Regime Switching, Learning, and the Great Moderation

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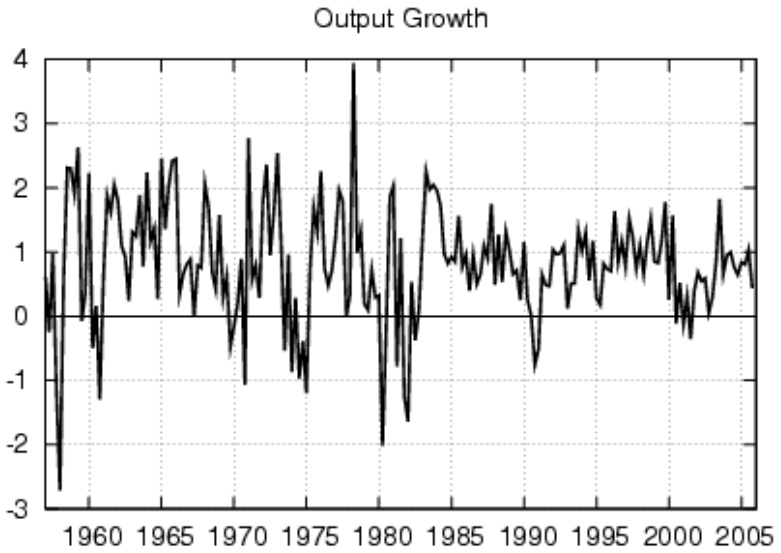
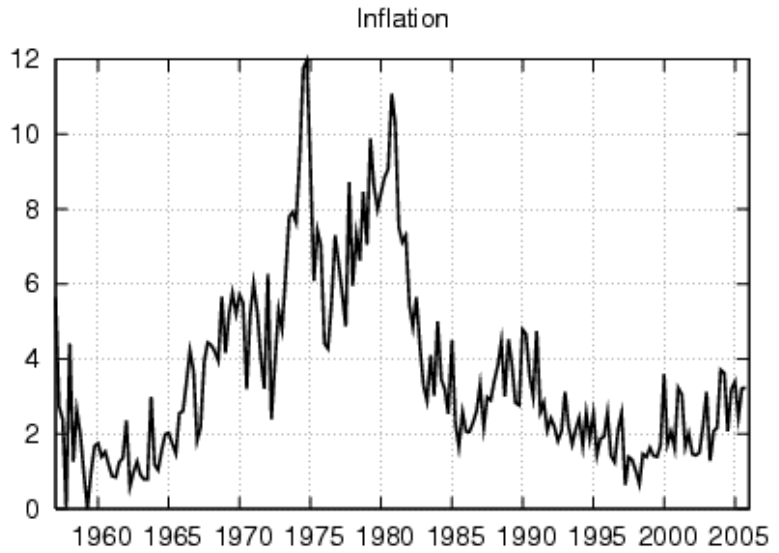
Time Varying Volatility





Purpose

- How much does "bad luck" explain changing volatility when adaptive expectations react to suspicions of structural changes.
- **Great Moderation:** seemingly permanent reduction in macroeconomic volatility since approximately 1982.
- **Bad Luck:** volatile periods were hit with bad shocks.
- **Adaptive Expectations:**
  - Least squares learning - agents run least-squares regressions
  - Predict output and inflation using lagged output, inflation, and interest rates as explanatory variables.

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Great Moderation Explanations

- Good vs. bad policy.
  - Lubik and Schorfheide (2004): find monetary policy was destabilizing pre-Volker.
  - Milani (2005): accounting for learning, little evidence of a change in monetary policy.
- Bad luck
  - Sims and Zha (2006): evidence points in favor of bad shocks.
  - Bullard and Singh (2007): bad luck + Bayesian learning.
- Learning
  - It is possible for learning *alone* to generate time-varying volatility.
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Learning Gain

- Learning gain: how much weight is given to the last (most recent) observation.
- Decreasing learning gain
  - Ordinary least squares - learning gain $= 1/n$.
  - As time progresses, sample size increases, learning gain decreases.
  - Implies agents do not suspect structural change.
  - Learning dynamics disappear over time.
- Constant learning gain
  - Gives more weight to most recent observations - weight declines geometrically with time.
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Dynamic Learning Gain

- Dynamic Gain Learning: agents endogenously switch between decreasing and constant learning gain.
  - Agents use decreasing gain unless forecast errors exceed a threshold.
  - Threshold = historical average absolute value forecast error.
  - Agents only suspect structural change when forecast errors are exceptionally high.
- Milani (2007): generates ARCH time-varying volatility
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Approach

- Use a standard, commonly estimated monetary model: New Keynesian Model.
  - Three equation model with optimizing consumers, sticky prices, monetary policy.
  - Stochastic shocks: demand shock, cost-push shock, monetary policy shock.
- Augment the model with dynamic gain learning.
- Also estimate model under RE and constant gain learning.
- Augment the model with Markov switching process for volatility.
  - Volatile regime: shocks have high variances.
  - Less volatile regime: shocks have relatively lower variances.
  - Economy switches between these two regimes by luck.

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Questions

- Does the dynamic gain model predict a lower likelihood economy was in volatile regime?
  - Spoiler: No.
- When is the economy in the volatile regime?
  - Spoiler: All models predict dates surrounding NBER recessions of 1970s.
- Does the dynamic gain model predict lower variances for volatile regime shocks?
  - Spoiler: Yes.
- When are agents using larger learning gain?
  - Spoiler: During most of the 1970s.
- What expectations mechanism fits the data best?
  - Spoiler: Rational expectations, constant gain learning, decreasing learning have nearly identical fit.

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New Keynesian Model: Optimal Consumer Behavior

- Consumers maximize net present value of lifetime utility, subject to their budget constraint.
- As the real interest rate increases, consumers decide to save more, consume less.
- The size of this effect depends on the **intertemporal elasticity of substitution**, estimated in paper.
- As the expected inflation rate rises, expected real interest rate falls.
- Habit formation: current consumption (current utility) depends on past consumption.
- **Degree of habit formation** is between 0 and 1, estimated in paper.
- Consumption subject to a *demand shock*.

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New Keynesian Model: Optimal Producer Behavior

- Monopolistically competitive firms.
- Exogenously sticky prices: it takes firms an uncertain amount time to appropriately adjust prices to maximize profits.
- Sticky prices enable monetary policy to have real effects on short-run output.
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- **Degree of indexation** is between 0 and 1, estimated in the paper.
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- Maximum Likelihood
  - Use Kim and Nelson (1999) method.
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Parameter Estimates

	Parameter	Rational Expectations	Dynamic Gain	Constant Gain
$\sigma_{n,L}$	Nat. Rate (Low)	0.1768 (0.3720)	0.0454 (0.0217)	0.0931 (0.0572)
$\sigma_{u,L}$	Cost Push (Low)	0.0023 (0.0001)	0.0045 (0.0004)	0.0042 (0.0001)
$\sigma_{r,L}$	MP Shock (Low)	0.0013 (0.0001)	0.0012 (0.0000)	0.0012 (0.0000)
$\sigma_{n,H}$	Nat. Rate (High)	0.4295 (0.9056)	0.0966 (0.0485)	0.1794 (0.1144)
$\sigma_{u,H}$	Cost Push (High)	0.0044 (0.0004)	0.0092 (0.0010)	0.0085 (0.0005)
$\sigma_{r,H}$	MP Shock (High)	0.0070 (0.0005)	0.0064 (0.0003)	0.0056 (0.0002)
p_L	P(Remain Low)	0.9609 (0.0224)	0.9724 (0.0097)	0.9780 (0.0109)
p_H	P(Remain High)	0.8099 (0.0578)	0.8924 (0.0264)	0.9412 (0.0159)
g	Learning Gain	–	0.0045 (0.0007)	0.0000 (0.0018)

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Expectations are not adaptive.

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Regimes are highly persistent.

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Learning predicts smaller variances of the natural rate shock.

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Regime-Switching Volatility

Rational Expectations

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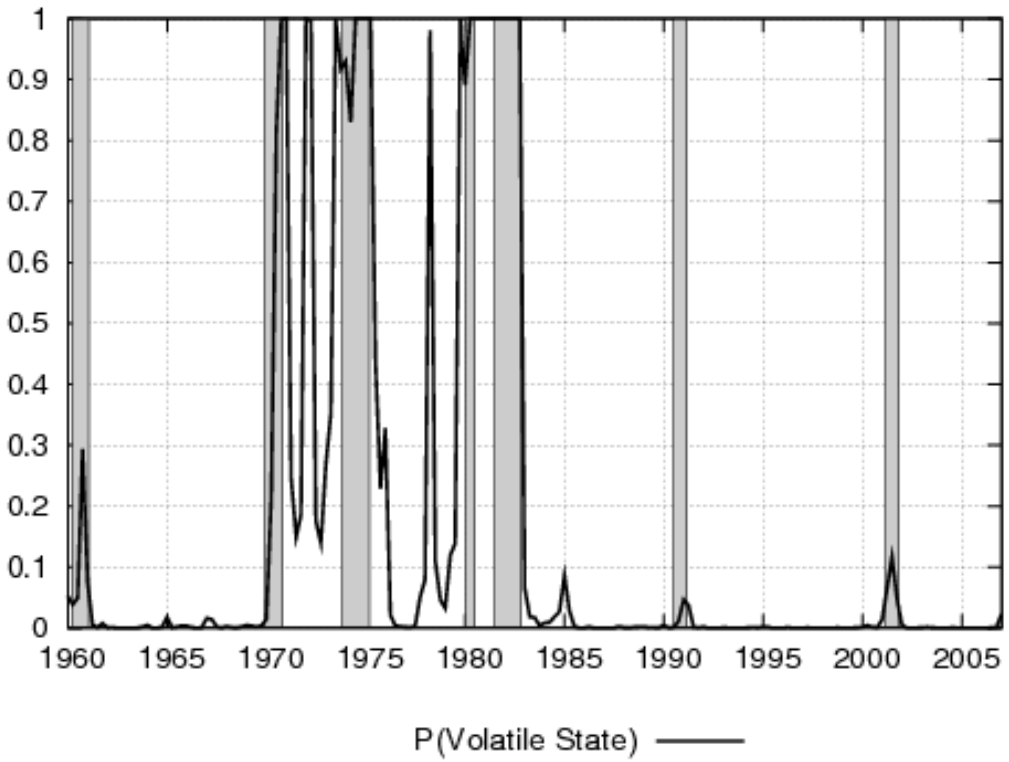
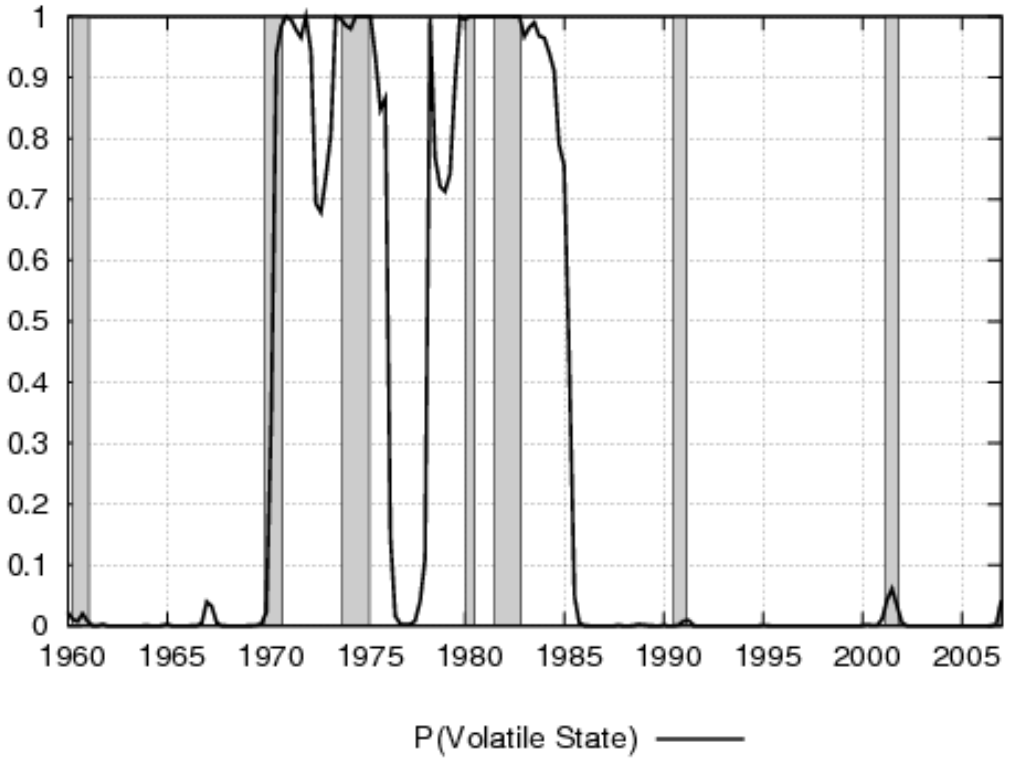


Expected 7.77 volatile years

Regime-Switching Volatility

Constant Gain Learning

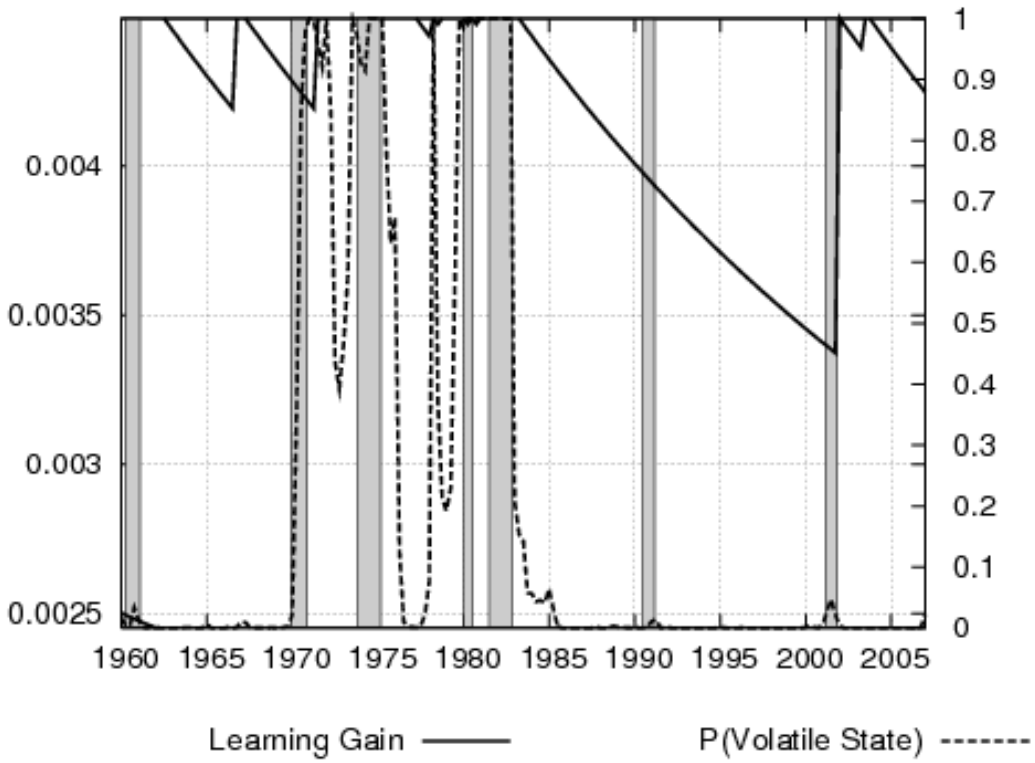
Probability Economy is in the Volatile Regime



Expected 12.26 volatile years

Regime-Switching Volatility

Dynamic Gain Learning
Probability Economy is in the Volatile Regime
and Evolution of the Learning Gain



Expected 9.17 volatile years

Forecast Errors Comparison

	Rational Expectations	Dynamic Gain	Constant Gain
RMSE Output Gap	3.12	3.13	3.18
RMSE Inflation	4.41	4.69	4.69
RMSE Federal Funds Rate	5.01	5.05	5.09
AR(1) Output Variance	0.0904 (0.0730)	0.1715 (0.0722)	0.1240 (0.0728)
AR(1) Inflation Variance	0.1760 (0.0716)	0.1364 (0.0699)	0.1073 (0.0653)
AR(1) Fed Funds Variance	0.3851 (0.0670)	0.3798 (0.0659)	0.3798 (0.0636)

- Rational Expectations actually (very slightly) fits data better than learning models.
- All models show some persistence in volatility of forecast errors.
- Models especially fail to explain changing volatility of the federal funds rate.

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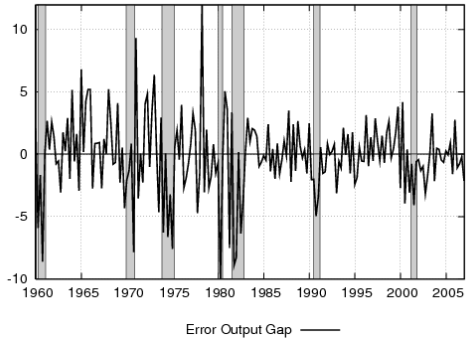
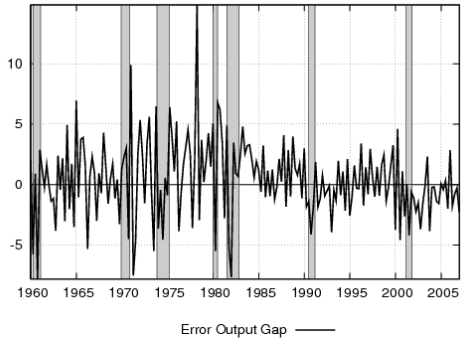
Forecast Errors: Output Gap

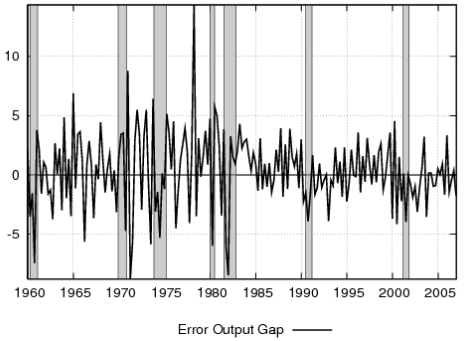
Rational Exp. (1.0)



Constant Gain (0.86)



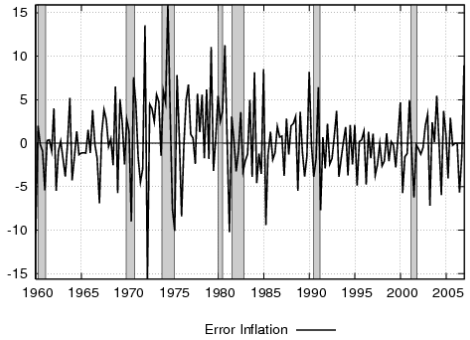
Dynamic Gain (0.82)



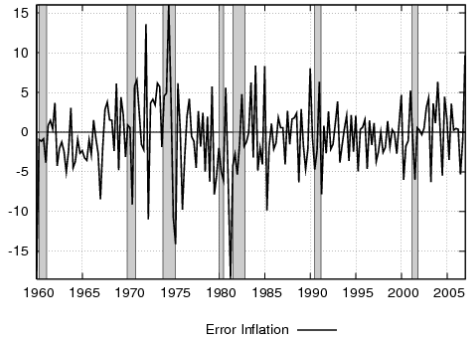
- (Correlation with Rational Expectations)
- All models made similar errors
- Most volatile during recessions in 1970s, early 1980s

Forecast Errors: Inflation

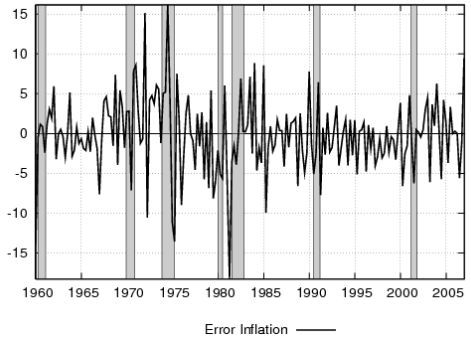
Rational Exp. (1.0)



Constant Gain (0.85)



Dynamic Gain (0.80)



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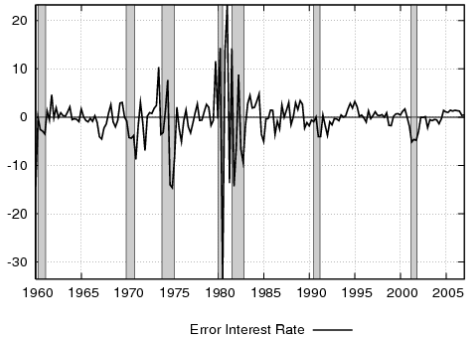
Forecast Errors: Federal Funds Rate

Rational Exp. (1.0)



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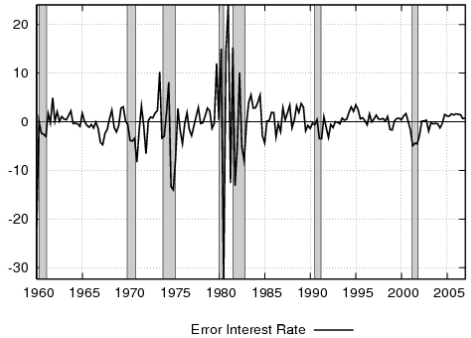

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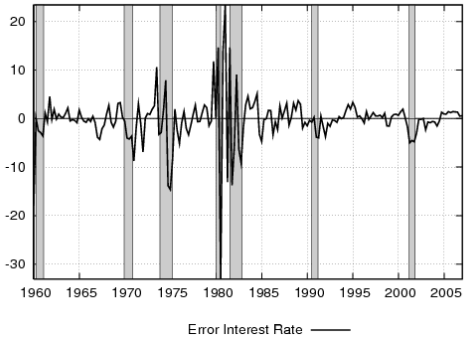

- (Correlation with Rational Expectations)
- Essentially identical errors.
- Do not explain change in policy in early 1980s.

Conclusions

- When allowing for regime-switching volatility, there is little evidence of adaptive expectations.
- Constant gain learning and dynamic gain learning both produce less volatility for the natural rate shock.
- Learning frameworks actually deliver a higher prediction for the time spent in volatile regime.
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- Rational expectations model actually yields smallest in-sample MSE.

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Research Program

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- New Keynesian model fails to deliver common features of data: persistence, volatility clustering, great moderation.
- My current papers: Empirical Examination of Learning.
  - Examine importance of choosing initial expectations.
  - Consider role of investment / capital accumulation.
  - Dynamic Gain.
- Future - Consider more dynamic expectations.
  - Branch (2004): Heterogeneous expectations.
  - Henzel (2008): Time-varying monetary policy - signal extraction learning.
  - Bullard, Evans, Honkapohja (2007): Near-rational exuberance.
  - Include survey forecasts (Michigan survey, Survey of Professional Forecasters).

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