Heterogeneous Expectations, Learning and European Inflation Dynamics

Anke Weber

International Monetary Fund

19 November 2010

The views expressed in this presentation are those of the author and do not necessarily represent those of the IMF or IMF policy.
Motivation

- Most central banks gear monetary policy directly towards maintaining inflation at low and stable level.

- Understanding of how the public forms inflation expectations is of crucial importance to obtain this objective:
  - Optimal monetary policy depends on expectations formation process of economic agents.
  - Bounded rationality may have an impact on communication strategy of central banks.
This paper:

- analyses whether adaptive learning provides accurate description of forecaster behaviour in Euro Area
  - simple recursive forecasting rules with time-varying coefficients
  - survey data on household expectations and professional forecasters
- assesses heterogeneity between countries and between households and experts
  - analysis of how country’s past inflation record influences learning
- assesses convergence of expectations to equilibrium and inflation goal of the ECB
Countries: Germany, France, Italy, Netherlands, Spain

main data series from 1961 (quarterly), 1981 (monthly)

Household expectations: Extracted from EC Consumer Survey.
- Survey asks approx. 20000 consumers for expectations of future (12 months ahead) and past price developments.
- Monthly frequency, 1990M1-2006M9
- Qualitative data
- quantified using modified version of probability method (Carlson and Parkin, 1975, Batchelor and Orr, 1988, Berk, 1999)

Expert expectations: Consensus economics.
- More than 700 experts recruited from major banks, economic research institutes and investment firms.
- Every quarter, experts are asked to provide forecasts on key macro variables, 1990Q1-2006Q3
General State Space Model

- Reduced form for inflation:

\[ \pi_t = b'_t x_t + \varepsilon_t \]  

(1)

where

\[ \mathbb{E}(\varepsilon_t) = 0 \]  
\[ \text{Var}(\varepsilon_t) = H_t. \]

\[ x_t = (1, \pi_{t-1})' \] (Model 1), or \[ x_t = (1, \pi_{t-1}, z_{t-1}, w_{t-1})' \] (Model 4)

- The state equation is given by

\[ b_t = b_{t-1} + \eta_t \]  

(2)

where

\[ \mathbb{E}(\eta_t) = 0 \]  
\[ \mathbb{E}(\eta_t \eta_t') = Q_t \]

- learning process converges only to equilibrium if \[ Q_t = 0 \] (Marcet and Sargent, 1989a,b)
Recursive least squares (RLS):

\[ \hat{b}_t = \hat{b}_{t-1} + \gamma_t R_t^{-1} x_t (\pi_t - \hat{b}'_{t-1} x_t) \]

\[ R_t = R_{t-1} + \gamma_t (x_t x'_t - R_{t-1}) \]

where \( \gamma_t = t^{-1} \) and \( R_t \) is matrix of second moments of \( x_t \).

Learning gain approaches zero as \( t \to \infty \).

Constant gain least squares (CGLS)

implies that \( \gamma_t = \gamma \).

discounts past observations geometrically.

more robust to structural change.

resembles OLS, but with rolling window of data, sample size \( \approx \frac{1}{\gamma} \).
Some Hypotheses

- **constant gain least squares (CGLS) learning performs better than recursive least squares (RLS) learning**
  - Branch and Evans’ (2006) results for US

- **households in high inflation countries use higher constant gains than those in low inflation countries**

- **professional forecasters use higher constant gains than households**
  - Mankiw and Reis (2007): Sticky information
  - Carroll (2003): households only occasionally update information sets from news reports

- **professional forecasters’ expectations more in line with inflation goal of ECB than households**
  - Arnold and Lemmen (2006): growth theory model, professional forecasters more inclined to take into account implications of monetary union
Divide sample for each country in three parts:

- Pre-forecasting period: prior beliefs are formed by estimating autoregressive equation of inflation.
- In-sample period: optimal gain and best fitting gain parameters are determined for CGLS.
  - generate forecasts for inflation, $\hat{b}_{t-12}x_t$ (monthly), $\hat{b}_{t-4}x_t$ (quarterly)
  - compute MSE and MSCEs with different $\gamma$
  - find $\gamma$ that minimises MSE and MSCE
  - For RLS sequence continues to be updated as $t^{-1}$.

- Out-of-sample forecasting period, compute out-of-sample MSEs and MSCEs
- also compute relative MSCEs for each country (Schumacher, 2007)
  - this has to do with predictability (Diebold and Kilian, 2001)
Optimal constant gains for period between 1990M1-1998M4 between 0.07 and 0.24

Out of sample forecast errors (1998M5-2006M9) to fit inflation with optimal model between 0.02 and 0.07.

Best fitting constant gains needed to fit household expectations significantly higher in "high inflation countries"

- 0.001 for Germany for AR(1) model of inflation compared to 0.03 and 0.05 for Italy and Spain respectively

Relative out of sample mean square comparison error smallest for Italy (0.06).

- compare to 0.3 in absolute terms

CGLS clearly dominates RLS in terms of fitting actual inflation and expectations
Results: Households

Italy

Figure 1: Italy, Actual Inflation

Actual Inflation
Forecasts from t-12 for t (CGLS; Model 1)
Results: Households

Italy

Figure 2: Italy, Household Expectations

- Household Inflation Expectations
- Forecasts from t-12 for t (CGLS; Model 4)
Results: Households versus Professional Forecasters

- Optimal constant gains for period between 1976Q1-1990Q3 between 0.1 and 0.3.
  - significantly higher than for US (estimates range from 0.01-0.12).
- Best fitting constant gains higher for experts than for households (1990Q4-2006Q3)
  - e.g. best fitting constant gain for experts in Italy is 0.17 compared to 0.07 for households (Model 1)
- Best fitting constant gains higher in Italy than in France and Germany for both households and experts
- No significant difference between our ability to fit expectations of experts and households
- CGLS again outperforms RLS
Results: Professional Forecasters

Italy

Figure 3: Italy, Actual Inflation

Actual Inflation
Forecasts from t-4 for t (CGLS; Model 1)
Results: Professional Forecasters

Italy

Figure 4: Italy, Experts

- Expert Expectations
- Forecasts from t-4 for t (CGLS; Model 2)
Testing for Convergence

- Let
  
  \[ b_{i,t} = b_{i,t-1} + \eta_{i,t} \]

- where
  
  \[ \varepsilon_t \sim N(0, \sigma^2) \text{ and } \eta_{i,t} \sim N(0, (Q_t^i)^2) \]

- and
  
  \[ Q_{i,t} = \lambda^2 Q_{i,t-1} \]

- test \( H_0 : \lambda = 1 \) against \( H_1 : \lambda < 1 \).

- test statistic proposed by Hall and St. Aubyn (1995) and St. Aubyn (1999):
  
  \[ HSA = \frac{\hat{\lambda} - 1}{\hat{\sigma}(\hat{\lambda})} \]
Results: Convergence

- Evidence that convergence to least squares is taking place
  - this is true for all countries including the Euro Area and both households and experts
  - given that $\lambda$ is very close to 1, this convergence is taking place at very slow rate

- Estimates generally converge to constant, coefficient on lagged values of $\pi_t$ becomes insignificant

- but constant not generally equal to inflation goal of ECB for households

- professional experts more inclined to incorporate implications of monetary union into their expectations
### Results: Convergence

<table>
<thead>
<tr>
<th>Country</th>
<th>$\hat{b}_1$</th>
<th>$\hat{b}_2$</th>
<th>Root MSE</th>
<th>P-value</th>
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<tbody>
<tr>
<td>Germany</td>
<td>1.4536</td>
<td>-0.0584</td>
<td>0.3550</td>
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<td>France</td>
<td>2.3013</td>
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<td>Euro Area</td>
<td>1.7892</td>
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<td>0.3176</td>
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**Table:** Households: Testing for Convergence: Final State Estimates
## Results: Convergence

<table>
<thead>
<tr>
<th></th>
<th>Final State</th>
<th>Root MSE</th>
<th>P-value</th>
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<tbody>
<tr>
<td><strong>Germany</strong></td>
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<td>$\hat{b}_1$</td>
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<td><strong>Italy</strong></td>
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<tr>
<td>$\hat{b}_1$</td>
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<td><strong>Euro Area</strong></td>
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<td>$\hat{b}_1$</td>
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</tr>
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**Table:** Experts: Testing for Convergence: Final State Estimates
Results: Convergence

Figure 5: Smoothed state estimates over time

Household Expectations Italy

Expert Expectations Italy
Conclusions

- **Learning Matters**
  - Overall constant gain learning performs well in out-of-sample forecasting
  - dominates RLS (compare to Branch and Evans, 2006).

- **Heterogeneity important**
  - best fitting constant gain in so-called high inflation countries higher
  - best fitting constant gain higher for professional forecasters than households

- **Convergence to equilibrium at very slow rate**
  - Households convergence to average past inflation rate of their country
  - Professionals more inclined to incorporate implications of EMU into their expectations