Learning about perceived inflation target and stabilisation policy

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Objectives

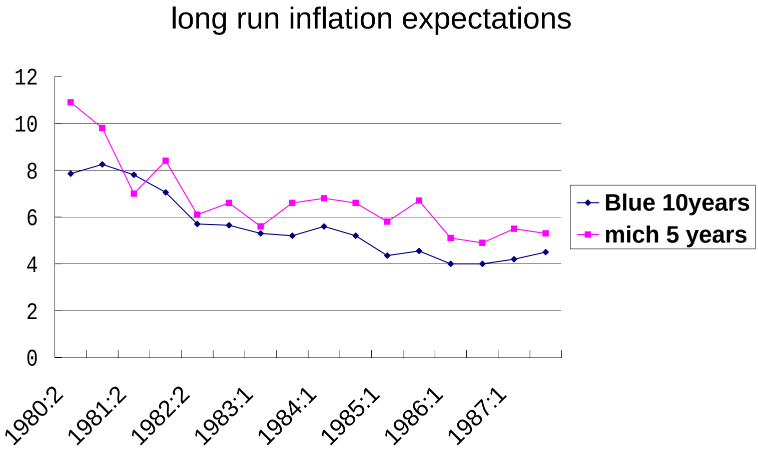
- Analyse the interaction between:
  - private-sector uncertainty about inflation target (π^*)
  - central-bank uncertainty about private-sector belief about π^* (perceived inflation target)
- Implications for
  - inflation persistence and volatility
  - time-varying inflation process

Motivation 1: Uncertainty about perceived inflation target

Measures of perceived inflation target are noisy when monetary policy loses nominal anchor
Example: US in late '70s-'80s

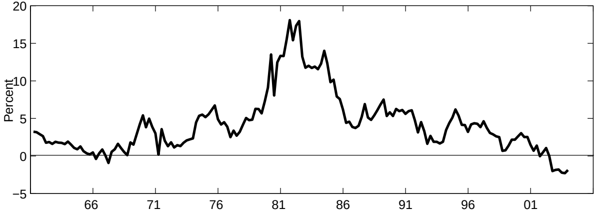
- Survey measures of LR inflation expectations as proxies
  - Blue chip survey: 8%
  - Michigan survey: 10-11%
- Model-based measures of belief about inflation target
  - Kozicki-Tinsley ('01, '05): 8 % (estimated target $\simeq 3.5\%$)
  - Bekaert et. al. ('05): 14%

Survey measures of perceived inflation target

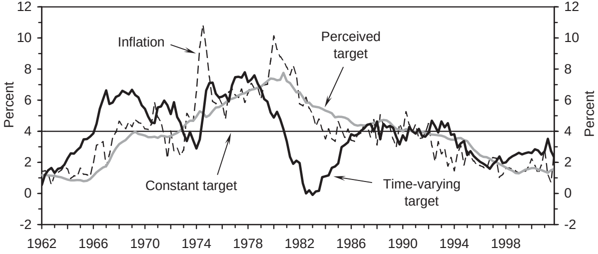


Model-based measures of perceived inflation target

Bakaert, Cho, Moleno '05



Kozicki and Tinsley '05



Motivation 2: inflation and misinformation

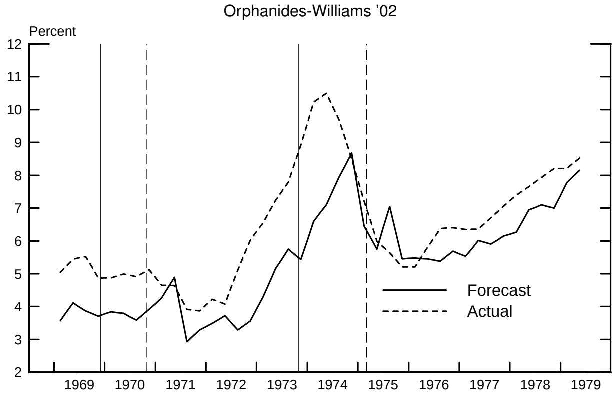
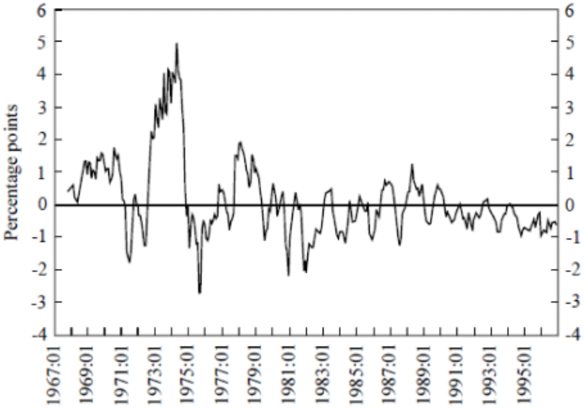


FIGURE 1: INFLATION FORECASTS AND OUTCOMES

- Forecast errors larger in the 70s

Motivation 2: inflation and misinformation

Romer and Romer '02



Motivation 2: inflation and misinformation

Orphanides-Williams '02

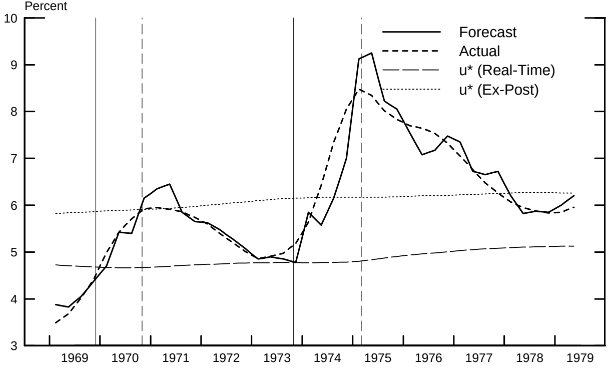


FIGURE 2: UNEMPLOYMENT FORECASTS AND OUTCOMES

- Estimate of natural rate biased. What caused this?

Related Literature: 'Great Inflation'

- Time inconsistency (Kydland-Prescott)
- Sunspot fluctuations (Clarida-Gali-Gertler, '99 QJE)
- Misspecified model (Sargent '99, Romer-Romer '02)
- Misinformation (Orphanides '01 AER, '02 AER, '03 JME)
- Imperfect credibility (Erceg-Levin, '03 JME)
- This paper is related to Orphanides and Erceg-Levin.
  - Weak nominal anchor disturbs stabilisation policy. How?
  - PS uncertainty about inflation target represents uncertainty facing Central Bank

Questions addressed

- Unobservable (or incredible) π^*
  - how does this affect private agents?
  - how does this affect central bank?
- What are the interaction between the two?

Issues

Feedback from private-sector (PS) uncertainty about π^* to monetary policy

- PS belief about π^*
  - unobservable to CB
  - CB cannot distinguish from other shocks
- Expectations formation by PS affected by CB information problem

Negative feedback on stabilisation

an example

Suppose nominal interest rate i_t increases

- Two possibilities ($i_t = r_t + E_{t|p}\pi_{t+1}$)
  - inflation expectations increased
  - natural rate increased
- When CB uncertain about PS belief about π^*, CB cannot distinguish those two.

Outline of the model

A simple model of inflation determination

- Flexible prices
- Exogenous output (exogenous natural interest rate = real rate)
- Monetary policy follows a simple rule
  (No optimisation. Focus on filtering and equilibrium)
- π^* unobservable to PS. Perceived target $\pi^*_{t|p}$
- $\pi^*_{t|p}$ unobservable to CB
  (Information structure explained in detail later)

Results

- Inflation persistence caused by:
  - PS filtering about π^*
  - CB filtering about $\pi^*_{t|p}$

  (Recursive nature of filtering)
- Inflation volatility caused by CB's failure to keep track of r_t (Feedback effects of PS uncertainty on stabilisation)
- Persistence and volatility decrease over time
- Weak nominal anchor and MP mistakes are related with each other

Structural Equations

Fisher equation

A version of 'expectational' IS curve

$$i_t = r_t + E_{t|p}\pi_{t+1} \quad \text{(IS)}$$

i_t: nominal interest rate;
r_t: natural rate; π_t: inflation

- Can be derived from Euler equation under flexible-price equilibrium (Woodford '04, Ch2)
- $E_{t|p}$: expectation operator conditional on PS information

Monetary policy rule

CB follows a simple rule:

$$i_t = \phi(\pi_t - \pi^*) + \pi^* + E_{t|c} r_t + u_t, \ \phi > 1. \quad \text{(MP)}$$

π^*: inflation target; u_t: monetary policy shock

- $E_{t|c}$: expectation conditional on CB information
- CB wants to keep track of natural rate r_t

Equilibrium

- Endogenous variables $\{i_t, \pi_t\}_{t=0}^{\infty}$ satisfy (IS) and (MP),
- taking exogenous variables $\left\{r_t^n, u_t\right\}_{t=0}^{\infty}$ as given,
- expectations are rational conditional on information set of PS and CB

Benchmark: When π^* is credible

- π^* is common knowledge
- From (IS) and (MP),

$$\pi_t = \pi^* + E_t \sum_{s=0}^{\infty} \phi^{-(s+1)} u_{t+s}$$

- When $E_t u_{t+s} = 0$ for $s > 1$,

$$\pi_t = \pi^* + \phi^{-1} u_t.$$

Benchmark: When π^* is credible

Equilibrium is given by

$$\pi_t = \pi^* + \phi^{-1} u_t.$$

- CB fully offsets the effects of r_t on π_t
- Inflation expectations anchored by π^*
- By looking at i_t, CB can identify r_t even if r_t not directly observable.
  $(i_t = r_t + E_t \pi_{t+1} = r_t + \pi^*)$

Equilibrium under incredible π^*

Assumptions on private-sector information

- π^* and u_t: unobservable.
  PS belief about π^*: denoted by $\pi^*_{t|p}$
- i_t, π_t, r_t, ϕ: observable
- CB belief ($E_{t|c}\pi^*_{t|p}$ and $E_{t|c}r_t$): observable (see next page)
  - Only need to analyse up to 3rd-order belief

Assumptions on Central-Bank information

- r_t, $E_{t|p}\pi_{t+1}$, $\pi^*_{t|p}$: unobservable
  - belief about belief: $E_{t|c}\pi^*_{t|p}$
  - belief about r_t: $E_{t|c}r_t$
  - CB announces its belief

  What we have in mind: CB publishes its economic outlook
- i_t, π_t, u_t, π^*: observable

Normality assumption

r_t and u_t are iid normal

$$r_t \sim N(0, \sigma_r^2),\ \gamma_r \equiv 1/\sigma_r^2 \text{ (precision)}$$

$$u_t \sim N(0, \sigma_u^2),\ \gamma_u \equiv 1/\sigma_u^2 \text{ (precision)}$$

- Common knowledge
- Can obtain analytical results
- The main results survive if we allow shock-persistence

Equilibrium given belief

From (IS) and (MP),

$$\pi_t = \phi^{-1}\left[(\phi-1)\pi^* - u_t + (r_t - E_{t|c} r_t) + E_{t|p}\pi_{t+1}\right]$$

- $r_t - E_{t|c} r_t$: CB estimation error
- Inflation given CB belief

$$\pi_t = \pi^* - \phi^{-1} u_t + \phi^{-1}(E_{t|c}\pi^*_{t|p} - \pi^*).$$

- Inflation given PA belief

$$\pi_t = \pi^* - \phi^{-1} u_t + \phi^{-1}(E_{t|p}\pi^* - \pi^*) + E_{t|p}\sum_{j=0}^{\infty}\phi^{-(j+1)}\left[r^n_{t+j} - E_{t+j|c} r^n_{t+j}\right]$$

- 2nd order belief matters

Private-sector filtering

PS observation equation (derived from MP rule)

$$i_t - \phi\pi_t - E_{t|c}r_t = (1-\phi)\pi^* + u_t.$$

- Observable: $z_t \equiv i_t - \phi\pi_t - E_{t|c}r_t$
- Sequential updating of $\pi^*_{t|p}$

Private-sector filtering

- Perceived inflation target after t observations:

$$\pi^*_{t|p} - \pi^* = b_t(\pi^*_{t-1|p} - \pi^*) + \frac{1-b_t}{1-\phi}u_t, \tag{1}$$

  - $b_t \to 1$ as $t \to \infty$
  - Private sector eventually learn π^*

Equilibrium and CB filtering

Simultaneity

- Equilibrium depends on CB policy
- CB policy depends on CB filtering
- CB filtering depends on statistical relation between observables and unobservables in equilibrium
- Solve by the method of undetermined coefficients (time-varying coefficients).

CB-filtering about $\pi^*_{t|p}$

- Observation equation (Fisher equation)

$$i_t = r_t + E_{t|p}\pi_{t+1}$$

- $E_{t|p}\pi_{t+1}$ is determined simultaneously with CB filtering
- Estimated perceived inflation target

$$E_{t|c}\pi^*_{t|p} - \pi^*_{t|p} = f_t(E_{t-1|c}\pi^*_{t-1|p} - \pi^*_{t-1|p}) + g_t r_t \quad (2)$$

- Estimated natural rate

$$E_{t|c}r_t - r_t = h_t(E_{t-1|c}r_{t-1} - r_{t-1}) + k_t r_t \quad (3)$$

- f_t, g_t, h_t, k_t: time-varying coefficients

Summary of Equilibrium

- Equilibrium is given by

$$\pi_t = \underbrace{\pi^* - \phi^{-1} u_t}_{\bar{\pi}_t} + \underbrace{\phi^{-1}(E_{t|c}\pi^*_{t|p} - \pi^*)}_{\tilde{\pi}_t}$$

- $\tilde{\pi}_t = \phi^{-1}\left\{\underbrace{(\pi^*_{t|p} - \pi^*)}_{\text{PS uncertainty}} + \underbrace{(E_{t|c}\pi^*_{t|p} - \pi^*_{t|p})}_{\text{CB uncertainty}}\right\}$
- $(\pi^*_{t|p} - \pi^*)$ is given by (1)
- $(E_{t|c}\pi^*_{t|p} - \pi^*_{t|p})$ is given by (2)

Implications for great inflation: persistence and volatility

Inflation dynamics

Our model implies $\tilde{\pi}_t$ is persistence and volatile

- $(E_{t|c}\pi^*_{t|p} - \pi^*_{t|p}) \propto (r_t - E_{t|c}r_t)$: represents estimation error of r_t.
- persistence: recursive nature of learning.
- volatility: Negative feedback of uncertainty about π^* on stabilisation policy

Great inflation

- High and persistent inflation in the late '70s-early '80s
- Orphanides ('01 AER, '02 AER, '03: JME): Mis-measurement in the output gap/natural interest rate
  - Misinformation is exogenously given.
- Erceg-Levin ('03 JME): weak nominal anchor (imperfect credibility) causes inflation persistence
  - Mainly focuses on persistence but not volatility.

Great inflation

- This paper connects Orphanides and Erceg-Levin
- Imperfect credibility creates uncertainty about perceived inflation target
- $\rightarrow$ identification of shocks difficult. $\rightarrow$ source of natural rate mis-measurement
- this causes policy mistakes, generating inflation volatility and persistence.

Policy implications

- Orphanides
  - Misinformation causes inflation
  - Policy recommendation: avoid responding to noisy estimates of output gap and natural rates
- Our paper
  - Weak nominal anchor creates misinformation
  - Policy recommendation: make nominal anchor strong. If MP becomes credible, misinformation becomes smaller.

Implications for great moderation: time-varying stochastic properties of inflation

Time-varying stochastic process of inflation

Our model implies

- $\pi_t \to \bar{\pi}_t$ as $t \to \infty$.
- Contribution of $\tilde{\pi}_t$ becomes smaller over time
  - π_t becomes less persistent over time
  - π_t becomes less volatile over time

Great moderation

- UK inflation: less volatile and less persistent after '92 (Benati '04)
- time-varying stochastic process of π (Cogley-Sargent ('02,'04), Stock-Watson ('02), Ahmed-Levin-Wilson ('04))
- good policy or good luck?
  Existing literature: likely to be good luck.

Bernanke's conjecture
(Bernanke '04 speech)

Econometric methods confuse good policy with good luck

- don't take into account of impact of systematic component of monetary policy on inflation expectations
- fluctuations caused by de-anchored expectations get confused with genuine non-policy shocks

Reduced-form regression of model-generated data

- Motivated by Stock-Watson (2002), Ahmed-Levin-Wilson (2004) etc
- Estimation of

$$\pi_t = c + \alpha\pi_{t-1} + \varepsilon_t$$

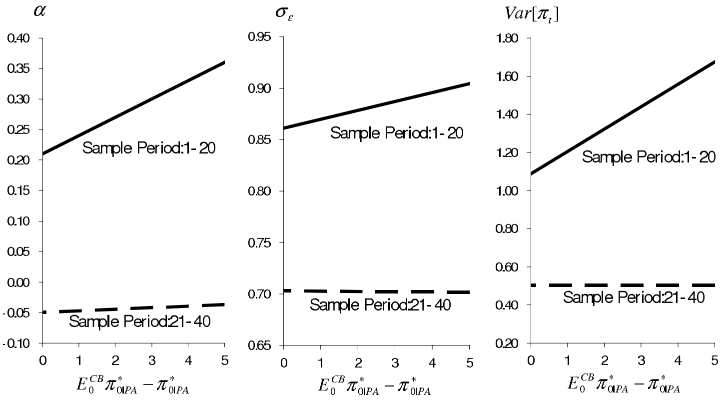
Reduced-form regression

- We are interested in:
  - change in α
  - change in $SD(\varepsilon_t)$
- Literature on 'great moderation' interprets
  - change in α as change in propagation
  - change in $SD(\varepsilon_t)$ as change in innovation

Numerical example

- $\pi^* = 2$, $\pi^*_{0|p} = 10$, $0 \leq E_{0|c}\pi^*_{0|p} - \pi^*_{0|p} \leq 5$
  - $\pi^*_{0|p}$ in line with US estimates in '80-'81
  - $E_{0|c}\pi^*_{0|p} - \pi^*_{0|p}$ in line with differences among US estimates of perceived target in '80s.
- $\gamma_r = 0.44$, $\gamma_u = 1$, $\phi = 1.5$
- Simulation for 40 periods, 1000 replications
- Estimate for two sub-samples (1-20, 21-40)
- Sensitivity analysis

Simulation results



- α and $SD(\varepsilon_t)$ become smaller in the second half
- α and $SD(\varepsilon_t)$ become larger as $E_{0|c}\pi^*_{0|p} - \pi^*_{0|p}$ becomes larger

Reduced-form regression of inflation

- Both 'innovation' and 'persistence' decline in reduced-form regression
- But, in our model, policy and structural shocks are constant over time
- In our model, change in stochastic process of π_t is generated by change in expectations (beliefs) —- consistent with Bernanke's conjecture

Summary

- Analysis of uncertainty about perceived inflation target
- Mis-measurement of natural rates endogenously determined
- A unified analysis of weak nominal anchor and misinformation
- Change in stochastic process of inflation driven by changes in expectations — existing literature on Great Moderation has not fully explored yet

Future work

- Implication for yield curve
  - Excess sensitivity of long rates due to lack of nominal anchor

APPENDIX

How is private-sector inflation expectation affected by CB-uncertainty about perceived target?

$$E_{t|p}\pi_{t+1} = (1-\phi^{-1})\pi^*_{t|p} + \phi^{-1}\underbrace{E_{t|p}E_{t+1|c}\pi^*_{t+1|p}}_{\text{3rd-order belief}}.$$

- In general, $E_{t|p}\pi_{t+1} \neq \pi^*_{t|p}$
- PS expectation about how CB will learn about future $\pi^*_{t+1|p}$ matters

CB-filtering about $\pi^*_{t|p}$

- Observation equation (Fisher equation)

$$i_t = r_t + E_{t|p}\pi_{t+1}$$

$$E_{t|p}\pi_{t+1} = (1-\phi^{-1})\pi^*_{t|p} + \phi^{-1}E_{t|p}E_{t+1|c}\pi^*_{t+1|p}$$

- CB knows $\pi^*_{t|p}$ evolves by:

$$\pi^*_{t|p} = a_t\pi^*_{0|p} + (1-a_t)\pi^* + \frac{1-a_t}{1-\phi}\bar{u}_t \qquad \text{(PSB)}$$

$\pi^*_{0|p}$: only uncertainty to CB

- $E_{t|p}\pi_{t+1}$ is determined simultaneously with CB filtering about $\pi^*_{0|p}$
- Solve by the method of undetermined coefficients (time-varying coefficients).

Equilibrium and CB filtering (1)

Solve by the method of undetermined coefficients.

- Define observables by
  $X_t \equiv i_t - (1 - a_t)\pi^* - \frac{1-a_t}{1-\phi}\bar{u}_t$.
- Guess:

$$A_t X_t = r_t + B_t \pi^*_{0|p} + C_t E_{t-1|c} \pi^*_{0|p} \qquad \text{(G)}$$

  A_t, B_t, C_t to be determined jointly with Kalman filtering about r_t.

- B_t represents the effects of initial perceived target ($\pi^*_{0|p}$) on current equilibrium

Equilibrium and CB filtering (2)

Derive Kalman filter based on (G), and substitute it back to (G). Then solve for A_t, B_t, C_t. Then B_t satisfies

$$B_t = a_t - \phi^{-1} a_{t+1} \frac{\frac{B_t^2}{B_{t+1}^2}\tau_{t|c}}{\frac{B_t^2}{B_{t+1}^2}\tau_{t|c} + \gamma_r},$$

$$\tau_{t|c} = \frac{B_{t-1}^2}{B_t^2}\tau_{t-1|c} + \gamma_r.$$

Once B_t is determined, A_t and C_t are determined.

Equilibrium and CB filtering (3)

Define new observation equation by

$$Y_t \equiv A_t X_t - C_t E_{t-1|c} \pi^*_{0|p} = \underbrace{r_t + B_t \pi^*_{0|p}}_{\text{unobservable}}.$$

Distribution of Y_t is

$$Y_t \sim N\left(B_t \pi^*_{0|p},\ \sigma_r^2\right).$$

Equilibrium and CB filtering (4)

Posterior mean of $B_t \pi^*_{0|p}$ at time t:

$$B_t E_{t|c} \pi^*_{0|p} = d_t B_t E_{t-1|c} \pi^*_{0|p} + (1 - d_t) Y_t, \qquad (4)$$

where

$$d_t \equiv \frac{\frac{B_{t-1}^2}{B_t^2} \tau_{t-1|c}}{\frac{B_{t-1}^2}{B_t^2} \tau_{t-1|c} + \gamma_r} \qquad (5)$$

and $\gamma_r \equiv 1/\sigma_r^2$.

Equilibrium properties (1)

- Simultaneity of equilibrium and CB filtering
- PS expectations about future CB filtering matters to π_t
- Current CB filtering depends on PS expectations about future CB filtering
- Intuition:
  - Forward-looking nature of inflation
  - Inflation determined by expectations about future MP
  - Future MP depends on future CB filtering

Equilibrium property (2)

B_t depends on:

- B_{t-1}: recursive nature of filtering
- B_{t+1}: forward-looking nature of inflation
  - π_t depends on PS expectations about future MP
  - future MP depends on filtering d_{t+1}
  - current filtering depends on PS expectations

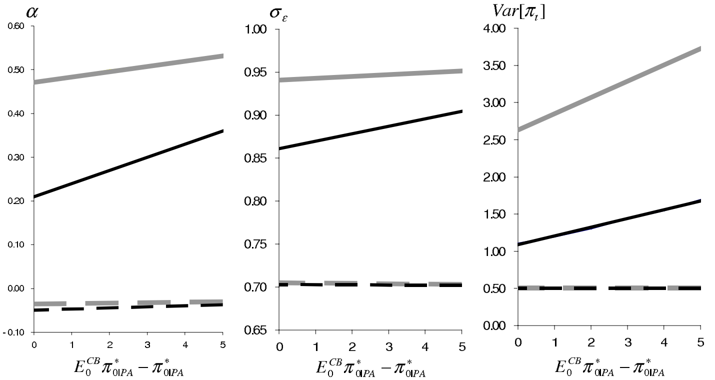
Sensitivity

Basic results robust against different $\pi^*_{0|p}$, ϕ, γ_u, $\tau_{0|PA}$

- High perceived target ($\pi^*_{0|p}$) results in high inflation persistence
- Aggressive MP (ϕ) results in smaller SD
- Smaller MP shock (larger γ_u) results in smaller SD and less persistence (because PS learning is quicker)
- More stubborn belief (larger $\tau_{0|PA}$) results in larger SD and more persistence (because PS learning is slower)

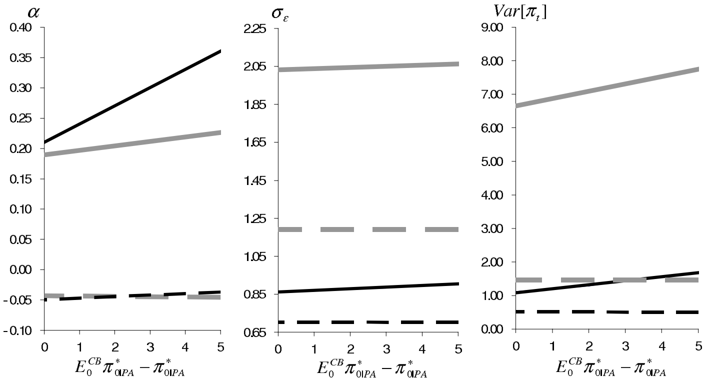
Sensitivity analysis (1)

Benchmark ($\pi^*_{0IPA} = 10$, Black line) vs. Higher perceived target ($\pi^*_{0IPA} = 20$, Gray line)



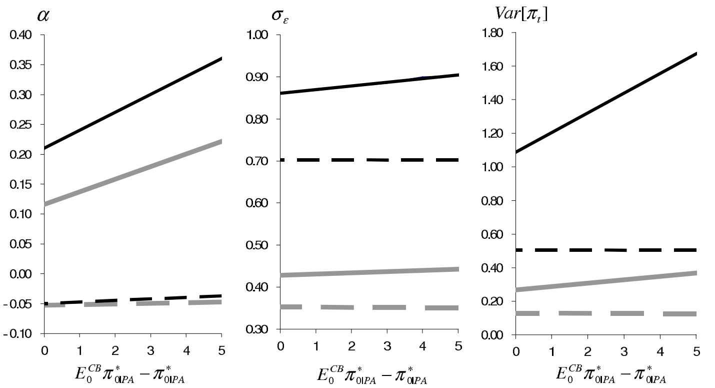
Sensitivity analysis (2)

Benchmark ($\phi = 1.5$, Black line) vs. Less aggressive monetary policy ($\phi = 1.1$, Gray line)



Sensitivity analysis (3)

Benchmark ($\gamma_u = 1$, Black line) vs. Smaller monetary policy shock ($\gamma_u = 4$, Gray line)



Sensitivity analysis (4)

Benchmark ($\tau_{0IPA} = 1$, Black line) vs. More stubborn belief ($\tau_{0IPA} = 10$, Gray line)