Price setting by monopolistic firms and the new Keynesian Phillips curve

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Having described the classical macro model with flexible prices we encountered the classical dichotomy, i.e. the independence of the real and the monetary sectors in the economy. We now turn to the new Keynesian model in which prices are sticky. In the classical model firms were competitive and took prices as given. Hence, no other assumptions about the behavior related to pricing were needed. Non-competitive firms set prices and take account of the conditions in the market, particularly their demand curves. Non-competitive firms choose higher prices than competitive firms and hence the equilibrium output will be lower and not efficient. The particular trick applied in the basic model is to consider a lump-sum subsidy, set by someone, being just sufficient to generate the equilibrium efficient output level.

Prices set by non-competitive firms do not in itself imply sticky prices, but rather the condition for it. This has been 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, i.e. costs for changing price tags, etc.

Firms' optimizing pricing behavior has been analyzed in different ways, often categorized[1] in:

- ✓ time-dependent or
- ✓ state-dependent

pricing behavior. Time-dependent pricing let prices be set in fixed or stochastic intervals but changed at certain points in time. In practice, a firm might change its price twice a year, January 1st and July 1st. Firms with a catalogue, like IKEA, might fix prices for at least a year. State-dependent pricing instead lets firms have a good (or maybe better) reason for changing their price. So, if a certain shock is big enough, the price will be changed. Otherwise, at smaller shocks, the cost of changing the price is the incentive to keep the price fixed.

In the basic new Keynesian model some firms change their prices, optimize, while other firms keep their prices fixed. Therefore, relative prices change and consequently the allocation of goods as well. The reallocation of goods implies an inefficient equilibrium. It is the purpose of monetary policy to try to affect this inefficient equilibrium towards a better resource allocation. This view presupposes that the sticky prices do not improve welfare by themselves. A discussion of these issues can be found in (Laurence Ball and David Romer, 1991) where the sticky prices could have external economies and improve welfare or external diseconomies and reduce welfare, depending on the effects for other agents.

In the basic Keynesian model firms pricing behavior follows the (Guillermo A. Calvo, 1983) model, in which in each period a fraction of the firms optimize and the other firms keep their prices fixed. The fractions are exogenous in that model. Models that use state-dependent pricing, for instance see (Mark Gertler and John Leahy, 2006), have also been used and generate Phillips curves (very) similar

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[1] For instance, see **Apel, Mikael; Friberg, Richard and Hallsten, Kerstin.** "Microfoundations of Macroeconomic Price Adjustment: Survey Evidence from Swedish Firms." *Journal of Money, Credit, and Banking*, 2005, *37*(2), pp. 313-38.

to those generated from the Calvo model. Let us now look closer at the basic model, in which consumer behavior is the same as in the classical model.

Firms in the basic Keynesian model

There is a continuum of firms indexed by $i \in [0,1]$. Each firm produces a differentiated good and they use the same technology, given by the production function

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

They face the demand curves

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

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

Each firm resets 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 in this case is actually 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

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

Dividing both sides by P_{t-1} yields

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

describes the aggregate price dynamics, and the rate of inflation is defined by $\prod_t \equiv \frac{P_t}{P_{t-1}}$ 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 a steady state with zero inflation, $\prod = 1, \pi = 0$, $P_t^* = P_{t-1} = P_t$. A log-linear approximation to the aggregate price index around that steady state yields

$$\pi_t = (1-\theta)(p_t^* - p_{t-1}) \tag{3}$$

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*, from t to t+k. The firm solves the problem

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} \left(P_t^* Y_{t+k|t} - \psi_{t+k}(Y_{t+k|t}) \right) \right\} \quad (4)$$

subject to the sequence of demand constraints

$$Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} C_{t+k} \quad (5)$$

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[2]. $\psi(.)$ is the cost function. The first order condition is

$$\sum_{t=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} Y_{t+k|t} \left(P_t^* - \mathrm{M} \psi_{t+k|t} \right) \right\} = 0 \quad (6)$$

where $\psi_{t+k|t} \equiv \psi'_{t+k} \left(Y_{t+k|t} \right)$ is the nominal marginal cost in period t+k for a firm which last reset their price in period t and $M = \dfrac{\varepsilon}{\varepsilon - 1}$ is the markup, depending on the constant price elasticity of demand. In the case there is no price rigidity, $\theta = 0$, (6) becomes $P_t^* = \mathrm{M} \psi_{t|t}$, and this implies that M can be interpreted as the desired markup in the case of flexible prices, or the "flex-price markup".

Solving the problem yields

$$p_t^* = \mu + (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t \left\{ mc_{t+k|t} + p_{t+k} \right\} \quad (7)$$

where $mc_{t+k|t}$ is the real marginal cost, i.e. $mc_t = -\mu_t$ and $\mu_t = \log M_t$, 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 nominal 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

$$\pi_t = \beta E_t \left\{ \pi_{t+1} \right\} + \lambda \left(mc_t - mc \right) \quad (8)$$

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

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[2] The interpretation might be easier if we take logs, i.e. $\log Q_{t+k|t} = -\left(k\rho + \sigma \Delta c_{t+k} \right) + \pi_{t+k}$ where ρ we know as a small positive number and the $Q_{t+k|t}$ something like 0.99 for a price expected to change 3 quarters ahead.

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

(8) can also be expressed as

$$\pi_t = \lambda \sum_{t=0}^{\infty} \beta^k E_t \{mc_{t+k} - mc\} \tag{9}$$

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, i.e. when current markups are low. Note that this is counterintuitive, inflation is high when markups are low, and depends on the forward-looking behavior.

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 the Phillips curve. We now have

$$\pi_t = \gamma + \beta E_t\{\pi_{t+1}\} + \kappa\left(y_t - y_t^n\right) \tag{10}$$

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, see (Jordi Gali, 2008), for a closed economy without a 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

$$Y_t = C_t \tag{11}$$

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 (11) to derive

$$y_t = E_t\{y_{t+1}\} - \frac{1}{\sigma}\left(i_t - E_t\{\pi_{t+1}\} - \rho\right) \tag{12}$$

which is sometimes called the dynamic IS curve.[3] It is based on forward-looking behavior on behalf of the consumers and producers. (12) can be rewritten in terms of the output gap as

$$y_t = y_t^n - \frac{1}{\sigma}\left(i_t - E_t\left\{\pi_{t+1}\right\} - r_t^n\right) + E_t\left\{y_{t+1} - y_{t+1}^n\right\} \tag{12'}$$

Under the assumption that the last term in (12') in the long run approaches zero, then (12') can be solved forward to yield

$$y_t = y_t^n - \frac{1}{\sigma}\sum_{k=0}^{\infty}\left(r_{t+k} - r_{t+k}^n\right) \tag{12''}$$

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 (10) and (12') 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 and independent of the real part of the economy. With price rigidities as 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 (12').

Monetary policy in the basic model – a preliminary view

We know that since prices now are sticky, monetary policy will have real effects. From the 3-equation model in (Wendy Carlin and David Soskice, 2006) we derived an optimal monetary policy rule as

$$i_t = \rho + \phi_\pi \pi_t + \phi_y\left(y_t - y_t^n\right) + v_t \tag{13}$$

but with $\rho = r_s$ and $v_t = 0$ and with ϕ_π and ϕ_y derived in the model and being functions of the parameters in the model (central bank preferences and price flexibility parameter). We can think of v_t as a stochastic shock with zero mean. We now study the simulations performed by (Jordi Gali, 2008) with this model. He chose $\phi_\pi = 1.5 \text{ and } \phi_y = 0.125$ which were consistent with observed values for the US economy under the Greenspan era. These values plus

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[3] Note that the Euler equation $c_t = E_t\left\{c_{t+1}\right\} - \frac{1}{\sigma}\left(i_t - E_t\left\{\pi_{t+1}\right\} - \rho\right)$ can be rewritten as

$c_{t+1} = c_t + \frac{1}{\sigma}\left(i_t - E_t\left\{\pi_{t+1}\right\} - \rho\right) + u_{t+1}$ assuming $c_{t+1} = E_t\left\{c_{t+1}\right\} + u_{t+1}$ with u_{t+1} being an unpredictable stochastic error variable with zero mean (or the unexpected consumption in t+1). The equation then shows how the optimizing consumer updates the consumption level as a resonse to news appearing in period t+1, but unknown in period t. The best guess is $E_t\left\{u_{t+1}\right\} = 0$.

$\beta < 1 \simeq 0.99$
$\rho \equiv -\log \beta \simeq 0.01$
$\sigma \simeq 1$
$\varphi \simeq 1$
$\alpha \simeq 0.33$
$\varepsilon = 6$
$\psi_{na} = 0$
$\upsilon_n = -0.2$
$\psi_{ya} = 1$
$\upsilon_y = -0.13$

for the other parts of the model showed the simulation results below for a monetary policy shock, a change in v_t. The monetary policy shocks were assumed to follow the time series process

$$v_t = \rho_v v_{t-1} + \varepsilon_t^v$$

where ρ_v is a persistence parameter. If ρ_v is close to unity, a shock in ε_t^v will have very long lasting

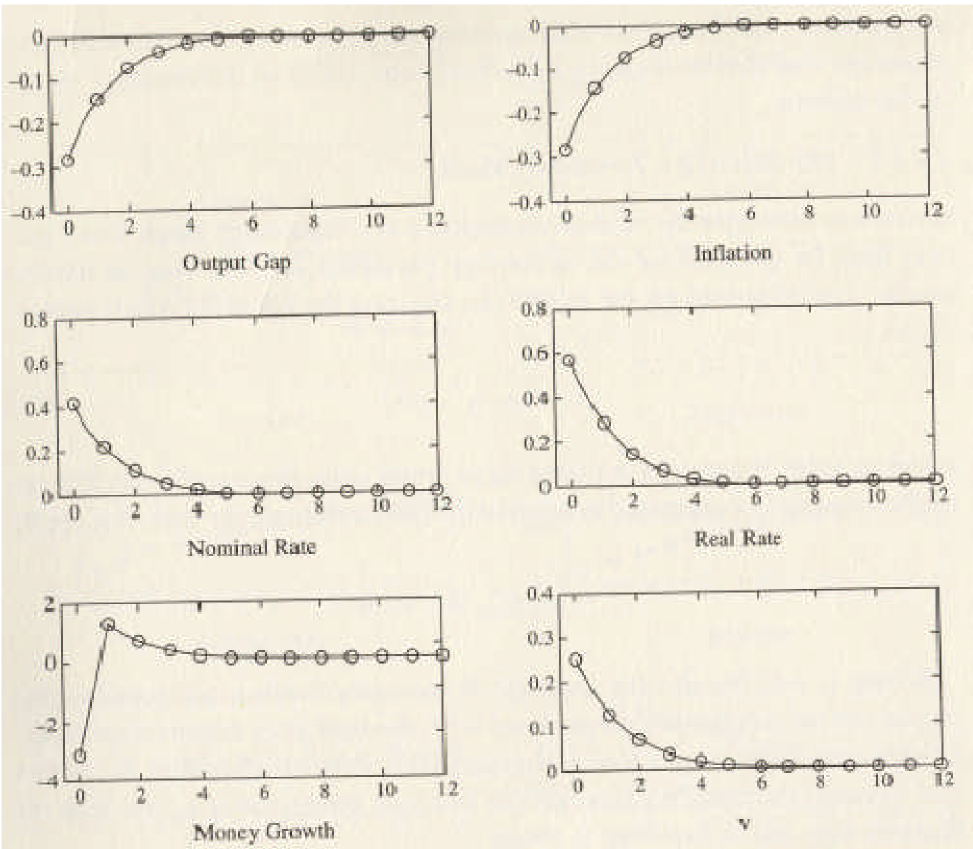

Diagram 1. The effects of a monetary policy shock. Source: (Jordi Gali, 2008)

effects. The value is here set to $\rho_v = 0.5$ which implies a moderate persistence. The size of the shock in ε_t^v corresponded to an increase of one percentage unit in the nominal interest rate, i.e. a contraction in monetary policy. The demand for money function

$$m_t - p_t = y_t - \eta i_t$$

is applied with the demand for money elasticity set to 4. As can be seen, the effects fades away after 6 quarters, as shown in diagram 1. The output gap and inflation is reduced by initially about 0.3 percentage points. The decrease in the output gap is due to the decrease in actual output rather than in the potential output since the latter is unaffected by monetary policy (compare with the classical model).

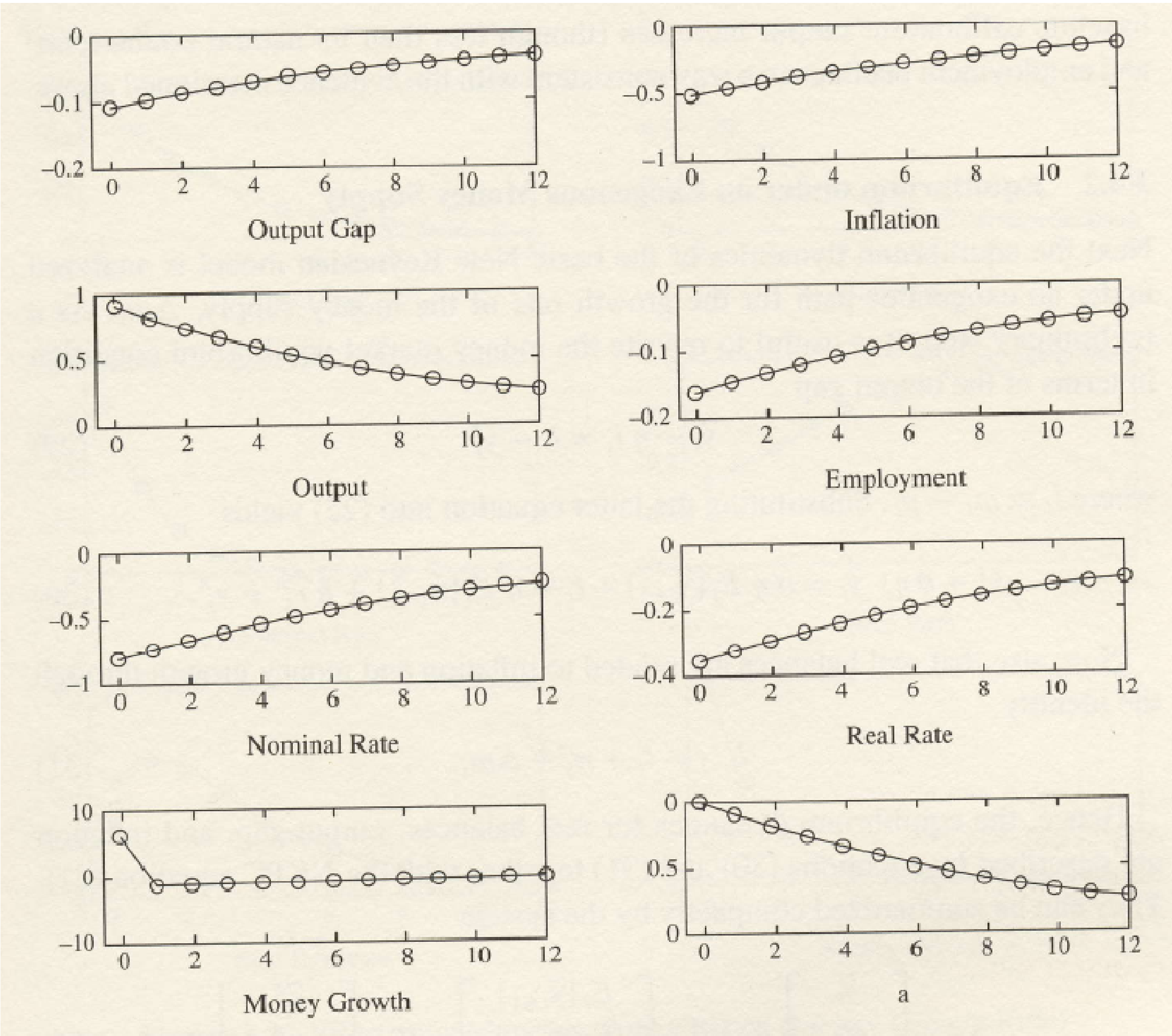

Diagram 2. The effects of a technology shock. Source: (Jordi Gali, 2008).

Note that the nominal rate of interest increases by less than the shock value, which is due to the initial impact on inflation and the output gap. The rise in the interest rate accordingly decreases the rate of money growth.

In diagram 2 the effects of a technology shock are shown. Again, the technology shocks are assumed to follow the process

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a$$

but be more persistent with $\rho_a = 0.9$. In this case, the potential output is affected but the effects on employment and output ambiguous and depending on the parameter values, particularly the value of σ. The effects on employment may increase, decrease or be unaffected ($\sigma = 1$).

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