Monetary Economics: Macro Aspects, 8/4 2004
Henrik Jensen

Plan for today:

1. Money in the short run: Incomplete nominal adjustment (II)
2. Sticky Prices and Wages

Literature: Walsh (Chapter 5, pp. 211-223 — plus relevant appendix)

3. Plan for next lectures

LECTURES NEXT MONDAY (March 15) ARE UNFORTUNATELY CANCELLED

NOTE: Electronic “internal” evaluation of the course is still “on” in this week

- Please visit the link on the webpage and spend a few minutes filling out the on-line forms!

Introductory remarks

- In the Lucas misperceptions model, money shocks have real effects due to imperfect information. Prices are flexible
- Most economists, however, believe that short-run price flexibility is a strong assumption
- I.e., some **nominal rigidity** is believed to prevail in the short run
  - If this is the case, monetary phenomena will have much stronger impact
  - E.g., with rigid prices, expansive monetary policy will likely translate directly into higher production
  - E.g., with rigid wages, monetary policy affects prices, thus directly affecting the real wage and employment
- Lot of research therefore examines the consequences of rigidities in wages and/or prices for
  - the transmission of monetary policy shocks
  - the possibility of using monetary policy to stabilize the economy against shocks

Sticky wages in MIU model

- A log-linearized version of the stochastic MIU model of Chapter 2 with endogenous labor supply is set up
- Differences
  - Utility function parameters: $b = \Phi$ is set to 1. This means that with flexible prices, money is superneutral (changes in real money holdings do not affect the marginal utility of consumption and thus the consumption-leisure choice)
  - No capital
- Hence, any real effects of money will have to arise from nominal rigidities (otherwise the model exhibits the **classical dichotomy**)
- Nominal rigidity is introduced — in the simplest possible form — by assuming that the **nominal** wage for period t is set in period $t-1$. It cannot change in period t (e.g., for contractual reasons)
- Wage determination: the nominal wage is set such that the **expected** real wage equals the expected marginal product of labor (with flexible wages, the **actual** real wage would equal the marginal product)
- With Cobb-Douglas production function $Y_t = \mathrm{e}^{e_t} N^{1-\alpha}$, $0 < \alpha < 1$, the marginal product is

$$(1-\alpha)\,\mathrm{e}^{e_t} N^{-\alpha} = (1-\alpha)\,Y_t/N_t$$

In log-deviations from steady-state, the real-wage-equal-to-the-marginal-product is

$$w_t - p_t = y_t - n_t \tag{5.9}$$

- To attain this condition in expectations, the nominal wage is in period $t-1$ set according to:

$$w_t^c = \mathrm{E}_{t-1}p_t + \mathrm{E}_{t-1}y_t - \mathrm{E}_{t-1}n_t = \mathrm{E}_{t-1}p_t + \mathrm{E}_{t-1}\omega_t^* \tag{5.15'}$$

  - Higher expected prices, higher contract wage to secure the real wage "target"
  - Higher $\mathrm{E}_{t-1}y_t -$ $\mathrm{E}_{t-1}n_t$, higher contract wage to "match" higher expected marginal product
- **Actual** employment for given contract wage is therefore

$$\begin{aligned} n_t &= y_t - (w_t^c - p_t) \\ &= (y_t - \mathrm{E}_{t-1}y_t) + (p_t - \mathrm{E}_{t-1}p_t) + \mathrm{E}_{t-1}n_t \end{aligned}$$

- Actual employment is higher than expected employment if
  - $y_t > \mathrm{E}_{t-1}y_t$ as the marginal product then is higher than expected, which the contract wage fails to "incorporate"
  - $p_t > \mathrm{E}_{t-1}p_t$ as the actual real wage then is lower than expected, making firms hire more labor
- To see implications of wage rigidity on actual output, consider the production function in logs:

$$y_t = (1-\alpha)\,n_t + e_t \tag{5.7}$$

- Insert the expression for employment:

$$y_t = (1-\alpha)\left[(y_t - \mathrm{E}_{t-1}y_t) + (p_t - \mathrm{E}_{t-1}p_t) + \mathrm{E}_{t-1}n_t\right] + e_t$$

- This can then be solved for output:

$$\alpha y_t = -(1-\alpha)\left[\mathrm{E}_{t-1}y_t - (p_t - \mathrm{E}_{t-1}p_t) - \mathrm{E}_{t-1}n_t\right] + e_t$$

- Make the "trick" of adding and subtracting $\mathrm{E}_{t-1}e_t$ thereby bringing out $\mathrm{E}_{t-1}y_t = (1-\alpha)\mathrm{E}_{t-1}n_t + \mathrm{E}_{t-1}e_t$:

$$\begin{aligned} \alpha y_t &= \mathrm{E}_{t-1}e_t - (1-\alpha)\left[\mathrm{E}_{t-1}y_t - (p_t - \mathrm{E}_{t-1}p_t) - \mathrm{E}_{t-1}n_t\right] \\ &\quad + e_t - \mathrm{E}_{t-1}e_t \\ &= \mathrm{E}_{t-1}y_t - (1-\alpha)\left[\mathrm{E}_{t-1}y_t - (p_t - \mathrm{E}_{t-1}p_t)\right] + e_t - \mathrm{E}_{t-1}e_t \end{aligned}$$

- One then finally gets:

$$\begin{aligned} y_t &= a\,(p_t - \mathrm{E}_{t-1}p_t) + \mathrm{E}_{t-1}y_t + (1+a)\,\varepsilon_t \qquad (5.17') \\ \varepsilon_t &\equiv e_t - \mathrm{E}_{t-1}e_t, \qquad a \equiv (1-\alpha)/\alpha > 0 \end{aligned}$$

  Hence, output exceeds its expected value if $p_t > \mathrm{E}_{t-1}p_t$

  - I.e., if prices are **surprisingly** high (and/or if productivity shock is higher than expected)

- Analogous to the output equation of the Lucas misperceptions model! But very different underlying reason:

  - In Lucas model nominal "surprises" cause confusion about relative prices
  - In sticky wage model, nominal "surprises" cause the actual real wage to differ from the expected

- Simple numerical example shows that the impact of a monetary shock is **much** larger that in the flexible price model
- If aggregate demand is

$$y_t = m_t - p_t \qquad (5.19)$$

  output is

$$y_t = (1-\alpha)\,(m_t - \mathrm{E}_{t-1}m_t) + \varepsilon_t \qquad (5.20')$$

- One percent positive money shock

=> $(1-\alpha)$ percent increase in output

=> With $1-\alpha = 0.64$ (labor's share of income), **significant** increase in output

- What about the persistent effect of money shocks found in data?
- Not present here.....
  - . . . after a shock, wages have adjusted fully after one period
  - . . . even with persistent shocks
- Is missing capital accumulation the cause?
  - No; cf. the weak persistence in flex-price model
  - Applies here as well

- Hence, while introduction of wage rigidity in the MIU model gives much stronger effects of monetary shocks (compared to the flex-price versions), the effects are not persistent
- Also, the transmission mechanism implies a countercyclical real wage; not in accordance with data
- Moreover, the introduction of a nominal rigidity raises the issue: *Who* is setting the nominal variable?
- To address this properly, one must model explicitly price- or wage setting agents
- This, on the other hand, must involve introducing monopoly power into the model
- This is exemplified in model extension where intermediate goods producers are price-setters and acting under **monopolistic competition** (they have monopoly power over their own, unique, intermediate good, but competes with other intermediate goods producers)
- Monopoly power, however, does not in itself create monetary non-neutrality
- Therefore, prices are assumed to be fixed for some time
- Also, they are assumed to be set (and reset), in an asynchronized — "staggered" — fashion; i.e., all monopolists do not set/reset prices at exact same dates
  - The latter feature is in attempt to generate persistent effects of money shocks

"Staggered" price setting and persistence of money shocks

Model of price setting under imperfect competition

- The economy has two sectors
- A final goods sector operating under perfect competition, using intermediate goods in production process
- An intermediate goods sector, where a continuum of monopolists set the price on their unique intermediate good
- Production function for final goods producers:

$$Y_t = \left[\int_0^1 Y_t(i)^q \, \mathrm{d}i \right]^{\frac{1}{q}}, \qquad 0 < q \leq 1 \tag{5.21}$$

where Y_t is final good and $Y_t(i)$ is intermediate good i, $i \in [0,1]$

- Profits of final goods producers:

$$P_t Y_t - \int_0^1 P_t(i) \, Y_t(i) \, \mathrm{d}i$$

where P_t is price on final good and $P_t(i)$ is price on intermediate good i

- Using the production function, profits are

$$P_t \left[\int_0^1 Y_t(i)^q \, \mathrm{d}i \right]^{\frac{1}{q}} - \int_0^1 P_t(i) \, Y_t(i) \, \mathrm{d}i$$

- Final goods producers take all prices as given (perfect competition), and choose profit-maximizing demands for intermediate goods.
  First-order condition:

$$P_t\left[\int_0^1 Y_t(i)^q \,\mathrm{d}i\right]^{\frac{1-q}{q}} Y_t(i)^{q-1} = P_t(i), \qquad i \in [0,1]$$

  Marginal revenue of each intermediate good equals its marginal cost

- This is rewritten by use of the production function:

$$P_t Y_t^{1-q} Y_t(i)^{q-1} = P_t(i) \qquad i \in [0,1]$$

- Resulting demand functions for intermediate goods:

$$Y_t(i) = \left[\frac{P_t}{P_t(i)}\right]^{\frac{1}{1-q}} Y_t \qquad i \in [0,1] \tag{5.22}$$

  Demand of good i is falling in the relative price ($1/(1-q)$ is elasticity of substitution)

- Tedious algebra shows that zero profits in the final goods sector requires (see Section 1 of "Technical notes")

$$P_t = \left[\int_0^1 P_t(i)^{\frac{q}{q-1}} \,\mathrm{d}i\right]^{\frac{q-1}{q}}$$

- Each intermediate goods producer has the profit function

$$\begin{aligned}\pi_t(i) &= P_t(i)\,Y_t(i) - r_t K_t(i) - W_t L_t(i)\\ &= [P_t(i) - P_t V_t]\,Y_t(i)\end{aligned}$$

  where V_t is the minimized real costs of producing one unit of the good. $P_t V_t$ thus denotes the nominal marginal cost of $Y_t(i)$

- The intermediate producer has monopoly power, and sets its price so as to maximize profits, taking into account the demand function for its product. I.e., it maximizes

$$\pi_t(i) = [P_t(i) - P_t V_t]\left[\frac{P_t}{P_t(i)}\right]^{\frac{1}{1-q}} Y_t$$

  with respect to $P_t(i)$ (taking as given P_t; thereby the term monopolistic competition)

- From the first-order condition one readily recover a familiar monopoly theory result:

$$P_t(i) = \frac{1}{q} P_t V_t, \qquad \frac{1}{q} > 1 \tag{5.25}$$

  Price is set as a **mark-up**, $1/q > 0$, over marginal costs

  - Note that $q \to 1$ implies that intermediate goods become perfect substitutes
  - No monopoly power, and mark up becomes 1
  - The case of perfect competition arises

- Note: imperfect competition does not in itself provide monetary non-neutrality (but $q < 1$ implies inefficiently low production)
- In a symmetric equilibrium, $P_t(i) = P_t$, $L_t(i) = L_t$ and proportional changes in prices and nominal wages have no real effects
- Assume therefore that price setters cannot adjust prices freely (this may even be optimal under "menu cost" arguments)

The model with sticky prices and staggered price setting

- Intermediate goods producers set a price, which has a duration of two periods
- Prices are set in **staggered** fashion: Half of the producers set prices in a given period, the other half in the next period:
  - Half sets prices in t, $t+2$, $t+4$, $t+6$, ...
  - Other half sets prices in $t+1$, $t+3$, $t+5$, $t+7$, ...
  - Generally, $\overline{P}_{t+j}$ is a price fixed for periods $t+j$ and $t+j+1$
- Important:
  - Any monopolist i setting prices in a period, cares about the **relative** price of its product, $P_t(i)/P_t$ in the period it sets the price **and** the **expected next-period relative price**
  - Two-period profit-maximization will therefore lead to a price-setting rule depending on **current** and **expected future aggregate prices**

- From the first-order condition for two-period profit maximization, one gets the optimal price set in t (in log deviations from steady state) (see Section 2 of "Technical notes"):

$$\overline{p}_t = \frac{1}{2}(p_t + \mathrm{E}_t p_{t+1}) + \frac{1}{2}(v_t + \mathrm{E}_t v_{t+1}) \qquad (5.30)$$

  Indeed $\overline{p}_t$ depends on current aggregate prices and real marginal costs, as well as **expected future** values
- The aggregate price is by definition a function of the prices set in the period, as well as the prices set in the previous period:

$$p_t = \frac{1}{2}(\overline{p}_t + \overline{p}_{t-1})$$

- Therefore, the optimal price in period t depends on past period's optimal prices and expected future optimal prices:

$$\overline{p}_t = \frac{1}{2}\overline{p}_{t-1} + \frac{1}{2}\mathrm{E}_t\overline{p}_{t+1} + (v_t + \mathrm{E}_t v_{t+1})$$

  This will account for potential **gradual adjustment** of aggregate prices, and thus potential persistence of monetary shocks
- Implications of this form of price rigidity is best analyzed under very simple assumptions (special cases of the MIU equations):
  - Real marginal costs are linearly related to output:

$$v_t = \gamma y_t, \qquad \gamma > 0$$

  - Aggregate demand is characterized by a quantity equation:

$$m_t - p_t = y_t$$

  - Nominal money supply follows a random walk:

$$\mathrm{E}_t m_{t+1} = m_t$$

- With these assumptions one can solve for $\overline{p}_t$ by the method of undetermined coefficients, to get (see Section 4 of "Technical notes"):

$$\overline{p}_t = a\overline{p}_{t-1} + (1-a)\,m_t, \qquad a = \frac{1-\sqrt{\gamma}}{1+\sqrt{\gamma}}, \qquad |a| < 1 \quad (5.32)$$

- The associated solution for aggregate prices, remembering $p_t = (1/2)\,(\overline{p}_t + \overline{p}_{t-1})$, is

$$p_t = ap_{t-1} + \frac{1}{2}\,(1-a)\,(m_t + m_{t-1})$$

Hence, for $|a| \neq 0$ aggregate prices exhibit **inertia,** implying **prolonged** real effects of a monetary shock

- Important parameter for the degree of inertia is γ, the sensitivity of real marginal costs to output (could depend inversely on labor supply wage elasticity)
  - Low sensitivity is often labelled a situation with high degree of **real rigidity**

- For $\gamma = 1$ highly sensitive real marginal costs, and $a = 0$, so aggregate price adjustment is immediate; real effect of money shock dies out after one period
  - With $\gamma = 1$, a one percent increase in nominal money will for given prices increase output by one percent. This increases real marginal costs by one percent, and all firms who can adjust prices adjust by raising prices by one percent. Aggregate prices will raise by 0.5 percent, and output raises in equilibrium by 0.5 percent (see Figure 5.1)
  - In next period, when all firms have had the opportunity to adjust prices, the aggregate price adjustment is complete, and $y = 0$ again

- With $\gamma < 1$, less sensitive real marginal costs, $a > 0$, and aggregate price adjustment is **inertial**; real effect of a money shock is persistent
  - Hence, even after **all** firms have had the opportunity to adjust prices, aggregate price adjustment is incomplete, and y has not returned to steady-state
  - Source of inertia is the **interplay** between prices' dependence on **past** prices and **expected future** prices

  - Those adjusting in period t do not adjust fully to a monetary shock as their real marginal cost does not rise sufficiently. Hence, aggregate prices will adjust by less than half of the change in the money supply
  - This will feed into next period's price adjustment, which will be dampened as it depends on the **past period's** dampened adjustment
  - This is known by current price setters, and given that **expected next-period** prices are important, equilibrium adjustment of current prices are further reduced
  - This process of less than full adjustment in each period **continues** into the future, making adjustment only gradual
  - See Figure 5.1 for "$a = 0.61$" (different "a" than in wage contract model!)

- This case of staggered price-setting therefore provides a framework for generating persistent real effects of monetary shocks
- The parameter γ, however, has to be rather low; i.e., a high degree of real rigidity is necessary
  - This could be a situation where real labor market imperfections (efficiency wage considerations, unionized wage setting), implies a rather rigid real wage. Then, real marginal costs will be rather insensitive to output

  - So, **high degree of real rigidity** (low γ) provides a case for **high degree of persistent nominal rigidity**

Summary

- Nominal rigidities give rise to substantial effects of monetary shocks as compared with full-information flexible price models and, to some extent, misperceptions models

- One-period nominal wage (or price) contracts give rise to no persistence of monetary shocks (in a dynamic general equilibrium model **with** capital accumulation; extremely little persistence)
- Modelling sticky price (or wage) setting calls for models of monopoly power
  - Monopoly power in itself not a source of non-neutrality of money
  - Particular price-setting structure important for the transmission of money shocks
  - With staggered price setting, persistent effect of money shocks; in particular with high degrees of real rigidity

Plan for next lectures

Wednesday, March 10

We solve some exercises:

- Solve Sample questions 1 and 2 from Recap Information 1 and 2, respectively
- Derive and interpret the two first-order conditions on page 7 on the slides of March 3 (hint: Solve the maximization problem by Lagrangian method)
- NB: Remember to prepare, as **you** will have to help solving the problems on the board!

Wednesday, March 17

1. Monetary credibility problems
2. Inflation and discretionary monetary policy
3. Reputational solution to credibility problems

Literature: Walsh (Chapter 8, pp. 363-384); Jensen (2003) (available on webpage))