Advanced Monetary Economics

Lecture 11

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What we have learned so far

- Monetary policy sets the short-run nominal interest rate.
- Changes in interest rates effect the economy (among other channels) through the interest-rate channel.
- We want to study a dynamic model for the interest-rate channel: the New Keynesian model.
- We have studied two building blocks of the New Keynesian model:
    1. Household and firm sector
    2. Monetary policy authority

- Prices have been assumed flexible $\longrightarrow$ Monetary policy has no effects on the real economy.

- flexible price are suitable for
  - thinking about why money exists and what is the value of money (direct utility, liquidity service, saved leisure)
  - thinking about the long-run optimal rate of interest rates (and inflation)
  - long run-analyses of links between money and inflation

Outlook

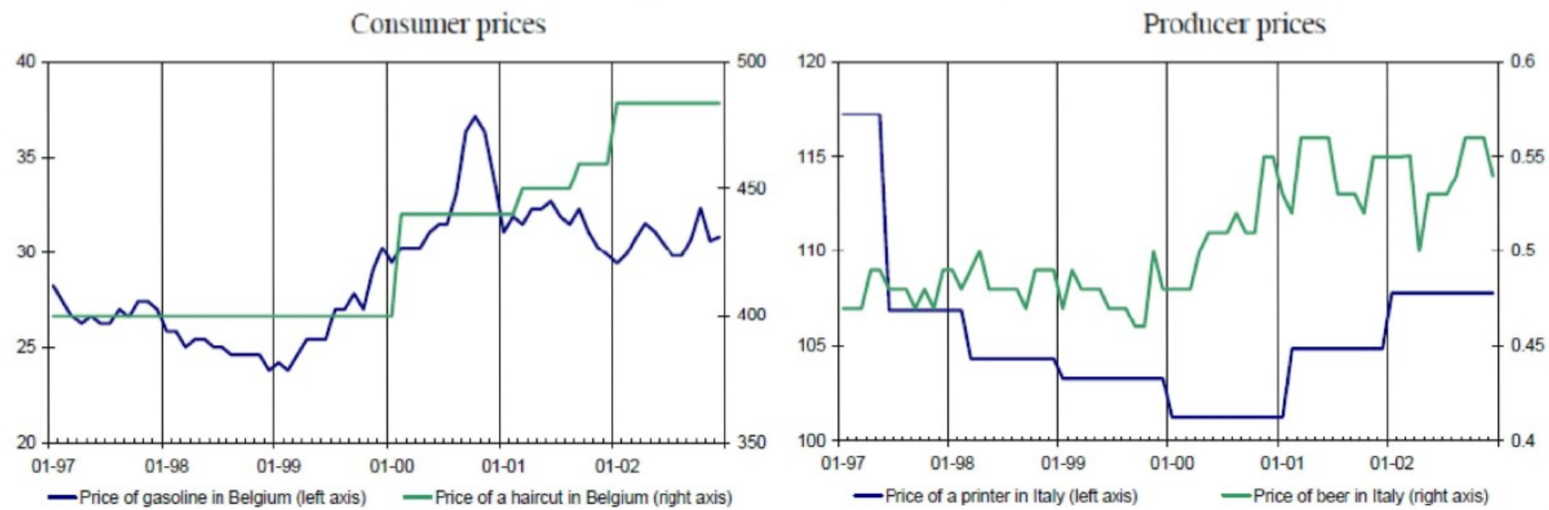
- Introduce sticky prices into the model.
- How do we think about sticky prices?
- Derive the New-Keynesian Phillips curve.
- Solve the New-Keynesian model.
- Reinvestigate the effects of monetary policy on the real economy.

1 More evidence

- Modern macro models are based on microeconomic foundations. Hence, before modelling price stickiness, let us check whether there is empirical support for this on the micro level.

- Some further evidence on infrequent price adjustment:

Figure 1 - Examples of individual price trajectories



Source: Álvarez et al (2005)

- A lot of heterogeneity in price durations across sectors and types of goods
  - services have the highest degree of price rigidities
  - unprocessed food and energy have the lowest degree of price rigidity
- Modeling assumption from now on: firms adjust prices infrequently
- What is the frequency of price readjustments? This is important information to calibrate the degree of price stickiness in New Keynesian models.

2 Firms

- Continuum of firms, indexed by $i \in [0, 1]$; each firm produces a differentiated good

- Technology is identical

$$Y_t(i) = A_t N_t(i)^{1-\alpha}$$

- Demand for good produced by firm i:

$$C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} C_t.$$

2.1 Calvo Pricing

- Only a fraction of firms can reset their prices with a certain probability. Think of it as a green light that flashes.

- This probability is given by $1 - \theta$. The probability of a red light is then θ.

- When firms are allowed to reset prices they take into account that they are probably not allowed to reset prices next periods.

- When a firm sets its price it maximizes discounted future profits until it can re-optimize again.

- Profits are discounted by the stochastic discount factor $\Lambda_{t,t+k}$.

- It denotes how the household values a payoff at point t given knowledge up to time $t+k$.

- This provides the link to the Euler (or asset pricing) equation.

- Definition of the real stochastic discount factor:

$$\Lambda_{t,t+k} \equiv \beta^k \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+k}}$$

2.2 Optimal price setting

- Firm i chooses price optimal price P_t^*

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k E_t \left[\Lambda_{k,t+k} \left(\frac{D_{t+k}(i)}{P_{t+k}} \right) \right]$$

- Reminder: $D(i)$ are nominal (!) dividends paid to households

- $D_t(i)$ is defined as

$$D_t(i) = P_t(i) Y_t(i) - \Psi \left(Y_t(i) \right)$$

where $\Psi(\cdot)$ is the nominal cost function depending on $Y_t(i)$.

- Optimal price setting implies that firm i chooses the optimal price P_t^*

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k E_t \left[\frac{\Lambda_{t,t+k}}{P_{t+k}} \left(P_t^*(i) Y_{t+k|t}(i) - \Psi \left(Y_{t+k|t}(i) \right) \right) \right]$$

where $Y_{t+k|t}$ is output in $t+k$ of a firm that last reset its price in period t

- The firm has to take the demand for $Y_t(i)$ into account when setting its price:

$$Y_{t+k|t}\,(i) = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon} C_{t+k}$$

- Preliminary considerations: derivative of $Y_t(i)$ with respect to P_t^* is

$$\begin{aligned}
\frac{\partial Y_t(i)}{\partial P_t^*} &= -\epsilon \frac{1}{P_{t+k}} \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon-1} C_{t+k} \\
&= -\epsilon \frac{1}{P_{t+k}} \frac{P_{t+k}}{P_t^*} \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon} C_{t+k} \\
&= -\epsilon P_t^{*-1} \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon} C_{t+k} \\
&= -\epsilon P_t^{*-1} Y_t(i)
\end{aligned}$$

- The derivative of $\Psi\left(Y_{t+k|t}(i)\right)$ w.r.t. P_t^* is

$$\begin{aligned}\frac{\partial\Psi\left(Y_{t+k|t}(i)\right)}{\partial P_t^*} &= \Psi'\left(Y_{t+k|t}(i)\right)\frac{\partial Y_t(i)}{\partial P_t^*} \\ &= \Psi'\left(Y_{t+k|t}(i)\right)\left(-\epsilon P_t^{*-1}Y_t(i)\right)\end{aligned}$$

- Optimality condition for pricing decision: firm i chooses price optimal price P_t^*

$$\max_{P_t^*}\sum_{k=0}^{\infty}\theta^k E_t\left[\frac{\Lambda_{t,t+k}}{P_{t+k}}\left(P_t^*(i)Y_{t+k|t}(i)-\Psi\left(Y_{t+k|t}(i)\right)\right)\right]$$

- The first-order condition is

$$\sum_{k=0}^{\infty}\theta^k E_t\left[\frac{\Lambda_{t,t+k}Y_{t+k|t}}{P_{t+k}}\left(P_t^*-\mathcal{M}\psi_{t+k|t}\right)\right]=0 \tag{1}$$

where $\psi_{t+k|t}=\Psi'\left(Y_{t+k|t}\right)$ and $\mathcal{M}=\frac{\epsilon}{\epsilon-1}$.

2.3 The New Keynesian Phillips curve

- The New Keynesian Phillips curve is a linear relationship derived from the first-order condition of the firms problem (1).

- It is

$$\pi_t = \beta E_t \pi_{t+1} + \chi \widehat{mc}_t.$$

- The New Keynesian Phillips curve is in the centre in the New Keynesian models.

- It relates price growth today (inflation, π_t) to expected price growth tomorrow (inflation, π_{t+1}) and marginal costs $\widehat{mc}_t$

- Solving this equation forward by using $\pi_{t+1} = \beta E_t \pi_{t+2} + \chi \widehat{mc}_{t+1}$ and the law of iterated expectations shows that inflation depends on expected future marginal costs

$$\pi_t = \chi \sum_{k=0}^{\infty} \beta^k E_t \widehat{mc}_{t+k}$$

- How inflation responds to the marginal costs depends on χ:

$$\chi = \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{(1-\alpha)}{(1-\alpha+\alpha\epsilon)}.$$

- Sticky prices $\longrightarrow$ π_t adjust sluggishly

- higher price stickiness θ implies lower $\chi \longrightarrow$ inflation responds less to marginal cost changes

- marginal costs are defined from the cost minimization problem of the firms

$$\min_{N_t(i)} \quad W_t N_t(i) \quad \text{s.t.} \quad Y_t(i) = A_t N_t(i)^{1-\alpha}$$

- The Lagragian is

$$\mathcal{L} = \frac{W_t}{P_t} N_t(i) + MC_t(i)\left(Y_t(i) - A_t N_t(i)^{1-\alpha}\right)$$

and the f.o.c.

$$\begin{aligned} \frac{W_t}{P_t} &= MC_t(i)(1-\alpha) A_t N_t(i)^{-\alpha} \\ MC_t(i) &= \frac{W_t/P_t}{(1-\alpha) A_t N_t(i)^{-\alpha}} \end{aligned}$$

- market clearing in the labor market implies

$$N_t = \int_0^1 N_t(i)\, di$$

so that real marginal costs are the same for all firms in the symmetric equilibrium

$$\begin{aligned} \frac{W_t/P_t}{(1-\alpha)\, A_t N_t^{-\alpha}} &= \int_0^1 MC_t\,(i)\, di \\ &= MC_t \end{aligned}$$

- log-linear marginal costs are a function of the real wage and the marginal product of labor

$$\begin{aligned} mc_t &= w_t - p_t - (a_t - \alpha n_t) - \log(1-\alpha) \\ &= w_t - p_t - \frac{1}{1-\alpha}(a_t - \alpha y_t) - \log(1-\alpha) \end{aligned}$$

where the second equality used that $y_t = a_t + (1-\alpha)\, n_t$.

2.4 Monetary policy transmission

- Monetary policy raises the nominal interest rate

- Prices are sticky (firms cannot adjust prices every period)

- Implies that nominal interest rate changes lead to temporary changes in the real interest rate

- This lowers the utility of current consumption compared to future consumption

- In case of flexible prices this would lead to a drop in prices such that in the end consumption and output would stay constant

- With sticky prices demand for consumption falls temporarily until prices have finally adjusted downwards

- Production decreases as demand falls

- Marginal costs fall

- Firms will adjust their price downwards if they can do so (Calvo)

- After a while prices adjust so that the real interest rate returns to its initial level. Output, consumption and inflation return to their initial level.

- In the long run monetary policy is neutral to real variables and only changes the price level.

3 Summary

- strong evidence in micro data for price stickiness

- Calvo pricing: probability to reset price $1 - \theta$

- firms take into account that they may not be able to reset price and that they have market power

- New Keynesian Phillips curve says inflation today depends on:

  – inflation tomorrow

  – future marginal costs

  – expectations

- future marginal costs depend on ouput

- nominal interest rate affect real rates (because prices are sticky), which affects output (Euler equation), which affects inflation today