Inflation Persistence: How Much Can We Explain?

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Monetary policy is a controversial topic. Economists are still divided into two factions: those who believe that monetary policy does have real (inflation-adjusted) effects and those who are convinced that it affects only nominal variables, that is, nominal interest rates and prices. Until recently, almost any macroeconomic model in which monetary policy has real effects was based on the assumption that expectations are formed in an adaptative way, implying that agents do not use all available information when making a decision. Critics of these models argue that, given this assumption, agents are not rational and as a result allow the monetary authority to trick them over and over.

In response to this important critique, a whole class of models—New Keynesian models—has been recently proposed. These types of models combine "old" Keynesian elements (imperfect competition and short-term nominal rigidities) with a dynamic general equilibrium environment (where prices and quantities are such that markets clear) in which agents form their expectations rationally.[1] The idea behind this approach is that when short-term prices are "sticky" or "rigid"—that is, when they adjust only slowly to market shortages or surpluses—a decrease in the nominal interest rate also implies a decrease in the real interest rate. Therefore, the consumption and investment components of aggregate demand increase, implying an increase in output. But over time the excess aggregate demand shifts prices upward, thereby restoring the level of output to its potential. A drawback of the simplest version of such models (in which only one type of nominal rigidity, either sticky prices or wages, is considered) is that it does not seem to be able to reproduce the observed persistence of inflation.

The objective of this article is to determine whether adding sticky wages to a basic sticky-price model overcomes this drawback. The analysis shows that this addition "partially" solves the problem. Empirical work at the micro level suggests that the average duration of price and wage contracts is typically three to six quarters. Chari, Kehoe, and McGrattan (1998) find that, in order to match the persistence of output changes to a monetary shock, their model must assume an implausible degree (ten quarters) of price stickiness, even when capital accumulation and adjustment costs of capital are introduced. Fuhrer and Moore (1995) also show that, in a model using a reasonable length of wage contracts, it is not possible to obtain the inflation persistence observed in the data.

As Galí and Gertler (1999) point out, these models imply an aggregate supply relationship (the new Phillips curve) that relates current inflation with expectations of future inflation and real unit-labor costs. Hence, the persistence of price inflation in New Keynesian models is driven by the persistence of real unit-labor costs. The problem of models with only one type of nominal rigidity is that, even with long-duration (sixteen quarters) price or wage contracts, real wages are still flexible and cannot induce enough persistence of inflation.

How can the baseline sticky-price model be modified so that the induced persistence of inflation in response to a monetary shock increases under plausible degrees of price or wage stickiness? A straightforward path would be to introduce some kind of backward-looking behavior in the determination of inflation. However, introducing backward-looking behavior implies departing from the assumption of rational expectations, and the Lucas (1976) critique applies.[2]

Economists are still divided into two factions: those who believe that monetary policy does have real (inflation-adjusted) effects and those who are convinced that it affects only nominal variables.

This article takes an alternative approach, exploring whether the combination of staggered price and wage setting, as in Erceg, Henderson, and Levin (2000), can match the inflation persistence observed in the data if reasonable durations of price and wage contracts are assumed. In this case, the forward-looking nature of the model is preserved. When both prices and nominal wages are sticky, so is the real wage, and therefore inflation persistence should increase.

This article analyzes whether adding staggered wage settings to the baseline sticky-price model solves the persistence-of-inflation problem when plausible durations of price and wage contracts are assumed. The analysis will show that, for a given duration of price contracts, real wage persistence significantly increases with the duration of wage contracts. This exercise is equivalent to adding sticky prices to a model with only staggered nominal wages. The exercise presented here is chosen because models containing only sticky prices are more widely used in the literature than those containing only staggered nominal wages.

Both the baseline sticky-price and the sticky-price and sticky-wage models have three main equations: an aggregate supply relationship (the new Phillips curve), an IS type of equation, and a monetary policy rule.[3] As mentioned above, the new Phillips curve relates current inflation with expectations of future inflation and real unit-labor costs. Understanding the inflation–real wage link is important in understanding why adding staggered wages to the baseline sticky-price model may solve the lack of persistence of inflation in these models. The IS curve relates output and the real rate of interest negatively, as in the undergraduate textbook version of the Keynesian model, and the IS curve includes expectations of future output. These two relationships manifest the forward-looking nature of the New Keynesian models, in which expectations are rational. To complete the model, a monetary policy rule is needed. Typically, it is modeled as an interest rate rule in which the short-term interest rate reacts to inflation and output gaps;[4] the nominal amount of money is determined from the money demand equation. Following the literature, this article uses an interest rate rule that relates today's nominal interest rates to past nominal interest rates through an interest rate–smoothing parameter. One might interpret this parameter as reflecting monetary policymakers' perceived aversion to moving the nominal rate by large steps.

The analysis in this article reveals the following: First, as most of the literature has proved, when only sticky prices and plausible-duration price contracts are considered, the model is not able to replicate the inflation persistence observed in the data. Second, in the baseline sticky-price model most of the persistence is driven by the exogenous nominal interest rate–smoothing parameter. Finally, when sticky wages are added to the baseline sticky-price model, it is possible for the inflation data autocorrelations to be reasonable approximations closely matched by the model.

The first part of the article analyzes the equations that describe a general equilibrium model with sticky prices. The discussion then shows how these equations are modified when staggered wages are added to the baseline sticky-price model. Next, the analysis examines how different parameterizations affect price-inflation persistence in the baseline sticky-price model. Finally, the study considers how those conclusions are affected when both sticky prices and wages are considered.

The Model

The baseline sticky-price model presented in this section merges Keynesian assumptions, such as imperfect competition and nominal rigidities, with the methodological advances in modern macroeconomic theory. As in traditional Keynesian models, monetary policy affects real variables in the short run. Unlike the traditional Keynesian models, in New Keynesian models the equations come from an optimization process of rational agents. Two models are considered: first, a model with sticky prices but flexible wages and then a model that introduces staggered wage setting into this baseline environment.

The baseline sticky-price model. Following Blanchard and Kiyotaki (1987), the model consists of

- a large number of identical households each supplying labor services,
- a large number of intermediate-good producers producing a specific good that is an imperfect substitute for the other goods, and
- a large number of identical, competitive final-good producers.

Households consume the final good, intermediate-good producers use labor services in their production process, and final-good producers use the intermediate good in their production of the final good. The model also assumes imperfect competition in the intermediate-good markets. Thus, each intermediate-good producer chooses its price, taking as given all other good prices and wages. The intermediate-good production sector suffers an aggregate technology shock that is common across firms. For this sector, the model assumes a linear production function in labor such that the marginal product of labor is equal to the technology shock.

On the monetary policy side, the model assumes that the central bank sets the nominal interest rate through a Taylor rule and supplies as much money as households demand. The Taylor rule relates today's nominal interest rate to past nominal interest rates, inflation, and output gaps. The model also assumes that monetary policy, that is, the Taylor rule, suffers from a monetary perturbation. This perturbation reflects the difference between the information that the monetary authority has when making decisions on interest rates and the information that the researcher can observe.

Intermediate-good producers face a Calvo-type restriction when setting prices: In any given period of time, each intermediate-good producer receives a signal that allows her to change the price. This signal arrives with probability $1 - \theta_p$ and thus with probability θ_p that she must keep last period's price. The reason the Calvo-type assumption has become so popular is its simplicity. Because the probability of receiving the "green light" signal is independent of the past history of signals, the pricing decisions of firms are identical. Therefore, one does not need to keep track of each firm's pricing decision to know the aggregate price outcome, and aggregation is simple.

The intuition behind this idea is as follows: Firms face some type of "menu cost" when they want to change prices, so they cannot change prices every period. In this environment the probability that a firm has its price fixed for one period is $1 - \theta_p$, for two periods is $\theta_p(1 - \theta_p)$, for three is $\theta_p^2(1 - \theta_p)$, and so on. Given these probabilities, the average number of periods that prices are going to be fixed can be calculated. Hence, this average duration of a price contract is equal to $[1 - \theta_p] + 2[\theta_p(1 - \theta_p)] + 3[\theta_p^2(1 - \theta_p)] + \ldots = 1/(1 - \theta_p)$. It is important to remember the relationship between θ_p and the average duration of price contracts.

This analysis will not go through the derivation of the main equations. (The reader is referred to Rabanal and Rubio-Ramírez 2003.) Instead, the discussion will introduce the key relationships and give some intuition. In all cases, the variables are expressed in logarithmic terms. Let y_t denote output; w_t, the nominal wage; p_t, the price level; and Δp_t, the price inflation rate.

The model is represented by the following set of equations:

$$(1)\quad y_t = -\frac{1}{\sigma}(r_t - E_t\Delta p_{t+1} - \rho_\beta) + E_t y_{t+1};$$

$$(2)\quad \Delta p_t = \beta E_t \Delta p_t + \kappa_p(w_t - p_t - a_t + \mu);$$

$$(3)\quad w_t - p_t = \vartheta + mrs_t;$$

$$(4)\quad mrs_t = (\sigma + \gamma)y_t - \gamma a_t,$$

and

$$\kappa_p = \frac{[(1-\theta_p\beta)(1-\theta_p)]}{\theta_p};$$

1. For another way of answering this critique, see Christiano and Eichenbaum (1992).
2. The Lucas critique implies that any Federal Reserve policy change will affect consumers' expectations, so the Federal Reserve cannot take consumers' expectations as constant.
3. An IS equation relates output today with output tomorrow as a function of the nominal interest rate and inflation.
4. Even though this article does not do so, it is also possible to model the interest rate rule as forward looking in the sense that it reacts to expected future inflation and output gaps. However, simulations suggest that our results would remain basically unchanged. Output gaps are the difference between actual and potential output.

$$(5) \quad a_t = \rho_a a_{t-1} + \varepsilon_t^a,$$

where β is the discount factor, ρ_β is equal to $\log(\beta)$, γ is the inverse of the elasticity of labor supply to real wage, σ is the inverse of the intertemporal elasticity of substitution, r_t is the nominal interest rate, mrs_t is the marginal rate of substitution between consumption and worked hours, μ is the desired markup on marginal product, w_t is the hourly wage, ϑ is the desired markup on the real wage, κ_p is the elasticity of inflation to the marginal cost, and a_t is the aggregate productivity shock. It is assumed that $\varepsilon_t^a \sim \text{iid}N(0, \sigma_a)$.

Equation (1) is a log-linearized version of the Euler equation, which arises from the household's optimal saving-consumption decision, after imposing the clearing market condition that consumption equals output. From equation (1) it is clear that the higher the nominal interest rate, r_t, or the lower tomorrow's expected inflation, $E_t\Delta p_{t+1}$, the lower today's output, y_t, and the higher the savings.

The baseline sticky-price model merges Keynesian assumptions, such as imperfect competition and nominal rigidities, with the methodological advances in modern macroeconomic theory.

Equation (1) can also be iterated forward to yield

$$(6) \quad y_t = -\frac{1}{\sigma} E_t \sum_{\tau=0}^{\infty} (r_{t+\tau} - \Delta p_{t+1+\tau} - \rho_\beta).$$

This iteration shows that output depends on current and expected future gaps between the real interest rate and its long-run value. Thus, one concludes that output is at its steady-state value only when real interest rates differ by the log of the discount factor and are expected to do so. In other words, when the real interest rate is high, savings are high and consumption (and, hence, output) is low; when the real interest rate is low, savings are low and consumption is high.

Equation (2) is called the New Keynesian Phillips curve, and it is obtained from the aggregation of price-optimal decisions of firms. Price inflation depends on tomorrow's expected price inflation, $E_t\Delta p_{t+1}$, and the percentage deviation of real wage, $w_t - p_t$, from the desired markup over the marginal product of labor, $a_t - \mu$, where μ is the desired markup on the marginal product and depends on the elasticity of substitution between different types of intermediate goods used to produce the final good. This equation is the most important piece of the New Keynesian models. As mentioned above, until the introduction of these models, almost any setup able to generate short-term real effects of monetary policy was based on backward-looking behavior. As equation (2) shows, this situation is no longer true: In this environment, inflation has a forward-looking root, and monetary policy affects output through its effects on future real interest rates and real wages.

If equation (2) is solved forward, the resulting equation is

$$(7) \quad \Delta p_t = -\kappa_p E_t \sum_{\tau=0}^{\infty} (w_{t+\tau} - p_{t+\tau} - a_{t+\tau} + \mu).$$

It reveals that price inflation depends on current and expected future gaps between real wages and the desired markup over the marginal product of labor. Thus, one concludes that price inflation is at its steady-state value only when real wages and the marginal product of labor differ by the desired markup and are expected to do so. If firms do not expect wages to increase over the marginal product of labor more than the desired markup, they will not increase prices, and inflation will be at its steady-state value.

Equation (3) relates the real wage, $w_t - p_t$, the marginal rate of substitution between consumption and worked hours, mrs_t, and the desired real-wage markup, ϑ, that depends on the elasticity of substitution between different types of labor used to produce each intermediate good. Equation (4) relates the marginal rate of substitution between consumption and worked hours, mrs_t, with output, y_t, and the aggregate productivity shock, a_t. This expression is obtained by imposing the clearing market condition that consumption equals total production and by using the production function that relates hours worked with output and the productivity shock. Equation (5) shows how the aggregate productivity shock, a_t, (or technology shock) evolves over time.

A monetary policy rule is needed to complete the general equilibrium model. This analysis will consider a Taylor-type rule with the following formulation:

$$(8) \quad r_t = \rho r_{t-1} + (1-\rho)(\gamma_\pi \Delta p_t + \gamma_x y_t) + \varepsilon_t,$$

where γ_π and γ_x are the elasticities of the nominal interest rate to current price inflation and output gap. ε_t is the monetary shock, and it is independent and identically distributed normally with zero mean and standard deviation σ_r.

Equation (8) relates today's nominal interest rate, r_t, to yesterday's nominal interest rate, r_{t-1}, price inflation, Δp_t, and output gap, y_t. It is assumed that ρ is between 0 and 1, $\gamma_\pi > 1$, and $\gamma_x > 0$. The interest rate–smoothing coefficient is included in the Taylor rule mainly for empirical reasons (see the paper by Clarida, Galí, and Gertler 2000). In addition, Woodford (2002) provides some theoretical background about why the central bank might be interested in smoothing interest rates. In this way, the nominal interest rate will have some exogenously driven persistence. This model imposes the condition $\gamma_\pi > 1$: The monetary authority increases the nominal interest rate more than one to one with respect to inflation to induce a unique, stationary solution to the system (see Woodford 2002).

In the baseline sticky-price model, and in the sticky-price and -wage model presented in the next section, two sources of uncertainty exist: one is technological, ε_t^a, and the other is monetary, ε_t.

Two key parameters drive inflation persistence in the baseline sticky-price model: First, θ_p modifies the slope in equation (2). Hence, the larger θ_p, the longer the duration of price contracts and the higher the generated persistence of inflation. The second, ρ, is the interest rate–smoothing coefficient. A higher ρ increases the persistence of both monetary shocks and output gaps, also making inflation more persistent. Given the importance of these two parameters, the next section demonstrates how different calibration choices for them modify the persistence of inflation that this model can generate.

The sticky-price and -wage model. As the next section of the article will show, with only sticky prices it is not enough to replicate the persistence of inflation that is observed in the data. Therefore, this section presents a version of the model with staggered prices and wages, as in Erceg, Henderson, and Levin (2000). The inclusion of nominal wage rigidities will increase the real wage and, one hopes, inflation inertia. The model setup is similar to the one presented in the last subsection. As before, the model consists of a continuum of households each supplying a specific labor service that is an imperfect substitute for the other labor services, a continuum of intermediate-good producers producing a specific good that is an imperfect substitute for the other goods, and a continuum of identical competitive final-good producers. As in the baseline sticky-price model, households consume the final good, intermediate-good producers use labor services in their production process, and final-good producers use the intermediate good in their production of the final good. The model also assumes imperfect competition on the intermediate-good markets. Thus, each intermediate-good producer chooses its price, taking as given all other good prices and wages. The intermediate-good production sector suffers an aggregate technology shock that is common across firms. For this sector, a linear production function in labor is assumed, so the marginal product of labor is equal to the technology shock. Finally, the central bank also sets the nominal interest rate, through a Taylor rule, and supplies as much money as households demand. Also, as in the previous model, it is assumed that the Taylor rule suffers from a monetary perturbation.

Just as in the baseline sticky-price model, producers of intermediate goods face a Calvo-type

With only sticky prices it is not enough to replicate the persistence of inflation that is observed in the data.

restriction when setting prices, as described earlier. In this new model, households face an additional Calvo-type restriction when setting their wages. In this environment the probability that a household has its wage fixed for one period is $1 - \theta_w$. Therefore, the average duration of a wage contract is equal to $1/(1 - \theta_w)$.

The model can be represented by the following set of equations:

$$(9) \quad y_t = -\frac{1}{\sigma}(r_t - E_t \Delta p_{t+1} - \rho_\beta) + E_t y_{t+1};$$

$$\Delta p_t = \beta E_t \Delta p_{t+1} + \kappa_p (w_t - p_t - a_t + \mu);$$

$$(10) \quad \Delta w_t = \beta E_t \Delta w_{t+1} + \kappa_w (mrs_t - (w_t - p_t) + \vartheta);$$

$$w_t - p_t = w_{t-1} - p_{t-1} + \Delta w_t - \Delta p_t;$$

$$mrs_t = (\sigma + \gamma) y_t - \gamma a_t;$$

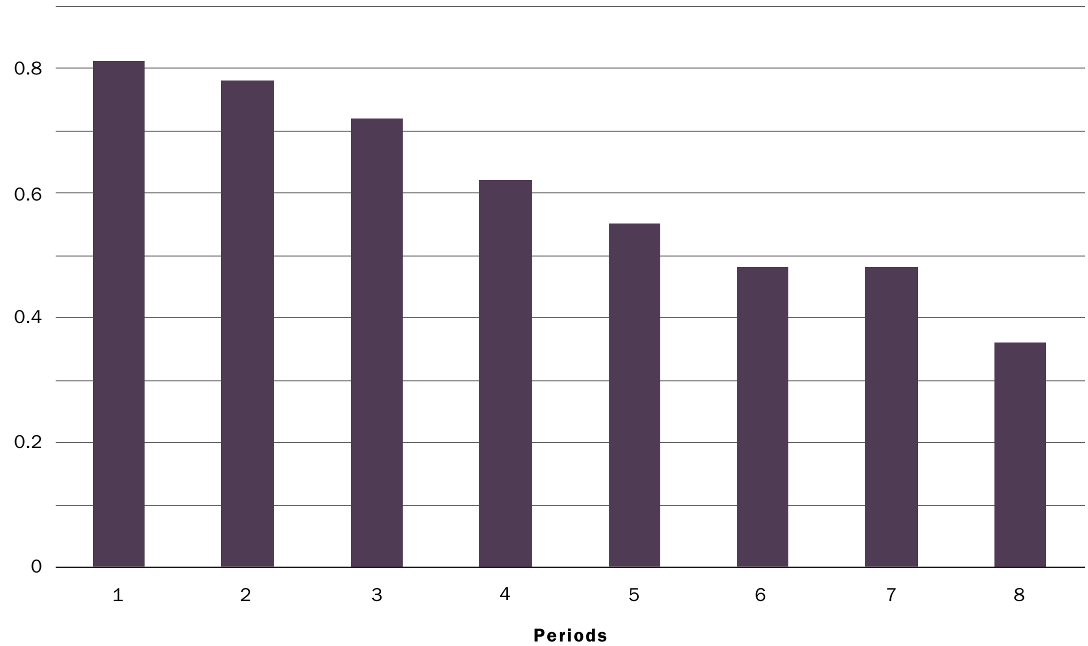
where

$$\kappa_p = \frac{[(1 - \theta_p \beta)(1 - \theta_p)]}{\theta_p};$$

$$\kappa_w = \frac{[(1 - \theta_w \beta)(1 - \theta_w)]}{\theta_w (1 + \gamma \varphi)}.$$

FIGURE 1

The Autocorrelation Function of the GDP Deflator for the Nonfarm Business Sector between 1960:01 and 2001:04



Again, a monetary policy rule is needed to complete the model. As before, a Taylor-type rule with the following structure is considered:

$$r_t = \rho r_{t-1} + (1-\rho)(\gamma_\pi \Delta p_t + \gamma_x y_t) + \varepsilon_t.$$

If the equations that describe the baseline sticky-price model are carefully compared with those that describe the sticky-price and sticky-wage model, two differences should be apparent. First, the inclusion of sticky wages does not modify the structure of the New Keynesian Phillips curve (equations [2] and [9] are identical). Second, mrs_t is no longer equal to a markup over real wages. Instead of equation (3), equation (10) now relates wage inflation to expected wage inflation and the percentage deviation of real wages, mrs_t, from the desired markup over the real wage of labor, $(w_t - p_t) - \vartheta$, in the same way the New Keynesian Phillips curve does.

Comparison of the two models. Although in the baseline sticky-price model θ_p and ρ drive inflation, in the sticky-price and -wage model a bigger θ_w implies a longer duration of wage contracts and, hence, a more persistent real wage. The New Keynesian Phillips curve (equation [9]) implied by this new version of the model relates price inflation persistence to real wage persistence; hence, a larger θ_w implies higher inflation persistence.

In the next section, the analysis explores how different calibration choices for these three parameters modify the persistence of inflation that this model can generate. Notably, because the New Keynesian Phillips curve remains unaltered, then in either model persistence in price inflation after a monetary shock hits the economy is driven by κ_p and the persistence of the real wage, $w_t - p_t$. The inclusion of nominal wage rigidities does not modify κ_p. Hence, the addition of nominal wage rigidities only increases the price-inflation persistence if it increases the persistence of real wages.

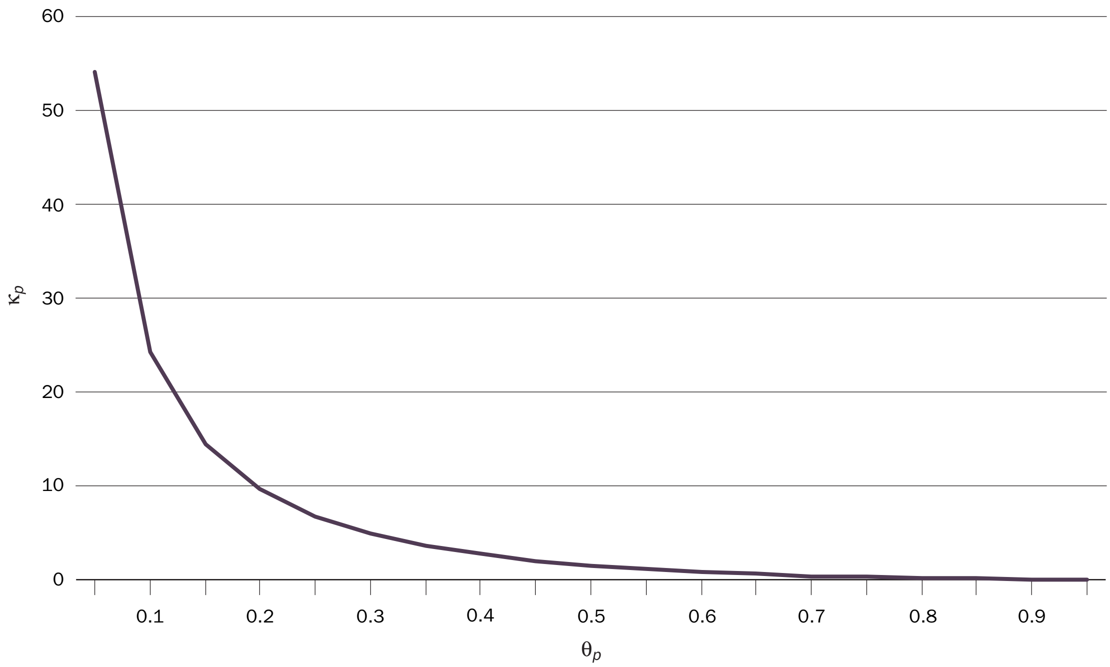
Inflation Persistence Analysis

To study the persistence of price inflation implied by the two models, this analysis first reports the observed autocorrelations of price inflation and then performs some numerical exercises to study the autocorrelation functions of price inflation implied by the basic sticky-price model when only a monetary shock is considered. Finally, the analysis does the same for the sticky-price and sticky-wage model.

To understand how much persistence in price inflation these models can generate given a plausible degree of price and wage stickiness, one could modify the parameters of the model (in particular, θ_p and θ_w) until κ_p or real-wage stickiness is such that price inflation matches observed inflation. As

FIGURE 2

The Elasticity of Inflation to Marginal Cost (κ_p) As a Function of the Probability of Price Change (θ_p) in the Sticky-Price Model



mentioned, the problem with this approach is that access to additional empirical evidence, such as surveys or data panels, provides us reasonable bounds for most of the parameters of the model. Thus, a plausible degree of price and wage stickiness means that the wage and price contract length implied by θ_p and θ_w are inside these bounds.

The autocorrelation function of price inflation. Figure 1 shows the autocorrelation function of the gross domestic product (GDP) deflator for the nonfarm business sector between 1960:01 and 2001:04. First, the autocorrelation function implied by the GDP deflator reported here is similar to the one implied by either the consumer price index (CPI) or the personal consumption expenditures index (PCE).

Second, even after five periods the autocorrelation is 0.5. The following analysis shows that New Keynesian models with only sticky prices have a number of problems replicating this slow decay of the autocorrelogram.

Persistence in the sticky-price model. The effects of θ_p on price inflation are twofold. First, it affects the slope of the New Keynesian Phillips curve:

$$\kappa_p = \frac{[(1-\theta_p\beta)(1-\theta_p)]}{\theta_p};$$

Second, θ_p affects the persistence of the percentage deviation of the real wage ($w_t - p_t$) with respect to the marginal product of labor (a_t).

Before studying the relationship between θ_p and real wage persistence, the analysis will first concentrate on understanding how the price contract duration, $1/(1 - \theta_p)$, affects κ_p. Notice the following relationship:

$$\frac{\partial \kappa_p}{\partial \theta_p} = -\frac{\sigma + \gamma}{\theta_p^2}(1 - \theta_p^2\beta) < 0.$$

This derivative implies that the higher θ_p (that is, the higher the price contract duration), the lower κ_p. One can observe this relationship in Figure 2, which plots κ_p as a function of θ_p. Under the limitation $\theta_p \to 1$, that is, when prices are fixed forever, $\kappa_p \to 0$ and $\pi_t = 0$ forever, implying the highest persistence possible.

As mentioned before, the issue is that, as Figure 3 shows, the higher θ_p, the higher the average duration of price contracts, $1/(1 - \theta_p)$. As many authors have reported (see, for example, Dutta, Berger, and Levy 1997; Blinder et al. 1998), observed average price change is not much longer than one year. This observation implies that analysis should be restricted to values of θ_p that imply durations no longer than five quarters, that is, $\theta_p \leq 4/5$.

FIGURE 3

Duration As a Function of the Probability of Price Change (θ_p) in the Sticky-Price Model

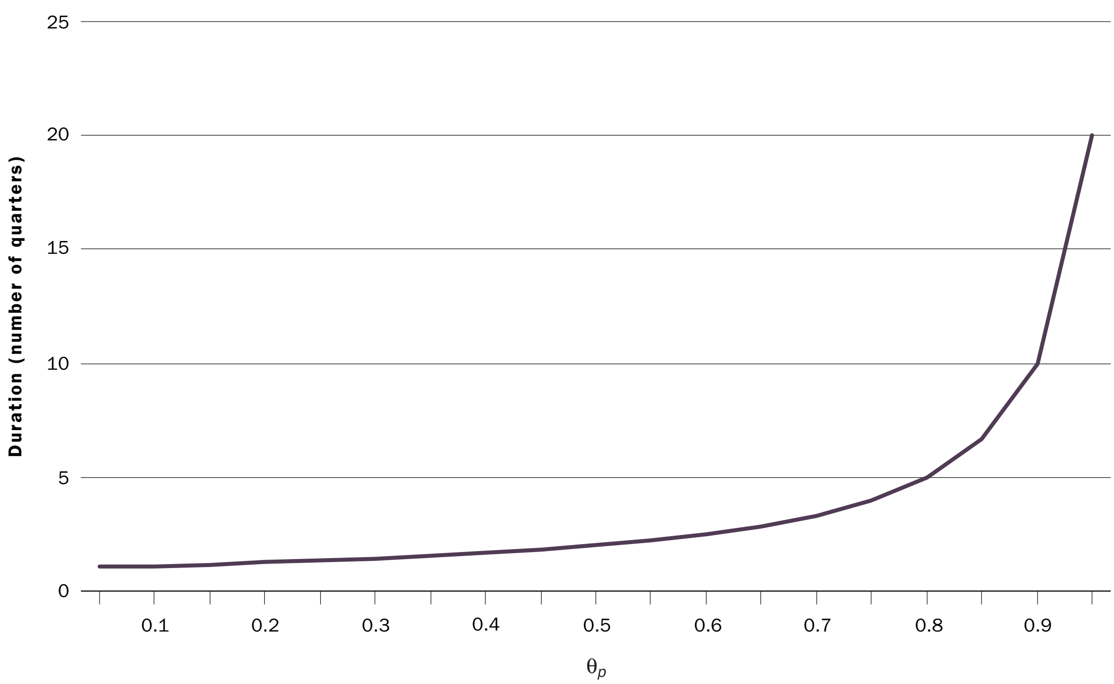


TABLE 1

Calibration for the Sticky-Price Model

Variable	Value
σ	1
γ	1
β	0.99
μ	1.2
ϑ	1.2
ρ	0.8
ρ_a	0.8
σ_r	1
σ_a	1
γ_π	1.5
γ_x	0.5
θ_p	$^3/_4$

The analysis has shown that increasing persistence by letting $\theta_p \rightarrow 1$ ($\kappa_p \rightarrow 0$) is not consistent with the evidence on price contract duration. The following numerical simulations study the effects of different parameter values of θ_p (different price contract durations) on price inflation persistence, examining the real-wage and price-inflation autocorrelation functions that the baseline sticky-price model generates under these conditions.

The baseline calibration used in the following analysis is shown in Table 1. The inverse intertemporal rate of substitution and the elasticity of labor supply, σ and γ, are set to 1. Because quarterly data are used, β being set to 0.99 implies a 4.1 percent annualized real interest rate. The calibration of μ and ϑ at 1.2 implies a 20 percent markup over marginal costs and real wages, respectively. Both ρ and ρ_a are set to 0.8, and σ_r and σ_a are set to 1. Taylor's rule elasticities, γ_π and γ_x, are set to Taylor's original guesses. θ_p is set to $^3/_4$, which implies an average duration of price contracts of four periods.

Figures 4 and 5 illustrate the autocorrelation functions of price inflation and real wages when only a monetary shock is considered for different average durations of price contracts. The longer the duration, the higher price inflation persistence. The intuition for this result is that when prices are sticky, a positive (negative) monetary shock will increase (decrease) demand and real output. The longer the average price contract lasts, the more persistent is the effect on output. As equations (3) and (4) show, real wages are linked to output, so the higher the output persistence, the higher the real wage persistence. Because no technology shock is involved, the marginal product of labor is constant, and the real wage and its deviation from the marginal product of labor exhibit the same auto-

FIGURE 4

The Autocorrelation Function of Price Inflation When Only a Monetary Shock Is Considered in the Sticky-Price Model

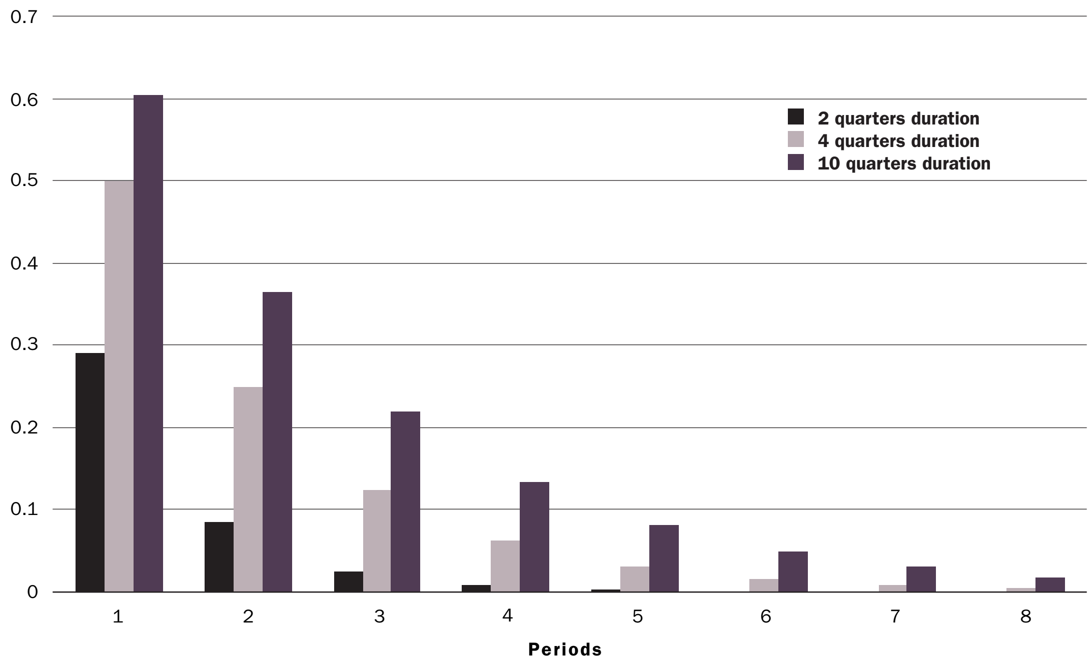


FIGURE 5

The Autocorrelation Function of Real Wages When Only a Monetary Shock Is Considered in the Sticky-Price Model

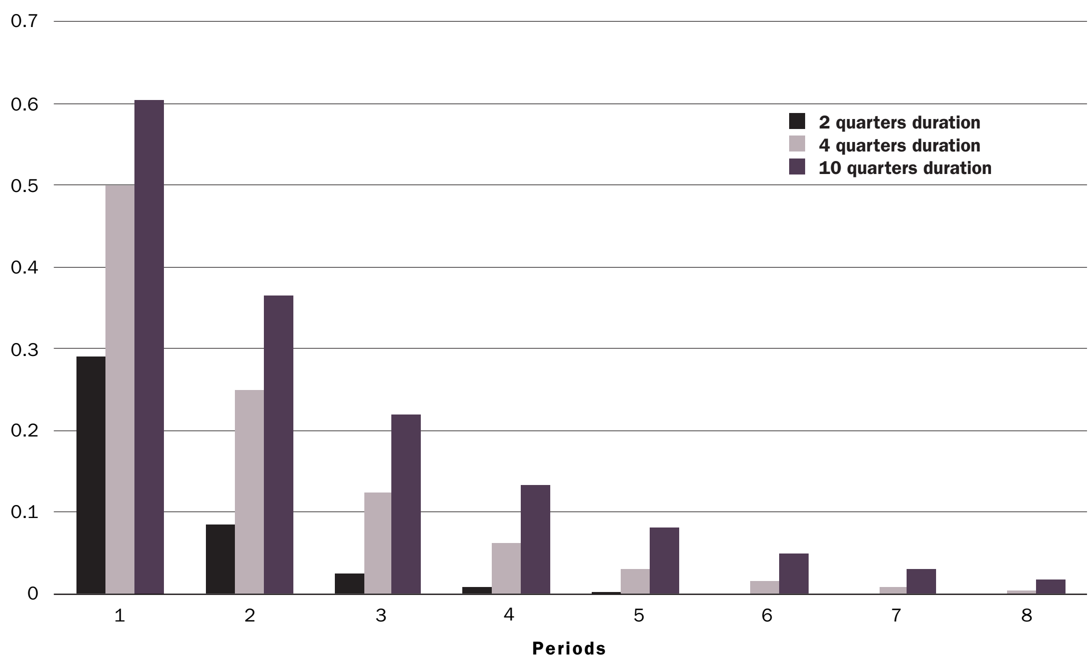


FIGURE 6

The Autocorrelation Function of Price Inflation When Only a Monetary Shock Is Considered for Different Values of ρ in the Sticky-Price Model

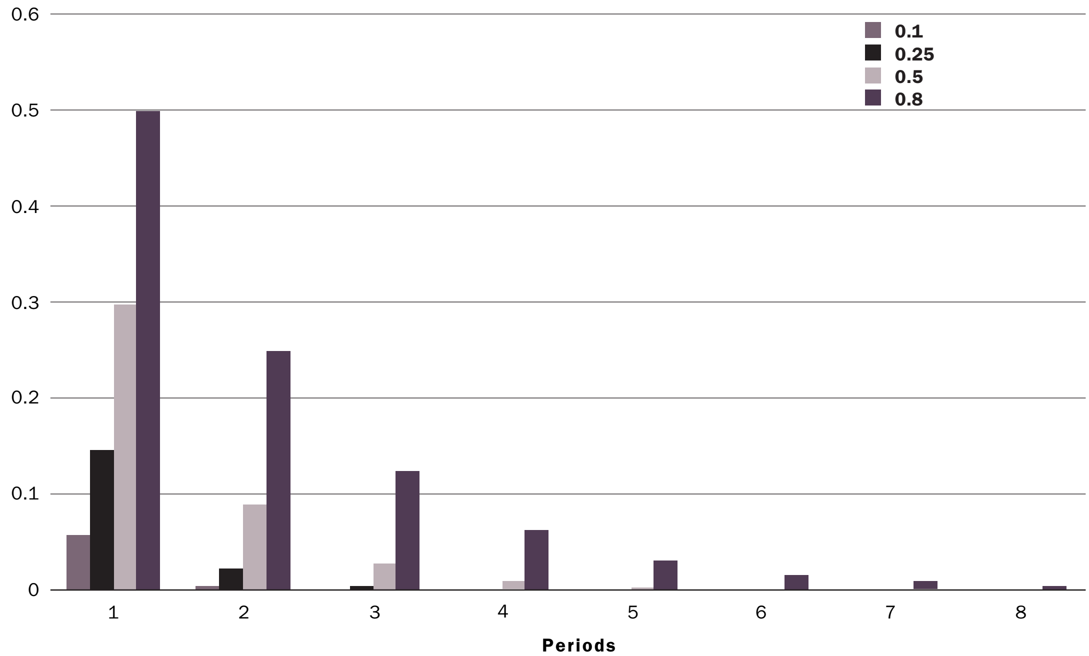


TABLE 2

Calibration for the Sticky-Price and Sticky-Wage Model

Variable	Value
σ	1
γ	1
β	0.99
μ	1.2
ϑ	1.2
ρ	0.8
ρ_a	0.8
σ_r	1
σ_a	1
γ_π	1.5
γ_x	0.5
θ_p	$^3/_4$
θ_w	$^4/_5$

correlation function. Thus, one can conclude that the longer the average contract, the more persistent is the effect on real wages and price inflation.

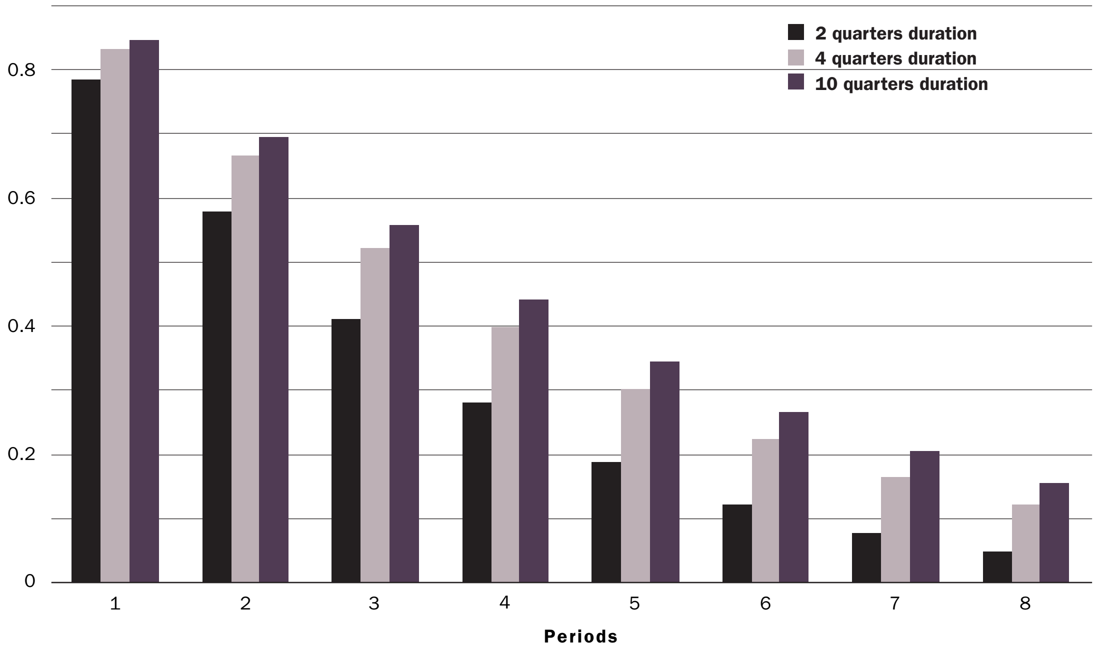
It is important to understand what the source of this persistence is. The following analysis considers how the source of exogenous nominal interest rate persistence, ρ, affects the persistence of inflation that this simple model is able to generate.

Figure 6 shows the autocorrelation function of price inflation for different values of ρ (the exogenous persistence parameter of the nominal interest rate) when only a monetary shock is considered. For low values of ρ, inflation persistence is very low. The intuition is as follows. Nominal interest rate persistence depends on ρ. As equation (6) shows, the higher (lower) the nominal interest rate persistence, the higher (lower) the output persistence. Because only a monetary shock is considered, real wages and output share the same autocorrelation function, so the higher (lower) the nominal interest rate persistence, the higher (lower) the real wage and price inflation persistence. Under these conditions, inflation persistence greatly depends on ρ, the nominal interest rate exogenous persistence. Indeed, Figure 6 shows that a model with only sticky prices does not amplify the inflation persistence of a monetary shock beyond that induced by ρ.

From this analysis one can conclude that the model with only sticky prices is not able to generate endogenous persistence beyond that obtained through the coefficient ρ. This conclusion raises the following questions: Is it possible to generate inflation persistence in this model? Is inflation persistence highly linked to ρ? Is there an obvious mechanism generating it? From the observations in Figure 6, it seems that the correct answer is that the inflation

FIGURE 7

The Autocorrelation Function of Price Inflation When Only a Monetary Shock Is Considered in the Sticky-Price and Sticky-Wage Model



persistence is highly related to ρ and that there is no other mechanism that can generate it.

These results indicate that the baseline sticky-price model is not able to generate enough endogenous inflation persistence, so the analysis next considers whether the sticky-price and sticky-wage model can do it.

Persistence in the sticky-price and sticky-wage model. As mentioned earlier, the inclusion of wage rigidities does not modify κ_p. Thus, the impact of wage rigidities on price inflation persistence should come through their effect on the persistence of the real wage. Table 2 lists the basic calibration used in this model. The parameters are set to the same values used in the baseline sticky-price model. θ_w is set to $^4/_5$, implying an average wage contract duration of five quarters.

Figures 7 and 8 show the autocorrelation function of price inflation and real wage for a given average duration of the price contract of four quarters ($\theta_p = {}^3/_4$) when different values of θ_w and just a monetary shock are considered. The inclusion of wage rigidities increases the persistence of both real wages and price inflation. In the sticky-price model, nominal wages move freely, making real wages not persistent. When both wages and prices are sticky, real wages display more persistence. As noted before, the persistence of the real wage deviation from the marginal product of labor drives price inflation persistence. In Figures 7 and 8, which consider only a money shock, the marginal product of labor does not move, and price inflation persistence also increases. One can conclude that the addition of nominal wage stickiness makes the reaction of price inflation to money shocks more persistent.

Figure 9 reports the autocorrelation function of price inflation for different values of ρ when only a monetary shock is considered. In the basic sticky-price model, the price inflation persistence depends greatly on ρ. Figure 9 shows that when both prices and wages are sticky, the persistence of inflation the model generates as a response to a monetary shock does not depend on ρ. The addition of sticky wages to the baseline sticky price model increases real wage persistence in such a way that, even with very low ρ, the model is able to generate a persistent inflation response. In addition, the introduction of staggered wage contracts to the sticky price model in a pure forward-looking model helps increase inflation persistence.

Conclusion

This article analyzes the ability of a model with both sticky prices and wages to solve one of the most important shortcomings of the baseline sticky-price model: the lack of persistence of inflation when

FIGURE 8

The Autocorrelation Function of Real Wages When Only a Monetary Shock Is Considered in the Sticky-Price and Sticky-Wage Model

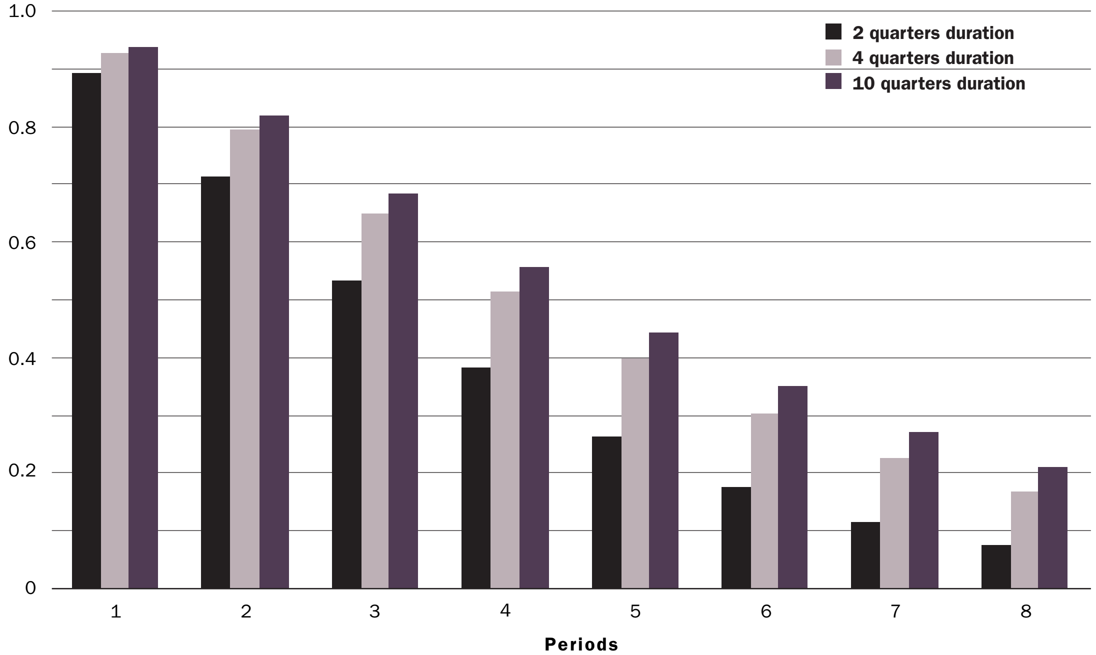
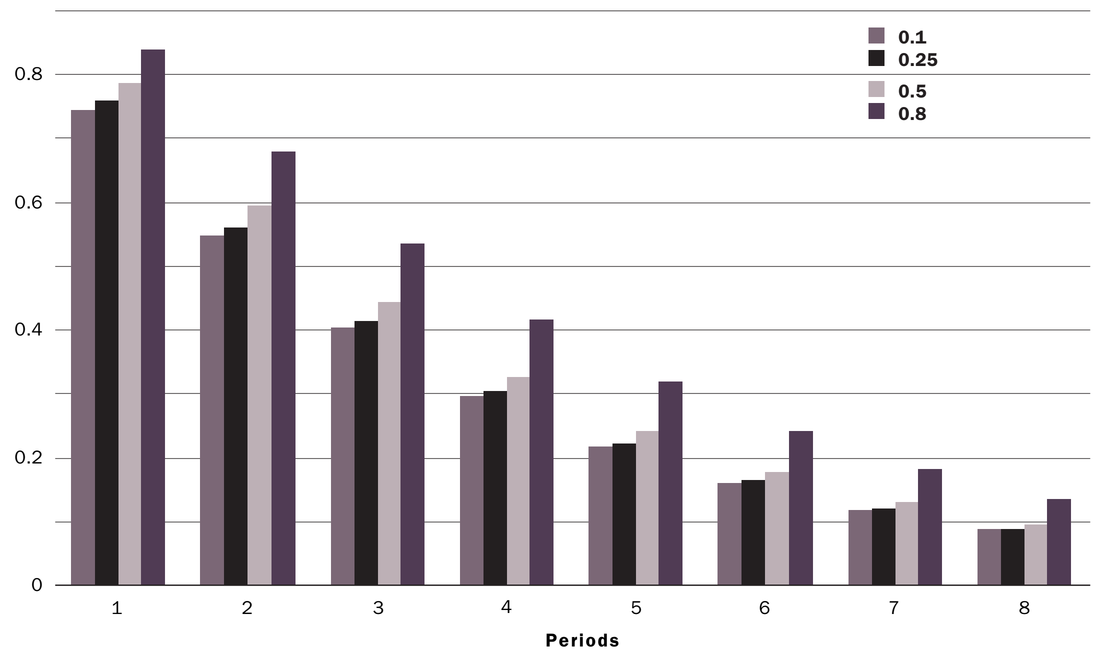


FIGURE 9

The Autocorrelation Function of Price Inflation When Only a Monetary Shock Is Considered for Different Values of ρ in the Sticky-Price and Sticky-Wage Model



only a monetary shock is considered. The findings show that, while the baseline sticky-price model cannot replicate the inflation persistence observed in the data unless an implausible degree of either price stickiness or exogenous nominal interest rate persistence is assumed, a model with both sticky prices and sticky wages can replicate more closely the autocorrelation function of inflation, even with acceptable levels of both price and wage stickiness. This result is important because some notable studies, such as Fuhrer and Moore (1995) and Chari, Kehoe, and McGrattan (1998), have criticized the incapability of this kind of model with nominal rigidities to match inflation persistence.

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