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

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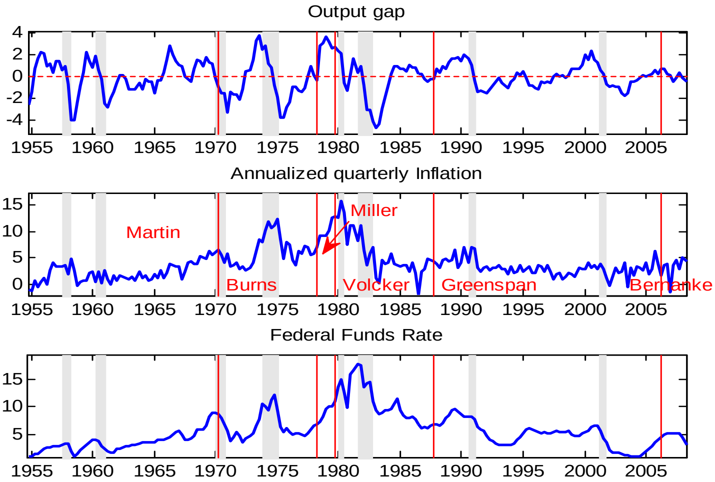
Second International Conference in memory of Carlo Giannini
January 20, 2010


Output gap
4
2
0
-2
-4
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Annualized quarterly Inflation
15
10
5
0
Martin
Burns
Miller
Volcker
Greenspan
Bernanke
Federal Funds Rate
15
10
5

Good Policy or Good Luck?

- **'Good Policy':** The changes described above are the result of a substantial switch in the anti-inflationary stance of the Federal Reserve
- **'Good Luck':** Changes in the volatilities of the structural disturbances were the key driver behind the stabilization of the U.S. economy

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

A MS-DSGE model

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:

$$\widetilde{y}_t = E_t(\widetilde{y}_{t+1}) - \tau^{-1}(\widetilde{R}_t - E_t(\widetilde{\pi}_{t+1})) + g_t \quad (1)$$

$$\widetilde{\pi}_t = \beta E_t(\widetilde{\pi}_{t+1}) + \kappa(\widetilde{y}_t - z_t) \quad (2)$$

Markov-switching Taylor rule:

$$\widetilde{R}_t = \rho_R(\xi_t^{sp})\widetilde{R}_{t-1} + (1 - \rho_R(\xi_t^{sp}))(\psi_1(\xi_t^{sp})\widetilde{\pi}_t + \psi_2(\xi_t^{sp})\widetilde{y}_t) + \epsilon_{R,t} \quad (3)$$

Heteroskedasticity is modelled as an independent Markov-switching process:

$$(\epsilon_{R,t}, \epsilon_{z,t}, \epsilon_{g,t}) \sim N(0, Q(\xi_t^{er})), \quad Q(\xi_t^{er}) = diag(\theta^{er}(\xi_t^{er})) \quad (4)$$

The model in state space form

The DSGE state vector

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

evolves according to the following law of motion:

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

$$\epsilon_t \sim N\left(0, Q\left(\theta^{er}, \xi_t^{er}\right)\right)$$

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:

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

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

$$Z = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Taylor rule parameters

$\xi_t^{sp} = 1 \ (Hawk)$

Parameter	*Mode*	*Mean*	$5th$ *prc*	$95th$ *prc*
ψ_1	2.2265	2.0528	1.3721	2.5916
ψ_2	0.2998	0.2744	0.1088	0.4529
ρ_R	0.7724	0.7530	0.6299	0.8323

$\xi_t^{sp} = 2 \ (Dove)$

Parameter	*Mode*	*Mean*	$5th$ *prc*	$95th$ *prc*
ψ_1	0.4844	0.5907	0.3505	0.9892
ψ_2	0.3161	0.3824	0.2112	0.7882
ρ_R	0.7668	0.7881	0.6994	0.8798

Volatilities

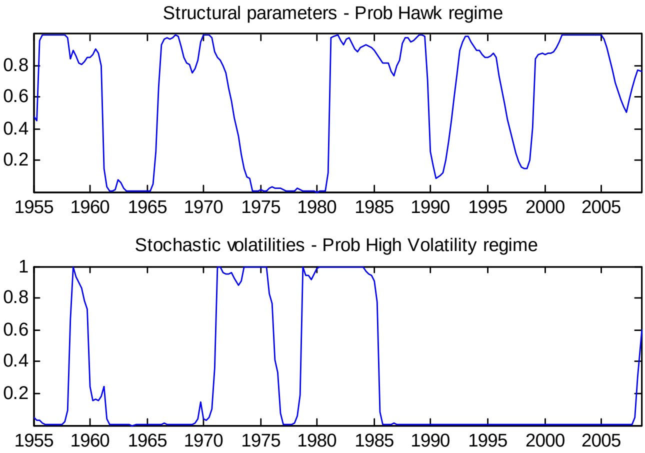
$\xi_t^{er} = 1$ (*High Volatility*)

Parameter	*Mode*	*Mean*	5*th prc*	95*th prc*
σ_R	0.3170	0.3211	0.2555	0.4097
σ_g	0.3509	0.3522	0.2689	0.4552
σ_z	1.4014	1.8538	1.2719	2.6622

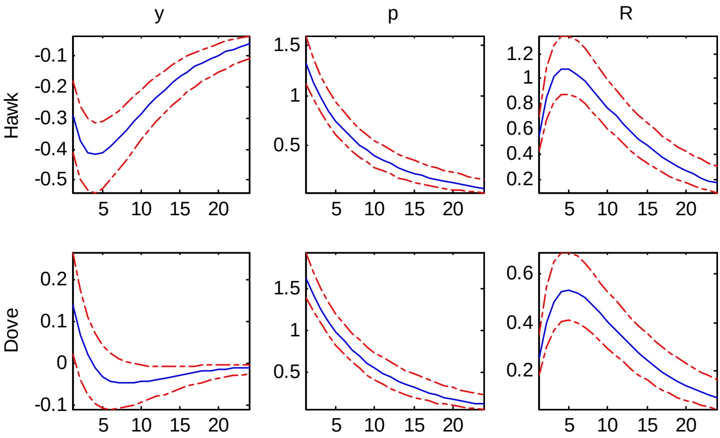
$\xi_t^{er} = 2$ (*Low Volatility*)

Parameter	*Mode*	*Mean*	5*th prc*	95*th prc*
σ_R	0.0679	0.0741	0.0616	0.0883
σ_g	0.1502	0.1483	0.1184	0.1821
σ_z	0.4727	0.5842	0.3961	0.8352

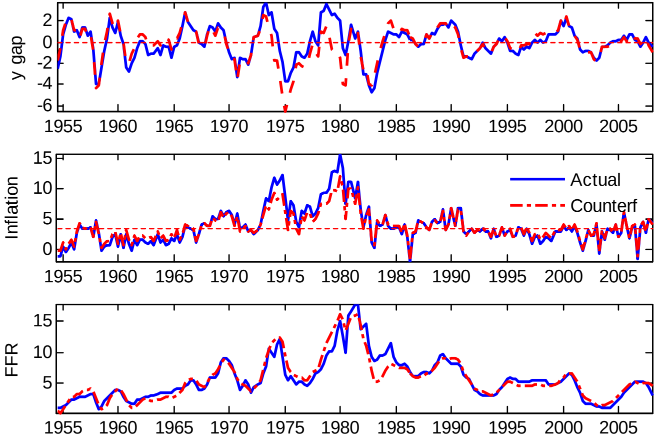
Probabilities of regimes 1 (posterior mode)



(Adverse) Supply shock



Hawk regime always in place



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

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

$$\begin{aligned} \psi_1\,(Eagle) &= 2\psi_1\,(Hawk) \\ \psi_2\,(Eagle) &= 0.5\psi_2\,(Hawk) \end{aligned}$$

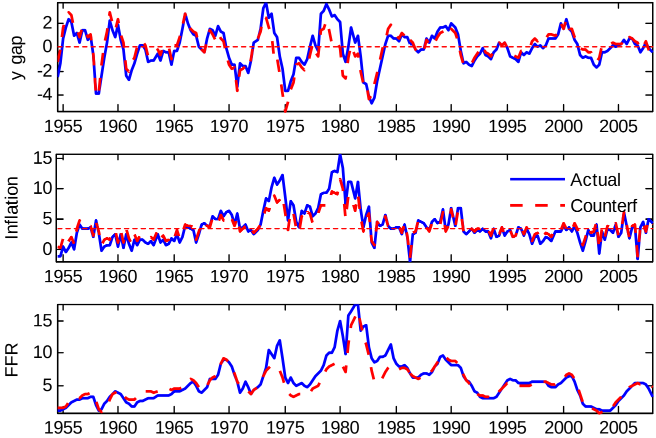
An *Eagle* on stage

- 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



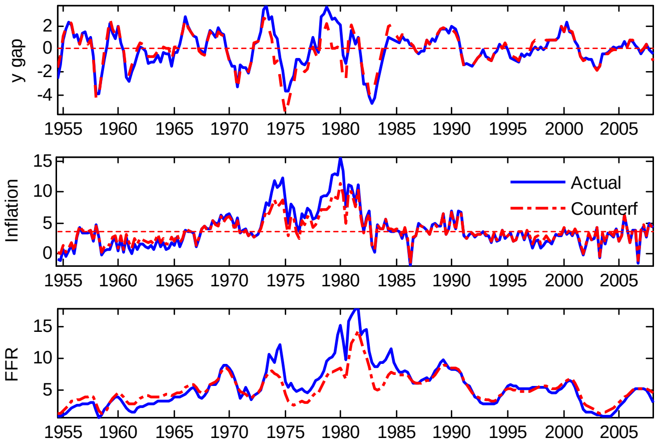
An *Eagle* behind the scenes

- 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

$$H^m = \begin{bmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{bmatrix} \Rightarrow H_E^m = \begin{bmatrix} p_{11} & 0 & p_{12} \\ p_{12} & 0.7p_{22} & 0 \\ 0 & 1-0.7p_{22} & p_{11} \end{bmatrix}$$

- However, the *Eagle* regime never occurs

An *Eagle* behind the scenes



Counterfactual sacrifice ratios

These are computed as

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

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

Counterfactual	*Mean*	5*th prc*	95*th prc*
Hawk	1.1133	0.8843	1.4349
Eagle behind	0.5292	0.4184	0.6736
Eagle on stage	0.6256	0.4976	0.7835

Gains and Losses

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

Counterfactual	$\widehat{D\%SSD}_y$	$\widehat{D\%SSD}_{\pi^A}$
Hawk	$+17.77\%$ $(+1.99\%, +38.97\%)$	-45.76% $(-56.57\%, -29.79\%)$
Eagle behind	$+1.12\%$ $(-5.59, +10.36)$	-55.89% $(-64.88, -45.78\%)$
Eagle on stage	$+16.99\%$ $(+7.68\%, +28.80)$	-66.36% $(-74.18\%, -57.61\%)$

Analytical variances

Consider the model in state space form:

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

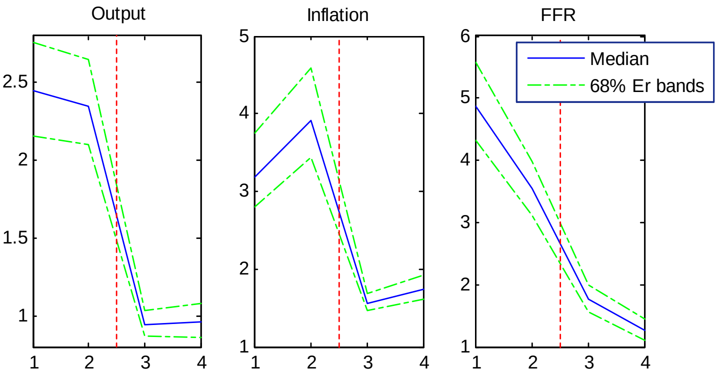
$$\epsilon_t \sim N\left(0, Q\left(\theta^{er}, \xi_t^{er}\right)\right)$$

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

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

$$V\left(Y_t|\theta^{sp}, \theta^{er}, \xi_t^{sp}, \xi_t^{er}, H^m\right) = ZV\left(S_t|\theta^{sp}, \theta^{er}, \xi_t^{sp}, \xi_t^{er}, H^m\right) Z' + \Lambda$$

Analytical standard deviations



$1 \longrightarrow$ (High Volat, *Hawk*) $2 \longrightarrow$ (High Volat, *Dove*)
$3 \longrightarrow$ (Low Volat, *Hawk*) $4 \longrightarrow$ (Low Volat, *Dove*)

Marginal Data Density

- Posterior odds ratio:

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

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

Model	$q = 0.1$	$q = 0.3$	$q = 0.5$
MS T.R.+heter.+ind H^m	$2,391.6$	$2,390.5$	$2,390.4$
MS T.R.+heter.	$2,390.1$	$2,390.1$	$2,390.0$
Just Good Luck (heter.)	$2,379.0$	$2,379.0$	$2,379.0$
One-time-only switch	$2,349.4$	$2,349.1$	$2,349.1$

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**