Learning and Judgment Shocks in U.S. Business Cycles

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Purpose

1. Explain how macroeconomic volatility in post-war U.S. is explained by...
   - traditional structural shocks,
   - shocks to judgment?
2. How much of judgment is explained by...
   - actual events,
   - and judgment shocks?

Definitions

- **Expectation**: value agents actually expect a variable to take in the future. Expectation = *econometric forecast* + *judgment*.
- **Econometric forecast**: forecast for future variable based on least-squares estimation using past data on output gap, inflation rate, interest rate.
- **Judgment**: aka "add-factors," value added to econometric forecast to reflect beliefs not evident in past data.
- **Structural shocks** or **fundamental shocks**: traditional shocks in the New Keynesian model.
- **Judgment shocks**: stochastic shocks to judgment that are independent of the structural shocks.

Expectations Framework

Constant Gain Learning

- Agents' expectations are informed by least-squares forecasts based on past data.
- Forecasts can be directly mapped to past data on observable variables: output gap, inflation, interest rates.

Expectation = Forecast + Judgment

- Judgment may be informative, include relevant information not in past data.
- Judgment may be ill-informed (destabilizing, independent stochastic shock)
- Agents' actual expectations are mapped to data from Survey of Professional Forecasters.

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Literature: Judgment

Central Banking Policy

- Reifschneider, Stockton, and Wilcox (1997)
- Svensson (2005)

Exuberance Equilibria

- Bullard, Evans, Honkapohja (2008), (2010).
- Judgment is independent from fundamentals: purely destabilizing.

Empirical Evaluation

- Missing?

New Keynesian Model

Consumer behavior

- Choose consumption and labor to maximize utility.
- Habit formation: utility on consumption depends on past consumption.

Producer behavior

- Monopolistically competitive intermediate goods markets.
- Intermediate goods subject to Calvo (1983) price friction.
- Price indexation.

Monetary Policy

- Taylor (1993) rule: inflation, expected future output gap, and past interest rate.

Structural Shocks

- Natural interest rate shock:

$$r_t^n = \rho_n r_{t-1}^n + \epsilon_{n,t}$$

- Cost push shock:

$$u_t = \rho_u u_{t-1} + \epsilon_{u,t}$$

- Monetary policy shock, $\epsilon_{r,t}$ is not autoregressive.

Learning

- Log-linearized New Keynesian model has the structural form:

$$\Omega_0 x_t = \Omega_1 x_{t-1} + \Omega_2 x^e_{t+1} + \Omega_3 x^e_{t+2} + \Psi z_t$$

$$z_t = A z_{t-1} + \epsilon_t$$

- All observable by the agents: $x_t = [\tilde{y}_t \ \pi_t \ \hat{r}_t]$
- Shocks not observable to agents that learn: $z_t = [r^n_t \ u_t \ \epsilon_{r,t}]'$
- Rational expectations solution:

$$E_t x_{t+1} = G x_t + H z_t$$

- Agents estimate G by constant gain least squares.
  - Regressors: constant, first lag of x_t.
  - Constant learning gain, g, measures degree to which expectations are adaptive.

Judgment

Judgment, η_t, is possibly informed by current structural shocks, and subject to is own shock:

$$\eta_t = \Phi z_t + \zeta_t,$$

$$\zeta_{y,t} = \rho_{\zeta,y}\zeta_{y,t-1} + \xi_{y,t},$$

$$\zeta_{\pi,t} = \rho_{\zeta,\pi}\zeta_{\pi,t-1} + \xi_{\pi,t},$$

Notation:

- η_t is 2x1 vector, includes judgment on $\tilde{y}^e_{t+1}$ and π^e_{t+1}.
- Φ: dependence of judgment on actual structural shocks.
- ζ_t: persistent expectational shocks.

Expectations

- Expectations are the sum of least squares forecasts ($E_t^* x_{t+1}$) and judgment (η_t).

$$\begin{aligned} x_{t+1}^e &= E_t^* x_{t+1} + \eta_t \\ &= E_t^* x_{t+1} + \Phi z_t + \zeta_t \end{aligned}$$

- Special cases:
  - $\Phi = HA$, structural shocks are perfectly observable, expectations rational.
  - $\Phi = 0$, structural shocks are completely unobservable.
  - $Var(\zeta) = 0$, there are no expectational shocks.
- Elements of ϕ, Φ, and $Var(\zeta)$ are estimated jointly with all other parameters.

Estimation

- Bayesian Estimation - Metropolis Hastings Simulation Procedure.
- Quarterly data from 1968:Q3 through 2007:Q1 on
  - Output gap: measured by Congressional Budget Office.
  - GDP deflator inflation rate.
  - Federal funds rate.
  - Survey of Professional Forecasters One-Quarter ahead forecast on real GDP.
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- Pre-sample (1954:Q3 - 1968:Q2) data on first three variables initialize VAR(1) learning forecasts.

Parameter Estimates

New Keynesian Model Parameters

	Median	5th PCT	95th PCT
η	0.0715	0.0207	0.1420
σ	2.9178	2.2683	3.5847
μ	2.0691	1.3988	2.8363
κ	0.0278	0.0161	0.0432
γ	0.8465	0.7241	0.9146
ρ_r	0.9210	0.8578	0.9572
ψ_y	0.3185	0.1054	0.5845
ψ_π	1.5262	1.2789	1.7665
ρ_n	0.9798	0.9629	0.9925
ρ_u	0.0619	0.0146	0.2714
σ_n	0.0302	0.0236	0.0376
σ_u	0.0039	0.0035	0.0045
σ_r	0.0037	0.0033	0.0040

Comments

1. Low persistence due to habit formation.
2. High inflation persistence.
3. High persistence in natural rate shock.
4. Low persistence in cost-push shock.

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$\rho_{\zeta,\pi}$	0.8729	0.7896	0.9460
$\sigma_{\zeta,y}$	0.0090	0.0082	0.0100
$\sigma_{\zeta,\pi}$	0.0050	0.0045	0.0055
$\phi_{y,n}$	-0.2220	-0.2937	-0.1466
$\phi_{y,u}$	0.0916	-0.2233	0.3346
$\phi_{y,r}$	-0.0394	-0.2990	0.3760
$\phi_{\pi,n}$	0.0252	0.0015	0.0503
$\phi_{\pi,u}$	-0.2890	-0.4411	-0.1428
$\phi_{\pi,r}$	-0.0679	-0.2102	0.0934

Comments

1. Typical learning gain $\sim 43 obs. \sim 11 years.$
2. High judgment persistence.
3. Informed judgment (non-zero).
4. Judgment not informed.

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Informative Content in Judgment

Judgment

Recall, judgment is a linear combination of concurrent structural shocks and its own stochastic disturbance:

$$\begin{aligned} \text{Judgment:} \quad & \eta_t = \Phi z_t + \zeta_t, \\ \text{Disturbance:} \quad & \zeta_t = \zeta_{t-1} + \xi_t, \end{aligned}$$

Variance Decomposition

What percentage of the variability in judgment (η_t) is,

1. informed by concurrent structural shocks (z_t)?
2. stochastic disturbances (ξ_t)?

Uses the estimates parameters in Φ, $\rho_{\zeta,y}$, $\rho_{\zeta,\pi}$ and the variances of z_t, $\xi_{y,t}$, $\xi_{\pi,t}$.

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Informative vs. Stochastic Judgment

Variance Decomposition

Stochastic Shock	Output Judg.	Inflation Judg.
Natural Rate Shock	86.5 %	12.1%
Cost-Push Shock	0.0%	1.1%
Monetary Policy Shock	0.0%	0.0%
Output Judgment Shock	13.5%	–
Inflation Judgment Shock	–	86.7%
Total	100.00%	100.00%

Comments

1. Expectations (judgment) are informed by the natural rate shock.
2. Expectations are not informed by cost-push shock.
3. Some variability in judgment for output are from stochastic disturbances.
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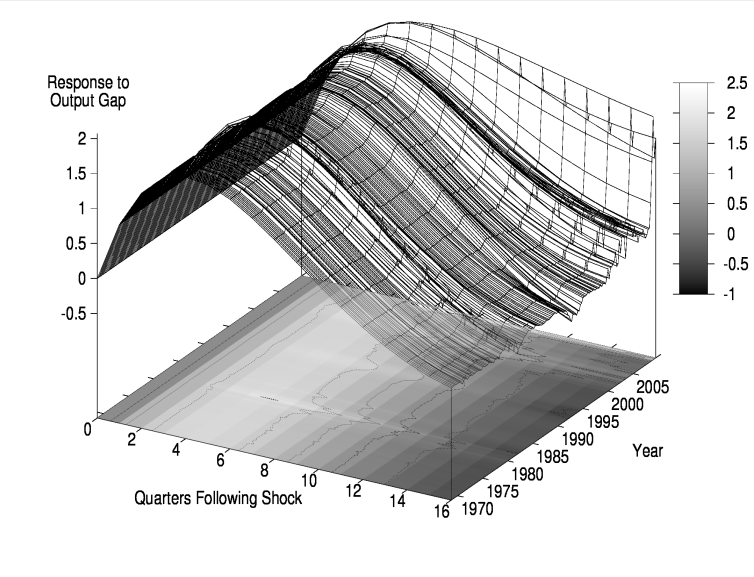
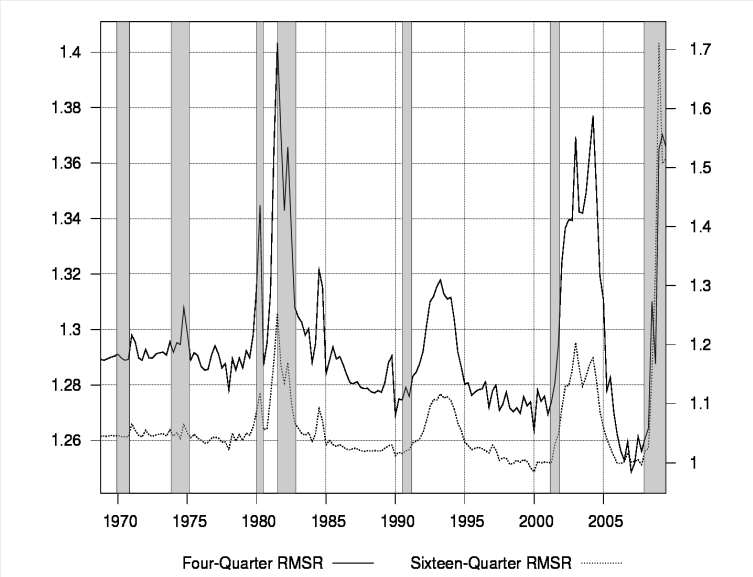
Impulse Responses: Output Judgment Shock

Response to Output Gap from Output Judgment Shock



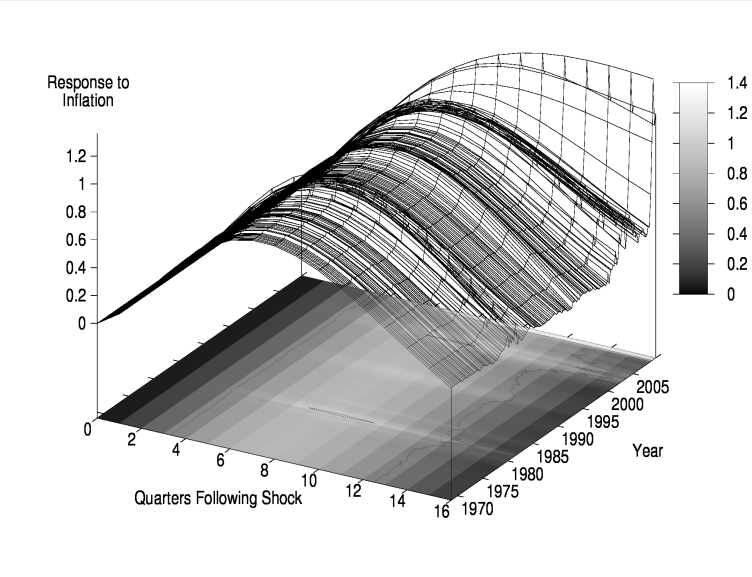


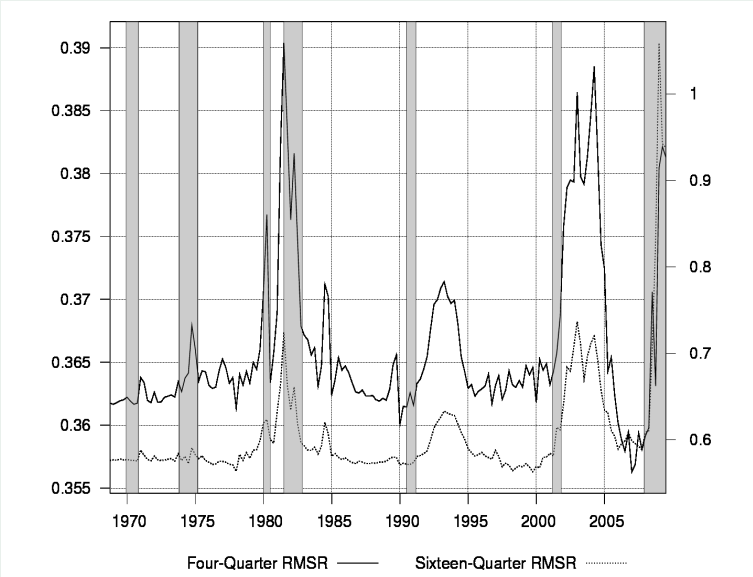
Comments

- Output judgment shock increases output.
- Larger IRF's coincide with 1980s volatility, rapid growth of 1990s, slow growth in 2000s, slow recovery 2010 recession.

Impulse Responses: Output Judgment Shock

Response to Inflation from Output Judgment Shock



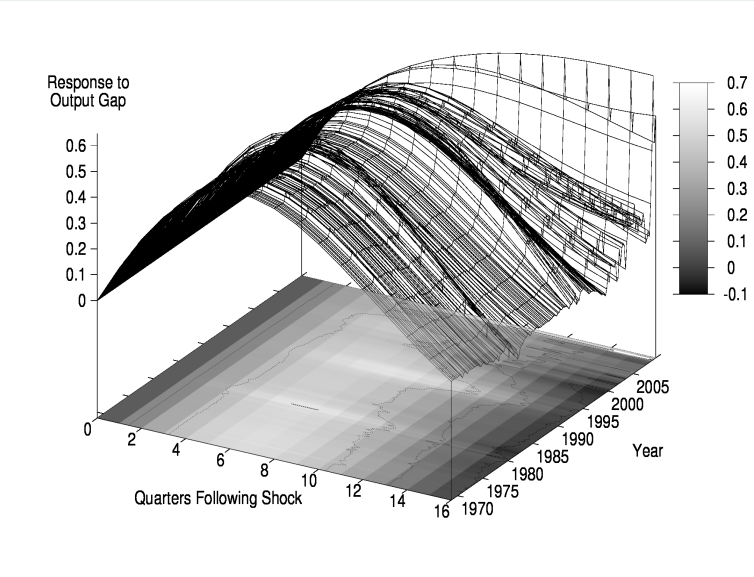


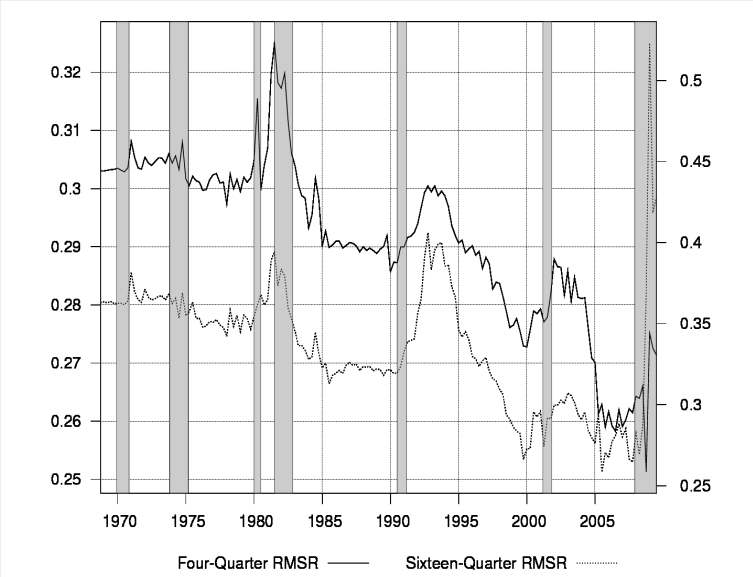
Comments

- Output judgment shock increases inflation.
- Larger IRF's occur during same time periods.

Impulse Responses: Inflation Judgment Shock

Response to Output Gap from Inflation Judgment Shock





Comments

- Inflation judgment shock increases output (reduces expected real interest rate).
- Inflation judgment IRFs on output have diminished over time.

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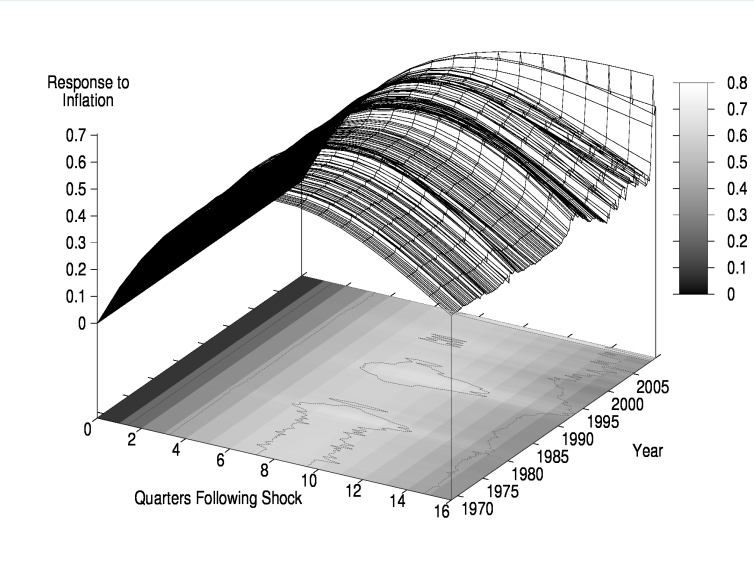

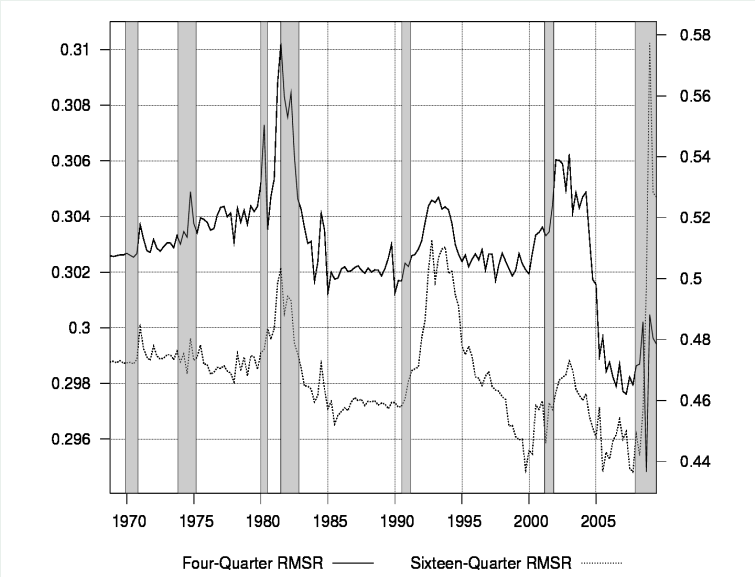

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- Inflation judgment shock increases inflation.
- Response is not symmetric over time. Largest in last few years of the sample.

Comparing Impulse Responses

Average Root Mean Squared Responses (One Std.Dev. Shock)

First Four Periods of IRF

Shock	Output	Inflation
Natural Rate	0.6018	0.1981
Cost-Push	0.1697	1.0864
Monetary Policy	0.6364	0.1787
Output Judgment	1.2952	0.3662
Inflation Judgment	0.2911	0.3029

First Sixteen Periods of IRF

Shock	Output	Inflation
Natural Rate	0.9918	0.6533
Cost-Push	0.1870	0.6953
Monetary Policy	0.7742	0.4854
Output Judgment	1.0627	0.6060
Inflation Judgment	0.3353	0.4694

Comments

- Output judgment shock has largest average impact on output.
- Cost-push shock has largest impact on inflation.
- Both output judgment and inflation judgment influence inflation dynamics.

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Inflation Judgment	0.2911	0.3029

First Sixteen Periods of IRF

Shock	Output	Inflation
Natural Rate	0.9918	0.6533
Cost-Push	0.1870	0.6953
Monetary Policy	0.7742	0.4854
Output Judgment	1.0627	0.6060
Inflation Judgment	0.3353	0.4694

Comments

- Output judgment shock has largest average impact on output.
- Cost-push shock has largest impact on inflation.
- Both output judgment and inflation judgment influence inflation dynamics.

Conclusions

- Judgment is a significant source of persistence for output and inflation.
- Inflation judgment is mostly dependent on stochastic disturbances.
- Output judgment is largely informed by concurrent natural rate shock.
- Both output and inflation judgment shocks are important drivers of business cycle fluctuations, along with natural rate shock and cost-push shock.