Monetary Policy under Behavioral Expectations: Theory and Experiment

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Disclaimer: The views expressed are those of the authors and do not necessarily reflect those of the Bank of Lithuania.
Outline

1. Introduction

2. Theory
   - Macroeconomic Model
   - Behavioral Model of Expectation Formation
   - Economic Behavior and Policy Implications

3. Experiment
   - Design and Implementation
   - Treatments and Hypotheses
   - Results

4. Discussion
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
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
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Discussion
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).
Macroeconomic Model

Aggregate New Keynesian Equations:

**IS:** \[ y_t = y^e_{t+1} - \varphi(i_t - \bar{\pi}^e_{t+1}) + g_t \]

**NKP:** \[ \pi_t = \lambda y_t + \rho \bar{\pi}^e_{t+1} + u_t \]

**MP:** \[ i_t = \max(\bar{\pi} + \phi_\pi(\pi_t - \bar{\pi}) + \phi_y(y_t - \bar{y}), 0) \]
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**: 
  \[ x_{1,t+1}^e = 0.65 x_{t-1} + 0.35 x_{1,t} \]

- **WTR**: 
  \[ x_{2,t+1}^e = x_{t-1} + 0.4(x_{t-1} - x_{t-2}) \]

- **STR**: 
  \[ x_{3,t+1}^e = x_{t-1} + 1.3(x_{t-1} - x_{t-2}) \]

- **LAA**: 
  \[ x_{4,t+1}^e = \frac{x_{t-1}^{av} + x_{t-1}}{2} + (x_{t-1} - x_{t-2}) \]
Switching between Heuristics

- Subjects choose between heuristics on the basis of past performance

\[ U_{h,t-1} = \frac{100}{1 + |x_{t-1} - x_{h,t-1}^e|} + \eta U_{h,t-2} \]

- 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: \( \sqrt{\frac{1}{T} \sum_{t=1}^{T} (\pi_t - \bar{\pi}^{av})^2} \)
- 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
Policy Implications and Intuition

**Figure**: Inflation volatility as function of $\phi_y$

(a) Rational model  
(b) Behavioral model
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?
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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
You are now in period 10

Enter your forecast for inflation in period 11

Enter your forecast for the output gap in period 11

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:

<table>
<thead>
<tr>
<th></th>
<th>T1 ($\phi_y = 0$)</th>
<th>T2 ($\phi_y = 0.5$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE</td>
<td></td>
<td></td>
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</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
<th>Inflation $T_1$</th>
<th>Output gap $T_1$</th>
<th>Inflation $T_2$</th>
<th>Output gap $T_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSM</td>
<td>0.072</td>
<td>0.141</td>
<td>0.040</td>
<td>0.022</td>
</tr>
<tr>
<td>RE</td>
<td>0.541</td>
<td>0.753</td>
<td>0.422</td>
<td>0.222</td>
</tr>
<tr>
<td>ADA</td>
<td>0.254</td>
<td>0.399</td>
<td>0.168</td>
<td>0.095</td>
</tr>
<tr>
<td>WTR</td>
<td>0.106</td>
<td>0.193</td>
<td>0.063</td>
<td>0.037</td>
</tr>
<tr>
<td>STR</td>
<td>0.246</td>
<td>0.415</td>
<td>0.088</td>
<td>0.068</td>
</tr>
<tr>
<td>LAA</td>
<td>0.107</td>
<td>0.180</td>
<td>0.063</td>
<td>0.037</td>
</tr>
</tbody>
</table>
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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
Parameters

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

- 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

\[
P_h = \frac{\exp(\beta U_h)}{\sum_h \exp(\beta U_h)}
\]

- \( \beta \) inversely proportional to noise variance
  - \( \beta \to \infty \): no errors
  - \( \beta \to 0 \): uniform probabilities