# Building and Employing a SOE Model

## using IRIS-Toolbox for Matlab

Michal Andrle

IMF/RES Economic Modeling Unit

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# Outline

The goal of the talk/course is to provide a 'hands on' experience of building a small open economy model.

1. Building a SOE model
   - infrastructure & software – quick review
   - reviewing stylised facts
   - motivating the model structure
2. The Model – parameterization & properties
   - parametrization, **evaluating IRFs**
   - pseudo-real time forecasting properties, model's moments
3. Creating scenarios & baseline forecast
   - **topical scenarios exercises**
   - determining initial conditions, **output-gap estimation**, interpreting history
   - conditioning on exogenous assumptions
   - imposing expert judgement
   - detailed analytics of the forecast dynamics (decomposition)

Focus on both economics & technique/infrastructure development. We'll work with the model code and run scenarios...

# Technical Infrastructure & Software

The project is based on the following components:

1. MATLAB
   - linear algebra numerical software, OOP support, weakly-typed, interpreted language and computing system (based on Fortran, C++ & Java)
   - understanding 'object-oriented approach' – exercises, getting the intuition
2. IRIS-Toolbox
   - Matlab-based Object-Oriented toolbox for DSGE modelling and time series
   - enriches Matlab with new types/objects (time series, model, database,. . . )
3. LaTeX, GIT
   - LaTeX used as a back-end for generating PDF reports
   - GIT distributed version control system keeps track of our project, changes and branches

# Stylised Facts (Indonesia)

...TBA

# Model

The model is a *reduced-form* DNK model in line with GPM-philosophy

- Theoretical motivation with New Keynesian monetary economics
- Flexible & pragmatic approach for forecasting and policy analysis
- Focus on business cycle frequencies

Deviations from a canonical IMF's GPM-SOE

- Accounting for a trend in real exchange rate
- Explicit treatment of administrated/regulated prices
- Rest-of-the-World (RoW) block treated as closed economy GPM
- Minor variations in dynamic specification

# The Model – A Bird's Eye View

Simplified version of core behavioral relationships:

$$
\begin{aligned}
y_t &= \beta_1 y_{t+1} + \beta_2 y_{t-1} - \beta_3(\hat{i}_t - \pi_{t+1}) + \beta_4 y_t^* + \beta_5 z_t + \varepsilon_t^y && (1)\\
\pi_t &= \lambda_1 \pi_{t+1} + (1-\lambda_1)\pi_{t-1} + \lambda_3 y_t + \lambda_4 z_t + \varepsilon_t^\pi && (2)\\
i_t &= \gamma_1 i_{t-1} + (1-\gamma_1)\left[\bar{i}_t + \gamma_2(\pi 4_{t+3} - \bar{\pi 4}_{t+3}) + \gamma_3 y_t\right] + \varepsilon_t^i && (3)\\
i_t &= i_t^* + s_{t+1}^e - s_t + prem_t && (4)
\end{aligned}
$$

Trend-cyclical structure: $X_t = \bar{X}_t + x_t$

- the model does not feature complete trend-cycle dichotomy
- flexible trend specification; either AR(1) or version of LLT model

$$
\begin{aligned}
X_t &= X_{t-1} + G_t + \varepsilon_t^X \qquad \varepsilon_t^X \sim N(0, \sigma_X^2) && (5)\\
G_t &= \rho G_{t-1} + (1-\rho) G_{ss} + \varepsilon_t^G \qquad \varepsilon_t^G \sim N(0, \sigma_G^2) && (6)
\end{aligned}
$$

# The Model – A Bird's Eye View (ii)

## Trend Real-Exchange Rate Appreciation

- Trend real exchange rate appreciation featured in many transition economies (productivity gains in non-traded goods, HBS effect)
- Hybrid-Uncovered Interest Parity (UIP) needs to be modified

$$i_t = i_t^{\star} + s_{t+1}^e - s_t + prem_t \tag{7}$$

$$s_{t+1}^e = \sigma s_{t+1} + (1-\sigma)\left\{s_{t-1} + (\bar{dz}_t - \bar{\pi}_t^* + \bar{\pi}_t)\right\} \tag{8}$$

Steady-state key arbitrage relationship:

$$r = r^* + dz + prem \quad \Longleftrightarrow \quad i - i^* = prem + ds + \pi^* - \pi \tag{9}$$

# The Model – A Bird's Eye View (iii)

## Administrative prices

- Exogenous process for contribution of administrated prices to headline CPI
- Weight of admin. prices in headline  18%
- In practise, not 'truly' exogenous – hydrocarbons and energy prices,. . .
- Parameter "$\rho$" co-determines 'expectations-spillovers' and the transmission mechanism

$$\pi_t = \alpha\pi_t^{net} + (1-\alpha)\pi_t^{adm} + \varepsilon_t^{w} \quad (10)$$

$$\pi_t^{adm} = \rho\pi_{t-1}^{adm} + (1-\rho)\pi^{ss} + \varepsilon_t^{adm} \quad (11)$$

## Commodity prices

TBA

# The Model – Parametrization (i)

**There are three groups of parameters**

- Steady-state parameters & 'equilibriums'
  – inflation targets, equilibrium real interest rate, potential output growth,...
- Dynamic parameters
  – persistence, output gap & exchange rate loadings,...
- Stochastic parameters
  – std. errors of shocks and measurement errors

Calibration vs. Estimation

- Short, noisy and unreliable data
- The economy evolves very quickly, the model is built for recent and future economic development
- Identification problems, which Bayesian methods do not solve

# The Model – Parametrization (ii)

Parameterization is tested by reviewing many model properties:

(i) *Economics* of Impulse Response Function (IRF)

(ii) Transfer function properties in time and frequency domain

(iii) Quasi real-time historical forecasting performance

(iv) Interpretation of historical shock decomposition

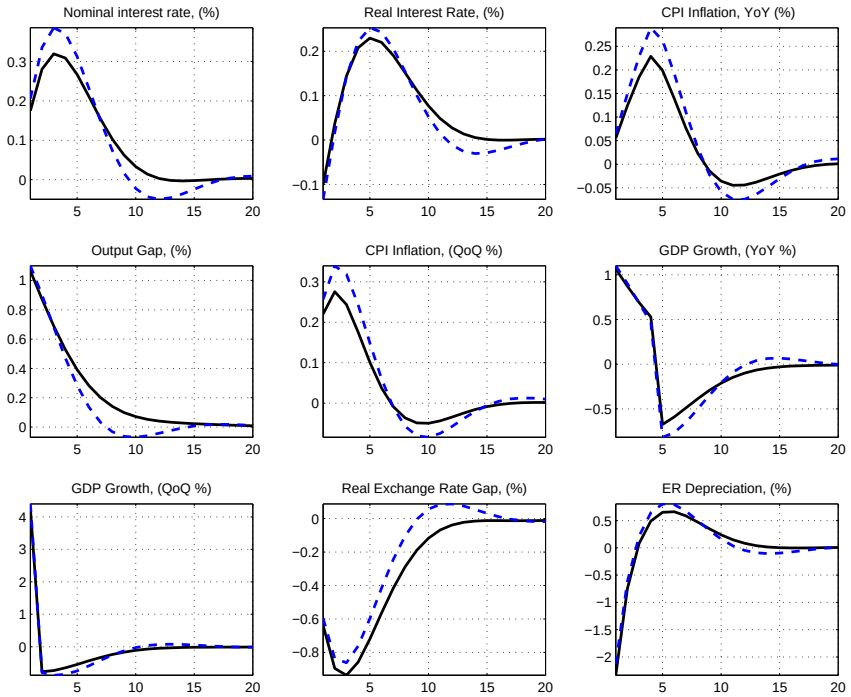
(v) . . .

Best is the enemy of the 'good'. . .

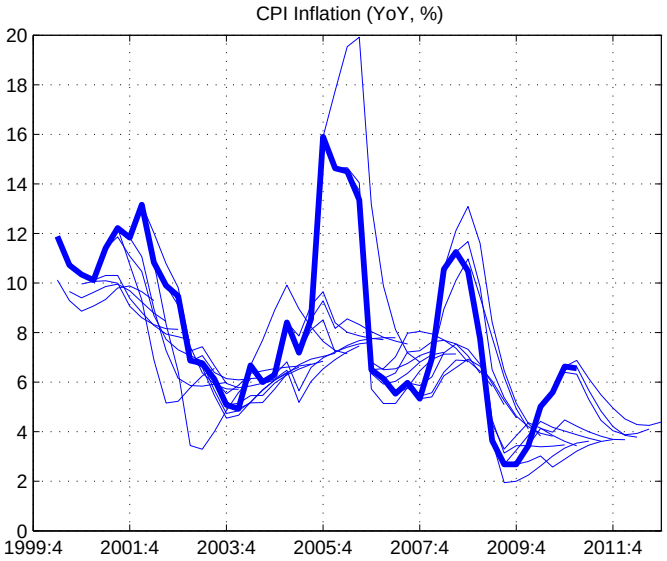
# The Model – Impulse Response Function (iii)

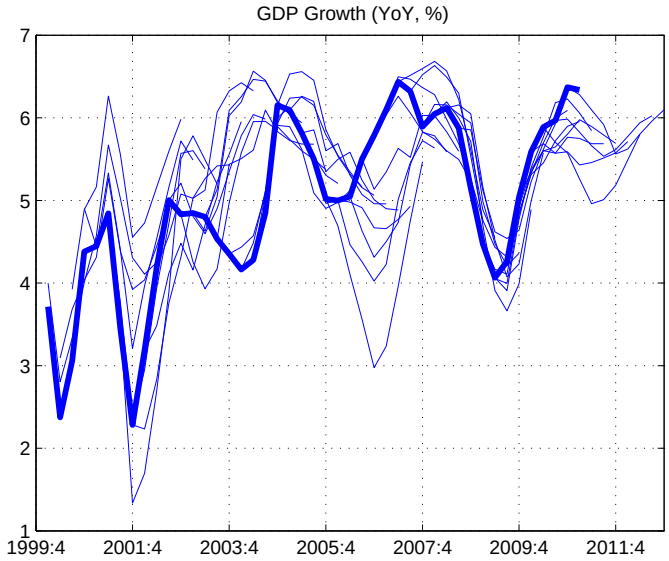
Impulse Response Functions (IRF) – 'hands on exercises'

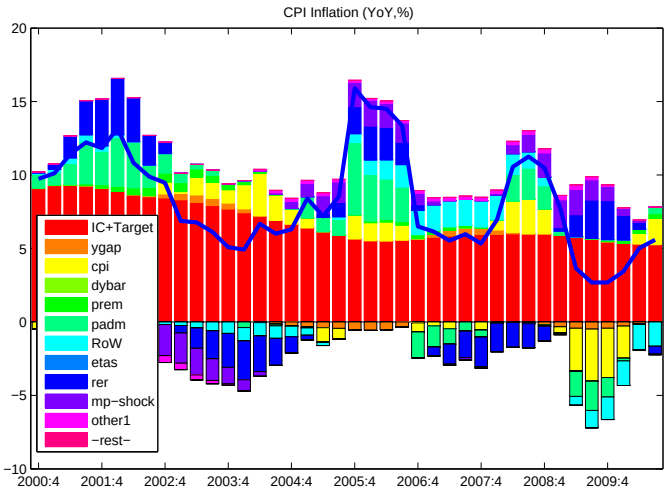
- Demand & Supply/Cost-push Shocks
- Exchange rate, monetary policy, administrated prices
- Understanding disinflation in the model, ...

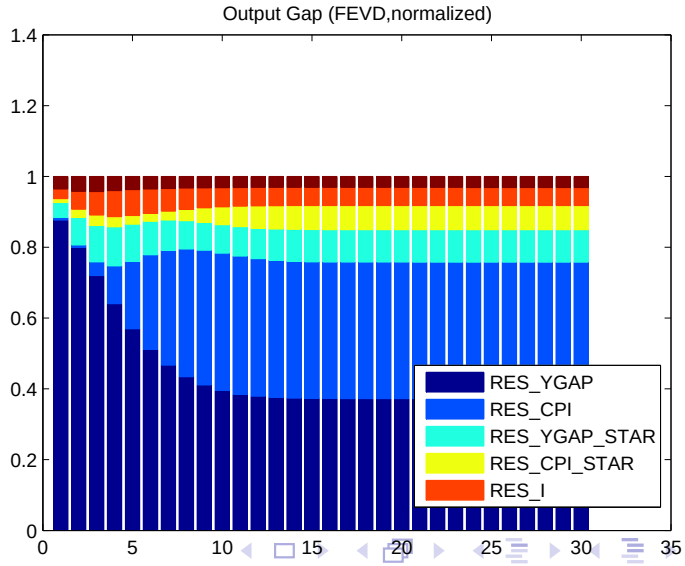


# The Model — Properties evaluation. . . (iv)



# Building Scenarios – Exercises & Analysis

- Falling behind the curve – delayed monetary policy
  - monetary accommodation dynamics implications
  - the role of anticipations and credibility
  - understanding economics and mathematics of reactions to anticipated events
- Administrative prices – expectations spillovers
  - expectation spillovers – the persistence of beliefs
  - the role of forcing terms in conditioning on exogenous variables
- Reserve requirements & risk-premiums
  - simulating ‘reserve-requirements’ changes in reduced form DNK model (?)

# Baseline Forecast

- **Analyzing the initial state of the economy**
  - output-gap and potential output growth
  - real exchange rate trend, risk premiums
  - interpreting the history using the model,. . .
- **Conditioning information**
  - foreign economy development, inflation target, regulated prices
  - implementing ‘now-casts’ and near-term forecasts
  - imposing expert-judgement
- **Forecast dynamics decomposition and analysis**
  - factors behind the forecast, delta-accounting w.r.t previous forecast
  - sensitivity analysis & scenarios

# Baseline Forecast – Initial State

Three basic approaches

- **Univariate**
  - ad-hoc detrending methods, pros & cons
  - HP/Leser filter, imposing prior restrictions
- **Multivariate UC models with ad-hoc detrending**
  - pros & cons
  - IMF's 'ModYUC' model, structure and properties
- **Model consistent filter & 'structural' shocks identification**
  - most challenging, consistent and insightful variant
  - running counter-factual simulations

# Baseline Forecast – Initial State (ii)

## Univariate detrending

- Stochastic trends extracted by band-pass or high pass Filtering (e.g. HP filter)
- Not much economics, business cycle identified with frequency-domain arguments (e.g. 6-32 quarters cycles)
- Plain/naive HP filter features very unpleasant 'end-point properties' and is ill-suited for real-time analysis
- Contrary to common belief, the HP/band-pass filter does not induce spurious cycles. HP is not very 'sharp' filter, its gain is quite smooth

## Prior-Consistent (LRX) filter with prior restrictions (exercise)

- User can impose the trend growth rate or the size of the gap with arbitrary precision
- Re-formulate the LLT problem with additional constraints, see e.g. Berg et al. (2006b)

$$\begin{aligned} \min_{\{T_t\}_1^{\mathbb{T}}} \quad &= \quad \sum_{t=1}^{\mathbb{T}} \left[ (Y_t - T_t)^2 + \lambda (\Delta^2 T_t)^2 \right] + \\ &+ \quad \sum_{i \in \mathbb{P}^{\mathbb{Y}}} \lambda_i^Y \{ (Y_i - T_i) - \tilde{Y}_i^{fix} \}^2 + \sum_{j \in \mathbb{P}^{\mathbb{T}}} \lambda_j^T \{ (T_j - T_{j-1}) - \tilde{G}_j^{fix} \}^2 \end{aligned} \tag{12}$$

# Baseline Forecast – Initial State (ii)

## Multivariate methods of trend-cyclical decomposition

- Combination of stochastic-trends with restrictions based on economic theory, most often a **Phillips Curve** and 'Okun's Law'
- Can employ multiple indicators of 'output gap' – capacity utilisation, unemployment,. . . to search for co-cycles and phase-shifts
- Most convenient to cast into state-space form, particularly due to very easy handling of missing observations

## Model-Consistent Estimation of Initial Conditions

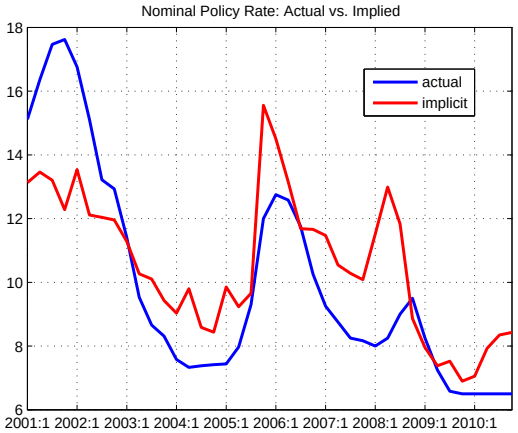
- Identification of unobserved variables using the complete REE model
- The State-Space form of the ARIMBI model analyzed using the insights from Kalman & WK filtering
- Allows to interpret the past development of the economy using the model optics and carry out counterfactual scenarios
- Output-gap estimates are consistent with the model and may/should differ from naive ad-hoc approaches

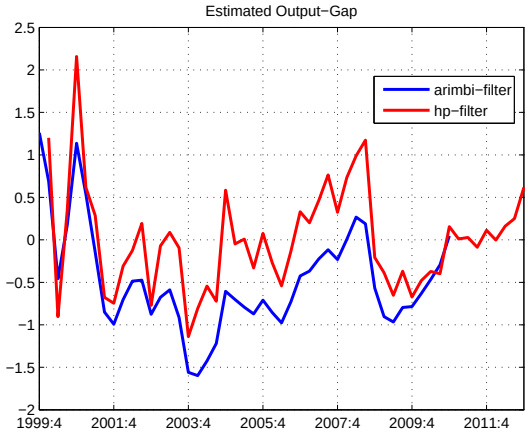
For theory of Kalman and WK filters, see Anderson and Moore (1979) and Wiener (1949)

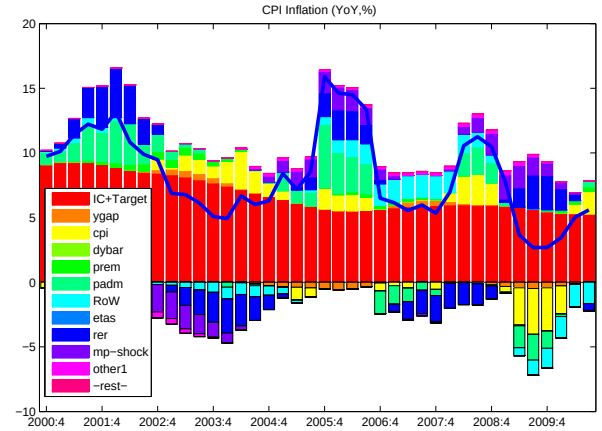
# Baseline Forecast – Initial State (iii)

## Initial Conditions (exercises & discussion)

- Counterfactuals – acatual vs. model-based estimates of policy rates
- 'Full-filter' estimate vs. HP estimates of output-gap
- Historical shock decompositions – taking the challenge



# Baseline Forecast – Conditioning Information

## Conditioning information

- The forecast features *endogenous interest rate response*
- Conditioning on selected variables and pieces of information
  - RoW: foreign interest rate, inflation and prices
  - Inflation target evolution
  - Evolution of exogenous trends & equilibrium values (potential output, etc.)

## Imposing expert judgment

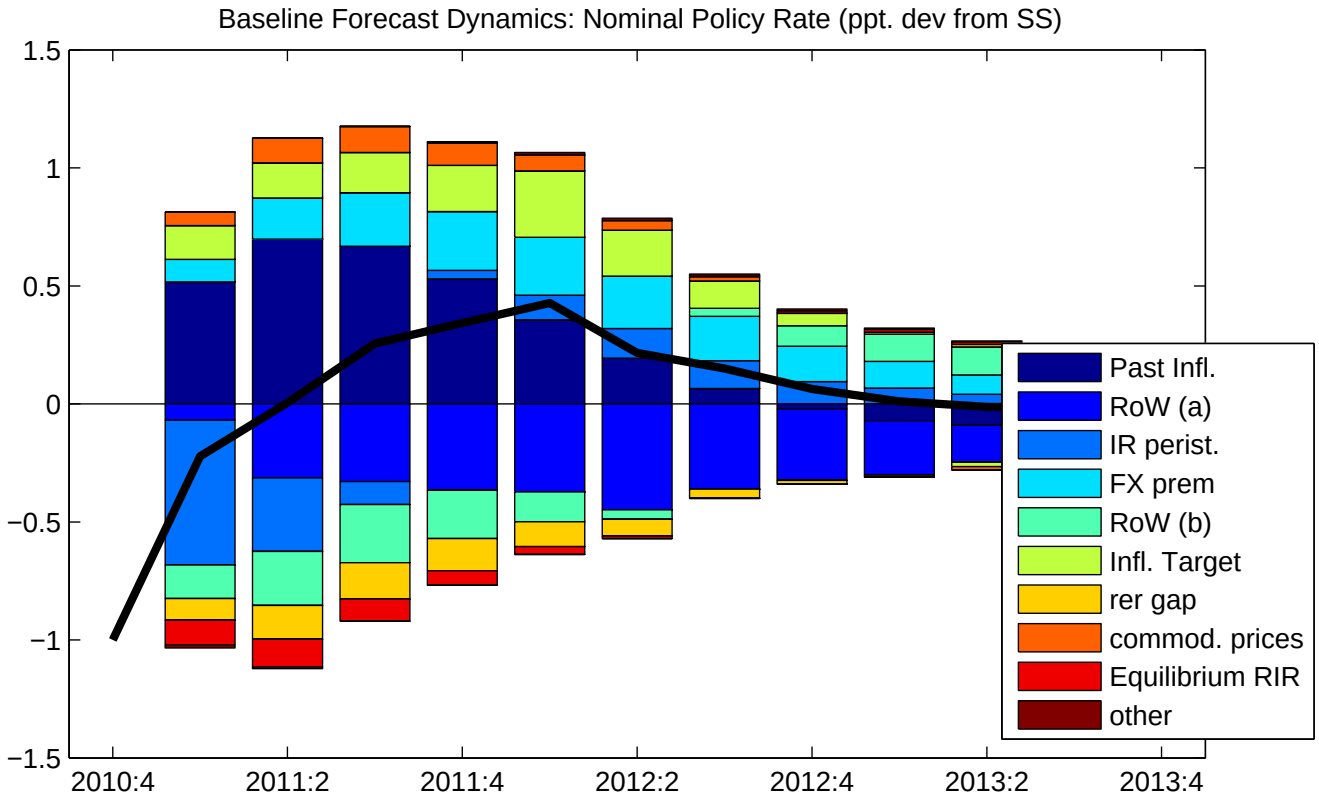
- Imposing values of selected macro-variables by a specified path of structural shocks
  - key question is selecting a particular shock to create a 'story' (e.g. demand or supply higher inflation pressures?)
- Hard-tunes vs. 'Soft-tunes/WZ'
  - Hard-tunes – point fix of a variable by a point shock impulse
  - Soft-tunes/Waggoner-Zha – select 'most likely' set of shocks

Algorithm used is a generalization of Waggoner and Zha (1999) allowing for anticipated shocks, described in Andrle (2007)

# Baseline Forecast – Dynamics & Analysis

Apart from economic reasoning, formal methods help to

- Understand and communicate the dynamics behind the baseline
- Explain deviations from the previous forecast and thus
- Provide clear picture why new interest rate path is projected



# Thank you for your attention.

Michal Andrle (IMF/RES Modeling Unit)

# Hands-On Exercises in Matlab

List of core exercises:

(i) Object-oriented programming – a primer (talking cats & dogs. . . ?)

(ii) Inspecting the model object & databases

(iii) Importance of version control for the project, examples (GIT, SVN, etc.)

(iv) Writing (understanding and modifying) a flexible IRFs simulator & reporting

(v) Running IRFs with multiple parameterizations, sensitivity analysis

(vi) Building scenarios
– falling behind the curve, administrated prices, RoW, . . .

(vii) Initial conditions identification
– HP/Leser filter with priors, Kalman filter basics, shock-decompositions
– running historical counter-factual, missing observations

(viii) Simulation dynamics decompositions
– baseline forecast delta-accounting, new vs. old forecast, scenario comparison

# References


1. Anderson, B.D.O. and J.B. Moore: *Optimal Filtering*, Prentice-Hall, N.J., 1979
2. Andrle, M., T. Hledik, O. Kamenik and J. Vlcek: *Implementing the New Structural Model of the Czech National Bank*, CNB WP No. 2, 2009a
3. Andrle, M., Ch. Freedman, R. Garcia-Saltos, D. Hermawan, D. Laxton and H. Munandar: *Adding Indonesia to the Global Projection Model*, IMF WP/09/253, 2009b
4. Andrle, M.: *Simulating linear state-space models*, Czech National Bank mimeo, 2007
5. Berg, A., P. Karam, and D. Laxton: *A Practical Model-Based Approach to Monetary Policy Analysis – Overview*, IMF Working Paper WP/06/80, 2006
6. Berg, A., P. Karam, and D. Laxton: *Practical Model-Based Monetary Policy AnalysisA How-To Guide*, IMF WP 06/81, 2006b
7. Waggoner, D. and T. Zha: *Conditional Forecasts In Dynamic Multivariate Models*, The Review of Economics and Statistics, MIT Press, vol. 81(4), pages 639-651, November
8. Wiener, N.: Extrapolation, Interpolation, and Smoothing of Stationary Time Series, MIT Press, 1949
9. Chacon, S.: Pro Git, Everything you need to know about the Git distributed source control tool, APress, 2009