_x \\
  F_i \\
\end{bmatrix} \begin{bmatrix}
  X_t \\
  \Xi_{t-1} \\
\end{bmatrix},
\]

\[
\begin{bmatrix}
  X_{t+1} \\
  \Xi_{t} \\
\end{bmatrix} = M \begin{bmatrix}
  X_t \\
  \Xi_{t-1} \\
\end{bmatrix} + \begin{bmatrix}
  C \\
  0 \\
\end{bmatrix} \epsilon_{t+1}.
\]

- $F_i$ policy function: depends on $A, B, C, H, D, W, \delta$, but not on $\Sigma_{\epsilon \epsilon}$ (certainty equivalence)
- $\Xi_{t-1}$ 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

\[ i_t = \rho_R i_{t-1} + (1 - \rho_R) \left[ \hat{\pi}_t^c + r_{\pi} (\hat{\pi}_{t-1}^c - \hat{\pi}_t^c) + r_y \hat{y}_{t-1} + r_x \hat{x}_{t-1} + r_{\Delta \pi} (\hat{\pi}_t^c - \hat{\pi}_{t-1}^c) + r_{\Delta y} (\hat{y}_t - \hat{y}_{t-1}) + \varepsilon_{Rt} \right] \]

- "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

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

for \( \tau \geq 0 \).
4. Optimal policy projections

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

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

\[
L_{t+\tau,t} = Y_{t+\tau,t}'WY_{t+\tau,t}.
\]

- \(0 < \delta \leq 1\) OK
4. Optimal policy projections

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

\[
\begin{bmatrix}
\ddot{x}_{t+\tau,t} \\
\ddot{i}_{t+\tau,t}
\end{bmatrix} = F
\begin{bmatrix}
\ddot{X}_{t+\tau,t} \\
\mathbb{E}_{t+\tau-1,t}
\end{bmatrix},
\]
\[
\begin{bmatrix}
\ddot{X}_{t+\tau+1,t} \\
\mathbb{E}_{t+\tau,t}
\end{bmatrix} = M
\begin{bmatrix}
\ddot{X}_{t+\tau,t} \\
\mathbb{E}_{t+\tau-1,t}
\end{bmatrix},
\]

for \( \tau \geq 0 \), where \( \ddot{X}_{t,t} = X_{t|t}, \mathbb{E}_{t-1,t} \) 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

Adolfson, Laséen, Lindé, and Svensson

Optimal Monetary Policy
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)

(\(\lambda_y = 1.1, \lambda_{\Delta_i} = 0.37\))  
(\(\lambda_y = 0, \lambda_{\Delta_i} = 0.01\))  
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