Regime Switches, Agents’ Beliefs, and Post-World War II U.S. Macroeconomic Dynamics

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Motivation
A MS-DSGE model
Estimates
Conclusions

Macroeconomic dynamics and Fed chairmanships
Regime switches and agents’ beliefs

Figure:
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Regime Switches and Agents’ Beliefs
Good Policy or Good Luck?

\begin{itemize}
\item **‘Good Policy’**: The changes described above are the result of a substantial switch in the anti-inflationary stance of the Federal Reserve.
\item **‘Good Luck’**: Changes in the volatilities of the structural disturbances were the key driver behind the stabilization of the U.S. economy.
\end{itemize}
Looking for a model that...

...allows for

- Changes in the behavior of the Federal Reserve
- Changes in the volatility of the structural shocks

and

- A role for agents’ beliefs around the behavior of the Federal Reserve
In a Markov-Switching Dynamic Stochastic General Equilibrium model:

- Structural parameters are allowed to differ across regimes
- Volatility of structural shocks can change over time
- Agents are aware of the possibility of regime changes and they take this into account when forming expectations: The law of motion of the state variables depends on agents’ beliefs
Allowing for Markov-switching regimes

Linearized Euler equation and expectations augmented Phillips curve:

\[ \tilde{y}_t = E_t(\tilde{y}_{t+1}) - \tau^{-1}(\tilde{R}_t - E_t(\tilde{\pi}_{t+1})) + g_t \]  

\[ \tilde{\pi}_t = \beta E_t(\tilde{\pi}_{t+1}) + \kappa(\tilde{y}_t - \tilde{z}_t) \]  

Markov-switching Taylor rule:

\[ \tilde{R}_t = \rho_R(\tilde{\zeta}_t)\tilde{R}_{t-1} + (1 - \rho_R(\tilde{\zeta}_t)) \left( \psi_1(\tilde{\zeta}_t)\tilde{\pi}_t + \psi_2(\tilde{\zeta}_t)\tilde{y}_t \right) + \epsilon_{R,t} \]  

Heteroskedasticity is modelled as an independent Markov-switching process:

\[ (\epsilon_{R,t}, \epsilon_{z,t}, \epsilon_{g,t}) \sim N(0, Q(\tilde{\zeta}_t)), \quad Q(\tilde{\zeta}_t) = \text{diag}(\theta^{er}(\tilde{\zeta}_t)) \]  

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Regime Switches and Agents' Beliefs
The model in state space form

The DSGE state vector

\[ S_t = \left[ \tilde{y}_t, \tilde{\pi}_t, \tilde{R}_t, g_t, z_t, E_t(\tilde{y}_{t+1}), E_t(\tilde{\pi}_{t+1}) \right]' \]

evolves according to the following law of motion:

\[ S_t = T(\theta^{sp}, \zeta^{sp}, H^m)S_{t-1} + R(\theta^{sp}, \zeta^{sp}, H^m)e_t \]
\[ e_t \sim N(0, Q(\theta^{er}, \zeta^{er})) \]

The probability of moving across regimes is given by:

\[ H^{sp}(\cdot, i) \sim D(a_{ii}^{sp}, a_{ij}^{sp}), \ H^{er}(\cdot, i) \sim D(a_{ii}^{er}, a_{ij}^{er}) \]
The model in state space form

The law of motion of the DSGE state vector can be combined with an observation equation:

$$ Y_t = D(\theta^{ss}) + ZS_t + \Lambda^{1/2} \nu_t $$

$$ Y_t = \begin{bmatrix} GDP_t \\ INFL_t^A \\ FFR_t \end{bmatrix} \quad D(\theta^{ss}) = \begin{bmatrix} 0 \\ 4\pi^* \\ 4(\pi^* + r^*) \end{bmatrix} $$

$$ Z = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} $$
## Taylor rule parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mode</th>
<th>Mean</th>
<th>5th prc</th>
<th>95th prc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\psi_1$</td>
<td>2.2265</td>
<td>2.0528</td>
<td>1.3721</td>
<td>2.5916</td>
</tr>
<tr>
<td>$\psi_2$</td>
<td>0.2998</td>
<td>0.2744</td>
<td>0.1088</td>
<td>0.4529</td>
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<tr>
<td>$\rho_R$</td>
<td>0.7724</td>
<td>0.7530</td>
<td>0.6299</td>
<td>0.8323</td>
</tr>
</tbody>
</table>

### $\zeta^{sp}_t = 1$ (Hawk)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mode</th>
<th>Mean</th>
<th>5th prc</th>
<th>95th prc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\psi_1$</td>
<td>0.4844</td>
<td>0.5907</td>
<td>0.3505</td>
<td>0.9892</td>
</tr>
<tr>
<td>$\psi_2$</td>
<td>0.3161</td>
<td>0.3824</td>
<td>0.2112</td>
<td>0.7882</td>
</tr>
<tr>
<td>$\rho_R$</td>
<td>0.7668</td>
<td>0.7881</td>
<td>0.6994</td>
<td>0.8798</td>
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</table>
### Volatilities

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\xi^e_t = 1$ (High Volatility)</th>
<th>Mode</th>
<th>Mean</th>
<th>5th prc</th>
<th>95th prc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_R$</td>
<td>0.3170</td>
<td>0.3211</td>
<td>0.2555</td>
<td>0.4097</td>
<td></td>
</tr>
<tr>
<td>$\sigma_g$</td>
<td>0.3509</td>
<td>0.3522</td>
<td>0.2689</td>
<td>0.4552</td>
<td></td>
</tr>
<tr>
<td>$\sigma_z$</td>
<td>1.4014</td>
<td>1.8538</td>
<td>1.2719</td>
<td>2.6622</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\xi^e_t = 2$ (Low Volatility)</th>
<th>Mode</th>
<th>Mean</th>
<th>5th prc</th>
<th>95th prc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_R$</td>
<td>0.0679</td>
<td>0.0741</td>
<td>0.0616</td>
<td>0.0883</td>
<td></td>
</tr>
<tr>
<td>$\sigma_g$</td>
<td>0.1502</td>
<td>0.1483</td>
<td>0.1184</td>
<td>0.1821</td>
<td></td>
</tr>
<tr>
<td>$\sigma_z$</td>
<td>0.4727</td>
<td>0.5842</td>
<td>0.3961</td>
<td>0.8352</td>
<td></td>
</tr>
</tbody>
</table>

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Regime Switches and Agents' Beliefs
Probabilities of regimes 1 (posterior mode)

Structural parameters - Prob Hawk regime

Stochastic volatilities - Prob High Volatility regime
(Adverse) Supply shock

![Graphs showing responses to (adverse) supply shocks in different regimes.](image-url)
Hawk regime always in place

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Regime Switches and Agents' Beliefs
The *Eagle* regime

A new type of counterfactual simulation:

- I introduce a third regime, the *Eagle* regime, that is meant to capture the behavior of an extremely conservative chairman, like Volcker
- Compared to the *Hawk* regime, under the *Eagle* regime the response...
  - ...to inflation is doubled
  - ...to output is halved

\[
\tilde{R}_t = \rho_R \tilde{R}_{t-1} + (1 - \rho_R)(\psi_1 \tilde{\pi}_t + \psi_2 \tilde{y}_t) + \epsilon_{R,t}
\]

\[
\begin{align*}
\psi_1 (Eagle) & = 2 \psi_1 (Hawk) \\
\psi_2 (Eagle) & = 0.5 \psi_2 (Hawk)
\end{align*}
\]
**An *Eagle* on stage**

- Only two regimes: The *Dove* and the *Eagle*

- The persistence of the *Eagle* regime is equal to the persistence of the *Hawk* regime. The persistence of the *Dove* regime is decreased by 30%.

\[
H^m = \begin{bmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{bmatrix} \Rightarrow H_E^m = \begin{bmatrix} p_{11} & 1 - 0.7p_{22} \\ p_{12} & 0.7p_{22} \end{bmatrix}
\]

- The *Eagle* regime occurs in place of the *Hawk* regime.
An *Eagle* on stage
An *Eagle* behind the scenes

- When agents observe the *Dove* regime, they regard the *Eagle* regime as the alternative scenario and they put a relatively large probability on its occurrence.

- The persistence of the *Eagle* regime is equal to the persistence of the *Hawk* regime and from the *Eagle* regime the economy can move only to the *Hawk* regime.

\[
H^m = \begin{bmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{bmatrix} \quad \Rightarrow \quad H^m_E = \begin{bmatrix} p_{11} & 0 & p_{12} \\ p_{12} & 0.7p_{22} & 0 \\ 0 & 1 - 0.7p_{22} & p_{11} \end{bmatrix}
\]

- However, the *Eagle* regime never occurs.

\[ H^m \]
An *Eagle* behind the scenes
Counterfactual sacrifice ratios

These are computed as

$$SR_{T_0, T_1} = \frac{\sum_{t=T_0}^{T_1} (y_t - \hat{y}_t)}{\sum_{t=T_0}^{T_1} (\pi_t - \hat{\pi}_t)}$$

Sacrifice ratios for the period 1970:I-1984:I:

<table>
<thead>
<tr>
<th>Counterfactual</th>
<th>Mean</th>
<th>5th prc</th>
<th>95th prc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawk</td>
<td>1.1133</td>
<td>0.8843</td>
<td>1.4349</td>
</tr>
<tr>
<td>Eagle behind</td>
<td>0.5292</td>
<td>0.4184</td>
<td>0.6736</td>
</tr>
<tr>
<td>Eagle on stage</td>
<td>0.6256</td>
<td>0.4976</td>
<td>0.7835</td>
</tr>
</tbody>
</table>
Gains and Losses

Percentage change in the sum of squared deviations from the target for the three counterfactuals:

<table>
<thead>
<tr>
<th>Counterfactual</th>
<th>$D%SSD_y$</th>
<th>$D%SSD_{\pi^A}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hawk</strong></td>
<td>$+17.77%$</td>
<td>$-45.76%$</td>
</tr>
<tr>
<td></td>
<td>($+1.99%, +38.97%$)</td>
<td>($-56.57%, -29.79%$)</td>
</tr>
<tr>
<td><strong>Eagle behind</strong></td>
<td>$+1.12%$</td>
<td>$-55.89%$</td>
</tr>
<tr>
<td></td>
<td>($-5.59, +10.36$)</td>
<td>($-64.88, -45.78%$)</td>
</tr>
<tr>
<td><strong>Eagle on stage</strong></td>
<td>$+16.99%$</td>
<td>$-66.36%$</td>
</tr>
<tr>
<td></td>
<td>($+7.68%, +28.80$)</td>
<td>($-74.18%, -57.61%$)</td>
</tr>
</tbody>
</table>
Consider the model in state space form:

\[ S_t = T(\theta^{sp}, \zeta^{sp}, H^m)S_{t-1} + R(\theta^{sp}, \zeta^{sp}, H^m)\epsilon_t \]

\[ \epsilon_t \sim N(0, Q(\theta^{er}, \zeta^{er})) \]

\[ Y_t = D(\theta^{ss}) + ZS_t + \Lambda^{1/2}v_t \]

For each Gibbs sampling draw, we can compute the covariance matrix as implied by the different regime combinations \((\zeta^{sp}, \zeta^{er})\):

\[ V(Y_t|\theta^{sp}, \theta^{er}, \zeta^{sp}, \zeta^{er}, H^m) = ZV(S_t|\theta^{sp}, \theta^{er}, \zeta^{sp}, \zeta^{er}, H^m)Z' + \Lambda \]
Analytical standard deviations

Output

Inflation

FFR

1 → (High Volat, Hawk)
3 → (Low Volat, Hawk)

2 → (High Volat, Dove)
4 → (Low Volat, Dove)
Marginal Data Density

- Posterior odds ratio:

\[
\frac{P(M_i | Y_T)}{P(M_j | Y_T)} = \frac{P(Y_T | M_i) P(M_i)}{P(Y_T | M_j) P(M_j)}
\]

- Comparing the different specifications (\(q\): fraction of draws that are included)

<table>
<thead>
<tr>
<th>Model</th>
<th>(q = 0.1)</th>
<th>(q = 0.3)</th>
<th>(q = 0.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS T.R.+heter.+ind (H^m)</td>
<td>2,391.6</td>
<td>2,390.5</td>
<td>2,390.4</td>
</tr>
<tr>
<td>MS T.R.+heter.</td>
<td>2,390.1</td>
<td>2,390.1</td>
<td>2,390.0</td>
</tr>
<tr>
<td>Just Good Luck (heter.)</td>
<td>2,379.0</td>
<td>2,379.0</td>
<td>2,379.0</td>
</tr>
<tr>
<td>One-time-only switch</td>
<td>2,349.4</td>
<td>2,349.1</td>
<td>2,349.1</td>
</tr>
</tbody>
</table>

Marginal data density (log)
The Good Luck - Good Policy Debate

1. There were regime changes in US monetary policy: The best performing model is one in which the behavior of the Fed moves between a *Hawk*- and a *Dove*- regime.

2. The idea that US economic history can be divided into *pre-* and *post-Volcker* turns out to be misleading:
   - The *Dove* regime was certainly in place during the ’70s.
   - The appointment of Volcker marked a change in the conduct of monetary policy.
   - On the other hand, regime changes have been relatively frequent.

3. Following an adverse technology shock, the Fed is willing to accept a severe recession in order to fight inflation only under the *Hawk* regime.
The role of agents’ beliefs

Counterfactual simulations show that:

1. Simply imposing the *Hawk* regime throughout the sample would not have prevented inflation from rising in the ’70s.

2. If in the ’70s agents had anticipated the appointment of a very conservative chairman, the Great Inflation would have been a less extreme event.

3. Monetary policy does not need to be constantly hawkish to guarantee low and stable inflation. Deviations are allowed as long as agents’ beliefs are not affected: *Constrained discretion*.