Materials 8 - Massaging RE IRFs and interpreting learning IRFs

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November 1, 2019

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1 Model summary with interest rate smoothing ρi_{t-1}

$$x_t = -\sigma i_t + \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t}\big((1-\beta)x_{T+1} - \sigma(\beta i_{T+1} - \pi_{T+1}) + \sigma r_T^n\big) \tag{1}$$

$$\pi_t = \kappa x_t + \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} (\alpha\beta)^{T-t}\big(\kappa\alpha\beta x_{T+1} + (1-\alpha)\beta\pi_{T+1} + u_T\big) \tag{2}$$

$$i_t = \psi_\pi \pi_t + \psi_x x_t + \rho i_{t-1} + \bar{i}_t \tag{3}$$

$$\hat{\mathbb{E}}_t z_{t+h} = \begin{bmatrix} \bar{\pi}_{t-1} \\ 0 \\ 0 \end{bmatrix} + b\, hx^{h-1} s_t \quad \forall h \geq 1 \qquad b = gx\ hx \qquad \text{PLM} \tag{4}$$

$$\bar{\pi}_t = \bar{\pi}_{t-1} + k_t^{-1} \underbrace{\big(\pi_t - (\bar{\pi}_{t-1} + b_1 s_{t-1})\big)}_{\text{fcst error using (4)}} \qquad (b_1 \text{ is the first row of } b) \tag{5}$$

$$k_t = \mathbb{I} \times (k_{t-1} + 1) + (1 - \mathbb{I}) \times \bar{g}^{-1} \tag{6}$$

$$\mathbb{I} = \begin{cases} 1 & \text{if } \theta_t \leq \bar{\theta} \\ 0 & \text{otherwise.} \end{cases} \tag{7}$$

$$\theta_t = |\hat{\mathbb{E}}_{t-1}\pi_t - \mathbb{E}_{t-1}\,\pi_t| / \sigma_s \qquad \text{CEMP criterion for the gain} \tag{8}$$

The alternative criterion for the choice of gain is a recursive variant of the CUSUM-test (Brown, Durbin, Evans 1975):

1. Let FE_t denote the short-run forecast error, and ω_t firms' estimate of the FE variance.
2. Let $\kappa \in (0, 1)$ and $\tilde{\theta}$ be the new threshold value for the criterion.
3. Then for initial (ω_0, θ_0), firms in every period estimate the criterion and the FEV as:

$$\omega_t = \omega_{t-1} + \kappa k_{t-1}^{-1}(FE_t^2 - \omega_{t-1}) \tag{9}$$

$$\theta_t = \theta_{t-1} + \kappa k_{t-1}^{-1}(FE_t^2/\omega_t - \theta_{t-1}) \tag{10}$$

$$k_t = \mathbb{I} \times (k_{t-1} + 1) + (1 - \mathbb{I}) \times \bar{g}^{-1} \tag{11}$$

$$\mathbb{I} = 1 \quad \text{if} \quad \theta_t \leq \tilde{\theta} \tag{12}$$

2 Compact notation - with lagged interest rate term in TR

$$z_t = A_p^{RE}\,\mathbb{E}_t\, z_{t+1} + A_s^{RE} s_t \tag{13}$$

$$z_t = A_a^{LH} f_a(t) + A_b^{LH} f_b(t) + A_s^{LH} s_t \tag{14}$$

$$s_t = P s_{t-1} + \epsilon_t \qquad \rightarrow \quad s'_t = hx\; s'_{t-1} + \epsilon'_t \tag{15}$$

$$\text{where} \quad s'_t \equiv \begin{pmatrix} r_t^n \\ \bar{i}_t \\ u_t \\ i_{t-1} \end{pmatrix} \quad hx \equiv \begin{pmatrix} \rho_r & 0 & 0 & 0 \\ 0 & \rho_i & 0 & 0 \\ 0 & 0 & \rho_u & 0 \\ gx_{3,1} & gx_{3,2} & gx_{3,3} & gx_{3,4} \end{pmatrix} \quad \epsilon'_t \equiv \begin{pmatrix} \varepsilon_t^r \\ \varepsilon_t^i \\ \varepsilon_t^u \\ 0 \end{pmatrix} \quad \text{and} \quad \Sigma' = \begin{pmatrix} \sigma_r & 0 & 0 & 0 \\ 0 & \sigma_i & 0 & 0 \\ 0 & 0 & \sigma_u & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \tag{16}$$

i_{t-1} is an endogenous state and breaks the link that previously had $P = hx$; now this is no longer true. In particular, using Matlabby notation, $P = hx(1:3, 1:3)$.

And the A_s^{RE} and A_s^{LH} are given by:

$$A_s^{RE} = \begin{pmatrix} \frac{\kappa\sigma}{w} & -\frac{\kappa\sigma}{w} & 1 - \frac{\kappa\sigma\psi_\pi}{w} & 0 \\ \frac{\sigma}{w} & -\frac{\sigma}{w} & -\frac{\sigma\psi_\pi}{w} & 0 \\ \psi_x(\frac{\sigma}{w}) + \psi_\pi(\frac{\kappa\sigma}{w}) & \psi_x(-\frac{\sigma}{w}) + \psi_\pi(-\frac{\kappa\sigma}{w}) + 1 & \psi_x(-\frac{\sigma\psi_\pi}{w}) + \psi_\pi(1 - \frac{\kappa\sigma\psi_\pi}{w}) & \rho \end{pmatrix} \tag{17}$$

$$A_s^{LH} = \begin{pmatrix} g_{\pi s} \\ g_{xs} \\ \psi_\pi g_{\pi s} + \psi_x g_{xs} + \begin{bmatrix} 0 & 1 & 0 & \rho \end{bmatrix} \end{pmatrix} \tag{18}$$

$$g_{\pi s} = (1 - \frac{\kappa\sigma\psi_\pi}{w}) \begin{bmatrix} 0 & 0 & 1 & 0 \end{bmatrix} (I_4 - \alpha\beta hx)^{-1} - \frac{\kappa\sigma}{w} \begin{bmatrix} -1 & 1 & 0 & \rho \end{bmatrix} (I_4 - \beta hx)^{-1} \tag{19}$$

$$g_{xs} = \frac{-\sigma\psi_\pi}{w} \begin{bmatrix} 0 & 0 & 1 & 0 \end{bmatrix} (I_4 - \alpha\beta hx)^{-1} - \frac{\sigma}{w} \begin{bmatrix} -1 & 1 & 0 & \rho \end{bmatrix} (I_4 - \beta hx)^{-1} \tag{20}$$

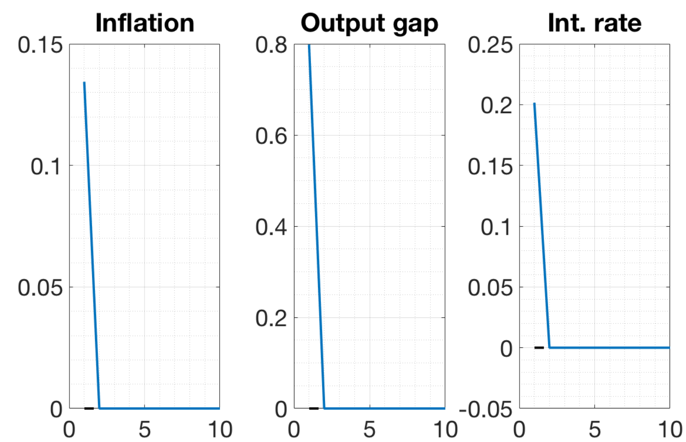
3 Current set of baseline parameters

β	0.99	stochastic discount factor	standard (Woodford 2003/2011)
σ	1	IES	consistent with long-run growth
α	0.5	Calvo probability of not adjusting	match 6-month duration of prices (can increase to 0.75)
ψ_π	1.5	coefficient of inflation in Taylor rule	Taylor
ψ_x	0	coefficient of output gap in Taylor rule	focus on π
$\bar{g}$	0.145	value of the constant gain	CEMP
$\bar{\theta}$	1	threshold deviation between $\hat{\mathbb{E}}$ & $\mathbb{E}$	CEMP: 0.029
ρ_r	0	persistence of natural rate shock	n.a.
ρ_i	0.6	persistence of monetary policy shock	CEMP: 0.877 (can increase to 0.78 if $\alpha = 0.75$)
ρ_u	0	persistence of cost-push shock	CEMP
σ_r	0.1	standard deviation of natural rate shock	n.a.
σ_i	0.359	standard deviation of mon. policy shock	CEMP
σ_u	0.277	standard deviation of cost-push shock	CEMP
θ	10	price elasticity of demand	Woodford 2003/2011, Chari, Kehoe & McGrattan 2000
ω	1.25	elasticity of marginal cost to output	Woodford 2003/2011, Chari, Kehoe & McGrattan 2000

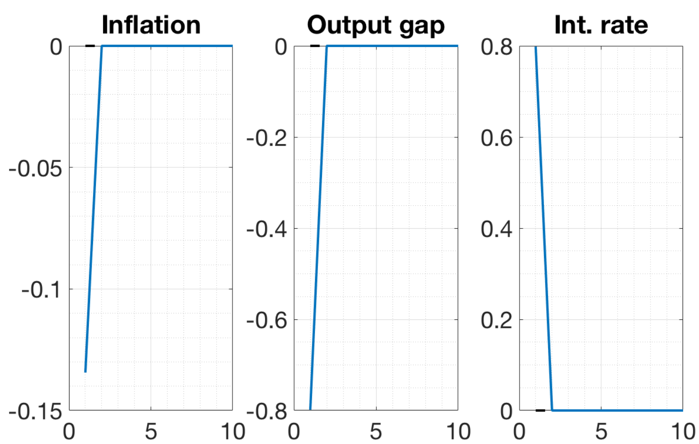
4 IRFs: RE only

4.1 RE: all shocks at a glance

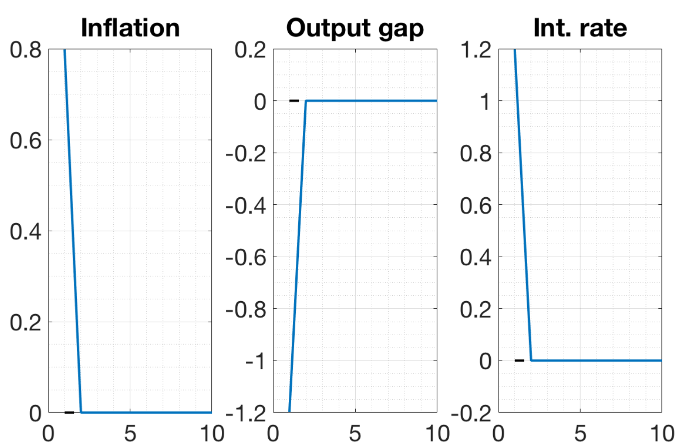
Figure 1: RE: all shocks at a glance



(a) Natural rate shock



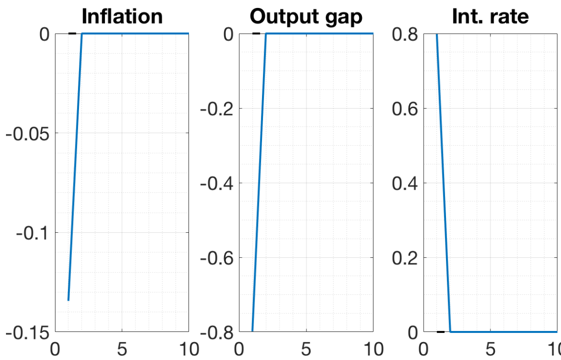
(b) Monetary policy shock



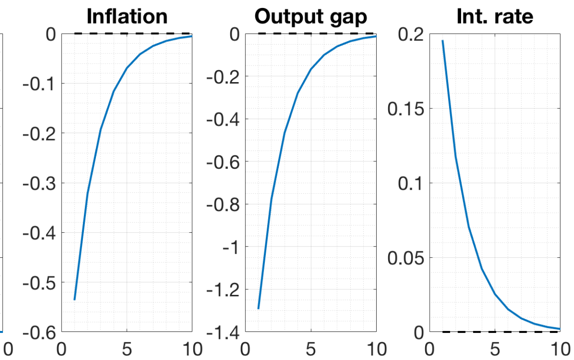
(c) Cost-push shock

4.2 RE: monetary policy shock for various ρ_i

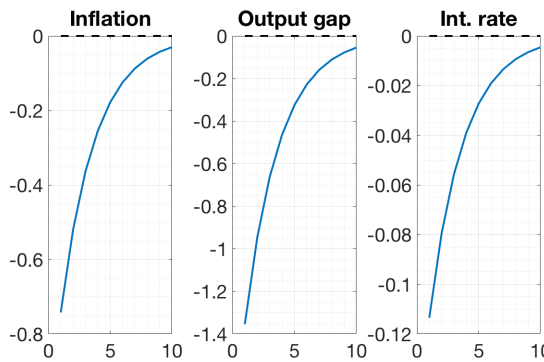
Figure 2: Mon.pol. shock, moving ρ_i



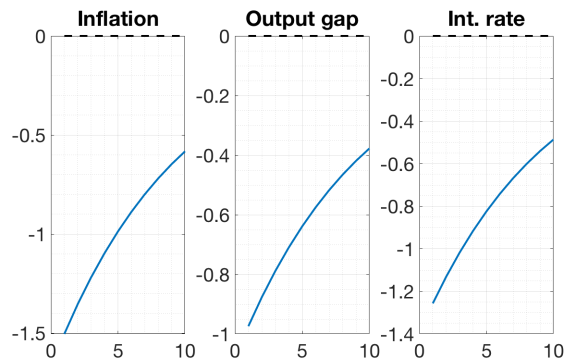
(a) $\rho_i = 0$



(b) $\rho_i = 0.6$



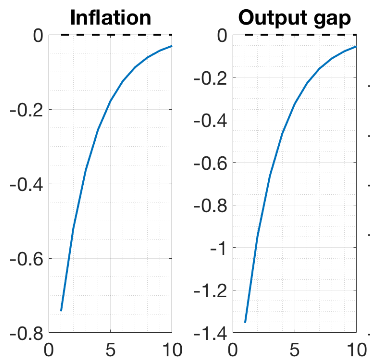
(c) $\rho_i = 0.7$



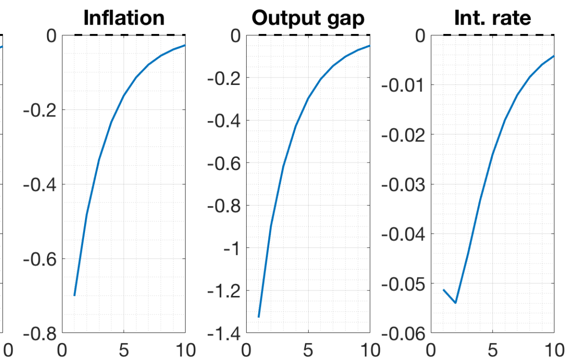
(d) $\rho_i = 0.9$

4.3 RE: monetary policy shock for various ρ (keep $\rho_i = 0.7$)

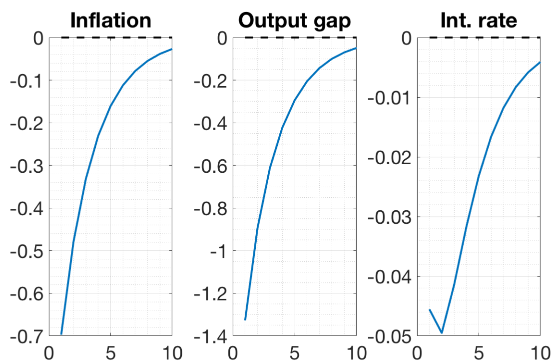
Figure 3: Mon.pol. shock, moving ρ



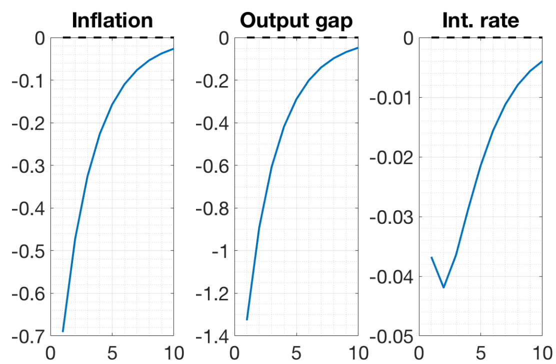
(a) $\rho = 0$



(b) $\rho = 0.6$



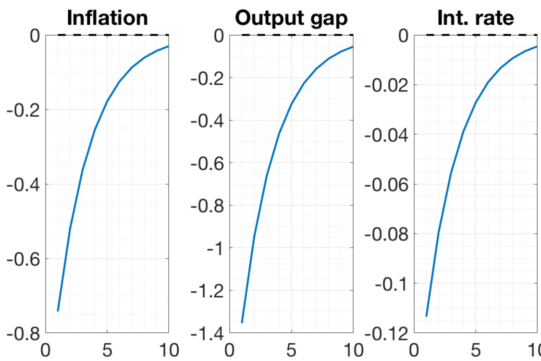
(c) $\rho = 0.7$



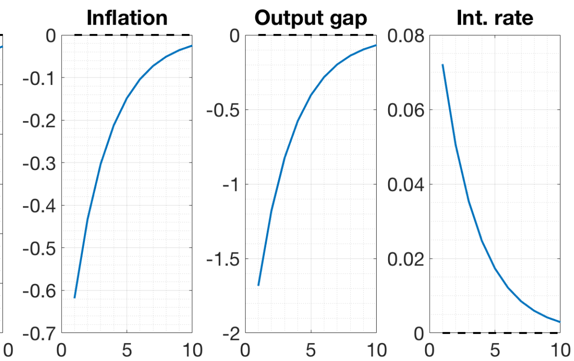
(d) $\rho = 0.9$

4.4 RE: monetary policy shock for various α (keep $\rho_i = 0.7$)

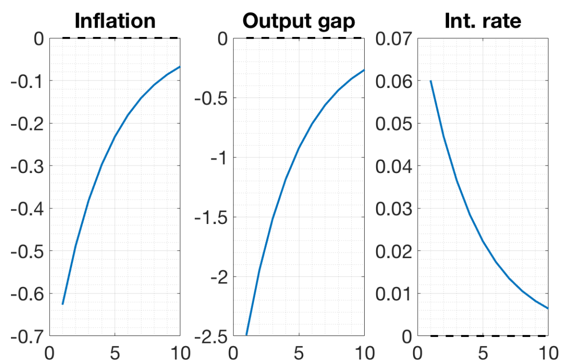
Figure 4: Mon.pol. shock, moving α



(a) $\alpha = 0.5$



(b) $\alpha = 0.6$

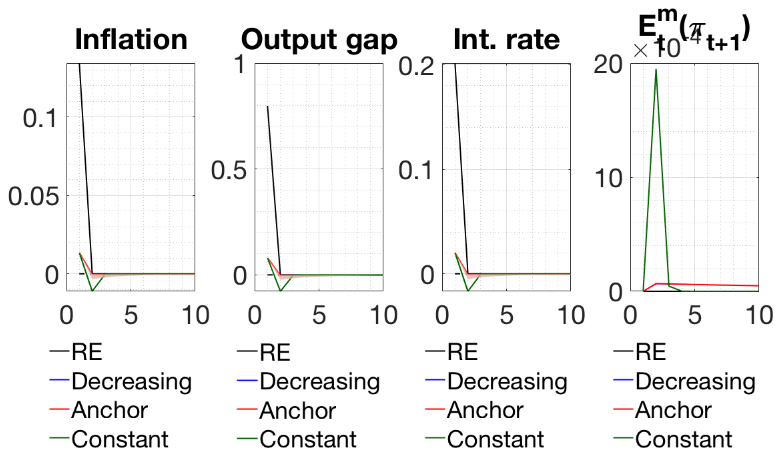


(c) $\alpha = 0.75$, $\rho_i = 0.78$

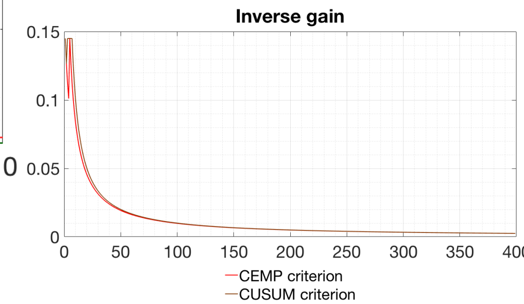
5 IRFs for learning, $\rho_i = 0.6, \alpha = 0.5$

5.1 Natural rate shock, varying ρ

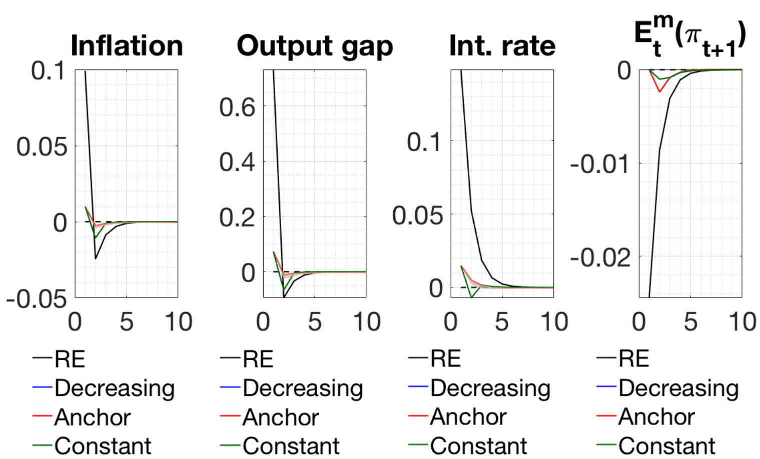
Figure 5: Moving ρ



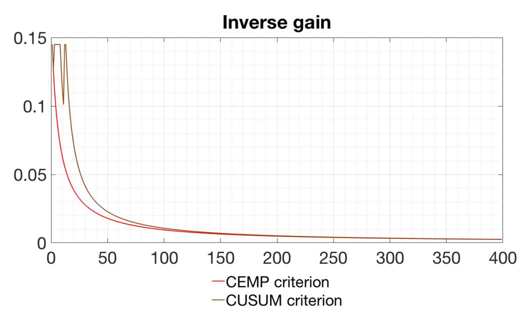
(a) IRFs, $\rho = 0$



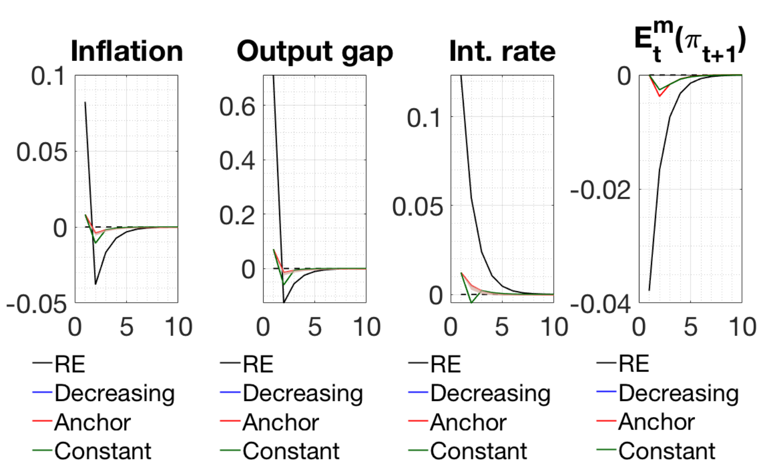
(b) Gain, $\rho = 0$



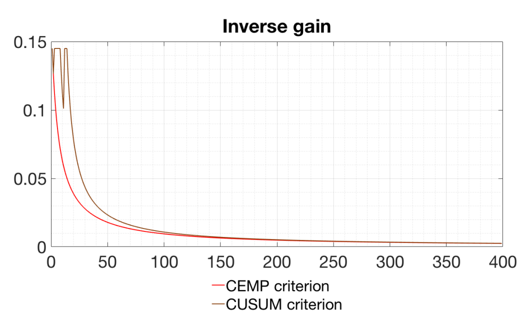
(c) IRFs, $\rho = 0.6$



(d) Gain, $\rho = 0.6$



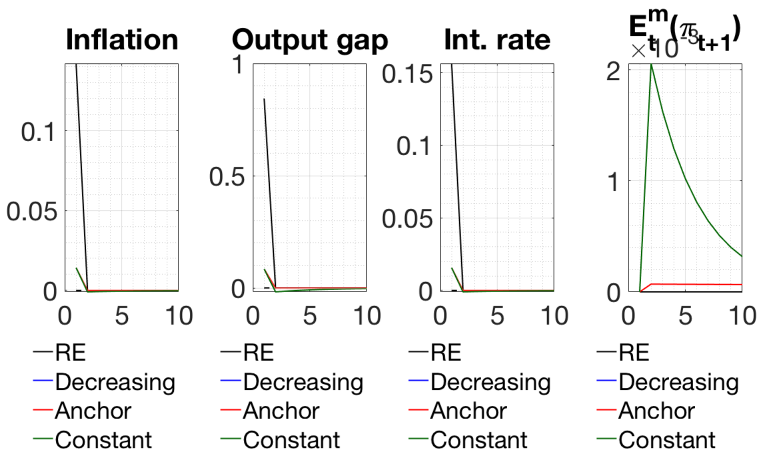
(e) IRFs, $\rho = 0.9$



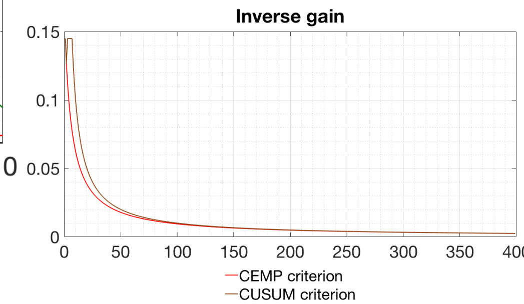
(f) Gain, $\rho = 0.9$

5.2 Natural rate shock, varying ψ_π

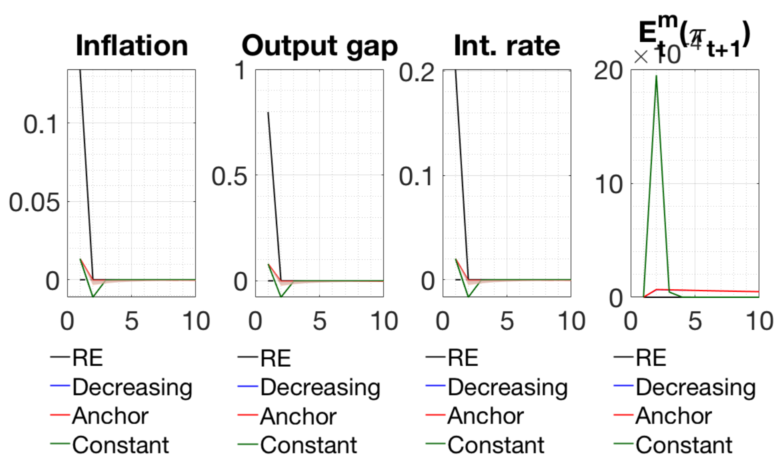
Figure 6: Moving ψ_π



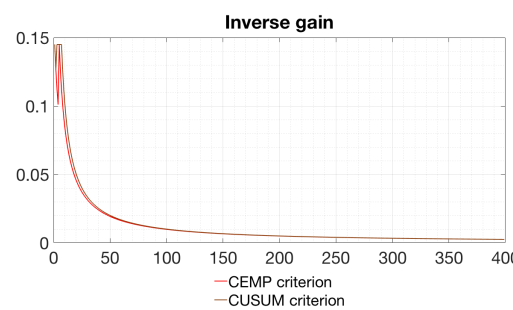
(a) IRFs, $\psi_\pi = 1.1$



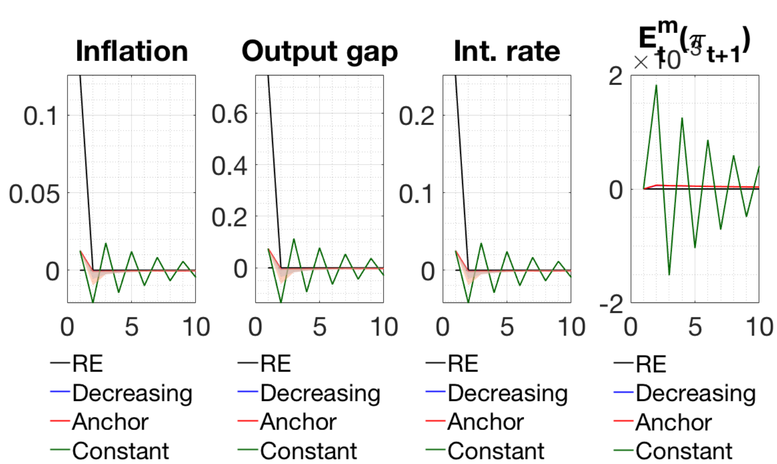
(b) Gain, $\psi_\pi = 1.1$



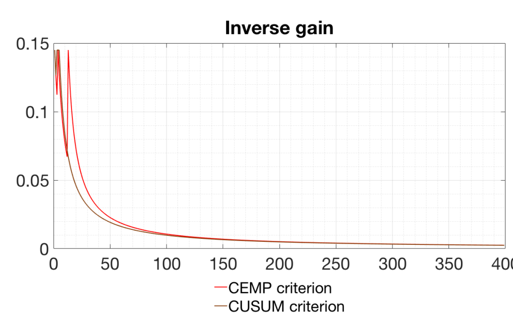
(c) IRFs, $\psi_\pi = 1.5$



(d) Gain, $\psi_\pi = 1.5$



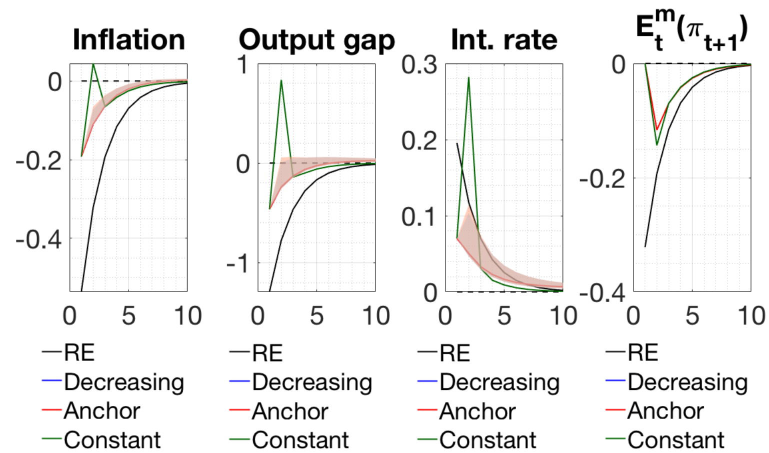
(e) IRFs, $\psi_\pi = 2$



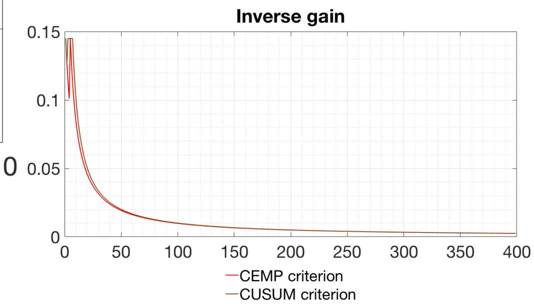
(f) Gain, $\psi_\pi =2$

5.3 Monetary policy shock, varying ρ

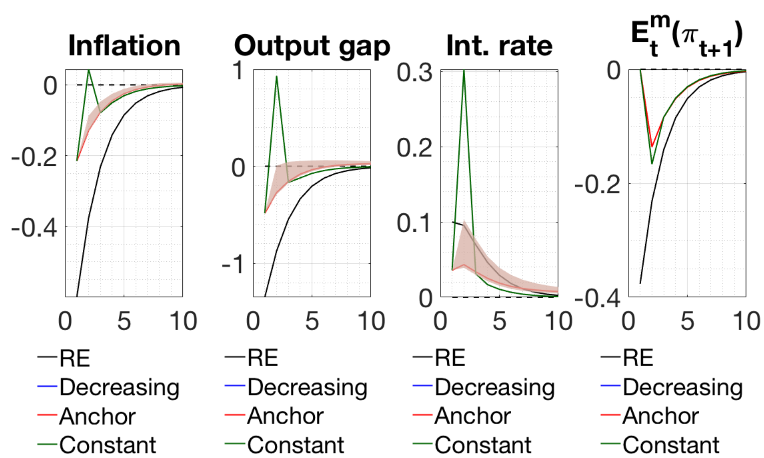
Figure 7: Moving ρ



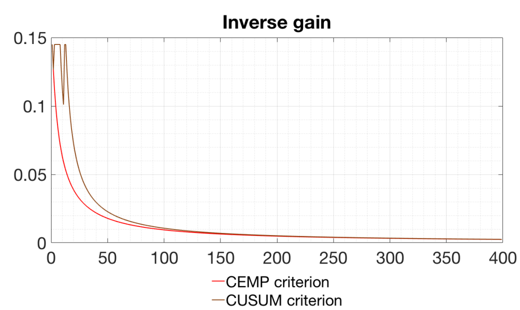
(a) IRFs, $\rho = 0$



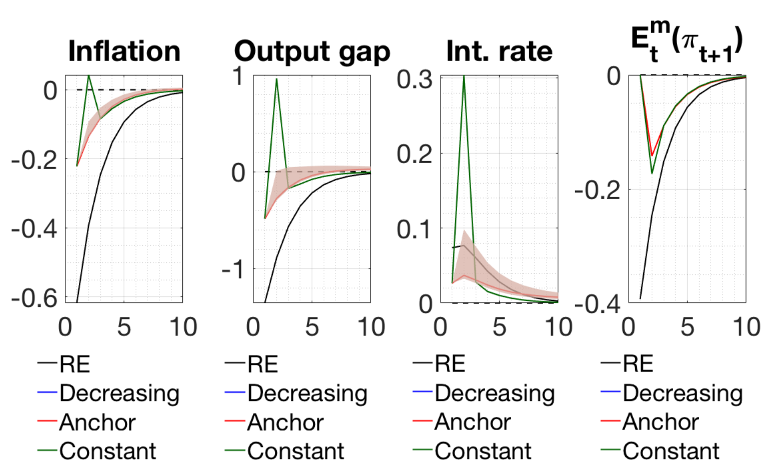
(b) Gain, $\rho = 0$



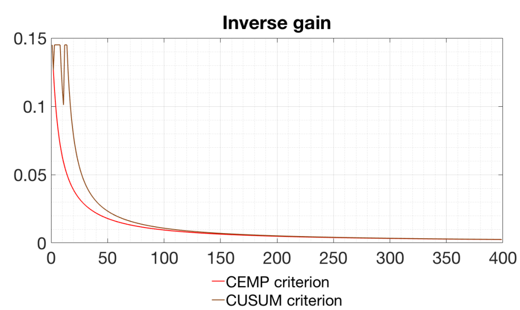
(c) IRFs, $\rho = 0.6$



(d) Gain, $\rho = 0.6$



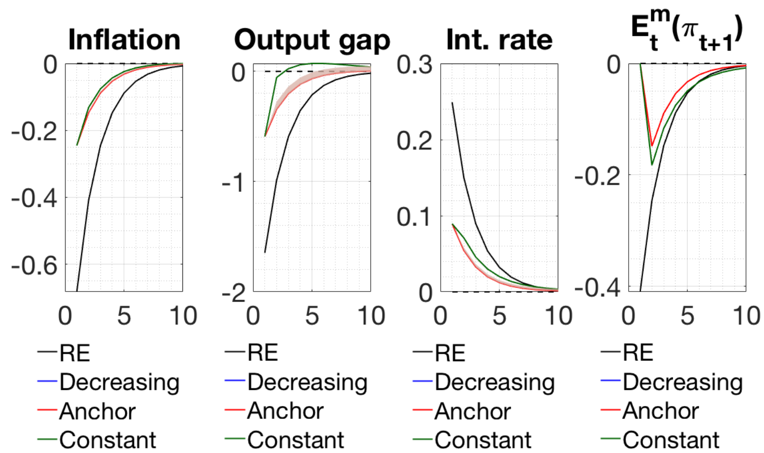
(e) IRFs, $\rho = 0.9$



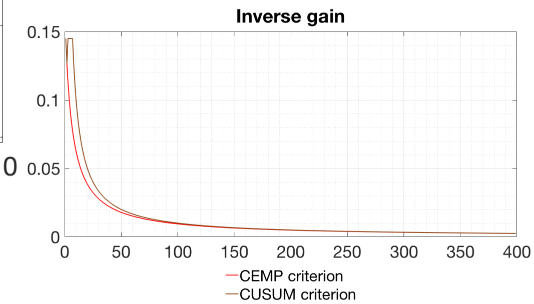
(f) Gain, $\rho = 0.9$

5.4 Monetary policy shock, varying ψ_π

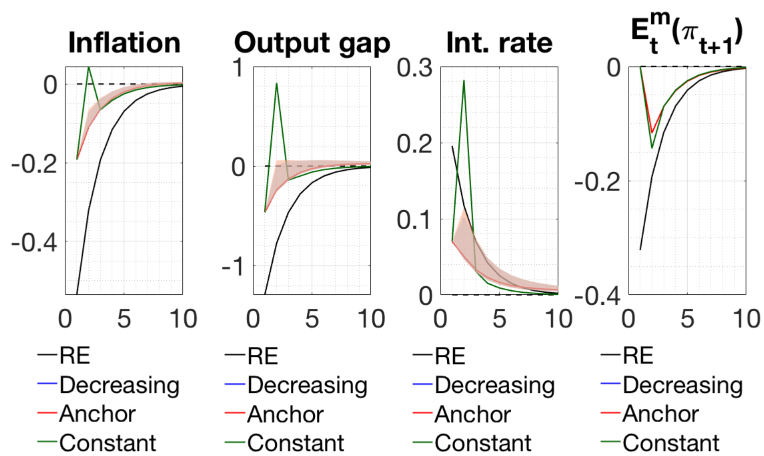
Figure 8: Moving ψ_π



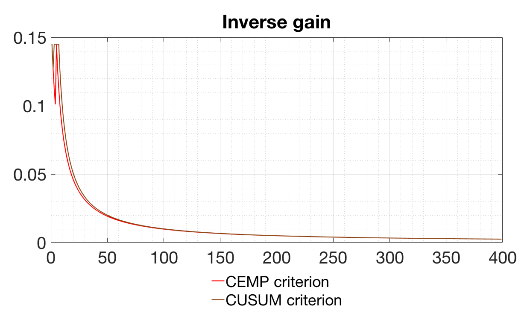
(a) IRFs, $\psi_\pi = 1.1$



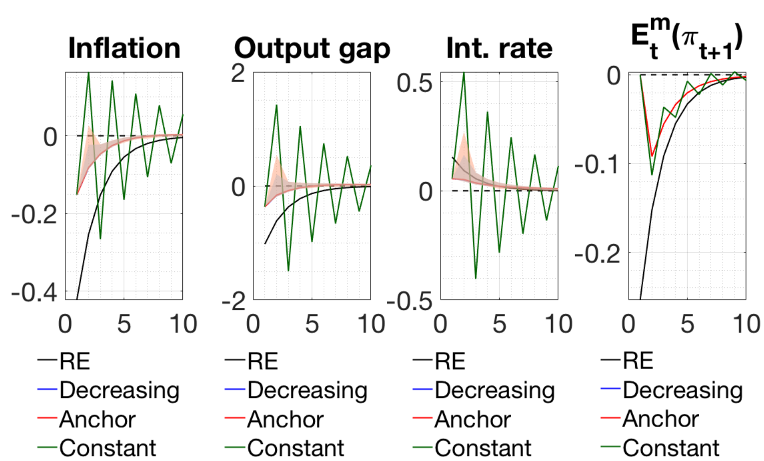
(b) Gain, $\psi_\pi = 1.1$



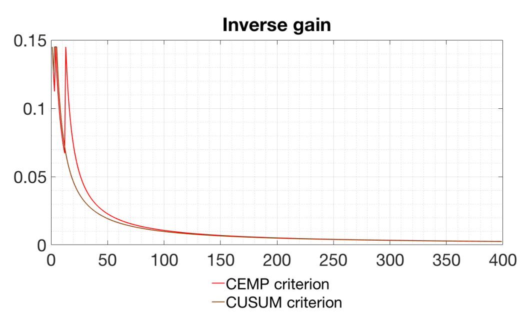
(c) IRFs, $\psi_\pi = 1.5$



(d) Gain, $\psi_\pi = 1.5$



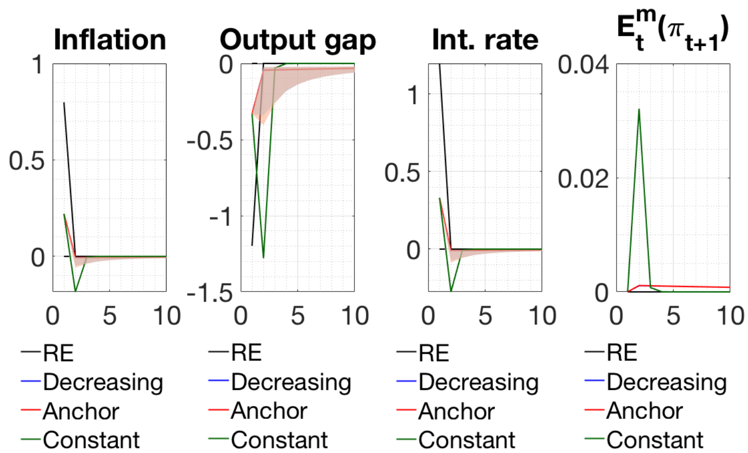
(e) IRFs, $\psi_\pi = 2$



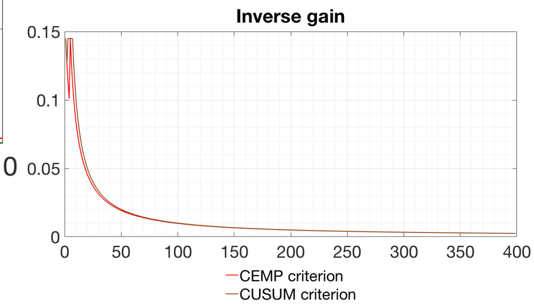
(f) Gain, $\psi_\pi = 2$

5.5 Cost-push shock, varying ρ

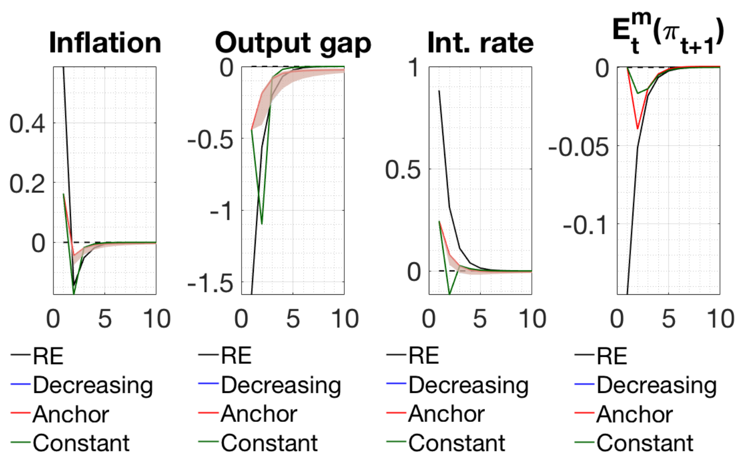
Figure 9: Moving ρ



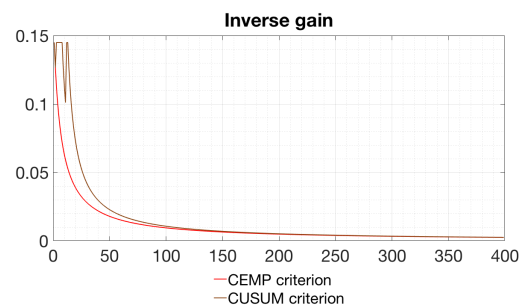
(a) IRFs, $\rho = 0$



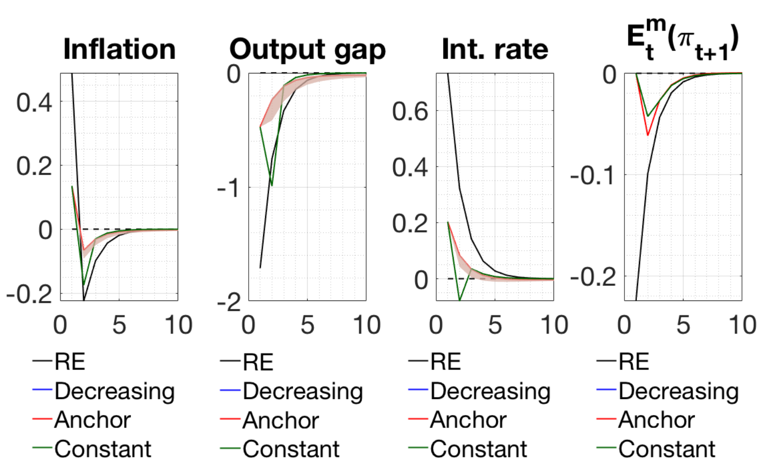
(b) Gain, $\rho = 0$



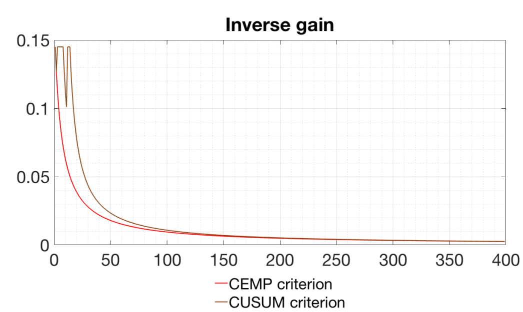
(c) IRFs, $\rho = 0.6$



(d) Gain, $\rho = 0.6$



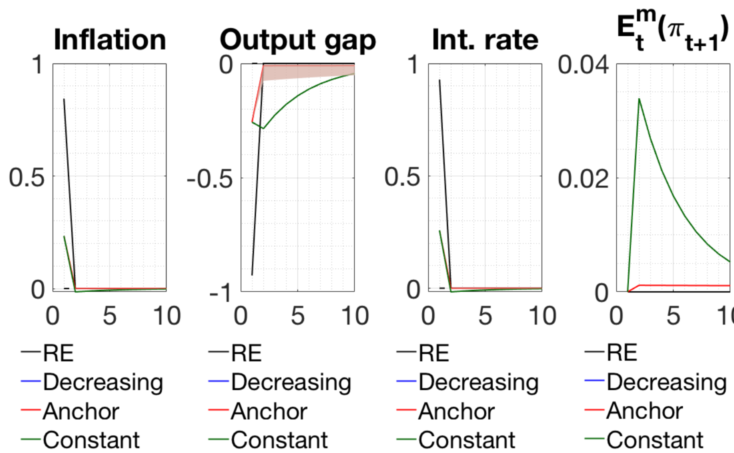
(e) IRFs, $\rho = 0.9$



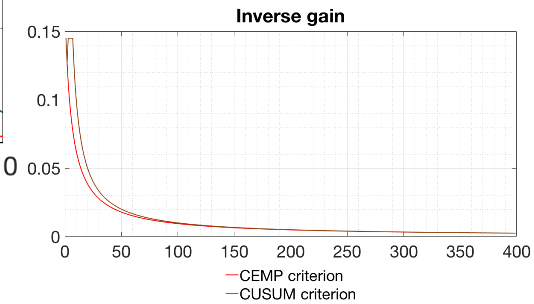
(f) Gain, $\rho = 0.9$

5.6 Cost-push shock, varying ψ_π

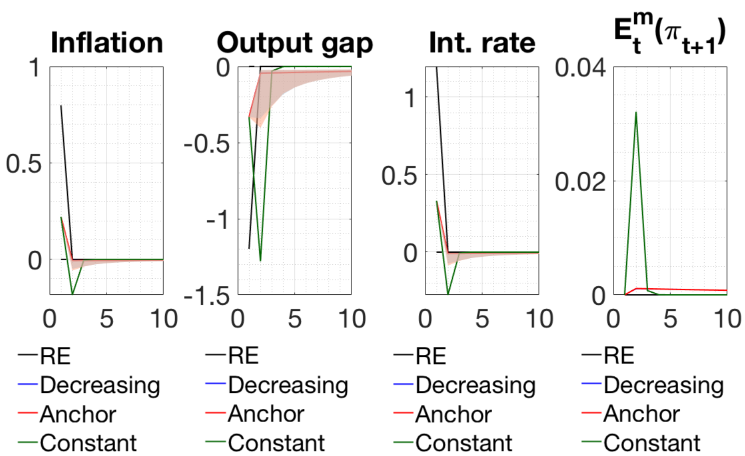
Figure 10: Moving ψ_π



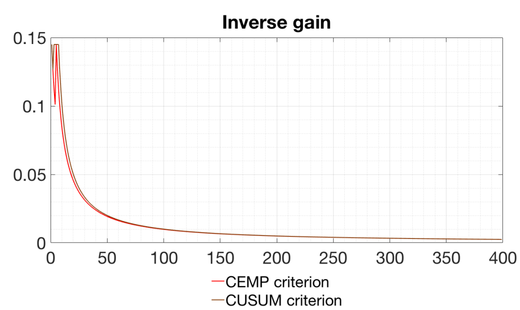
(a) IRFs, $\psi_\pi = 1.1$



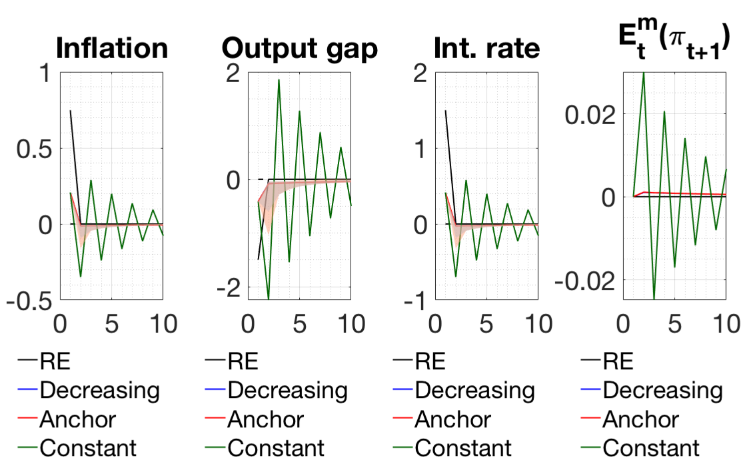
(b) Gain, $\psi_\pi = 1.1$



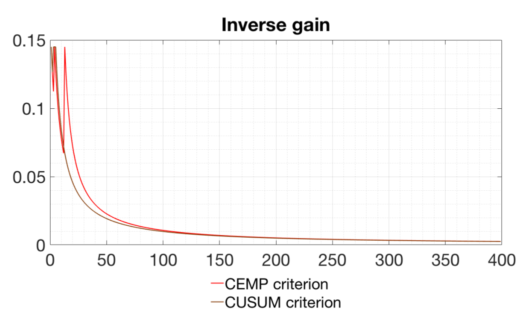
(c) IRFs, $\psi_\pi = 1.5$



(d) Gain, $\psi_\pi = 1.5$



(e) IRFs, $\psi_\pi = 2$



(f) Gain, $\psi_\pi = 2$

5.7 Further analysis plots

Figure 11: An IRF of the endogenous gain for a monetary policy shock

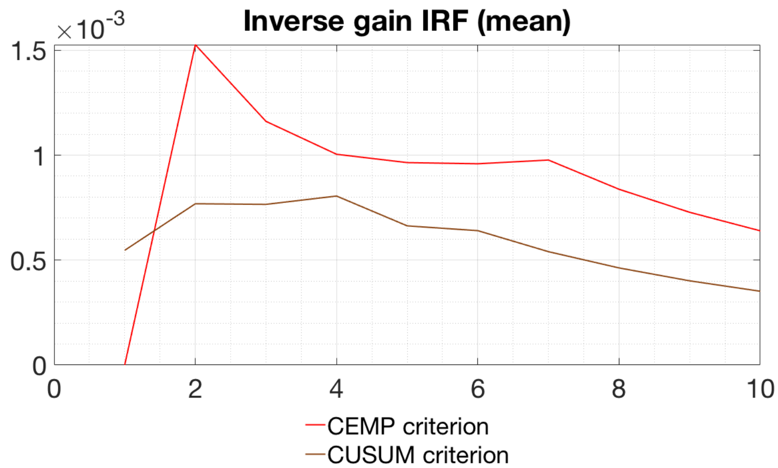


Figure 12: A constant gain learning IRF for a monetary policy shock