Monetary Policy under Behavioral Expectations: Theory and Experiment

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Outline

Introduction

- Expectations play a crucial role in modern macroeconomic models
- The standard assumption is that expectations are formed rationally
- However, a lot of evidence of boundedly rational and irrational behavior in economics
- What happens to the models and their conclusions if rational expectations are replaced by a behavioral model of expectation formation?

Introduction

- Behavioral expectations benchmark: heuristic switching model (from earlier work)
- We compare results on aggregate economic behavior
  - Focus on inflation volatility (where the models yield different results)
  - Inflation volatility / price stability of crucial importance to central banks
- We derive testable hypotheses from the models with rational and behavioral expectations and test them in a learning to forecast experiment

Introduction

Looking at it from the applied side:

- How is inflation volatility affected if the central bank reacts to the output gap with its interest rate decisions (in addition to reacting to inflation)?
- Should a central bank that only cares about inflation (e.g. ECB) only react to inflation or also to the output gap?

These questions can be investigated theoretically and experimentally

- In the experiment, we solely vary the feedback mechanism from expectations to realizations
  - We do this by varying one parameter of the Taylor Rule

Macroeconomic Model

- The aggregate equations are those of a standard New Keynesian closed economy
- These equations are also fully microfounded under behavioral expectations (see Appendix A of the paper)
- I will only show aggregate equations in this talk
- Standard calibration for parameters (Clarida, Galí & Gertler, 2000)

▸ Calibration

Macroeconomic Model

Aggregate New Keynesian Equations:

$$\text{IS:} \qquad y_t = \bar{y}^e_{t+1} - \varphi(i_t - \bar{\pi}^e_{t+1}) + g_t$$

$$\text{NKP:} \qquad \pi_t = \lambda y_t + \rho \bar{\pi}^e_{t+1} + u_t$$

$$\text{MP:} \qquad i_t = max(\bar{\pi} + \phi_\pi(\pi_t - \bar{\pi}) + \phi_y(y_t - \bar{y}), 0)$$

Expectation Formation

- Standard in the literature: Rational Expectations (RE)
- However, expectations are unlikely to be rational in the real world
- As behavioral expectation formation mechanism, we consider a heuristic switching model (HSM) that has performed well in earlier work

Heuristics

- Two ingredients, heuristics and switching mechanism

  Individuals use the following four heuristics (2 period ahead forecasts):

$$ADA: \quad x^e_{1,t+1} = 0.65x_{t-1} + 0.35x^e_{1,t}$$

$$WTR: \quad x^e_{2,t+1} = x_{t-1} + 0.4(x_{t-1} - x_{t-2})$$

$$STR: \quad x^e_{3,t+1} = x_{t-1} + 1.3(x_{t-1} - x_{t-2})$$

$$LAA: \quad x^e_{4,t+1} = \frac{x^{av}_{t-1} + x_{t-1}}{2} + (x_{t-1} - x_{t-2})$$

Switching between Heuristics

- Subjects choose between heuristics on the basis of past performance

$$U_{h,t-1} = \frac{100}{1 + |x_{t-1} - x^e_{h,t-1}|} + \eta U_{h,t-2}$$

- Updating

$$n_{h,t} = \delta n_{h,t-1} + (1-\delta) \frac{\exp(\beta U_{h,t-1})}{\sum_h \exp(\beta U_{h,t-1})}$$

Price Stability

- We care about price stability only
- This is the mandate of the ECB (and the sole objective of some other central banks)
- Which measure of price (in)stability / inflation volatility?

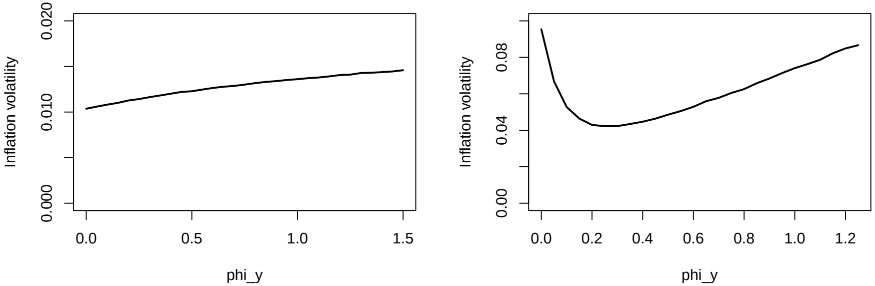
Measuring Inflation Volatility

- Mean squared deviation from target: $\frac{1}{T}\sum_{t=1}^{T}(\pi_t - \bar{\pi})^2$
- Standard deviation: $\sqrt{\frac{1}{T}\sum_{t=1}^{T}(\pi_t - \pi^{av})^2}$
- Absolute deviation: $\frac{1}{T-1}\sum_{t=2}^{T}|\pi_t - \pi_{t-1}|$
- Relative deviation: $\frac{1}{T-1}\sum_{t=2}^{T}(\pi_t - \pi_{t-1})^2$

- We use the relative deviation
- The results are similar for all measures

Example

Policy Implications and Intuition



(a) Rational model

(b) Behavioral model

Figure: Inflation volatility as function of ϕ_y

Policy Implications and Intuition

- Policy implications of the behavioral model are straightforward:
  A CB that only cares about price stability should still react to the output gap!
- What's the intuition of the results?

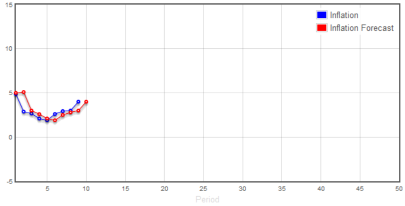
Design and Implementation

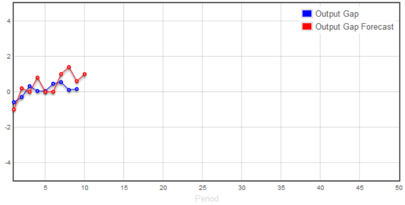
- Subjects forecast output gap and inflation
- Average forecasts of each group used as expectation in the macro model
- Groups of 6

Design and Implementation

- Subjects receive only qualitative information about the experimental economy
- Subjects paid either for inflation or output gap forecasting
- Inflation target always 3.5
- Between subjects design & within session randomization

Charts





Information table

Turn	Inflation	Your Inflation Forecast	Output Gap	Your Output Gap Forecast	Interest Rate	Your Score (O)	Your Score (I)
10		4.00		1.00			
9	4.01	3.00	0.16	0.60	5.05	69.23	49.83
8	3.00	2.80	0.11	1.40	3.52	43.62	83.17
7	2.94	2.50	0.55	1.00	3.65	69.00	69.58
6	2.61	1.90	0.46	0.00	3.11	68.60	58.40
5	1.89	2.10	0.04	0.00	1.83	96.13	82.86
4	2.09	2.60	0.05	0.80	2.13	57.00	66.34
3	2.67	3.00	0.32	0.00	3.13	75.67	75.21
2	2.88	5.10	-0.29	0.20	3.14	66.91	31.07
1	4.87	5.00	-0.59	-1.00	5.98	70.98	88.62

Player Actions

You are now in period 10

Enter your forecast for inflation in period 11

Enter your forecast for the output gap in period 11

Submit

Player Information

Your total score for output gap is 617.14

Your total score for inflation is 605.09

Please submit your forecast.

Treatments

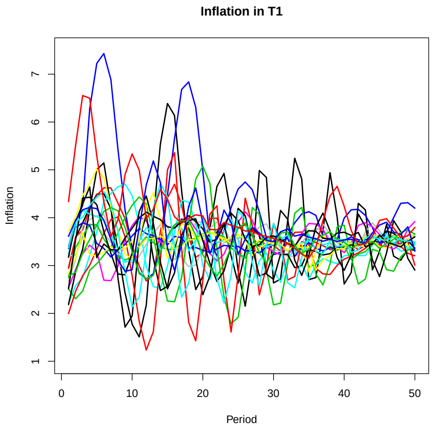
- Two treatments, only difference is in the Taylor rule
- T1: $\phi_\pi = 1.5,\ \phi_y = 0$
- T2: $\phi_\pi = 1.5,\ \phi_y = 0.5$

Hypotheses

- Outcome of interest is inflation volatility
- Null-hypothesis derived from RE, alternative from BE:

	T1 ($\phi_y = 0$)	T2 ($\phi_y = 0.5$)
RE		
BE		

Inflation Data



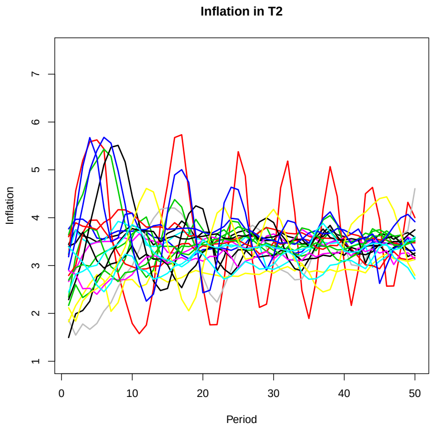


Figure: Realized inflation for all groups in both treatments

Inflation Volatility

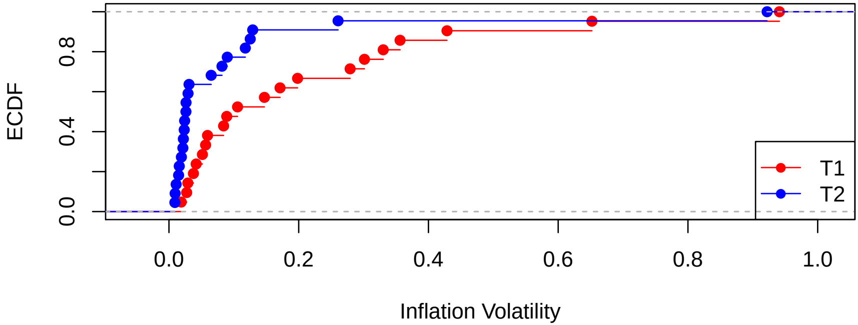


Figure: Empirical distribution functions of inflation volatility

- Difference statistically significant (Wilcoxon rank-sum, $p<0.01$)

Further Data: Output Gap

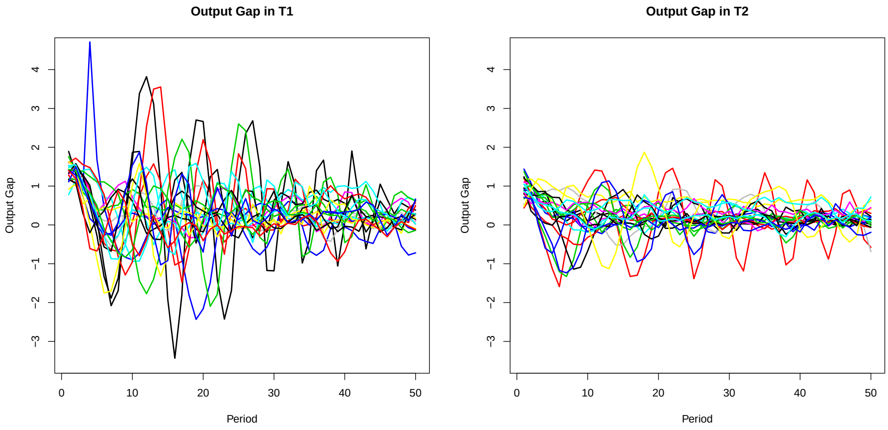
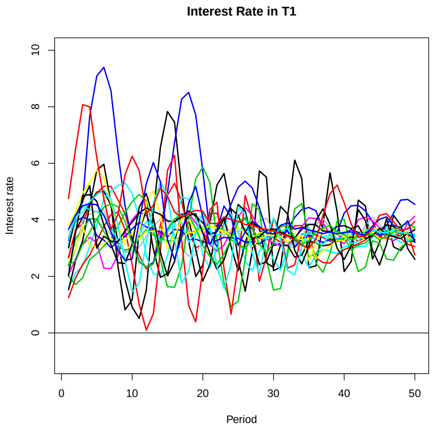


Figure: Realized output gap in both treatments

Further Data: Interest Rates



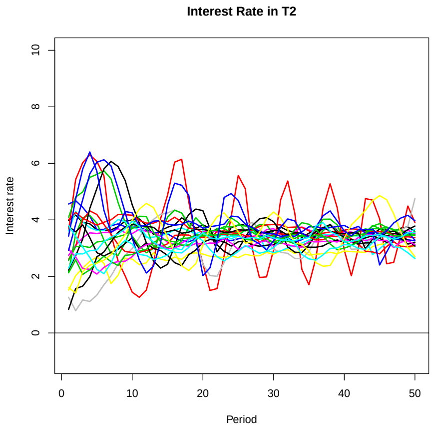


Figure: Interest rate in both treatments

Performance of HSM and other Models

Mean squared errors of two-period-ahead predictions from different models of expectation formation

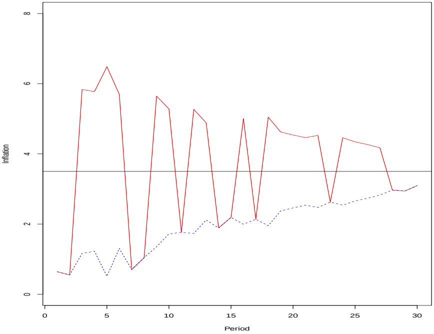
	Inflation $T1$	Output gap $T1$	Inflation $T2$	Output gap $T2$
HSM	0.072	0.141	0.040	0.022
RE	0.541	0.753	0.422	0.222
ADA	0.254	0.399	0.168	0.095
WTR	0.106	0.193	0.063	0.037
STR	0.246	0.415	0.088	0.068
LAA	0.107	0.180	0.063	0.037

Discussion

- Policy recommendations from models with rational expectations may be misguided
- Model with behavioral expectations gives different policy recommendations: Even a CB only interested in price stability should target output!
- We obtain experimental support for this policy recommendation and for the behavioral model

Thank you for your attention!

Measuring Volatility: Example



Return

Parameters

- Parameters for the NK equations (in quarterly terms; Clarida, Galí, Gertler 2000)
  - $\varphi = 1$
  - $\lambda = 0.075$
  - $\rho = 0.99$

Return

- Parameters for the heuristic switching model:
  - $\delta = 0.9$
  - $\eta = 0.7$
  - $\beta = 0.4$

NK Model with Heterogeneous Expectations

- NK model consistent with heterogeneous expectations of the form

$$(y_t, \pi_t) = F\left(\bar{E}_t y_{t+1}, \bar{E}_t \pi_{t+1}, \theta_t, \xi_t\right)$$

$\theta_t \equiv \int_i (E_{i,t} c_{i,t+1} - E_{i,t} c_{t+1})$
$\xi_t \equiv (1-\omega)\beta \int_i (E_{i,t} p_{i,t+1} - E_{i,t} p_{t+1})$

Random Utility Model

- Agents i observe performance of each rule h with some noise

$$\tilde{U}_h = U_h + \epsilon_{hi}$$

- $P_h = Pr[\tilde{U}_h > \{\tilde{U}_{h'}\}_{\forall h' \neq h}] = Pr[U_h + \epsilon_{hi} > \{U_{h'} + \epsilon_{h'i}\}_{\forall h' \neq h}]$
- When error terms are IID following double exponential

$$P_h = \exp(\beta U_h) / \sum_h \exp(\beta U_h)$$

- β inversely proportional to noise variance
  - $\beta \to \infty$: no errors
  - $\beta \to 0$: uniform probabilities