Three Essays in Adaptive Expectations in New Keynesian Monetary Economies

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Dissertation Defense
Indiana University

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1. Initial Expectations in New Keynesian Models with Learning
2. Empirical Significance of Learning in a New Keynesian Model with Firm-Specific Capital
3. Regime Switching, Learning, and the Great Moderation

How does least squares learning affect our understanding of
post-war U.S. data?

- Does it explain prolonged inflation?
    - Orphanides and Williams (2005a)
- Does it explain time-varying volatility? Great Moderation?
    - Primiceri (QJE, 2005)
    - Orphanides and Williams (JEDC, 2005b)
    - Milani (2007)
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Initial Expectations in New Keynesian Models with Learning

- Examine constant gain learning in a standard New Keynesian model.
  - No capital, output used for consumption.
  - Habit formation.
  - Calvo (JME 1983) sticky prices.
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- Case 1: Rational Expectations.
    - Agents observe structural shocks (natural rate shock, cost push shock).
- Case 2: Constant gain least squares learning.
    - Agents observe structural shocks.
    - Expectations initialized to rational expectations solution.
- Case 3: Constant gain learning with a limited information set.
    - Shocks are not observable, not used as explanatory variables.
    - Expectations on remaining variables set equal to rational expectations solution.
- Case 4: Constant gain learning with pre-sample initial expectations.
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- Maximum Likelihood
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	Parameter	Case 1	Case 2	Case 3	Case 4
η	Habit Persistence	0.9929 (0.0892)	0.6515 (0.0174)	0.9577 (0.4132)	0.7065 (0.2465)
σ^{-1}	Inverse IES	0.0015 (0.0281)	0.4162 (0.0536)	0.0308 (0.5686)	0.2457 (0.4541)
γ	Price Indexation	0.0000 (0.0377)	0.7126 (0.0238)	0.9994 (0.0754)	0.6322 (0.1325)
ρ_r	MP Persistence	0.8857 (0.0195)	0.7843 (0.0030)	0.8558 (0.0208)	0.7043 (0.0391)
ψ_y	MP Output Gap	0.3864 (0.1228)	0.0758 (0.0163)	0.1434 (0.0320)	0.2265 (0.0451)
ψ_π	MP Inflation	3.6813 (0.6479)	1.7419 (0.0343)	2.2153 (0.2974)	1.5009 (0.0942)
ρ_n	Natural Rate Pers.	0.3636 (0.0381)	0.7699 (0.0045)	0.3060 (0.0406)	0.5102 (0.0434)
ρ_u	Cost Push Pers.	0.8568 (0.0155)	0.2398 (0.0366)	0.0000 (0.0438)	0.2880 (0.0684)
σ_n	Natural Rate Std. Dev.	0.0635 (0.0128)	0.0055 (0.0000)	0.2173 (0.0584)	0.0328 (0.0112)
σ_u	Cost Push Std. Dev.	0.0021 (0.0001)	0.0066 (0.0003)	0.0122 (0.0005)	0.0100 (0.0008)
σ_r	Policy Shock Std. Dev.	0.0032 (0.0001)	0.0031 (0.0001)	0.0030 (0.0000)	0.0031 (0.0001)
π^*	Steady State Inflation	3.5304 (0.2017)	3.2369 (0.3026)	4.5971 (0.4958)	4.0443 (0.3728)
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Learning predicts consumption and monetary policy decisions are
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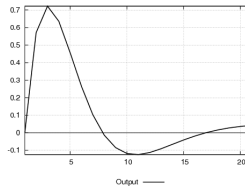Learning models predict significant inflation persistence.

- Does learning influence the impact a structural shock has on the economy?
- Minimal impact from learning occurs when expectations are at the RE steady state.
- Absent of shocks, state variables still evolve when expectations are away from their steady state.
- Methodology:
    - Take expectations at time 2008:Q4.
    - Simulate data with a one standard deviation shock to natural interest rate.
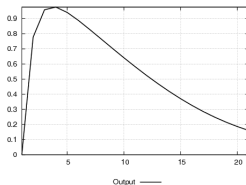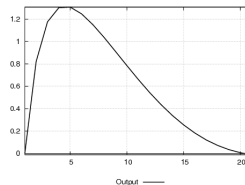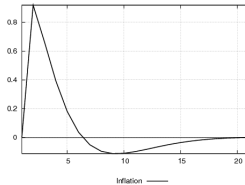   - Simulate data absent of any shocks.
    - Take the difference.

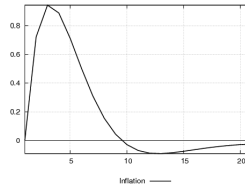- Does learning influence the impact a structural shock has on the economy?
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Case 2

Case 3
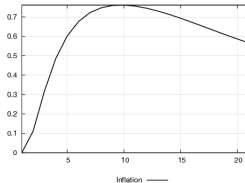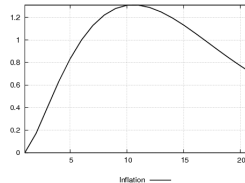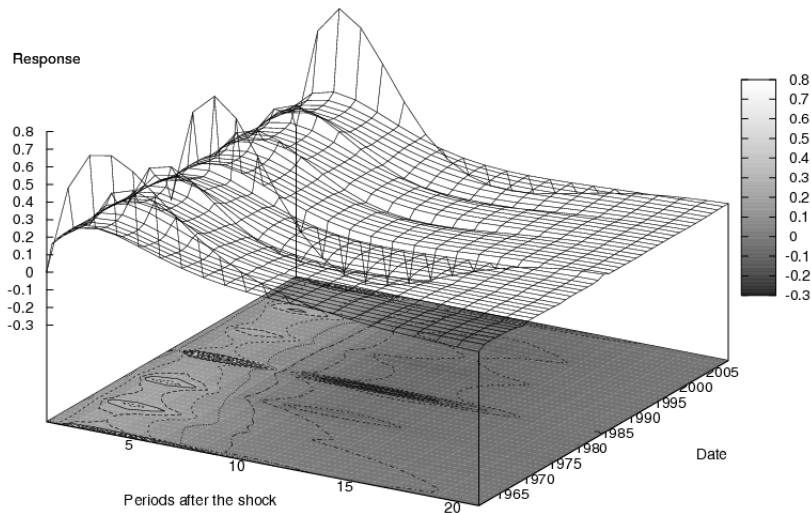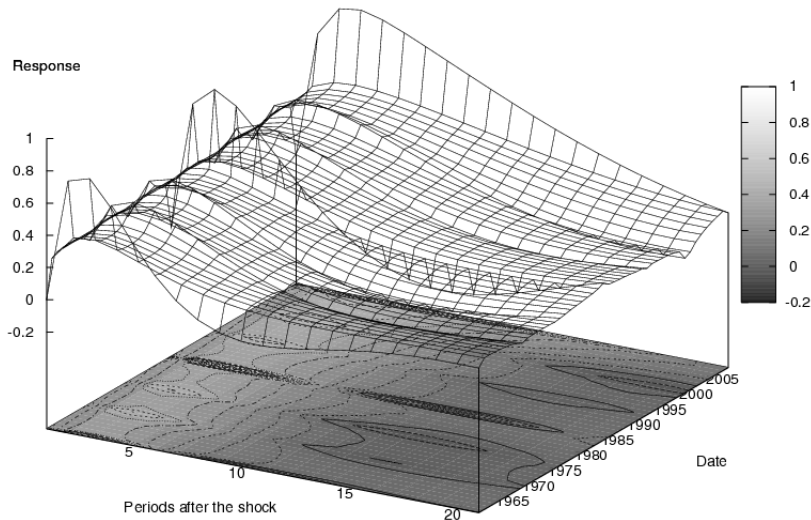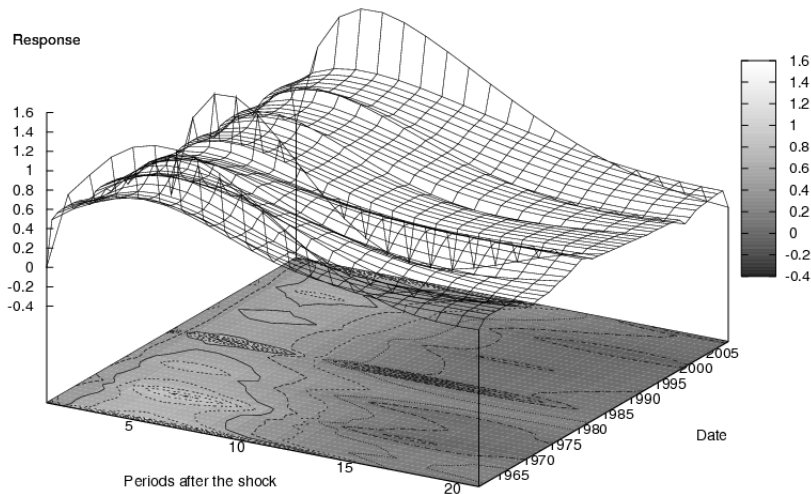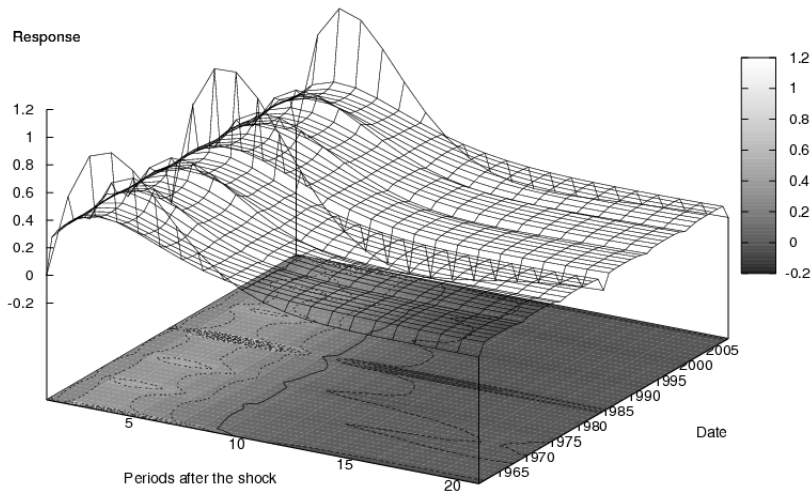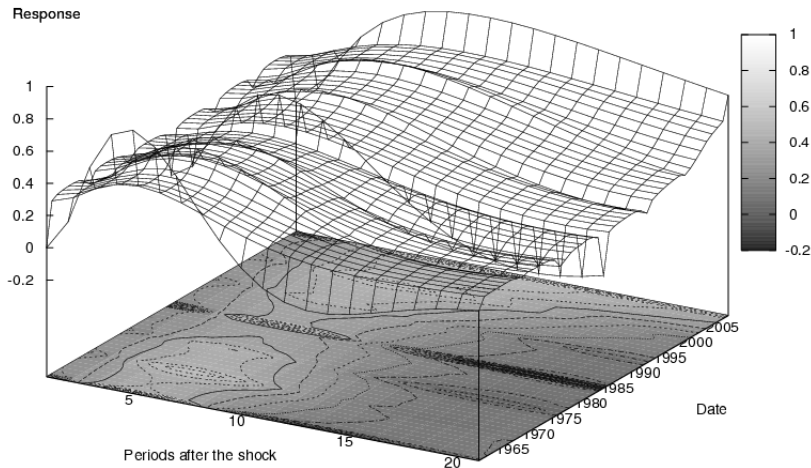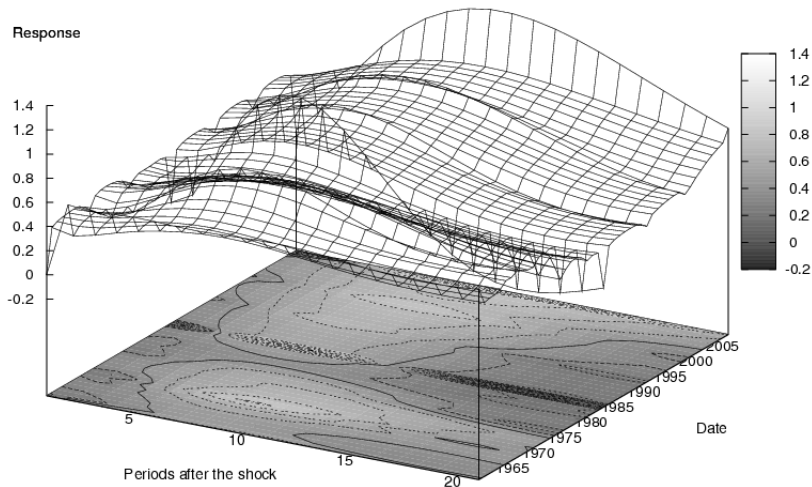
Case 4

Case 1

Case 2

Case 3

Case 4

Case 1 (1.0)
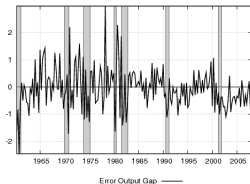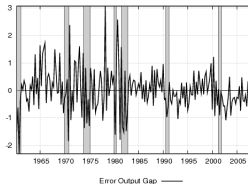
Error Output Gap ———

Case 2 (0.98)

Error Output Gap ———

Case 3 (0.97)

Error Output Gap ———

Case 4 (0.92)

Error Output Gap ———

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

Case 1 (1.0)   Case 2 (0.93)
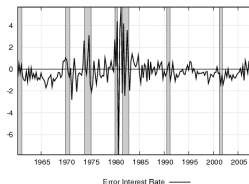
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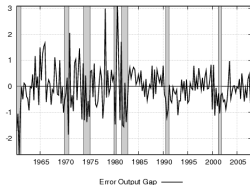- Largest errors during recessions in 1970s, early 1980s

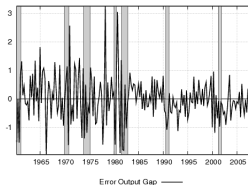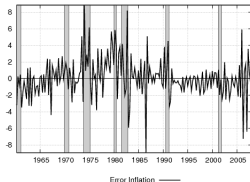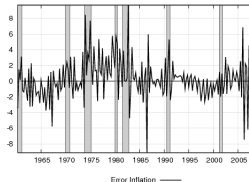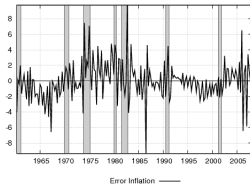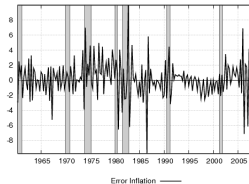Case 3 (0.90)   Case 4 (0.89)

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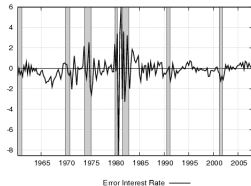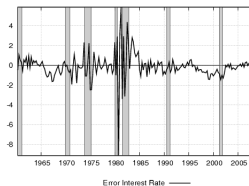
- (Correlation with Rational Expectations)
- All models made similar errors
- Learning *does not explain* change in policy beginning 1979/1980.

Case 3 (0.95)

Case 4 (0.91)

- Learning gain is statistically significant.

- Incorporating learning leads to parameter estimates that imply less sensitivity to expectations.

- Largest errors for every specification still occur during 1970s and early 1980s.

- Learning + Limited information sets leads to prolonged and oscillatory impulse responses.

- 3D Impulse Responses show the United States was more sensitive to shocks following recessions in 1970s, early 1980s, and now.

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  sets influence results on...
    - parameter estimates?
    - impact of structural shocks?
    - forecast errors?
- Look at the same four cases for initial conditions and agents'
  information sets.

- Pre-sample period: 1953:Q3 - 1969:Q4, Sample period: 1970:Q1-2008:Q1

- Data:

    - Real consumption per capita
    - Real gross private domestic investment per capita
    - CPI inflation
    - Federal Funds rate

- Consumption and Investment is de-trended:

$$CONS_t^* = \frac{CONS_t}{(1+g_y)^t}, \quad INV_t^* = \frac{INV_t}{(1+g_y)^t}$$

    - $g_y \equiv$ average quarterly growth rate of $CONS_t + INV_t$.

- Pre-sample period: 1953:Q3 - 1969:Q4, Sample period: 1970:Q1-2008:Q1
- Data:
    - Real consumption per capita
    - Real gross private domestic investment per capita
    - CPI inflation
    - Federal Funds rate
- Consumption and Investment is de-trended:

$$CONS_t^* = \frac{CONS_t}{(1+g_y)^t}, \quad INV_t^* = \frac{INV_t}{(1+g_y)^t}$$

- $g_y \equiv$ average quarterly growth rate of $CONS_t + INV_t$.

- Pre-sample period: 1953:Q3 - 1969:Q4, Sample period: 1970:Q1-2008:Q1
- Data:
  - Real consumption per capita
  - Real gross private domestic investment per capita
  - CPI inflation
  - Federal Funds rate
- Consumption and Investment is de-trended:

$$CONS_t^* = \frac{CONS_t}{(1+g_y)^t}, \quad INV_t^* = \frac{INV_t}{(1+g_y)^t}$$

- $g_y \equiv$ average quarterly growth rate of $CONS_t + INV_t$.

- Maximum Likelihood
- Calibrate parameters:
    - Discount factor $\beta = 0.9925$
    - Steady state inflation $\pi^* = 3.52$.
    - Depreciation rate $\delta = 0.025$.
    - Steady state level of (de-trended) output set equal to average.
    - Phillips curve slope $\kappa = 0.1$.
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    - Phillips curve slope $\kappa = 0.1$.
    - Capital share of income $\alpha = 0.24$.

	Parameter	Case 1	Case 2	Case 3	Case 4
η	Habit Persistence	0.1060 (0.0272)	0.1289 (0.0399)	0.1224 (0.0264)	0.2728 (0.0232)
σ	IES	0.1603 (0.0342)	0.0513 (0.0072)	0.0157 (0.0001)	0.1220 (0.0175)
μ	Inverse Elas. Labor	30.6713 (8.9559)	0.0499 (0.0771)	2.0877 (0.4286)	0.3324 (0.2817)
c_y	C/Y Ratio	0.8339 (0.0038)	0.8672 (0.0024)	0.8361 (0.0000)	0.8289 (0.0028)
ϕ	Capital Adj. Cost	7.6832 (1.4003)	24.8826 (1.4036)	26.8332 (4.1201)	26.9755 (1.7912)
γ	Price Indexation	0.3624 (0.1929)	0.0000 (0.0349)	0.5236 (0.0852)	0.6090 (0.1214)
ρ_r	MP Persistence	0.1945 (0.0497)	0.6592 (0.0141)	0.7250 (0.0280)	0.0956 (0.1061)
ψ_y	MP Output	0.0000 (0.0172)	0.0576 (0.0090)	0.0458 (0.0092)	0.0041 (0.0131)
ψ_π	MP Inflation	2.1212 (0.1893)	1.4448 (0.0658)	1.7735 (0.1278)	1.8491 (0.0974)
ρ_ξ	Pref. Shock Pers.	0.9826 (0.0069)	0.9925 (0.0040)	0.9636 (0.0070)	1.0000 (0.0000)
ρ_z	Tech. Shock Pers.	0.9668 (0.0058)	0.6741 (0.0254)	0.9638 (0.0193)	0.9506 (0.0121)
ρ_ι	Inv. Shock Pers.	0.9060 (0.0151)	0.9301 (0.0084)	0.9297 (0.0103)	0.9234 (0.0173)
σ_ξ	Pref. Shock Std. Dev.	0.0926 (0.0252)	0.1647 (0.0211)	0.6165 (0.0511)	0.6879 (0.0446)
σ_z	Tech. Shock Std. Dev.	0.0104 (0.0003)	0.0199 (0.0018)	0.0294 (0.0037)	0.0730 (0.0191)
σ_ι	Inv. Shock Std. Dev.	0.0206 (0.0021)	0.1130 (0.0149)	0.0387 (0.0016)	0.0683 (0.0069)
σ_r	MP Shock Std. Dev.	0.0027 (0.0003)	0.0032 (0.0001)	0.0036 (0.0001)	0.0053 (0.0003)
g	Learning Gain	–	0.0240 (0.0043)	0.0236 (0.0026)	0.0381 (0.0038)

	Parameter	Case 1	Case 2	Case 3	Case 4
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Learning gain is statistically significant.

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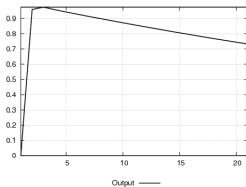Learning predicts that consumption decisions are less responsive to changes in expectations.

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g	Learning Gain	–	0.0240 (0.0043)	0.0236 (0.0026)	0.0381 (0.0038)

Learning predicts much more elastic labor supply, indicating
investment decisions less responsive to expectations of future
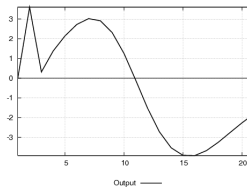output and capital.

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g	Learning Gain	–	0.0240 (0.0043)	0.0236 (0.0026)	0.0381 (0.0038)

Learning predicts larger capital adjustment cost, indicating
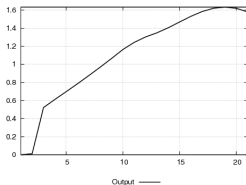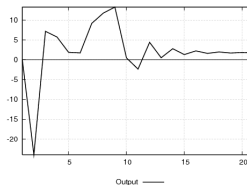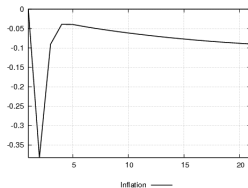investment decisions less responsive to expectations of future
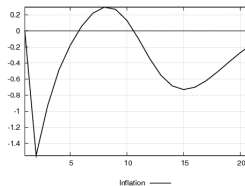output and capital.

Case 1

Case 2

Case 3
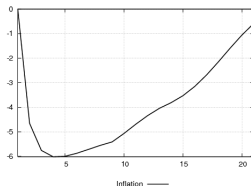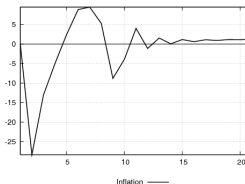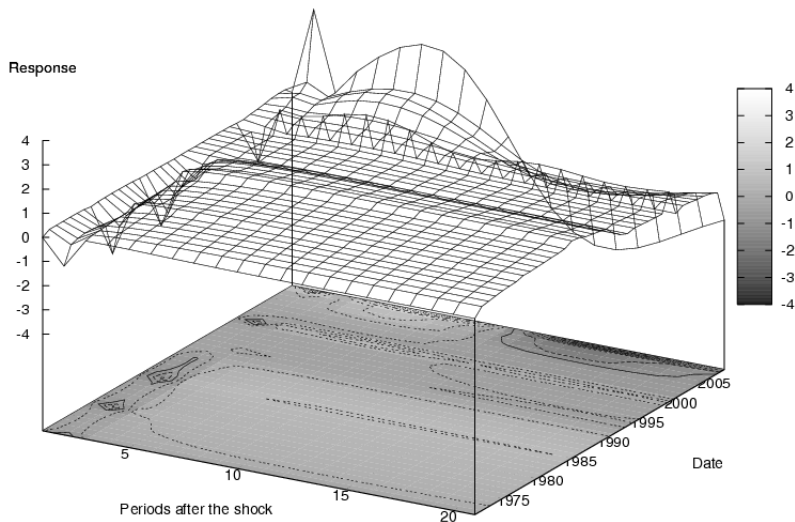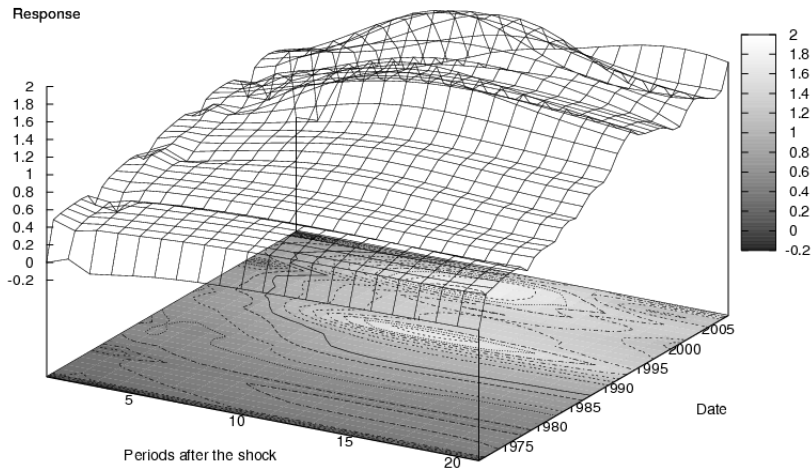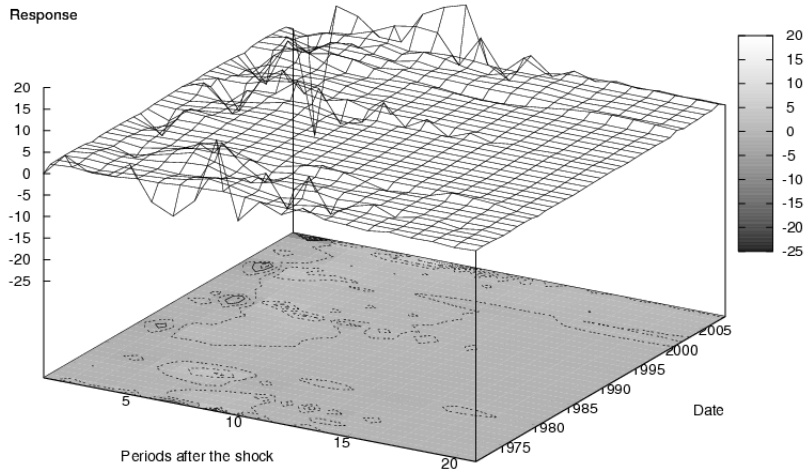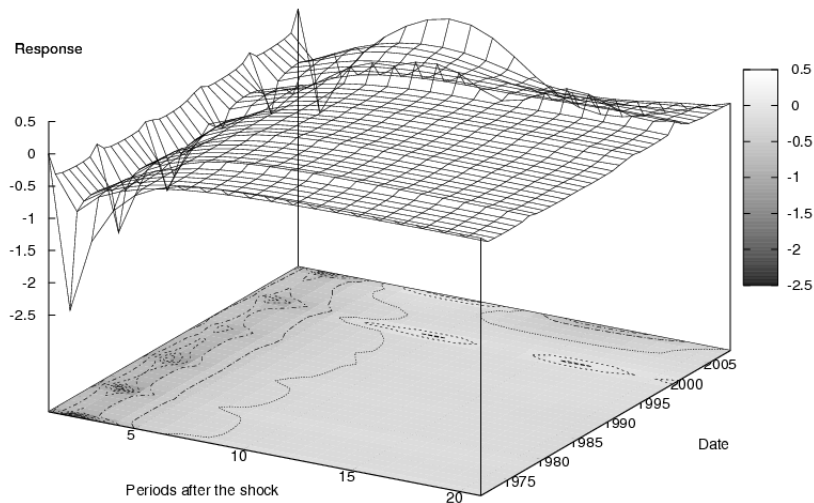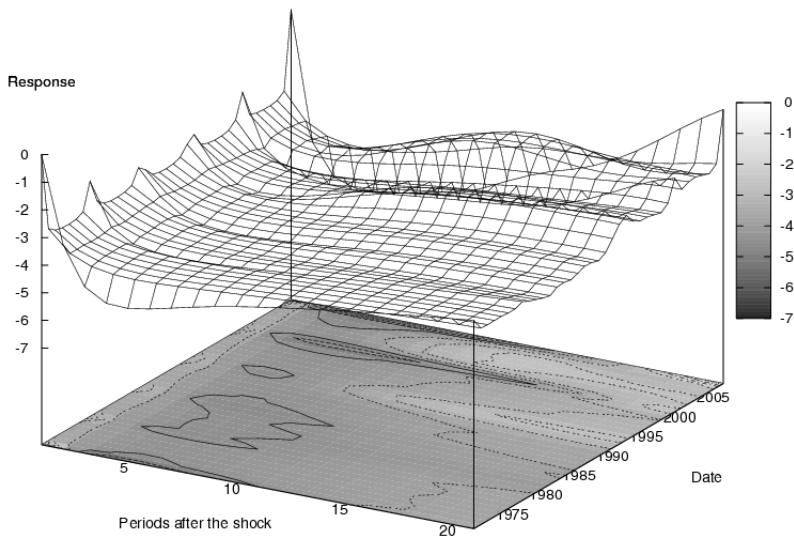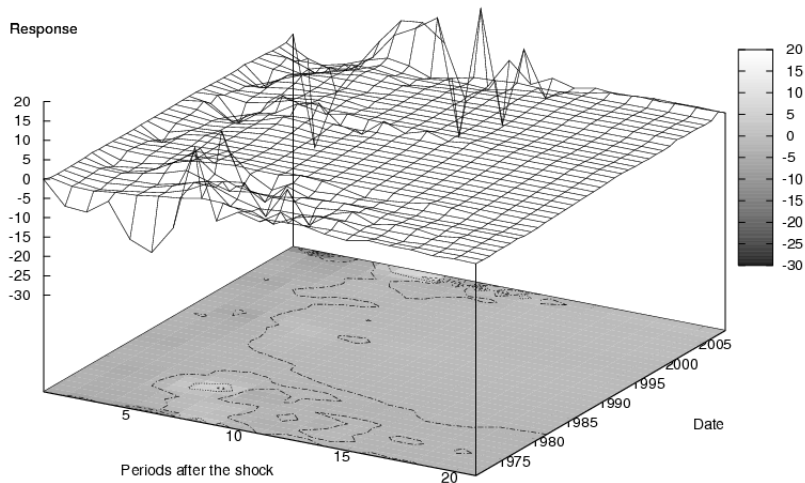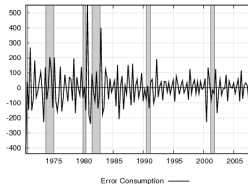
Case 4

Case 1

Case 2

Case 3

Case 4

Response

Response

Periods after the shock

Date

Case 1 (1.0)

Error Consumption ——

Case 2 (0.95)

Error Consumption ——

Case 3 (0.99)

Error Consumption ——

Case 4 (0.70)

Error Consumption ——

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

Case 1 (1.0)

Error Investment ——

Case 2 (0.85)

Error Investment ——
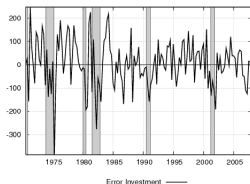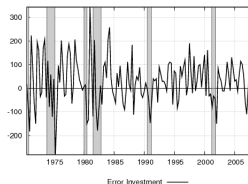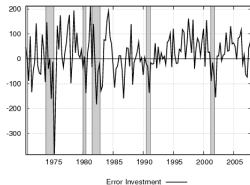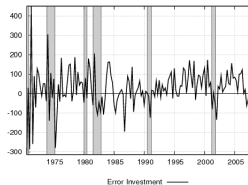
- (Correlation with Rational Expectations)
- Models with RE initial expectations make similar errors
- Large errors before 1985.

Case 3 (0.86)
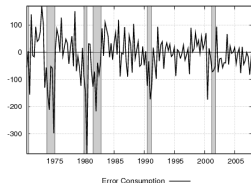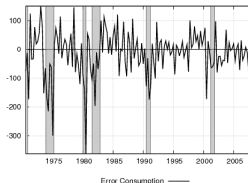

Error Investment ——
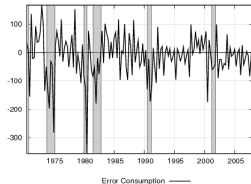
Case 4 (0.48)

Error Investment ——
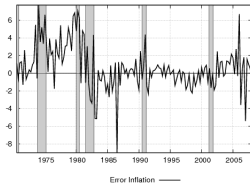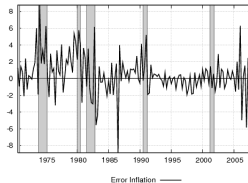
Case 1 (1.0)

Case 2 (0.92)

Case 3 (0.65)
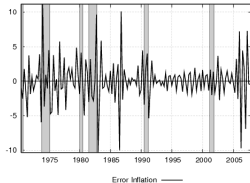
Case 4 (0.65)
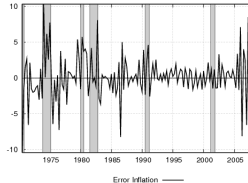
- (Correlation with Rational Expectations)
- Models with limited information somewhat less correlated with RE.
- Largest errors during mid-1970s and early 1980s recessions, and today.

Case 1 (1.0)

Error Interest Rate ———

Case 2 (0.95)

Error Interest Rate ———

Case 3 (0.95)

Error Interest Rate ———

Case 4 (0.69)

Error Interest Rate ———
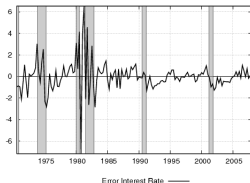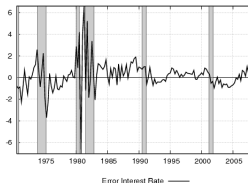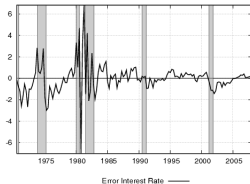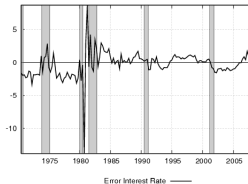
- (Correlation with Rational Expectations)
- All models fail to account for change in policy at beginning of Paul Volcker period.

- Learning gain is statistically significant.

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- Not presented: learning models do not significantly out-perform rational expectations in in-sample and out-of-sample forecast error measures.

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Regime Switching, Learning, and Great Moderation

- Three equation New Keynesian model (same as Essay 1)
- Examine whether dynamic gain learning [Marcet and Nicolini (AER 2003)] can explain time-varying volatility.

    - Agents start using decreasing learning gain consistent with OLS.
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- Learning process:

$$\hat{G}_t^* = \hat{G}_{t-1}^* + g_t(x_{t-1} - \hat{G}_{t-1}^* x_{t-2}^*) x_{t-2}^{*\prime} R_t^{-1}$$

$$R_t = R_{t-1} + g_t(x_{t-2}^* x_{t-2}^{*\prime} - R_{t-1})$$

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$$g_t^{-1} = \begin{cases} g_{t-1}^{-1} + 1 & \text{if } \frac{1}{J}\sum_{j=1}^{J}\frac{1}{n}\sum_{v=1}^{n}\left|x_{t-j}(v) - \hat{G}_{t-j}^*(v)x_{t-j-1}^*\right| < \nu_t \\ g^{-1} & \text{otherwise} \end{cases}$$

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- Variances of natural rate, cost push, and monetary policy shocks switching according to a Markov chain.

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Var\left[\epsilon_t(s_t)\right] = \left\{ \begin{array}{l} \left[\begin{array}{ccc} \sigma_{n,L}^2 & 0 & 0 \\ 0 & \sigma_{u,L}^2 & 0 \\ 0 & 0 & \sigma_{r,L}^2 \end{array} \right], \text{ if } s_t = L \\ \left[\begin{array}{ccc} \sigma_{n,H}^2 & 0 & 0 \\ 0 & \sigma_{u,H}^2 & 0 \\ 0 & 0 & \sigma_{r,H}^2 \end{array} \right], \text{ if } s_t = H \end{array} \right\}
$$

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- Data: output gap, CPI inflation rate, federal funds rate.
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	Parameter	Rational Expectations	Dynamic Gain	Constant Gain
η	Habit Formation	0.3643 (0.0478)	0.2580 (0.0308)	0.3659 (0.0288)
σ	IES	0.0073 (0.0154)	0.2560 (0.1171)	0.1824 (0.1140)
μ	Elas. Labor	0.0000 (40.9507)	0.3219 (2.2075)	0.0001 (5.0920)
κ	Phillips Coefficient	0.0011 (0.0186)	0.0237 (0.0256)	0.0054 (0.0146)
γ	Price Indexation	0.8945 (0.0330)	0.9849 (0.1926)	0.9990 (0.0004)
ρ_r	MP Persistence	0.9355 (0.0289)	0.9234 (0.0084)	0.9196 (0.0092)
ψ_y	MP Output	0.2507 (0.0498)	0.1878 (0.0367)	0.2758 (0.0425)
ψ_π	MP Inflation	1.9577 (0.2591)	1.7363 (0.1687)	1.6354 (0.1189)
ρ_n	Nat. Rate Pers.	0.8705 (0.0353)	0.7484 (0.0267)	0.6936 (0.0272)
ρ_u	Cost Push Pers.	0.0000 (0.0000)	0.0062 (0.0376)	0.0031 (0.0085)
π_*	SS Inflation	3.5446 (0.2808)	4.4419 (0.2220)	5.3272 (0.2825)
$\sigma_{n,L}$	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.

Parameter Estimates

/ 48

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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)

Learning predicts smaller variances of the natural rate shock.

	Parameter	Rational Expectations	Dynamic Gain	Constant Gain
η	Habit Formation	0.3643 (0.0478)	0.2580 (0.0308)	0.3659 (0.0288)
σ	IES	0.0073 (0.0154)	0.2560 (0.1171)	0.1824 (0.1140)
μ	Elas. Labor	0.0000 (40.9507)	0.3219 (2.2075)	0.0001 (5.0920)
κ	Phillips Coefficient	0.0011 (0.0186)	0.0237 (0.0256)	0.0054 (0.0146)
γ	Price Indexation	0.8945 (0.0330)	0.9849 (0.1926)	0.9990 (0.0004)
ρ_r	MP Persistence	0.9355 (0.0289)	0.9234 (0.0084)	0.9196 (0.0092)
ψ_y	MP Output	0.2507 (0.0498)	0.1878 (0.0367)	0.2758 (0.0425)
ψ_π	MP Inflation	1.9577 (0.2591)	1.7363 (0.1687)	1.6354 (0.1189)
ρ_n	Nat. Rate Pers.	0.8705 (0.0353)	0.7484 (0.0267)	0.6936 (0.0272)
ρ_u	Cost Push Pers.	0.0000 (0.0000)	0.0062 (0.0376)	0.0031 (0.0085)
π_*	SS Inflation	3.5446 (0.2808)	4.4419 (0.2220)	5.3272 (0.2825)
$\sigma_{n,L}$	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)
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Variances of cost push and monetary shock are similar.

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Variances of cost push and monetary shock are similar.

Rational Expectations
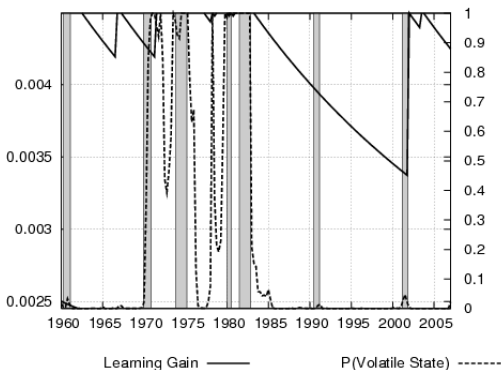Probability Economy is in the Volatile Regime

P(Volatile State) ———
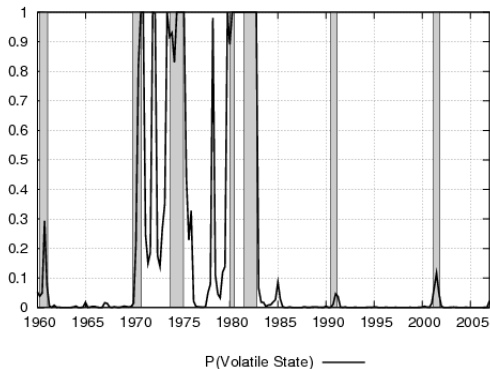
Expected 7.77 volatile years

Constant Gain Learning
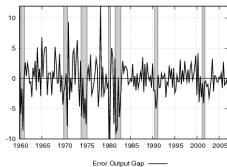Probability Economy is in the Volatile Regime

P(Volatile State) ⎯⎯⎯
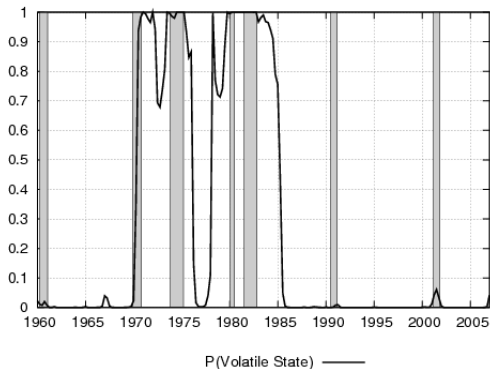
Expected 12.26 volatile years

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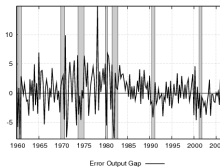Probability Economy is in the Volatile Regime
and Evolution of the Learning Gain

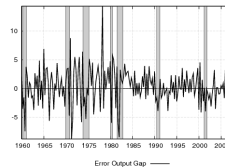Learning Gain ———   P(Volatile State) -------

Expected 9.17 volatile years

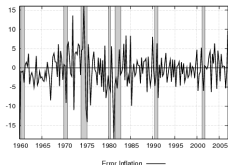Rational Exp. (1.0)   Constant Gain (0.86)   Dynamic Gain (0.82)

Error Output Gap ——   Error Output Gap ——   Error Output Gap ——

- (Correlation with Rational Expectations)
- All models made similar errors
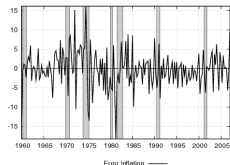- Most volatile during recessions in 1970s, early 1980s
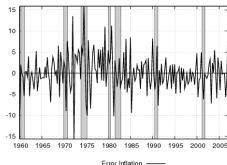
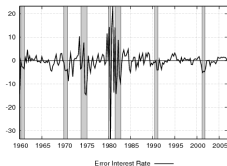Rational Exp. (1.0)   Constant Gain (0.85)   Dynamic Gain (0.80)
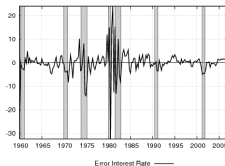

- (Correlation with Rational Expectations)
- All models made similar errors.
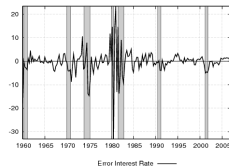- Most volatile during recessions in 1970s, early 1980s.

Rational Exp. (1.0)   Constant Gain (0.99)   Dynamic Gain (0.99)

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

- 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.

- All models make similar forecast errors at similar points in sample.

- Not presented: the rational expectations model actually yields smallest in-sample MSE.

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