Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy

by

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Motivation

- Want to Contribute to Quest for Quantitatively Realistic Model of Monetary Transmission Mechanism.
- Would like to Understand Reasons for Inflation Inertia and Output Persistence.

A Strategy for Estimating a Monetary Model

- Estimate a 'Reduced Form' Model of the Monetary Transmission Mechanism.
- Quantify Notions of 'Inflation Inertia' and 'Output Persistence'.
- Estimate a General Equilibrium Model that is Consistent With Reduced Form.
- *Reality*: In GE, 'Everything' Matters - Can't 'Split Off' Monetary Economics, Investment Economics, Labor Economics.
- To Interpret Macro Data, Must Inevitably Think About a Range of Issues:
  (a) Nominal Frictions:
    * Sticky Prices, Wages, etc.

  (b) Real Features:
    * Adjustment Costs in Investment, Variable Capital Utilization, Habit Persistence in Preferences.

Our Question

- What Nominal Frictions and Real Features are Necessary for a Model to Conform Well with Reduced Form?

Alternative Strategy for Estimating A Model:

- Compute Unconditional Moments of Data.
- Estimate Model Based on All Moments (Maximum Likelihood).
- Disadvantages of All-Moment Approach:
  - Need to Determine All Shocks in the Model, Not Just Monetary Policy Shocks.
- Advantage of All-Moment Approach.
  - In the End, Want a Model With All Shocks.
- Advantage of Our Limited Information Approach.
  - Can Make Progress Learning About Structure of Economy Without Having to Take a Stand on the Nature of the Non-Monetary Shocks.

Outline

(1) Reduced Form Estimate of the Monetary Transmission Mechanism

(2) The Model

(3) Assigning Values to Model Parameters

(4) Empirical Evaluation of Model

Identification of Monetary Policy Shocks

- Monetary Policy Rule:

$$
\begin{aligned}
R_t &= \alpha Y_t + \beta P_t + \text{lagged variables} + \varepsilon_t \\
\varepsilon_t &\sim \text{ Monetary Policy Shock}
\end{aligned}
$$

- Identification Assumptions:

(1) ε_t Has No Contemporaneous Effect on $Y_t,\ P_t$
(2) $Y_t,\ P_t$ Only Variables Observed Contemporaneously

Identification of Response to Monetary Policy Shocks

- Step 1: Compute ε_t, Error Term in Projection of R_t on Y_t, P_t, lagged variables
- Step 2: Project Economic Variables on Current and Past Values of ε_t
- Population Projections Estimated Using a VAR Fit to Data.

VAR Procedure

- VAR variables, Z_t:

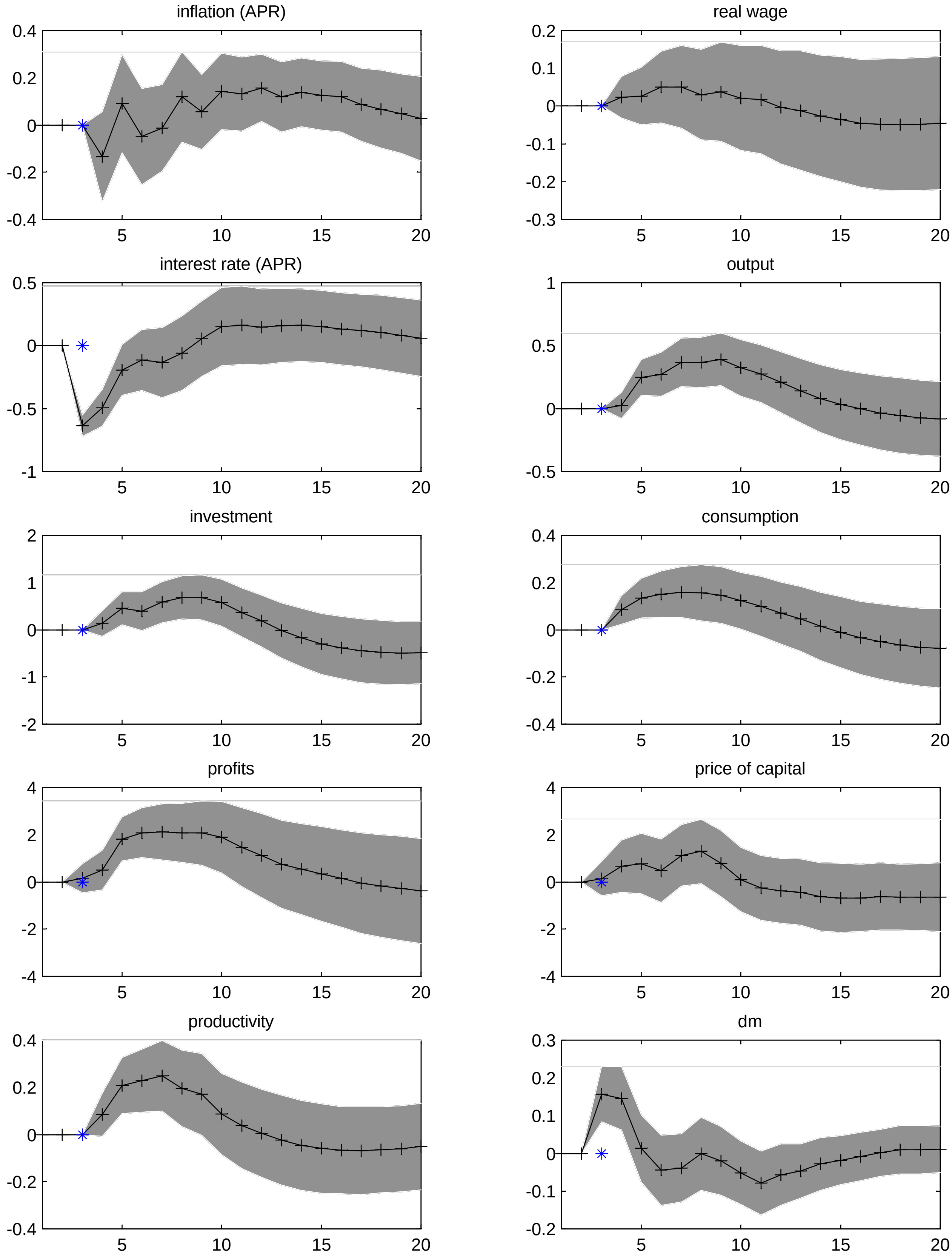
$$Z_t = \begin{pmatrix} \ln(GDP \text{ deflator}) \\ \ln(GDP) \\ \ln(C) \\ \ln(I) \\ \ln(W/P) \\ \ln(\text{Labor Productivity}) \\ \text{Federal Funds Rate} \\ \ln(\text{Profits}) \\ \ln(\text{Price of Capital}) \\ \Delta \ln(M2) \end{pmatrix}$$

- Contemporaneous variables in Ω_t: first 6 variables in Z_t.
- Ordering of First 6, Last Three Irrelevant.
- 4 lag VAR, 1965Q3 - 1995Q3.

Results of Monetary Policy Shock Analysis

- After a Positive Monetary Shock, ε_t:
  - hump-shaped, response of output, consumption, investment with peak effect after about 1.5-2 years.
  - hump-shaped response inflation, with peak response after about 2 years.
  - interest rate down for one year.
  - profits, real wage, labor productivity up.
  - lots of internal propagation!

Estimated VAR Impulse Responses



Next Step:

- Construct a Model that is Consistent With Identifying Assumptions in Monetary Shock Analysis
- Do Same Projections in the Model as in the Data
- Estimate Combination of Frictions Needed for Outcome of Model and Data Projections to be Quantitatively Similar.

Findings of Model Analysis:

- Model Does Well at Accounting for Facts
  - Average Duration of Price Contracts: Roughly 2 Quarters
  - Average Duration of Wage Contracts: Roughly 3.3 Quarters
- Internal Propagation in Model Strong
- Inference is Sensitive to Getting the ‘Real’ Side of the Model Right.
  - Habit Persistence in Preferences.
  - Adjustment Costs in Investment.
  - Variable Capital Utilization.

Model

- Timing Assumptions.
- Firms.
- Households.
- Monetary Authority.

Timing

(1) Agents Make Price/Wage Setting, Consumption, Investment, Capital Utilization Decisions.

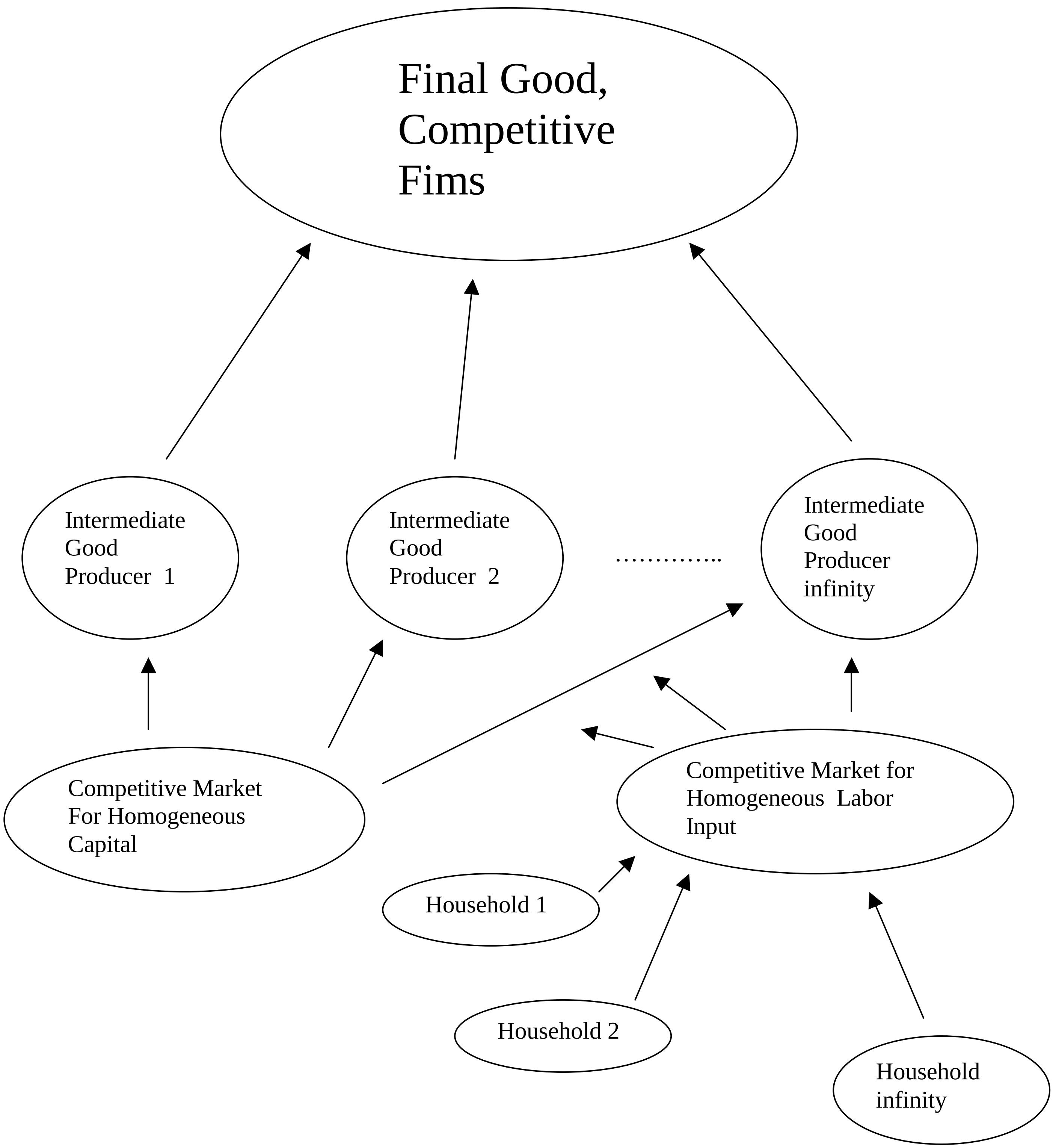
(2) Monetary Policy Shock Realized.

(3) Household Money Demand Decision Made.

(4) Production, Employment, Purchases Occur, and Markets Clear.

- Note: Wages, Prices and Output Predetermined Relative to Policy Shock.

Firm Sector


Final Good, Competitive Fims
Intermediate Good Producer 1
Intermediate Good Producer 2
…………..
Intermediate Good Producer infinity
Competitive Market For Homogeneous Capital
Competitive Market for Homogeneous Labor Input
Household 1
Household 2
Household infinity

Firms

Final Good Firms

- Technology:

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{1}{\lambda_f}} di \right]^{\lambda_f}, \; 1 \leq \lambda_f < \infty$$

- Objective:

$$\max P_t Y_t - \int_0^1 P_{it} Y_{it} di$$

- Foncs and Prices:

$$\left(\frac{P_t}{P_{it}} \right)^{\frac{\lambda_f}{\lambda_f - 1}} = \frac{Y_{it}}{Y_t}, \; P_t = \left[\int_0^1 P_{it}^{\frac{1}{1-\lambda_f}} di \right]^{(1-\lambda_f)}.$$

Intermediate Good Firms -

- Each Y_{it} Produced by a Monopolist, With Demand Curve:

$$\left(\frac{P_t}{P_{it}}\right)^{\frac{\lambda_f}{\lambda_f - 1}} = \frac{Y_{it}}{Y_t}.$$

- Technology:

$$Y_{it} = K_{it}^{\alpha} L_{it}^{1-\alpha} - \phi, \; 0 < \alpha < 1.$$

- Calvo Price Setting:
  - With Probability $1-\xi_p$, i^{th} Firm Sets Price, P_{it}, Optimally, to $\tilde{P}_t$.
  - With Probability ξ_p,

$$P_{it} = \pi_{t-1} P_{i,t-1},\ \pi_t = \frac{P_t}{P_{t-1}}.$$

  - Conventional Price-updating:

$$P_{it} = \bar{\pi} P_{i,t-1}.$$

- Firms Setting Prices Optimally at t
  Choose $\tilde{P}_t$ to max:

$$\upsilon_t\left[\tilde{P}_t Y_{it} - MC_t Y_{it}\right]$$
$$+\beta\xi_p \upsilon_{t+1}\left[\tilde{P}_t \pi_t Y_{i,t+1} - MC_{t+1} Y_{i,t+1}\right]$$
$$+\left(\beta\xi_p\right)^2 \upsilon_{t+2}\left[\tilde{P}_t \pi_t \pi_{t+1} Y_{i,t+2} - MC_{t+2} Y_{i,t+2}\right]$$
$$+\ldots$$

subject to:

$$\left(\frac{P_t}{\tilde{P}_t}\right)^{\frac{\lambda_f}{\lambda_f - 1}} = \frac{Y_{it}}{Y_t}.$$

υ_t ~ value of a dividend at t
MC_t ~given

- Scaling:

$$\begin{aligned}\tilde{p}_t &= \frac{\tilde{P}_t}{P_t},\ w_t = \frac{W_t}{P_t} \\ r_t^k &= \frac{\text{rental rate on capital}}{P_t} \\ s_t &= \frac{MC_t}{P_t}.\end{aligned}$$

- Real Marginal Cost:

$$s_t = \left(\frac{1}{1-\alpha}\right)^{(1-\alpha)} \left(\frac{1}{\alpha}\right)^{\alpha} (r_t^k)^{\alpha}(w_t R_t)^{1-\alpha}$$

- Linear approximation:

$$\hat{x}_t \equiv \frac{x_t - x}{x}.$$

- Approximate (Linearized) Solution:

$$\begin{aligned}\widehat{\tilde{p}}_t \; = \; & \hat{s}_t + \sum_{l=1}^{\infty} \left(\beta \xi_p\right)^l \left(\hat{s}_{t+l} - \hat{s}_{t+l-1}\right) \\ & + \sum_{l=1}^{\infty} \left(\beta \xi_p\right)^l \left(\hat{\pi}_{t+l} - \hat{\pi}_{t+l-1}\right)\end{aligned}$$

- $\hat{s}_{t+l} = \hat{s}_t, \hat{\pi}_{t+l} = \hat{\pi}_t \Rightarrow \widehat{\tilde{p}}_t = \hat{s}_t$

- Aggregate Price Level:

$$
\begin{aligned}
P_t &= \left[\int_0^1 P_{it}^{\frac{1}{1-\lambda_f}} di\right]^{(1-\lambda_f)} \\
&= \left[(1-\xi_p)\tilde{P}_t^{\frac{1}{1-\lambda_f}} + \xi_p \left(\pi_{t-1}P_{t-1}\right)^{\frac{1}{1-\lambda_f}}\right]^{1-\lambda_f}
\end{aligned}
$$

- Scale:

$$
1 = \left[(1-\xi_p)\tilde{p}_t^{\frac{1}{1-\lambda_f}} + \xi_p \left(\frac{\pi_{t-1}}{\pi_t}\right)^{\frac{1}{1-\lambda_f}}\right]^{1-\lambda_f}
$$

- Approximately

$$
\widehat{\tilde{p}}_t = \frac{\xi_p}{1-\xi_p}\left[\hat{\pi}_t - \hat{\pi}_{t-1}\right].
$$

- Combining:

$$\hat{\pi}_t = \frac{1}{1+\beta}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta}E_{t-1}\hat{\pi}_{t+1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{(1+\beta)\,\xi_p}E_{t-1}\hat{s}_t,$$

- Or:

$$\hat{\pi}_t = \hat{\pi}_{t-1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p}E_{t-1}\sum_{j=0}^{\infty}\beta^j\hat{s}_{t+j}$$

- Note: Damped Inflation Response Requires Damped Marginal Cost Response.

- Under Standard Approach to Indexing:

$$\hat{\pi}_t = \beta E_{t-1}\hat{\pi}_{t+1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p} E_{t-1}\hat{s}_t.$$

- Fuhrer-Moore (1995), Gali-Gertler (1997), Casares-McCallum (2000), Mankiw (2000), Walsh (1998):
  - Standard Approach Fits Data Badly.
  - Need Lagged Inflation.

Households

- Wage Decision.
- Consumption Decision.
- Investment Decision.
- Capital Utilization Decision.
- Portfolio Decision.

- State Contingent Securities
  - Allow Household to Insulate Consumption, Asset Holdings from Realization of Idiosyncratic Calvo Uncertainty.
  - This Simplifies Computation of Equilibrium.
  - Ignore State Contingent Securities in the Presentation.
  - Households Are Different With Respect to Wages and Employment.

- Preferences:

$$E_{t-1}^{h}\sum_{l=0}^{\infty}\beta^{l-t}\left[u(c_{t+l}-bc_{t+l-1})-z(h_{j,t+l})+v(q_{t+l})\right].$$

b ~habit parameter

$$\begin{aligned} q &= \frac{Q}{P} \\ u(\cdot) &= \log(\cdot) \\ z(\cdot) &= \frac{\psi_0}{2}\left(\cdot\right)^2 \\ v(\cdot) &= \psi_q \frac{\left(\cdot\right)^{1-\sigma_q}}{1-\sigma_q} \end{aligned}$$

Habit Persistence and Response of Consumption

- Recall that After an Expansionary Monetary Policy Shock, we see
  - hump-shaped rise in consumption
  - decline in real interest rate.
- Euler Equation in Standard Model:

$$\frac{u_{c,t}}{\beta u_{c,t+1}} \approx \frac{c_{t+1}}{\beta c_t} = \frac{g_{t+1}}{\beta} = \frac{R_t}{\pi_{t+1}},\ \pi_{t+1} = \frac{P_{t+1}}{P_t}.$$

- Problem: Can't Have g_t High and $\frac{R_t}{\pi_{t+1}}$ Simultaneously!

- Habit Persistence in Preferences (example):

$$u(c_t - b\bar{c}_{t-1}),\ \bar{c}_{t-1}\ \tilde{}\ \text{aggregate consumption}$$

- Euler Equation:

$$\frac{u_{c,t}}{\beta u_{c,t+1}} \approx \frac{c_{t+1} - bc_t}{\beta\left(c_t - bc_{t-1}\right)} = \frac{g_{t+1} - b}{\beta\left(1 - \frac{b}{g_t}\right)}$$

$$\approx \frac{g_{t+1} - bg_t}{\beta(1-b)}$$

- Result:
  - g_{t+1} and g_t Can Both be High, as Long as $g_{t+1} < bg_t$.
  - Consistent with Simultaneous Hump-Shape c Response and Low Real Rate.
- Habit Persistence Also Helpful for Understanding Asset Prices

- Flow Budget Constraint (Ignoring Insurance Considerations):

$$
\begin{aligned}
M_{t+1} &= R_t\left[M_t - Q_t + (\mu_t - 1)M_t^a\right] \\
&\quad + Q_t + P_t w_t l_t + P_t r_t^k u_t \bar{k}_t + D_t \\
&\quad - P_t\left(c_t + i_t + a(u_t)\bar{k}_t\right) \\
k_t &= u_t \bar{k}_t, \text{ capital services} \\
\bar{k}_{t+1} &= (1-\delta)\bar{k}_t + F(i_t, i_{t-1})
\end{aligned}
$$

Q_t ~cash balances

M_t ~beginning-of-period t Household Money

M_t^a ~beginning-of-period t Aggregate Money

D_t ~profits

μ_t ~gross money growth rate

$M_t - Q_t + (\mu_t - 1)M_t^a$ ~deposits at financial intermediary

$a(\cdot)$ ~costs of utilizing capital more intensively

u_t ~utilization rate of capital

$F(i_t, i_{t-1})$ ~cost of adjusting investment

k_t ~capital services

$\bar{k}_t$ ~physical capital.

Structure of the Labor Market

- Intermediate Good Firms Use Labor Aggregate:

$$L_t = \left[\int_0^1 h_{j,t}^{\frac{1}{\lambda_w}} dj \right]^{\lambda_w}.$$

- Price of L_t :

$$W_t = \left[\int_0^1 \left(W_t(i)\right)^{\frac{1}{1-\lambda_w}} di \right]^{1-\lambda_w}.$$

- Demand for Household Labor Service, $h_{j,t}$:

$$h_{j,t} = \left(\frac{W_t}{W_{j,t}} \right)^{\frac{\lambda_w}{\lambda_w - 1}} L_t, \; 1 \leq \lambda_w < \infty.$$

$W_{j,t}$ ~wage set by household
L_t ~homogeneous aggregate labor
W_t ~wage rate of aggregate labor

Calvo-style Wage Setting:

- With Probability $1-\xi_w$, i^{th} Household Sets Wage, W_{it}, Optimally, to $\tilde{W}_t$.
- With Probability ξ_w,

$$W_{it} = \pi_{t-1} W_{i,t-1},\ \pi_t = \frac{P_t}{P_{t-1}}.$$

- First Order Condition:

$$E_{t-1} \sum_{l=0}^{\infty} (\xi_w \beta)^l \, h_{j,t+l} \left[\psi_{t+l} \frac{\tilde{W}_t X_{t,l}}{P_{t+l}} - \lambda_w z_{h,t+l} \right] = 0.$$

$\dfrac{\psi_t}{P_t}$ value of one dollar (Multiplier on Budget Constraint)

Cash Balance Decision, Q_t

- Households Set Q_t To Maximize Utility

$$v'\left(\frac{Q_t}{P_t}\right)\frac{1}{P_t}+\frac{\psi_t}{P_t}=\frac{\psi_t}{P_t}R_t,$$

- Q_t/P_t Decreasing in R_t.
- Liquidity Effect Due to This Equation.
  - c_t, i_t, Y_t, L_t, P_t, W_t Predetermined Relative to Monetary Shock
  - Loan Market Clearing:

$$W_tL_t=\mu_tM_t-Q_t$$

  - Q_t Must Absorb all Money Injections.
  - Can Only Happen With Fall in R_t.
- This is a ‘Limited Participation Story’
  - But With A Different Twist

Consumption Decision

$$E_{t-1}\frac{u_{c,t}}{P_t} = \beta E_{t-1}\frac{u_{c,t+1}}{P_{t+1}}R_{t+1}.$$

Capital Utilization Decision

$$E_{t-1}u_{c,t}\left[r_t^k - a'(u_t)\right] = 0$$

- Why Have Variable Capital Utilization?
- Motivation I:
  - In Data, Y/L Rises after Expansionary Monetary Policy Shock.
  - Standard Model: $L \uparrow \Rightarrow \frac{Y}{L} \downarrow$
  - One Resolution:
    Distinguish Physical Stock of Capital, $\bar{k}$, and Services from Capital, $u\bar{k}$. If $u \uparrow$ when $L \uparrow$, maybe $\frac{Y}{L} = \left(\frac{u\bar{k}}{L}\right)^{\alpha} \uparrow$
- Motivation II:
  Variable Capacity Utilization Reduces Upward Pressure On Rental Rate of Capital and, hence, on Marginal Costs After Expansionary Monetary Policy Shock.

Investment and Adjustment Costs

- Why Do We Need Costs of Adjusting Capital?
- Rate of Return on Capital:

$$R_t^k = \frac{r_{t+1}^k + P_{k',t+1}(1-\delta)}{P_{k',t}},$$

$$\begin{aligned}
& P_{k',t} \,\tilde{}\, \text{ consumption price of installed capital} \\
\delta & \in (0,1) \sim \text{depreciation rate.} \\
r_{t+1}^k & = s_{t+1} MP_{t+1}^k, \text{ rental rate on capital} \\
& MP_t^k \sim \text{marginal product of capital} \\
s_{t+1} & = \frac{MC_t}{P_t} = \frac{1}{\text{markup}}
\end{aligned}$$

- Almost Any Model,

$$\frac{R_t}{\pi_{t+1}} \approx R_t^k = \frac{r_{t+1}^k + P_{k',t+1}(1-\delta)}{P_{k',t}}.$$

- So, If a Positive Money Shock Drives Down Real Rate, Then

$$R_t^k \downarrow$$

- This is Trouble For Standard Models ($P_{k',t} = 1$, $s_t = 1$):

$$R_t^k \text{ down requires } MP_t^k \text{ down}$$

- Problem:

  MP^k down Requires Surge in Investment, especially with employment up.

- With Adjustment Costs, No Surge in Investment
- Cost-of-Change Adjustment Costs:

$$k' = (1-\delta)k + F(\frac{I}{I_{-1}})I$$

  Good for 'Hump-shaped Investment Response'.
- Other Reasons for Interest in Adjustment Costs:
  - Important for Understanding Asset Prices.
  - Necessary for Movements in Price of Capital.

Investment Decision

- Household Owns the Capital Stock and Carries Out Capital Accumulation.
- Technology for Capital Accumulation:

$$\bar{k}_{t+1} = (1-\delta)\bar{k}_t + F(i_t, i_{t-1}),$$

$$F(i_t, i_{t-1}) = (1 - S\left(\frac{i_t}{i_{t-1}}\right))i_t.$$

- Euler Equation for $\bar{k}_{t+1}$:

$$E_{t-1}\psi_t = \beta E_{t-1}\psi_{t+1}\frac{u_{t+1}r_{t+1}^k - a(u_{t+1}) + P_{k',t+1}(1-\delta)}{P_{k',t}}.$$

$P_{k',t}$ ~marginal cost, in units of consumption goods, of installed, physical capital

- Euler Equation for i_t:

$$E_{t-1}\psi_t = E_{t-1}\left[\psi_t P_{k',t} F_{1,t} + \beta\psi_{t+1} P_{k',t+1} F_{2,t+1}\right].$$

- After linearization:

$$\hat{i}_t = \hat{i}_{t-1} + \frac{1}{S''}\sum_{j=0}^{\infty}\beta^j E_{t-1}\hat{P}_{k',t+j}.$$

Empirical Factors Underlying Model Design and Estimation Results

- Contemporaneous Impact of Positive Money Shock: P and Y Don't Change, R Falls.
- Positive Monetary Shock Has Hump-Shape Impact on Investment, Consumption, Output and Employment.
- Positive Monetary Shock Has Hump-Shape Impact on Productivity.
- Positive Monetary Shock Drives Up Output, and Has Little Impact on Prices.

Contemporaneous Impact of Positive Money Shock

- Quantity and Price Decisions Predetermined Relative to Monetary Policy Shock.
- Household Portfolio Decisions Taken After Monetary Shock.
  - Limited Participation
  - To Absorb the Extra Liquidity, R Must Fall

Positive Monetary Shock Has Hump-Shape Impact on Investment, Consumption, Output and Employment

- Low Real Interest Rate After Positive Monetary Shock Raises Incentive to Invest
  - Investment Adjustment Costs Put Hump-Shape Pattern in Investment Response
- Habit Persistence in Preferences Put Hump in Consumption.
  - $U(c - bc_{-1})$
- Hump In Investment and Consumption Produces Hump in Output.

Positive Monetary Shock Has Hump-Shape Impact on Productivity

- Production Function:

$$Y = K^{\alpha} L^{1-\alpha} - \phi$$

- Labor Productivity:

$$\begin{aligned} \frac{Y}{L} &= \left(\frac{K}{L}\right)^{\alpha} - \frac{\phi}{L} \\ &= \left(\frac{u\bar{k}}{L}\right)^{\alpha} - \frac{\phi}{L} \end{aligned}$$

- Positive Money Shock Drives Y/L Up Because of:
  - Variable Capital Utilization
  - Fixed Cost in Production, ϕ

Recap: Positive Monetary Shock Drives Up Output, and Has Little Impact on Prices

- Price-Markup Behavior of Firms:

$P =$ marginal cost(labor cost, capital rental cost)

  - sticky wages prevent a rise in labor costs after positive money shock
  - variable capital utilization prevents a rise in capital costs after positive money shock

- Households

$$U(c, \frac{M}{P})$$

  - M up Implies M/P up.
  - With Rise in M/P, Demand More c.

– Rise in c Demanded Drives up Output.

Reduced Form Expression for Inflation in Model

$$\hat{\pi}_t = \frac{1}{1+\beta}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta}E_{t-1}\hat{\pi}_{t+1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{(1+\beta)\,\xi_p}E_{t-1}\hat{s}_t,$$

- Or:

$$\hat{\pi}_t = \hat{\pi}_{t-1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p}E_{t-1}\sum_{j=0}^{\infty}\beta^j\hat{s}_{t+j}$$

- Damped Inflation Response Requires Damped Marginal Cost Response.
- Econometric Estimates Emphasize Model Features That Mute Response of Marginal Cost to Shocks.

Next:

- Assigning Parameter Values
- Analysis of Quantitative Model

Econometric Methodology

Three Types of Parameters:

- Parameter Set 1: Parameters that Do Not Enter Formal Estimation Criterion.
- Parameter Set 2: Parameters that Govern Monetary Policy.
- Parameter Set 3: Parameters Estimated Using Estimated Impulse Response Functions.

Parameter Set 1: Parameters that Don't Enter Formal Estimation Criterion		
discount factor	β	$1.03^{-.25}$
capital's share	α	0.36
capital depreciation rate	δ	0.025
markup, labor suppliers	λ_w	1.05
mean, money growth	μ	1.017
labor utility parameter	ψ_0	set to imply $L = 1$
real balance utility parameter	ψ_q	set to imply $Q/M = 0.44$
fixed cost of production	ϕ	set to imply ss profits $=$ 0

Parameter Set 2: Parameters Characterizing Monetary Policy

$$\mu_t = \mu + \theta_0 \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + ...$$

where

$$\mu_t = \log \frac{M_t}{M_{t-1}}.$$

Parameters Taken From Estimated Response of μ_t to ε_t.

- Parameter Set 3:

$$\gamma \equiv (\lambda_f, \xi_w, \xi_p, \sigma_q, S'', b, \sigma_a).$$

- Estimation Criterion:

$$J = \min_{\gamma} (\hat{\psi} - \psi(\gamma))' V^{-1} (\hat{\psi} - \psi(\gamma)),$$

  - $\psi(\gamma)$ model impulse responses
  - $\hat{\psi}$ estimated impulse responses from VAR
  - V estimate of sampling uncertainty in $\hat{\psi}$
    (actually, we used the diagonal part of V only)

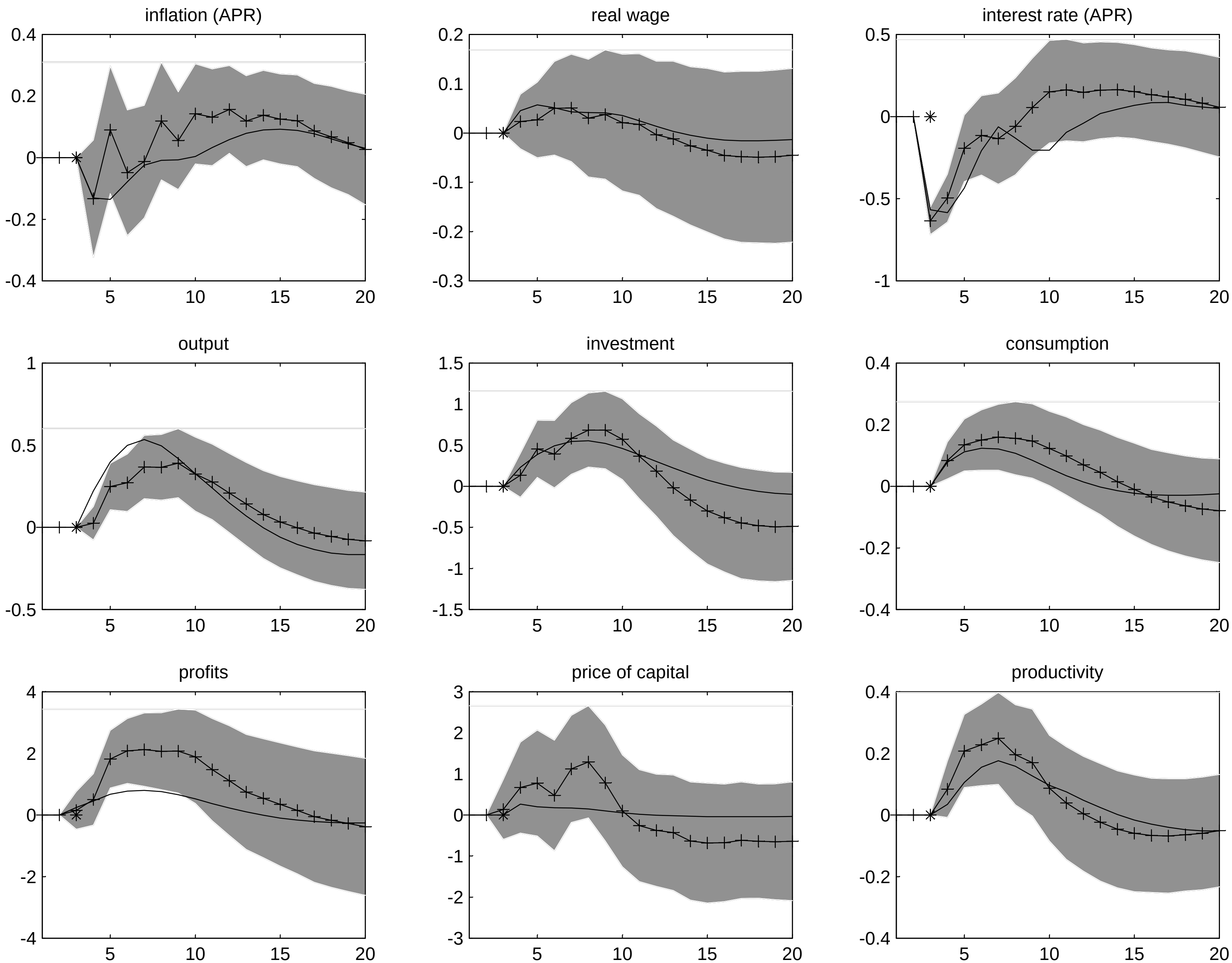
ESTIMATED PARAMETER VALUES							
Model	λ_f	ξ_w	ξ_p	σ_q	S''	b	σ_a
Benchmark	1.46 $(.16)$	$.70$ $(.07)$	$.50$ $(.23)$	9.66 $(.78)$	3.60 (2.24)	$.63$ $(.14)$	$.01$

- Properties of Estimates:
  - $\xi_w \rightarrow$ wage contracts last 3.3 quarters
  - $\xi_p \rightarrow$ price contracts last 2 quarters
  - ξ_p 'less important' than ξ_w
  - σ_q implies $-d \log q / dR = 1.05$
  - σ_a small $\rightarrow$ capital rental rate constant
  - Habit a Little Lower Than B-C-F
  - λ_f Consistent with Rotemberg-Woodford (1995)

Properties of Estimated Model

- Model Does Well Statistically
- Enormous Inflation Inertia: Takes 3 Years to Start Rising
- Persistence in Output: Peak Effect In One Year.
- Hump-shaped response of Output, Investment, Consumption, Labor Productivity.
- Large, Persistent Liquidity Effects.
- Small Real Wage Response.
- Model Has Much Internal Propagation.

Figure 1: Model and Data Impulse Responses



Conclusion

A Model Was Displayed, Which Accounts for the Salient Features of What Happens After a Monetary Policy Shock.

- Sticky Wages and Variable Capital Utilization Generates 'Inflation Inertia' and 'Output Persistence'.
- Habit Persistence and Investment Adjustment Costs Generate Hump-Shaped Investment, Output, Consumption Responses.
- Fixed Costs and Variable Capital Utilization Generate Hump-Shaped Labor Productivity Response.