Price setting by monopolistic firms and the new Keynesian Phillips curve

The basic standard model is based on pricing by firms in monopolistic competition. This is required in order to obtain rigid prices based on optimizing behavior. In perfect competition firms take prices as given. However, monopolistic competition by itself does not imply Keynesian results in the sense of generating cycles or output gaps, as shown by (Olivier Jean Blanchard and Nobuhiro Kiyotaki, 1987). They also show that shocks in aggregate demand affect equilibrium output if the firm faces menu costs. Firms' optimizing pricing behavior has been analysed in at least two different ways:

- ✓ Calvo pricing
- ✓ quadratic adjustment costs

and in both cases the resulting new Keynesian Phillips curve is of the same shape. In the case of state dependent pricing, based on adjustment costs, it seems better founded in optimizing behavior and the firm might choose not to change the price in face of the adjustment costs. However, the Calvo pricing model is the more common model in the recent literature[1] and the one described here:

There is a continuum of firms indexed by $i \in [0,1]$. Each firm produces a differentiated good but use the same technology:

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

and faces the demand curve

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

while taking the aggregate price level P_t and the aggregate consumption index C_t as given.

Each firm may only reset their price with probability $1-\theta$ in any given period, independent of the time elapsed since the last adjustment. The probability $1-\theta$ is exogenous. Hence, the pricing scheme is neither time nor state dependent. In each period a fraction $1-\theta$ of the producers reset their prices and a fraction θ keep them unchanged. Therefore, the *average duration* of a price is $\frac{1}{1-\theta}$ and θ is a measure of price rigidity. This implies that the aggregate price level evolves according to

$$P_t = \left[\theta \left(P_{t-1} \right)^{1-\varepsilon} + (1-\theta) \left(P_t^* \right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$$

and dividing both sides by P_{t-1} yields

[1] See **Calvo, Guillermo A.** "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics*, 1983, *12*(3), pp. 383-98. for the original version or **Carlin, Wendy and Soskice, David.** *Macroeconomics: Imperfections, Institutions, and Policies*. Oxford: Oxford University Press, 2006, **Gali, Jordi.** *Monetary Policy, Inflation, and the Business Cycle*. Princeton: Princeton University Press, 2008. for summaries.

$$\prod_t^{1-\varepsilon} = \theta + (1-\theta)\left(\frac{P_t^*}{P_{t-1}}\right)^{1-\varepsilon} \quad (2)$$

describes the aggregate price dynamics, and the rate of inflation is defined by $\prod_t = \frac{P_t}{P_{t-1}}$ while P_t^* is the average price level of the prices set by firms who are actually optimizing in that period. It follows that in steady state with zero inflation, i.e. $\prod = 1, \pi = 0$, $P_t^* = P_{t-1} = P_t$. A log-linear approximation to the aggregate price index around that steady state yields

$$\pi_t = (1-\theta)(p_t^* - p_{t-1})$$

i.e. inflation is due to the firms optimizing in period t on average choose a price that differs from the average price in the previous period. Therefore, one needs to analyze the factors behind the firms choice of optimal price, P_t^*.

The firm's optimal price

The optimizing firm will choose the price P_t^* that maximizes the current market value of the profits generated while that price remains effective. The firm solves the problem

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} \left(P_t^* Y_{t+k|t} - \psi_{t+k}(Y_{t+k|t}) \right) \right\}$$

subject to the sequence of demand constraints

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

for k=0,1,2,... and $Q_{t,t+k} \equiv \beta^k (C_{t+k}/C_t)^{-\sigma}(P_t/P_{t-1})$ is the stochastic discount factor for nominal payoffs. $\psi(.)$ is the cost function.

Solving the problem yields

$$p_t^* = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t \left\{ mc_{t+k|t} + p_{t+k} \right\}$$

where $mc_{t+k|t}$ is the real marginal cost, i.e. $mc_t = -\mu_t$. meaning that the share of firms that are optimizing in period t will set a price that is a markup on a weighted average of their current and expected marginal costs, with the weights being proportional to the probability of the price remaining effective at each horizon θ^k .

Equilibrium

The inflation equation (NKPC) in equilibrium is derived as

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \lambda(mc_t - mc) \tag{i}$$

where *mc* is the log of real marginal cost in stedy state and

$$\lambda \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}\frac{(1-\alpha)}{(1-\alpha+\alpha\varepsilon)}$$

(i) can also be expressed as

$$\pi_t = \lambda\sum_{t=0}^{\infty}\beta^k E_t\{mc_{t+k} - mc\}$$

i.e. as a discounted sum of current and expected future deviations of marginal cost from its steady state value.

The intuition behind the curve is that inflation depends on how much current marginal cost deviates from the optimal current price and what the future inflation rate is expected to be; firms are forward-looking. Note that $\lambda > 0$; firms tend to raise price if marginal cost is high relative to the current price.

It can also be shown that

$$mc_t - mc = \left(\alpha + \frac{\varphi+\alpha}{1-\alpha}\right)(y_t - y_t^n)$$

i.e. the real marginal cost is proportional to the so called output gap $y_t - y_t^n$, which might be useful when it comes to estimating this Phillips curve. We now have

$$\pi_t = \gamma + \beta E_t\{\pi_{t+1}\} + \kappa(y_t - y_t^n) \tag{i'}$$

where $\kappa = \lambda\left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right)$.

Next, there is also an equilibrium in the goods market. In the most basic model, as presented by (Jordi Gali, 2008), for a closed economy without public sector, equilibrium is defined by

$$Y_t(i) = C_t(i)$$

for all i and all t. Letting $Y_t = \left(\int_0^1 Y_t(i)^{1-\frac{1}{\varepsilon}}di\right)^{\frac{\varepsilon}{\varepsilon-1}}$ it follows

$$Y_t = C_t$$

on the aggregate level. Of course, the demand side can be modeled in more detail, e.g. with a public sector and trade. We can now utilize the first-order condition for the consumer and the above equilibrium condition to derive

$$y_t = E_t\{y_{t+1}\} - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - \rho) \tag{ii}$$

which is sometimes called the dynamic IS curve. It is based on forward-looking behavior on behalf of the consumers and producers. (ii) can be rewritten in terms of the output gap as

$$y_t = y_t^n - \frac{1}{\sigma}\left(i_t - E_t\left\{\pi_{t+1}\right\} - r_t^n\right) + E_t\left\{y_{t+1} - y_{t+1}^n\right\} \tag{ii'}$$

Under the assumption that the last term in (ii') in the long run approaches zero, then (ii') can be solved forward to yield

$$y_t = y_t^n - \frac{1}{\sigma}\sum_{k=0}^{\infty}\left(r_{t+k} - r_{t+k}^n\right) \tag{ii''}$$

where $r_t \equiv i_t - E_t\left\{\pi_{t+1}\right\}$ is the real interest rate, i.e. the real return on a one period bond. This implies that the output gap is proportional to the real interest rate gap, i.e. the difference between the real interest rate and the natural interest rate.

Equations (i') and (ii') plus an exogenous process for the natural rate of interest r_t^n forms the private sector part of the basic new Keynesian model. This is a recursive type of model in that the NKPC determines inflation given a path for the output gap, while the dynamic IS curve determines the output gap conditional on a path for the natural and real rate of interest.

Without price rigidity there would be no case for active monetary policy, money would be neutral or there would be classical dichotomy, i.e. no output gaps and real and nominal sectors independent. With price rigidities as implied in the Calvo model one has to take into account the effects of monetary policy, i.e. the determination of the nominal interest rate in (ii').