Advancing Regime-Switching Models for Macroeconomic Analysis Using the RISE Toolbox

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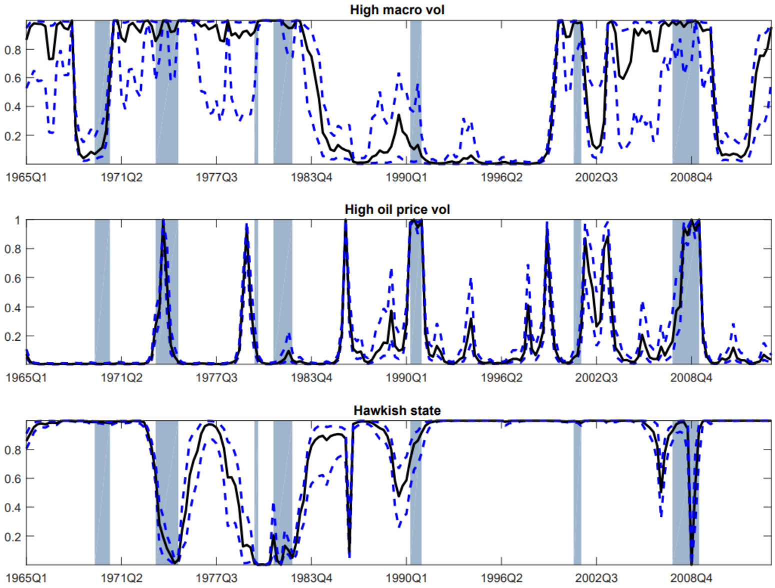
The Need for Advanced Modeling Tools

- Policymakers rely on macroeconomic models to design frameworks for promoting stability and growth.
- But traditional models assume constant parameters and a unique steady state, designed for normal times, not well-equipped to navigate:
  - Nonlinearities and unsteady steady states.
  - Recurring natural disasters and external shocks.
  - Fragmentation of global markets and economies.
  - Financial crises, sudden stops, and occasionally-binding constraints.
  - Changes in behavior: discretionary periods and commitment in others.

Chronology of Some Major Economic Shocks

- **1969–1970 Recession**: Tight monetary policy post-Vietnam War.
- **1973–1975 Oil Crisis**: OPEC oil embargo and energy crisis.
- **1980–1982 Recessions**: Volcker's monetary tightening to control inflation.
- **1990–1991 Recession**: Oil price spike (Gulf War) and savings & loan crisis.
- **2001 Recession**: Dot-com bubble burst and 9/11 attacks.
- **2007–2009 Great Recession**: Global financial crisis and housing market collapse.
- **2020 COVID-19 Recession**: Global pandemic disrupting demand and supply chains.

Bjørnland, Larsen and Maih (2018)



Hubrich & Tetlow (2015): High Stress Regime

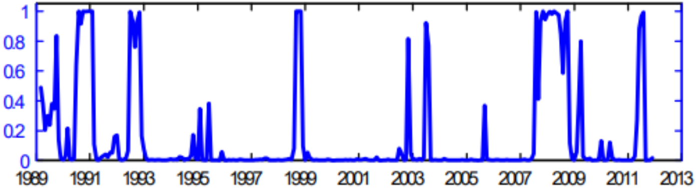


Figure 3: Probability of high-stress coefficient state, smoothed estimates, $3v2c$ model specification

Alstadheim, Bjørnland, Maih (2021)

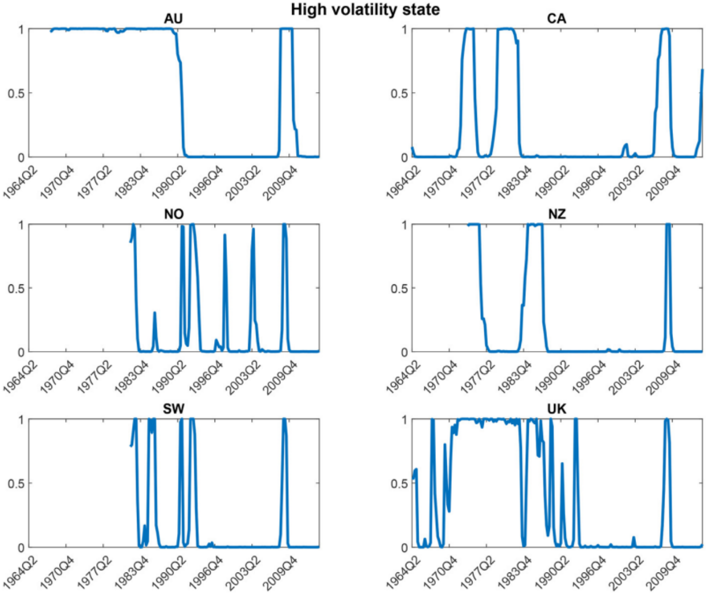


Fig. 2. Smoothed Probabilities of high volatility (S_t^{Vol}=High).

Why Regime-Switching Models

Models that are designed to be flexible and adaptive to changing circumstances are needed to address these challenges.

- Allow for different dynamics under various economic conditions.
- Essential for understanding behavior in crises vs normal times.

Why RISE

- Built for regime-switching models: solution, estimation, simulations, forecasting, policy analysis.
- Enables the development of flexible models that can adapt to changing circumstances and the complex non-linear dynamics of an unstable world.
- User-friendly for macroeconomic analysis and developed in Matlab.

Why MATLAB?

- **Numerical power**: Efficient for complex calculations.
- **Flexibility**: Ideal for solving non-linear models.
- **Wide library support**: Built-in functions for optimization and statistics.
- **User-friendly**: Fast prototyping for macroeconomic analysis.
- **Great support**: Responsive technical support for smooth implementation.

What is RISE? I

RISE: Rationality in Switching Environments, a toolbox for solving, simulating and estimating regime-switching models.

Time Series Modeling:

- VARs and Panel VARs
- SVARs and Proxy SVARs
- DSGE-VARs

What is RISE? II

DSGE Modeling:

- Higher-order Perturbation Solutions
- Optimal Policy: Ramsey, Discretion, Loose Commitment, Stochastic Replanning
- Tools for bounded rationality
- Occasionally binding constraints

What is RISE? III

Simulation Capabilities:

- Forecasting and Conditional Forecasting
- Perfect foresight under regime switching
- Stochastic Simulation
- Uncertainty Quantification

What is RISE? IV

Filtration and Estimation Capabilities:

- Nonlinear filters
- Maximum Likelihood, Bayesian Estimation, (Bayesian) Indirect Inference
- Customizable priors on parameters and model properties.

The generic Regime-Switching Model I

$$E_t \sum_{r_{t+1}=1}^{h} p_{r_t,r_{t+1}}\left(\mathcal{I}_t\right) f_{r_t}\left(x_{t+1}\left(r_{t+1}\right), x_t\left(r_t\right), x_{t-1}, \theta_{r_t}, \theta_{r_{t+1}}, \varepsilon_t\right) = 0$$

- $p_{r_t,r_{t+1}}\left(I_t\right)$: Probability of transitioning from state r_t to state r_{t+1}.
- f_{r_t}: Nonlinear function representing the current regime dynamics.
- $x_t\left(r_t\right)$: Vector of endogenous variables in regime r_t.
- θ_{r_t}: Parameters specific to regime r_t.
- $\varepsilon_t \sim N\left(0, I\right)$: Vector of stochastic shocks.

The generic Regime-Switching Model II

Uncertainty Comes from:

- Structural shocks.
- Behavioral changes governed by switching processes (exogenous and endogenous).

Takeaways:

- These shocks and regime switches induce nonlinearity, generating real-world instability.
- All models mentioned earlier are special cases of this framework

A Simple Regime-Switching DSGE Model I

Model Overview:

- Two regimes: Dovish vs Hawkish monetary policy.
- Regime-switching governed by a Markov process.

Endogenous Variables	**Exogenous Variables**
π_t: Inflation	$\varepsilon_{z,t}$: Demand shock
y_t: Output	$\varepsilon_{r,t}$: Monetary policy shock
r_t: Interest rate	$\varepsilon_{\eta,t}$: Cost-push shock
$\pi_{z,t}$: Demand	
η_t: Cost-push process	

A Simple Regime-Switching DSGE Model II

Model Equations (Part 1)

1. Euler Equation

$$y_t = E_t y_{t+1} - E_t(r_t - \pi_{t+1}) + E_t \pi_{z,t+1}$$

2. New Keynesian Phillips Curve

$$(\pi_t - \alpha \cdot \pi_{t-1}) = \frac{(\eta - 1) \cdot (1 + \chi)}{\kappa \cdot \pi_\star^2} \cdot y_t$$
$$+ \beta \cdot E_t(\pi_{t+1} - \alpha \cdot \pi_t) - \frac{1}{\kappa \cdot \pi_\star^2} \cdot \eta_t$$

3. Interest Rate Rule

$$r_t = \rho \cdot r_{t-1} + (1 - \rho) \cdot \psi_{\text{regime}} \cdot \pi_t + \sigma_r \cdot \varepsilon_{r,t}$$

A Simple Regime-Switching DSGE Model III

Model Equations (Part 2)

4. Cost-push process

$$\eta_t = \rho_\eta \cdot \eta_{t-1} + \sigma_\eta \cdot \varepsilon_{\eta,t}$$

5. Demand process

$$\pi_{z,t} = \rho_z \cdot \pi_{z,t-1} + \sigma_z \cdot \varepsilon_{z,t}$$

A Simple Regime-Switching DSGE Model IV

Parameter	**Value**	**Description**
β	0.99	Discount factor
κ	161	Price adjustment cost coefficient
π_{ss}	$1.02^{0.25}$	Steady-state inflation
α	0.5	Indexation to past inflation
η	6	Elasticity of substitution
χ	0.7	Inverse Frisch elasticity
ρ	0.7	Interest rate smoothing
ρ_z	0.75	Persistence of technology shock
ρ_η	0.75	Persistence of cost-push shock
σ_z	0.05	Std. dev. of demand shock
σ_η	0.05	Std. dev. of cost-push shock
σ_r	0.05	Std. dev. of monetary policy shock
$pol\_tp\_1\_2$	0.05	Transition prob. regime 1 to 2
$pol\_tp\_2\_1$	0.1	Transition prob. regime 2 to 1
$\psi(pol, 1)$	2.5	Policy reaction to inflation (regime 1)
$\psi(pol, 2)$	0.9	Policy reaction to inflation (regime 2)

RISE Implementation I

Declarations

```
%% Log-linearized New Keynesian DSGE model

@endogenous Y "Output", R "Interest rate", PAI "Inflation", ETA "Cost-push",
PI_Z "Technology"

@exogenous EPS_R "Monetary Policy shock", EPS_Z "Demand shock", EPS_ETA "Cost-push shock"

@parameters alpha "Price indexation on past inflation", beta "discount factor",
kappa "price adjustment cost coeff.", eta "steady-state elast. of subst. across goods",
chi "inverse Frisch elast. of substitution", rho "interest rate smoothing",
psi "policy reaction to inflation", sigma_r "std: monetary policy shock",
sigma_eta "std: cost-push shock", sigma_z "std: demand shock",
rho_eta "persistence: cost-push", rho_z "persistence: demand",
paiss "steady-state inflation"
```

RISE Implementation II

Model Equations

```
@model

    "First Order Condition for Bonds"
    Y{t} = Y{t+1} - (R{t} - PAI{t+1}) + PI_Z{t+1};

    "New Keynesian Phillips Curve"
    PAI{t} - alpha * PAI{t-1} = (eta - 1) * (1 + chi)/ (kappa * paiss^2) * Y{t} ...
         + beta * (PAI{t+1} - alpha * PAI{t})- (1 / (kappa * paiss^2)) * ETA{t};

    "Interest Rate Rule"
    R{t} = rho * R{t-1} + (1 - rho) * psi * PAI{t} + sigma_r * EPS_R{t};

    "Cost-push Shock Process"
    ETA{t} = rho_eta * ETA{t-1} - sigma_eta * EPS_ETA{t};

    "Technology Shock Process"
    PI_Z{t} = rho_z * PI_Z{t-1} + sigma_z * EPS_Z{t};
```

Model Solution I

MODEL SOLUTION #1/1

SOLVER :: mfi

Regime 1 : const = 1 & Hawkish

	ETA	R	PAI	PI_Z	Y
ETA{-1}	0.75	-0.0042389	-0.0056519	0	0.036397
R{-1}	0	0.58954	-0.14728	0	-1.5034
PAI{-1}	0	0.27214	0.36285	0	-0.92156
PI_Z{-1}	0	0.10809	0.14412	0.75	1.3219
EPS_ETA	-0.05	0.0002826	0.00037679	0	-0.0024265
EPS_R	0	0.04211	-0.01052	0	-0.10739
EPS_Z	0	0.0072062	0.0096082	0.05	0.088125
	ETA	R	PAI	PI_Z	Y

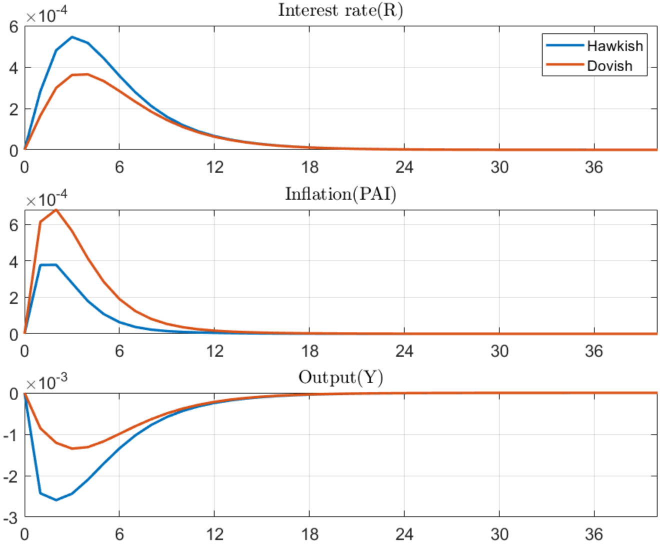
Regime 2 : const = 1 & Dovish

	ETA	R	PAI	PI_Z	Y
ETA{-1}	0.75	-0.002482	-0.0091927	0	0.012837
R{-1}	0	0.63887	-0.22641	0	-2.0524
PAI{-1}	0	0.11358	0.42068	0	-0.36936
PI_Z{-1}	0	0.063292	0.23441	0.75	1.9227
EPS_ETA	-0.05	0.00016547	0.00061285	0	-0.00085581
EPS_R	0	0.045634	-0.016172	0	-0.1466
EPS_Z	0	0.0042194	0.015628	0.05	0.12818

Model Solution II

State Var	Variable	Hawkish	Dovish	Difference
ETA{-1}	Y	0.03640	0.01284	**+0.02356**
	R	-0.00424	-0.00248	**-0.00176**
	PAI	-0.00565	-0.00919	**+0.00354**
R{-1}	Y	-1.50340	-2.05240	**+0.549**
	R	0.58954	0.63887	**-0.04933**
	PAI	-0.14728	-0.22641	**+0.07913**
PAI{-1}	Y	-0.92156	-0.36936	**-0.5522**
	R	0.27214	0.11358	**+0.15856**
	PAI	0.36285	0.42068	**-0.05783**
PI_Z{-1}	Y	1.32190	1.92270	**-0.6008**
	R	0.10809	0.06329	**+0.0448**
	PAI	0.14412	0.23441	**-0.09029**
EPS_ETA	Y	-0.00243	-0.00086	**-0.00157**
	R	0.00028	0.00017	**+0.00011**
	PAI	0.00038	0.00061	**-0.00023**
EPS_R	Y	-0.10739	-0.14660	**+0.03921**
	R	0.04211	0.04563	**-0.00352**
	PAI	-0.01052	-0.01617	**+0.00565**
EPS_Z	Y	0.08813	0.12818	**-0.04005**
	R	0.00721	0.00422	**+0.00299**
	PAI	0.00961	0.01563	**-0.00602**

IRF: Cost-Push Shock



Conclusion

Advancing Macroeconomic Analysis with RISE

- **Flexible Modeling:** Captures dynamics in both normal and crisis periods with regime-switching models.
- **Policy Analysis:** Powerful tools for forecasting, estimation, and simulation under uncertainty.
- **User-Friendly:** Easily solves complex models in MATLAB with precision.
- **Driving Insightful Policy Decisions:** Helps design frameworks to navigate today's unstable and fragmented global economy.

"We have not succeeded in answering all our problems.
The answers we have found only serve to raise a whole set of new questions.
In some ways we feel we are as confused as ever, but we believe we are confused on a higher level and about more important things."

— Earl C. Kelley

Thank You!

For more information, feel free to reach out:
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Explore the RISE Toolbox at:
https://github.com/jmaih/RISE_toolbox

I look forward to your feedback and collaboration!

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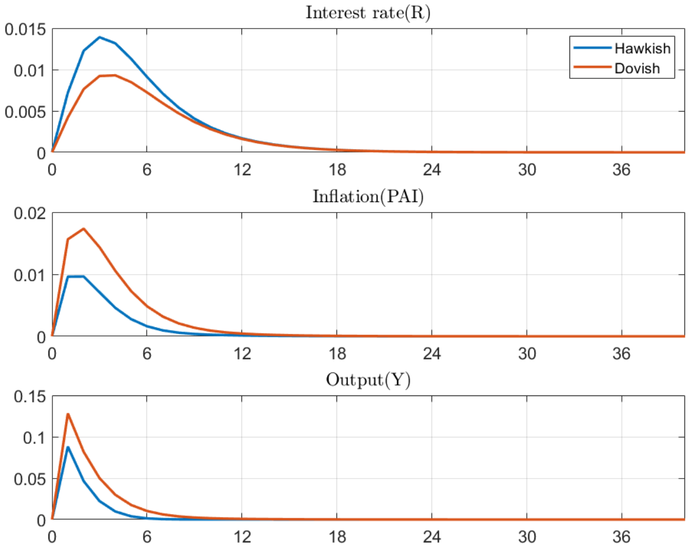
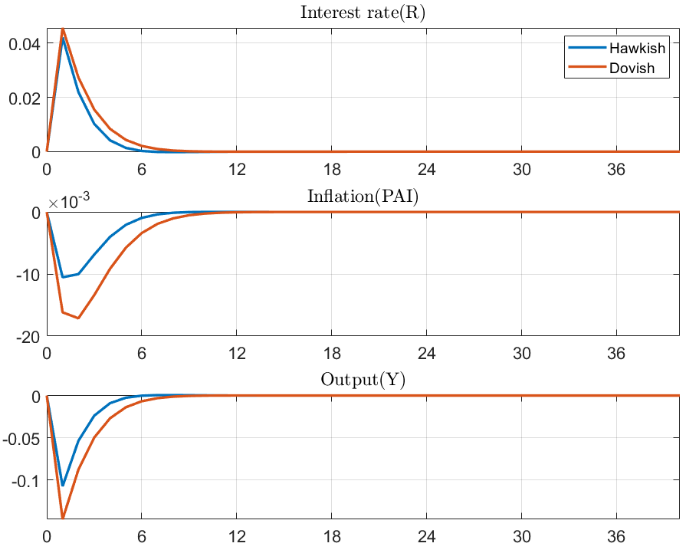
IRF: Demand Shock



IRF: Monetary Policy Shock



MATLAB Script for Running Experiments I

```
%% Housekeeping
clearvars
clc
close all

%% Create the model

mdl=rise('model_switch');

%% Parameter values
p=struct();
p.beta=0.99;
p.kappa=161;
p.paiss=1.02^0.25;
p.alpha = 0.5;
```

MATLAB Script for Running Experiments II

```
p.eta = 6;
p.chi = 0.7;
p.rho = 0.7;
p.rho_z=0.75;
p.rho_eta=0.75;
p.sigma_z=0.05;
p.sigma_eta=0.05;
p.sigma_r=0.05;
p.pol_tp_1_2=.1/2;
p.pol_tp_2_1=.1;
p.psi_pol_1=2.5;
p.psi_pol_2=0.9;

mdl=set(mdl,'parameters',p);
```

MATLAB Script for Running Experiments III

```
%% solve the model

mdl=solve(mdl);

print_solution(mdl)

%% Dynamic response to shocks

myirfs=irf(mdl);

vList={'R','PAI','Y'};

quick_irfs(mdl,myirfs,vList)
```