The Evolution of the Fed's Inflation Target in an Estimated Model under RE and Learning*

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Abstract

This paper aims to infer the evolving Fed's inflation target by estimating a monetary model under the assumptions of RE and learning. The results emphasize how different assumptions about expectations may have important effects on the inferred target movements.

Keywords: time-varying inflation target, learning, expectations, Bayesian estimation.

JEL classification: E50, E52, E58.

1 Introduction

Monetary models traditionally assume that central banks have an inflation target that remains constant over time.

The results by Clarida, Galí, and Gertler (2000) and Lubik and Schorfheide (2004), however, who showed that monetary policy failed to respond aggressively enough to the rising inflation in the 1970s, suggest that the Fed may have had a higher inflation target in that decade. Indeed, the papers by Favero and Rovelli (2003), Surico (2006), and Dennis (2004) identify one-time shifts in the

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inflation target after 1979. Kozicki and Tinsley (2005) estimate a backward-looking model to derive a continuously-changing inflation target. Leigh (2005) and Belaygorod and Dueker (2005) similarly estimate a time-varying inflation target focusing on post-Volcker samples. The paper by Ireland (2005) concentrates both on estimating the changes of the Fed's inflation target over time and in analyzing its patterns, causes, and consequences.

The above papers provide evidence that the inflation target has moved over time, rising to 6-8% in the 1970s and declining to around 2% in the 1980s-1990s. The causes of its changes, instead, remain unclear.

Obviously, the simplest scenario may be that the Federal Reserve has intentionally adopted a higher target in the 1970s. But different interpretations are possible. For example, some studies (e.g., Sargent 1999, Primiceri 2006, Milani 2005) argue that Fed's learning about the economy may have been responsible for the run-up of inflation. Primiceri (2006) and Milani (2005) emphasize that the 1960s may have induced the Fed to perceive a low persistence in inflation and a large inflation/output trade-off, which led to overly optimistic forecasts in the 1970s and made the Fed unwilling to increase interest rates by large amounts.

If this interpretation is correct, then it is possible that the Fed did not have a higher target in the 1970s. It may have been the slowness in learning that the economy was changing that contributed to the rising inflation.

This hypotheses has not been considered in previous research when estimating the inflation target. The cited papers, in fact, typically extract the target from an economy characterized by rational expectations (RE). The target series, however, may importantly differ depending on the assumptions one makes about expectations.

This paper therefore tries to estimate a changing inflation target under the assumption that both the Fed and the private sector are learning. The paper then compares the estimated targets under RE and under learning.

2 The Model

In this section, I present a New-Keynesian model (e.g., Woodford 2003) in which I allow the central bank to employ a time-varying inflation target. The target is *exogenous.* The model is described by the following loglinearized equations

$$\pi_t = \kappa x_t + \beta \widehat{E}_t \pi_{t+1} + u_t \tag{1}$$

$$x_t = \widehat{E}_t x_{t+1} - \sigma \left(i_t - \widehat{E}_t \pi_{t+1} \right) + g_t \tag{2}$$

$$i_t = \rho i_{t-1} + (1-\rho) \left[\pi_t^* + \psi_\pi \left(\widehat{E}_t \pi_{t+1} - \pi_t^* \right) + \psi_x \widehat{E}_t x_{t+1} \right] + \varepsilon_t \tag{3}$$

$$g_t = \phi_g g_{t-1} + \nu_t^g \tag{4}$$

$$u_t = \phi_u u_{t-1} + \nu_t^u \tag{5}$$

$$\pi_t^* = \pi_{t-1}^* + \nu_t^{\pi^*} \tag{6}$$

where $\widehat{E}_t$ denotes subjective expectations ($\widehat{E}_t = E_t$, the usual mathematical expectations operator, under RE). π_t denotes inflation, x_t the output gap, and i_t the nominal interest rate. Equation (1) is the forward-looking New-Keynesian Phillips curve that can be derived from the optimizing behavior of firms under Calvo price setting. $0 < \beta < 1$ represents the discount factor, while κ denotes the slope of the Phillips curve. Equation (2) represents the loglinearized intertemporal Euler equation that derives from households' optimal choice of consumption. $\sigma > 0$ represents the intertemporal elasticity of substitution of consumption. u_t and g_t denote AR(1) shocks, with $\nu_t^u \sim iid\left(0, \sigma_u^2\right)$ and $\nu_t^g \sim iid\left(0, \sigma_g^2\right)$. The central bank follows a Taylor rule (eq. (3)) by adjusting the nominal interest rate in response to deviations of forecasts of inflation and output gap from their targets. The inflation target π_t^* follows a random walk.

I shall estimate the model assuming either RE or learning. Under learning, I will assume that economic agents use the following perceived law of motion

(PLM) to form their expectations

$$Y_t = \phi_{0,t} + \phi_{1,t} Y_{t-1} + \epsilon_t \tag{7}$$

where $Y_t \equiv [\pi_t, x_t]'$ and where $\phi_{0,t}$ and $\phi_{1,t}$ denote a vector of constants and a matrix of coefficients. As additional data become available, they update their estimates according to the constant-gain learning formula[1]

$$\widehat{\phi}_t = \widehat{\phi}_{t-1} + \overline{\mathbf{g}} R_{t-1}^{-1} Y_{t-1} (Y_t - Y'_{t-1} \widehat{\phi}_{t-1}) \tag{8}$$

$$R_t = R_{t-1} + \overline{\mathbf{g}} (Y_{t-1} Y'_{t-1} - R_{t-1}) \tag{9}$$

where $\widehat{\phi}_t = vec(\phi_{0,t}, \phi_{1,t})'$ describes the updating of the learning rule coefficients, and R_t the updating of the second moments matrix of the stacked regressors $Y_{t-1} \equiv \{1, \pi_t, x_t\}_0^{t-1}$. $\overline{\mathbf{g}}$ denotes the constant gain coefficient. Economic agents use their PLM and the data up to $t-1$ to form expectations of future output gap and inflation in $t+1$.

3 Estimating the Federal Reserve's Changing Inflation Target

I use Bayesian methods in the estimation to fit the series for inflation, output gap, and the federal funds rate.[2] I jointly estimate the structural parameters of the model and the time-varying inflation target under different expectations assumptions: RE and subjective expectations with learning. The target is unobserved and derived through runs of Kalman filter and Kalman smoother. I fix $\beta = 0.99$, $\chi_\pi = 1.5$, $\chi_x = .5$, $\phi_g = 0.9$, and $\phi_u = 0.9$. I also fix the constant gain $\overline{\mathbf{g}}$ to the value estimated in Milani (2004b), i.e. 0.0183, and use pre-sample (1951-1959) data to initialize the learning algorithm. Table 1 reports infor-

[1] Branch and Evans (2006) show that constant-gain learning outperforms several alternatives in forecasting output and inflation.

[2] See Milani (2004b, 2005, 2006) for more details on the estimation. I use quarterly U.S. data for the period 1960:I-2005:II. For output gap I use the log difference between GDP and CBO Potential GDP.

mation about the priors. Table 2 presents posterior estimates under RE and learning.

Under RE, I estimate $\sigma = .006$ and $\kappa = .013$. Under learning, instead, the estimates become $\sigma = .064$ and $\kappa = .078$. Figure 1 shows the evolution of agents' beliefs. As in Milani (2004a), the agents perceive a negative intercept and a low autoregressive term in inflation until the early 1970s, together with a large sensitivity to changes in output. These estimates lead economic agents to underestimate inflation in the period (Figure 2).

Figure 3 shows the evolution of the Fed's inflation target. The implied target under RE starts low in 1960, but it rises to 6% at the beginning of the 1970s. The target remains high during the 1970s, until Volcker's disinflation reduces it from 6% to 2%. The target remains slightly above 2% during most of the 1980s-1990s. This behavior is not far from that found by Ireland (2005).

Under learning, the inflation target starts from above 5%, but it is estimated around 4% from the late 1960s to 1975. The target starts to decline already in 1975 to fall below 1% during Volcker's disinflation. The target equals 2% in the early 1990s, but it jumps to 5% in the second half of the decade, although with no effects on realized inflation, before a slight decline after 2003.

4 Discussion

I have estimated a monetary model under the alternative assumptions of RE and learning to infer the evolution of the Fed's inflation target from 1960 to 2005. The evidence of time variation in the target is robust to the different assumptions about expectations. But the implied target series look different in several sample periods. The target assumes values around 6% in the first half of the 1970s under RE, and values around 4% under learning, giving some merit to the learning interpretation of rising inflation. Under learning, the target starts to fall in 1975, whereas under RE the decline starts only after 1978. Finally, after 1995, under learning, but not under RE, the Fed seems to behave as if the target is again higher.

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Parameters	Prior Distr.	Prior Mean	95% Prior Prob. Interval
β	–	.99	–
κ	G	.25	$[.03, .70]$
σ	G	1	$[.12, 2.79]$
ρ	–	.9	–
χ_π	–	1.5	–
χ_x	–	.5	–
ρ_r	–	.9	–
ρ_u	–	.9	–
ρ_{π^*}	–	1	–
σ_ε	IG	1	$[.34, 2.81]$
σ_r	IG	1	$[.34, 2.81]$
σ_u	IG	1	$[.34, 2.81]$
σ_{π^*}	IG	1	$[.34, 2.81]$
$\overline{\mathbf{g}}$	–	.0183	–

Table 1 - Prior Distributions. *Note: G=Gamma, IG=Inverse Gamma.*

	Rational Expectations		**Learning**	
Parameters	Post. Mean	95% Post. Prob. Int.	Post. Mean	95% Post. Prob. Int.
β	.99	–	.99	–
κ	.006	$[.0009, .015]$	.064	$[.01, .15]$
σ	.013	$[.003, .029]$	.078	$[.01, .22]$
ρ	.9	–	.9	–
χ_π	1.5	–	1.5	–
χ_x	.5	–	.5	–
ρ_r	.9	–	.9	–
ρ_u	.9	–	.9	–
ρ_{π^*}	1	–	1	–
σ_ε	.9	$[.81, 1]$	.91	$[.82, 1]$
σ_r	.1	$[.08, .11]$	1.5	$[1.36, 1.66]$
σ_u	.15	$[.13, .17]$	.84	$[.76, .92]$
σ_{π^*}	.38	$[.23, .54]$	.70	$[.32, 1.34]$
$\overline{\mathbf{g}}$	–	–	.0183	–

Table 2 - Posterior Estimates: Monetary Model with RE and Learning.

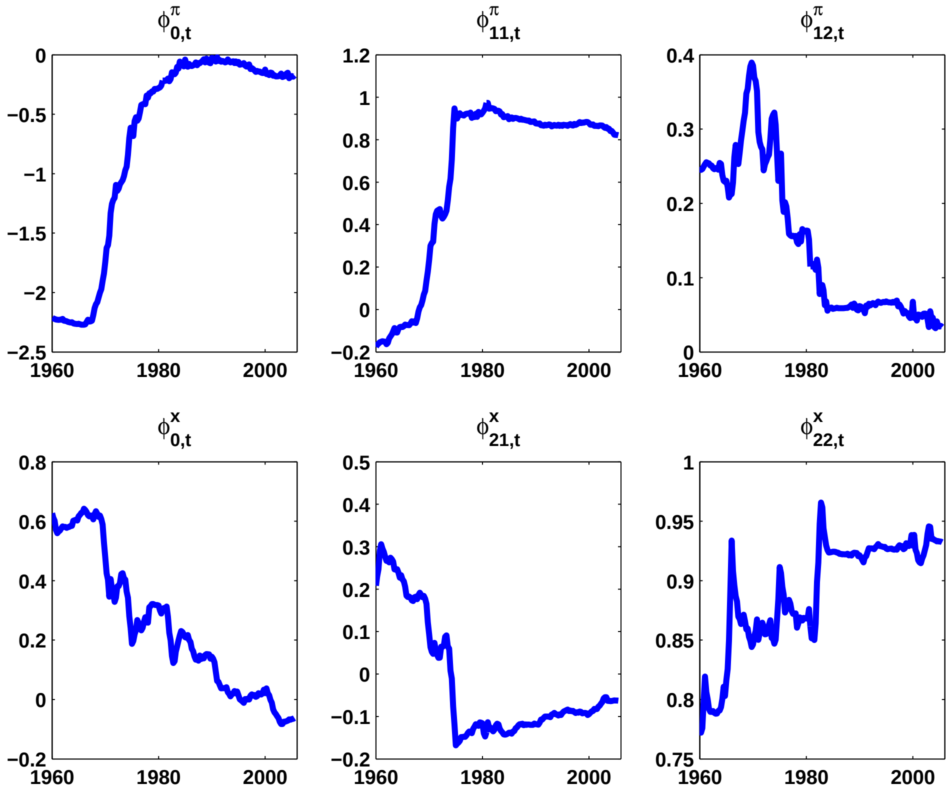

Figure 1: Evolution of agents' beliefs, 1960:I-2005:II.

Note: Agents' learning rule is:

$$\begin{pmatrix} \pi_t \\ x_t \end{pmatrix} = \begin{pmatrix} \phi^{\pi}_{0,t} \\ \phi^{x}_{0,t} \end{pmatrix} + \begin{pmatrix} \phi^{\pi}_{11,t} & \phi^{\pi}_{12,t} \\ \phi^{x}_{21,t} & \phi^{x}_{22,t} \end{pmatrix} \begin{pmatrix} \pi_{t-1} \\ x_{t-1} \end{pmatrix} + \begin{pmatrix} \epsilon^{\pi}_t \\ \epsilon^{x}_t \end{pmatrix}.$$

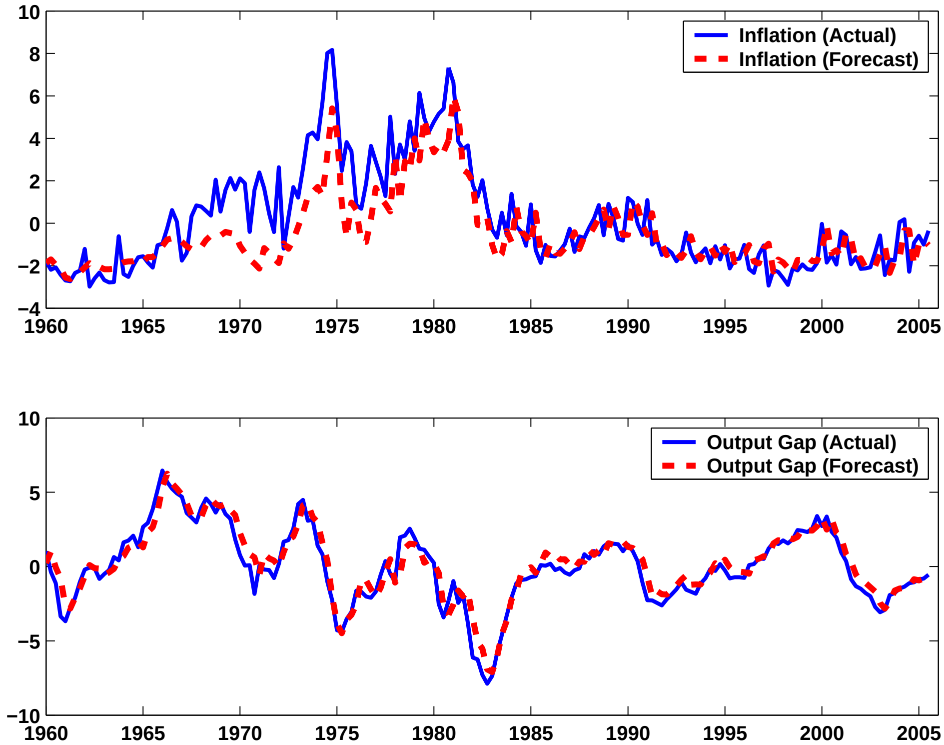

Figure 2: Inflation and Output Gap Forecasts.

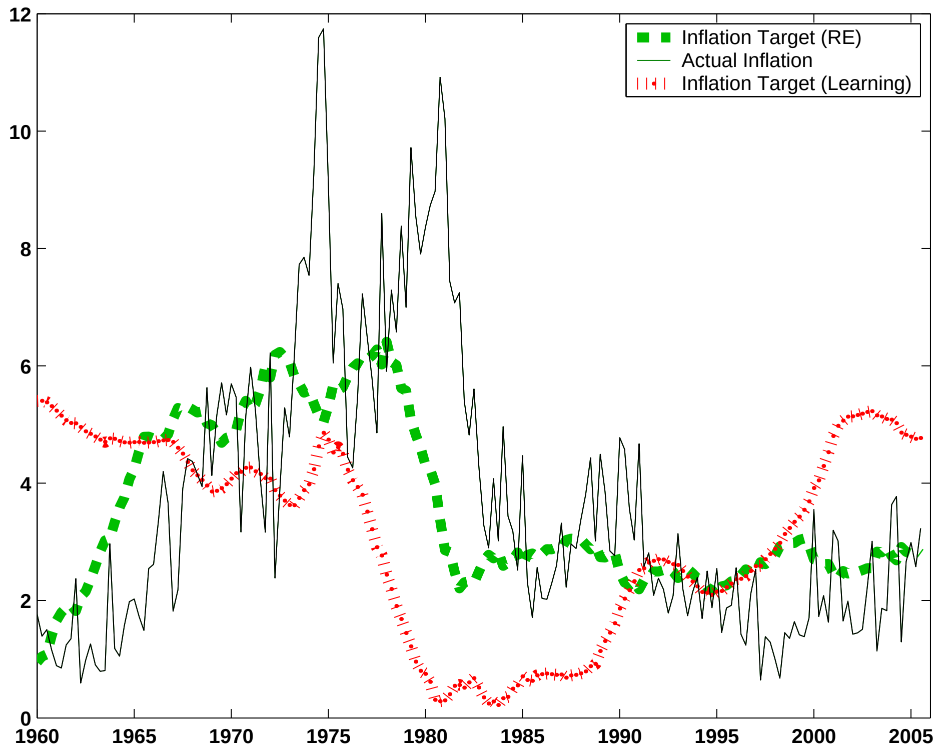

Figure 3: Actual Inflation and Estimated Time-Varying Inflation Targets under RE and Learning.