Empirical Significance of Learning in a New Keynesian Model with Firm-Specific Capital

James Murray
Indiana University

October 5, 2007

Learning vs. Rational Expectations

- Rational Expectations: agents have knowledge of economy's structure, all parameters, distribution of shocks.
- Learning: Agents form expectations with least squares forecasts.
- Popular assumption: agents use the correct specification.
- Misspecifications:
  - Some variables in economy are unobservable to agents.
  - Agents ignore multi-variate structure, use univariate methods.
  - Agents use additional variables.

Learning vs. Rational Expectations

- Rational Expectations: agents have knowledge of economy's structure, all parameters, distribution of shocks.
- Learning: Agents form expectations with least squares forecasts.
- Popular assumption: agents use the correct specification.
- Misspecifications:
  - Some variables in economy are unobservable to agents.
  - Agents ignore multi-variate structure, use univariate methods.
  - Agents use additional variables.

Learning vs. Rational Expectations

- Rational Expectations: agents have knowledge of economy's structure, all parameters, distribution of shocks.
- Learning: Agents form expectations with least squares forecasts.
- Popular assumption: agents use the correct specification.
- Misspecifications:
  - Some variables in economy are unobservable to agents.
  - Agents ignore multi-variate structure, use univariate methods.
  - Agents use additional variables.

Learning vs. Rational Expectations

- Rational Expectations: agents have knowledge of economy's structure, all parameters, distribution of shocks.
- Learning: Agents form expectations with least squares forecasts.
- Popular assumption: agents use the correct specification.
- Misspecifications:
  - Some variables in economy are unobservable to agents.
  - Agents ignore multi-variate structure, use univariate methods.
  - Agents use additional variables.

Learning and Monetary Models

- Prolonged inflation following a shock:
  - Orphanides and Williams (RED 2005).
- Bad monetary policy prescriptions:
  - Orphanides and Williams (JEDC 2005), Primiceri (QJE 2006).
- Output and inflation persistence:
  - Milani (2005).

Learning and Monetary Models

- Prolonged inflation following a shock:
  - Orphanides and Williams (RED 2005).
- Bad monetary policy prescriptions:
  - Orphanides and Williams (JEDC 2005), Primiceri (QJE 2006).
- Output and inflation persistence:
  - Milani (2005).

Learning and Monetary Models

- Prolonged inflation following a shock:
  - Orphanides and Williams (RED 2005).
- Bad monetary policy prescriptions:
  - Orphanides and Williams (JEDC 2005), Primiceri (QJE 2006).
- Output and inflation persistence:
  - Milani (2005).

Initial Conditions

- Initial beliefs can play a major role.
- Orphanides and Williams (JEDC 2005):
  - Central Bank began under-estimating natural rate of unemployment.
- Primiceri:
  - Central Bank began under-estimating unemployment and inflation persistence.
- Milani:
  - Many initial beliefs set to pre-sample VAR(1).
  - Assumes lower inflation persistence, sensitivity of output to inflation.
  - Assumes shocks are observable, sets initial impacts to zero.
- Missing from empirical literature:
  - Systematic way for specifying initial conditions.
  - Estimate initial conditions.
  - Sensitivity analysis to initial conditions.

Initial Conditions

- Initial beliefs can play a major role.
- Orphanides and Williams (JEDC 2005):
  - Central Bank began under-estimating natural rate of unemployment.
- Primiceri:
  - Central Bank began under-estimating unemployment and inflation persistence.
- Milani:
  - Many initial beliefs set to pre-sample VAR(1).
  - Assumes lower inflation persistence, sensitivity of output to inflation.
  - Assumes shocks are observable, sets initial impacts to zero.
- Missing from empirical literature:
  - Systematic way for specifying initial conditions.
  - Estimate initial conditions.
  - Sensitivity analysis to initial conditions.

Initial Conditions

- Initial beliefs can play a major role.
- Orphanides and Williams (JEDC 2005):
  - Central Bank began under-estimating natural rate of unemployment.
- Primiceri:
  - Central Bank began under-estimating unemployment and inflation persistence.
- Milani:
  - Many initial beliefs set to pre-sample VAR(1).
  - Assumes lower inflation persistence, sensitivity of output to inflation.
  - Assumes shocks are observable, sets initial impacts to zero.
- Missing from empirical literature:
  - Systematic way for specifying initial conditions.
  - Estimate initial conditions.
  - Sensitivity analysis to initial conditions.

Initial Conditions

- Initial beliefs can play a major role.
- Orphanides and Williams (JEDC 2005):
  - Central Bank began under-estimating natural rate of unemployment.
- Primiceri:
  - Central Bank began under-estimating unemployment and inflation persistence.
- Milani:
  - Many initial beliefs set to pre-sample VAR(1).
  - Assumes lower inflation persistence, sensitivity of output to inflation.
  - Assumes shocks are observable, sets initial impacts to zero.
- Missing from empirical literature:
  - Systematic way for specifying initial conditions.
  - Estimate initial conditions.
  - Sensitivity analysis to initial conditions.

Initial Conditions

- Initial beliefs can play a major role.
- Orphanides and Williams (JEDC 2005):
  - Central Bank began under-estimating natural rate of unemployment.
- Primiceri:
  - Central Bank began under-estimating unemployment and inflation persistence.
- Milani:
  - Many initial beliefs set to pre-sample VAR(1).
  - Assumes lower inflation persistence, sensitivity of output to inflation.
  - Assumes shocks are observable, sets initial impacts to zero.
- Missing from empirical literature:
  - Systematic way for specifying initial conditions.
  - Estimate initial conditions.
  - Sensitivity analysis to initial conditions.

Strategies for Initial Conditions

- Use the rational expectations solution.
  - Benefit: Initial conditions are consistent with model.
  - Draw back: Learning dynamics are small near the RE equilibrium. (Williams 2003).
- Assume limited information set.
  - Agents cannot observe realizations of stochastic shocks.
  - Initialize beliefs of remaining coefficients equal to RE solution.
  - Benefit: more realistic.
- Using limited information, set initial beliefs to pre-sample least squares estimates.
  - Benefit: Most likely to mirror actual beliefs.
  - Draw back: sometimes so far from RE the learning model is unstable (Slobodyan and Wouters 2007).
- Jointly estimate initial conditions.
  - Draw back: many additional parameters, over-fitting problem.

Strategies for Initial Conditions

- Use the rational expectations solution.
  - Benefit: Initial conditions are consistent with model.
  - Draw back: Learning dynamics are small near the RE equilibrium. (Williams 2003).
- Assume limited information set.
  - Agents cannot observe realizations of stochastic shocks.
  - Initialize beliefs of remaining coefficients equal to RE solution.
  - Benefit: more realistic.
- Using limited information, set initial beliefs to pre-sample least squares estimates.
  - Benefit: Most likely to mirror actual beliefs.
  - Draw back: sometimes so far from RE the learning model is unstable (Slobodyan and Wouters 2007).
- Jointly estimate initial conditions.
  - Draw back: many additional parameters, over-fitting problem.

Strategies for Initial Conditions

- Use the rational expectations solution.
  - Benefit: Initial conditions are consistent with model.
  - Draw back: Learning dynamics are small near the RE equilibrium. (Williams 2003).
- Assume limited information set.
  - Agents cannot observe realizations of stochastic shocks.
  - Initialize beliefs of remaining coefficients equal to RE solution.
  - Benefit: more realistic.
- Using limited information, set initial beliefs to pre-sample least squares estimates.
  - Benefit: Most likely to mirror actual beliefs.
  - Draw back: sometimes so far from RE the learning model is unstable (Slobodyan and Wouters 2007).
- Jointly estimate initial conditions.
  - Draw back: many additional parameters, over-fitting problem.

Strategies for Initial Conditions

- Use the rational expectations solution.
  - Benefit: Initial conditions are consistent with model.
  - Draw back: Learning dynamics are small near the RE equilibrium. (Williams 2003).
- Assume limited information set.
  - Agents cannot observe realizations of stochastic shocks.
  - Initialize beliefs of remaining coefficients equal to RE solution.
  - Benefit: more realistic.
- Using limited information, set initial beliefs to pre-sample least squares estimates.
  - Benefit: Most likely to mirror actual beliefs.
  - Draw back: sometimes so far from RE the learning model is unstable (Slobodyan and Wouters 2007).
- Jointly estimate initial conditions.
  - Draw back: many additional parameters, over-fitting problem.

General Form

- Linear Dynamic Stochastic General Equilibrium models:

$$\Omega_0 x_t = \Omega_1 x_{t-1} + \Omega_2 E_t^* x_{t+1} + \Psi v_t$$

$$v_t = A v_{t-1} + \epsilon_t$$

  - x_t vector of time t macroeconomic variables, observable to agents at following time period.
  - z_t: vector of time t shocks, possibly observable to agents in current period.
- Rational expectations solution:

$$x_t = G x_{t-1} + M v_t$$

General Form

- Linear Dynamic Stochastic General Equilibrium models:

$$\Omega_0 x_t = \Omega_1 x_{t-1} + \Omega_2 E_t^* x_{t+1} + \Psi v_t$$

$$v_t = A v_{t-1} + \epsilon_t$$

  - x_t vector of time t macroeconomic variables, observable to agents at following time period.
  - z_t: vector of time t shocks, possibly observable to agents in current period.
- Rational expectations solution:

$$x_t = G x_{t-1} + M v_t$$

General Form

- Linear Dynamic Stochastic General Equilibrium models:

$$\Omega_0 x_t = \Omega_1 x_{t-1} + \Omega_2 E_t^* x_{t+1} + \Psi v_t$$

$$v_t = A v_{t-1} + \epsilon_t$$

  - x_t vector of time t macroeconomic variables, observable to agents at following time period.
  - z_t: vector of time t shocks, possibly observable to agents in current period.

- Rational expectations solution:

$$x_t = G x_{t-1} + M v_t$$

General Form

- Linear Dynamic Stochastic General Equilibrium models:

$$\Omega_0 x_t = \Omega_1 x_{t-1} + \Omega_2 E_t^* x_{t+1} + \Psi v_t$$

$$v_t = A v_{t-1} + \epsilon_t$$

  - x_t vector of time t macroeconomic variables, observable to agents at following time period.
  - z_t: vector of time t shocks, possibly observable to agents in current period.
- Rational expectations solution:

$$x_t = G x_{t-1} + M v_t$$

Learning

- Agents estimate elements of G and M by least squares.
- Information at available at time t: x_{t-1}, v_t:
  - X_t: vector of regressors: $X_t' = [1\ x_{t-2}'\ v_{t-1}']$.
  - Y_t: vector of dependent variables: $Y_t = x_{t-1}$.
- When v_t is observable, I suppose agents know A.
- Let Φ_t vector of least squares estimates of the coefficients in matrices G and M.
- Ordinary Least Squares estimate of ϕ_t:

$$\Phi_t' = \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau X_\tau' \right)^{-1} \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau Y_\tau' \right)$$

Learning

- Agents estimate elements of G and M by least squares.
- Information at available at time t: x_{t-1}, v_t:
  - X_t: vector of regressors: $X_t' = [1\ x_{t-2}'\ v_{t-1}']$.
  - Y_t: vector of dependent variables: $Y_t = x_{t-1}$.
- When v_t is observable, I suppose agents know A.
- Let Φ_t vector of least squares estimates of the coefficients in matrices G and M.
- Ordinary Least Squares estimate of ϕ_t:

$$\Phi_t' = \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau X_\tau' \right)^{-1} \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau Y_\tau' \right)$$

Learning

- Agents estimate elements of G and M by least squares.
- Information at available at time t: x_{t-1}, v_t:
  - X_t: vector of regressors: $X_t' = [1\ x_{t-2}'\ v_{t-1}']$.
  - Y_t: vector of dependent variables: $Y_t = x_{t-1}$.
- When v_t is observable, I suppose agents know A.
- Let Φ_t vector of least squares estimates of the coefficients in matrices G and M.
- Ordinary Least Squares estimate of ϕ_t:

$$\Phi_t' = \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau X_\tau' \right)^{-1} \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau Y_\tau' \right)$$

Learning

- Agents estimate elements of G and M by least squares.
- Information at available at time t: x_{t-1}, v_t:
  - X_t: vector of regressors: $X_t' = [1\ x_{t-2}'\ v_{t-1}']$.
  - Y_t: vector of dependent variables: $Y_t = x_{t-1}$.
- When v_t is observable, I suppose agents know A.
- Let Φ_t vector of least squares estimates of the coefficients in matrices G and M.
- Ordinary Least Squares estimate of ϕ_t:

$$\Phi_t' = \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau X_\tau' \right)^{-1} \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau Y_\tau' \right)$$

Learning

- Agents estimate elements of G and M by least squares.
- Information at available at time t: x_{t-1}, v_t:
  - X_t: vector of regressors: $X_t' = [1\ x_{t-2}'\ v_{t-1}']$.
  - Y_t: vector of dependent variables: $Y_t = x_{t-1}$.
- When v_t is observable, I suppose agents know A.
- Let Φ_t vector of least squares estimates of the coefficients in matrices G and M.
- Ordinary Least Squares estimate of ϕ_t:

$$\Phi_t' = \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau X_\tau' \right)^{-1} \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau Y_\tau' \right)$$

Learning

- Agents estimate elements of G and M by least squares.
- Information at available at time t: x_{t-1}, v_t:
  - X_t: vector of regressors: $X_t' = [1\ x_{t-2}'\ v_{t-1}']$.
  - Y_t: vector of dependent variables: $Y_t = x_{t-1}$.
- When v_t is observable, I suppose agents know A.
- Let Φ_t vector of least squares estimates of the coefficients in matrices G and M.
- Ordinary Least Squares estimate of ϕ_t:

$$\Phi_t' = \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau X_\tau' \right)^{-1} \left(\frac{1}{t-1} \sum_{\tau=2}^{t} X_\tau Y_\tau' \right)$$

Learning Algorithm

- Recursive form:

$$\Phi_t = \Phi_{t-1} + g_t(Y_t - \Phi_{t-1}X_t)X_t'R_t^{-1}$$

$$R_t = R_{t-1} + g_t(X_tX_t' - R_{t-1})$$

  - Where $g_t = 1/(t-1)$.
- OLS learning: dynamics disappear in the long run.
- Constant gain learning: $g_t = g$.

Learning Algorithm

- Recursive form:

$$\Phi_t = \Phi_{t-1} + g_t(Y_t - \Phi_{t-1}X_t)X_t'R_t^{-1}$$

$$R_t = R_{t-1} + g_t(X_tX_t' - R_{t-1})$$

  - Where $g_t = 1/(t-1)$.
- OLS learning: dynamics disappear in the long run.
- Constant gain learning: $g_t = g$.

Learning Algorithm

- Recursive form:

$$\Phi_t = \Phi_{t-1} + g_t(Y_t - \Phi_{t-1}X_t)X_t'R_t^{-1}$$

$$R_t = R_{t-1} + g_t(X_tX_t' - R_{t-1})$$

  - Where $g_t = 1/(t-1)$.
- OLS learning: dynamics disappear in the long run.
- Constant gain learning: $g_t = g$.

Learning Algorithm

- Recursive form:

$$\Phi_t = \Phi_{t-1} + g_t(Y_t - \Phi_{t-1}X_t)X_t'R_t^{-1}$$

$$R_t = R_{t-1} + g_t(X_tX_t' - R_{t-1})$$

  - Where $g_t = 1/(t-1)$.
- OLS learning: dynamics disappear in the long run.
- Constant gain learning: $g_t = g$.

Learning Algorithm

- Recursive form:

$$\Phi_t = \Phi_{t-1} + g_t(Y_t - \Phi_{t-1}X_t)X_t'R_t^{-1}$$

$$R_t = R_{t-1} + g_t(X_tX_t' - R_{t-1})$$

  - Where $g_t = 1/(t-1)$.
- OLS learning: dynamics disappear in the long run.
- Constant gain learning: $g_t = g$.

Learning Algorithm

- Recursive form:

$$\Phi_t = \Phi_{t-1} + g_t(Y_t - \Phi_{t-1}X_t)X_t'R_t^{-1}$$

$$R_t = R_{t-1} + g_t(X_tX_t' - R_{t-1})$$

  - Where $g_t = 1/(t-1)$.
- OLS learning: dynamics disappear in the long run.
- Constant gain learning: $g_t = g$.

Motivation for Constant Gain Learning

- Learning dynamics persist in the long run.
- Reasonable approximation to a rolling window estimation procedure.
  - Typically 30-50 year windows are used in forecasting quarterly macroeconomic variables.
  - Johnston Williamson (2007): data available for U.S. output and price level back to 1790.
- Swanson and White (RES 1997):
  - Adaptive estimation procedures out-perform non-adaptive procedures.
  - Multivariate procedures out-perform univariate procedures.
  - Linear models out-perform non-linear models.
  - Adaptive, multivariate, linear models outperform professional forecast surveys.

Motivation for Constant Gain Learning

- Learning dynamics persist in the long run.
- Reasonable approximation to a rolling window estimation procedure.
  - Typically 30-50 year windows are used in forecasting quarterly macroeconomic variables.
  - Johnston Williamson (2007): data available for U.S. output and price level back to 1790.
- Swanson and White (RES 1997):
  - Adaptive estimation procedures out-perform non-adaptive procedures.
  - Multivariate procedures out-perform univariate procedures.
  - Linear models out-perform non-linear models.
  - Adaptive, multivariate, linear models outperform professional forecast surveys.

Motivation for Constant Gain Learning

- Learning dynamics persist in the long run.
- Reasonable approximation to a rolling window estimation procedure.
  - Typically 30-50 year windows are used in forecasting quarterly macroeconomic variables.
  - Johnston Williamson (2007): data available for U.S. output and price level back to 1790.
- Swanson and White (RES 1997):
  - Adaptive estimation procedures out-perform non-adaptive procedures.
  - Multivariate procedures out-perform univariate procedures.
  - Linear models out-perform non-linear models.
  - Adaptive, multivariate, linear models outperform professional forecast surveys.

Motivation for Constant Gain Learning

- Learning dynamics persist in the long run.
- Reasonable approximation to a rolling window estimation procedure.
  - Typically 30-50 year windows are used in forecasting quarterly macroeconomic variables.
  - Johnston Williamson (2007): data available for U.S. output and price level back to 1790.
- Swanson and White (RES 1997):
  - Adaptive estimation procedures out-perform non-adaptive procedures.
  - Multivariate procedures out-perform univariate procedures.
  - Linear models out-perform non-linear models.
  - Adaptive, multivariate, linear models outperform professional forecast surveys.

Motivation for Constant Gain Learning

- Learning dynamics persist in the long run.
- Reasonable approximation to a rolling window estimation procedure.
  - Typically 30-50 year windows are used in forecasting quarterly macroeconomic variables.
  - Johnston Williamson (2007): data available for U.S. output and price level back to 1790.
- Swanson and White (RES 1997):
  - Adaptive estimation procedures out-perform non-adaptive procedures.
  - Multivariate procedures out-perform univariate procedures.
  - Linear models out-perform non-linear models.
  - Adaptive, multivariate, linear models outperform professional forecast surveys.

Motivation for Constant Gain Learning

- Learning dynamics persist in the long run.
- Reasonable approximation to a rolling window estimation procedure.
  - Typically 30-50 year windows are used in forecasting quarterly macroeconomic variables.
  - Johnston Williamson (2007): data available for U.S. output and price level back to 1790.
- Swanson and White (RES 1997):
  - Adaptive estimation procedures out-perform non-adaptive procedures.
  - Multivariate procedures out-perform univariate procedures.
  - Linear models out-perform non-linear models.
  - Adaptive, multivariate, linear models outperform professional forecast surveys.

Motivation for Constant Gain Learning

- Learning dynamics persist in the long run.
- Reasonable approximation to a rolling window estimation procedure.
  - Typically 30-50 year windows are used in forecasting quarterly macroeconomic variables.
  - Johnston Williamson (2007): data available for U.S. output and price level back to 1790.
- Swanson and White (RES 1997):
  - Adaptive estimation procedures out-perform non-adaptive procedures.
  - Multivariate procedures out-perform univariate procedures.
  - Linear models out-perform non-linear models.
  - Adaptive, multivariate, linear models outperform professional forecast surveys.

Motivation for Constant Gain Learning

- Learning dynamics persist in the long run.
- Reasonable approximation to a rolling window estimation procedure.
  - Typically 30-50 year windows are used in forecasting quarterly macroeconomic variables.
  - Johnston Williamson (2007): data available for U.S. output and price level back to 1790.
- Swanson and White (RES 1997):
  - Adaptive estimation procedures out-perform non-adaptive procedures.
  - Multivariate procedures out-perform univariate procedures.
  - Linear models out-perform non-linear models.
  - Adaptive, multivariate, linear models outperform professional forecast surveys.

New Keynesian Monetary Model

- Examine two popular specifications
  1. Standard three equation model: IS equation, Phillips curve, monetary policy. Woodford (2003).
  2. Add endogenous capital. Woodford (IJCB 2005).
- Details behind IS equation:
  - Utility maximizing consumers.
  - Habit formation in utility function (source of persistence).
  - Intertemporal substitution.
  - Goods market clearing.
- Details behind the Phillips curve:
  - Profit maximizing firms.
  - Sticky prices.
  - Price indexation (source of persistence).
  - Labor market clearing.
- Monetary Policy (Taylor rule):
  - Interest rate set in respond to output gap, inflation, past interest rate.

New Keynesian Monetary Model

- Examine two popular specifications
  1. Standard three equation model: IS equation, Phillips curve, monetary policy. Woodford (2003).
  2. Add endogenous capital. Woodford (IJCB 2005).
- Details behind IS equation:
  - Utility maximizing consumers.
  - Habit formation in utility function (source of persistence).
  - Intertemporal substitution.
  - Goods market clearing.
- Details behind the Phillips curve:
  - Profit maximizing firms.
  - Sticky prices.
  - Price indexation (source of persistence).
  - Labor market clearing.
- Monetary Policy (Taylor rule):
  - Interest rate set in respond to output gap, inflation, past interest rate.

New Keynesian Monetary Model

- Examine two popular specifications
  1. Standard three equation model: IS equation, Phillips curve, monetary policy. Woodford (2003).
  2. Add endogenous capital. Woodford (IJCB 2005).
- Details behind IS equation:
  - Utility maximizing consumers.
  - Habit formation in utility function (source of persistence).
  - Intertemporal substitution.
  - Goods market clearing.
- Details behind the Phillips curve:
  - Profit maximizing firms.
  - Sticky prices.
  - Price indexation (source of persistence).
  - Labor market clearing.
- Monetary Policy (Taylor rule):
  - Interest rate set in respond to output gap, inflation, past interest rate.

New Keynesian Monetary Model

- Examine two popular specifications
  1. Standard three equation model: IS equation, Phillips curve, monetary policy. Woodford (2003).
  2. Add endogenous capital. Woodford (IJCB 2005).
- Details behind IS equation:
  - Utility maximizing consumers.
  - Habit formation in utility function (source of persistence).
  - Intertemporal substitution.
  - Goods market clearing.
- Details behind the Phillips curve:
  - Profit maximizing firms.
  - Sticky prices.
  - Price indexation (source of persistence).
  - Labor market clearing.
- Monetary Policy (Taylor rule):
  - Interest rate set in respond to output gap, inflation, past interest rate.

New Keynesian Monetary Model

- Examine two popular specifications
  1. Standard three equation model: IS equation, Phillips curve, monetary policy. Woodford (2003).
  2. Add endogenous capital. Woodford (IJCB 2005).
- Details behind IS equation:
  - Utility maximizing consumers.
  - Habit formation in utility function (source of persistence).
  - Intertemporal substitution.
  - Goods market clearing.
- Details behind the Phillips curve:
  - Profit maximizing firms.
  - Sticky prices.
  - Price indexation (source of persistence).
  - Labor market clearing.
- Monetary Policy (Taylor rule):
  - Interest rate set in respond to output gap, inflation, past interest rate.

New Keynesian Monetary Model

- Examine two popular specifications
  1. Standard three equation model: IS equation, Phillips curve, monetary policy. Woodford (2003).
  2. Add endogenous capital. Woodford (IJCB 2005).
- Details behind IS equation:
  - Utility maximizing consumers.
  - Habit formation in utility function (source of persistence).
  - Intertemporal substitution.
  - Goods market clearing.
- Details behind the Phillips curve:
  - Profit maximizing firms.
  - Sticky prices.
  - Price indexation (source of persistence).
  - Labor market clearing.
- Monetary Policy (Taylor rule):
  - Interest rate set in respond to output gap, inflation, past interest rate.

Firm Specific Capital

- Output is produced with labor and capital.
- Investment is subject to adjustment cost.
- Capital depreciates at a constant rate.
- Firm specific capital
  - No perfect capital rental market.
  - Capital cannot be transfered between firms.
  - Individual capital stocks affect an individual firm's marginal costs.

Firm Specific Capital

- Output is produced with labor and capital.
- Investment is subject to adjustment cost.
- Capital depreciates at a constant rate.
- Firm specific capital
  - No perfect capital rental market.
  - Capital cannot be transfered between firms.
  - Individual capital stocks affect an individual firm's marginal costs.

Firm Specific Capital

- Output is produced with labor and capital.
- Investment is subject to adjustment cost.
- Capital depreciates at a constant rate.
- Firm specific capital
  - No perfect capital rental market.
  - Capital cannot be transfered between firms.
  - Individual capital stocks affect an individual firm's marginal costs.

Firm Specific Capital

- Output is produced with labor and capital.
- Investment is subject to adjustment cost.
- Capital depreciates at a constant rate.
- Firm specific capital
  - No perfect capital rental market.
  - Capital cannot be transfered between firms.
  - Individual capital stocks affect an individual firm's marginal costs.

Firm Specific Capital

- Output is produced with labor and capital.
- Investment is subject to adjustment cost.
- Capital depreciates at a constant rate.
- Firm specific capital
  - No perfect capital rental market.
  - Capital cannot be transfered between firms.
  - Individual capital stocks affect an individual firm's marginal costs.

Firm Specific Capital

- Output is produced with labor and capital.
- Investment is subject to adjustment cost.
- Capital depreciates at a constant rate.
- Firm specific capital
  - No perfect capital rental market.
  - Capital cannot be transfered between firms.
  - Individual capital stocks affect an individual firm's marginal costs.

Firm Specific Capital

- Output is produced with labor and capital.
- Investment is subject to adjustment cost.
- Capital depreciates at a constant rate.
- Firm specific capital
  - No perfect capital rental market.
  - Capital cannot be transfered between firms.
  - Individual capital stocks affect an individual firm's marginal costs.

Stochastic shocks

- Specification 1: Three equation model (without capital)
  - Natural interest rate shock.
  - Cost-push shock.
  - Monetary policy shock.
- Specification 2: Model with capital
  - Preference shock.
  - Technology shock.
  - Investment technology shock.
  - Monetary policy shock.

Stochastic shocks

- Specification 1: Three equation model (without capital)
  - Natural interest rate shock.
  - Cost-push shock.
  - Monetary policy shock.
- Specification 2: Model with capital
  - Preference shock.
  - Technology shock.
  - Investment technology shock.
  - Monetary policy shock.

Five Expectations Frameworks

- Estimate two NK specifications by maximum likelihood.
- For each specification, estimate five expectations frameworks:
  1. Rational Expectations
  2. Learning with RE solution for initial Φ_t, R_t.
  3. Learning with limited information set.
     - Shocks are unobservable.
     - Initial coefficients on remaining variables set equal to RE solution.
  4. Limited information set with pre-sample coefficients.
  5. Limited information set with estimated initial conditions.

Five Expectations Frameworks

- Estimate two NK specifications by maximum likelihood.
- For each specification, estimate five expectations frameworks:
  1. Rational Expectations
  2. Learning with RE solution for initial Φ_t, R_t.
  3. Learning with limited information set.
     - Shocks are unobservable.
     - Initial coefficients on remaining variables set equal to RE solution.
  4. Limited information set with pre-sample coefficients.
  5. Limited information set with estimated initial conditions.

Five Expectations Frameworks

- Estimate two NK specifications by maximum likelihood.
- For each specification, estimate five expectations frameworks:
  1. Rational Expectations
  2. Learning with RE solution for initial Φ_t, R_t.
  3. Learning with limited information set.
     - Shocks are unobservable.
     - Initial coefficients on remaining variables set equal to RE solution.
  4. Limited information set with pre-sample coefficients.
  5. Limited information set with estimated initial conditions.

Five Expectations Frameworks

- Estimate two NK specifications by maximum likelihood.
- For each specification, estimate five expectations frameworks:
  1. Rational Expectations
  2. Learning with RE solution for initial Φ_t, R_t.
  3. Learning with limited information set.
     - Shocks are unobservable.
     - Initial coefficients on remaining variables set equal to RE solution.
  4. Limited information set with pre-sample coefficients.
  5. Limited information set with estimated initial conditions.

Five Expectations Frameworks

- Estimate two NK specifications by maximum likelihood.
- For each specification, estimate five expectations frameworks:
  1. Rational Expectations
  2. Learning with RE solution for initial Φ_t, R_t.
  3. Learning with limited information set.
     - Shocks are unobservable.
     - Initial coefficients on remaining variables set equal to RE solution.
  4. Limited information set with pre-sample coefficients.
  5. Limited information set with estimated initial conditions.

Five Expectations Frameworks

- Estimate two NK specifications by maximum likelihood.
- For each specification, estimate five expectations frameworks:
  1. Rational Expectations
  2. Learning with RE solution for initial Φ_t, R_t.
  3. Learning with limited information set.
     - Shocks are unobservable.
     - Initial coefficients on remaining variables set equal to RE solution.
  4. Limited information set with pre-sample coefficients.
  5. Limited information set with estimated initial conditions.

Five Expectations Frameworks

- Estimate two NK specifications by maximum likelihood.
- For each specification, estimate five expectations frameworks:
  1. Rational Expectations
  2. Learning with RE solution for initial Φ_t, R_t.
  3. Learning with limited information set.
     - Shocks are unobservable.
     - Initial coefficients on remaining variables set equal to RE solution.
  4. Limited information set with pre-sample coefficients.
  5. Limited information set with estimated initial conditions.

Pre-sample Initial Conditions

- Learning algorithm for constant gain least squares:

$$\Phi_t = \left(\sum_{\tau=0}^{t-1} (1-g)^t X_{t-\tau} X'_{t-\tau} \right)^{-1} \left(\sum_{\tau=0}^{t-1} (1-g)^\tau X_{t-\tau} Y'_{t-\tau} \right)$$

- Learning gain g estimated jointly with parameters of New Keynesian model.

Pre-sample Initial Conditions

- Learning algorithm for constant gain least squares:

$$\Phi_t = \left(\sum_{\tau=0}^{t-1} (1-g)^t X_{t-\tau} X'_{t-\tau} \right)^{-1} \left(\sum_{\tau=0}^{t-1} (1-g)^\tau X_{t-\tau} Y'_{t-\tau} \right)$$

- Learning gain g estimated jointly with parameters of New Keynesian model.

Pre-sample Initial Conditions

- Learning algorithm for constant gain least squares:

$$\Phi_t = \left(\sum_{\tau=0}^{t-1} (1-g)^t X_{t-\tau} X'_{t-\tau} \right)^{-1} \left(\sum_{\tau=0}^{t-1} (1-g)^\tau X_{t-\tau} Y'_{t-\tau} \right)$$

- Learning gain g estimated jointly with parameters of New Keynesian model.

Pre-sample Initial Conditions

- Specification 1:
  - Y_t vector includes output gap, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's output gap, inflation rate, federal funds rate..
- Specification 2:
  - Y_t vector includes consumption, capital stock, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's consumption, capital stock, inflation rate, federal funds rate.
  - All these variables expressed as percentage deviation from the steady state.
  - Data on capital stock constructed using data on investment.

Pre-sample Initial Conditions

- Specification 1:
  - Y_t vector includes output gap, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's output gap, inflation rate, federal funds rate..
- Specification 2:
  - Y_t vector includes consumption, capital stock, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's consumption, capital stock, inflation rate, federal funds rate.
  - All these variables expressed as percentage deviation from the steady state.
  - Data on capital stock constructed using data on investment.

Pre-sample Initial Conditions

- Specification 1:
  - Y_t vector includes output gap, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's output gap, inflation rate, federal funds rate..
- Specification 2:
  - Y_t vector includes consumption, capital stock, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's consumption, capital stock, inflation rate, federal funds rate.
  - All these variables expressed as percentage deviation from the steady state.
  - Data on capital stock constructed using data on investment.

Pre-sample Initial Conditions

- Specification 1:
  - Y_t vector includes output gap, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's output gap, inflation rate, federal funds rate..
- Specification 2:
  - Y_t vector includes consumption, capital stock, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's consumption, capital stock, inflation rate, federal funds rate.
  - All these variables expressed as percentage deviation from the steady state.
  - Data on capital stock constructed using data on investment.

Pre-sample Initial Conditions

- Specification 1:
  - Y_t vector includes output gap, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's output gap, inflation rate, federal funds rate..
- Specification 2:
  - Y_t vector includes consumption, capital stock, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's consumption, capital stock, inflation rate, federal funds rate.
  - All these variables expressed as percentage deviation from the steady state.
  - Data on capital stock constructed using data on investment.

Pre-sample Initial Conditions

- Specification 1:
  - Y_t vector includes output gap, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's output gap, inflation rate, federal funds rate..
- Specification 2:
  - Y_t vector includes consumption, capital stock, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's consumption, capital stock, inflation rate, federal funds rate.
  - All these variables expressed as percentage deviation from the steady state.
  - Data on capital stock constructed using data on investment.

Pre-sample Initial Conditions

- Specification 1:
  - Y_t vector includes output gap, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's output gap, inflation rate, federal funds rate..
- Specification 2:
  - Y_t vector includes consumption, capital stock, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's consumption, capital stock, inflation rate, federal funds rate.
  - All these variables expressed as percentage deviation from the steady state.
  - Data on capital stock constructed using data on investment.

Pre-sample Initial Conditions

- Specification 1:
  - Y_t vector includes output gap, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's output gap, inflation rate, federal funds rate..
- Specification 2:
  - Y_t vector includes consumption, capital stock, inflation rate, federal funds rate.
  - X_t vector includes constant, previous period's consumption, capital stock, inflation rate, federal funds rate.
  - All these variables expressed as percentage deviation from the steady state.
  - Data on capital stock constructed using data on investment.

Data

- Quarterly data for 1960:Q1 through 2005:Q4.
- Pre-sample data: Quarterly data for 1954:Q1 through 1959:Q4.
- Specification 1: Model with no capital:
  - CBO measure of the output gap.
  - Annualized quarterly inflation rate of the GDP deflater.
  - Annualized quarterly federal funds rate.
- Specification 2: Endogenous capital:
  - Real private consumption expenditures per capita.
  - Real gross private domestic investment per capita.
  - Output is defined as the sum of consumption and investment.
  - Annualized quarterly inflation rate of the GDP deflator.
  - Annualized quarterly federal funds rate.
- Consumption and Investment: trend growth rate removed.

Data

- Quarterly data for 1960:Q1 through 2005:Q4.
- Pre-sample data: Quarterly data for 1954:Q1 through 1959:Q4.
- Specification 1: Model with no capital:
  - CBO measure of the output gap.
  - Annualized quarterly inflation rate of the GDP deflater.
  - Annualized quarterly federal funds rate.
- Specification 2: Endogenous capital:
  - Real private consumption expenditures per capita.
  - Real gross private domestic investment per capita.
  - Output is defined as the sum of consumption and investment.
  - Annualized quarterly inflation rate of the GDP deflator.
  - Annualized quarterly federal funds rate.
- Consumption and Investment: trend growth rate removed.

Data

- Quarterly data for 1960:Q1 through 2005:Q4.
- Pre-sample data: Quarterly data for 1954:Q1 through 1959:Q4.
- Specification 1: Model with no capital:
  - CBO measure of the output gap.
  - Annualized quarterly inflation rate of the GDP deflater.
  - Annualized quarterly federal funds rate.
- Specification 2: Endogenous capital:
  - Real private consumption expenditures per capita.
  - Real gross private domestic investment per capita.
  - Output is defined as the sum of consumption and investment.
  - Annualized quarterly inflation rate of the GDP deflator.
  - Annualized quarterly federal funds rate.
- Consumption and Investment: trend growth rate removed.

Data

- Quarterly data for 1960:Q1 through 2005:Q4.
- Pre-sample data: Quarterly data for 1954:Q1 through 1959:Q4.
- Specification 1: Model with no capital:
  - CBO measure of the output gap.
  - Annualized quarterly inflation rate of the GDP deflater.
  - Annualized quarterly federal funds rate.
- Specification 2: Endogenous capital:
  - Real private consumption expenditures per capita.
  - Real gross private domestic investment per capita.
  - Output is defined as the sum of consumption and investment.
  - Annualized quarterly inflation rate of the GDP deflator.
  - Annualized quarterly federal funds rate.
- Consumption and Investment: trend growth rate removed.

Data

- Quarterly data for 1960:Q1 through 2005:Q4.
- Pre-sample data: Quarterly data for 1954:Q1 through 1959:Q4.
- Specification 1: Model with no capital:
  - CBO measure of the output gap.
  - Annualized quarterly inflation rate of the GDP deflater.
  - Annualized quarterly federal funds rate.
- Specification 2: Endogenous capital:
  - Real private consumption expenditures per capita.
  - Real gross private domestic investment per capita.
  - Output is defined as the sum of consumption and investment.
  - Annualized quarterly inflation rate of the GDP deflator.
  - Annualized quarterly federal funds rate.
- Consumption and Investment: trend growth rate removed.

No Capital: RE vs. Learning (RE Init.)

		Case 1		Case 2	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.4241	0.1216
Inverse IES	σ	0.5152	0.4401	0.5236	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0001	0.0002
Price Indexation	γ	0.9900	0.0634	0.9901	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9207	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4949	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9995	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8489	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0000	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.0736	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0029	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9905	1.2739
Learning Gain	g	–	–	0.0067	0.0070
Log-likelihood			-459.9390		-459.5154
MSE Output Gap			0.6087		0.6061
MSE Inflation			1.3313		1.3269
MSE Fed. Funds Rate			1.6480		1.6519

No Capital: RE vs. Learning (RE Init.)

		Case 1		Case 2	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.4241	0.1216
Inverse IES	σ	0.5152	0.4401	0.5236	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0001	0.0002
Price Indexation	γ	0.9900	0.0634	0.9901	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9207	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4949	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9995	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8489	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0000	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.0736	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0029	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9905	1.2739
Learning Gain	g	–	–	0.0067	0.0070
Log-likelihood			-459.9390		-459.5154
MSE Output Gap			0.6087		0.6061
MSE Inflation			1.3313		1.3269
MSE Fed. Funds Rate			1.6480		1.6519

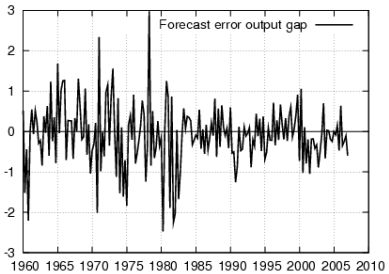
No Capital: RE vs. Learning (RE Init.)

		Case 1		Case 2	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.4241	0.1216
Inverse IES	σ	0.5152	0.4401	0.5236	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0001	0.0002
Price Indexation	γ	0.9900	0.0634	0.9901	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9207	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4949	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9995	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8489	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0000	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.0736	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0029	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9905	1.2739
Learning Gain	g	–	–	0.0067	0.0070
Log-likelihood			-459.9390		-459.5154
MSE Output Gap			0.6087		0.6061
MSE Inflation			1.3313		1.3269
MSE Fed. Funds Rate			1.6480		1.6519

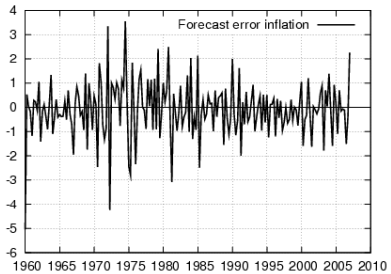
No Capital: Forecast Errors

Rational Expectations

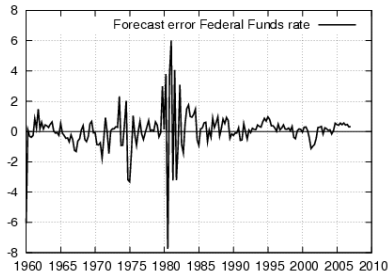
Output gap



Inflation

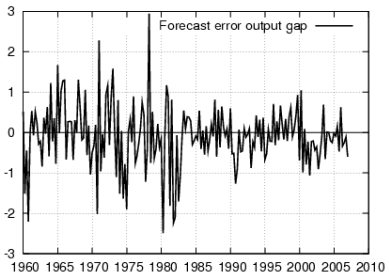


Fed Funds Rate

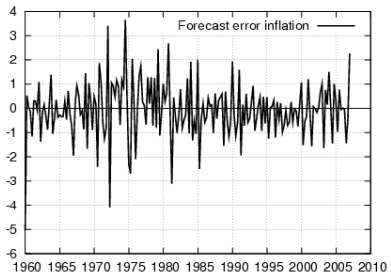


Learning with RE Initial Conditions

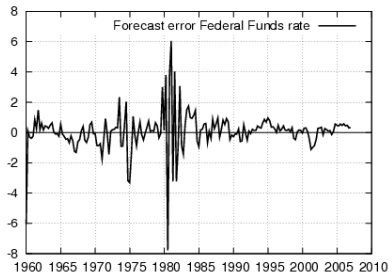
Output gap (0.9993)



Inflation (0.9973)



Fed Funds Rate (0.9999)



No Capital: RE vs. Learning (Unobservable Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.3027	0.1216
Inverse IES	σ	0.5152	0.4401	0.2251	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0004	0.0002
Price Indexation	γ	0.9900	0.0634	0.9999	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9131	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4762	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9865	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8413	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0002	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.2736	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0054	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9539	1.2739
Learning Gain	g	–	–	0.0042	0.0070
Log-likelihood			-459.9390		-458.8326
MSE Output Gap			0.6087		0.6032
MSE Inflation			1.3313		1.3371
MSE Fed. Funds Rate			1.6480		1.6378

No Capital: RE vs. Learning (Unobservable Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.3027	0.1216
Inverse IES	σ	0.5152	0.4401	0.2251	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0004	0.0002
Price Indexation	γ	0.9900	0.0634	0.9999	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9131	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4762	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9865	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8413	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0002	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.2736	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0054	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9539	1.2739
Learning Gain	g	–	–	0.0042	0.0070
Log-likelihood			-459.9390		-458.8326
MSE Output Gap			0.6087		0.6032
MSE Inflation			1.3313		1.3371
MSE Fed. Funds Rate			1.6480		1.6378

No Capital: RE vs. Learning (Unobservable Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.3027	0.1216
Inverse IES	σ	0.5152	0.4401	0.2251	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0004	0.0002
Price Indexation	γ	0.9900	0.0634	0.9999	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9131	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4762	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9865	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8413	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0002	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.2736	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0054	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9539	1.2739
Learning Gain	g	–	–	0.0042	0.0070
Log-likelihood			-459.9390		-458.8326
MSE Output Gap			0.6087		0.6032
MSE Inflation			1.3313		1.3371
MSE Fed. Funds Rate			1.6480		1.6378

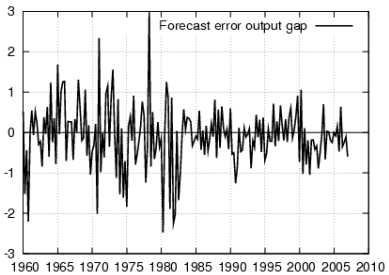
No Capital: RE vs. Learning (Unobservable Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.3027	0.1216
Inverse IES	σ	0.5152	0.4401	0.2251	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0004	0.0002
Price Indexation	γ	0.9900	0.0634	0.9999	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9131	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4762	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9865	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8413	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0002	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.2736	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0054	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9539	1.2739
Learning Gain	g	–	–	0.0042	0.0070
Log-likelihood			-459.9390		-458.8326
MSE Output Gap			0.6087		0.6032
MSE Inflation			1.3313		1.3371
MSE Fed. Funds Rate			1.6480		1.6378

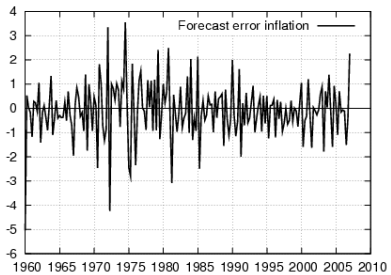
No Capital: Forecast Errors

Rational Expectations

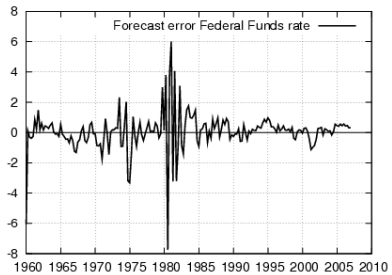
Output gap



Inflation

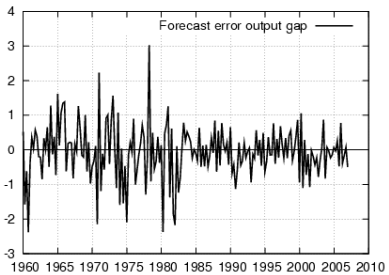


Fed Funds Rate

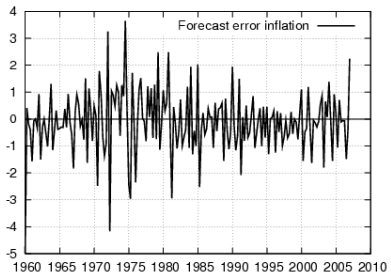


Learning Without Observable Shocks

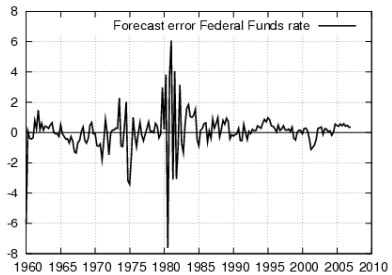
Output gap (0.9846)



Inflation (0.9960)



Fed Funds Rate (0.9996)



No Capital: RE vs. Learning (Pre-sample init.)

		Case 1		Case 4	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.5293	0.1216
Inverse IES	σ	0.5152	0.4401	0.2502	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0064	0.0002
Price Indexation	γ	0.9900	0.0634	0.9989	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.8454	0.0214
MP Output	ψ_y	0.4946	0.1901	0.3200	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.5109	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.6810	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.4419	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.5835	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0086	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.8862	1.2739
Learning Gain	g	–	–	0.0828	0.0070
Log-likelihood			-459.9390		-573.3274
MSE Output Gap			0.6087		0.7989
MSE Inflation			1.3313		2.7104
MSE Fed. Funds Rate			1.6480		1.7396

No Capital: RE vs. Learning (Pre-sample init.)

		Case 1		Case 4	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.5293	0.1216
Inverse IES	σ	0.5152	0.4401	0.2502	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0064	0.0002
Price Indexation	γ	0.9900	0.0634	0.9989	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.8454	0.0214
MP Output	ψ_y	0.4946	0.1901	0.3200	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.5109	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.6810	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.4419	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.5835	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0086	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.8862	1.2739
Learning Gain	g	–	–	0.0828	0.0070
Log-likelihood			-459.9390		-573.3274
MSE Output Gap			0.6087		0.7989
MSE Inflation			1.3313		2.7104
MSE Fed. Funds Rate			1.6480		1.7396

No Capital: RE vs. Learning (Pre-sample init.)

		Case 1		Case 4	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.5293	0.1216
Inverse IES	σ	0.5152	0.4401	0.2502	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0064	0.0002
Price Indexation	γ	0.9900	0.0634	0.9989	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.8454	0.0214
MP Output	ψ_y	0.4946	0.1901	0.3200	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.5109	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.6810	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.4419	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.5835	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0086	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.8862	1.2739
Learning Gain	g	–	–	0.0828	0.0070
Log-likelihood			-459.9390		-573.3274
MSE Output Gap			0.6087		0.7989
MSE Inflation			1.3313		2.7104
MSE Fed. Funds Rate			1.6480		1.7396

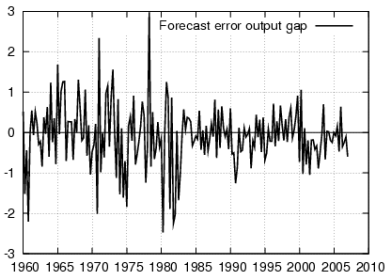
No Capital: RE vs. Learning (Pre-sample init.)

		Case 1		Case 4	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.5293	0.1216
Inverse IES	σ	0.5152	0.4401	0.2502	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0064	0.0002
Price Indexation	γ	0.9900	0.0634	0.9989	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.8454	0.0214
MP Output	ψ_y	0.4946	0.1901	0.3200	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.5109	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.6810	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.4419	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.5835	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0086	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.8862	1.2739
Learning Gain	g	–	–	0.0828	0.0070
Log-likelihood			-459.9390		-573.3274
MSE Output Gap			0.6087		0.7989
MSE Inflation			1.3313		2.7104
MSE Fed. Funds Rate			1.6480		1.7396

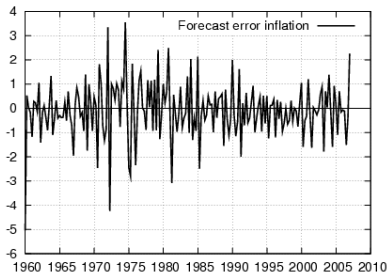
No Capital: Forecast Errors

Rational Expectations

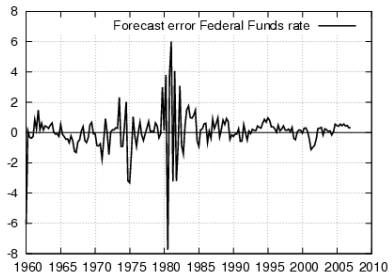
Output gap



Inflation

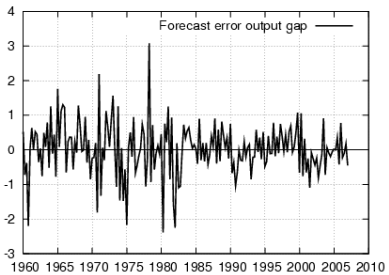


Fed Funds Rate

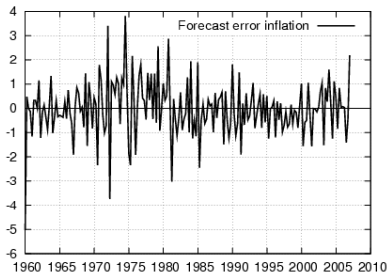


Learning with Pre-sample Initial Conditions

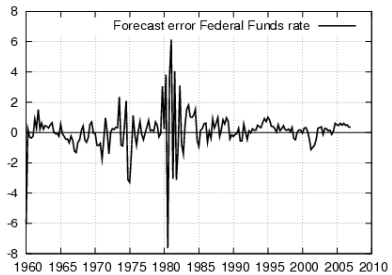
Output gap (0.7344)



Inflation (0.7617)



Fed Funds Rate (0.9481)



No Capital: RE vs. Learning (Pre-sample init.)

		Case 1		Case 5	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.3052	0.1216
Inverse IES	σ	0.5152	0.4401	0.1960	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0001	0.0002
Price Indexation	γ	0.9900	0.0634	0.9893	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9193	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4944	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9992	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8488	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0000	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.2310	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0054	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9894	1.2739
Learning Gain	g	–	–	0.0000	0.0070
Log-likelihood			-459.9390		-449.3276
MSE Output Gap			0.6087		0.5679
MSE Inflation			1.3313		1.2922
MSE Fed. Funds Rate			1.6480		1.6486

No Capital: RE vs. Learning (Pre-sample init.)

		Case 1		Case 5	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.3052	0.1216
Inverse IES	σ	0.5152	0.4401	0.1960	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0001	0.0002
Price Indexation	γ	0.9900	0.0634	0.9893	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9193	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4944	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9992	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8488	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0000	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.2310	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0054	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9894	1.2739
Learning Gain	g	–	–	0.0000	0.0070
Log-likelihood			-459.9390		-449.3276
MSE Output Gap			0.6087		0.5679
MSE Inflation			1.3313		1.2922
MSE Fed. Funds Rate			1.6480		1.6486

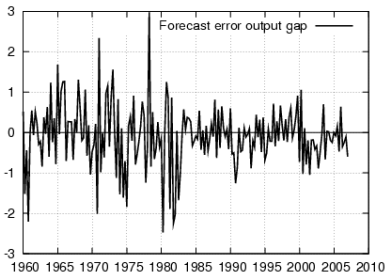
No Capital: RE vs. Learning (Pre-sample init.)

		Case 1		Case 5	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.4221	0.1062	0.3052	0.1216
Inverse IES	σ	0.5152	0.4401	0.1960	0.4865
Phillips Slope	κ	0.0001	0.0002	0.0001	0.0002
Price Indexation	γ	0.9900	0.0634	0.9893	0.0907
MP Persistence	ρ_r	0.9207	0.0207	0.9193	0.0214
MP Output	ψ_y	0.4946	0.1901	0.4944	0.1967
MP Inflation	ψ_π	1.9994	0.0000	1.9992	0.0000
Nat. Rate Pers.	ρ_n	0.8488	0.0684	0.8488	0.0645
Cost Push Pers.	ρ_u	0.0000	0.0692	0.0000	0.0608
Nat. Rate Std. Dev.	σ_n	0.0751	0.0706	0.2310	0.0741
Cost Push Std. Dev.	σ_u	0.0029	0.0002	0.0054	0.0003
MP Std. Dev.	σ_r	0.0030	0.0001	0.0030	0.0001
SS Inflation	π^*	5.9904	1.2374	5.9894	1.2739
Learning Gain	g	–	–	0.0000	0.0070
Log-likelihood			-459.9390		-449.3276
MSE Output Gap			0.6087		0.5679
MSE Inflation			1.3313		1.2922
MSE Fed. Funds Rate			1.6480		1.6486

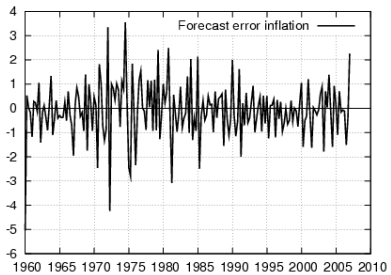
No Capital: Forecast Errors

Rational Expectations

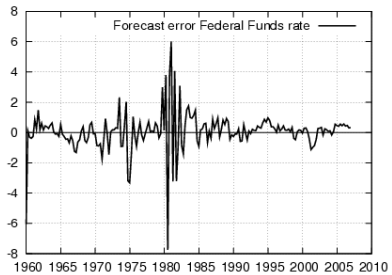
Output gap



Inflation

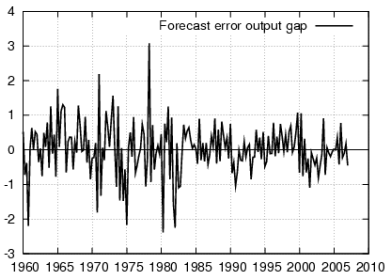


Fed Funds Rate

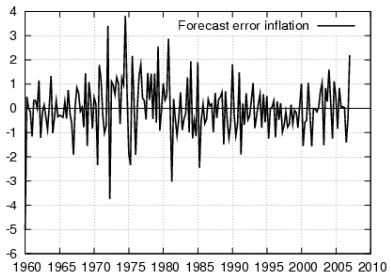


Learning with Estimated Initial Conditions

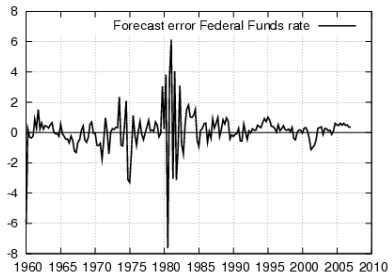
Output gap (0.9682)



Inflation (0.9896)



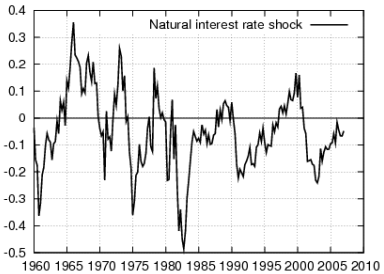
Fed Funds Rate (0.9997)



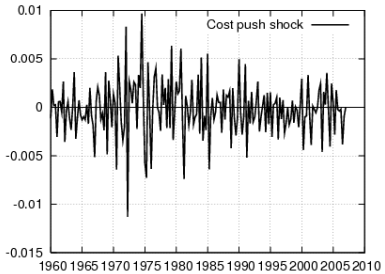
No Capital: Evolution of Shocks

Rational Expectations

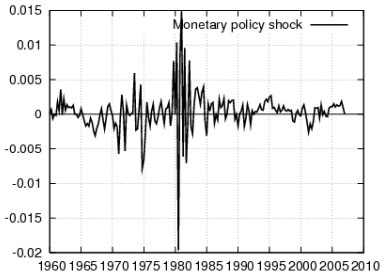
Nat. Rate



Cost Push

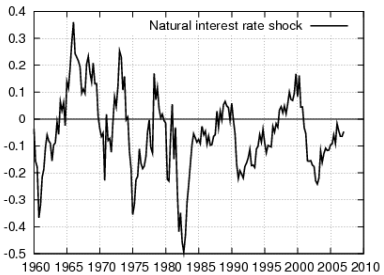


Policy Shock

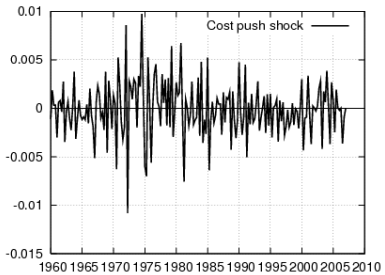


Learning with RE Initial Conditions

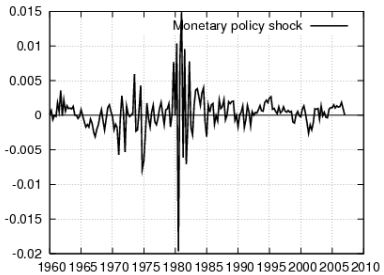
Nat. Rate (0.9996)



Cost Push (0.9965)



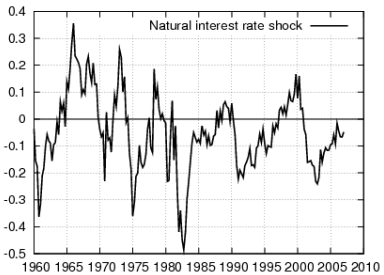
Policy Shock (1.0000)



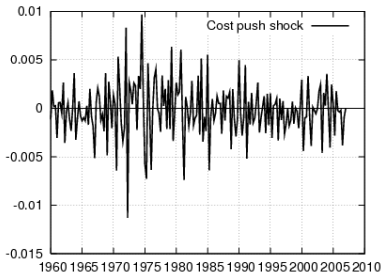
No Capital: Evolution of Shocks

Rational Expectations

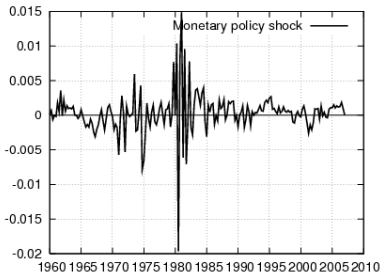
Nat. Rate



Cost Push

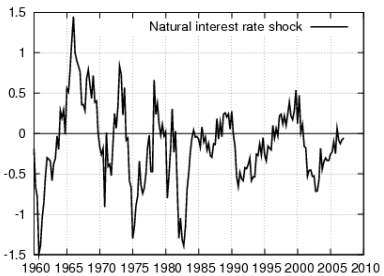


Policy Shock

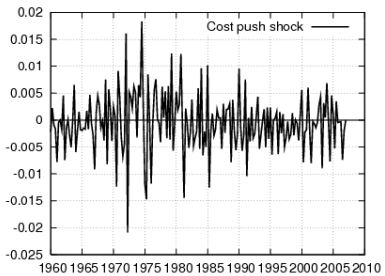


Learning Without Observable Shocks

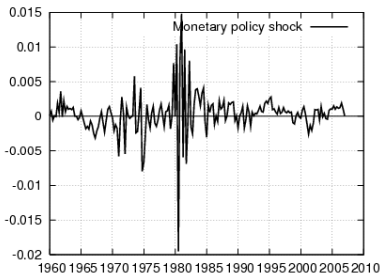
Nat. Rate (0.9731)



Cost Push (0.9932)



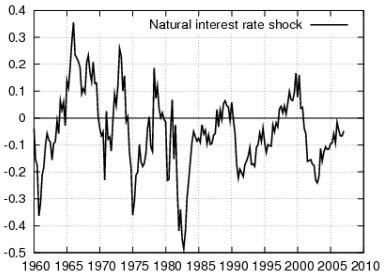
Policy Shock (0.9995)



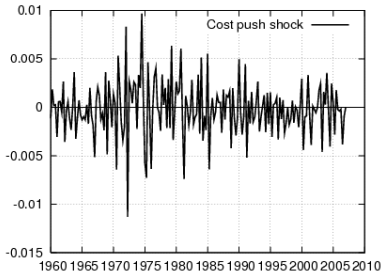
No Capital: Evolution of Shocks

Rational Expectations

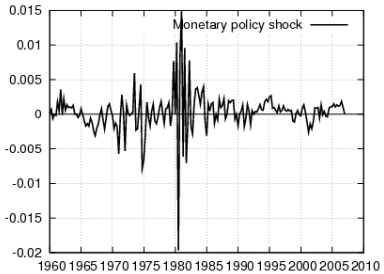
Nat. Rate



Cost Push

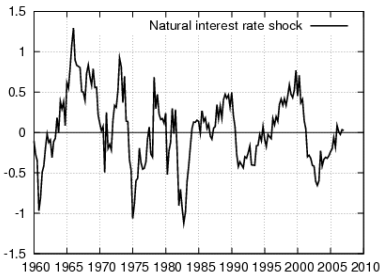


Policy Shock

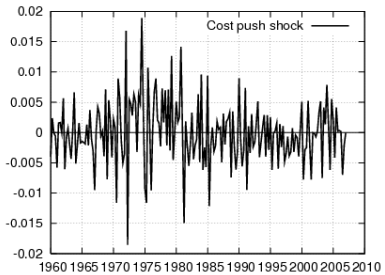


Learning with Pre-sample Initial Conditions

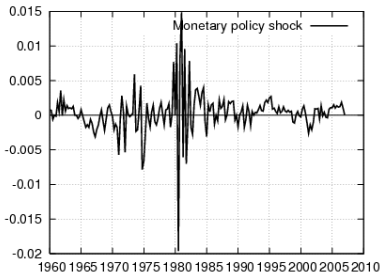
Nat. Rate (0.3652)



Cost Push (0.6110)



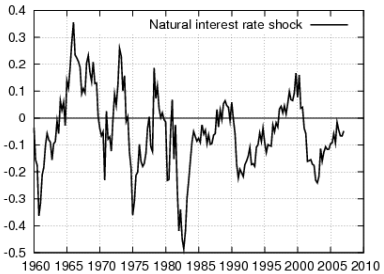
Policy Shock (0.9619)



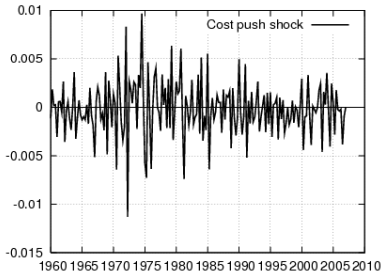
No Capital: Evolution of Shocks

Rational Expectations

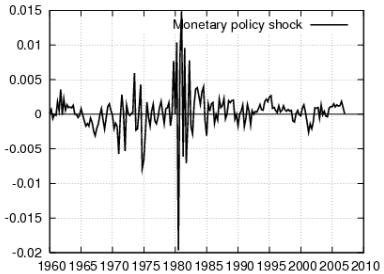
Nat. Rate



Cost Push

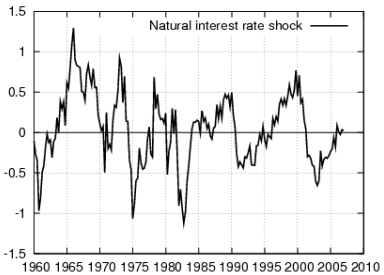


Policy Shock

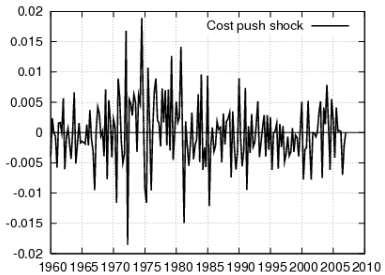


Learning with Estimated Initial Conditions

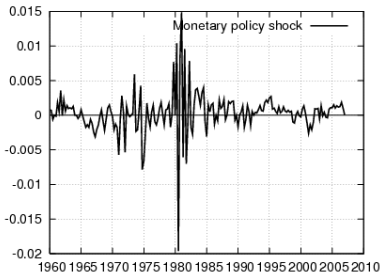
Nat. Rate (0.9769)



Cost Push (0.9832)



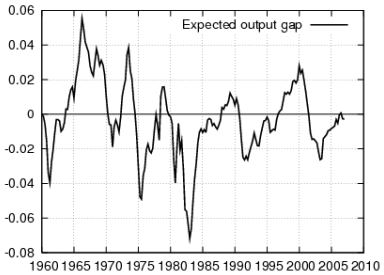
Policy Shock (0.9998)



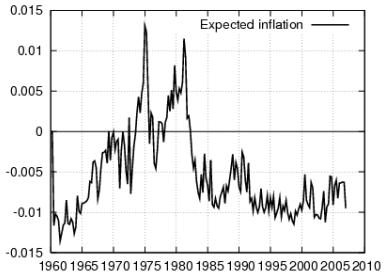
No Capital: Evolution of Expectations

Rational Expectations

Output Gap

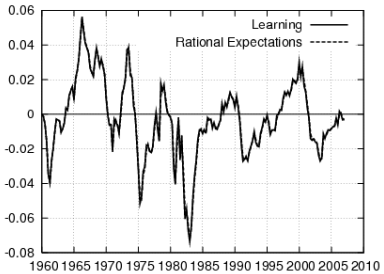


Inflation

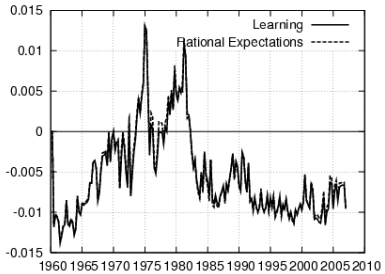


Learning with RE Initial Conditions

Output Gap



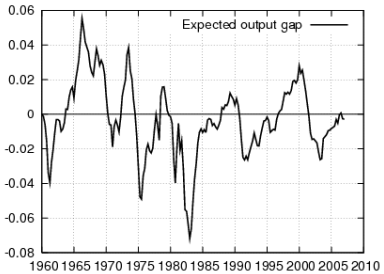
Inflation



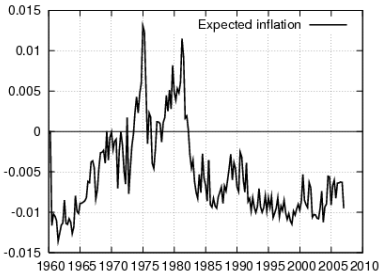
No Capital: Evolution of Expectations

Rational Expectations

Output Gap

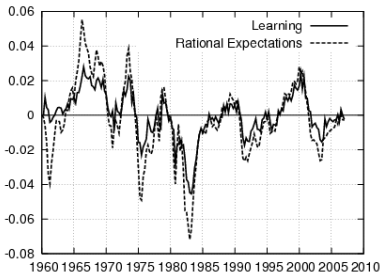


Inflation

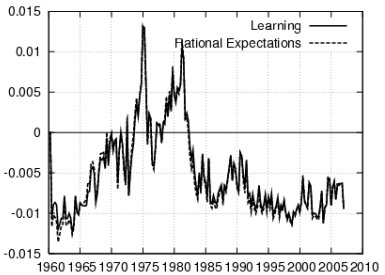


Learning Without Using Shocks

Output Gap



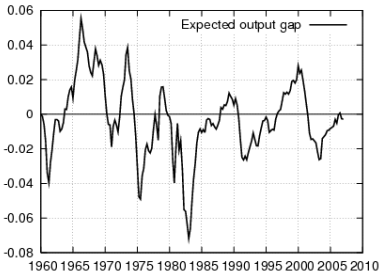
Inflation



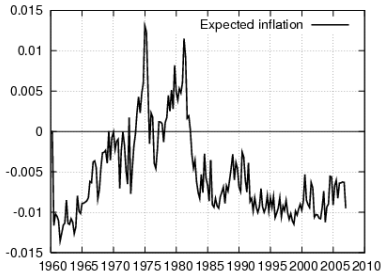
No Capital: Evolution of Expectations

Rational Expectations

Output Gap

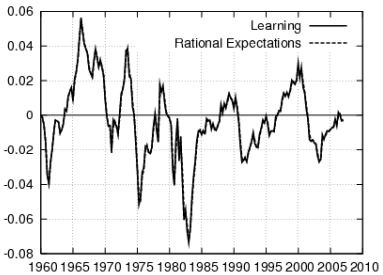


Inflation

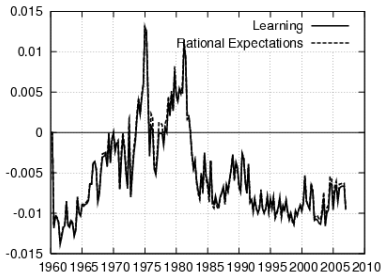


Learning with Pre-sample Initial Conditions

Output Gap



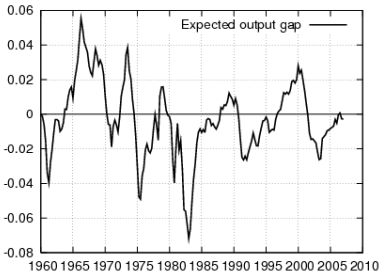
Inflation



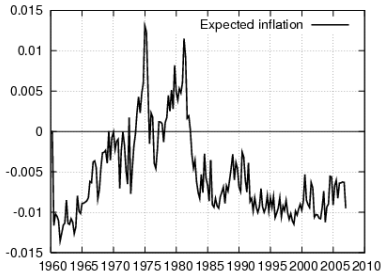
No Capital: Evolution of Expectations

Rational Expectations

Output Gap

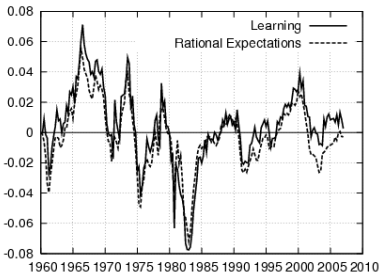


Inflation

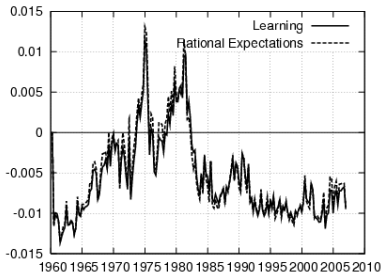


Learning with Estimated Initial Conditions

Output Gap



Inflation



Endogenous Capital: RE vs. Learning (RE Init.)

		Case 1		Case 2	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.9181	0.1017
Inverse IES	σ	0.3432	0.7774	0.3432	0.7967
Capital Share	α	0.3584	0.1189	0.3584	0.1219
Cons / Output	c_y	0.8753	0.0044	0.8753	0.0044
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9883	2.8850
Phillips Slope	κ	0.0090	0.0036	0.0090	0.0039
Price Indexation	γ	0.0001	0.0768	0.0001	0.0769
MP Persistence	ρ_r	0.7481	0.0472	0.7481	0.0570
MP Output	ψ_y	0.1003	0.0379	0.1003	0.0379
MP Inflation	ψ_π	1.0014	0.1195	1.0014	0.1219
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9716	0.0134
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.5647	0.1160
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9050	0.0435
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.0094	0.0044
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.0306	0.0099
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3587	0.2741
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0033	0.0003
SS Inflation	π^*	0.2209	4.2127	0.2209	4.2253
SS Output ($10,000)	y^*	1.4085	0.0212	1.4085	0.0213
Learning gain	g	–	–	0.0000	0.0147
Log-likelihood			-2391.5472		-2391.5472
MSE Consumption			7285.1049		7285.1049
MSE Investment			14454.2922		14454.2922
MSE Inflation			1.2633		1.2633
MSE Fed. Funds Rate			1.7499		1.7499

Endogenous Capital: RE vs. Learning (RE Init.)

		Case 1		Case 2	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.9181	0.1017
Inverse IES	σ	0.3432	0.7774	0.3432	0.7967
Capital Share	α	0.3584	0.1189	0.3584	0.1219
Cons / Output	c_y	0.8753	0.0044	0.8753	0.0044
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9883	2.8850
Phillips Slope	κ	0.0090	0.0036	0.0090	0.0039
Price Indexation	γ	0.0001	0.0768	0.0001	0.0769
MP Persistence	ρ_r	0.7481	0.0472	0.7481	0.0570
MP Output	ψ_y	0.1003	0.0379	0.1003	0.0379
MP Inflation	ψ_π	1.0014	0.1195	1.0014	0.1219
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9716	0.0134
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.5647	0.1160
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9050	0.0435
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.0094	0.0044
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.0306	0.0099
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3587	0.2741
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0033	0.0003
SS Inflation	π^*	0.2209	4.2127	0.2209	4.2253
SS Output ($10,000)	y^*	1.4085	0.0212	1.4085	0.0213
Learning gain	g	–	–	0.0000	0.0147
Log-likelihood			-2391.5472		-2391.5472
MSE Consumption			7285.1049		7285.1049
MSE Investment			14454.2922		14454.2922
MSE Inflation			1.2633		1.2633
MSE Fed. Funds Rate			1.7499		1.7499

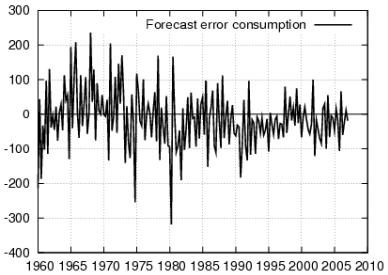
Endogenous Capital: RE vs. Learning (RE Init.)

		Case 1		Case 2	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.9181	0.1017
Inverse IES	σ	0.3432	0.7774	0.3432	0.7967
Capital Share	α	0.3584	0.1189	0.3584	0.1219
Cons / Output	c_y	0.8753	0.0044	0.8753	0.0044
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9883	2.8850
Phillips Slope	κ	0.0090	0.0036	0.0090	0.0039
Price Indexation	γ	0.0001	0.0768	0.0001	0.0769
MP Persistence	ρ_r	0.7481	0.0472	0.7481	0.0570
MP Output	ψ_y	0.1003	0.0379	0.1003	0.0379
MP Inflation	ψ_π	1.0014	0.1195	1.0014	0.1219
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9716	0.0134
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.5647	0.1160
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9050	0.0435
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.0094	0.0044
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.0306	0.0099
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3587	0.2741
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0033	0.0003
SS Inflation	π^*	0.2209	4.2127	0.2209	4.2253
SS Output ($10,000)	y^*	1.4085	0.0212	1.4085	0.0213
Learning gain	g	–	–	0.0000	0.0147
Log-likelihood			-2391.5472		-2391.5472
MSE Consumption			7285.1049		7285.1049
MSE Investment			14454.2922		14454.2922
MSE Inflation			1.2633		1.2633
MSE Fed. Funds Rate			1.7499		1.7499

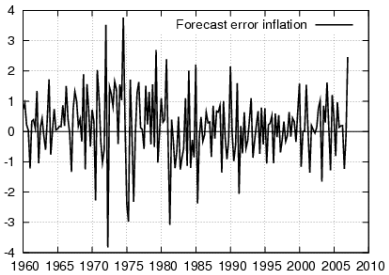
Endogenous Capital: Forecast Errors

Rational Expectations

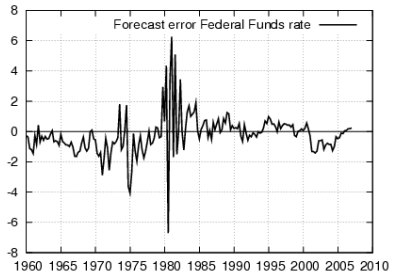
Consumption



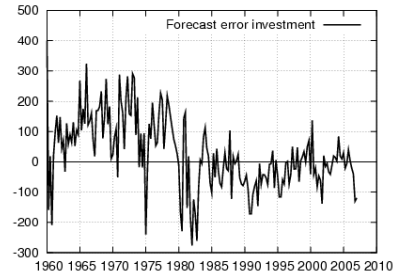
Inflation



Fed. Funds

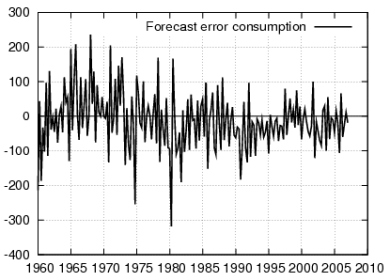


Investment

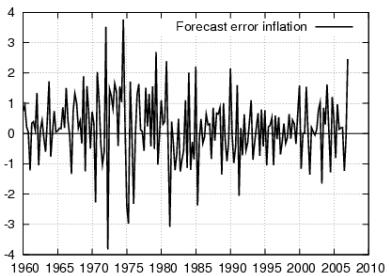


Learning with RE Initial Conditions

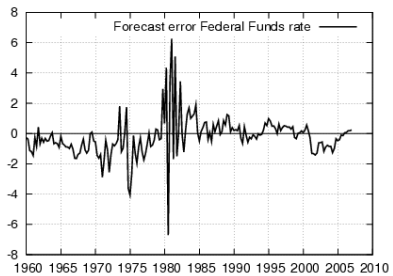
Consumption (1.0000)



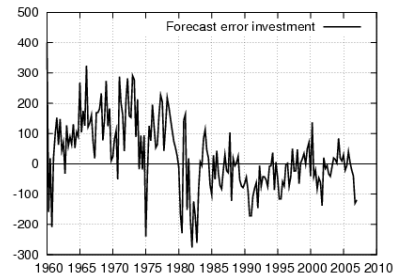
Inflation (1.0000)



Fed. Funds (1.0000)



Investment (1.0000)



Endogenous Capital: RE vs. Learning (No Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8393	0.1888
Inverse IES	σ	0.3432	0.7774	0.3771	0.8493
Capital Share	α	0.3584	0.1189	0.3870	0.2697
Cons / Output	c_y	0.8753	0.0044	0.8987	0.0000
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9747	2.1739
Phillips Slope	κ	0.0090	0.0036	0.0158	0.0065
Price Indexation	γ	0.0001	0.0768	0.0007	0.0774
MP Persistence	ρ_r	0.7481	0.0472	0.8031	0.0365
MP Output	ψ_y	0.1003	0.0379	0.1005	0.0478
MP Inflation	ψ_π	1.0014	0.1195	1.0285	0.1656
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9689	0.0461
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.6644	0.1550
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9182	0.0050
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.1133	0.0708
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1026	0.0189
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3532	0.1867
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0031	0.0001
SS Inflation	π^*	0.2209	4.2127	3.8982	1.4266
SS Output ($10,000)	y^*	1.4085	0.0212	1.4200	0.0181
Learning gain	g	–	–	0.0052	0.0019
Log-likelihood			-2391.5472		-2320.0228
MSE Consumption			7285.1049		9532.5647
MSE Investment			14454.2922		11044.5295
MSE Inflation			1.2633		1.2455
MSE Fed. Funds Rate			1.7499		1.6766

Endogenous Capital: RE vs. Learning (No Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8393	0.1888
Inverse IES	σ	0.3432	0.7774	0.3771	0.8493
Capital Share	α	0.3584	0.1189	0.3870	0.2697
Cons / Output	c_y	0.8753	0.0044	0.8987	0.0000
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9747	2.1739
Phillips Slope	κ	0.0090	0.0036	0.0158	0.0065
Price Indexation	γ	0.0001	0.0768	0.0007	0.0774
MP Persistence	ρ_r	0.7481	0.0472	0.8031	0.0365
MP Output	ψ_y	0.1003	0.0379	0.1005	0.0478
MP Inflation	ψ_π	1.0014	0.1195	1.0285	0.1656
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9689	0.0461
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.6644	0.1550
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9182	0.0050
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.1133	0.0708
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1026	0.0189
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3532	0.1867
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0031	0.0001
SS Inflation	π^*	0.2209	4.2127	3.8982	1.4266
SS Output ($10,000)	y^*	1.4085	0.0212	1.4200	0.0181
Learning gain	g	–	–	0.0052	0.0019
Log-likelihood			-2391.5472		-2320.0228
MSE Consumption			7285.1049		9532.5647
MSE Investment			14454.2922		11044.5295
MSE Inflation			1.2633		1.2455
MSE Fed. Funds Rate			1.7499		1.6766

Endogenous Capital: RE vs. Learning (No Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8393	0.1888
Inverse IES	σ	0.3432	0.7774	0.3771	0.8493
Capital Share	α	0.3584	0.1189	0.3870	0.2697
Cons / Output	c_y	0.8753	0.0044	0.8987	0.0000
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9747	2.1739
Phillips Slope	κ	0.0090	0.0036	0.0158	0.0065
Price Indexation	γ	0.0001	0.0768	0.0007	0.0774
MP Persistence	ρ_r	0.7481	0.0472	0.8031	0.0365
MP Output	ψ_y	0.1003	0.0379	0.1005	0.0478
MP Inflation	ψ_π	1.0014	0.1195	1.0285	0.1656
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9689	0.0461
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.6644	0.1550
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9182	0.0050
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.1133	0.0708
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1026	0.0189
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3532	0.1867
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0031	0.0001
SS Inflation	π^*	0.2209	4.2127	3.8982	1.4266
SS Output ($10,000)	y^*	1.4085	0.0212	1.4200	0.0181
Learning gain	g	–	–	0.0052	0.0019
Log-likelihood			-2391.5472		-2320.0228
MSE Consumption			7285.1049		9532.5647
MSE Investment			14454.2922		11044.5295
MSE Inflation			1.2633		1.2455
MSE Fed. Funds Rate			1.7499		1.6766

Endogenous Capital: RE vs. Learning (No Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8393	0.1888
Inverse IES	σ	0.3432	0.7774	0.3771	0.8493
Capital Share	α	0.3584	0.1189	0.3870	0.2697
Cons / Output	c_y	0.8753	0.0044	0.8987	0.0000
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9747	2.1739
Phillips Slope	κ	0.0090	0.0036	0.0158	0.0065
Price Indexation	γ	0.0001	0.0768	0.0007	0.0774
MP Persistence	ρ_r	0.7481	0.0472	0.8031	0.0365
MP Output	ψ_y	0.1003	0.0379	0.1005	0.0478
MP Inflation	ψ_π	1.0014	0.1195	1.0285	0.1656
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9689	0.0461
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.6644	0.1550
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9182	0.0050
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.1133	0.0708
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1026	0.0189
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3532	0.1867
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0031	0.0001
SS Inflation	π^*	0.2209	4.2127	3.8982	1.4266
SS Output ($10,000)	y^*	1.4085	0.0212	1.4200	0.0181
Learning gain	g	–	–	0.0052	0.0019
Log-likelihood			-2391.5472		-2320.0228
MSE Consumption			7285.1049		9532.5647
MSE Investment			14454.2922		11044.5295
MSE Inflation			1.2633		1.2455
MSE Fed. Funds Rate			1.7499		1.6766

Endogenous Capital: RE vs. Learning (No Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8393	0.1888
Inverse IES	σ	0.3432	0.7774	0.3771	0.8493
Capital Share	α	0.3584	0.1189	0.3870	0.2697
Cons / Output	c_y	0.8753	0.0044	0.8987	0.0000
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9747	2.1739
Phillips Slope	κ	0.0090	0.0036	0.0158	0.0065
Price Indexation	γ	0.0001	0.0768	0.0007	0.0774
MP Persistence	ρ_r	0.7481	0.0472	0.8031	0.0365
MP Output	ψ_y	0.1003	0.0379	0.1005	0.0478
MP Inflation	ψ_π	1.0014	0.1195	1.0285	0.1656
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9689	0.0461
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.6644	0.1550
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9182	0.0050
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.1133	0.0708
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1026	0.0189
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3532	0.1867
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0031	0.0001
SS Inflation	π^*	0.2209	4.2127	3.8982	1.4266
SS Output ($10,000)	y^*	1.4085	0.0212	1.4200	0.0181
Learning gain	g	–	–	0.0052	0.0019
Log-likelihood			-2391.5472		-2320.0228
MSE Consumption			7285.1049		9532.5647
MSE Investment			14454.2922		11044.5295
MSE Inflation			1.2633		1.2455
MSE Fed. Funds Rate			1.7499		1.6766

Endogenous Capital: RE vs. Learning (No Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8393	0.1888
Inverse IES	σ	0.3432	0.7774	0.3771	0.8493
Capital Share	α	0.3584	0.1189	0.3870	0.2697
Cons / Output	c_y	0.8753	0.0044	0.8987	0.0000
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9747	2.1739
Phillips Slope	κ	0.0090	0.0036	0.0158	0.0065
Price Indexation	γ	0.0001	0.0768	0.0007	0.0774
MP Persistence	ρ_r	0.7481	0.0472	0.8031	0.0365
MP Output	ψ_y	0.1003	0.0379	0.1005	0.0478
MP Inflation	ψ_π	1.0014	0.1195	1.0285	0.1656
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9689	0.0461
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.6644	0.1550
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9182	0.0050
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.1133	0.0708
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1026	0.0189
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3532	0.1867
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0031	0.0001
SS Inflation	π^*	0.2209	4.2127	3.8982	1.4266
SS Output ($10,000)	y^*	1.4085	0.0212	1.4200	0.0181
Learning gain	g	–	–	0.0052	0.0019
Log-likelihood			-2391.5472		-2320.0228
MSE Consumption			7285.1049		9532.5647
MSE Investment			14454.2922		11044.5295
MSE Inflation			1.2633		1.2455
MSE Fed. Funds Rate			1.7499		1.6766

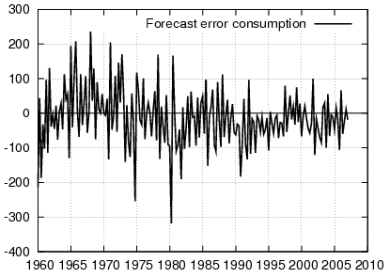
Endogenous Capital: RE vs. Learning (No Shocks)

		Case 1		Case 3	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8393	0.1888
Inverse IES	σ	0.3432	0.7774	0.3771	0.8493
Capital Share	α	0.3584	0.1189	0.3870	0.2697
Cons / Output	c_y	0.8753	0.0044	0.8987	0.0000
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9747	2.1739
Phillips Slope	κ	0.0090	0.0036	0.0158	0.0065
Price Indexation	γ	0.0001	0.0768	0.0007	0.0774
MP Persistence	ρ_r	0.7481	0.0472	0.8031	0.0365
MP Output	ψ_y	0.1003	0.0379	0.1005	0.0478
MP Inflation	ψ_π	1.0014	0.1195	1.0285	0.1656
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9689	0.0461
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.6644	0.1550
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9182	0.0050
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.1133	0.0708
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1026	0.0189
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.3532	0.1867
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0031	0.0001
SS Inflation	π^*	0.2209	4.2127	3.8982	1.4266
SS Output ($10,000)	y^*	1.4085	0.0212	1.4200	0.0181
Learning gain	g	–	–	0.0052	0.0019
Log-likelihood			-2391.5472		-2320.0228
MSE Consumption			7285.1049		9532.5647
MSE Investment			14454.2922		11044.5295
MSE Inflation			1.2633		1.2455
MSE Fed. Funds Rate			1.7499		1.6766

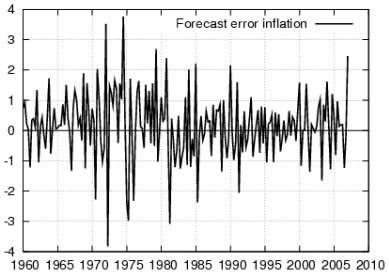
Endogenous Capital: Forecast Errors

Rational Expectations

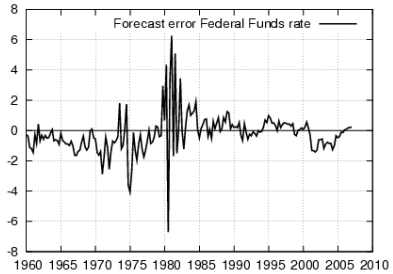
Consumption



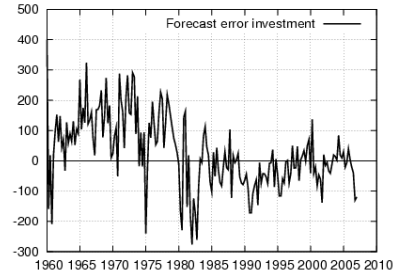
Inflation



Fed. Funds

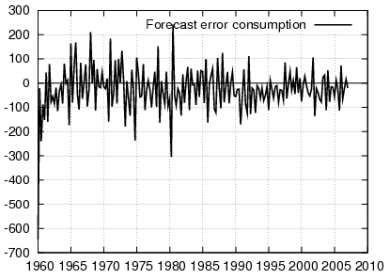


Investment

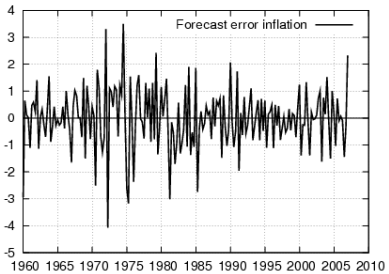


Learning Without Observable Shocks

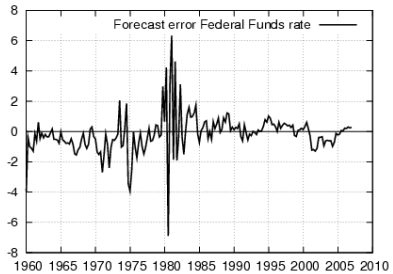
Consumption (0.9150)



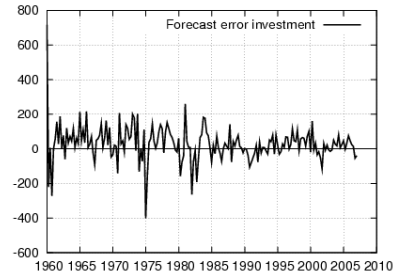
Inflation (0.9635)



Fed. Funds (0.9719)



Investment (0.7828)



Endogenous Capital: RE vs. Learning (Pre-sample)

		Case 1		Case 4	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.7685	0.2555
Inverse IES	σ	0.3432	0.7774	0.6433	1.7938
Capital Share	α	0.3584	0.1189	0.3177	0.3785
Cons / Output	c_y	0.8753	0.0044	0.8944	0.0036
Cost Capital Adj.	ϕ	6.9883	1.4836	6.8234	2.6605
Phillips Slope	κ	0.0090	0.0036	0.0113	0.0035
Price Indexation	γ	0.0001	0.0768	0.0877	0.1071
MP Persistence	ρ_r	0.7481	0.0472	0.8975	0.0382
MP Output	ψ_y	0.1003	0.0379	0.1565	0.1132
MP Inflation	ψ_π	1.0014	0.1195	1.0462	0.1866
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.8205	0.0357
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.9007	0.0286
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9999	0.0000
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.3079	0.1910
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1064	0.0133
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.4362	0.4727
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0032	0.0001
SS Inflation	π^*	0.2209	4.2127	0.0035	0.9250
SS Output ($10,000)	y^*	1.4085	0.0212	1.4074	0.0089
Learning gain	g	–	–	0.0060	0.0012
Log-likelihood			-2391.5472		-2506.8255
MSE Consumption			7285.1049		9584.1202
MSE Investment			14454.2922		44510.7805
MSE Inflation			1.2633		3.5212
MSE Fed. Funds Rate			1.7499		1.5378

Endogenous Capital: RE vs. Learning (Pre-sample)

		Case 1		Case 4	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.7685	0.2555
Inverse IES	σ	0.3432	0.7774	0.6433	1.7938
Capital Share	α	0.3584	0.1189	0.3177	0.3785
Cons / Output	c_y	0.8753	0.0044	0.8944	0.0036
Cost Capital Adj.	ϕ	6.9883	1.4836	6.8234	2.6605
Phillips Slope	κ	0.0090	0.0036	0.0113	0.0035
Price Indexation	γ	0.0001	0.0768	0.0877	0.1071
MP Persistence	ρ_r	0.7481	0.0472	0.8975	0.0382
MP Output	ψ_y	0.1003	0.0379	0.1565	0.1132
MP Inflation	ψ_π	1.0014	0.1195	1.0462	0.1866
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.8205	0.0357
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.9007	0.0286
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9999	0.0000
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.3079	0.1910
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1064	0.0133
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.4362	0.4727
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0032	0.0001
SS Inflation	π^*	0.2209	4.2127	0.0035	0.9250
SS Output ($10,000)	y^*	1.4085	0.0212	1.4074	0.0089
Learning gain	g	–	–	0.0060	0.0012
Log-likelihood			-2391.5472		-2506.8255
MSE Consumption			7285.1049		9584.1202
MSE Investment			14454.2922		44510.7805
MSE Inflation			1.2633		3.5212
MSE Fed. Funds Rate			1.7499		1.5378

Endogenous Capital: RE vs. Learning (Pre-sample)

		Case 1		Case 4	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.7685	0.2555
Inverse IES	σ	0.3432	0.7774	0.6433	1.7938
Capital Share	α	0.3584	0.1189	0.3177	0.3785
Cons / Output	c_y	0.8753	0.0044	0.8944	0.0036
Cost Capital Adj.	ϕ	6.9883	1.4836	6.8234	2.6605
Phillips Slope	κ	0.0090	0.0036	0.0113	0.0035
Price Indexation	γ	0.0001	0.0768	0.0877	0.1071
MP Persistence	ρ_r	0.7481	0.0472	0.8975	0.0382
MP Output	ψ_y	0.1003	0.0379	0.1565	0.1132
MP Inflation	ψ_π	1.0014	0.1195	1.0462	0.1866
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.8205	0.0357
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.9007	0.0286
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9999	0.0000
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.3079	0.1910
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1064	0.0133
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.4362	0.4727
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0032	0.0001
SS Inflation	π^*	0.2209	4.2127	0.0035	0.9250
SS Output ($10,000)	y^*	1.4085	0.0212	1.4074	0.0089
Learning gain	g	–	–	0.0060	0.0012
Log-likelihood			-2391.5472		-2506.8255
MSE Consumption			7285.1049		9584.1202
MSE Investment			14454.2922		44510.7805
MSE Inflation			1.2633		3.5212
MSE Fed. Funds Rate			1.7499		1.5378

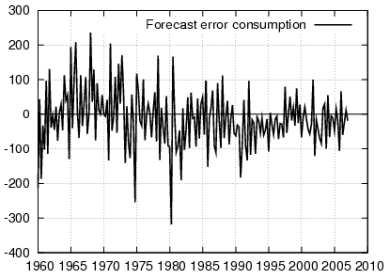
Endogenous Capital: RE vs. Learning (Pre-sample)

		Case 1		Case 4	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.7685	0.2555
Inverse IES	σ	0.3432	0.7774	0.6433	1.7938
Capital Share	α	0.3584	0.1189	0.3177	0.3785
Cons / Output	c_y	0.8753	0.0044	0.8944	0.0036
Cost Capital Adj.	ϕ	6.9883	1.4836	6.8234	2.6605
Phillips Slope	κ	0.0090	0.0036	0.0113	0.0035
Price Indexation	γ	0.0001	0.0768	0.0877	0.1071
MP Persistence	ρ_r	0.7481	0.0472	0.8975	0.0382
MP Output	ψ_y	0.1003	0.0379	0.1565	0.1132
MP Inflation	ψ_π	1.0014	0.1195	1.0462	0.1866
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.8205	0.0357
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.9007	0.0286
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9999	0.0000
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.3079	0.1910
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.1064	0.0133
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.4362	0.4727
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0032	0.0001
SS Inflation	π^*	0.2209	4.2127	0.0035	0.9250
SS Output ($10,000)	y^*	1.4085	0.0212	1.4074	0.0089
Learning gain	g	–	–	0.0060	0.0012
Log-likelihood			-2391.5472		-2506.8255
MSE Consumption			7285.1049		9584.1202
MSE Investment			14454.2922		44510.7805
MSE Inflation			1.2633		3.5212
MSE Fed. Funds Rate			1.7499		1.5378

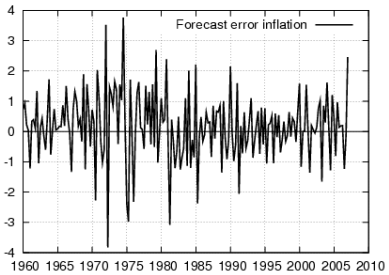
Endogenous Capital: Forecast Errors

Rational Expectations

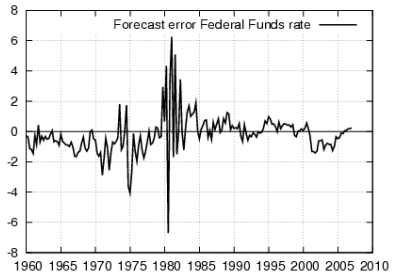
Consumption



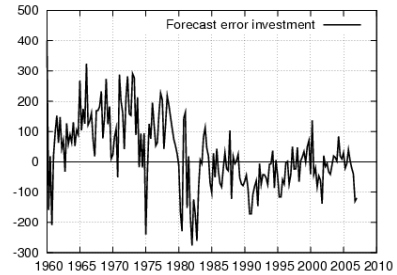
Inflation



Fed. Funds

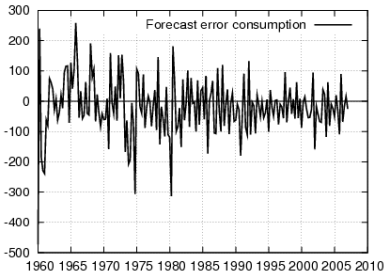


Investment

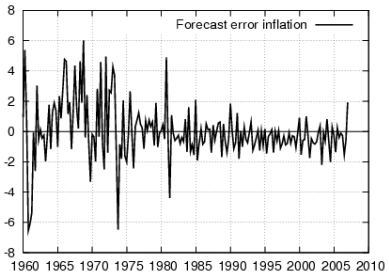


Learning with Pre-sample Initial Conditions

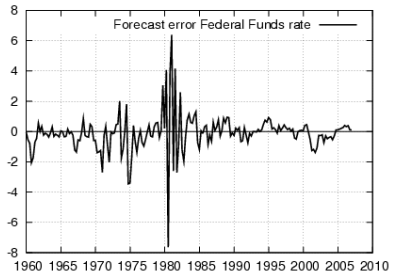
Consumption (0.8813)



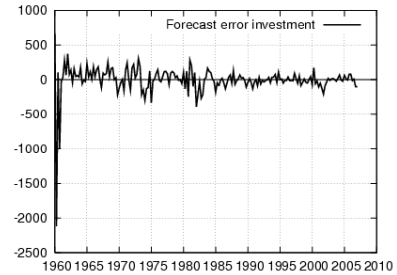
Inflation (0.6142)



Fed. Funds (0.9301)



Investment (0.5128)



Endogenous Capital: RE vs. Learning (Estimated)

		Case 1		Case 5	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8564	6.7771
Inverse IES	σ	0.3432	0.7774	0.1667	16.3052
Capital Share	α	0.3584	0.1189	0.3662	0.6600
Cons / Output	c_y	0.8753	0.0044	0.8851	0.0122
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9999	0.0001
Phillips Slope	κ	0.0090	0.0036	0.0287	0.0201
Price Indexation	γ	0.0001	0.0768	0.0002	0.3186
MP Persistence	ρ_r	0.7481	0.0472	0.9136	0.0641
MP Output	ψ_y	0.1003	0.0379	0.1296	0.2032
MP Inflation	ψ_π	1.0014	0.1195	1.0089	0.4514
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9582	0.0411
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.1614	0.1110
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9075	0.0902
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.0609	0.0920
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.0709	0.0220
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.0918	0.2118
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0030	0.0001
SS Inflation	π^*	0.2209	4.2127	0.2202	4.7265
SS Output ($10,000)	y^*	1.4085	0.0212	1.4177	0.0783
Learning gain	g	–	–	0.0005	0.0018
Log-likelihood			-2391.5472		-2237.0404
MSE Consumption			7285.1049		6702.3679
MSE Investment			14454.2922		6304.4836
MSE Inflation			1.2633		1.1815
MSE Fed. Funds Rate			1.7499		1.4896

Endogenous Capital: RE vs. Learning (Estimated)

		Case 1		Case 5	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8564	6.7771
Inverse IES	σ	0.3432	0.7774	0.1667	16.3052
Capital Share	α	0.3584	0.1189	0.3662	0.6600
Cons / Output	c_y	0.8753	0.0044	0.8851	0.0122
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9999	0.0001
Phillips Slope	κ	0.0090	0.0036	0.0287	0.0201
Price Indexation	γ	0.0001	0.0768	0.0002	0.3186
MP Persistence	ρ_r	0.7481	0.0472	0.9136	0.0641
MP Output	ψ_y	0.1003	0.0379	0.1296	0.2032
MP Inflation	ψ_π	1.0014	0.1195	1.0089	0.4514
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9582	0.0411
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.1614	0.1110
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9075	0.0902
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.0609	0.0920
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.0709	0.0220
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.0918	0.2118
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0030	0.0001
SS Inflation	π^*	0.2209	4.2127	0.2202	4.7265
SS Output ($10,000)	y^*	1.4085	0.0212	1.4177	0.0783
Learning gain	g	–	–	0.0005	0.0018
Log-likelihood			-2391.5472		-2237.0404
MSE Consumption			7285.1049		6702.3679
MSE Investment			14454.2922		6304.4836
MSE Inflation			1.2633		1.1815
MSE Fed. Funds Rate			1.7499		1.4896

Endogenous Capital: RE vs. Learning (Estimated)

		Case 1		Case 5	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8564	6.7771
Inverse IES	σ	0.3432	0.7774	0.1667	16.3052
Capital Share	α	0.3584	0.1189	0.3662	0.6600
Cons / Output	c_y	0.8753	0.0044	0.8851	0.0122
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9999	0.0001
Phillips Slope	κ	0.0090	0.0036	0.0287	0.0201
Price Indexation	γ	0.0001	0.0768	0.0002	0.3186
MP Persistence	ρ_r	0.7481	0.0472	0.9136	0.0641
MP Output	ψ_y	0.1003	0.0379	0.1296	0.2032
MP Inflation	ψ_π	1.0014	0.1195	1.0089	0.4514
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9582	0.0411
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.1614	0.1110
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9075	0.0902
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.0609	0.0920
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.0709	0.0220
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.0918	0.2118
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0030	0.0001
SS Inflation	π^*	0.2209	4.2127	0.2202	4.7265
SS Output ($10,000)	y^*	1.4085	0.0212	1.4177	0.0783
Learning gain	g	–	–	0.0005	0.0018
Log-likelihood			-2391.5472		-2237.0404
MSE Consumption			7285.1049		6702.3679
MSE Investment			14454.2922		6304.4836
MSE Inflation			1.2633		1.1815
MSE Fed. Funds Rate			1.7499		1.4896

Endogenous Capital: RE vs. Learning (Estimated)

		Case 1		Case 5	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8564	6.7771
Inverse IES	σ	0.3432	0.7774	0.1667	16.3052
Capital Share	α	0.3584	0.1189	0.3662	0.6600
Cons / Output	c_y	0.8753	0.0044	0.8851	0.0122
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9999	0.0001
Phillips Slope	κ	0.0090	0.0036	0.0287	0.0201
Price Indexation	γ	0.0001	0.0768	0.0002	0.3186
MP Persistence	ρ_r	0.7481	0.0472	0.9136	0.0641
MP Output	ψ_y	0.1003	0.0379	0.1296	0.2032
MP Inflation	ψ_π	1.0014	0.1195	1.0089	0.4514
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9582	0.0411
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.1614	0.1110
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9075	0.0902
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.0609	0.0920
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.0709	0.0220
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.0918	0.2118
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0030	0.0001
SS Inflation	π^*	0.2209	4.2127	0.2202	4.7265
SS Output ($10,000)	y^*	1.4085	0.0212	1.4177	0.0783
Learning gain	g	–	–	0.0005	0.0018
Log-likelihood			-2391.5472		-2237.0404
MSE Consumption			7285.1049		6702.3679
MSE Investment			14454.2922		6304.4836
MSE Inflation			1.2633		1.1815
MSE Fed. Funds Rate			1.7499		1.4896

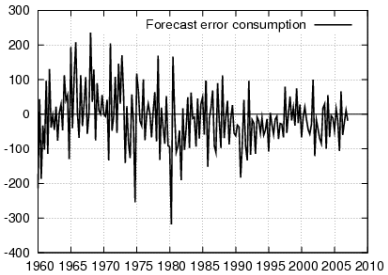
Endogenous Capital: RE vs. Learning (Estimated)

		Case 1		Case 5	
Description	Parameter	Estimate	Std. Dev.	Estimate	Std. Dev.
Habit Formation	η	0.9181	0.1007	0.8564	6.7771
Inverse IES	σ	0.3432	0.7774	0.1667	16.3052
Capital Share	α	0.3584	0.1189	0.3662	0.6600
Cons / Output	c_y	0.8753	0.0044	0.8851	0.0122
Cost Capital Adj.	ϕ	6.9883	1.4836	6.9999	0.0001
Phillips Slope	κ	0.0090	0.0036	0.0287	0.0201
Price Indexation	γ	0.0001	0.0768	0.0002	0.3186
MP Persistence	ρ_r	0.7481	0.0472	0.9136	0.0641
MP Output	ψ_y	0.1003	0.0379	0.1296	0.2032
MP Inflation	ψ_π	1.0014	0.1195	1.0089	0.4514
Tech. Shock Pers.	ρ_z	0.9716	0.0133	0.9582	0.0411
Pref. Shock Pers.	ρ_ξ	0.5647	0.1159	0.1614	0.1110
Inv. Shock Pers.	ρ_μ	0.9050	0.0426	0.9075	0.0902
Tech. Shock Std. Dev.	σ_z	0.0094	0.0041	0.0609	0.0920
Inv. Shock Std. Dev.	σ_μ	0.0306	0.0070	0.0709	0.0220
Pref. Shock Std. Dev.	σ_ξ	0.3587	0.2699	0.0918	0.2118
MP Shock Std. Dev.	σ_r	0.0033	0.0002	0.0030	0.0001
SS Inflation	π^*	0.2209	4.2127	0.2202	4.7265
SS Output ($10,000)	y^*	1.4085	0.0212	1.4177	0.0783
Learning gain	g	–	–	0.0005	0.0018
Log-likelihood			-2391.5472		-2237.0404
MSE Consumption			7285.1049		6702.3679
MSE Investment			14454.2922		6304.4836
MSE Inflation			1.2633		1.1815
MSE Fed. Funds Rate			1.7499		1.4896

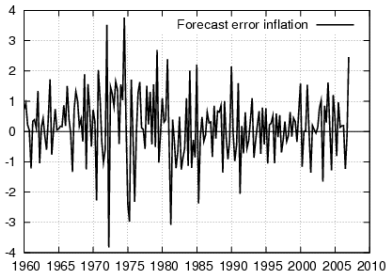
Endogenous Capital: Forecast Errors

Rational Expectations

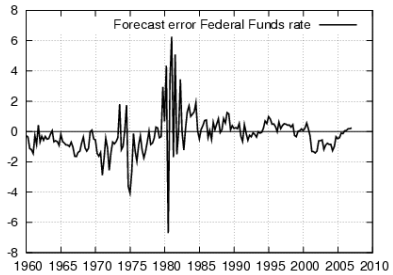
Consumption



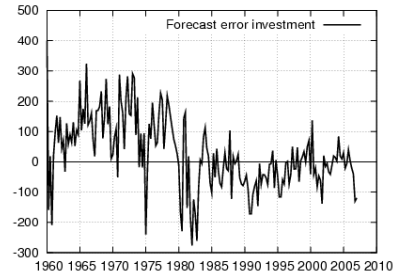
Inflation



Fed. Funds

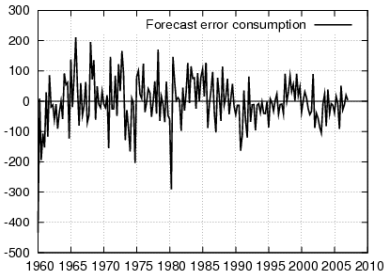


Investment

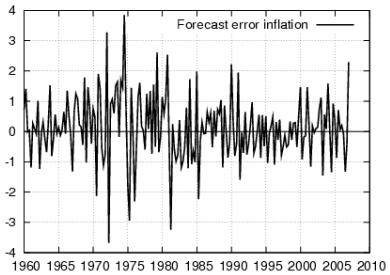


Learning with Estimated Initial Conditions

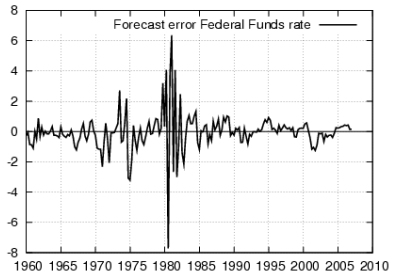
Consumption (0.8977)



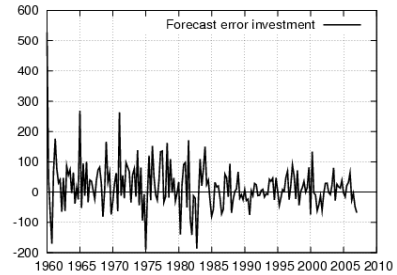
Inflation (0.9843)



Fed. Funds (0.9245)



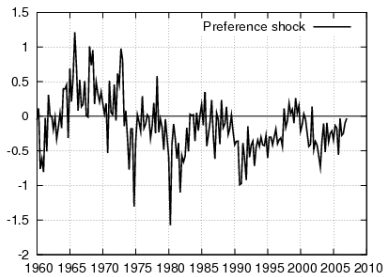
Investment (0.6910)



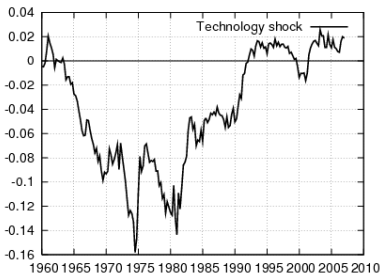
Endogenous Capital: Evolution of Shocks

Rational Expectations

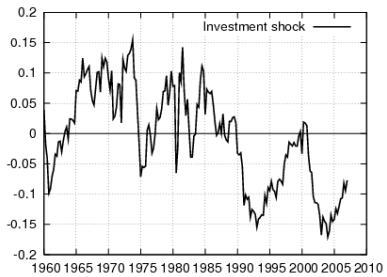
Preference



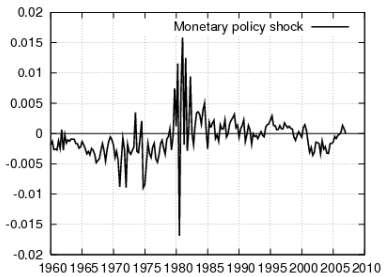
Technology



Investment

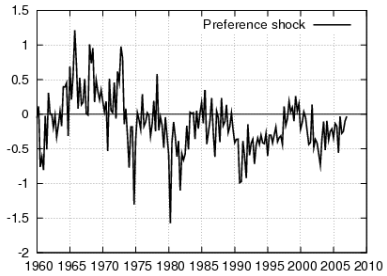


Policy Shock

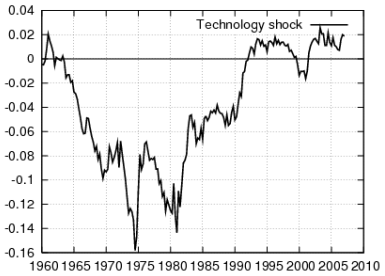


Learning with RE Initial Conditions

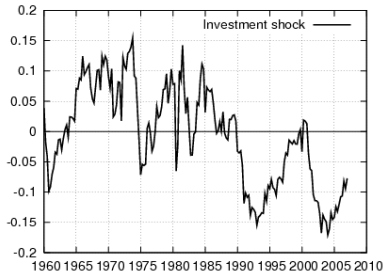
Preference (1.0000)



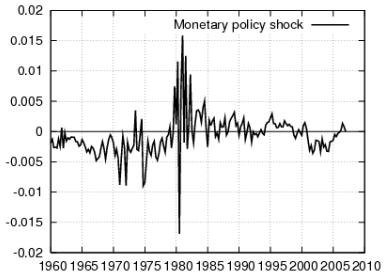
Technology (1.0000)



Investment (1.0000)



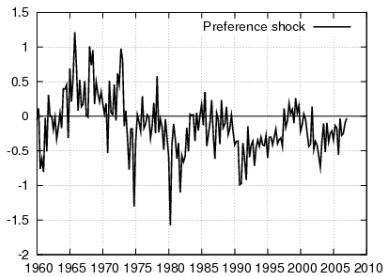
Policy Shock (1.0000)



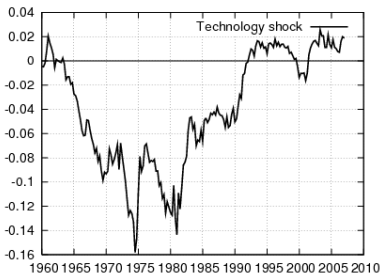
Endogenous Capital: Evolution of Shocks

Rational Expectations

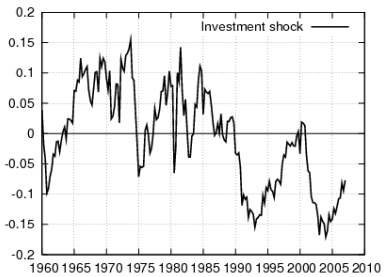
Preference



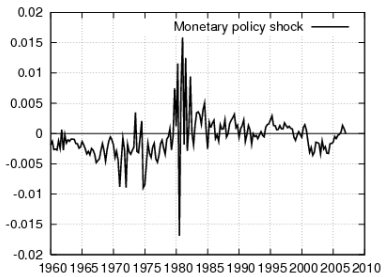
Technology



Investment

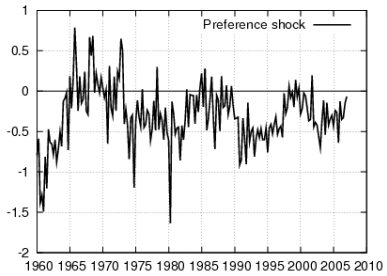


Policy Shock

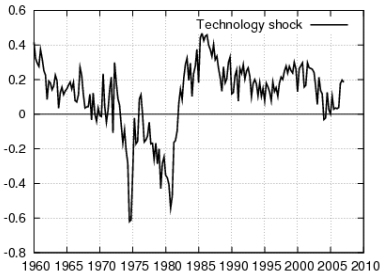


Learning Without Observable Shocks

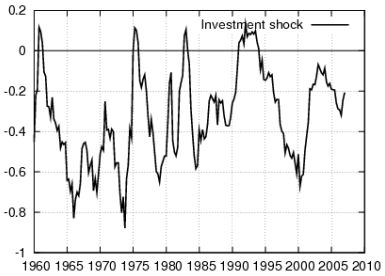
Preference (0.8697)



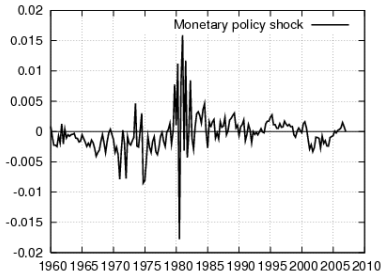
Technology (0.6534)



Investment (-0.8120)



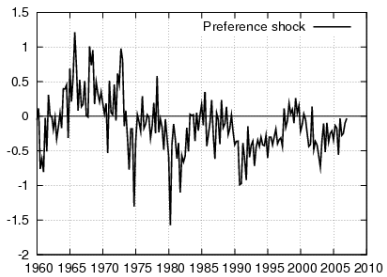
Policy Shock (0.9867)



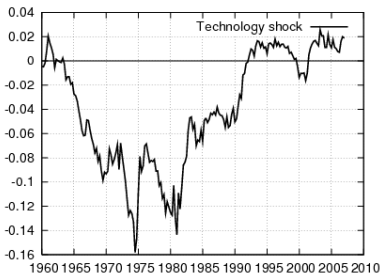
Endogenous Capital: Evolution of Shocks

Rational Expectations

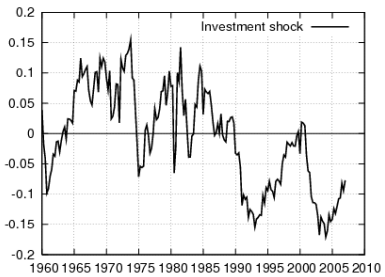
Preference



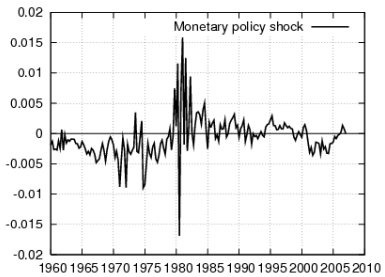
Technology



Investment

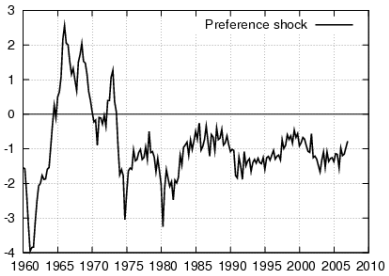


Policy Shock

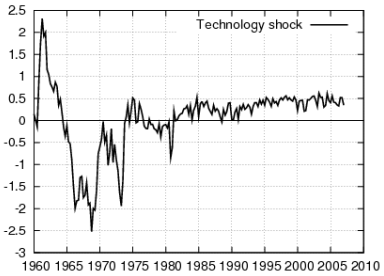


Learning with Pre-sample Initial Conditions

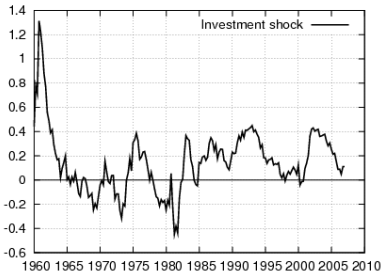
Preference (0.7522)



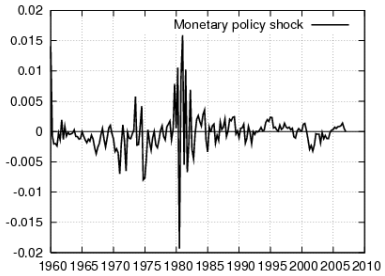
Technology (0.5440)



Investment (-0.6584)



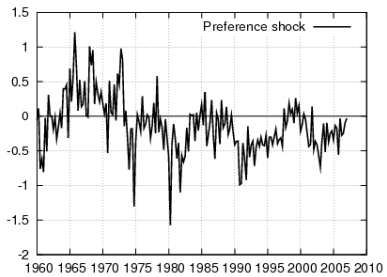
Policy Shock (0.8697)



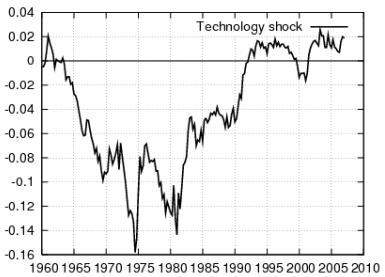
Endogenous Capital: Evolution of Shocks

Rational Expectations

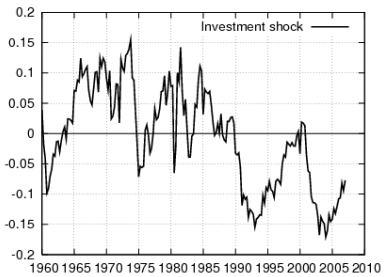
Preference



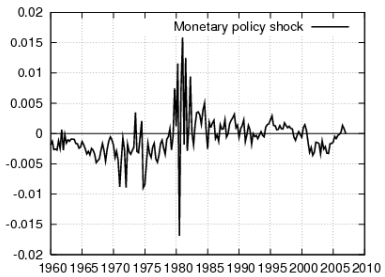
Technology



Investment

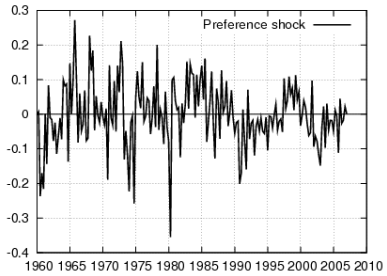


Policy Shock

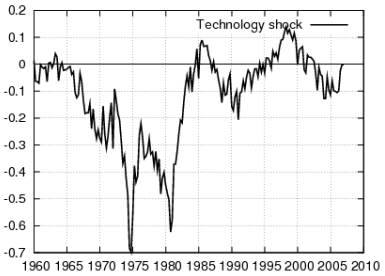


Learning with Estimated Initial Conditions

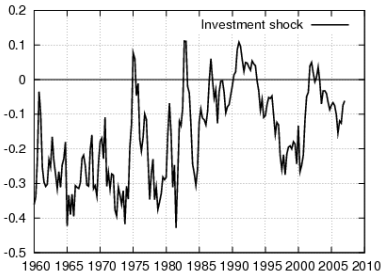
Preference (0.8200)



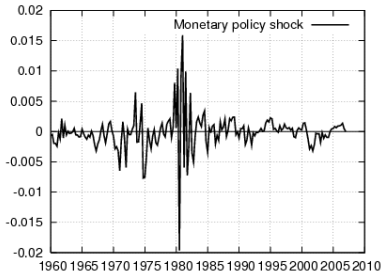
Technology (0.8365)



Investment (-0.7371)



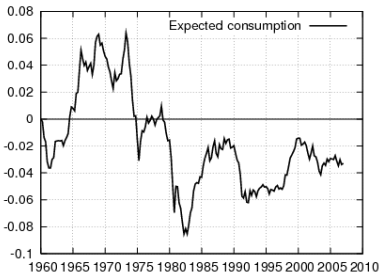
Policy Shock (0.8917)



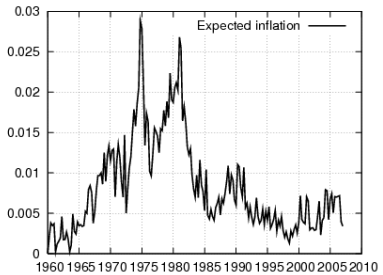
Endogenous Capital: Evolution of Expectations

Rational Expectations

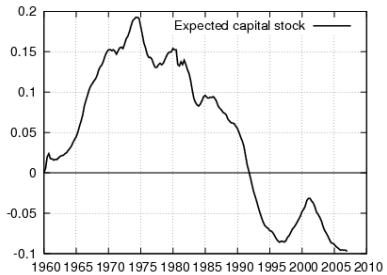
Consumption



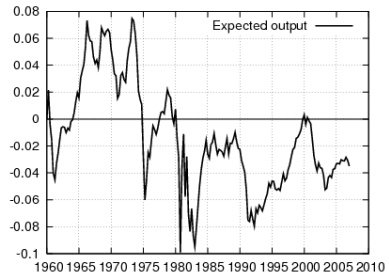
Inflation



Capital Stock

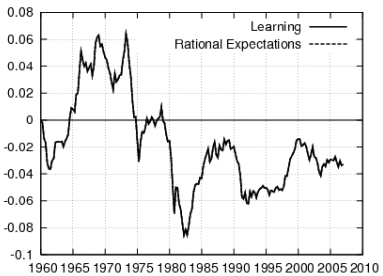


Output

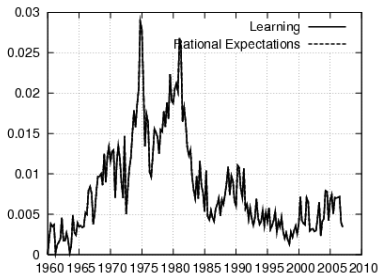


Learning with RE Initial Conditions

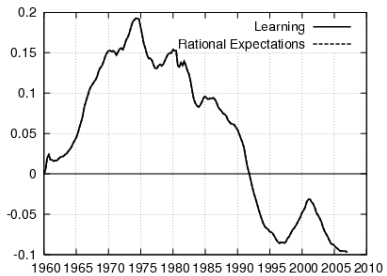
Consumption



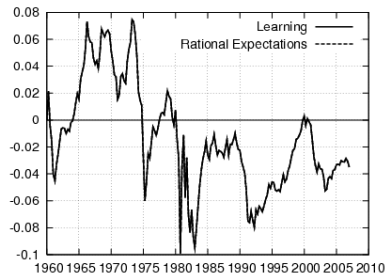
Inflation



Capital Stock



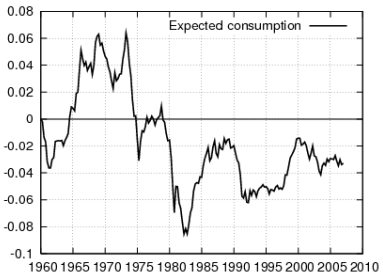
Output



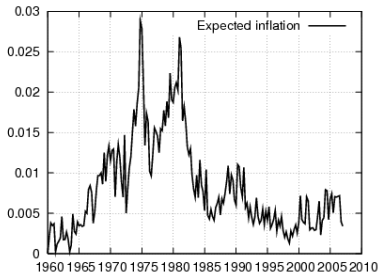
Endogenous Capital: Evolution of Expectations

Rational Expectations

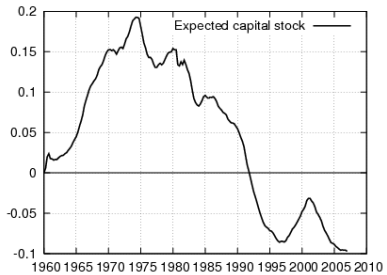
Consumption



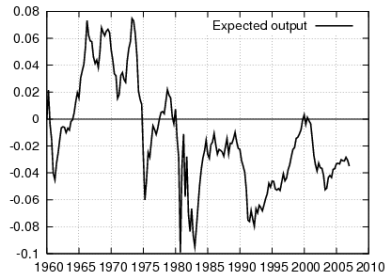
Inflation



Capital Stock

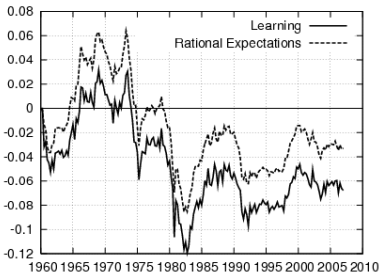


Output

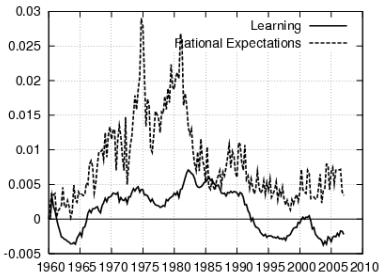


Learning Without Using Shocks

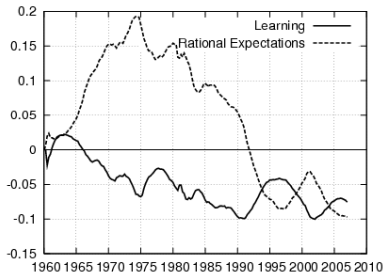
Consumption



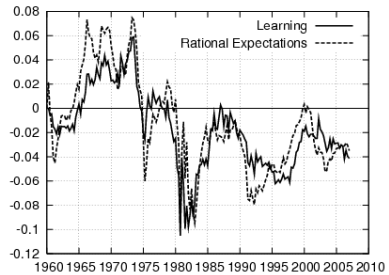
Inflation



Capital Stock



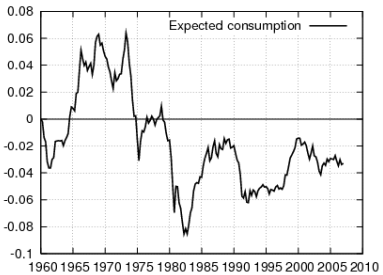
Output



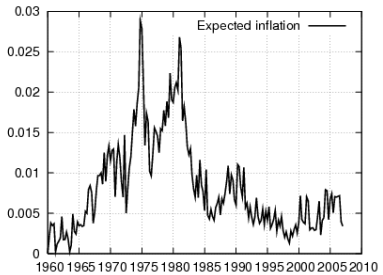
Endogenous Capital: Evolution of Expectations

Rational Expectations

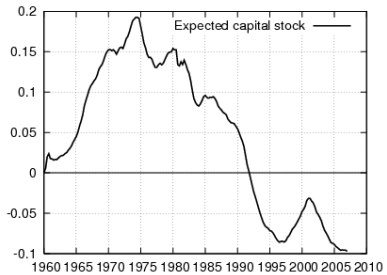
Consumption



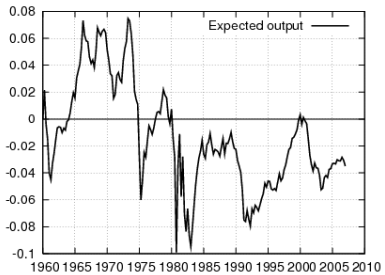
Inflation



Capital Stock

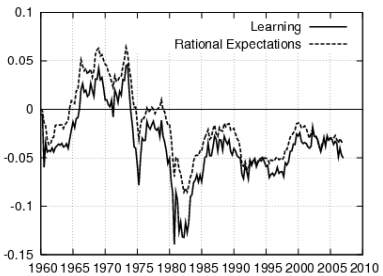


Output

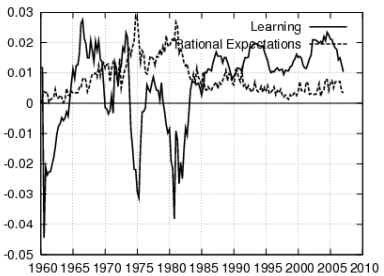


Learning with Pre-sample Initial Conditions

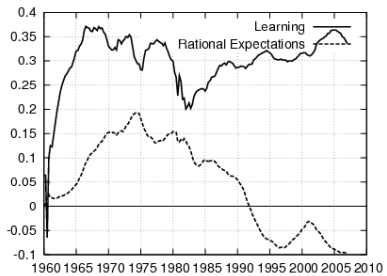
Consumption



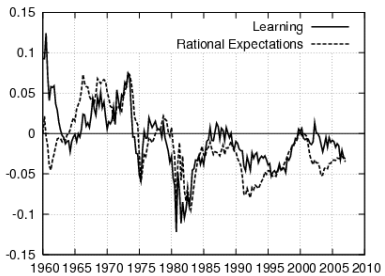
Inflation



Capital Stock



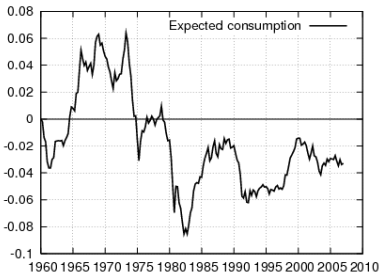
Output



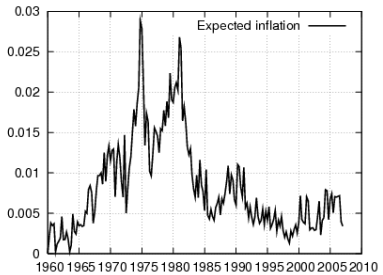
Endogenous Capital: Evolution of Expectations

Rational Expectations

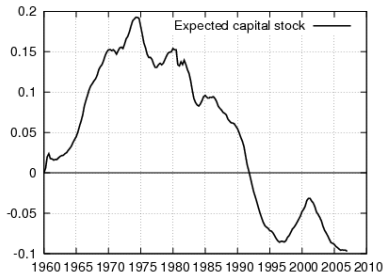
Consumption



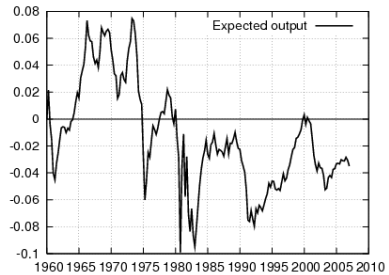
Inflation



Capital Stock

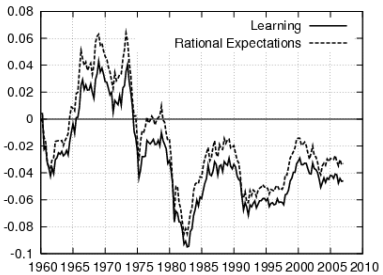


Output

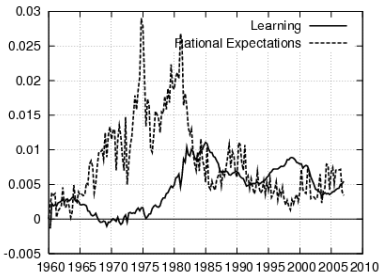


Learning with Estimated Initial Conditions

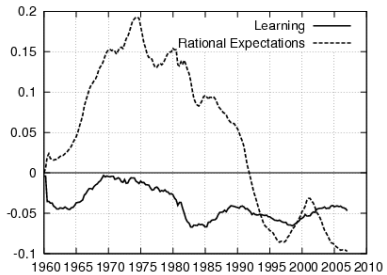
Consumption



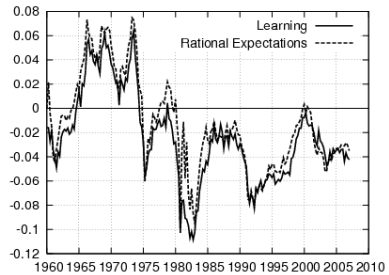
Inflation



Capital Stock



Output



Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.

Conclusion

- Summary of findings:
  - Learning does not better explain data.
  - No capital: negligible differences in forecast errors, shocks, and expectations.
  - Making shocks unobservable causes MLE to predict more volatile shocks.
  - Best fitting models: Learning without observable shocks.
  - Worst fitting models: Pre-sample initial conditions.
  - Unobservable shocks creates less volatile expectations.
  - Learning expectations about capital stock causes opposite predictions for investment shocks.
- Learning failures:
  - Fails to explain persistence.
  - Fails to explain Great Inflation / Great Moderation.