Inflation Persistence and the Phillips Curve Revisited

Marika Karanassou
Queen Mary, Universtity of London*
and IZA

Dennis J. Snower
Kiel Institute for the World Economy†
Christian-Albrechts-University and CEPR

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Abstract

A major criticism of staggered nominal contracts in New Keynesian models is that they give rise to the so called "persistency puzzle" - although they generate price inertia, they cannot account for the stylised fact of inflation persistence. It is thus commonly asserted that, in the context of the new Phillips curve (NPC), inflation is a jump variable. This paper calls this persistency puzzle into question, showing that it rests on two inappropriate assumptions: a zero discount rate and the exogeneity of the forcing variable (e.g. output gap, marginal costs, unemployment rate). We show that when the discount rate is positive in a general equilibrium setting (in which real variables not only affect inflation, but are also influenced by it), standard wage-price staggering models can generate both substantial inflation persistence and a nonzero inflation-unemployment tradeoff in the long-run.

Keywords: Inflation dynamics, persistence, wage-price staggering, new Phillips curve, monetary policy, frictional growth.

JEL Classifications: E31, E32, E42, E63.

*Department of Economics, Queen Mary, University of London, Mile End Road, London E1 4NS, UK; tel.: 020 7882-5090; email: M.Karanassou@qmul.ac.uk

†President, Kiel Institute for the World Economy, Düsternbrooker Weg 120, 24105 Kiel, Germany; tel: + 49 431 8814 235; email: d.snower@ifw-kiel.de

1 Introduction

A common criticism of staggered nominal contracts in New Keynesian models is that, although they can account for price inertia, they do not generate inflation inertia. This "persistency puzzle"[1] - that the New Phillips Curve (NPC) cannot account for the inflation inertia implied by the empirical evidence - has received much attention in the recent literature. In their influential paper, Fuhrer and Moore (1995) argued that there is no inflation persistence independent of the persistence in the shocks. The seminal contributions of Phelps (1978) and Taylor (1980a) imply that inflation responds instantaneously to exogenous macroeconomic shifts - hence the jargon "inflation is a jump variable". The "persistency puzzle" is widely recognised as a deficiency of the new Phillips curve (NPC) that rests on the nominal contracting model; it cannot account for the high degree of inflation persistence commonly described by the empirical evidence. This insight has spawned a large literature that attempts to provide new explanations for inflation persistence (Blanchard and Gali (2005), and Mankiw and Reis (2002) are two prominent recent examples).[2]

This paper calls the persistency puzzle into question. We show that (i) in the context of standard stochastic, dynamic general equilibrium systems, inflation is not a jump variable when (plausibly) the discount rate is positive, there is nominal inertia, and inflation and unemployment are both endogenous variables responding to monetary shocks, and (ii) the jump-variable characteristic of inflation occurs when the discount rate is zero but, in that case, there is (implausibly) also no short-run tradeoff between inflation and unemployment. Our analysis indicates that the standard versions of the contract model can generate substantial inflation persistence (i.e. inflation persistence is an inherent feature of wage/price staggering). It also shows that the cumulative amount of inflation undershooting and overshooting is intimately related with the inflation-unemployment tradeoff in the long-run.

Our intuitive argument may be summarised as follows. The NPC postulates that current inflation depends linearly on expected future inflation and some real variable, x_t, such as output, the output gap, real marginal costs, or the unemployment rate: $\pi_t = \beta E_t \pi_{t+1} + a x_t$, where π_t is inflation, x_t is the real variable, β is the discount factor ($\beta = 1/(1+r)$, and r is the interest rate. From this, it is commonly inferred that there is no inflation persistence independent of the persistence in x_t. After all, a one-period shock to x_t affects inflation for only one period. For this argument to hold, the real variable x_t must be viewed as exogenous. But in the context of all reasonable macro models

[1] See, for example, Westelius (2005) for this nomenclature.

[2] See also Christiano, Eichenbaum, and Evans (2001), Dotsey, King, and Wolman (1997), Estrella and Fuhrer (1998), Galí, Gertler, and López-Salido (2001), Huang and Liu (2001), Roberts (1997), and many others.

of the Phillips curve, x_t is not exogenous. Rather, inflation and, say, unemployment are both endogenous. Commonly, unemployment depends, among other things, on real money balances (or some other relation between money and a nominal variable). And real money balances, in turn, depend on prices, whose evolution is given by the inflation rate. Once the influence of inflation on unemployment is taken into account in a general equilibrium context, it can be shown that inflation recovers only gradually from temporary shocks and does not respond instantaneously to permanent shocks.

The paper is organised as follows. Section 2 gives a short overview of the persistency puzzle. Section 3 derives the inflation dynamics implied by the workhorse model of the NPC, first under a temporary money growth shock, and then under a permanent one. The associated impulse response functions and measures of persistence are also obtained. Section 4 derives the slope of the Phillips curve and shows that it is intimately related to inflation undershooting. Section 5 extends the workhorse model of the NPC in various standard ways. Section 6 presents an overview of our analysis. Finally, Section 7 concludes.

2 A Quick Overview of the Persistency Puzzle

In its simplest form, price staggering assumes that nominal wages are fixed for two periods and there are two contracts that are evenly staggered. Then the current price level P_t depends on past and expected future prices, as well as the real variable x_t (standing for the output gap, the wage share, the unemployment rate, etc.):

$$P_t = \alpha P_{t-1} + (1-\alpha) E_t P_{t+1} + \gamma x_t, \tag{1}$$

where the price level P_t is set at the beginning of period t for periods t and $t+1$, and $E_t(\cdot)$ is the expectation of the variable conditional upon information available at time t. (All variables are in logs.) The demand sensitivity parameter γ describes how strongly prices are influenced by the "forcing" variable x_t. The coefficient α is a discounting parameter, $\alpha = \frac{1}{1+\beta}$.

This price setting equation implies the following New Phillips Curve:[3]

$$\pi_t = \beta E_t \pi_{t+1} + \gamma (1+\beta) x_t, \tag{2}$$

where inflation (π_t) is the first difference of the log price level, $\pi_t \equiv P_t - P_{t-1}$. To derive the result of Fuhrer and Moore (1995, p. 129) that 'All of the persistence in inflation derives from the persistence in the driving term', we use recursive substitution

[3]To obtain the New Keynesian Phillips curve (2), subtract from both sides of the price-setting eq. (1) (i) P_{t-1} to get $\pi_t - (1-\alpha) P_{t-1} = (1-\alpha) E_t P_{t+1} + \gamma x_t$, and (ii) $(1-\alpha) P_t$ so that $\alpha \pi_t = (1-\alpha) E_t \pi_{t+1} + \gamma x_t$.

and express equation (2) as

$$\pi_t = \gamma (1+\beta) \sum_{j=0}^{\infty} \beta^j E_t x_{t+j}. \tag{3}$$

The above equation shows that a one-off change in the driving force variable in period t cannot affect inflation beyond that period. This explains the conventional view that inflation is a jump variable in the NPC, i.e. following a permanent increase in money growth at period t, inflation jumps up to its new long-run value.

This view, however, relies crucially on the assumption that the real variable x_t is exogenous. Although some recent studies (e.g. Mankiw and Reis (2002)) acknowledge the endogeneity of the "forcing" variable x_t, and, thus, the persistent inflation effects of a temporary shock, they still hold the view that inflation behaves as a jump variable when the shock is permanent. In other words, the NPC generates inflation persistence when the shock is temporary, but not permanent. We show that this result rests on the assumption of a zero discount rate.

When the discount rate is zero, i.e. the discount factor is unity, equal weights are attached to the backward- and forward-looking components of the wage/price contract underlying the NPC. By contrast, a positive discount rate is associated with "intertemporal weighting asymmetry" in pricing behaviour, in the sense that a larger weight is attached to the backward-looking component than to the forward-looking one. Yet since the discount factor is close to unity in actual terms, the conventional wisdom dismisses the intertemporal weighting asymmetry as mere theoretical nicety. However, we show that for plausible parameter values, the intertemporal weighting asymmetry leads to inflation undershooting and a nonvertical Phillips curve in the long-run.[4] This is because a positive (albeit low) discount rate generates an interplay between nominal staggering and permanent money growth changes: prices chase after a moving target (the flexible-price equilibrium), but due to the intertemporal weighting asymmetry, they never catch up with this target. This phenomenon we call *frictional growth*.

3 Inflation Dynamics

In what follows we show that the interaction of the intertemporal weighting asymmetry and the endogeneity of the "forcing" variable plays a crucial dual role: (i) it generates inflation persistence, i.e. inflation is not a jump variable, and (ii) it gives rise to a long-run tradeoff between inflation and unemployment.

[4] Note that our analysis, in line with the NPC literature, contains no money illusion, no permanent nominal rigidities, and no departure from rational expectations.

In the standard macro models, output (unemployment rate) usually depends positively (negatively) on real money balances. So, for simplicity, we write:

$$x_t = M_t - P_t, \tag{4}$$

where M_t denotes the money supply. Substituting this equation into equation (1), we obtain the following price equation:[5]

$$P_t = \phi P_{t-1} + \theta E_t P_{t+1} + \left(\frac{\gamma}{1+\gamma}\right) M_t, \tag{5}$$

where $\phi = \frac{\alpha}{1+\gamma}$, $\theta = \frac{1-\alpha}{1+\gamma}$. The corresponding inflation equation is[6]

$$\pi_t = \phi \pi_{t-1} + \theta E_t \pi_{t+1} + \left(\frac{\gamma}{1+\gamma}\right) \mu_t + \theta v_t, \tag{6}$$

where $\mu_t \equiv M_t - M_{t-1}$ is the money growth rate and $v_t = P_t - E_{t-1}P_t$ is an expectational error.[7]

In this equation, current inflation depends on past inflation, as well as on expected future inflation, and thus the possibility of inflation persistence reemerges. The degree of persistence is of course related to the stochastic process generating the money supply. To analyse the inflation dynamics, it is convenient to rewrite the price equation (5) as[8]

$$P_t = \lambda_1 P_{t-1} + \frac{\gamma}{\lambda_2 (1-\alpha)} \sum_{j=0}^{\infty} \left(\frac{1}{\lambda_2}\right)^j E_t M_{t+j}, \tag{7}$$

where λ_1 and λ_2 are the roots of equation (5):

$$\lambda_{1,2} = \frac{1 \mp \sqrt{1-4\phi\theta}}{2\theta} = \frac{1 \mp \sqrt{1 - 4\frac{\alpha(1-\alpha)}{(1+\gamma)^2}}}{2\left(\frac{1-\alpha}{1+\gamma}\right)}, \tag{8}$$

[5] To derive this equation, observe that $P_t = \alpha P_{t-1} + (1-\alpha) E_t P_{t+1} + \gamma (M_t - P_t) \Rightarrow P_t = \left(\frac{\alpha}{1+\gamma}\right) P_{t-1} + \left(\frac{1-\alpha}{1+\gamma}\right) E_t P_{t+1} + \left(\frac{\gamma}{1+\gamma}\right) M_t$.

[6] To derive the inflation equation, lag eq. (5) once: $P_{t-1} = \phi P_{t-2} + \theta E_{t-1} P_t + \left(\frac{\gamma}{1+\gamma}\right) M_{t-1}$, and subtract it from (5) to get $\pi_t = \phi \pi_{t-1} + \theta E_t P_{t+1} - \theta E_{t-1} P_t + \left(\frac{\gamma}{1+\gamma}\right) \mu_t$. Now add and subtract θP_t on the right-hand side of the above to obtain the inflation staggered equation in terms of the *exogenous* growth rate of money: $\pi_t = \phi \pi_{t-1} + \theta E_t \pi_{t+1} + \left(\frac{\gamma}{1+\gamma}\right) \mu_t + \theta (P_t - \theta E_{t-1} P_t)$.

[7] The error term $v_t = P_t - E_{t-1}P_t$ is included in Roberts (1995, 1997), but ignored by Fuhrer and Moore (1995) and much of the subsequent literature. It can be shown that, in the above price staggering model, this error term does not affect the dynamic structure of inflation; it only rescales its impulse response function to a temporary monetary shock.

[8] To see this, write (5) as $(1-\lambda_1 B)(1-\lambda_2 B) E_t P_t = \frac{-\gamma B M_t}{(1-\alpha)}$, where B is the backshift operator. This gives $(1-\lambda_1 B) E_t P_t = \frac{\gamma}{\lambda_2(1-\alpha)} \sum_{j=0}^{\infty} \left(\frac{1}{\lambda_2}\right)^j E_t M_{t+j}$ which leads to (7) since $E_t P_t = P_t$.

and $0 < \lambda_1 < 1$ and $\lambda_2 > 1$. In words, prices depend on past prices and expected future money supplies. Thus different stochastic monetary processes give rise to different price dynamics. We now consider two such processes in turn.

- A temporary money growth shock: The persistent after-affects of inflation to this temporary shock we refer to as *inflation persistence.* The greater the inflation effect after the shock has disappeared, the greater is inflation persistence.
- A permanent money growth shock: Since this shock leads to a permanent change in inflation, it is desirable to have a different name for the inflation effects. Thus the delayed inflation effects of a permanent monetary shock we call *inflation under-responsiveness.* The more slowly inflation responds to a permanent shock, the more under-responsive inflation is.

Although the persistent after-effects of a temporary money growth shock and the delayed after-effects of a permanent money growth shock are two distinct phenomena, they are, rather confusingly, both denoted by the word "persistence" in the prevailing literature.

3.1 A Temporary Money Growth Shock - Persistence

Let the money growth be stationary, fluctuating randomly around its mean (μ):

$$\mu_t = \mu + \varepsilon_t, \text{ where } \varepsilon_t \sim iid\left(0, \sigma^2\right). \tag{9}$$

A positive shock ε_t represents a temporary rise in money growth or, equivalently, a sudden, permanent increase in the money supply. The money supply is a random walk: $M_t = \mu + M_{t-1} + \varepsilon_t$, so that $E_t M_{t+j} = M_t + j\mu$, for $j \geq 0$. Substituting this last expression into the price equation (7), we obtain the closed form rational expectations solution of price:[9]

$$P_t = \lambda_1 P_{t-1} + (1 - \lambda_1) M_t + \frac{(1 - \lambda_1)}{(\lambda_2 - 1)}\mu. \tag{10}$$

The first difference of this equation yields the closed form rational expectations solution of inflation:

$$\pi_t = \lambda_1 \pi_{t-1} + (1 - \lambda_1)\mu + (1 - \lambda_1)\varepsilon_t. \tag{11}$$

(In the long-run $\pi = \mu$, i.e. there is no money illusion, as for the other models below.)

[9] The associated real money balances equation is

$$(M_t - P_t) = \lambda_1 (M_{t-1} - P_{t-1}) + \lambda_1 \mu + \lambda_1 \varepsilon_t.$$

A one-period shock to money growth $\varepsilon_t = 1$, $\varepsilon_{t+j} = 0$ for $j > 0$ (i.e. a permanent increase in the level of money supply) is associated with the following impulse response function (IRF) of inflation:

$$\mathsf{R}^{\pi}_{t+j} = \lambda_1^j (1 - \lambda_1), \; j = 0, 1, 2, ... \tag{12}$$

Thus the responses die out geometrically (recall that $0 < \lambda_1 < 1$), and the rate of decline is given by the autoregressive parameter λ_1. In this context, we measure inflation persistence (σ) as the future impact of the monetary shock to inflation, i.e. the sum of the inflation responses for all periods after the shock has occurred ($t + j$, $j \geq 1$):[10]

$$\sigma \equiv \sum_{j=1}^{\infty} \mathsf{R}^{\pi}_{t+j} = \lambda_1. \tag{13}$$

By equation (8), we see that the degree of persistence rises with the discount rate (and α) and falls with the demand sensitivity parameter γ. It can be shown that inflation has this qualitative pattern of persistence when money growth follows any stationary ARMA process.

It is worth noting that, by equation (11), the immediate impact (contemporaneous response), $1 - \lambda_1$, can also be interpreted as the short-run slope, e_{SR}, of inflation with respect to money growth. Furthermore, the total impact of this monetary shock to inflation (i.e. the sum of future responses, i.e. persistence, and contemporaneous response), in this case unity, is simply the long-run slope of inflation with respect to money growth:

$$e_{LR} = e_{SR} + \sigma. \tag{14}$$

In other words, in general, the long-run slope (or elasticity)[11] can be decomposed into the short-run slope (or elasticity) and our measure of persistence (13).

[10] Other measures of persistence are the half life of the shock, the sum of the autoregressive parameters, and the largest autoregressive root. The virtues and faults of these measures are pointed out in a recent application by Pivetta and Reis (2007).

[11] In a log-linear model the impulse response function gives the elasticities of the dependend variable through time.

3.2 A Permanent Money Growth Shock - Responsiveness

For simplicity, let money growth be a random walk:[12]

$$\mu_t = \mu_{t-1} + \varepsilon_t, \text{ where } \varepsilon_t \sim iid\left(0, \sigma^2\right). \tag{15}$$

In this case a positive one-period unit shock (ε_t) represents a permanent increase in money growth which, in the absence of money illusion, leads to a unit increase in the long-run inflation rate. Note that the case of a negative shock represents a sudden dissinflation.

By the price equation (7) and the random walk (15), we obtain the following price dynamics:[13]

$$P_t = \lambda_1 P_{t-1} + (1-\lambda_1) M_t + \left(\frac{1-\lambda_1}{\lambda_2 - 1}\right)\mu_t. \tag{16}$$

The associated closed form rational expectations solution of inflation is

$$\pi_t = \lambda_1 \pi_{t-1} + (1-\lambda_1)\mu_t + \left(\frac{1-\lambda_1}{\lambda_2 - 1}\right)\varepsilon_t. \tag{17}$$

It can be shown that the corresponding impulse response function (IRF) of inflation to the permanent unit increase in money growth is:

$$R^{\pi}_{t+j} = 1 - \lambda_1^j (1-\lambda_1)\left(\frac{2\alpha - 1}{\gamma}\right), \; j = 0, 1, 2, ... \tag{18}$$

Observe that, since λ_1 is positive and less than unity, the long-run response of inflation is $\lim\limits_{j\to\infty} R^{\pi}_{t+j} \equiv R^{\pi}_{LR} = 1$, i.e., in the long-run inflation stabilises at the new level of money growth.

In this context, we measure the persistence of inflation as the cumulative inflation effect of the money growth shock that arises because inflation does not adjust immediately to the new long-run equilibrium. As we explained above, we call this measure *inflation responsiveness* to distinguish it from the persistence of inflation that results from a temporary shock.

In particular, suppose that the economy, in an initial long-run equilibrium,[14] is perturbed by a one-period money growth shock ($\varepsilon_t = 1$, $\varepsilon_{t+j} = 0$ for $j > 0$). The inflation responsiveness is the sum of the differences through time between the inflation rate responses (18) and the new (post-shock) long-run equilibrium inflation rate. In other

[12] The qualitative conclusions of this analysis do not hinge on the random walk assumption. Any money growth process involving a permanent change in the money growth (e.g. an $I(0)$ money growth process with a change in money growth regime, or a permanent change in the monetary authority's reaction function) would do.

[13] To see this, observe that $\sum\limits_{j=0}^{\infty}\left(\frac{1}{\lambda_2}\right)^j E_t M_{t+j} = \left(\frac{\lambda_2}{\lambda_2 - 1}\right) M_t + \frac{\lambda_2}{(\lambda_2-1)^2}\mu_t$, and $\frac{\gamma}{(\lambda_2-1)(1-\alpha)} = 1 - \lambda_1$.

[14] This assumption only serves expositional simplicity.

words, inflation responsiveness is the cumulative amount of inflation undershooting and overshooting:

$$\rho \equiv \sum_{j=0}^{\infty} \left(R_{t+j}^{\pi} - 1 \right). \tag{19}$$

If inflation responds to the permanent shock by instantaneously jumping to its new long-run equilibrium, then $\rho = 0$, i.e. inflation is *perfectly responsive*.[15] In this case inflation can be described as a jump variable. If, on the other hand, the cumulative amount of undershooting exceeds the cumulative amount of overshooting, then inflation is *under-responsive* and $\rho < 0$. Finally, if the cumulative amount of overshooting exceeds the total amount of undershooting, then inflation is *over-responsive* and $\rho > 0$.

Substitution of the impulse response function (18) into the responsiveness equation (19) gives

$$\rho = -\frac{2\alpha - 1}{\gamma}. \tag{20}$$

This result shows that the workhorse NPC model (2) has the following interesting implications for inflation dynamics:

1. If the discount rate r is zero (i.e. $\beta = 1$, so that $\alpha = 1/2$), then inflation is perfectly responsive. In other words, it is a jump variable, along the same lines as in the recent literature on "inflation persistence" under staggered nominal contracts.

2. If the discount rate is positive (i.e. $\beta < 1$, so that $\alpha > 1/2$), then inflation is under-responsive. In particular, it gradually approaches its new equilibrium from below at a rate that depends on the autoregressive parameter λ_1.

As shown in Section 5, the above implications hold only for staggered price setting, but not for staggered wage setting.

It is worth emphasizing that the temporary and permanent shocks are associated with the inflation dynamics equations (11) and (17), respectively, and thus give rise to IRFs with distinct properties.[16] A summary of these properties is provided by the distinct measures of persistence and responsiveness.

Next, we show that the cumulative amount of inflation undershooting and overshooting is closely related to the slope of the long-run Phillips curve.

[15] Using the jargon of the prevailing literature, inflation displays no persistence.

[16] Note that, although (11) and (17) have identical autoregressive components and satisfy the restriction of no money illusion in the long-run, their inflation dynamics are distinct.

4 The Slope of the Phillips Curve

In order to derive the Phillips curve, we need to consider the unemployment effects of permanent changes in money growth (corresponding to different long-run inflation rates).[17]

Recall that the forcing variable x depends on real money balances ($x_t = M_t - P_t$), which (by the price equation (16)) are

$$M_t - P_t = \lambda_1 (M_{t-1} - P_{t-1}) + (1 - \lambda_1) \left(\frac{2\alpha - 1}{\gamma} \right) \mu_t. \tag{21}$$

Since the unemployment rate, u_t, is negatively related to real money balances, $u_t = -(M_t - P_t)$, we have the following closed form rational expectations solution for unemployment:

$$u_t = \lambda_1 u_{t-1} - (1 - \lambda_1) \left(\frac{2\alpha - 1}{\gamma} \right) \mu_t. \tag{22}$$

The IRF of unemployment gives the responses through time of unemployment to a permanent unit increase in money growth:

$$\begin{aligned} R^u_{t+j} &= -(1 - \lambda_1) \left(\frac{2\alpha - 1}{\gamma} \right) \sum_{i=0}^{j} \lambda_1^i \\ &= -\left(\frac{2\alpha - 1}{\gamma} \right) \left(1 - \lambda_1^{j+1} \right), \ j = 0, 1, 2, ... \end{aligned} \tag{23}$$

Note that, since λ_1 is positive and less than unity, the long-run response of unemployment is $\lim_{j \to \infty} R^u_{t+j} \equiv R^u_{LR} = -\left(\frac{2\alpha - 1}{\gamma} \right)$.

The Phillips curve tradeoff, at any point in time, is obtained by the ratio of the inflation response (18) to the unemployment response (23):

$$(\text{slope of the PC})_{t+j} = \frac{R^\pi_{t+j}}{R^u_{t+j}}, \ j = 0, 1, 2, ... \tag{24}$$

The long-run inflation-unemployment tradeoff can be derived either from (24),[18] or via the long-run solution of the unemployment dynamics equation (22):

$$u_t = -\left(\frac{2\alpha - 1}{\gamma} \right) \mu_t.$$

[17] These permanent changes may be motivated by changes in a central bank's inflation target or other policy rule.

[18] In this case we have

$$\frac{\lim_{j \to \infty} R^\pi_{t+j}}{\lim_{j \to \infty} R^u_{t+j}} \equiv \frac{R^\pi_{LR}}{R^u_{LR}} = \frac{1}{-\left(\frac{2\alpha - 1}{\gamma} \right)} = -\left(\frac{\gamma}{2\alpha - 1} \right).$$

The latter implies that the long-run Phillips curve is given by

$$\pi_t = -\left(\frac{\gamma}{2\alpha - 1}\right) u_t, \tag{25}$$

since $\pi_t = \mu_t$ in the long-run.

Observe that in the context of the workhorse NPC model (2), the slope of the long-run Phillips curve, $-\left(\frac{\gamma}{2\alpha-1}\right)$, is simply the inverse of inflation under-responsiveness (20), i.e. the inverse of the cumulative amount of inflation undershooting.

When the discount rate is zero, i.e. $\alpha = 1/2$, inflation is a jump variable (perfectly responsive, $\rho = 0$) and, thus, the Phillips curve is vertical. This is an implausible, counter-factual special case, not just because the discount rate is zero, but also because - as equation (22) shows - it is not just the long-run Phillips curve that is vertical; the short-run Phillips curve is vertical as well.

By contrast, when the discount rate is positive ($\alpha > 1/2$), inflation is under-responsive ($\rho < 0$), and the long-run Phillips curve is downward-sloping. The higher is the undershooting of inflation, the flatter the long-run Phillips curve.

As already mentioned, it is often casually asserted that, since the discount factor is close to unity in practice, the long-run Phillips curve must be close to vertical. Inspection of the long-run Phillips curve (25), however, shows this presumption to be false. As we can see, the slope of this Phillips curve depends on both the discount parameter α and demand sensitivity parameter γ. Table 1 presents the slope for various common values of α and commonly estimated values of γ.[19] It is clear that for a range of plausible parameter values the long-run Phillips curve is quite flat and, correspondingly, inflation displays significant undershooting.

Table 1: Slope of the long-run Phillips curve

			slope				
r (%)	β	α	$\gamma = 0.01$	$\gamma = 0.02$	$\gamma = 0.05$	$\gamma = 0.07$	$\gamma = 0.10$
1.0	0.990	0.502	−2.01	−4.02	−10.1	−14.1	−20.1
2.0	0.980	0.505	−1.01	−2.02	−5.05	−7.07	−10.1
3.0	0.971	0.507	−0.68	−1.35	−3.38	−4.74	−6.77
4.0	0.962	0.510	−0.51	−1.02	−2.55	−3.57	−5.10
5.0	0.953	0.512	−0.41	−0.82	−2.05	−2.87	−4.10

Our analysis calls into question the conventional view that the long-run Phillips curve is either vertical or nearly vertical and that forward-looking Phillips curves are difficult to reconcile with substantial inflation persistence. The endogeneity of the forcing variable, on one hand, and the intertemporal weighting asymmetry (due to a positive discount

[19] Taylor (1980b) estimates it to be between 0.05 and 0.1; Sachs (1980) finds it in the range 0.07 and 0.1; Gordon (1982) gives an estimate of 0.1; Gali and Gertler (1999) estimate it to be between 0.007 and 0.047; calibration of microfounded models (e.g. Huang and Liu, 2002) assigns higher values. The discount rate applies to a period of analysis which is half the contract span.

rate), on the other, can generate sufficient inflation persistence and produce an inflation-unemployment tradeoff both in the short- and long-run. This is the result of *frictional growth*, a phenomenon that, in the context of the NPC model, encapsulates the interplay of frictions (nominal staggering) and growth (permanent shocks to money growth).

Table 2 summarises the properties of the NPC model in the absence of frictional growth ($\alpha = 1/2$), and in the presence of frictional growth ($\alpha < 1/2$).

Table 2: Inflation dynamics and the slope of the NPC

	Inflation dynamics	Short-run Phillips curve	Long-run Phillips curve
$\alpha = \frac{1}{2}$	jump variable	vertical	vertical
$\alpha > \frac{1}{2}$	undershooting	downward-sloping	downward-sloping

5 Extensions

To gain some perspective on the determinants of inflation persistence and responsiveness, we now examine these phenomena in the context of other forms of nominal staggering.

5.1 Price Staggering and Future Demand

Whereas the price setting equation (1) is common in the literature on inflation persistence, microfoundations of staggered price setting suggest that current prices (set over periods t and $t+1$) depend not only on current demand (x_t) but also on future demand (x_{t+1}). Thus, let us consider the following price setting behavior:

$$P_t = \alpha P_{t-1} + (1-\alpha) E_t P_{t+1} + \gamma \left[\alpha x_t + (1-\alpha) E_t x_{t+1}\right]. \tag{26}$$

Substituting real money balances (4) into this equation, we obtain

$$P_t = \phi_p P_{t-1} + \theta_p E_t P_{t+1} + \left(\frac{\gamma}{1+\gamma\alpha}\right) \left[\alpha M_t + (1-\alpha) E_t M_{t+1}\right], \tag{27}$$

where $\phi_p = \frac{\alpha}{1+\gamma\alpha}$, and $\theta_p = \frac{(1-\gamma)(1-\alpha)}{(1+\gamma\alpha)}$. In this model the lead parameter is positive under the plausible assumption that $\gamma < 1$. The sum of both the lag and lead parameters is less than one.

Expressing this difference equation as

$$P_t = \lambda_1 P_{t-1} + \frac{\gamma}{\lambda_2 (1-\gamma)(1-\alpha)} \sum_{j=0}^{\infty} \left(\frac{1}{\lambda_2}\right)^j E_t \left[\alpha M_{t+j} + (1-\alpha) M_{t+1+j}\right], \tag{28}$$

where[20]

$$\lambda_{1,2}=\frac{1\mp\sqrt{1-4\phi_p\theta_p}}{2\theta_p}=\frac{1\mp\sqrt{1-4\frac{\alpha(1-\gamma)(1-\alpha)}{(1+\gamma\alpha)^2}}}{2\frac{(1-\gamma)(1-\alpha)}{(1+\gamma\alpha)}}, \tag{29}$$

$0<\lambda_1<1$, and $\lambda_2>1$, we find how price dynamics depend on the stochastic monetary process. Once again, we examine inflation persistence arising from a temporary money growth shock and inflation responsiveness arising from a permanent money growth shock.

We begin with a **temporary money growth shock.** When money growth follows the stationary process (9), the rational expectations solution of (28) is

$$P_t=\lambda_1 P_{t-1}+(1-\lambda_1)M_t+\kappa(1-\lambda_1)\mu, \tag{30}$$

where $\kappa=\lambda_2/(\lambda_2-1)-\alpha$. Consequently inflation is given by

$$\pi_t=\lambda_1\pi_{t-1}+(1-\lambda_1)\mu+(1-\lambda_1)\varepsilon_t. \tag{31}$$

Observe that this inflation dynamics equation has the same structure with the inflation dynamics (11) of model (1). Thus, the impulse response function is $\mathsf{R}^{\pi}_{t+j}=\lambda_1^j(1-\lambda_1)$, $j=0,1,2,...$, and inflation persistence is simply equal to the autoregressive coefficient λ_1 given in equation (29). Note that the magnitude of the autoregressive parameter λ_1 is what differentiates the inflation responses generated by the price staggering models (1) and (26).

Now consider a **permanent money growth shock**. When money growth follows the random walk process (15), the rational expectations solution of (28) is

$$P_t=\lambda_1 P_{t-1}+(1-\lambda_1)M_t+\kappa(1-\lambda_1)\mu_t, \tag{32}$$

First differencing the above gives the following inflation equation:

$$\pi_t=\lambda_1\pi_{t-1}+(1-\lambda_1)\mu_t+\kappa(1-\lambda_1)\varepsilon_t. \tag{33}$$

It can be shown that the inflation responses of the above model to a permanent shock are given by

$$\begin{aligned} R^{\pi}_{t+j} &= 1-\lambda_1^j\left[\lambda_1-\kappa(1-\lambda_1)\right] \\ &= 1-\lambda_1^j(1-\lambda_1)\left(\frac{2\alpha-1}{\gamma}\right),\ j=0,1,2,... \end{aligned} \tag{34}$$

It can also be shown that the closed form rational expectations solution for unemployment

[20] It can be shown that $(1-\lambda_1)=\frac{\gamma}{(\lambda_2-1)(1-\gamma)(1-\alpha)}$.

is

$$u_t = \lambda_1 u_{t-1} - (1-\lambda_1)\left(\frac{2\alpha - 1}{\gamma}\right)\mu_t. \tag{35}$$

Once again, inflation is perfectly responsive when $\alpha = 1/2$, it is under-responsive when $\alpha > 1/2$, and the degree of under-responsiveness is inversely related to the slope of the long-run Phillips curve.

5.2 Wage Staggering

Consider the following common wage staggering model:

$$W_t = \alpha W_{t-1} + (1-\alpha) E_t W_{t+1} + \gamma x_t. \tag{36}$$

Assuming constant returns to labor, the price is a constant mark-up over the relevant wages:

$$P_t = \frac{1}{2}(W_t + W_{t-1}). \tag{37}$$

Substitution of the price mark-up (37) and real money balances (4) equations into the wage setting equation (36) gives

$$W_t = \phi_w W_{t-1} + \theta_w E_t W_{t+1} + \left(\frac{2\gamma}{2+\gamma}\right) M_t, \tag{38}$$

where $\phi_w = \frac{2\alpha-\gamma}{2+\gamma}$, $\theta_w = \frac{2(1-\alpha)}{2+\gamma}$. We can write the above second order difference equation as

$$W_t = \lambda_1 W_{t-1} + \frac{\gamma}{\lambda_2 (1-\alpha)} \sum_{j=0}^{\infty} \left(\frac{1}{\lambda_2}\right)^j E_t M_{t+j}, \tag{39}$$

where $\lambda_{1,2} = \frac{1 \mp \sqrt{1-4\phi_w\theta_w}}{2\theta_w}$, $0 < \lambda_1 < 1$, and $\lambda_2 > 1$.

In this context, consider the inflation effects of a **temporary money growth shock**. We substitute the money growth stochastic process (9) into (39) to obtain the wage dynamics equation:

$$W_t = \lambda_1 W_{t-1} + (1-\lambda_1) M_t + \left(\frac{1-\lambda_1}{\lambda_2 - 1}\right)\mu. \tag{40}$$

Insert this wage dynamics equation into the price mark-up equation (37) to obtain the price dynamics equation:

$$P_t = \lambda_1 P_{t-1} + \frac{1}{2}(1-\lambda_1) M_t + \frac{1}{2}(1-\lambda_1) M_{t-1} + \left(\frac{1-\lambda_1}{\lambda_2 - 1}\right)\mu. \tag{41}$$

Therefore, inflation is given by

$$\pi_t = \lambda_1 \pi_{t-1} + (1-\lambda_1)\mu + \frac{1}{2}(1-\lambda_1)\varepsilon_t + \frac{1}{2}(1-\lambda_1)\varepsilon_{t-1}. \tag{42}$$

The responses of inflation to a period-t unit money growth shock are:

$$\begin{aligned} \mathsf{R}_t^{\pi} &= \frac{1}{2}(1-\lambda_1), \\ \mathsf{R}_{t+j}^{\pi} &= \frac{\lambda_1^{j-1}}{2}\left(1-\lambda_1^2\right), \; j = 1,2,3,... \end{aligned} \tag{43}$$

Thus inflation persistence is

$$\sigma = \frac{1+\lambda_1}{2}. \tag{44}$$

Now turning to the inflation effects of a **permanent change in money growth**, the rational expectations solution of the model gives the following dynamics equation:

$$W_t = \lambda_1 W_{t-1} + (1-\lambda_1) M_t + \left(\frac{1-\lambda_1}{\lambda_2 - 1}\right)\mu_t, \tag{45}$$

$$P_t = \lambda_1 P_{t-1} + (1-\lambda_1) M_t + \frac{1}{2}(1-\lambda_1)\left(\frac{2-\lambda_2}{\lambda_2-1}\right)\mu_t + \frac{1}{2}\left(\frac{1-\lambda_1}{\lambda_2-1}\right)\mu_{t-1}, \tag{46}$$

$$M_t - P_t = \lambda_1 (M_{t-1} - P_{t-1}) + (1-\lambda_1)\left(\frac{2\alpha-1}{\gamma}\right)\mu_t - \frac{1}{2}\left(\frac{1-\lambda_1}{\lambda_2-1}\right)\varepsilon_t, \tag{47}$$

$$\pi_t = \lambda_1 \pi_{t-1} + (1-\lambda_1)\mu_t + \frac{1}{2}(1-\lambda_1)\left(\frac{2-\lambda_2}{\lambda_2-1}\right)\varepsilon_t + \frac{1}{2}\left(\frac{1-\lambda_1}{\lambda_2-1}\right)\varepsilon_{t-1}. \tag{48}$$

It can be shown that the responses through time of inflation to a period-t permanent unit money growth shock are:

$$\begin{aligned} R_t^{\pi} &= 1 - \frac{1}{2}\left[(1-\lambda_1)\left(\frac{2\alpha-1}{\gamma}\right) + \frac{1+\lambda_1}{2}\right] < 1, \\ R_{t+j}^{\pi} &= 1 - \lambda_1^{j-1}\frac{\left(1-\lambda_1^2\right)}{2}\left(\frac{2\alpha-1}{\gamma} - \frac{1}{2}\right), \; j = 1,2,..., \\ \lim_{j\to\infty} R_{t+j}^{\pi} &= 1. \end{aligned} \tag{49}$$

As for the price staggering model, inflation responsiveness is $\rho \equiv -\frac{2\alpha-1}{\gamma}$. By this measure, again, inflation is perfectly responsive when the discount rate is zero ($\alpha = 1/2$) and under-responsive when the discount rate is positive ($\alpha > 1/2$). However, in neither case does inflation jump immediately to its long-run equilibrium value. Specifically, the instantaneous (period-t) response of inflation is to undershoot both when $\alpha = 1/2$ and $\alpha > 1/2$.

In period-1, when $\alpha = 1/2$, inflation overshoots and thereafter converges geometrically to its long-run equilibrium. In this case inflation undershooting and overshooting cancel out, inflation is perfectly responsive, $\rho = 0$, and the long-run Phillips curve is vertical. On the other hand, when $\alpha > 1/2$, inflation can either remain below its new equilibrium level in period-1, if $\frac{2\alpha-1}{\gamma} > \frac{1}{2}$,[21] or overshoot if $\frac{2\alpha-1}{\gamma} < \frac{1}{2}$. Since $0 < \lambda_1 < 1$, period-2 onwards inflation converges to its equilibrium in a geometric fashion.

Finally, we consider a wage staggering model in which the nominal wage depends not only on current demand (x_t) but also on future demand (x_t), along the lines originally proposed by Taylor (1980a):

$$W_t = \alpha W_{t-1} + (1-\alpha) E_t W_{t+1} + \gamma \left[\alpha x_t + (1-\alpha) E_t x_{t+1}\right]. \tag{50}$$

It is straightforward to show that the associated impulse response functions of inflation to a temporary and permanent money growth shock have the same functional forms as in the previous model. The only difference between the impulse response functions of the two wage staggering models (36) and (50) lies in the autoregressive root of their rational expectations dynamic equations.[22]

6 Overview of our Analysis

We have examined four macro versions of the new Phillips curve:

⟨1⟩ *PS*-(x_t) stands for the price staggering model in which prices depend only on current demand - the workhorse model in the NPC literature.

⟨2⟩ *PS*-(x_t, x_{t+1}) is the model in which prices also depend on future demand.

⟨3⟩ *WS*-(x_t), and

⟨4⟩ *WS*-(x_t, x_{t+1}) represent the corresponding wage staggering models.

We analysed the inflation dynamics implied by the above models by considering two types of monetary shocks: (i) a temporary shock, i.e. a one-off unit increase in money growth, and (ii) a permanent shock, i.e. a permanent unit increase in money growth.

[21] That is, when $\alpha > 1/2$, inflation undershoots and converges to its equilibrium from below if

$$r > \frac{2\gamma}{2-\gamma}, \text{ or } \gamma < \frac{2r}{2+r}.$$

[22] For the above Taylor model, it can be shown that $\lambda_1 = \frac{1-\sqrt{1-4\phi_w\theta_w}}{2\theta_w}$, $\phi_w = \alpha\left(\frac{2-\gamma}{2+\gamma}\right)$, $\theta_w = (1-\alpha)\left(\frac{2-\gamma}{2+\gamma}\right)$, and $0 < \lambda_1 < 1$. For a detailed analysis of this model see Karanassou, Sala and Snower (2005).

To avoid confusion, we have used the terms of persistence and responsiveness to summarise the impulse response functions of inflation associated with a temporary and a permanent shock, respectively. In other words, in the context of the above macro models,

- *inflation persistence* denotes inflation inertia in the presence of the temporary shock, whereas
- *inflation under-responsiveness* denotes inflation inertia in the presence of a permanent shock.

Table 3 outlines our results on inflation persistence, over the NPC models ⟨1⟩-⟨4⟩. As we have seen, the responses to a temporary shock can be divided into (i) the short-run slope (e_{SR}), i.e. the contemporaneous response, (ii) the persistence (σ), i.e. the sum of future responses, and (iii) the long-run slope (e_{LR}), i.e. the sum of all responses ($e_{LR} = e_{SR} + \sigma$).[23] We find that a temporary money growth shock always has prolonged after-effects on inflation (regardless of whether the discount rate is zero or positive, or whether there is price or wage staggering).

Table 3: Inflation persistence after a shift in the money supply

	autoregressive coefficient $\lambda_1 = \frac{1-\sqrt{1-4\phi\theta}}{2\theta}$		responses		
Models	ϕ	θ	Short-run e_{SR} :	Persistence σ :	Long-run e_{LR} :
PS-(x_t)	$\frac{\alpha}{1+\gamma}$	$\frac{1-\alpha}{1+\gamma}$	$1-\lambda_1$	λ_1	1
PS-(x_t, x_{t+1})	$\frac{\alpha}{(1+\gamma\alpha)}$	$\frac{(1-\gamma)(1-\alpha)}{(1+\gamma\alpha)}$	$1-\lambda_1$	λ_1	1
WS-(x_t)	$\frac{2\alpha-\gamma}{2+\gamma}$	$\frac{2(1-\alpha)}{2+\gamma}$	$\frac{1}{2}(1-\lambda_1)$	$\frac{1}{2}(1+\lambda_1)$	1
WS-(x_t, x_{t+1})	$\frac{\alpha(2-\gamma)}{2+\gamma}$	$\frac{(1-\alpha)(2-\gamma)}{2+\gamma}$	$\frac{1}{2}(1-\lambda_1)$	$\frac{1}{2}(1+\lambda_1)$	1

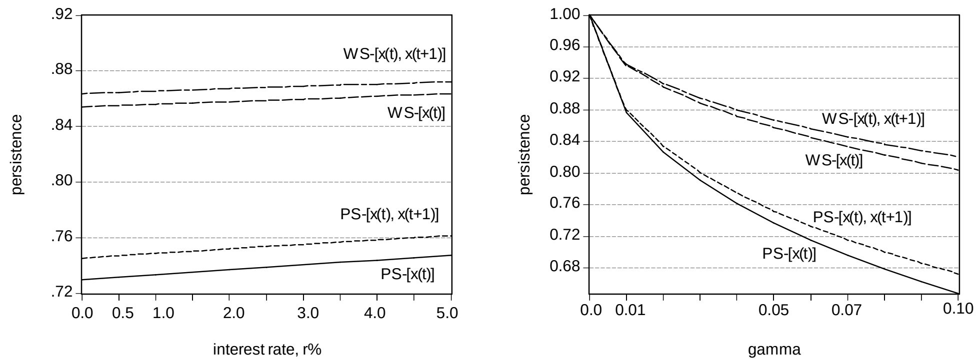
The dependence of inflation persistence on the discount rate r and the demand sensitivity parameter γ, for our four macro models, are pictured in Figures 1. Observe that, for given values of r and γ, there is more inflation persistence (i) under wage staggering than under price staggering and (ii) when nominal variables depend on both present and future demands than when they depend on present demands alone. Furthermore, note that variations in the demand sensitivity parameter over the frequently estimated range have a strong effect on inflation persistence, whereas the discount rate (over the standard range) has a relatively weak effect.[24]

[23] Strictly speaking, the short-run slope is the immediate impact, whereas the long-run slope is the total impact of the temporary shock.

[24] Since the demand sensitivity parameter (γ) is assumed positive and nonzero, the unit value of persistence in Figure 1b for $\gamma = 0$ represents a limiting case $\left(\text{i.e., } \lim_{\gamma\to 0}\sigma = 1\right)$.

Figures 1

a. Inflation persistence and interest rate (gamma=0.05) | **b. Inflation persistence and gamma (r=2%)**



Tables 4a-b summarise our results on inflation responsiveness over the NPC models $\langle 1\rangle$-$\langle 4\rangle$. Recall that the contemporaneous response of a permanent money growth shock is denoted by R_t^π and the future responses by R_{t+j}^π, $j \geq 1$. The degree of inflation responsiveness ρ has been shown to be the inverse of the slope of the long-run Phillips curve. This measure of responsiveness is zero (denoting perfect responsiveness) when the discount rate is zero ($\alpha = 1/2$) and negative (denoting under-responsiveness) when the discount rate is positive ($\alpha > 1/2$). However, this does not imply that inflation necessarily jumps to its long-run value whenever the discount rate is zero. On the contrary, we have shown that under staggered wage setting inflation is never a jump variable, regardless of the discount rate.

Table 4a: Inflation responsiveness , $\alpha > 1/2$

Models	R_t^π	R_{t+j}^π $j=1,2,\ldots$	ρ
PS-(x_t)	< 1	< 1	$-\left(\frac{2\alpha-1}{\gamma}\right)$
PS-(x_t, x_{t+1})	< 1	< 1	$-\left(\frac{2\alpha-1}{\gamma}\right)$
WS-(x_t)	< 1	$\lesseqgtr 1$ if $r \gtrless \frac{2\gamma}{2-\gamma}$	$-\left(\frac{2\alpha-1}{\gamma}\right)$
WS-(x_t, x_{t+1})	< 1	$\lesseqgtr 1$ if $r \gtrless \frac{2\gamma}{2-\gamma}$	$-\left(\frac{2\alpha-1}{\gamma}\right)$

In all models, when $\alpha > 1/2$, the immediate response of inflation is to undershoot ($R_t^\pi < 1$). In the wage-staggering versions of the NPC (the bottom two rows in Table 4a), inflation will continue to undershoot its equilibrium after period-t if $\frac{2\alpha-1}{\gamma} > \frac{1}{2}$, i.e. if $r > \frac{2\gamma}{2-\gamma}$. Otherwise, inflation overshoots in period $t+1$ and then gradually converges (from above) to its new equilibrium.

When $\alpha = 1/2$ (see Table 4b), the inflation generated by the price staggering models is a jump variable and both the short- and long-run Phillips curves are vertical. In other words, there is no inflation "persistence" and the monetary policy has no real effects in the economy. With wage staggering, when $\alpha = 1/2$, inflation responsiveness remains zero but inflation does not immediately jump to its new value. Initially inflation undershoots, and then it overshoots before it starts approaching its new equilibrium. The net effect is zero and so $\rho = 0$. Thus, the Phillips curve is downwards sloping in the short-run and becomes vertical in the long-run.

Table 4b: Inflation responsiveness , $\alpha = 1/2$

Models	R_t^{π}	R_{t+j}^{π} $j=1,2,...$	ρ	PC (short-run)
PS-(x_t)	1	1	0	vertical
PS-(x_t, x_{t+1})	1	1	0	vertical
WS-(x_t)	< 1	> 1	0	downward-sloping
WS-(x_t, x_{t+1})	< 1	> 1	0	downward-sloping

Figures 2

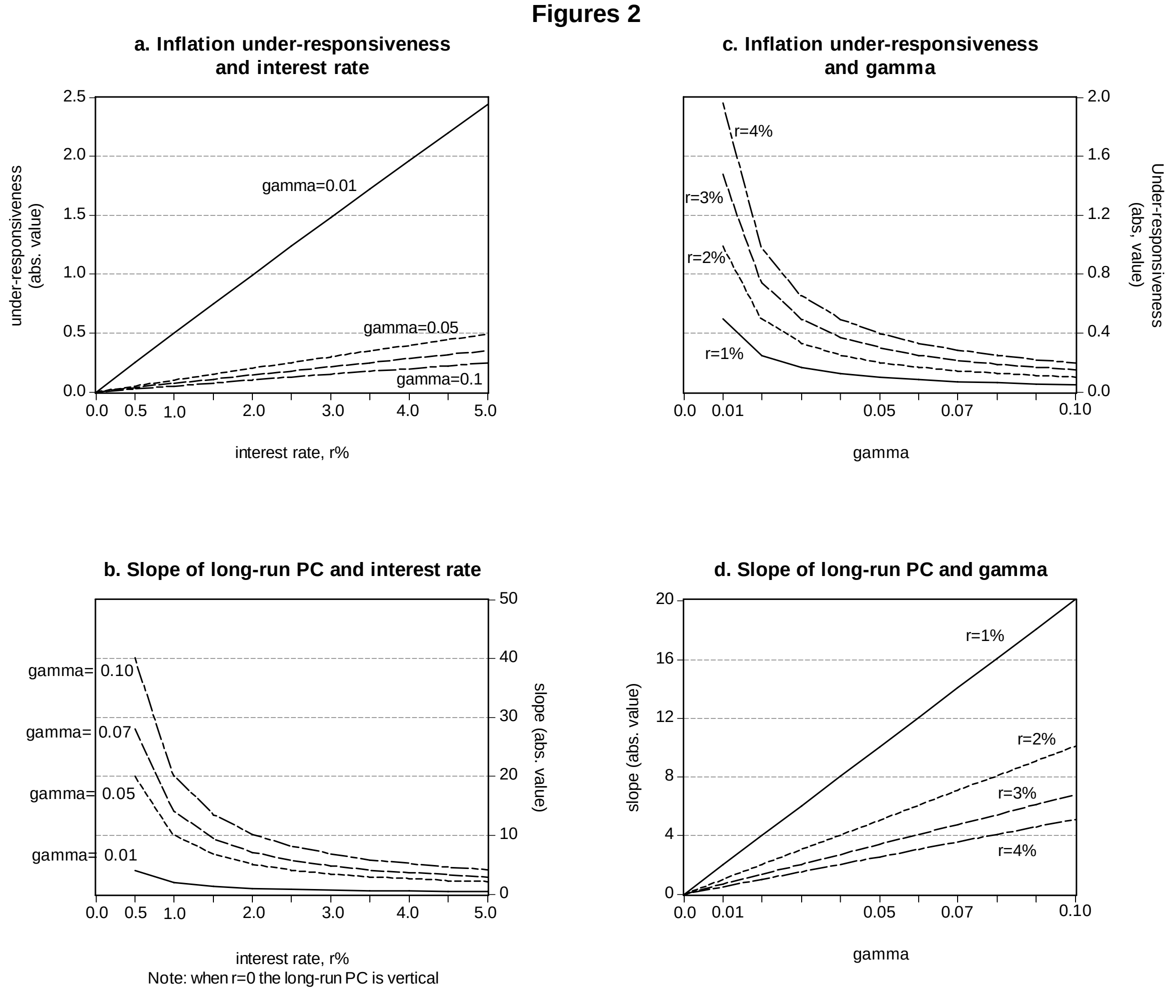


Figure 2a pictures the relation between inflation under-responsiveness (in absolute value terms) and the interest rate; Figure 2b is the corresponding relation between the slope of the long-run Phillips curve and the interest rate. When the interest rate is zero the Phillips curve is vertical, while a positive interest rate produces a downward sloping PC. The higher is the interest rate, the more under-responsive inflation and the flatter the Phillips curve. Along the same lines, Figures 2c and 2d show how inflation under-responsiveness and the slope of the long-run Phillips curve depend on the demand sensitivity parameter γ. The lower is gamma, the more under-responsive inflation and the flatter the Phillips curve.

These results have one common thrust: the "persistency puzzle" proposition is highly misleading. Under plausible parameter values, high degrees of inflation persistence and under-responsiveness may arise in the context of standard wage-price staggering models.

7 Concluding Remarks

It is commonly asserted that inflation is a jump variable in the new Phillips curve - this is at odds with the stylised fact of inflation persistence. We showed that this so called persistency puzzle is highly misleading, relying on the exogeneity of real variables and the assumption of a zero discount rate. When the discount rate is positive in a general equilibrium setting (in which real variables not only affect inflation, but are also influenced by it) inflation persistence re-emerges.

In the context of the standard models of the NPC, we first derived the closed form rational expectations solutions of inflation, real money balances, and the unemployment rate under one-off and permanent unit increases in money growth. We then measured inflation inertia by obtaining the impulse response function (IRF) of inflation with respect to each type of shock. We distinguished the phenomenon of "inflation persistence" in response to a temporary money growth shock from "inflation responsiveness" in response to a permanent one.

Finally, we derived the time-varying slope of the NPC as the ratio of the inflation and unemployment IRFs. We found that the long-run slope is the inverse of inflation under-responsiveness (i.e., the cumulative amount of undershooting).

We showed that when the discount rate is zero, the conventional wisdom is confirmed: inflation is a jump variable and the workhorse NPC is vertical. By contrast, when the discount rate is positive, there is substantial inflation undershooting and the NPC is downwards sloping in the long-run.

References

[1] Christiano, L. J., Eichenbaum, M., and C. Evans (2001): Nominal rigidities and the dynamic effects of a shock to monetary policy, NBER Working paper 8403, National Bureau of Economic Research, Cambridge, MA.

[2] Dotsey, M., King, R.G., and A.L. Wolman (1997): Menu costs, staggered price-setting, and elastic factor supply, Working paper 97-2, Federal Reserve Bank of Richmond.

[3] Estrella, A., and J. C. Fuhrer (1998): Dynamic inconsistencies: counterfactual implications of a class of rational expectations models, Working paper 98-5, Federal Reserve Bank of Boston.

[4] Fuhrer, J. C., and G. R. Moore (1995): Inflation Persistence, *Quarterly Journal of Economics*, 110, Feb., 127-159.

[5] Galí, J., Gertler, M., and J. D. López-Salido (2001): European inflation dynamics, *European Economic Review*, 45, 1237-1270.

[6] Huang, K.X.D., and Z. Liu (2001): Production chains and general equilibrium aggregate dynamics, *Journal of Monetary Economics*, 48, 437-462.

[7] Huang, K.X.D., and Z. Liu (2002): Staggered price-setting, staggered wage setting, and business cycle persistence, *Journal of Monetary Economics*, 49, 405-433.

[8] Karanassou, M., Sala, H., and D. J. Snower (2005): A Reappraisal of the Inflation Unemployment Tradeoff, *European Journal of Political Economy*, 21, 1-32.

[9] Mankiw, N. G., and R. Reis (2002): Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve, *Quarterly Journal of Economics*, 117 (4), 1295-1328.

[10] Phelps, E. S. (1978): Disinflation without Recession: Adaptive Guideposts and Monetary Policy, *Weltwirtschaftliches Archiv*, C, 239-265.

[11] Pivetta, F., and R. Reis (2007): The Persistence of Inflation in the United States, *Journal of Economic Dynamics and Control*, 31, 1326-1358.

[12] Roberts, J. M. (1995): New Keynesian Economics and the Phillips Curve, *Jounral of Money, Credit, and Banking*, 27, 975-984.

[13] Roberts, J.M. (1997): Is inflation sticky?, *Journal of Monetary Economics*, 39, 173-196.

[14] Sachs, J., (1980): The changing cyclical behavior of wages and prices: 1890-1976, *American Economic Review,* 70, 78-90.

[15] Taylor, J.B. (1979): Staggered Wage Setting in a Macro Model, American Economic Review, No. 69, May, pp. 108-113.

[16] Taylor, J. B. (1980a): Aggregate Dynamics and Staggered Contracts, *Journal of Political Economy*, 88 (1), 1-23.

[17] Taylor, J. B. (1980b): Output and Price Stability: An International Comparison, *Journal of Economic Dynamics and Control*, 2, 109-132.

[18] Westelius, N. J. (2005): Discretionary Monetary Policy and Inflation persistence, *Journal of Monetary Economics*, 52 (2), 477-496.