Heterogeneous Expectations, Learning and European Inflation Dynamics

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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

Motivation

- 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

Data

- 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:

$$\pi_t = \mathbf{b}_t' \mathbf{x}_t + \varepsilon_t \tag{1}$$

where

$$E(\varepsilon_t) = 0 \text{ and } Var(\varepsilon_t) = H_t.$$

- $\mathbf{x}_t = (1, \pi_{t-1})'$ (Model 1), or $\mathbf{x}_t = (1, \pi_{t-1}, z_{t-1}, w_{t-1})'$(Model 4)
- The state equation is given by

$$\mathbf{b}_t = \mathbf{b}_{t-1} + \boldsymbol{\eta}_t \tag{2}$$

where

$$E(\boldsymbol{\eta}_t) = 0 \text{ and } E(\boldsymbol{\eta}_t \boldsymbol{\eta}_t') = \mathbf{Q}_t$$

- learning process converges only to equilibrium if $\mathbf{Q}_t = \mathbf{0}$ (Marcet and Sargent, 1989a,b)

Learning Algorithms

- Recursive least squares (RLS):

$$\widehat{\mathbf{b}}_t = \widehat{\mathbf{b}}_{t-1} + \gamma_t \mathbf{R}_t^{-1} \mathbf{x}_t (\pi_t - \widehat{\mathbf{b}}'_{t-1} \mathbf{x}_t)$$

$$\mathbf{R}_t = \mathbf{R}_{t-1} + \gamma_t (\mathbf{x}_t \mathbf{x}'_t - \mathbf{R}_{t-1})$$

  - where $\gamma_t = t^{-1}$ and $\mathbf{R}_t$ is matrix of second moments of $\mathbf{x}_t$.
  - in state space framework implies that $\mathbf{Q}_t = \mathbf{0}$ and $H_t = 1$.
  - 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*
  - Sims (2003, 2006): Theory of Rational Inattention
- *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

Simple Learning Rules-Estimation Methods

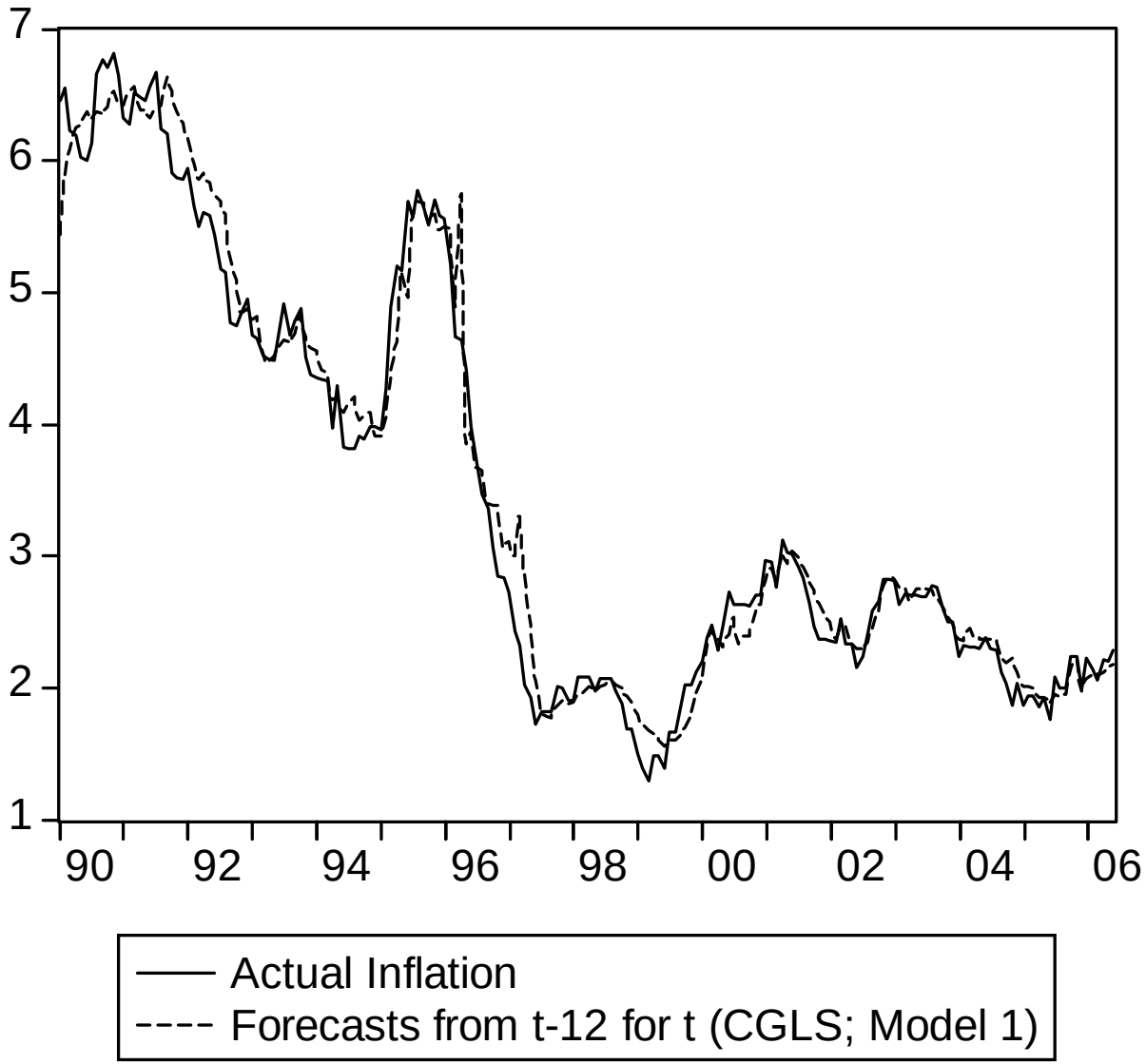
- Divide sample for each country in three parts:
  - Pre-forecasting period: prior beliefs are formed by estimating autoregressive equation of inflation.
  - In-sample period: optimal gain and best fitting gain parameters are determined for CGLS.
    - generate forecasts for inflation, $\widehat{\mathbf{b}}_{t-12}\mathbf{x}_t$ (monthly), $\widehat{\mathbf{b}}_{t-4}\mathbf{x}_t$ (quarterly)
    - compute MSE and MSCEs with different γ
    - find γ 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)

Results: Households

- 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

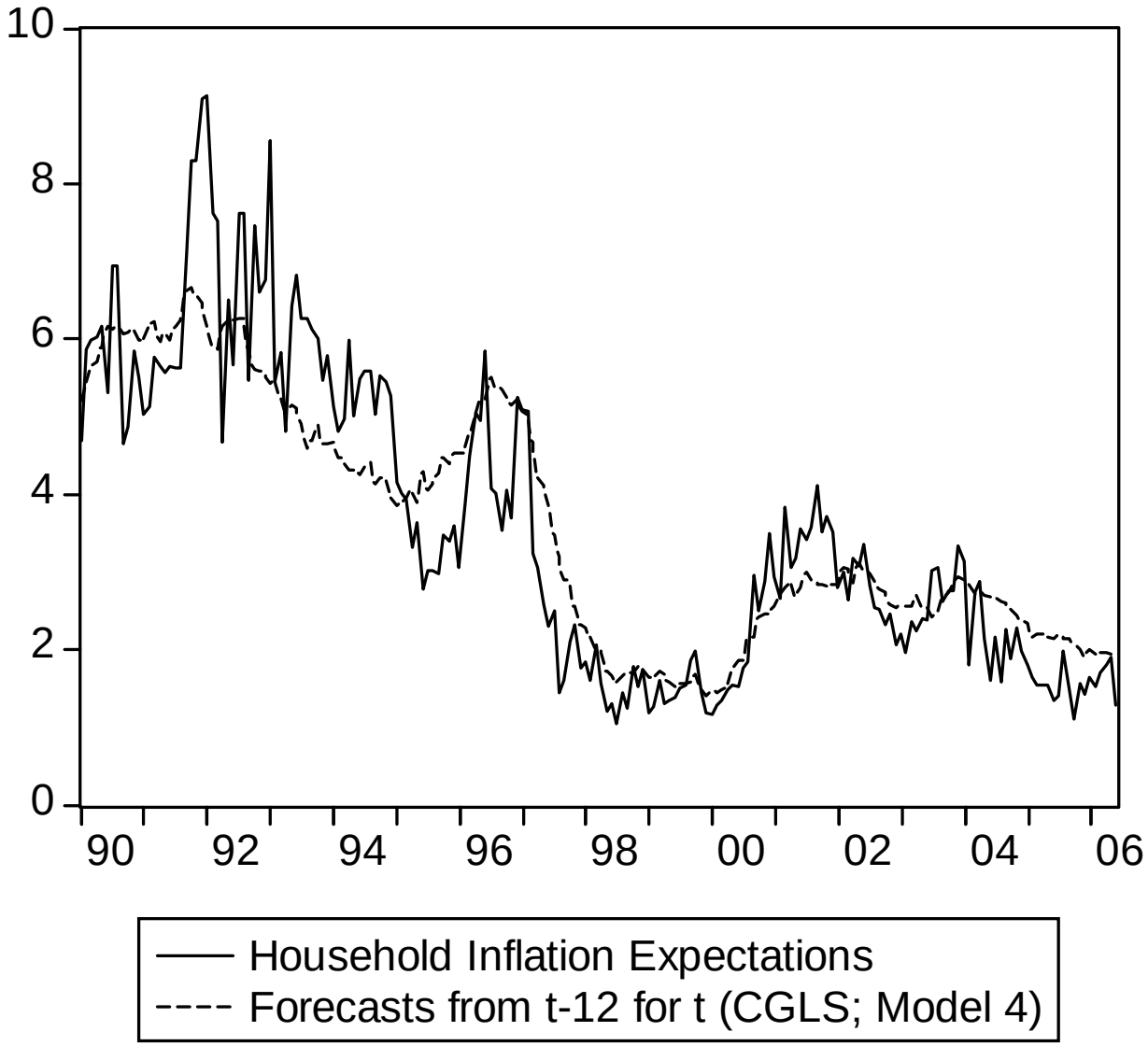
Results: Households

Italy



Results: Households

Italy

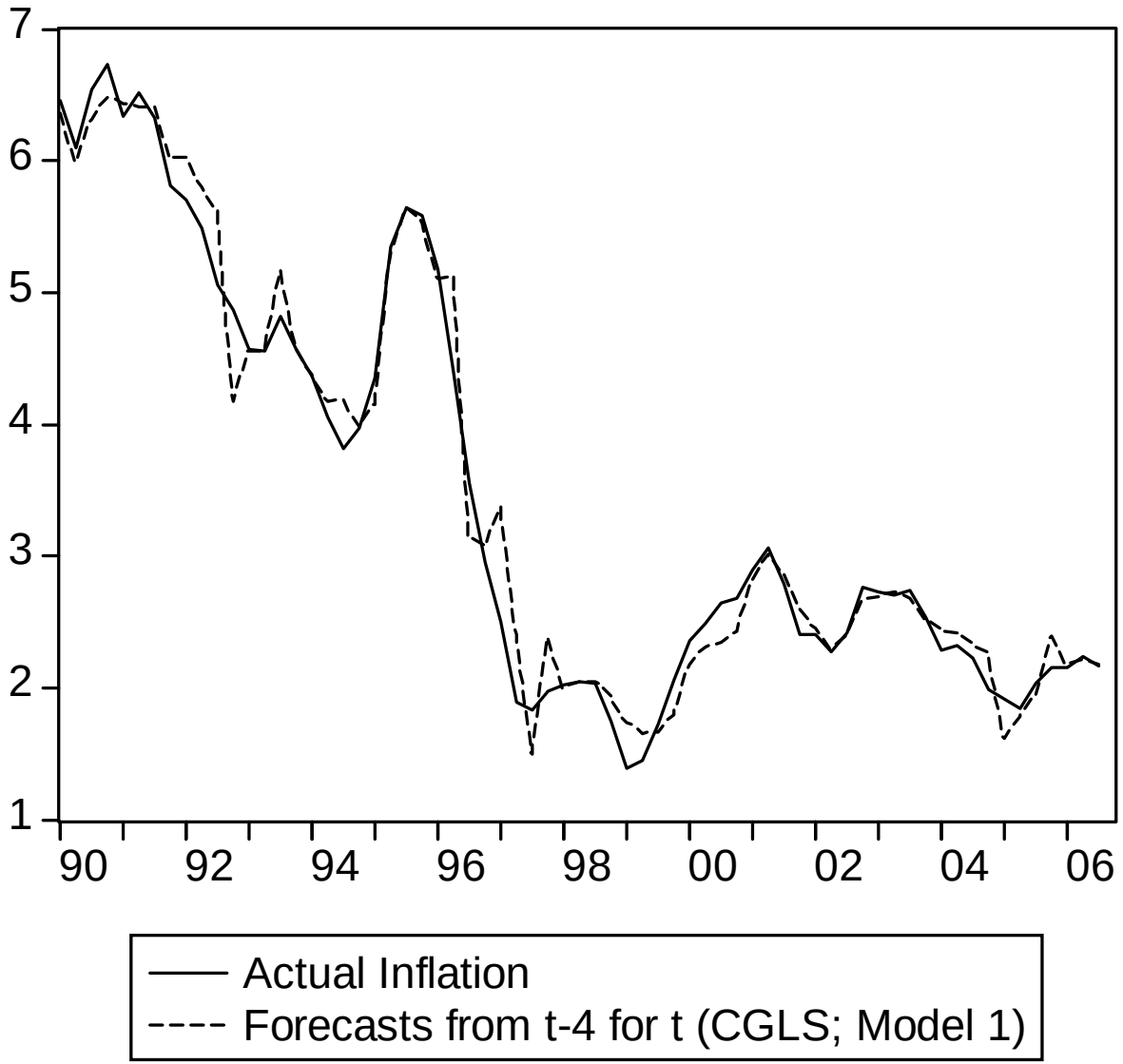


Results: Households versus Professional Forecasters

- 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

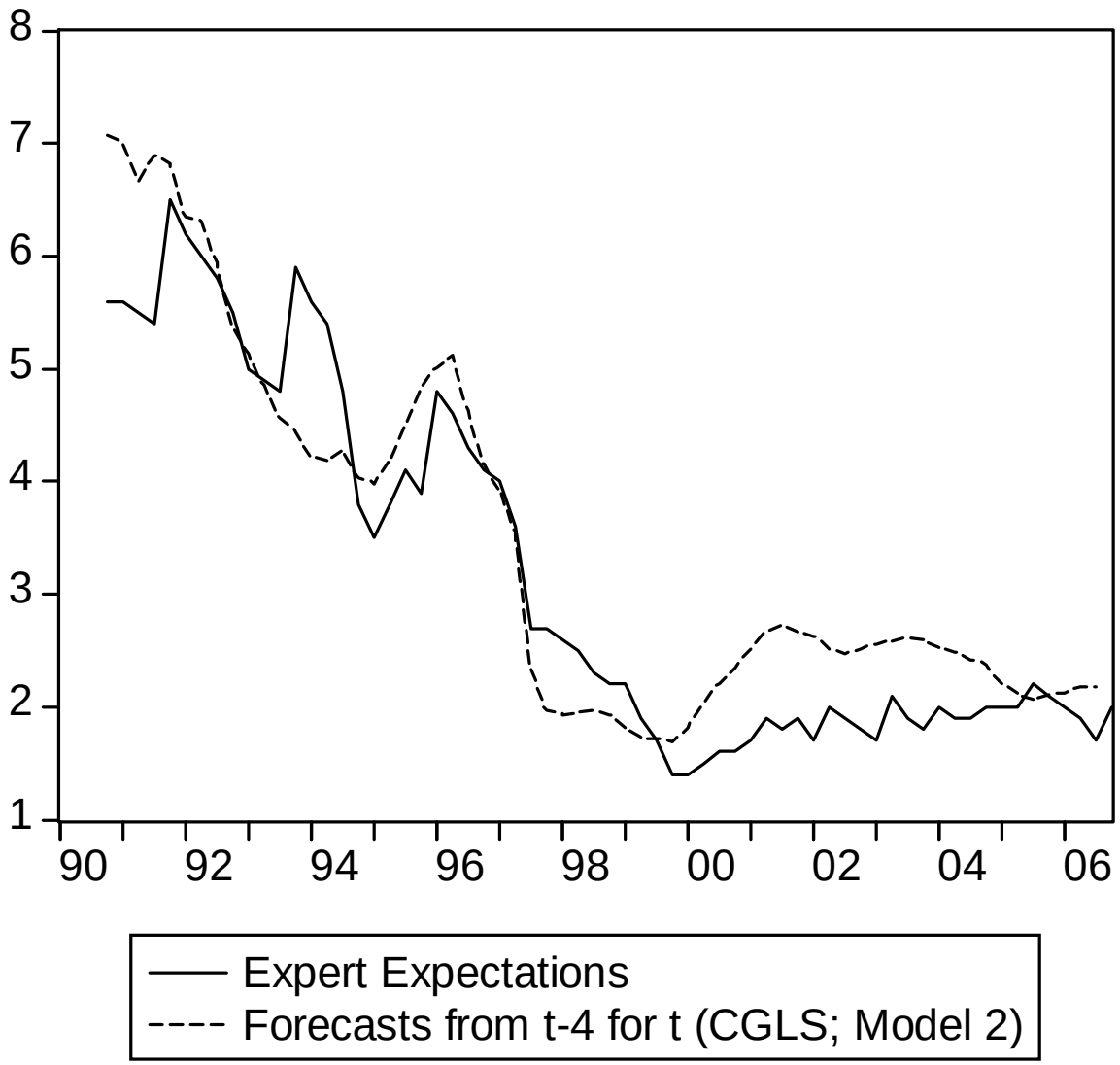
Results: Professional Forecasters

Italy



Results: Professional Forecasters

Italy



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):
$$HSA = \frac{\widehat{\lambda} - 1}{\widehat{\sigma}(\widehat{\lambda})}$$

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 λ is very close to 1, this convergence is taking place at very slow rate
- Estimates generally converge to constant, coefficient on lagged values of π_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

		Final State	Root MSE	P-value
Germany	$\widehat{b}_1$	1.4536	0.3550	0.0000
	$\widehat{b}_2$	-0.0584	0.2934	0.8422
France	$\widehat{b}_1$	2.3013	0.4103	0.0000
	$\widehat{b}_2$	0.2106	0.1934	0.2759
Italy	$\widehat{b}_1$	3.0022	0.734328	0.0000
	$\widehat{b}_2$	-0.7352	0.3493	0.0353
Netherlands	$\widehat{b}_1$	1.1782	0.4746	0.0131
	$\widehat{b}_2$	0.1214	0.1172	0.3002
Spain	$\widehat{b}_1$	4.4108	1.2780	0.0006
	$\widehat{b}_2$	-0.1406	0.2512	0.5755
Euro Area	$\widehat{b}_1$	1.7892	0.3176	0.0000
	$\widehat{b}_2$	0.2662	0.1455	0.0673

Table: Households: Testing for Convergence: Final State Estimates

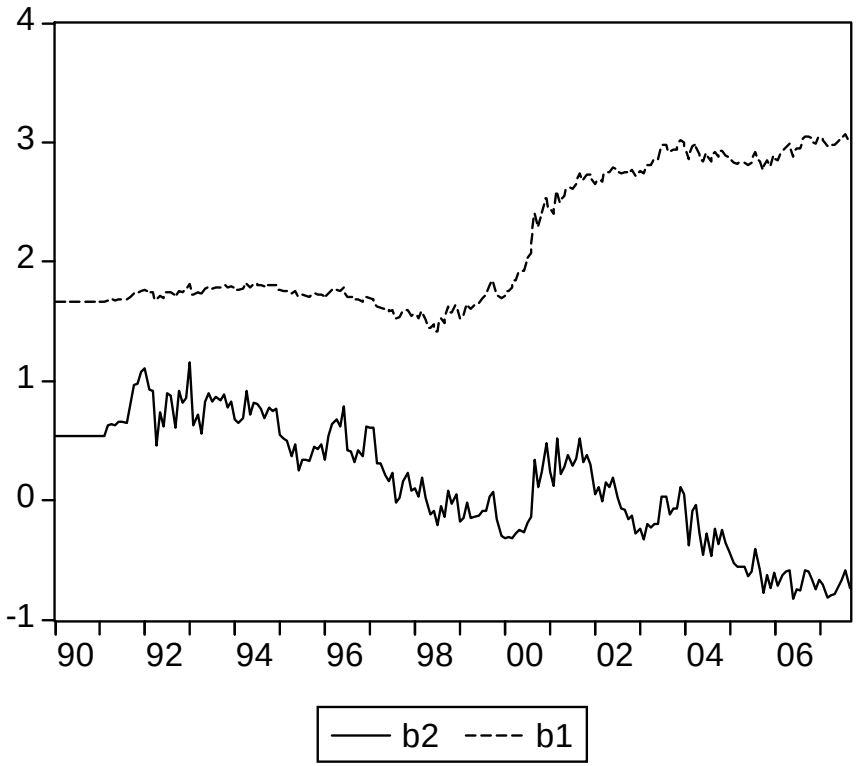
Results: Convergence

		Final State	Root MSE	P-value
Germany	$\widehat{b}_1$	1.6322	0.2622	0.0000
	$\widehat{b}_2$	0.3248	0.1644	0.0482
France	$\widehat{b}_1$	1.7068	0.1753	0.0000
	$\widehat{b}_2$	-0.0021	0.0510	0.9716
Italy	$\widehat{b}_1$	1.6705	0.1825	0.0000
	$\widehat{b}_2$	0.0591	0.0872	0.4980
Netherlands	$\widehat{b}_1$	1.7160	0.1622	0.0000
	$\widehat{b}_2$	-0.0050	0.0534	0.9260
Spain	$\widehat{b}_1$	2.9048	0.3512	0.0000
	$\widehat{b}_2$	0.1007	0.0455	0.0270
Euro Area	$\widehat{b}_1$	1.7463	0.2636	0.0000
	$\widehat{b}_2$	0.1548	0.1156	0.1806

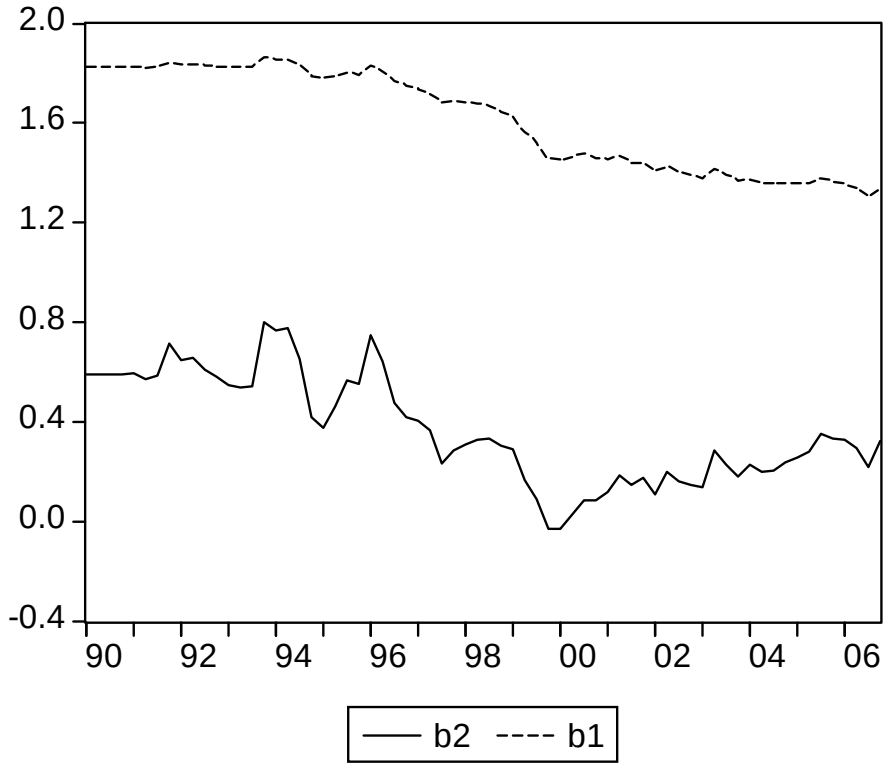
Table: Experts: Testing for Convergence: Final State Estimates

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