Markov Switching Monetary Policy in a Two-Country DSGE Model

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Objective

1. In a simple two-country DSGE model to analyze the cross country effects when monetary policy switches regimes.
2. Is a shift in Foreign MP responsible for changes in Home CPI and output volatility? Are they negligible?
3. How important is the formation of expectations in the Home country for the dynamics of output and inflation?
4. What is the optimal reaction of the home CB, conditional on foreign MP switching regimes?

Closed economy MS-DSGE models

- Farmer et al. (2011), Bekaert et al. (2011), Liu et al. (2008, 2009), Davig and Leeper (2007).
- A non-zero probability of a regime switch in the future has effects on inflation today.
- Stabilizing and amplifying effects.
- But, what are the international effects?
- The dynamics of domestic variables may change, even though domestic conditions are unchanged.
- How should the home Central Bank react in this case?

What do the data say?

- Focus on the US and the Eurozone.
- Monthly Real-Time Data: 1999:1 to 2010:6 (Output, CPI rate, Eurozone interbank overnight rate, Federal Funds rate, RER).
- Database: ECB Real-Time database and Philadelphia Fed.
- Estimation of a structural VAR model.

Methodology

- I follow a strategy similar to that in Bovin and Giannoni (2006).
- Stability tests, $Andrews - Quandt \quad sup - Wald$ and $Andrews - Ploberger$ test.
- At first, I estimate the model for the whole sample and then for two different sub-samples.

Parameter Stability Tests

	Regressors						
Dep. vrb	CPI_{Euro}	Gap_{Euro}	i_{Euro}	RER	CPI_{US}	Gap_{US}	i_{US}
CPI_{Euro}	0.0181	0.9491	0.0189	0.0415	0.0174	0.4007	0.0353
Gap_{Euro}	0.7225	0.2944	0.7338	0.7030	0.7407	0.3018	0.6947
i_{Euro}	0.0508	0.6871	0.1231	0.0432	0.0499	0.5500	0.0825
RER	0.0008	0.5122	0.0002	0.0015	0.0007	0.7031	0.0047
CPI_{US}	0.5558	0.4223	0.2338	0.6056	0.5608	0.4859	0.1903
Gap_{US}	0.0112	0.0561	0.0132	0.0429	0.0112	0.1491	0.0388
i_{US}	0.0025	0.6122	0.0000	0.0030	0.0026	0.2339	0.1093

Notes: P-values reported. Red: Significant at 1% s.l., Blue: Significant at 5% s.l.

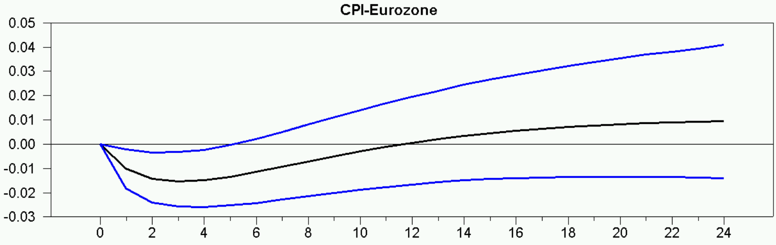
Parameter Stability Tests

- The Andrews-Ploberger test identifies the break date in June 2004.

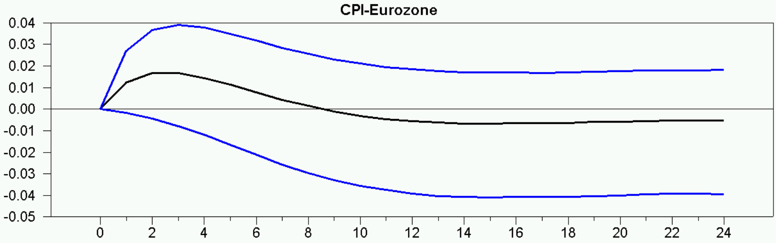
"In January 2004, the Committee expressed an intention to be "patient" regarding the removal of monetary policy accommodation. In May 2004, a month before the Committee began to increase its target for the federal funds rate, it said that accommodation was likely to be removed at a pace that would be "measured"."

Ben Bernanke, Annual Meeting of the AEA, Atlanta, January 2010

Sample: 1999:1 - 2004:6

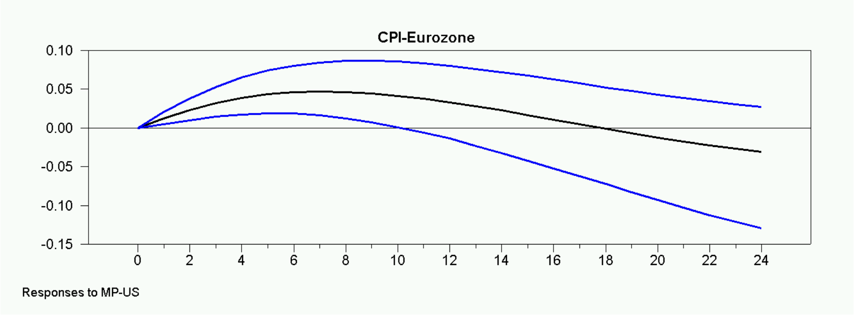


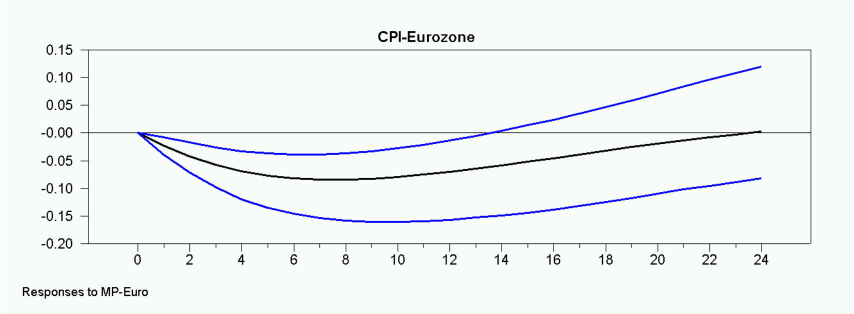
Responses to MP-US



Responses to MP-Euro

Sample 2004:7 - 2010:6





What drives the changes in IRFs?

- Is it a change in US monetary policy, or a change in the nonpolicy part of the VAR?
- Counterfactual Analysis in order to disentangle the effects.

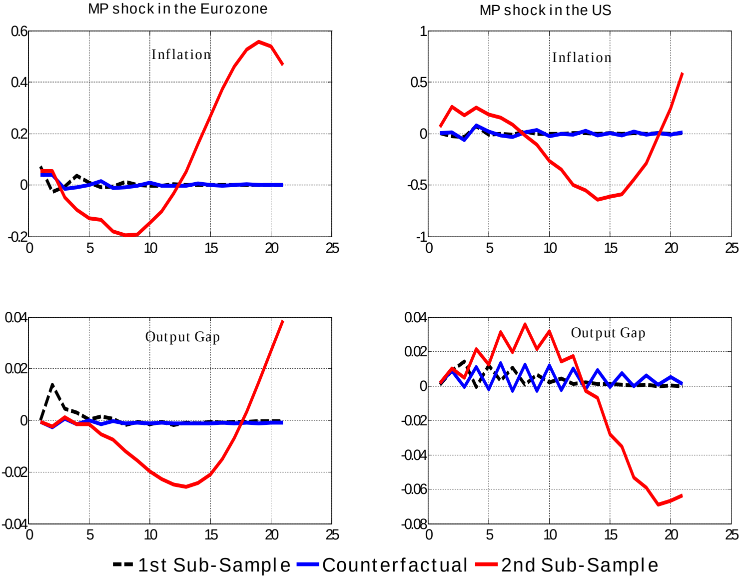
Counterfactual Analysis

- Let T_S be the set of the estimated parameters of the US policy rule. S denotes the period within which they are estimated
- Let K_S be the set of the estimated parameters in the Eurozone CPI and US GDP equation.
- Let N_S be the set of the estimated parameters in the remaining part of the VAR.
- Hence, $(T_{pre-2004:6}, K_{pre-2004:6}, N_{pre-2004:6})$ is the set of parameters from the 1st sub-sample.
- $(T_{post-2004:6}, K_{post-2004:6}, N_{post-2004:6})$ is the set of parameters from the 2nd sub-sample.

Counterfactual Analysis

- At first, I am allowing for changes in the US output Gap and the Eurozone CPI equation coefficients only.
- That is, I fix all other parameters and I compute the new IRFs in the 1st sub-sample to see how they change.
- Therefore, the set of parameters that will be used is: $(T_{pre-2004:6},\ K_{post-2004:6},\ N_{pre-2004:6})$.

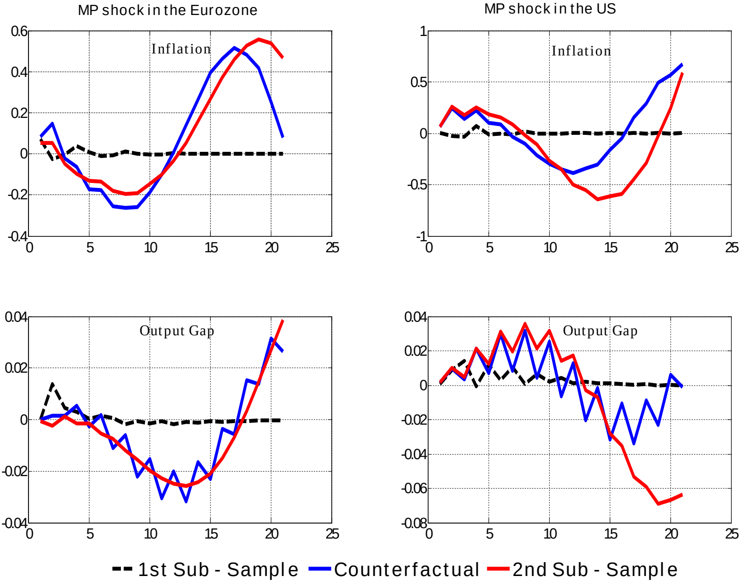
Counterfactual Analysis



Counterfactual Analysis

- Now I allow for changes in the parameters of the US interest rate equation only.
- Hence the set of coefficients that will be used is: $(T_{post-2004:6},\ K_{pre-2004:6},\ N_{pre-2004:6})$.

Counterfactual Analysis



More evidence

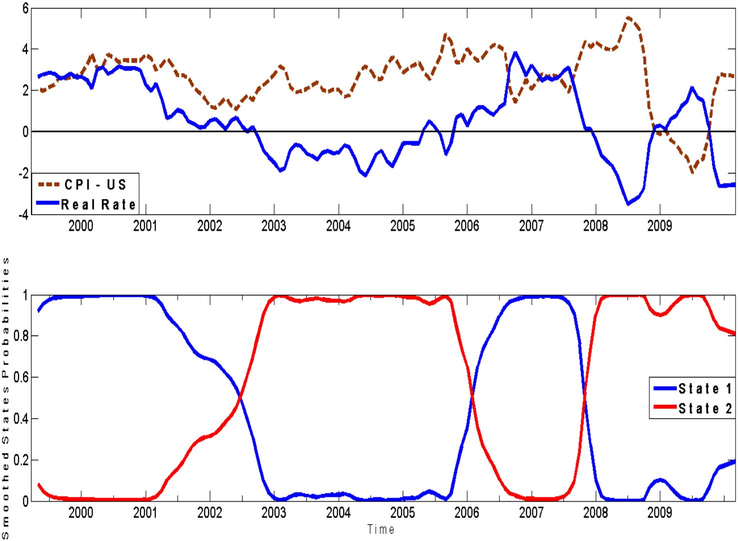
- An MS interest rate rule for the US

$$i_t = \alpha_0(s_t) + \alpha_\pi(s_t)\pi_t + \alpha_x(s_t)x_t + \varepsilon_t \tag{1}$$

States	*Hawkish*	*Dovish*
	$s_t = 1$ ($p11 = 0.91$)	$s_t = 2$ ($p22 = 0.91$)
α_π	1.4562(0.00)	0.3798(0.02)
α_x	0.5934(0.01)	0.4803(0.02)
σ_ε	1.8785e-003	2.2436e-003

Log likelihood value = -235.8437. P-values in parentheses

More evidence



Empirical findings

1. US monetary policy has changed since the start of the Euro. Monetary policy in the Eurozone seems to be much more stable.
2. Changes in the US monetary policy seem to be the main driving force behind the changes in the dynamics of inflation and output in the Eurozone.
3. The Fed seems not to be hawkish (active) at all times.

The model

- Two country DSGE
- Rule-of-thumb behavior in consumption and price setting
- Local currency pricing
- Only the foreign CB changes the coefficients in its rule.

The Model

- Aggregate per capita consumption

$$C_t = \psi C_t^O + (1 - \psi) C_t^R$$

- Rule-of-thumb consumers

$$C_t^R = C_{t-1}$$

The Model

- Utility maximizing consumers

$$U_t = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{C^{1-\sigma}}{1-\sigma} - \chi \frac{L_s^{1+\gamma}}{1+\gamma} \right]$$

s.t.

$$P_t C_t + Q_{t,t+1} B_{t+1} = B_t + W_t L_t + \Pi_t$$

Pricing

- Calvo pricing

$$P_{H,t} = \left[\omega P_{H,t-1}^{1-\theta} + (1-\omega)\widetilde{p_t}(h)^{1-\theta}\right]^{\frac{1}{1-\theta}}$$

where

$$\tilde{p}_t(h) = \zeta p_t^B(h) + (1-\zeta)\, p_t^F(h),\ \zeta \in (0,1)$$

- Rule-of-thumb firms

$$p_t^B(h) = P_{H,t-1} + \pi_{H,t-1} \quad \text{and} \quad p_t^{B*}(h) = P_{H,t-1}^{*} + \pi_{H,t-1}^{*}$$

Pricing

- Forward looking firms

$$y_t(z) = A_t L_t$$

- Profit maximization

$$maxE_t \sum_{s=0}^{\infty} \omega^s Q_{t,t+s} \left\{ \widetilde{p_t}(h) y^h_{t+s}(h) + \varepsilon_t \widetilde{p_t}(h)^* y^f_{t+s}(h) - W^h_{t+s} L^h_{t+s} \right\}$$

- Optimal prices

$$p_t(h) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=0}^{\infty} \omega^s Q_{t,t+s} MC_{t+s} y_{t+s}^h (p_t(h))}{E_t \sum_{s=0}^{\infty} \omega^s Q_{t,t+s} y_{t+s}^h (p_t(h))}$$

$$p_t^*(h) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=0}^{\infty} \omega^s Q_{t,t+s} MC_{t+s} y_{t+s}^f (p_t(h))}{E_t \sum_{s=0}^{\infty} \omega^s Q_{t,t+s} y_{t+s}^f (p_t(h)) \varepsilon_{t+s}}$$

- Market Clearing

$$Y_t = C_{H,t} + C_{H,t}^* + G_t, \; Y_t^* = C_{F,t} + C_{F,t}^* + G_t^*$$

$$g_t = \rho_g g_{t-1} + \varepsilon_t, \; g_t^* = \rho_g^* g_{t-1}^* + \varepsilon_t^*$$

Welfare Loss

As in Rotemberg & Woodford (1998) and Benigno and Woodford (2006)

$$W_t = U + U_C(\hat{C_t^O} + \frac{1}{2}(1 + \frac{U_{CC}C}{U_C})\hat{C_t^O}^2) - U_L(\hat{L}_t + \frac{1}{2}(1 + \frac{U_{LL}L}{U_L})\hat{L}_t^2$$

Welfare loss

$$W_t = -\frac{1}{2} u_c C\{\lambda_1(y_t - y_t^n)^2 + \lambda_2(y_t - y_{t-1})^2 + \lambda_3(y_t^* - y_t^{*n})^2 + \lambda_4(y_t^* - y_{t-1}^*)^2 + \ldots$$

$$+\lambda_5 \pi_{H,t}^2 + \lambda_6(\pi_{H,t} - \pi_{H,t-1})^2 + \lambda_7(\pi_{H,t}^*)^2 + \lambda_8(\pi_{H,t}^* - \pi_{H,t-1}^*)^2 + \ldots$$

$$+\lambda_9(q_t - q_t^n)^2 + +lags\} + t.i.p. + O(||\xi||^3)$$

Markov Switching

- Foreign country changes with an equal (across countries) probability.
- Monetary policy in the home country is assumed to remain unchanged, initially.
- I define two kinds of behavior (regimes) for the foreign central bank, a hawkish and a dovish.
- Hawkish implies $\phi^*_{\pi^*} > 1$ and dovish, $\phi^*_{\pi^*} < 1$.

Markov Switching

- Interest rate rules for the home and foreign country receive the following form

$$i_t = i_{t-1}^{\rho} \left(\left(\frac{\pi_t}{\tilde{\pi}} \right)^{\phi_\pi} y_t^{\phi_y} \right)^{1-\rho} e^{\varepsilon_t} \tag{2}$$

$$i_t^* = i_{t-1}^{*\rho^*_{s_t}} \left(\xi^*_{s_t} \left(\frac{\pi_t^*}{\tilde{\pi}^*} \right)^{\phi^*_{\pi^*,s_t}} y_t^{*\phi^*_{y^*,s_t}} \right)^{1-\rho^*_{s_t}} e^{\varepsilon_t^*} \tag{3}$$

Markov Switching

- s_t is the realized policy regime taking values, $s_t \in \{1, 2\}$.
- s_t follows a Markov process with transition probabilities $p_{ji} = P[s_t = i | s_{t-1} = j]$ where $i, j = 1, 2$.
- Therefore, $E_t \pi_{t+1} = E\left[\pi_{t+1} | \Omega_t^{-s}\right]$, with $\Omega_t^{-s} \left\{s_{t-1}, \ldots, \varepsilon_t, \varepsilon_{t-1}, \ldots \varepsilon_t^*, \varepsilon_{t-1}^*, \ldots\right\}$, where $\Omega_t = \Omega_t^{-s} \cup \{s_t\}$.

Solution Technique

- Farmer, Waggoner & Zha (2011).
- The model has a state space representation

$$A(s_t)X_t = B(s_t)X_{t-1} + \Psi(s_t)\eta_t + \Pi(s_t)\varepsilon_t$$

Solution Technique

- The algorithm finds the Minimum State Variable solution

$$X_t = g_{1,s_t} X_{t-1} + g_{2,s_t} \varepsilon_t$$

- Mean square stability: max eigenvalue less than one. In this model $\lambda_{max} = 0.9705$.
- Determinacy in each regime individually.

The steady state

Proposition: *The steady state equilibrium values of home and foreign aggregate output, consumption and the real wage are independent of monetary policy and are thus invariant to foreign monetary policy regime shifts. Moreover, as long as home monetary policy does not change regimes, it is enough that*

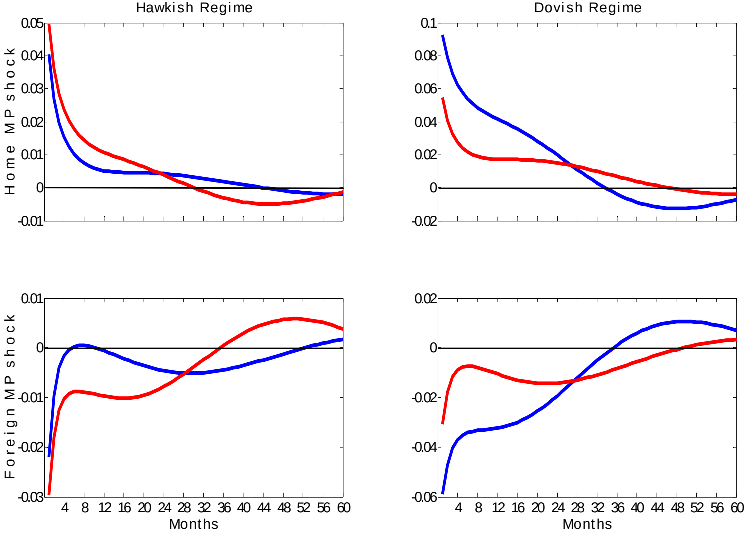
$$\xi^*_{s_t} = \frac{1}{\beta}\tilde{\pi}^* \bar{y}^{*-\phi^*_{y^*,s_t}},$$

where $\bar{y}^*$ *is the steady state foreign output gap, so that the steady state nominal variables are given by* $\pi = \tilde{\pi}, \quad \pi^* = \tilde{\pi}^*$, $R = \frac{\lambda}{\beta}\tilde{\pi}$ *and* $R^* = \frac{\lambda^*}{\beta}\tilde{\pi}^*$, *and which are independent of regime changes as well.*

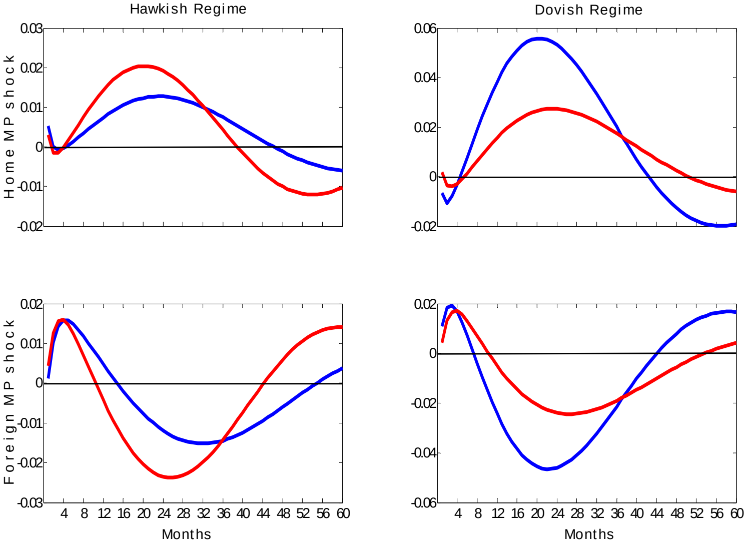
Parametrization

Preference		$\beta = 0.99$	$\sigma = 1.1$	$\gamma = 4$
		$\psi = \psi^{*}$=0.6		
Price setting		$\omega = \omega^{*} = 0.8$	$\zeta = \zeta^{*} = 0.6$	
Home bias		$\delta = \delta^{*} = 0.67$		
Policy Rules:				
Home		$\phi_{\pi} = 1.5$	$\phi_{y} = 0.5$	$\rho = 0.75$
Foreign	Regime 1	$\phi^{*}_{\pi,1} = 1.4562$	$\phi^{*}_{y,1} = 0.5934$	$\rho^{*}_{1} = 0.6$
	Regime 2	$\phi^{*}_{\pi,2} = 0.3798$	$\phi^{*}_{y,2} = 0.4803$	$\rho^{*}_{2} = 0.6$

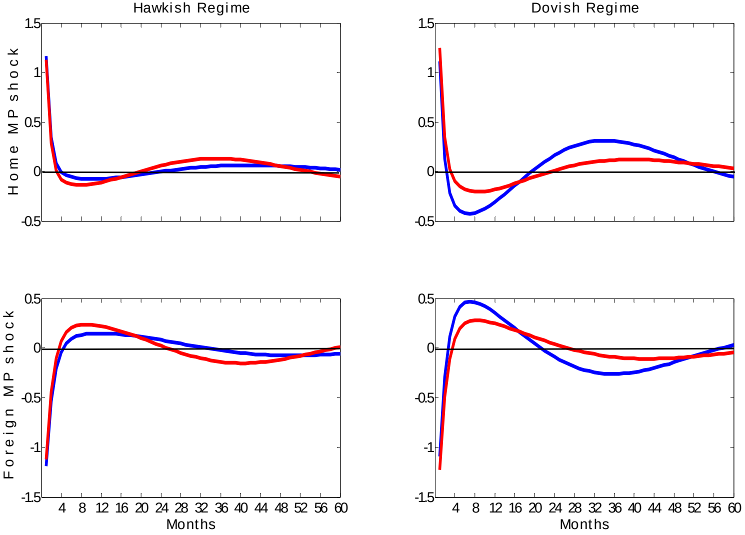
Impulse Responses - Foreign CPI



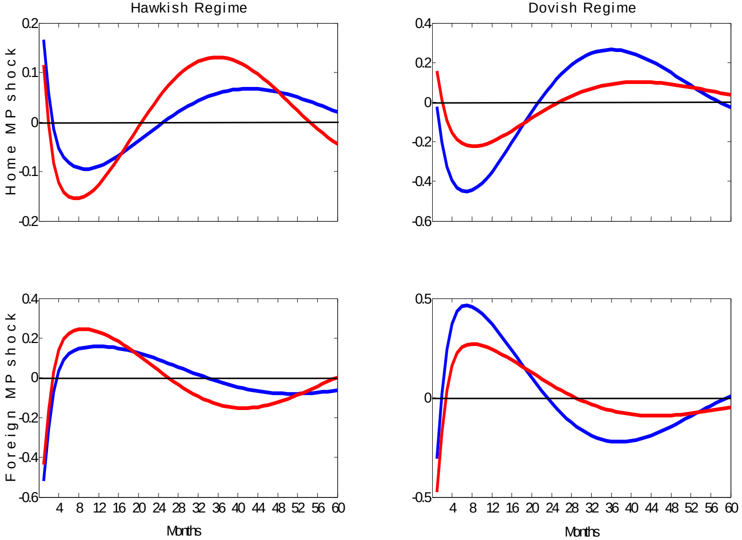
Impulse Responses - Home CPI



Impulse Responses - Foreign output



Impulse Responses - Home output



Relative Volatilities

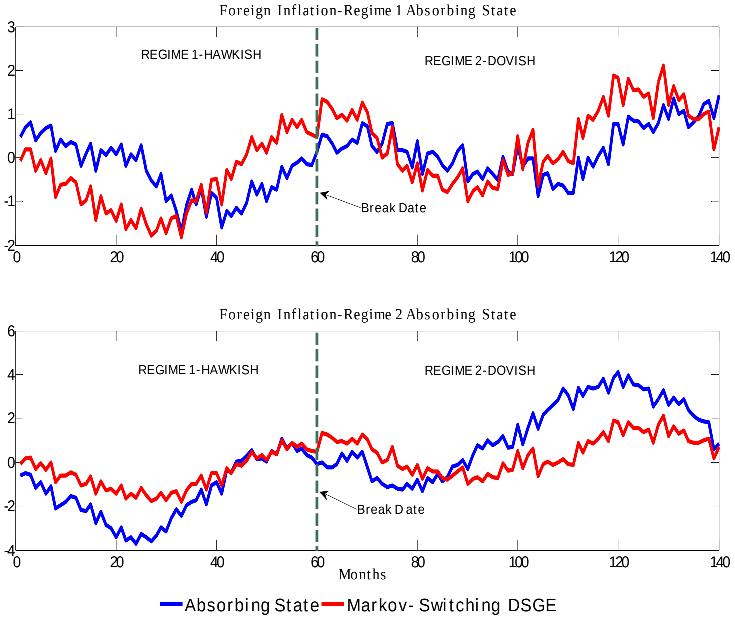
	Inflation		Output	
	Home	*Foreign*	*Home*	*Foreign*
Hawkish	1.1713	1.7205	1.2709	1.3255
Dovish	0.7078	0.4495	0.7456	0.7455

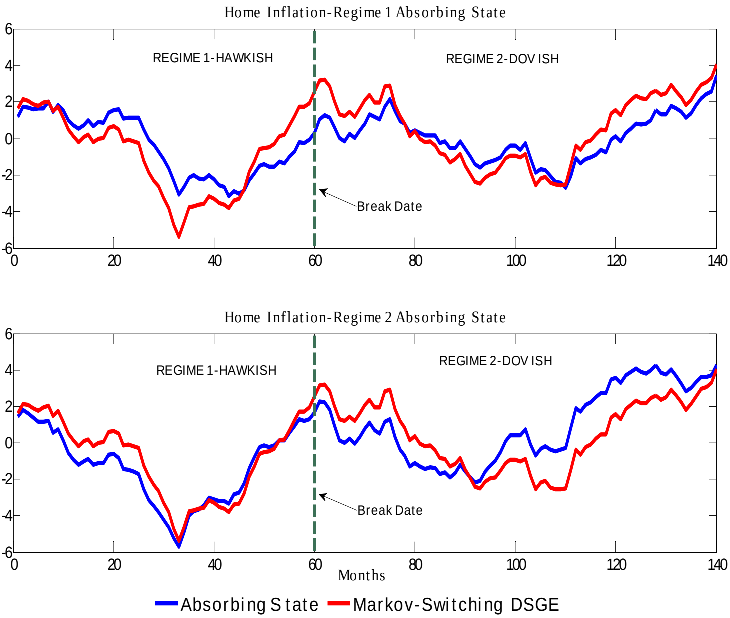
Notes: Volatilities relative to the absorbing state

Relative Losses

	Losses	
	Home	*Foreign*
Hawkish	1.6289	1.4633
Dovish	0.5610	0.4942

Notes: Losses relative to the absorbing state


Foreign Inflation-Regime 1 Absorbing State
REGIME 1-HAWKISH
REGIME 2-DOVISH
Break Date
3
2
1
0
-1
-2
0
20
40
60
80
100
120
140
Foreign Inflation-Regime 2 Absorbing State
REGIME 1-HAWKISH
REGIME 2-DOVISH
Break Date
6
4
2
0
-2
-4
0
20
40
60
80
100
120
140
Months
Absorbing State
Markov- Switching DSGE


Home Inflation-Regime 1 Absorbing State
REGIME 1-HAWKISH
REGIME 2-DOVISH
Break Date
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
120
140
Home Inflation-Regime 2 Absorbing State
REGIME 1-HAWKISH
REGIME 2-DOVISH
Break Date
Months
Absorbing State
Markov-Switching DSGE

Dynamic Programming

- I extend Soderlind's (1998) algorithm for solving optimal policy problems in RE models to a Markov-switching RE framework.
- Loss function

$$\sum_{t=0}^{\infty} \beta^t L(h_t, i_t) \quad (4)$$

where

$$L(h_t, i_t) = h_t' R h_t + i_t Q i_t \quad (5)$$

subject to h_0, s_0 given, and the model describing the economy

$$h_{t+1} = A(s_{t+1}) h_t + B(s_{t+1}) i_t + C\varepsilon_{t+1} \qquad t \geq 0 \quad (6)$$

Dynamic Programming

- The Bellman

$$V(h_t, j) = max_{i_t} \left\{ L(h_t, i_t) + \beta \Sigma_{i=1}^{2} p_{ji} E_t \left[V(h_{t+1}, i) \right] \right\} \quad (7)$$

The value function for this problem is

$$V(h_t, j) = h_t^{'} P_j h_t + d_j, \quad j = 1, 2 \quad (8)$$

where P_j is a 29×29 symmetric positive semidefinite matrix, while d_i is a scalar. The optimal policy is given by

$$i(h_t, j) = -F_j h_t, \quad j = 1, 2 \quad (9)$$

Dynamic Programming

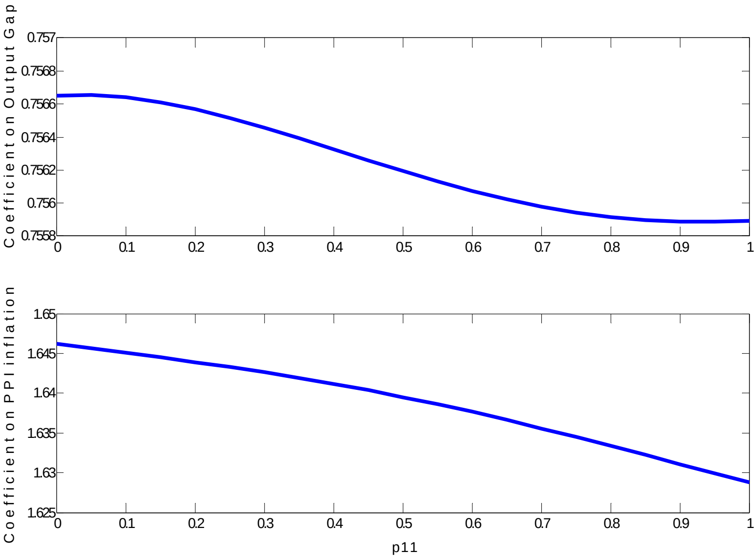
where F_j is specified as

$$F_j = \left(Q + \beta p_{j1} B_1^{'} P_i B_1 + \beta p_{j2} B_2^{'} P_i B_2\right)^{-1} \beta \left(p_{j1} A_1^{'} P_i B_1 + p_{j2} A_2^{'} P_i B_2\right) \tag{10}$$

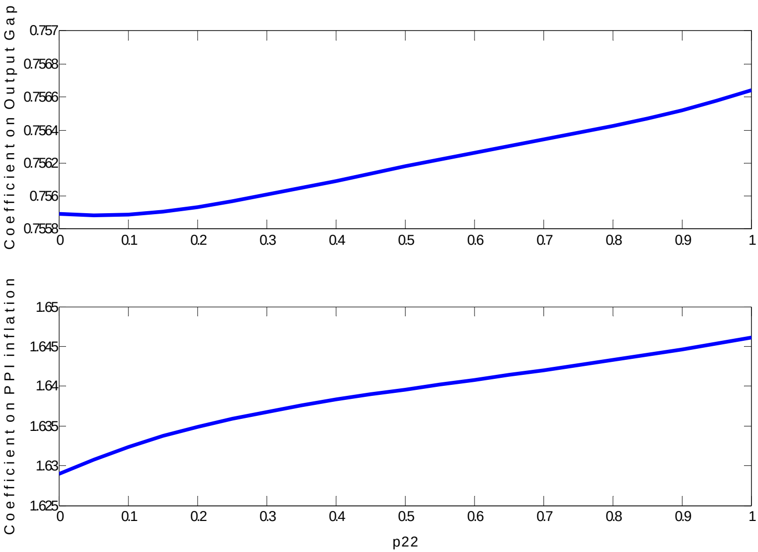
where matrix P_i has been already determined by a set of interrelated Riccati equations, which specify a system with the following form

$$\begin{aligned} P_j = {} & R + \beta p_{j1} A_1^{'} P_i A_1 + \beta p_{j2} A_2^{'} P_i A_2 - \dots \\ & -\beta^2 \left(p_{j1} A_1^{'} P_i B_1 + p_{j2} A_2^{'} P_i B_2\right) \left(Q + \beta p_{j1} B_1^{'} P_i B_1 + \beta p_{j2} B_2^{'} P_i B_2\right)^{-1} \\ & \left(p_{j1} B_1^{'} P_i A_1 + p_{j2} B_2^{'} P_i A_2\right) \end{aligned} \tag{11}$$

How should the home CB react?



How should the home CB react?



Relative benefits

Relative Losses

	Baseline Calibration	
	Home	*Foreign*
Hawkish	1.6289	1.4633
Dovish	0.5610	0.4942
	Optimal	
	Home	*Foreign*
Hawkish	1.0002	1.0918
Dovish	1.0000	0.9853

How bad is a suboptimal rule?

Relative Losses

	Home	*Foreign*
Hawkish	3.4663	2.0603
Dovish	3.6832	5.2785

Notes: Losses relative to optimal

Conclusion

- Changes in foreign monetary policy have significant effects on home inflation, output and welfare, even though conditions in the home country are perfectly stable.
- Expectations about foreign monetary policy are enough to either stabilize, or destabilize home CPI and output.
- Those findings are also validated by the data.
- The behavior of inflation and output in the Eurozone changed mainly due to changes in US MP.

Conclusions

- Optimal monetary policy in the home country suggests that the latter should change its policy over time conditional on foreign monetary policy.
- As the probability of staying in the Hawkish regime falls, the home CB should become more aggressive towards inflation fluctuations.
- Hence, home CB must offset the effect a switch on foreign MP has on home inflation expectations.
- Optimal policy eliminates completely the effects of changes in foreign MP in the home country. Moreover, it reduces dramatically fluctuations in foreign welfare loss.