Macro II

John Hassler

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Firms and price setting friction

- Recall that the purpose of the heterogenous goods was to allow market power. Thus, assume each product is produced by a sole monopolist.
- Productivity shock A_t and labor wedge τ_{lt} drive most of the cyclical variation. Other wedges (investment wedge) is not very important for the cyclical variation. Suggests price or wage rigidity. Here former.
- Using a production function $Y_t(i) = A_t N_t(i)^{1-\alpha}$ nominal production costs are $\Psi_t(Y_t(i)) \equiv W_t \left(\frac{Y_t(i)}{A_t}\right)^{\frac{1}{1-\alpha}}$.
- In every period, each firm can reset it's price with probility $1-\theta$ (Calvo, 1983) and there (common) choice is P_t^*. A log-linear approximation of price dynamics around a zero inflation steady state then yields (see Gali for proof) that $\pi_t = (1-\theta)(p_t^* - p_{t-1})$ where p_{t-1} is the log of last periods price index and p_t^* is the price (common to all that reset) chosen by those who reset.
- Other types of price frictions: Taylor, state dependent. Why is Calvo convenient?

Frictionless price setting

- Now, suppose for a minute $\theta = 0$. Then, the optimal output choice solves

$$\max_{Y_t(i)} P_t(i) Y_t(i) - \Psi_t(Y_t(i))$$

$$s.t. P_t(i) = P_t \left(\frac{Y_t(i)}{C_t} \right)^{-\frac{1}{\varepsilon}}$$

- Recall that demand constraint comes from consumer optimization.
- Note also that without price frictions, it doesn't matter if the firm chooses price or quantity. Later, it will.

Optimal frictionless price

- FOC for monopolist– marginal revenue equal to marginal cost

$$P_t(i) + Y_t(i)\frac{\partial P_t(i)}{\partial Y_t(i)} = \Psi_t'(Y_t(i)) \equiv \psi_t(Y_t(i))$$

- Using that inverse demand function implies $\frac{\partial P_t(i)}{\partial Y_t(i)} = \frac{-1}{\varepsilon}\frac{P_t}{Y_t(i)}\left(\frac{Y_t(i)}{C_t}\right)^{-\frac{1}{\varepsilon}} = \frac{-1}{\varepsilon}\frac{P_t(i)}{Y_t(i)}$, this is

$$\begin{aligned} P_t(i) - \frac{1}{\varepsilon}P_t(i) &= \Psi_t'(Y_t(i)) \equiv \psi_t(Y_t(i)) \\ P_t^*(i)\left(1 - \frac{1}{\varepsilon}\right) &= \psi_t(Y_t(i)) \\ P_t^*(i) &= \frac{\varepsilon}{\varepsilon - 1}\psi_t(Y_t(i)) \end{aligned}$$

- A markup on marginal cost given by $\frac{\varepsilon}{\varepsilon-1}$. Interpret by comparing to $\left(\frac{P_t}{P_t(i)}\right)^{\varepsilon} = \frac{C_t(i)}{C_t}$. What happes if ε approach unity from above?

Price setting with frictions

- With frictions, the firms sets a price that will be fixed for an uncertain number of periods and that has to accept the sales the price gives.
- The objective for all firms that sets a new price in period t, denoted P_t^*, is to maximize the PDV of profits given by

$$E_t \sum_{s=0}^{\infty} \theta^s Q_{t,t+s} \left(P_t^* Y_{t+s|t} - \Psi_{t+s} \left(Y_{t+s|t} \right) \right)$$

  where $Y_{t+s|t}$ is output of firms in $t+s$ that set price in t satisfying the demand equation $Y_{t+s|t} = \left(\frac{P_{t+s}}{P_t^*} \right)^{\varepsilon} C_{t+s}$.
- $Q_{t,t+s}$ is the nominal discount factor given by $\beta^s \frac{U_C(C_{t+s}, 1-N_{t+s})}{U_C(C_t, 1-N_t)} \frac{P_t}{P_{t+s}}$.

Optimal price with frictions

- Write the FOC for P_t^*, using $\frac{\partial Y_{t+s|t}}{\partial P_t^*} = -\varepsilon \frac{Y_{t+s|t}}{P_t^*}$

$$
\begin{aligned}
0 &= E_t \sum_{s=0}^{\infty} \theta^s Q_{t,t+s} \left(Y_{t+s|t} + P_t^* \frac{\partial Y_{t+s|t}}{\partial P_t^*} - \Psi'_{t+s}\left(Y_{t+s|t}\right) \frac{\partial Y_{t+s|t}}{\partial P_t^*} \right) \\
&= E_t \sum_{s=0}^{\infty} \theta^s Q_{t,t+s} \left(Y_{t+s|t} - \varepsilon Y_{t+s|t} + \psi_{t+s}\left(Y_{t+s|t}\right) \varepsilon \frac{Y_{t+s|t}}{P_t^*} \right) \\
&= E_t \sum_{s=0}^{\infty} \theta^s Q_{t,t+s} Y_{t+s|t} \left(1 - \varepsilon + \psi_{t+s}\left(Y_{t+s|t}\right) \frac{\varepsilon}{P_t^*} \right)
\end{aligned}
$$

- Multiply by $\frac{-P_t^*}{\varepsilon - 1}$ yields

$$
0 = E_t \sum_{s=0}^{\infty} \theta^s Q_{t,t+s} Y_{t+s|t} \left(P_t^* - \frac{\varepsilon}{\varepsilon - 1} \psi_{t+s}\left(Y_{t+s|t}\right) \right)
$$

- Interpret!

FOC linearization

- Rewrite FOC by dividing by P_{t-1} and defining real marginal cost $MC_{t+s,t} \equiv \frac{\psi_{t+s}\left(Y_{t+s|t}\right)}{P_{t+s}}$:

$$0 = E_t \sum_{s=0}^{\infty} \theta^s Q_{t,t+s} Y_{t+s|t} \left(\frac{P_t^*}{P_{t-1}} - \frac{\varepsilon}{\varepsilon - 1} MC_{t+s,t} \frac{P_{t+s}}{P_{t-1}} \right)$$

- The FOC can be log-linearized around a zero inflation steady state to yield

$$p_t^* - p_{t-1} = (1 - \beta\theta) \sum_{s=0}^{\infty} (\beta\theta)^s E_t \left(\Theta \left(mc_{t+s|t} - mc\right) + \left(p_{t+s} - p_{t-1}\right)\right)$$

where $mc_{t+s|t} = \ln\left(\frac{\psi_{t+s|t}}{P_{t+s}}\right)$, i.e., the log of the real marginal cost and mc is the average such given by $-\ln\frac{\varepsilon}{\varepsilon-1}$ and $\Theta \equiv \frac{1-\alpha}{1-\alpha+\alpha\varepsilon} \leq 1$.
- RHS is a discounted sum of future deviations of marginal costs from its average and prices from the current.
- Thus the firms that reset their price set a high price if they expect high marginal costs and high inflation.

When is inflation high?

- The sum $p_t^* - p_{t-1} = (1-\beta\theta)\sum_{s=0}^{\infty}(\beta\theta)^s E_t\left(\Theta\left(mc_{t+s|t} - mc\right) + (p_{t+s} - p_{t-1})\right)$ can be written recursively as

$$p_t^* - p_{t-1} = \beta\theta E_t\left(p_{t+1}^* - p_t\right) + (1-\beta\theta)\,\Theta\left(mc_{t|t} - mc\right) + \pi_t$$

  adjusting firms set high price if marginal costs are high and they expect high inflation (the latter both for the direct reason and that high future inflation means high future costs).

- Using $\pi_t = (1-\theta)\left(p_t^* - p_{t-1}\right)$ we get

$$\pi_t = \beta E_t \pi_{t+1} + \lambda\left(mc_{t|t} - mc\right)$$

  where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}\Theta$ which can be solved forward to yield

$$\pi_t = \lambda \sum_{s=0}^{\infty} \beta^s E_t\left(mc_{t+s|t} - mc\right)$$

- Inflation depends on a discounted sum of expected real marginal costs.

When are marginal costs high?

- Gali shows that

$$mc_{t|t} - mc = \left(\sigma + \frac{\varphi + \alpha}{1 - \alpha}\right) \tilde{y}_t$$

  where $\tilde{y}_t \equiv y_t - y_t^n$, i.e., the deviation of output from the natural level (flex price) y_t^n. Interpret the dependence of the parameters!

- Thus, marginal costs high coincides with production high
- Using this in the inflation equation $\pi_t = \beta E_t \pi_{t+1} + \lambda \left(mc_{t|t} - mc\right)$ gives

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t$$

  where κ is a constant that depends on $\sigma, \varphi, \beta, \varepsilon, \theta$ and α.

- $\kappa \equiv \lambda \left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right) = \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{1-\alpha}{1-\alpha+\alpha\varepsilon} \left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right)$.
- This is the *New Keynesian Phillips curve!*

New Keynesian IS-curve

- To complete the New Keynesian model we use that $Y_t = C_t$ in the Euler equation we derived above.
- Define output gaps $\tilde{y}_t \equiv y_t - y_t^n$ where y_t^n is frictionless output and define the natural real interest rate $r_t^n \equiv \rho + \sigma E_t \Delta y_{t+1}^n$, giving an IS-type curve

$$\begin{aligned}
c_t &= E_t c_{t+1} - \frac{1}{\sigma}\left(i_t - E_t \pi_{t+1} - \rho\right) \\
y_t &= E_t y_{t+1} - \frac{1}{\sigma}\left(i_t - E_t \pi_{t+1} - \rho\right) \\
\tilde{y}_t + y_t^n &= E_t\left(\tilde{y}_{t+1} + y_{t+1}^n\right) - \frac{1}{\sigma}\left(i_t - E_t \pi_{t+1} - \rho\right) \\
\tilde{y}_t &= E_t\left(\tilde{y}_{t+1} + \Delta y_{t+1}^n\right) - \frac{1}{\sigma}\left(i_t - E_t \pi_{t+1} - \left(r_t^n - \sigma E_t \Delta y_{t+1}^n\right)\right) \\
\tilde{y}_t &= E_t \tilde{y}_{t+1} - \frac{1}{\sigma}\left(i_t - E_t \pi_{t+1} - r_t^n\right)
\end{aligned}$$

- With a rule for the nominal interest rate and a process for productiviy A_t (AR-1) we have *A New Keynesian Model.*

A New Keynesian Model

- NK-IS-curve

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - \frac{1}{\sigma} \left(i_t - E_t \pi_{t+1} - r_t^n \right)$$

- NK-Phillips Curve

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t$$

- Monetary policy (here a Taylor rule)

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

- Need ϕ_π to be sufficiently large given ϕ_y (and conversely) for uniqueness (unstable roots) – intuition.

Shocks and solution

- Shocks in the model;
  - productivity, usually taken to be AR-1 as in RBC (supply)
  - monetary policy (demand)
  - both affect the output gap and inflation.
- Solved by guessing and verifying as in RBC case (or using computer packages).

Policy inThe New Keynesian Model

- The monopoly implies a distortion – too low output. Can be corrected with a labor subsidy.
- If this is done, two distortions remain:
  1. Price frictions imply the possibility of temporary deviations from flexprice output.
  2. Variations in optimal nominal price, due to e.g., inflation, leads to price dispersion.
- Can study optimal policy in the model. Typically a tradeoff between stabilizing output and inflation.
- Benchmark policy often of the Taylor-type

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

Effects of policy and technology

- An unexpected positive shock to the interest rate (negative demand shock):
  - decreases output, decreases inflation, increases real interest rate.
- A postitive shock to productivity (positive supply shock)
  - increases output but can lead to less hours worked, output gap falls, inflation falls.

Effects of monetary policy shock

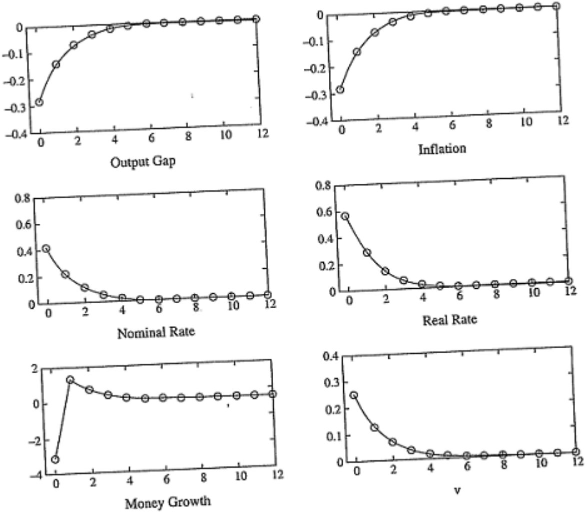

Figure 3.1 Effects of a Monetary Policy Shock (Interest Rate Rule)

Effects of technology shock

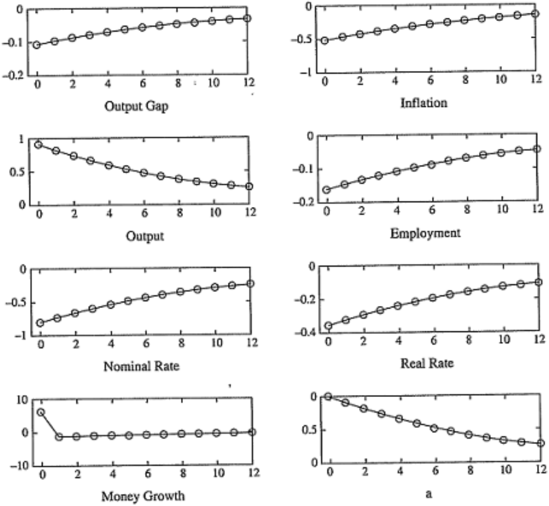

Figure 3.2 Effects of a Technology Shock (Interest Rate Rule)

Extensions

- Model can be extended in many different directions; including capital and investment, heterogeneity (HANK), open economy, more production sectors, state dependent pricing,...
- More frictions:
  - both price and wage rigidities (Broer et al. critique)
  - credit friction (financial accelerator)
  - zero lower bound and other monetary policy tools
  - involuntary unemployment
  - learning (e.,g, about monetary policy)
  - near rationality
  - see chap 8 in Gali.
- Works quite well for "normal" business cycles.
- Current challenge – abnormal crises.