Monetary policy, output and inflation in the short run

Lecture 9

Readings

- G. Mankiw, *Macroeconomics*, 7th edition, Chapter 13 (only parts treated in the class notes)

Motivation (I)

- We have studied how monetary policy affects aggregate demand taking as given prices and inflation

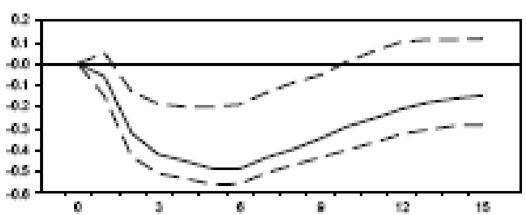
$$\frac{1}{C_1} = \beta(1+r_1)\frac{1}{C_2} \qquad 1+r_1 = (1+i_1)\frac{P_1}{P_2}$$

- Here we study how monetary policy affects output and inflation
- Need to think about how prices (of goods and labor) and inflation are determined
- Need to think about aggregate supply
- Need to think about a general equilibrium analysis (aggregate demand and aggregate supply)

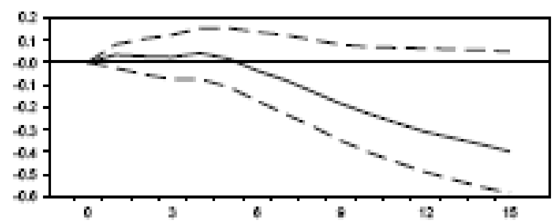
Motivation (II)

- Evidence of slow adjustment of output and prices to monetary policy

MP shock → Output



MP shock → Price level



- Short run non neutrality but long run neutrality
- How can we explain this?
- Our hypothesis for short run non neutrality: price stickiness
- Consistent with evidence on the response of the price level to monetary policy shocks

Plan

- Model of aggregate supply: the sticky price model
- Effects of monetary policy on output and prices in the short run
- Phillips curve → short run trade-off faced by policymakers between two measures of economic performance, output (or unemployment) and inflation

Aggregate supply: a sticky price model

- Our sticky price model of AS will imply:
  - Long-run AS vertical: shifts in AD affect price level but output remains at the natural level
  - Short-run AS upward sloping: shifts in AD cause fluctuations in output
- Natural level of output: level of output arising when all prices are flexible
- Temporary deviations of output from natural level $\rightarrow$ booms and busts of business cycle
- Other models of AS (sticky wages, imperfect information, …) have a different market friction causing output to deviate from natural level; but AS curve is similar

Short-run aggregate supply

- Short run AS of the form

$$y_t = y_t^n + \alpha(p_t - p_t^e) \text{ with } \alpha > 0$$

  - y_t = output; y_t^n = natural rate of output; p_t = price level; p_t^e = expected price level
  - y_t deviates from y_t^n when the price level p_t deviates from the expected price level p_t^e
  - Parameter α indicates how much y_t responds to unexpected changes in p_t
  - $1/\alpha$ is the slope of the AS curve

- Different AS models (sticky prices, sticky wages, imperfect information,…) tell a different story about why unexpected changes in *P* are associated with fluctuations in *Y*

Sticky price model

- Firms do not instantly adjust prices in response to changes in AD: prices are sticky
- Several possible reasons
  - Prices may be set by long-term contracts between firms and customers
  - Firms may decide to changes prices only infrequently simply not to annoy their customers
  - Once a firm has printed and distributed its catalog or price list, it is costly to alter prices
- Note if we want to consider how firms set prices we need to assume that firms have some monopoly power (in fact perfectly competitive firms are price takers as opposed to price setters)

Firms

- There is a large number of identical firms, indexed by *i*

- Firm *i* produces output $Y_t(i)$ using labor $N_t(i)$ according to the following technology

$$Y_t(i) = A_t N_t(i)$$

where A_t denotes labor productivity

Firms, cont.

- Firms are monopolistically competitive

    1. They sell differentiated goods, can choose the price of their own product, but have no control over prices set by other firms and thus, no control over the aggregate price level

    2. They face the following demand for their product

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t$$

where $P_t(i)$ is price set by firm i, P_t is aggregate price level, Y_t is aggregate demand and $\varepsilon > 1$ is the price elasticity of demand

Pricing decision of individual firms, problem

- Firm *i* maximizes profits subject to (i) the demand for its product and (ii) technology
- The firm's maximization problem is to choose $P_t(i)$ to max profits

$$\frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t}{P_t} N_t(i)$$

$$s.t. \begin{cases} Y_t(i) = A_t N_t(i) \\ Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t \end{cases}$$

Pricing decision of individual firms, solution

- Substituting the constraints into the objective function gives

$$\max \left(\frac{P_t(i)}{P_t}\right)^{1-\varepsilon} Y_t - \frac{W_t}{P_t}\frac{1}{A_t}\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t$$

- Taking the first order condition yields

$$(1-\varepsilon)\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon}\frac{1}{P_t}Y_t - \frac{W_t}{P_t}\frac{1}{A_t}(-\varepsilon)\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon-1}\frac{1}{P_t}Y_t = 0$$

- Simplifying

$$P_t(i) = \frac{\varepsilon}{\varepsilon-1}\frac{W_t}{A_t}$$

Optimal price

- Optimal price

$$P_t(i) = \underbrace{\frac{\varepsilon}{\varepsilon - 1}}_{\text{markup}, \mu} \underbrace{\frac{W_t}{A_t}}_{\substack{\text{nominal} \\ \text{marginal cost}, MC_t}}$$

- The optimal price is a markup over marginal costs

$$P_t(i) = \mu \, MC_t$$

  - markup depends on price elasticity of demand $\mu = \frac{\varepsilon}{\varepsilon - 1}$
  - marginal cost is the wage corrected by productivity $MC_t = \frac{W_t}{A_t}$

Households

- There are many identical households
- Households obtain utility from consuming goods and suffer disutility from supplying labor
- Households' utility in period *t* is given by

$$\log C_t - \frac{(N_t)^a}{a}$$

where a > 1

- Households' budget constraint in period *t* is given by

$$C_t + \frac{B_t}{P_t} = (1 + r_{t-1})\frac{B_{t-1}}{P_{t-1}} + \frac{W_t}{P_t} N_t$$

Labor supply decision of households

- Households choose N_t to max

$$\log C_t - \frac{(N_t)^a}{a} \quad \text{s.t.} \quad C_t = \frac{W_t}{P_t} N_t - \frac{B_t}{P_t} + (1 + r_{t-1}) \frac{B_{t-1}}{P_{t-1}}$$

- Substituting the constraint into the objective function

$$\log \underbrace{\left(\frac{W_t}{P_t} N_t - \frac{B_t}{P_t} + (1 + r_{t-1}) \frac{B_{t-1}}{P_{t-1}} \right)}_{C_t} - \frac{N_t^{\ a}}{a}$$

- Taking the first order condition

$$\frac{1}{C_t} \frac{W_t}{P_t} - \not{a} \frac{(N_t)^{a-1}}{\not{a}} = 0$$

Optimal labor supply

- The optimal labor supply equates benefit and cost of supplying one additional unit of labor

$$\underbrace{\frac{1}{C_t}\frac{W_t}{P_t}}_{\substack{\text{marginal benefit}\\ \text{of labor supply}}} = \underbrace{\left(N_t\right)^{a-1}}_{\substack{\text{marginal cost}\\ \text{of labor supply}}}$$

- Marginal benefit of LS:

  supply one additional unit of labor → earn (W_t/P_t) → utility increases by ($1/C_t$) x (W_t/P_t)

- Marginal cost of LS:

  supply one additional unit of labor → disutility increases by $(N_t)^{a-1}$

Wage

- Wage from labor supply is

$$\frac{W_t}{P_t} = C_t \left(N_t\right)^{a-1}$$

- Use
  - goods market clearing: $C_t = Y_t$
  - technology: $Y_t = A_t N_t$

- Obtain the equilibrium wage

$$\frac{W_t}{P_t} = \left(\frac{Y_t}{A_t}\right)^a A_t$$

Wage, cont.

- Recall the optimal price

$$P_t(i) = \mu \frac{W_t}{A_t} = \underbrace{\mu}_{\text{markup}} \underbrace{\frac{W_t / P_t}{A_t}}_{\text{real marginal cost}} \underbrace{P_t}_{\text{overall price level}}$$

- Substituting wage in optimal price

$$P_t(i) = \mu \frac{W_t / P_t}{A_t} P_t \Rightarrow P_t(i) = \mu \frac{(Y_t / A_t)^a A_t}{A_t} P_t$$

$$\Rightarrow \quad P_t(i) = \mu \left(\frac{Y_t}{A_t} \right)^a P_t$$

Potential or natural output

- Natural level of output: level of output arising when prices are flexible
- With flexible prices all firms set the same price: $P_t(i) = P_t$
- Using the optimal price equation

$$P_t(i) = \mu\left(\frac{Y_t}{A_t}\right)^a P_t \;\Rightarrow\; P_t = \mu\left(\frac{Y_t}{A_t}\right)^a P_t \;\Rightarrow\; 1 = \mu\left(\frac{Y_t}{A_t}\right)^a$$

- This gives us the natural level of output

$$Y_t^n = \frac{A_t}{\mu^{1/a}}$$

that depends only on (i) technology A_t & (ii) degree of monopolistic competition in good markets μ

Optimal price

- Rearrange optimal price as

$$P_t(i) = \mu\left(\frac{Y_t}{A_t}\right)^a P_t \quad \Rightarrow \quad P_t(i) = \left(\frac{Y_t}{A_t / \mu^{1/a}}\right)^a P_t$$

so that, using the expression for natural output, we can write

$$P_t(i) = \left(\frac{Y_t}{Y_t^n}\right)^a P_t$$

- Taking logs

$$\log P_t(i) = a(\log Y_t - \log Y_t^n) + \log P_t$$

- Rewrite

$$p_t(i) = a(y_t - y_t^n) + p_t$$

Sticky prices

- Suppose now that there are two types of firms

  1. Flexible price firms set prices according to

  $$p_t(i) = a(y_t - y_t^{\;n}) + p_t$$

  2. Sticky price firms announce their prices in advance based on expected economic conditions and set prices according to

  $$p_t(i) = a(y_t^{\;e} - y_t^{\;n,e}) + p_t^{\;e}$$

  For simplicity assume further that $y_t^e = y_t^{n,e}$ so that sticky price firms set prices based on what they expect other firms will do, that is

  $$p_t(i) = p_t^{\;e}$$

Sticky prices, cont.

- Let s = fraction of sticky price firms; and $1 - s$ = fraction of flexible price firms

- Aggregating pricing decisions of all firms, overall price level is weighted average given by

$$p_t = sp_t^{\ e} + (1-s)[a(y_t - y_t^{\ n}) + p_t]$$

- Solving for p_t yields

$$p_t = p_t^{\ e} + [(1-s)a/s](y_t - y_t^{\ n})$$

Sticky price, cont.

- Interpretation of the overall price level

$$p_t = p_t^e + [(1-s)a/s](y_t - y_t^n)$$

1. First term: suppose firms expect a high price level p_t^e $\rightarrow$ firms expect high nominal costs $\rightarrow$ sticky price firms set a high price $p_t(i)$ $\rightarrow$ flexible price firms set a high price $p_t(i)$ also $\rightarrow$ this leads to a high overall price level p_t $\rightarrow$ hence, a high p_t^e leads to a high p_t

2. Second term: high output y_t $\rightarrow$ high demand $\rightarrow$ flexible price firms set a high price $p_t(i)$ $\rightarrow$ this leads to a high overall price level p_t $\rightarrow$ hence, a high y_t leads to a high p_t

   The effect of y_t on p_t depends on the proportion of flexible price firms 1 - s

- Rearranging the equation

$$y_t = y_t^n + \alpha(p_t - p_t^e) \quad \text{with} \quad \alpha = [s/(1-s)a]$$

Sticky-price model: deviation of y_t from y_t^n positively associated with deviation of p_t from p_t^e

Aggregate supply

- Both the sticky price and the sticky wage model lead to an aggregate supply equation of the form

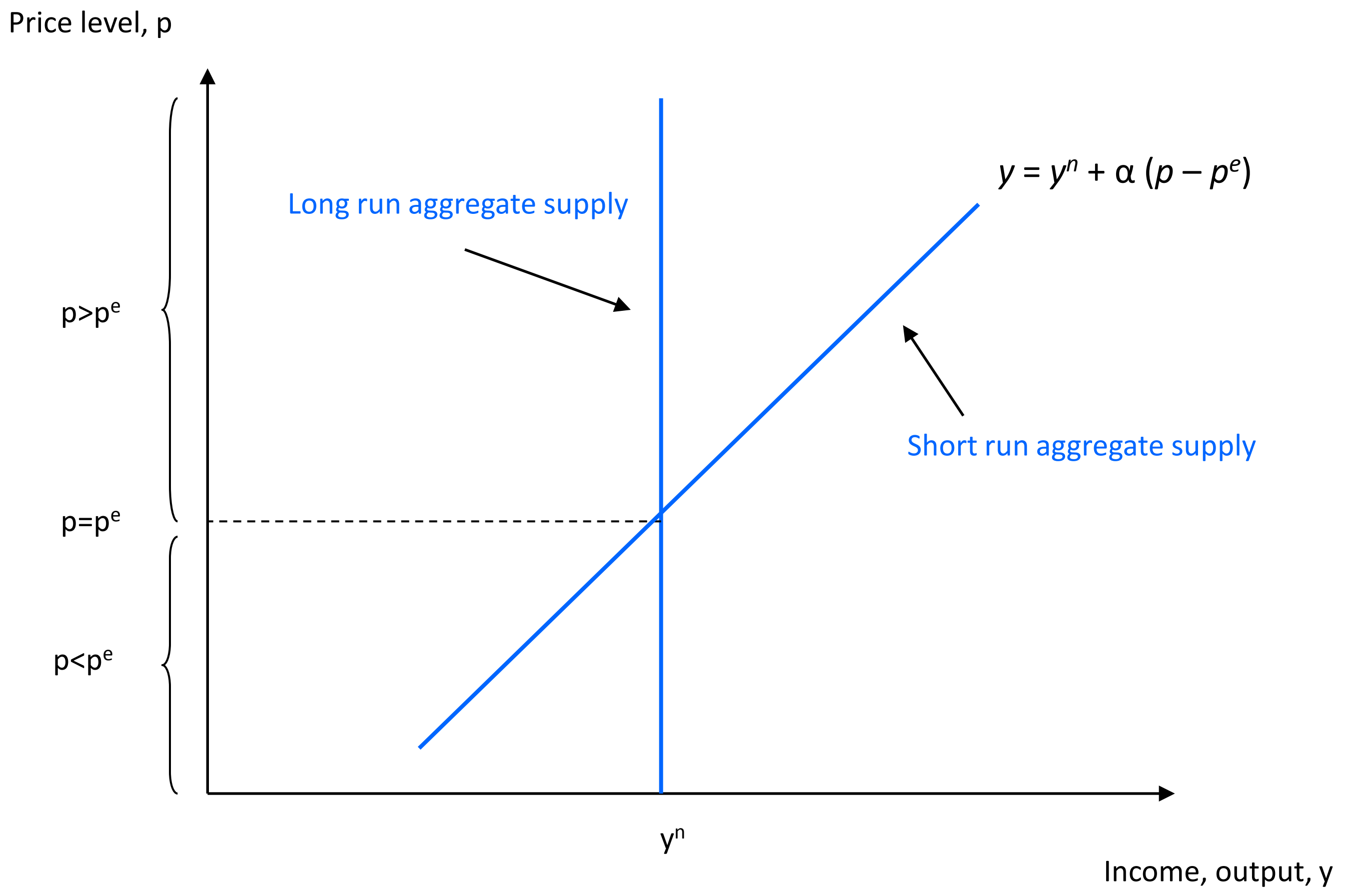
$$y_t = y_t^{\,n} + \alpha(p_t - p_t^{\,e}) \quad \text{with} \quad \alpha > 0$$

- Sticky price and sticky wage models are not incompatible: the real world seems to be characterized by both frictions, as well as other frictions

- According to this equation, deviation of output y_t from the natural level y_t^n are related to deviation of the price level p_t from the expected price level p_t^e

1. If $p_t > p_t^e$ then $y_t > y_t^n$
2. If $p_t < p_t^e$ then $y_t < y_t^n$

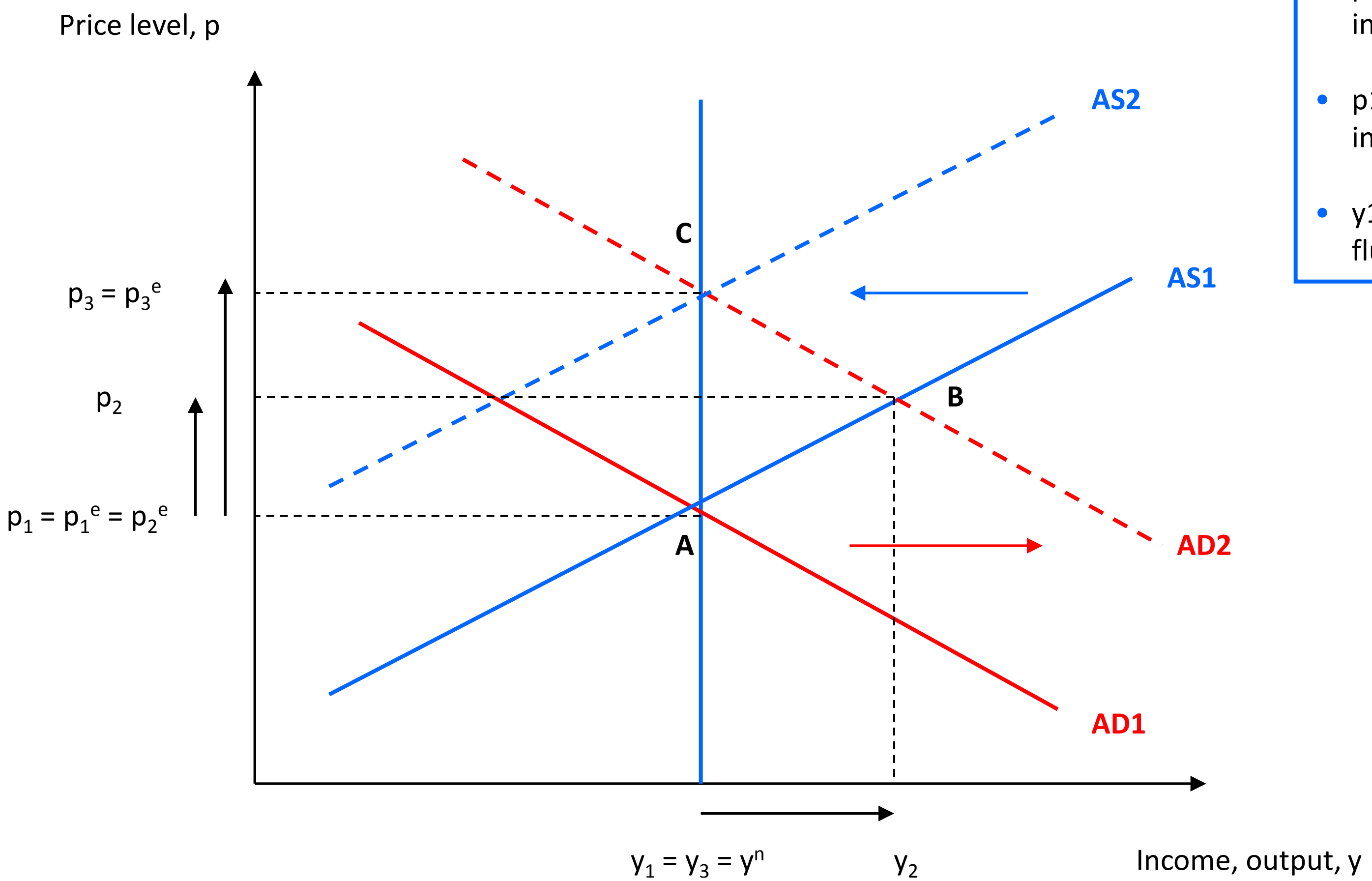
Aggregate supply in the short and long run



Effect of an increase in aggregate demand

- Consider an unexpected increase in aggregate demand, say, an unexpected monetary policy expansion
- In the short run the equilibrium moves from point A to point B
- The increase in aggregate demand raises the actual price level from p_1 to p_2
- Because people did not expect the increase, in the short run the expected price level remains at p_2^e and output raises from y_1 to y_2, which is above the natural level y^n
- Boom does not last forever, in the long run the expected price level rises to catch up with reality, causing the short run aggregate supply to shift upward
- As the expected price level rises from p_2^e to p_3^e, the equilibrium of the economy moves form B to C
- The actual price level rises from p_2 to p_3 and output falls from y_2 to y_3
- The economy returns to the natural level of output but at a higher price

Effects of an increase in aggregate demand



- p1 to p2: short run increase in p
- p1 to p3: long run increase in p
- y1 to y2: short run fluctuation in y

Short run non neutrality and long run neutrality of monetary policy

- Long run monetary neutrality and short run monetary non neutrality are perfectly compatible
- Movement of the economy from A to B: short run monetary non neutrality
- Movement of the economy from A to C: long run monetary neutrality
- Reconcile short run and long run effect of monetary policy by emphasizing slow adjustment of expectations about the price level in presence of frictions (price rigidities)

The Phillips curve

- Goals of policymakers are low inflation, high employment, high output
- Often these goals conflict: expansionary monetary policy raises output and thus lowers unemployment, but also raise the price level and thus raises inflation
  - Expansionary monetary policy moves the economy up the short run aggregate supply curve raising output, decreasing unemployment but increasing inflation
  - Contractionary monetary policy moves the economy down the short run aggregate supply curve decreasing inflation but lowering output and increasing unemployment
- Phillips curve is a way to write the short run aggregate supply curve in terms of
  - inflation and output gap (difference between output and its natural level) or
  - Inflation and unemployment gap (difference between unemployment and its natural rate)
- Phillips curve: short run trade-off faced by policymakers in stabilizing inflation and output/unemployment

The Phillips curve, cont.

- Write the aggregate supply equation as an equation relating
  - expected inflation
  - output or unemployment gap (cyclical output or cyclical unemployment)
  - supply shocks
- Phillips curve can be written as

$$\pi = \pi^e + \lambda x + v$$

$$\pi = \pi^e - \gamma\ (u - u^n)\ x + v$$

where x is the output gap, λ and γ are parameters that measure the response of inflation to cyclical fluctuations in output and unemployment, respectively, and v is a supply shock

Deriving the Phillips curve

- Start with the short run AS (recall that variables are in logs, denoted with lower cases)

$$y = y^n + \alpha\,(p - p^e)$$

- Solve for p

$$p = p^e + (1/\alpha)\,(y - y^n)$$

- Subtract last year price level p_{-1} from both sides

$$p - p_{-1} = p^e - p_{-1} + (1/\alpha)\,(y - y^n)$$

$$\pi = \pi^e + (1/\alpha)\,(y - y^n)$$

Deriving the Phillips curve, cont.

- Rearrange and add a supply shock v to represent exogenous events affecting inflation

$$\pi = \pi^e + \lambda x + v$$

with $x = y - y^n$ and $\lambda = 1/\alpha$

- Phillips curve in terms of unemployment gap can be obtained using a version of Okun's law

$$y - y^n = -\vartheta\,(u - u^n)$$

- Substituting

$$\pi = \pi^e - \gamma\,(u - u^n) + v$$

with $\gamma = \lambda\,\vartheta$