LECTURE 9

EXOGENOUS PRICE RIGIDITIES AND PERSISTENCE OF MONETARY SHOCKS

- Aim: finding a logically consistent model in which monetary policy has real, and possibly persistent, effects.
- Lucas imperfect information model suffers from two problems: 1) the effect of monetary policy is not persistent; 2) no real role for monetary policy, publishing information about aggregate variables would be a better solution.
- In models in which the effect of monetary policy is not persistent, unsystematic monetary policy is effective under rational expectations only if the monetary authority has an informational advantage.
- Need nominal rigidities lasting longer than the horizon over which agents update their information for monetary policy to be effective without an informational advantage on the part of the monetary authority.

1 Price setting under perfect information

1.1 Flexible prices

- Aggregate demand

$$y_t = m_t - p_t \tag{1}$$

- Price setting equation: firms increase the price of their product when output is higher (as marginal cost increases with aggregate output level)

$$p_t^i - p_t = (1-a)y_t \tag{2}$$

with $0 < a \leq 1$. If $a = 1$ firms do not adjust prices in response to changes in aggregate output (constant marginal cost).

Replacing for y_t using the aggregate demand we obtain

$$p_t^i = ap_t + (1-a)m_t. \tag{3}$$

- Symmetric equilibrium: all firms have the same technology and (unlike in Lucas' model) there are no idiosyncratic shocks. So it makes sense to look at symmetric equilibria in which p_t^i is the same for all firms. In a symmetric equilibrium the average price level equals the price level for the individual firms; i.e. $p_t^i = p_t$.

Symmetric equilibrium: Vector $[y_t, p_t^i, p_t, E_t p_t]$ such that (1) and (2) (or (3)) hold, $p_t^i = p_t$ and $E_t p_t$ satisfies the same equations in expectation.

This implies $y_t = 0$, $p_t^i = p_t = m_t$ and $E_t p_t = E_t m_t$.

1.2 Rigid prices

Aggregate demand is the same, but now firms set their prices for the current period (i.e. only for one period) before observing aggregate output and the money supply. Hence, they must set their price on the basis of their expectations about aggregate variables.

The counterparts of (2) and (3) are

$$p_t^i = E_t p_t \tag{4}$$

and

$$p_t^i = a E_t p_t + (1 - a) E_t m_t. \tag{5}$$

Symmetric equilibrium with prices rigid for one period: Vector $[y_t, p_t^i, p_t, E_t p_t]$ such that (1) and (4) (or (5)) hold, $p_t^i = p_t$ and $E_t p_t$ satisfies the same equations in expectation.

Since all firms set prices equal to $E_t p_t$, use aggregate demand in deviations from expectations to obtain

$$y_t = (m_t - E_t m_t) - (p_t - E_t p_t) = m_t - E_t m_t. \tag{6}$$

- Only unanticipated monetary policy affects output.
- If the monetary authority has no informational advantage (cannot observe/react to current shock) systematic monetary policy is ineffective.

Suppose now prices are set by all firms *at the same time* every *two* periods.

We have two equations for equilibrium output depending on whether prices have been set at the beginning of the current period or of the previous one. In the first case, (6) holds. In the second case it is

$$y_t = (m_t - E_{t-1}m_t) - (p_t - E_{t-1}p_t) = m_t - E_{t-1}m_t. \tag{7}$$

Now, provided shocks are autocorrelated, systematic monetary policy is effective in periods in which prices are not set, because the monetary authority can react to information which has accrued in the previous period which is observed by private agents (so no informational advantage) but to which agents cannot respond until the following period.

At best monetary policy is effective for a span of time over which prices cannot be revised and is totally ineffective in periods in which prices are revised.

Not much progress.

What if price setting is staggered? Not all firms set prices at the same time.

2 Price staggering

Now price setting is no longer synchronised. Half of producers set prices in even periods and half in odd ones.

2.1 Predetermined prices (Fischer contracts)

Prices are set for two periods but can differ between periods.

The aggregate price level is

$$p_t = \frac{1}{2}\left(p_{t,t} + p_{t-1,t}\right), \tag{8}$$

where $p_{s,t}$ is the price set in period s for time t.

A time-t price setter has to set prices in time t and $t+1$. Using the price setting rule (3) these are

$$p^i_{t,t} = aE_t p_t + (1-a)E_t m_t \tag{9}$$

and

$$p^i_{t,t+1} = aE_t p_{t+1} + (1-a)E_t m_{t+1}. \tag{10}$$

Important: the closer a is to 1 (the flatter marginal cost) the more firms react to the aggregate price level but not to output (hence the money supply).

Replacing for p_t and p_{t+1} and imposing symmetry (9) and (10) become

$$p_{t,t} = bp_{t-1,t} + (1-b)E_t m_t \tag{11}$$

and

$$p_{t,t+1} = bE_t p_{t+1,t+1} + (1-b)E_t m_{t+1} \tag{12}$$

where

$$b = \frac{a}{2-a}. \tag{13}$$

Here is where staggering bites. Because of staggering, the firm-level price set in the current period (equation (11)) must take into account previously set prices for the current period. Yet, the latter (equation (12)) is purely forward looking because it does not have to be the same as in period $t-1$.

Solve for $p_{t,t}$ replacing for $p_{t-1,t}$ using (12) to obtain

$$p_{t,t} = b\left[bE_{t-1}p_{t,t} + (1-b)E_{t-1}m_t\right] + (1-b)E_t m_t. \tag{14}$$

Take expectations based on $t-1$ info and rearrange to obtain

$$E_{t-1}p_{t,t} = b^2 E_{t-1}p_{t,t} + b(1-b)E_{t-1}m_t + (1-b)E_{t-1}(E_t m_t). \tag{15}$$

The **law of iterated expectations** implies $E_{t-1}(E_t m_t) = E_{t-1} m_t$. Replacing in (15) we obtain

$$E_{t-1} p_{t,t} = E_{t-1} m_t. \tag{16}$$

This can be used to replace for $E_t p_{t+1,t+1}$ in equation (12) to obtain

$$p_{t,t+1} = bE_t m_{t+1} + (1-b)E_t m_{t+1} = E_t m_{t+1}. \tag{17}$$

The price level for next period is fully forward-looking (not persistent). We can now solve for

$$p_t = \frac{1}{2}(p_{t,t} + p_{t-1,t}) = \frac{1}{2}\left[bE_{t-1} m_t + (1-b)E_t m_t\right] + \frac{1}{2}E_{t-1} m_t \tag{18}$$

$$\frac{1}{2}(1-b)E_t m_t + \frac{1}{2}(1+b)E_{t-1} m_t \tag{19}$$

Finally replacing in the aggregate demand curve

$$y_t = \frac{1}{2}(1-b)(m_t - E_t m_t) + \frac{1}{2}(1+b)(m_t - E_{t-1} m_t). \tag{20}$$

- Monetary policy is effective even if monetary authority does not have an informational advantage; i.e. if it observes only past but not current shocks. The reason is that firms which have set their price in the previous period cannot react to a shock which took place after they set their price, but the monetary authority can.

- For the same reason, systematic policy is effective provided shocks are autocorrelated. Suppose aggregate demand is subject to shocks.

$$y_t = m_t + v_t - p_t. \tag{21}$$

Equation (20) becomes

$$y_t = \frac{1}{2}(1-b)(m_t+v_t-E_t[m_t+v_t])+\frac{1}{2}(1+b)(m_t+v_t-E_{t-1}[m_t+v_t]). \tag{22}$$

Suppose $v_t = \rho v_{t-1} + \varepsilon_t$ with εt white noise. It is

$$y_t = \frac{1}{2}(1-b)(m_t+\varepsilon_t-E_t[m_t])+\frac{1}{2}(1+b)(m_t+\varepsilon_t+\rho\varepsilon_{t-1}-E_{t-1}[m_t]) \tag{23}$$

Consider the systematic policy $m_t = \delta\varepsilon_{t-1}$ with δ to be determined. It is

$$y_t = \frac{1}{2}(1+b)(\delta\varepsilon_{t-1} + \varepsilon_t + \rho\varepsilon_{t-1}). \tag{24}$$

The variance of output is minimized by setting $\delta = -\rho$. If $\rho \neq 0$, (shocks are persistent) role for systematic monetary policy.

- Problem: monetary policy can affect output for a period no longer than the period for which each price is predetermined. Effect of monetary policy is not persistent.

2.2 Fixed prices (Taylor contracts)

This or some variant of it has become the standard model used to talk about stabilization policy.

Prices are still set for two periods but now they **cannot** differ across periods. That is

$$p_{t,t} = p_{t,t+1} = x_t. \tag{25}$$

x_t is just shortand for the price set in period t.

The aggregate price level is

$$p_t = \frac{1}{2}(x_t + x_{t-1}) \tag{26}$$

Price is now average of present and past prices (backward-looking)

Firms are constrained to fix the same price for two periods. We assume that they set it as the average of the optimal prices that they would set if they were allowed to set different prices in different periods

$$x_t = \frac{1}{2}(p^{*i}_{t,t} + p^{*i}_{t,t+1}) \tag{27}$$

where the variables are starred to denote optimal values in the set up of the previous section. From equation (9) and (10) we have

$$p^{*i}_{t,t} = aE_t p_t + (1-a)E_t m_t \tag{28}$$

and

$$p^{*i}_{t,t+1} = aE_t p_{t+1} + (1-a)E_t m_{t+1}. \tag{29}$$

Imposing symmetry - $p^{*i}_{t,t} = p_{t,t}$ and $p^{*i}_{t,t+1} = p_{t,t+1}$, the above two equations can be rewritten as

$$p_{t,t} = bp_{t-1,t} + (1-b)E_t m_t \tag{30}$$

and

$$p_{t,t+1} = bE_t p_{t+1,t+1} + (1-b)E_t m_{t+1} \tag{31}$$

where

$$b = \frac{a}{2-a}. \tag{32}$$

Replacing in (27) we then have

$$x_t = \frac{1}{2}(bx_{t-1} + (1-b)E_t m_t) + \frac{1}{2}(bE_t x_{t+1} + (1-b)E_t m_{t+1}). \tag{33}$$

Second order stochastic difference equation with solution (guess and verify)

$$x_t = \lambda x_{t-1} + \frac{\lambda(1-b)}{b}\sum_{i=0}^{\infty}\lambda^i \left\{E_t m_{t+i} + E_t m_{t+i+1}\right\}, \tag{34}$$

with

$$\lambda = \frac{1-\sqrt{1-b^2}}{b} \tag{35}$$

strictly between zero and one.

Firm-level price is a forward looking variable but persistent, if $\lambda > 0$.

As in the previous case, prices set the period before matter for setting the current price. Yet, past prices are no longer purely forward-looking because they are constrained to be the same in $t-1$ and t. The price set in period $t-1$

for period t cannot reflect only expectations about period t as firms cannot set different prices across the two periods. Hence, the price trades off its optimality for period $t-1$ against its optimality for period t.

Suppose $m_t = m_{t-1} + \varepsilon_t$. This implies

$$x_t = \lambda x_{t-1} + \frac{2\lambda(1-b)}{b(1-\lambda)} m_t = \lambda x_{t-1} + (1-\lambda) m_t. \tag{36}$$

This implies

$$p_t = \lambda p_{t-1} + \frac{1}{2}(1-\lambda)(m_{t-1} + m_{t-2}). \tag{37}$$

and

$$y_t = \lambda y_{t-1} + \left[m_t - \frac{1}{2}(1+\lambda) m_{t-1} - \frac{1}{2}(1-\lambda) m_{t-2} \right]. \tag{38}$$

Output is autocorrelated (no longer "only surprises matter"). An innovation in the money supply has persistent effects on output.

The persistence is driven by λ, which is a decreasing function of b. If $b = 1$, which requires $a = 1$, the effects of monetary policy are fully persistent. Output is a random walk.

If a is large, so are b and λ. If marginal cost is constant, firms are only concerned about the relative price of their output. In response to changes in the nominal money supply the want to keep their relative price constant, so they do not adjust. This implies that prices stay constant (aggregate supply is horizontal and does not shift up).

Problems:

- λ (smaller than 0.5) for a large number of goods.
- The model implies persistence price level but not inflation rate. To see this note that

$$\pi_t = p_t - p_{t-1} = \frac{1}{2}(x_t - x_{t-2}) \tag{39}$$

  Difficult to square with high unemployment cost of reducing inflation in the 70s.
- Proposed solution. People react only little to new information (rational inattention).

Microfoundations for staggering and more than one period price setting.

- Menu costs: adjusting prices is costly but benefit from adjustment small if prices are chosen optimally.
- But if marginal cost increases (i.e. wage setting curve not very elastic) the cost of not adjusting soon becomes large. Need real rigidity too.
- Why decisions are not syncronized in response to shocks? Input-output chains (it takes time for changes in prices to work their way through the input-output chain).
- Bottom line: still lots of problems from a logical point of view, yet may be on the right track. We are learning.