Econ 212a: Business Cycles
Lecture 6
Monopolistic Competition and Sticky Prices

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Spring 2023

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Recap

So far: effects of monetary policy in a world with flexible prices

- no effects on real allocation, (super) neutrality of money
- immediate response of prices
- "medium to long run effects"

Today ...

- we show that this is **empirically implausible** in the short run:
  - strong real effects, very slow response of prices!
- we incorporate price rigidity into our monetary RBC model

Empirical evidence on the transmission of monetary policy

Overview over empirical evidence on monetary policy

- To test neutrality, ideally want to regress GDP growth on past money supply or interest rate changes
- **Q:** What's the issue with that?
- Three separate approaches:
  1. narrative identification (eg Friedman Schwartz 1963, Romer Romer 1989, 2004)
     - idea: construct monetary policy surprises either from specific dates, or by partialing out expected inflation and output from Δi_t
  2. structural VAR (eg Christiano, Eichenbaum, Evans 1999, 2005)
     - idea: assume Δi_t has no immediate effect on real economy
  3. high-frequency identification (eg Gertler Karadi '15, Nakamura Steinsson '16)
     - idea: measure monetary surprises using Fed funds futures market
- Sometimes these are combined. Will focus on VARs for today.

Main idea behind SVAR methodology

- Imagine we want to get at the effect of i_t on log output y_t. Plausible:

$$y_t = b_{12} i_t + \gamma_{11} y_{t-1} + \gamma_{12} i_{t-1} + \epsilon_{yt}$$
$$i_t = b_{21} y_t + \gamma_{21} y_{t-1} + \gamma_{22} i_{t-1} + \epsilon_{it}$$

- **Key identification issue:** y_t and i_t are *simultaneously* determined.
- Simple solution: We assume it away, e.g. by setting $b_{12} = 0$
  - monetary policy does not affect output contemporaneously
- This allows us to estimate this system: Pack first equation into second, run standard reduced form VAR of (y_t, i_t) on lags, back out b_{21}, γ's, ϵ's
- Next: generalize this ...

SVAR methodology: general case

- In general, have a vector of variables $\mathbf{y}_t$, simultaneously determined

$$\mathbf{B}\mathbf{y}_t = \Gamma \mathbf{y}_{t-1} + \epsilon_t \qquad \text{where } \mathbb{E}\left[\epsilon_t \epsilon_t'\right] = \mathbf{I}$$

- Not always clear for larger matrices $\mathbf{B}$, which / how many entries need to be "fixed" to get identification
- To see "how much info on $\mathbf{B}$ we can get", convert into reduced form VAR

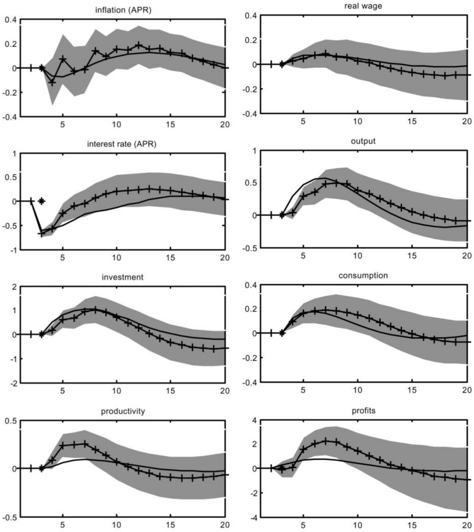
$$\mathbf{y}_t = \mathbf{B}^{-1}\Gamma \mathbf{y}_{t-1} + \mathbf{B}^{-1}\epsilon_t$$

- This we can estimate. Get: $\mathbf{B}^{-1}\Gamma$ and cov matrix of residual, $\Sigma \equiv \mathbf{B}^{-1}\left(\mathbf{B}^{-1}\right)'$.
- Σ has info on $\mathbf{B}$! How much? $\rightarrow$ can decompose $\Sigma = \mathbf{L} \cdot \mathbf{L}'$ where $\mathbf{L}$ is lower-diagonal since Σ is positive definite.
- Any $\mathbf{B}$ must satisfy $\mathbf{B}^{-1} = \mathbf{L}\mathbf{Q}$ where $\mathbf{Q}$ is orthonormal matrix, $\mathbf{Q}\mathbf{Q}' = \mathbf{I}$. Model is identified when a $\mathbf{Q}$ is chosen!

Cholesky identification and monetary policy

- **Cholesky identification:** Pick $\mathbf{Q} = \mathbf{I}$, so that $\mathbf{B} = \mathbf{L}^{-1}$, lower diagonal.
    - our simple 2-variable example was special case of this
    - order variables such that variable i of $\mathbf{y}_t$ has no contemporaneous effect on variables $1, \ldots, i-1$
- **Impulse response (IRF)** to shock i: $\mathbf{y}_t = \left(\mathbf{B}^{-1}\Gamma\right)^t \cdot (\mathbf{L})_i$
    - useful: imagine we only want IRFs to a single variable, others respond with lag
    - then: don't need to order the other variables!
- Main application: macro variables + nominal rate $\mathbf{y}_t = (y_t, c_t, \pi_t, i_t)'$
    - assume i_t has no contemporaneous effect
- Next: Evidence on this from Christiano Eichenbaum Evans (2005)

Christiano, Eichenbaum, Evans 2005 evidence



Main empirical findings on monetary policy

1. Hump-shaped response of output, consumption and investment
   - peak at around 1.5 years, return to trend after 3
2. Hump-shaped response of inflation, peaking after two years
   - this corresponds to an extremely slow *price* response!
3. Money, real profits and wages rise

Alternative identification typically deliver similar findings. **Not at all neutral!**

Next: let's **model short-run non-neutrality** of monetary policy

Monopolistic competition with flexible prices

Monopolistic competition

- Will write a version of our monetary RBC model, except:
  - no capital, no TFP, production function simply $Y_t = f(N_t)$
  - continuum of firms, each **monopolistically competitive**
- Monopolistic competition is necessary to study price rigidity:
  - if firms are all price takers, we can't have any rigidity!
- To get mon. comp. off the ground, need **continuum of consumption goods**
  - consumption c_{it}, $i \in [0, 1]$, price p_{it}, aggregated into CES bundle

- Household side looks very familiar

$$\max \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t U \left(C_t, N_t, \frac{M_t}{P_t} \right) \right]$$

subject to

$$\int p_{it} c_{it} di + B_t + M_t + T_t$$
$$\leq W_t N_t + (1 + i_{t-1}) B_{t-1} + M_{t-1} + D_t \tag{1}$$

- **New: profits D_t and consumption bundle**

$$C_t \equiv \left(\int c_{it}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \qquad \epsilon > 1$$

Two-stage budgeting

- We can solve utility maximization problem by first solving "inner problem"
- Maximize $C_t \equiv \left(\int c_{it}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$ subject to fixed expenditure $E_t = \int p_{it} c_{it} di$
- Solution:

$$c_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\epsilon} E_t / P_t$$

where price index P_t is given by

$$P_t = \left(\int p_{it}^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$$

- Substituting this into the formula for C_t, we find that at the optimum,

$$C_t = E_t / P_t \qquad \Leftrightarrow \qquad \int p_{it} c_{it} di = P_t C_t$$

Firm side

- Firms have same technology, $y_{it} = f(n_{it})$ (no capital here!)
- For reasons that become clear later, allow for labor tax τ^w
- Firms solve static profit maximization problem:

$$\Pi_{it} = \max_{p_{it}, y_{it}, n_{it}} \{p_{it} \cdot y_{it} - (1 + \tau^w) W_t \cdot n_{it}\}$$

subject to

$$y_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\epsilon} C_t \qquad \text{and} \qquad y_{it} = f(n_{it})$$

- Key: demand for i's goods not perfectly elastic, $\epsilon < \infty$. Firms will earn monopoly rents!

Solving the firm side

- Substitute out p_{it} using $p_{it} = P_t \left(\frac{y_{it}}{C_t}\right)^{-1/\epsilon}$ and $n_{it} = f^{-1}(y_{it})$

$$\Pi_{it} = \max_{y_{it}} \left\{ P_t \left(\frac{y_{it}}{C_t}\right)^{-1/\epsilon} \cdot y_{it} - (1+\tau^w) W_t \cdot f^{-1}(y_{it}) \right\}$$

- FOC:

$$P_t \left(\frac{y_{it}}{C_t}\right)^{-1/\epsilon} \cdot \left(1 - \frac{1}{\epsilon}\right) = (1+\tau^w) W_t \cdot \frac{1}{f'(n_{it})}$$

which we can rearrange into

$$p_{it} = \underbrace{\frac{\epsilon}{\epsilon - 1}}_{\text{monopoly markup}} \cdot \underbrace{(1+\tau^w) \cdot W_t \cdot \frac{1}{f'(n_{it})}}_{\text{marginal cost}}$$

- **Price = constant markup over marginal cost**

Aggregating the firm side

- In equilibrium: all firms are identical! $n_{it} = N_t$, $p_{it} = P_t$ and so real wage

$$\frac{W_t}{P_t} = \underbrace{\frac{\epsilon - 1}{\epsilon}}_{\text{monopoly markdown}} \cdot \frac{1}{1 + \tau^w} \cdot f'(n_{it})$$

- Monopoly markdown is the only way in which the monopolistic competition model with flexible prices differs from our previous model.
- Can offset the monopoly markdown by subsidizing labor, $\tau^w = -1/\epsilon$
- Everything else unchanged, model still has monetary neutrality ...

Rigid prices

- Imagine all firms chose their price before date 0, at some fixed level $\overline{P}$
  - this is extreme, of course, will allow them to re-optimize next time!
- How does monetary policy act?
- Assume separable utility

$$U(c,n,m) = \log c - v(n) + \theta \frac{m^{1-\eta^{-1}}}{1-\eta^{-1}}$$

Assume a given deterministic path of money supply M_t. Assume $\tau^W = -1/\epsilon$.

Real equilibrium conditions

$$C_t^{-1} = \beta \left(1 + r_{t+1}\right) C_{t+1}^{-1}$$

$$C_t v'(N_t) = \frac{W_t}{P_t} = f'(N_t)$$

$$C_t = Y_t = f(N_t)$$

nominal ones:

$$\theta \left(\frac{M_t}{P_t}\right)^{-\eta^{-1}} = C_t^{-1} \cdot \frac{i_t}{1 + i_t}$$

$$1 + i_t = \left(1 + r_{t+1}\right) \frac{P_{t+1}}{P_t}$$

Before: Decoupling of real vs nominal ... **now no longer:** $P_t = \overline{P}$. What changes?

Equilibrium conditions with fixed prices

Real equilibrium conditions

$$C_t^{-1} = \beta\,(1 + r_{t+1})\,C_{t+1}^{-1}$$

$$C_t v'(N_t) = \frac{W_t}{\overline{P}} \neq f'(N_t)$$

$$C_t = Y_t = f(N_t)$$

nominal ones:

$$\theta \left(\frac{M_t}{\overline{P}}\right)^{-\eta^{-1}} = C_t^{-1} \cdot \frac{i_t}{1 + i_t}$$

$$1 + i_t = 1 + r_{t+1}$$

Now: $M_t \uparrow$ lowers $i_t \downarrow$ ("liquidity effect"), lowers $r_{t+1} \downarrow$, pushes up $C_t \uparrow$, $N_t \uparrow$, $Y_t \uparrow$ ...

Signs are in line with evidence.

Log-linearized equilibrium conditions

$$\hat{C}_t = \hat{C}_{t+1} - \Delta r_{t+1}$$
$$\hat{C}_t + \frac{v''(N)N}{v'(N)}\hat{N}_t = \hat{W}_t$$
$$\hat{C}_t = \hat{Y}_t = \frac{f'(N)N}{f(N)}\hat{N}_t$$
$$-\eta^{-1}\hat{M}_t = -\hat{C}_t + \Delta i_t$$
$$\Delta i_t = \Delta r_{t+1}$$

Solving this … we get

$$\hat{Y}_t = \hat{C}_t = \sum_{s=0}^{\infty}\left(\frac{1}{2}\right)^s \eta^{-1}\hat{M}_{t+s}$$

Exactly the flipside from before: now **quantities** respond to $\hat{M}_{t+s}$!