Macro II

John Hassler

Spring 2020

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.
- In data, it seems like productivity shocks A_t and in particular, deviations from the optimality condition associated with the labor/leisure choice are important for business cycle variations. Suggests price and/or wage rigidity. We here focus on 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). Intuitively that this implies (see Gali for proof) that a log-linear approximation of price dynamics is

$$\pi_t = p_t - p_{t-1} = (1-\theta)(p_t^* - p_{t-1})$$

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.

Frictionless price setting

- Now, suppose for a minute $\theta = 0$. Then, consider 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.

Optimal frictionless price

- FOC for monopolist– marginal revenue equal to marginal cost

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

- Use the inverse demand function from previous page $\frac{\partial P_t(i)}{\partial Y_t(i)} = \frac{-1}{\varepsilon}\frac{P_t}{Y_t(i)}\left(\frac{Y_t(i)}{C_t}\right)^{-\frac{1}{\varepsilon}} = \frac{-1}{\varepsilon}\frac{P_t(i)}{Y_t(i)}$. Then we get

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

- A markup on marginal cost given by $\frac{\varepsilon}{\varepsilon-1}$. Why do we need $\varepsilon > 1$? Interpret by comparing to $\left(\frac{P_t}{P_t(i)}\right)^{\varepsilon} = \frac{C_t(i)}{C_t}$.

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 set 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 $\frac{\partial Y_{t+s|t}}{\partial P_t^*} = -\varepsilon \frac{Y_{t+s|t}}{P_t^*}$

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

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

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

- Sum of weighted deviations from statically optimal price.
- The larger is θ, $Q_{t,t+s}$ and $Y_{t+s|t}$the more the firm cares about the future. Why?

When is inflation high?

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

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

- From the equation we see that the firms that resets its price will set a high price (relative to P_{t-1}) if it expects marginal costs and future price levels to be high.
- By taking logs, linearizing and doing some manipulations, the qualitative statement can be made more precise.

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

where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{1-\alpha}{1-\alpha+\alpha\varepsilon}$.

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.

- 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 last class. Bonds?
- 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).

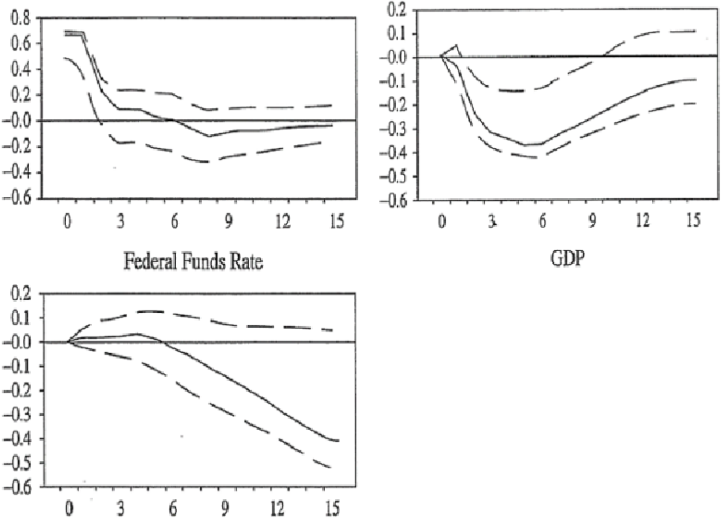
Policy inThe New Keynesian Model

- 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

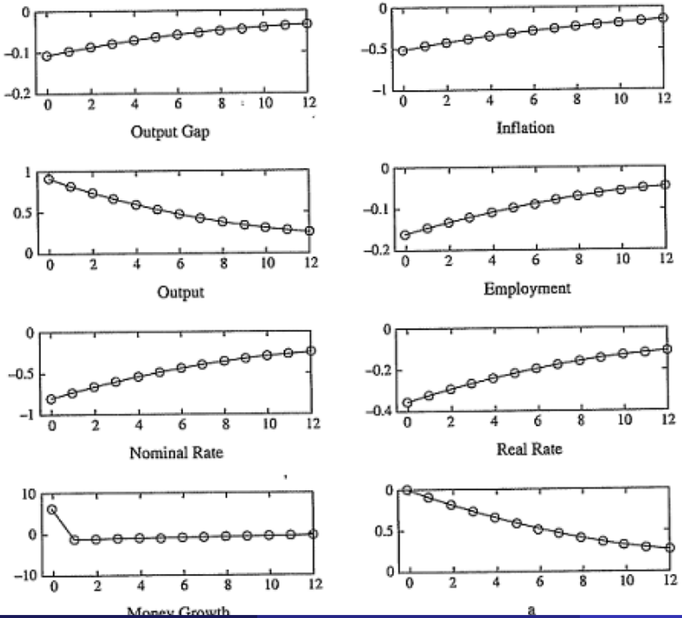
$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

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.


0.8
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
0 3 6 9 12 15
Federal Funds Rate
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0 3 6 9 12 15
GDP
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0 3 6 9 12 15

Effects of technology shock



Extensions

- Model can be extended in many different directions; including capital and investment, open economy, heterogenous agents (HANK), more production sectors, state dependent pricing,...
- More frictions:
  - both price and wage rigidities
  - 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.