Learning, Uncertainty, and Monetary Policy

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December 3, 2021

Forthcoming: *Annals of Economics and Statistics*. This paper should not be reported as representing the views of the BcL or the Eurosystem. The views expressed are those of the author and may not be shared by other researchers or policymakers at the BcL or the Eurosystem.

What I Do

Standard New Keynesian model.

- Unobserved monetary policy regime.
- Signal extraction problem.

Insights:

- Contractionary effects of increases in MPU.
  - As documented by Husted et al. (2019).
- Lower sensitivity to monetary regime changes.

The Model

Key Inter-temporal Equations

Euler equation for one-period bonds:

$$1 = \beta \mathrm{E}_t \left[\left(\frac{c_t}{c_{t+1}} \right)^{\omega} \frac{r_t}{1 + \pi_{t+1}} \right].$$

Euler equation for capital:

$$q_t = \beta \mathrm{E}_t \left\{ \left(\frac{c_t}{c_{t+1}} \right)^{\omega} \left[r^k_{t+1} - \Gamma(i_{t+1}/k_t) - \Gamma_k(i_{t+1}/k_t)k_t + q_{t+1}(1 - \delta) \right] \right\}$$

Phillips Curve:

$$\psi\pi_t(1+\pi_t) = 1+\epsilon\left[mc_t - 1\right]+\beta \mathrm{E}_t \left[\left(\frac{c_t}{c_{t+1}} \right)^{\omega} \psi\pi_{t+1}(1 + \pi_{t+1}) \frac{y_{t+1}}{y_t} \right].$$

Monetary Policy

Inflation targeting with time-varying inflationary stance:

$$r_t = \max\left[1, \rho r_{t-1} + (1-\rho)(\bar{r} + \phi_t \pi_{t-1}) + u_t\right].$$

ϕ_t follows a 2-state Markov chain with transition matrix P.

- Active regime: $\phi_H > 1$.
- Passive regime: $\phi_L < 1$.

$u_t \sim \mathcal{N}(0, \sigma_u^2)$ intra-regime shifts in policy.

Similar to Leeper and Zha (2003) and Bianchi and Melosi (2018).

Expectations Formation I

Full information benchmark.

- Households and firms do observe ϕ_t.

Limited information scenario.

- Households and firms do not observe ϕ_t, for u_t blurs it.
- Hamilton (1989) filter yields:

$$\lambda_t^i = \mathrm{P}(\phi_t = \phi_i | r_t, \cdots, r_0, \pi_{t-1}, \cdots, \pi_0).$$

- Weight each realisation of ϕ_t by its conditional likelihood λ_t^i [Richter and Throckmorton (2015)].

Expectations Formation II

Under full information, given $\phi_t = \phi_i$:

$$\mathrm{E}_t \overbrace{[\mathrm{F}(\mathbf{x}_{t+1}, \mathbf{x}_t)]}^{\text{Model}} = \underbrace{\sum_{j=L}^{H} p_{i,j}}_{\text{Regime, } \phi_{t+1}} \underbrace{\int_{-\infty}^{\infty} \mathrm{F}(\mathbf{x}_{t+1}, \mathbf{x}_t)\, \overbrace{\vartheta(u_{t+1})}^{\text{Normal pdf}}\, du_{t+1}}_{\text{Discretionary shock, } u_{t+1}},$$

Under limited information, given λ_t^i:

$$\mathrm{E}_t [\mathrm{F}(\mathbf{x}_{t+1}, \mathbf{x}_t)] = \underbrace{\sum_{i=L}^{H} \lambda_t^i}_{\text{Beliefs}} \sum_{j=L}^{H} p_{i,j} \int_{-\infty}^{\infty} \mathrm{F}(\mathbf{x}_{t+1}, \mathbf{x}_t) \vartheta(u_{t+1}) du_{t+1}.$$

Expectations Formation III

The unobserved monetary regime generates forecast errors.

- These errors distort current decisions via the three inter-temporal conditions.

With accurate beliefs, both economies behave identically.

- Deviations from Rational Expectations are a function of how far agents' beliefs are from the truth.

With $\lambda_t^i < 1$, limited information smooths expectations.

- Agents put weight on choices they would make in either regime.

Measuring Monetary Policy Uncertainty (MPU)

Hamilton filter gives λ_t^i for $i \in \{L, H\}$.

$\lambda_t^i = 0.5 \rightarrow$ total uncertainty; $\lambda_t^i = 1 \rightarrow$ total certainty.

I follow Richter and Throckmorton (2015), and measure uncertainty as:

$$\zeta_t = \frac{\sqrt{0.5} - \sqrt{\sum_{i=L}^{H}(\lambda_t^i - 0.5)^2}}{\sqrt{0.5}},$$

which ranges from 0 (total certainty) to 1 (total uncertainty).

Calibration and Model Solution

Calibration and Model Solution

Table 1: Parameter values.

	Symbol	Value		Symbol	Value
Taste and technology			**Monetary policy**		
Discount factor	β	0.99	Smoothness parameter	ρ	0.60
Inv. Inter. elasticity	ω	1.00	Passive regime	ϕ_L	0.20
Inverse Frisch elasticity	η	1.00	Active regime	ϕ_H	2.00
Leisure parameter	χ	6.88	Trans. probability matrix	$p_{L,L}$	0.70
Elasticity of substitution	ϵ	10.0	Trans. probability matrix	$p_{H,H}$	0.85
Price adjustment	ψ	105	STD discretionary shock (%)	σ_u	0.10
Capital's share of output	α	0.33			
Capital depreciation (%)	δ	2.50			
Capital Adjustment cost	γ	6.00			

Remarks:

- Deviations from Taylor principle are short, yet pronounced.
- The ergodic mean of ϕ_t is larger than 1.
- Beliefs are often close to reality.
- Movements in ζ_t resemble those observed in US data. Example

Model solution: textbook projection method.

- Chebyshev polynomials.
- Orthogonal collocation.

The Real Effects of Increases in MPU

Understanding the Mechanism I

Using simulated data, I estimate:

$$\underbrace{\hat{Z}_{t+h}}_{\text{In \% dev. from SS}} = \mu_h + \beta_h \underbrace{\zeta_t}_{\text{In levels}} + \gamma_h \underbrace{X_t}_{\text{Controls}} + \epsilon_{t+h}.$$

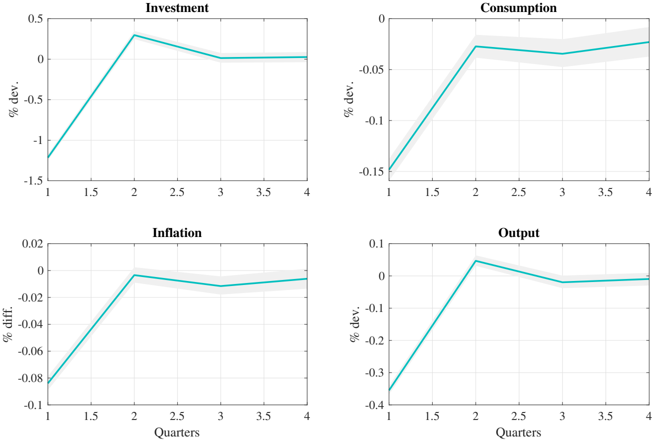
$\{\beta_h\}_{h \geq 0}$ is the Local Projection IRF of $\hat{Z}$ with respect to ζ_t.

- Z deviates from its SS level by β_h% for every extra unit of ζ_t.

Recall that, on impact, ζ_t does not react to changes in economic activity.

Understanding the Mechanism II

Figure 1: Impulse responses to a one-standard deviation increase in MPU.



Impulse response computed via Jorda (2005) Local Projection methods.

Sensitivity Analysis

Table 2: Impact response to a one-standard deviation increase in MPU.

	Capital adjustment cost		
	$\gamma = 2$	$\gamma = 6$ (baseline)	$\gamma = 10$
Panel A			
Investment	-1.70	-1.19	-0.14
Consumption	-0.12	-0.15	-0.04
Inflation	-0.10	-0.08	-0.02
Output	-0.43	-0.34	-0.06
	Price adjustment cost		
	$\psi = 70$	$\psi = 105$ (baseline)	$\psi = 140$
Panel B			
Investment	-0.49	-1.19	-1.19
Consumption	-0.07	-0.15	-0.15
Inflation	-0.02	-0.08	-0.07
Output	-0.16	-0.34	-0.35
	Inverse elasticity of intertemporal substitution		
	$\omega = 1$ (baseline)	$\omega = 3$	$\omega = 8$
Panel C			
Investment	-1.19	-0.92	-0.48
Consumption	-0.15	-0.05	0.00
Inflation	-0.08	-0.08	0.02
Output	-0.34	-0.23	-0.10

Limited Information and the Transmission Mechanism

Growth Rates and Regime Changes I

On a long simulation, I identify all quarters featuring a regime change.

I then compare the absolute value of the growth rate of output and inflation with their unconditional means.

Formally, I first identify all periods t^* in which $\phi_{t^*} = \phi_i$ and $\phi_{t^*-1} = \phi_j$ for $i \neq j$, where $i, j \in \{L, H\}$. Next, I compute:

$$\eta_x = \frac{\text{mean}\left[\left|\log(x_{t^*}) - \log(x_{t^*-1})\right|\right]}{\text{mean}\left[\left|\log(x_t) - \log(x_{t-1})\right|\right]},$$

where $x = \{Y, \pi\}$.

Growth Rates and Regime Changes II

Table 3: Growth rates and regime changes.

	Rational Expectations	Limited Information		
		Unconditional	Conditional on	
			High ζ_t	Low ζ_t
Output, η_y	2.45	1.49	1.31	1.69
Inflation, η_π	2.74	1.84	1.35	2.40

In column 4 (5), the numerator of η_x is conditioned on ζ_t being higher (lower) than its 0.8 (0.2) percentile.

Learning makes the economy less sensitive to changes in the central bank's reaction function.

- In line with Bloom et al. (2018).

Concluding Remarks

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New Keynesian model with unobserved monetary regime changes.

Insights:

- Negative effects of increases in MPU.
- Lower sensitivity to monetary regime changes.

Fruitful areas of research:

- Uncertainty and unconventional monetary policy measures.
- Uncertainty and rules-versus-discretion debate.

Beliefs and MPU index

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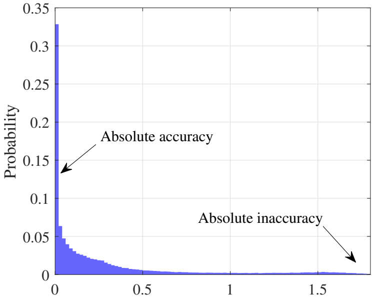
Figure 2: Belief's accuracy.



Density function of $\theta_t = |\phi_t - (\lambda_t^L \phi_L + (1 - \lambda_t^L)\phi_H)|$.

Table 4: Moments of MPU index.

	Model	US Data	
	ζ	BBD	HRS
STD to Mean	1.23	0.52	0.42
Skewness	1.41	1.25	1.92
Kurtosis	4.17	4.72	8.92

BBD: Baker-Bloom-Davis. HRS: Husted-Rogers-Sun.