

Advanced Macroeconomics II

Monetary Models with Nominal Rigidities

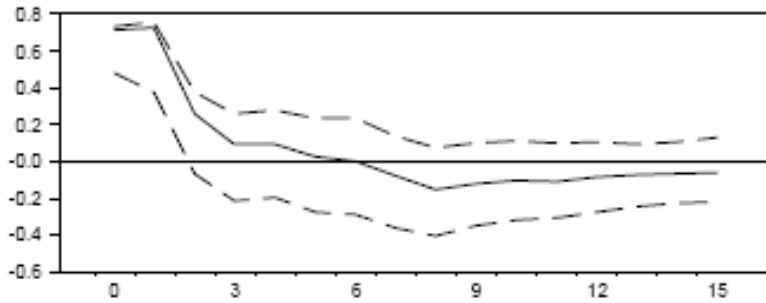
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Motivation

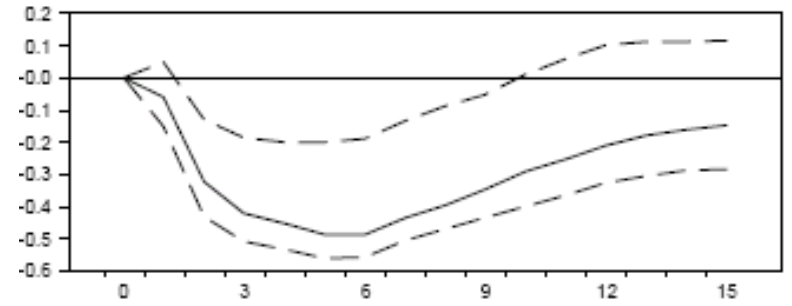
Empirical Evidence

- Macro evidence on the effects of monetary policy shocks
 - (i) persistent real effects
 - (ii) sluggish adjustment of aggregate price level
 - (iii) liquidity effect
- Micro evidence on patterns of price setting

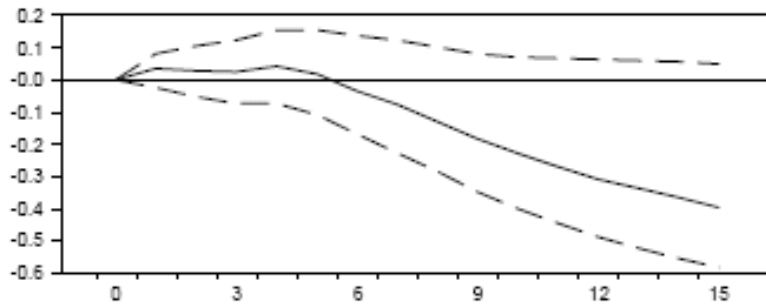
Figure 1. Estimated Dynamic Response to a Monetary Policy Shock



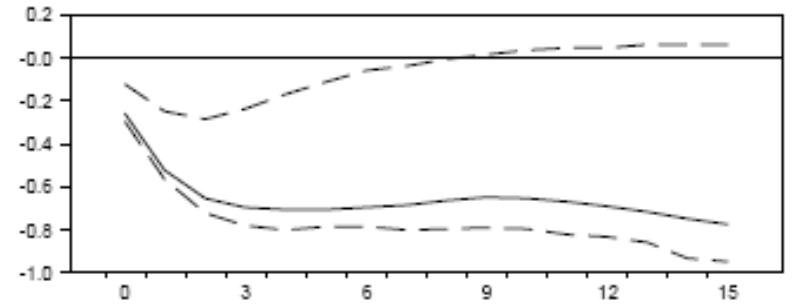
Federal funds rate



GDP

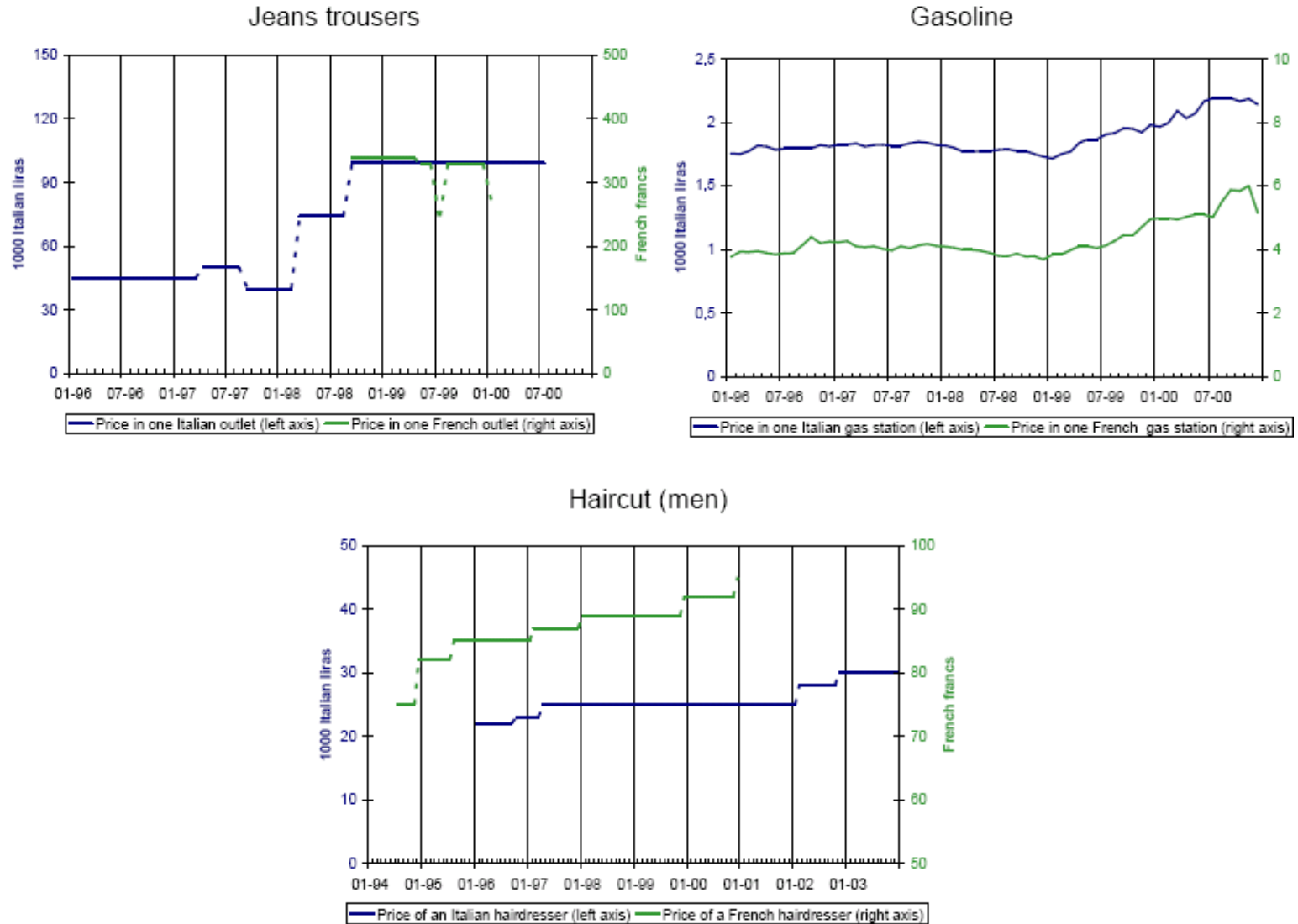


GDP deflator



M2

Figure 1 - Examples of individual price trajectories (French and Italian CPI data)



Note : Actual examples of trajectories, extracted from the French and Italian CPI databases. The databases are described in Baudry *et al.* (2004) and Veronese *et al.* (2005). Prices are in levels, denominated in French Francs and Italian Lira respectively. The dotted lines indicate events of price changes.

Source: Dhyne et al. (JEP, 2006)

TABLE 1. Measures of price stickiness in the euro area and the US (% per month unless otherwise stated).

Statistics		Euro area	US
CPI*	Frequency	15.1	24.8
	Average duration (<i>months</i>)	13.0	6.7
	Median duration (<i>months</i>)	10.6	4.6
PPI†	Frequency	20.0	n.a
Surveys‡	Frequency	15.9	20.8
	Average duration (<i>months</i>)	10.8	8.3
NKPC§	Average durations (<i>months</i>)	13.5–19.2	7.2–8.4
Internet prices¶	Frequency	79.2	64.3

Models with Nominal Rigidities

- differentiated goods and monopolistic competition in goods market
- sticky prices
- competitive labor market, closed economy, no capital accumulation

Maintained assumptions

- households' optimality conditions

$$c_t = E_t\{c_{t+1}\} - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - \rho)$$

$$w_t - p_t = \sigma c_t + \varphi n_t$$

$$m_t - p_t = c_t - \eta i_t$$

- continuum of firms/differentiated goods, indexed by $i \in [0, 1]$
- technology: $Y_t(i) = A_t N_t(i)^{1-\alpha}$
- implied marginal cost:

$$\psi_t(i) = w_t - a_t + \alpha n_t(i) - \log(1 - \alpha)$$

Monopolistic Competition with Flexible Prices

Firm's problem

$$\max_{P_t(i)} P_t(i)Y_t(i) - \mathcal{C}_t(Y_t(i))$$

subject to demand schedule:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} C_t$$

Optimality condition:

$$P_t(i) = \mathcal{M}\Psi_t(i)$$

where $\mathcal{M} \equiv \frac{\epsilon}{\epsilon-1}$ ("optimal gross markup") and $\Psi_t(i) \equiv \mathcal{C}'_t(Y_t(i))$ ("marginal cost").

In logs:

$$\begin{aligned} p_t(i) &= \mu + \psi_t(i) \\ &= \mu + w_t - (a_t - \alpha n_t(i) + \log(1 - \alpha)) \end{aligned}$$

where $\mu \equiv \log \mathcal{M}$ and $\psi_t(i) \equiv \log \Psi_t(i)$.

Equilibrium

- *Goods market*

$$y_t(i) = c_t(i), \quad i \in [0, 1] \quad \implies \quad y_t = c_t$$

- *Aggregate demand*

$$y_t = E_t\{y_{t+1}\} - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - \rho)$$

- *Labor market*

$$n_t = \frac{1}{1 - \alpha}(y_t - a_t)$$
$$w_t = p_t + \sigma c_t + \varphi n_t$$

- *Price setting*

$$p_t = \mu + w_t - (a_t - \alpha n_t + \log(1 - \alpha))$$

- *Asset market*

$$B_t = 0$$

Equilibrium values:

$$n_t = \frac{1 - \sigma}{\sigma(1 - \alpha) + \varphi + \alpha} a_t + \frac{\log(1 - \alpha) - \mu}{\sigma(1 - \alpha) + \varphi + \alpha}$$

$$y_t = c_t = \frac{1 + \varphi}{\sigma(1 - \alpha) + \varphi + \alpha} a_t + \frac{(1 - \alpha)(\log(1 - \alpha) - \mu)}{\sigma(1 - \alpha) + \varphi + \alpha}$$

$$w_t - p_t = \frac{\sigma + \varphi}{\sigma(1 - \alpha) + \varphi + \alpha} a_t + \frac{(\sigma(1 - \alpha) + \varphi)(\log(1 - \alpha) - \mu)}{\sigma(1 - \alpha) + \varphi + \alpha}$$

$$r_t \equiv i_t - E_t\{\pi_{t+1}\} = \rho - \frac{\sigma(1 + \varphi)(1 - \rho_a)}{\sigma(1 - \alpha) + \varphi + \alpha} a_t$$

⇒ role of market power (μ)

⇒ inefficiencies

⇒ monetary policy neutrality

⇒ role of monetary policy and optimal monetary policy as in the classical model

Monopolistic Competition with Constant Prices

Assumptions:

- constant prices: $p_t = p = 0$ (normalization), $t = 0, 1, 2, \dots$
- non-negative markup: $\mu_t = p - \psi_t \geq 0$, $t = 0, 1, 2, \dots$

Equilibrium

$$\begin{aligned}y_t &= c_t \\y_t &= E_t\{y_{t+1}\} - \frac{1}{\sigma}(i_t - \rho) \\n_t &= \frac{1}{1 - \alpha}(y_t - a_t) \\w_t &= \sigma y_t + \varphi n_t \\\mu_t &= -w_t + a_t - \alpha n_t + \log(1 - \alpha)\end{aligned}$$

Monetary policy (I): Interest rate rule

$$i_t = \rho + \phi_y y_t + v_t$$

where

$$v_t = \rho_v v_{t-1} + \varepsilon_t^v$$

Equilibrium:

$$y_t = -\frac{1}{\sigma(1 - \rho_v) + \phi_y} v_t$$
$$n_t = -\frac{1}{[\sigma(1 - \rho_v) + \phi_y](1 - \alpha)} v_t - \frac{1}{1 - \alpha} a_t$$

\implies *non-neutrality* of monetary policy: two dimensions

\implies technology shocks lower employment, unless offset by policy response

Exercise: derive an interest rate rule that will replicate the flexible price equilibrium

Monetary policy (II): Exogenous money supply

Combining money demand and aggregate demand:

$$y_t = \frac{1}{1 + \sigma\eta} \sum_{k=0}^{\infty} \left(\frac{\sigma\eta}{1 + \sigma\eta} \right)^k E_t\{m_{t+k}\}$$

Example: $m_t = \rho_m m_{t-1} + \varepsilon_t^m$

$$y_t = \frac{1}{1 + \sigma\eta(1 - \rho_m)} m_t$$
$$n_t = \frac{1}{(1 - \alpha)[1 + \sigma\eta(1 - \rho_m)]} m_t - \frac{1}{1 - \alpha} a_t$$

\implies *non-neutrality* of money supply changes (anticipated and unanticipated)

\implies technology shocks lower employment, unless offset by policy response

The Basic New Keynesian Model

- *The New Keynesian Phillips Curve*

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa \tilde{y}_t$$

where $\tilde{y}_t \equiv y_t - y_t^n$ ("output gap").

- *Dynamic IS equation*

$$\tilde{y}_t = -\frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - r_t^n) + E_t\{\tilde{y}_{t+1}\}$$

- *Interest rate rule*

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \hat{y}_t + v_t$$

The New Keynesian Phillips Curve

- *Assumption*: probability of price adjustment: $1 - \theta$ (independent across firms)
 - \Rightarrow fraction of firms keeping price unchanged: θ
 - $\Rightarrow \theta \in [0, 1]$: index of price rigidity

- *Price level evolution*

$$p_t = \theta p_{t-1} + (1 - \theta) p_t^*$$

- *Optimal price setting*

$$p_t^* = \mu + (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t\{\psi_{t+k}\}$$

- *Combining both equations*

$$\pi_t = \beta E_t\{\pi_{t+1}\} - \lambda(\mu_t - \mu)$$

where $\mu_t \equiv p_t - \psi_t$ (average price markup) and $\lambda \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}$ (assuming $\alpha = 0$).

- *Average markup* (assumption: $\alpha = 0$)

$$\mu_t = p_t - (w_t - a_t)$$

- *Labor market equilibrium*

$$w_t - p_t = \sigma c_t + \varphi n_t$$

$$n_t = y_t - a_t$$

- *Goods market equilibrium*

$$y_t = c_t$$

- *Average price markup and the output gap*

$$\mu_t = (1 + \varphi)a_t - (\sigma + \varphi)y_t$$

With flexible prices:

$$\mu = (1 + \varphi)a_t - (\sigma + \varphi)y_t^n$$

$$\Rightarrow y_t^n = -\frac{\mu}{\sigma + \varphi} + \frac{1 + \varphi}{\sigma + \varphi}a_t$$

Combining both equations:

$$\mu_t - \mu = -(\sigma + \varphi) \tilde{y}_t$$

- *New Keynesian Phillips curve*

$$\pi_t = \beta E_t \{ \pi_{t+1} \} + \kappa \tilde{y}_t$$

where $\kappa \equiv \lambda(\sigma + \varphi)$

- *Properties*

(i) "Forward-looking"

$$\pi_t = \kappa \sum_{k=0}^{\infty} \beta^k E_t \{ \tilde{y}_{t+k} \}$$

⇒ past inflation is irrelevant

(ii) No trade-off between stabilization of inflation and output gap.

⇒ "Divine coincidence" (Blanchard-Galí)

⇒ no costs of disinflations.

(iii) Two "output gap" concepts:

$$\hat{y}_t = y_t - f(t)$$

$$\tilde{y}_t \equiv y_t - y_t^n$$

⇒ complicates empirical evaluation (Galí-Gertler 1998).

Dynamic IS Equation

- Intertemporal optimality condition + good market equilibrium

$$y_t = E_t\{y_{t+1}\} - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - \rho)$$

Combined with $\tilde{y}_t \equiv y_t - y_t^n$

$$\tilde{y}_t = -\frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - r_t^n) + E_t\{\tilde{y}_{t+1}\}$$

where

$$\begin{aligned} r_t^n &\equiv \rho + \sigma E_t\{\Delta y_{t+1}^n\} \\ &= \rho + \frac{\sigma(1 + \varphi)}{\sigma + \varphi} E_t\{\Delta a_{t+1}\} \end{aligned}$$

Monetary Policy

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \hat{y}_t + v_t$$

The Basic New Keynesian Model

- *The New Keynesian Phillips Curve*

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa \tilde{y}_t$$

where $\tilde{y}_t \equiv y_t - y_t^n$ ("output gap").

- *Dynamic IS equation*

$$\tilde{y}_t = -\frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - r_t^n) + E_t\{\tilde{y}_{t+1}\}$$

- *Interest Rate Rule*

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \hat{y}_t + v_t$$

- *Exogenous variables*

$$v_t = \rho_v v_{t-1} + \varepsilon_t^v$$

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a$$

Solving for the Equilibrium

- Assumptions (for simplicity):

(i) $\{v_t\}$ and $\{a_t\}$ white noise ($\rho_a = \rho_v = 0$)

(ii) $i_t = \rho + \phi_\pi \pi_t + v_t$

(iii) $\sigma = 1$

$$\Rightarrow \widehat{r}_t^n = -a_t$$

$$\Rightarrow \widehat{y}_t^n = a_t$$

- Conjecture ("method of undetermined coefficients"):

$$\widetilde{y}_t = \psi_{ya} a_t + \psi_{yv} v_t$$

$$\pi_t = \psi_{\pi a} a_t + \psi_{\pi v} v_t$$

- Solution

$$\tilde{y}_t = -\frac{1}{1 + \kappa\phi_\pi}a_t - \frac{1}{1 + \kappa\phi_\pi}v_t$$

$$\pi_t = -\frac{\kappa}{1 + \kappa\phi_\pi}a_t - \frac{\kappa}{1 + \kappa\phi_\pi}v_t$$

$$\hat{y}_t = \tilde{y}_t + \hat{y}_t^n = \frac{\kappa\phi_\pi}{1 + \kappa\phi_\pi}a_t - \frac{1}{1 + \kappa\phi_\pi}v_t$$

$$\hat{n}_t = \hat{y}_t - a_t = -\frac{1}{1 + \kappa\phi_\pi}a_t - \frac{1}{1 + \kappa\phi_\pi}v_t$$

$$i_t = \rho - \frac{\kappa\phi_\pi}{1 + \kappa\phi_\pi}a_t + \frac{1}{1 + \kappa\phi_\pi}v_t$$

$$m_t = \frac{\kappa(\phi_\pi(1 + \eta) - 1)}{1 + \kappa\phi_\pi}a_t - \frac{1 + \kappa + \eta}{1 + \kappa\phi_\pi}v_t + p_{t-1}$$

- Discussion

Simulations of Calibrated Model (Galí 2008/ rev2015)

- Calibration

$$\beta = 0.99, \sigma = 1, \varphi = 5, \epsilon = 9$$

$$\alpha = 1/4$$

$$\phi_\pi = 1.5, \phi_y = 0.5/4$$

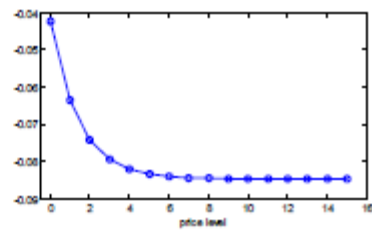
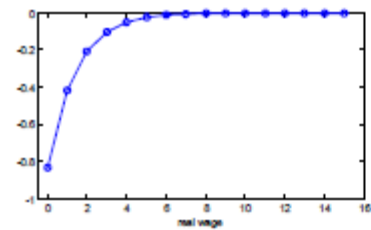
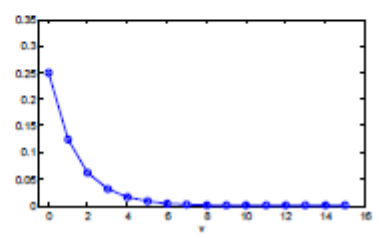
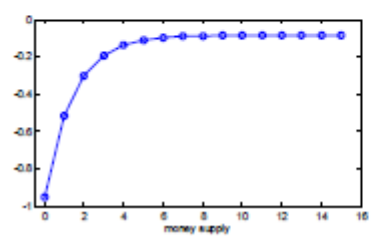
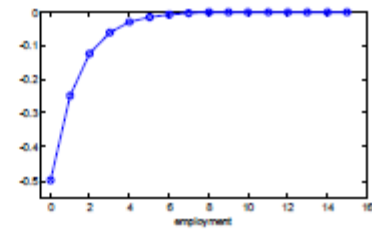
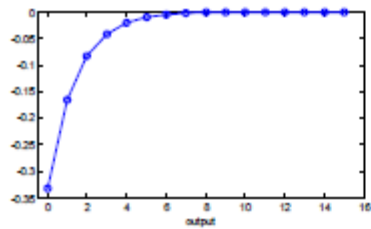
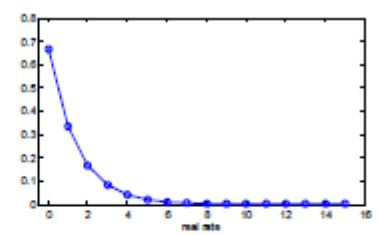
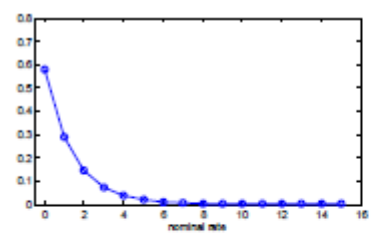
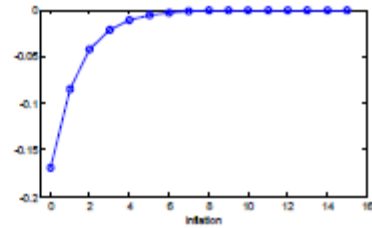
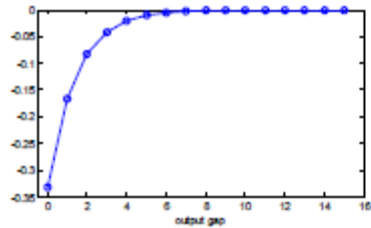
$$\theta = 3/4$$

$$\eta = 4$$

$$\rho_v = 0.5, \rho_a = 0.9$$

- Effects of monetary policy shock
- Effects of technology shock

Dynamic responses to a monetary policy shock: Interest rate rule



Dynamic responses to a technology shock: Interest rate rule

