Price Resetting and Inertia*

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Abstract

The Calvo scheme represents the standard specification of price resetting in the NK model. We show that using this rather than a fixed duration (Taylor) scheme matters importantly for the dynamics of the model as it allows it to generate output inertia without an "excessive" price stickiness.

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Introduction

In spite of its great popularity, the standard New Keynesian (NK) model has many important empirical flaws. The most important ones concern inflation and output dynamics (Mankiw and Reis, 2002).

This failure has motivated a search for more successful specifications. A popular remedy is to introduce either myopic (Gali and Gertler, 1999) or backward looking agents (Christiano eta al., 2005). The assumption of myopia or backward price indexation in combination with real rigidities can produce inertia in inflation and output. Both schemes are controversial.

Collard and Dellas, 2005, dissect the NK in order to identify the features that are responsible for the model's ability to produce inertial behavior. Their focus is the various real rigidities as well as the price resetting rule. While their analysis is quite comprehensive, it does not investigate the role played by the price resetting scheme, namely, whether it involves random (Calvo) or fixed (Taylor) duration. The main differences between these schemes is that *all* firms adjust their prices periodically under the latter. Under the former, there is a subset of the firms that is stuck in a time warp. Collard and Dellas's omission is due to the widely held presumption that the business cycle properties of the NK model are roughly invariant to the type of the updating scheme. And the observed preference for the Calvo scheme owes to its greater tractability.

In this paper we show that this presumption is not valid. Random vs fixed duration may not matter for the model's ability to generate plausible inflation dynamics. But it matters for obtaining inertia in output, at least for empirically plausible levels of price stickiness.

1 The Model

1.1 The Household

Household preferences are given by:[1]

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau} \left[\log(c_{t+\tau} - \vartheta c_{t+\tau-1}) + \frac{\nu^m}{1-\sigma_m} \left(\frac{M_{t+\tau}}{P_{t+\tau}} \right)^{1-\sigma_m} - \frac{\nu^h}{1+\sigma_h} h_{t+\tau}^{1+\sigma_h} \right] \tag{1}$$

where $0 < \beta < 1$ is a constant discount factor, c is consumption, M/P is real balances and h is the work effort. ϑ is the habit persistence parameter.

The budget constraint is

$$E_t B_{t+1} Q_t + M_t + P_t(c_t + i_t + z(u_t)k_t) = B_t + M_{t-1} + P_t v_t u_t k_t + W_{jt} h_{jt} + \Omega_t + \Pi_t \tag{2}$$

[1] $E_t(.)$ denotes mathematical conditional expectations. Expectations are conditional on information available at the beginning of period t.

where W_t is the real wage; P_t is the nominal price of the domestic final good; c_t is consumption and i is investment expenditure; k_t is the amount of physical capital owned by the household and leased to the firms at the real rental rate v_t. Only a fraction u_t of the capital stock is utilized in any period. M_{t-1} is the amount of money that the household brings into period t, and M_t is the end of period t money holdings. N_t is a nominal lump–sum transfer received from the monetary authority; T_t is the lump–sum taxes paid to the government and used to finance government consumption. The capital stock evolves according to

$$k_{t+1} = \left(1 - \Phi\left(\frac{i_t}{i_{t-1}}\right)\right) i_t + (1-\delta)k_t \tag{3}$$

where $\delta \in [0,1]$ denotes the rate of depreciation. We assume that $\Phi(\cdot)$ satisfies $\Phi(1) = \Phi'(1) = 0$ and $\varphi = \Phi''(1) > 0$. This investment adjustment cost specification is the one used by Christiano et al., 2005.

1.2 Final sector

The final good is produced by combining intermediate goods according to the CES function

$$y_t = \left(\int_0^1 y_t(i)^\theta \mathrm{d}i\right)^{\frac{1}{\theta}} \tag{4}$$

where $\theta \in (-\infty, 1)$. θ determines the elasticity of substitution between the various inputs. The producers in this sector are assumed to behave competitively.

1.3 Intermediate goods producers

Each firm i, $i \in (0,1)$, produces an intermediate good using capital and labor according to

$$y_t(i) = \begin{cases} A_t(u_t(i)k_t(i))^\alpha h_t(i)^{1-\alpha} - \Psi & \text{if } A_t(u_t(i)k_t(i))^\alpha h_t(i)^{1-\alpha} \geqslant \Psi \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

where $\alpha \in (0,1)$. $u_t(i)k_t(i)$ and $h_t(i)$ respectively denote capital and labor inputs. A_t is an exogenous stationary stochastic technology shock. $\Psi > 0$ denotes the fixed cost of production. We assume that each firm i operates under perfect competition in the input markets but is monopolistically competitive in the goods market and therefore sets the price for the good it produces. We consider two alternatives: Prices are set according to the random duration scheme á la Calvo. Or, prices are set according to the fixed duration scheme á la Taylor. That is, a fraction of the firms set their prices for a *fixed* number of periods

We now describe the pricing decisions under the random and fixed duration schemes (á la Calvo and Taylor respectively).

1.3.1 Random Duration

Following Calvo, we assume that in each and every period, a firm either gets the chance to adjust its price (with probability γ) or it does not. If it does not get the chance, then it sets its price according to

$$P_{it} = \xi_t P_{it-1} \tag{6}$$

Following Christiano et al., 2005, we assume that the non-optimizing firms index their prices to the lagged, aggregate rate of inflation ($\xi_t = \pi_{t-1}$).

A firm i that sets its price optimally in period t, chooses $P_t^\star$

$$P_t^\star = \frac{1}{\theta} \frac{\mathbb{E}_t \sum_{\tau=0}^{\infty} (1-\gamma)^\tau \Phi_{t+\tau} P_{t+\tau}^{\frac{2-\theta}{1-\theta}} \Xi_{t,\tau}^{\frac{1}{\theta-1}} \psi_{t+\tau} y_{t+\tau}}{\mathbb{E}_t \sum_{\tau=0}^{\infty} (1-\gamma)^\tau \Phi_{t+\tau} \Xi_{t,\tau}^{\frac{\theta}{\theta-1}} P_{t+\tau}^{\frac{1}{\theta-1}} y_{t+\tau}} \tag{7}$$

where ψ is real marginal cost, P is the aggregate price index, $\Phi_{t+\tau}$ is an appropriate discount factor derived from the household's optimality conditions and

$$\Xi_{t+\tau} = \begin{cases} \prod_{\ell=0}^{\tau-1} \xi_{t+\ell} & \text{for } \tau \geqslant 1 \\ 1 & \tau = 0 \end{cases}$$

In each period, a fraction γ of contracts ends and $(1-\gamma)$ survives. The aggregate price level is

$$P_t = \left(\gamma P_t^{\star \frac{\theta}{\theta-1}} + (1-\gamma)(\xi_t P_{t-1})^{\frac{\theta}{\theta-1}} \right)^{\frac{\theta-1}{\theta}} \tag{8}$$

1.3.2 Fixed Duration

We assume that intermediate producers set prices for N periods of time in a staggered fashion. In each and every period, a fraction $1/N$ of producers chooses a new optimal price $P_t^\star(i)$. During the following $N-1$ periods this price evolves according to

$$P_{it} = \xi_t P_{it-1} \tag{9}$$

with either $\xi_t = \overline{\pi}$ or $\xi_t = \pi_{t-1}$ as in the Calvo case above.

The ntermediate producers are indexed so that producers $i \in [0, 1/N]$ set new prices in 0, N, $2N$, ..., those indexed by $i \in [1/N, 2/N]$ set prices in 1, $N+1$, $2N+1$, ... Prices are set so as to maximize the expected sum of discounted profits from period t to period $t+N-1$, that is

$$\mathbb{E}_t \sum_{\tau=0}^{N-1} \Phi_{t+\tau} \left(P_t^\star(i) \Xi_{t,\tau} - P_{t+\tau} s_{t+\tau} \right) y_{t+\tau}(i)$$

subject to the total demand it faces

$$y_{t+\tau}(i) = \left(\frac{\Xi_{t,\tau}P_t^\star(i)}{P_{t+\tau}}\right)^{\frac{1}{\theta-1}} y_{t+\tau}$$

where $\Phi_{t+\tau}$ is an appropriate discount factor. The optimal price is

$$P_t^\star(i) = P_t^\star = \frac{1}{\theta}\frac{\mathbb{E}_t \sum_{\tau=0}^{N-1} \Phi_{t+\tau}\Xi_{t,\tau}^{\frac{1}{\theta-1}} P_{t+\tau}^{\frac{\theta-2}{\theta-1}} s_{t+\tau}y_{t+\tau}}{\mathbb{E}_t \sum_{\tau=0}^{N-1} \Phi_{t+\tau}\Xi_{t,\tau}^{\frac{\theta}{\theta-1}} P_{t+\tau}^{\frac{-1}{\theta-1}} y_{t+\tau}} \tag{10}$$

Price setting is independent of specific firm characteristics, hence all firms choose the same price. From (??), the aggregate price index is given by

$$P_t = \left(\frac{1}{N}\sum_{\tau=0}^{N-1}(\Xi_{t-\tau,\tau}P_{t-\tau}^\star)^{\frac{\theta}{\theta-1}}\right)^{\frac{\theta-1}{\theta}} \tag{11}$$

1.4 The monetary authorities

Monetary policy follows an exogenous money supply rule

$$M_{t+1} = M_t + \Omega_t \tag{12}$$

where Ω_t evolves according to

$$\Omega_t = (\mu_t - 1)M_t$$

μ_t is the -exogenous- gross growth rate of the money supply.

2 Parametrization

The model is parameterized on US quarterly data for the post WWII period. The data are taken from the Federal Reserve Database.[2] The parameters are reported in table 1.

The parametrization of preferences follows Christiano et al., 2005. More precisely, we set $\vartheta = 0.65$, $\sigma_h = 1$ and $\sigma_m = 10.62$. ν_h is set such that the model generates a total fraction of time devoted to market activities of 31%. The value of ν_m is selected such that the model reproduces the average ratio of M1 money to nominal consumption expenditures. The nominal growth of the economy, $\overline{\mu}$, is set such that the average quarterly rate of inflation over the period is $\overline{\pi} = 1.2\%$ per quarter. The capital utilization function $z(u_t)$ satisfies $z(1) = 0$, $z''(1)/z'(1) = \sigma_z$. We use the value $\sigma_z = 0.01$. We also set $\varphi = 2.5$.

[2]URL: http://research.stlouisfed.org/fred/

Table 1: Calibration: Benchmark case

Discount factor	β	0.988
Inverse labor supply elasticity	σ_h	1.00
Habit persistence	ϑ	0.65
Elasticity of money in the utility function	σ_m	10.62
Capital elasticity of intermediate output	α	0.232
Adjustment costs parameter	φ	2.500
Depreciation rate	δ	0.025
Capital utilization	σ_z	0.01
Parameter of markup	θ	0.833
Length of price stickiness	N	2 to 8
Probability of optimal price resetting	γ	0.5 to 0.125
Shocks and policy parameters		
Persistence of money growth	ρ_m	0.500
Volatility of money shock	σ_m	0.009
Steady state money supply growth (gross)	μ	1.012

Gross money growth takes the form

$$\mu_t = (1 - \rho_m)\overline{\mu} + \rho_m \mu_{t-1} + \epsilon_{mt}$$

where $|\rho_m| < 1$, $\overline{\mu} = E(\mu_t)$ and ϵ_{mt} is iid. This is Mankiw and Reis' parametrization.

3 Results

We focus on the most important stylized facts that have been singled out by Mankiw and Reis, 2002, in their attempt to establish the good performance of the sticky information model. Mankiw and Reis study the IRFs of output and inflation to a one–standard-deviation policy shock.

Figure 1 reports the response of inflation and output to a money supply shock under the random and fixed duration scheme respectively. The response of inflation exhibits a hump shape under both schemes. Importantly, the model does not require an excessive amount of price rigidity in order to produce inflation inertia (the hump). A frequency of resetting of four quarters suffices. The picture is different at the output front. The Calvo scheme can generate a –small[3]– hump under a plausible degree of price stickiness (four quarters). This is not true for the fixed duration scheme as a hump first appears when the frequency of price resetting is set to six periods. It thus appears that the random duration helps the sticky price model with regard to output inertia in

[3]Note that we are using all the important real rigidities identified by Christiano et al., 2005. Adding sticky wages and expenditure lags does not solve the problem.

the sense that it makes it possible to produce a hump with a plausible degree of nominal rigidity (four quarters vs six for the fixed duration). While this improvement may appear small, it is quite critical because an average, aggregate price stickiness of four quarters represents an upper limit of acceptable values that can be supported by the existing micro evidence.

4 Conclusions

We have examined whether the assumption of random duration plays a critical role in the model of sticky *prices*. The answer is rather yes. The model of sticky prices has no difficulty generating a hump in inflation under fixed duration pricing, as long as the model also includes backward price indexation. But in order to produce a hump in output, it requires *more* price rigidity than its corresponding random duration version. For the commonly used value of four quarters, the Taylor scheme fails to generate sufficient inertia, in spite of the inclusion of several real rigidities (while the Calvo scheme *does*). Hence, the use of random duration pricing is not innocuous.

References

Chari, V., Patrick Kehoe and Ellen McGrattan, 2000, "Sticky Price Models of the Business Cycle: The Persistence Problem," Econometrica 68:5, 1151-1179.

Christiano, Lawrence, Charles Evans, and Martin Eichenbaum, 2005, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," Journal of Political Economy, 113 (1),1-45.

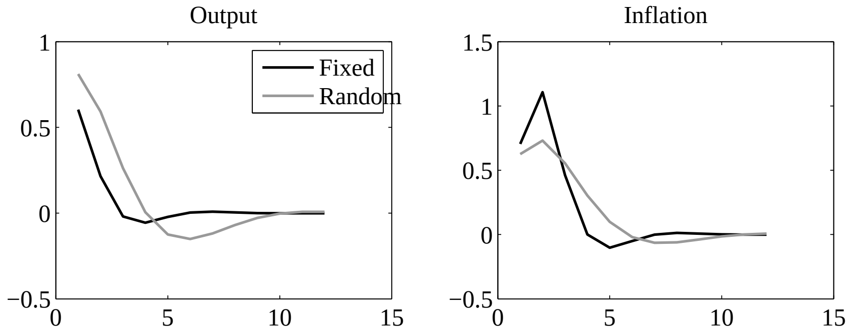
Collard, Fabrice and Harris Dellas, 2005, "Dissecting the New Keynesian Model," mimeo.

Gali, Jordi and Mark Gertler, 1999, "Inflation Dynamics: A Structural Econometric Analysis," Journal of Monetary Economics, 44(2), 195-222.

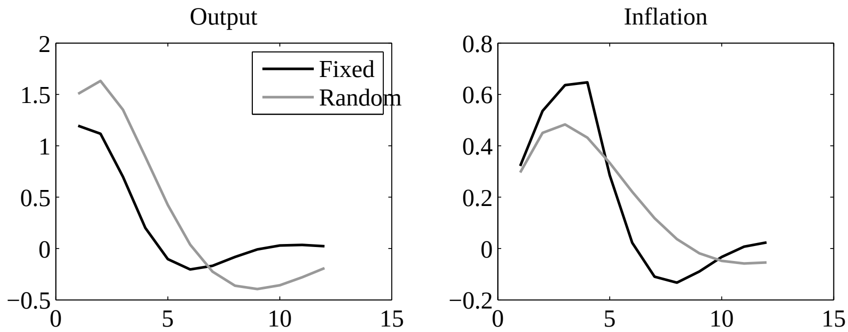
Mankiw, Gregory, and Ricardo Reis, 2002, "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve," Quarterly Journal of Economics, 1295–1328.

Figure 1: Fixed (Taylor) vs Random (Calvo) Resetting

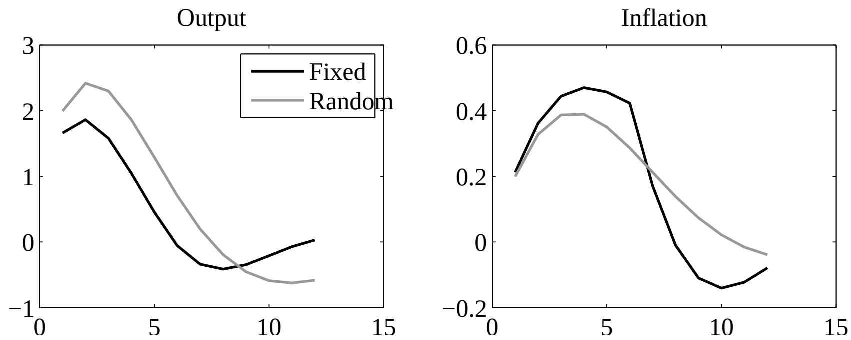
(a) 2 periods



(b) 4 periods



(c) 6 periods



(d) 8 periods