

# *The Persistence of Inflation and the Cost of Disinflation*

**S**ome economic questions can be considered only within the context of an economic model. For example, “How costly would it be (in terms of lost jobs and output) to lower the inflation rate to zero?” is a question that, because it is counterfactual, can only be answered by creating an economic model that allows us to estimate the effects of pursuing counterfactual economic policies. Models are not all created equal, however, so that the answer to this question can vary widely depending upon the characteristics of the model used to address the question.

This article will argue that one cannot answer the above question accurately without using a model that properly captures an important feature of the real world: the persistence of inflation. In essence, the more persistence inflation exhibits, the harder monetary policy has to push on it to bring it down. The harder monetary policy has to push, the more it will disrupt the real economy, and the greater will be the cost associated with disinflating.

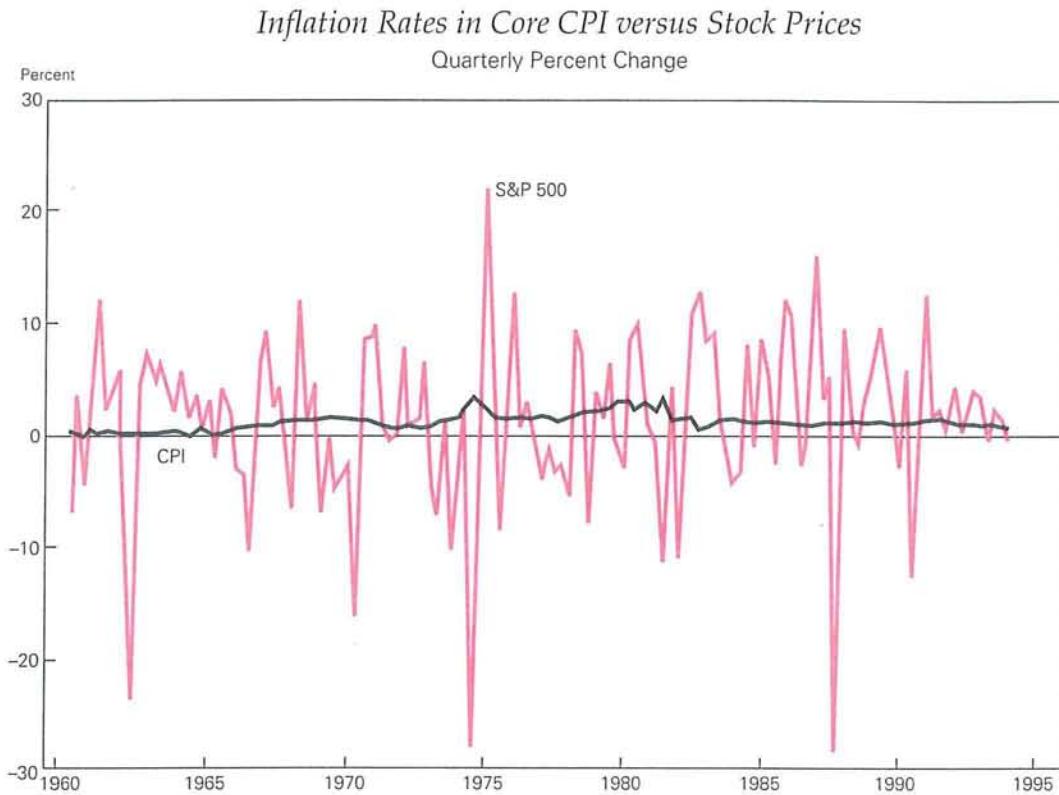
While there is wide agreement that inflation is persistent and that disinflations have been costly, the source of persistence and the reason for the cost are not widely agreed upon. As will be discussed below, persistence of inflation and the cost of disinflating may arise for several reasons, including the inertia that wage and price contracts impart to the inflation rate, the inertia that slowly adjusting expectations may impart to inflation, or the inertia that imperfect credibility may impart to inflation.<sup>1</sup> This study will demonstrate the importance of persistence in a model of inflation, and then consider each of the explanations given above.

Different sources of inflation persistence bear different implications for the conduct of monetary policy. If disinflations are costly because the Federal Reserve lacks credibility, then the Fed should determine whether and how it can improve its credibility. If persistence arises from other aspects of price-setting behavior, then monetary policy must accept the costs of disinflation unless these behaviors change.

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Figure 1



Source: U.S. Bureau of Labor Statistics, Consumer Price Index, all items less food and energy, seasonally adjusted. Standard & Poor's Index of Stock Prices, U.S. 500 Common Stocks.

## I. Defining Persistence

What do economists mean when they talk about the “persistence” of an economic variable? Persistence refers to the tendency for a variable to stay away from its average level for an extended period when perturbed.<sup>2</sup> For example, when the unemployment rate deviates significantly from its “natural” rate, most economists would not expect it to return immediately. Similarly, this study will show that historically, when inflation has deviated from the rate that the monetary authority desires, its return to the desired rate takes quarters or years, not weeks or months. Failure of the model to incorporate this “inflation persistence” can produce misleading policy prescriptions.

The persistence of inflation in the prices of goods and services contrasts sharply with the lack of persistence in the inflation in prices of financial assets. A

leading example is the price of stocks traded on the New York Stock Exchange. The rate of change in a basket of stock prices, which averages out idiosyncratic movements of individual stocks, shows little or no persistence. A graphical comparison of these two qualitatively different behaviors is displayed in Figure 1, which shows the monthly percentage changes in the consumer price index (CPI) and the Standard & Poor's composite stock index. The difference in the volatility

<sup>1</sup> Blinder (1991) and Carlton (1986) provide survey evidence of the prevalence of price and wage contracting arrangements.

<sup>2</sup> Thus, this definition assumes the existence of an average level. For many economic measures—the inflation rate, the unemployment rate, the savings rate—this assumption may be a reasonable approximation to reality. For others—the general price level, the level of GDP—it is clearly false. However, even for the latter measures, their *growth* rates may well tend to settle at an average level.



of the two series is obvious and striking. Stock prices are about as likely to rise as to fall markedly from month to month, regardless of which direction they were headed last month. The CPI changes only a bit from month to month, and the tendency for positive (negative) changes to be followed by positive (negative) changes is pronounced.

Common-sense economic reasons can be given for the difference in the behavior of these two types of prices. The prices of financial assets may be thought of as the valuation that the financial markets place on

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the expected stream of returns to holding the asset. For equities, the price will reflect the (discounted) expected earnings that a firm will accrue over its lifetime, or the dividends that the firm is expected to pay to shareholders over its lifetime. Thus, the price depends on the market's *expectations*, which are free to change from minute to minute.

In contrast, the prices of goods and services—the prices of chicken and haircuts, for example—cannot move as freely as the prices of financial assets. While their prices may reflect in part the expectations of market participants, they also depend on the cost of inputs to production and the terms of contracts with suppliers and buyers. The largest of the input costs for most goods and services is the cost of labor, which varies slowly as salaries and benefits are adjusted, usually annually. Thus, it is unlikely that the average level of goods and services prices, as reflected in the CPI, for example, will exhibit the same flexibility as the average level of financial asset prices.

### *Measuring the Persistence of Inflation*

One commonly used measure of the persistence in an economic measure is its *autocorrelation function*. The autocorrelation function, as its name suggests, describes the correlation of an economic time series with its own history. For example, a variable would be

said to exhibit a positive autocorrelation if an above-average (below-average) reading for the variable over the past few time periods tended to be followed by an above-average (below-average) reading for the variable in the current period. A variable is said to exhibit negative autocorrelation when an above-average (below-average) reading over the last few quarters tends to be followed by a below-average (above-average) reading in the current quarter. The variable exhibits zero autocorrelation when positive readings in past quarters are not followed systematically by either positive or negative readings.

Thus, the autocorrelation function provides a measure of the persistence in an economic time series. When economic conditions push inflation away from its average level, if it tends to stay away, then we will see positive autocorrelation in the rate of inflation. If instead, when economic conditions push inflation away from its norm, it reverts immediately to its norm, we will see no autocorrelation in the rate of inflation.

Figure 2 displays the autocorrelation functions for several measures of inflation over the past 25 years. As the panels in the figure show, all of the measures of inflation exhibit a good deal of persistence: Higher-than-average levels of inflation over the past 1 to 12 quarters tend to be followed by higher-than-average levels of inflation today. This appears to be a strong qualitative feature of the inflation data, not dependent upon the precise definition of inflation nor on the sample period over which the autocorrelation function is computed. In contrast, the autocorrelation function for the stock price index in the bottom panel shows little or no significant autocorrelation; it is not very persistent at all.

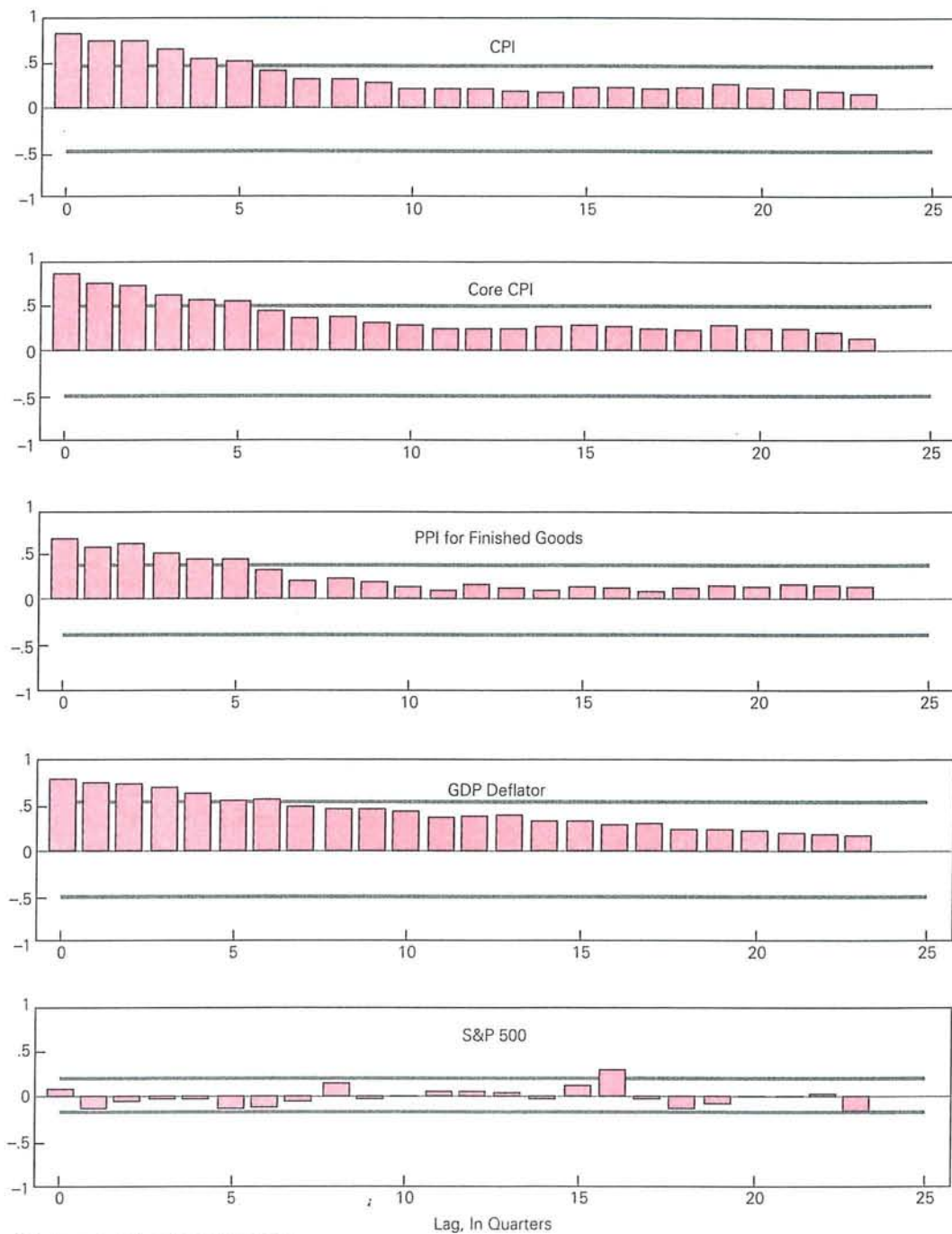
Figure 3 displays the response over time of inflation to a perturbation of inflation from its average level (for example, an oil price shock).<sup>3</sup> As the figure illustrates, inflation historically has not returned quickly to its average level in response to shocks, but has instead remained away from its average level for several years, only gradually returning to its resting place.<sup>4</sup> The rate of change of stock prices, on the other hand, shows no such persistence.

<sup>3</sup> The responses are computed from regressions of measures of inflation on their own lags and a constant.

<sup>4</sup> This simple description of inflation does not distinguish among different types of shocks to inflation. For example, inflation might respond differently to a supply shock, such as a change in the relative price of oil, than it responds to a demand shock, such as unexpectedly accommodative monetary policy. Note that in Figure 2, the average level to which all the inflation rates return is set arbitrarily to zero.

Figure 2

*Autocorrelation Functions for Various Inflation Rates*

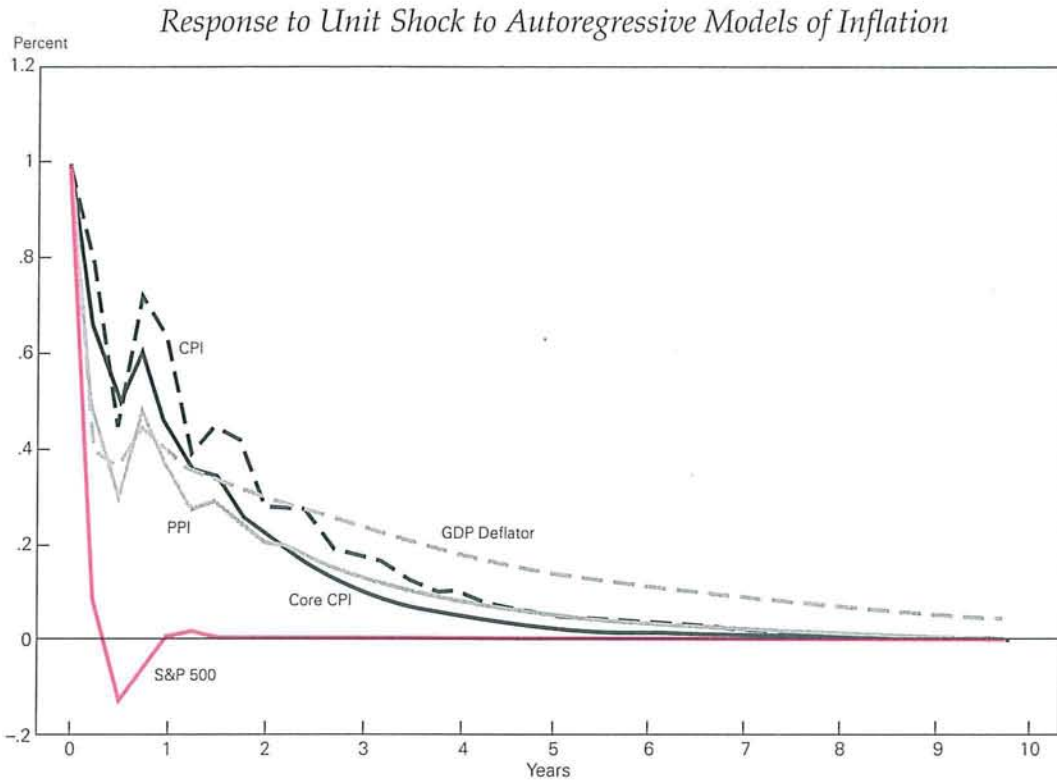


Note: Lines denote two standard error bands.

Source: U.S. Bureau of Labor Statistics, Consumer Price Index, all items, seasonally adjusted; Consumer Price Index, all items less food and energy, seasonally adjusted; Producer Price Index, finished goods, seasonally adjusted; U.S. Bureau of Economic Analysis, Gross Domestic Product Implicit Deflator. Standard & Poor's Index of Stock Prices, U.S. 500 Common Stocks.



Figure 3



The persistence of interactions among economic variables may also be characterized by correlation functions. Thus, a change in output may affect inflation for several quarters after the change (a persistent effect) or it may affect inflation only concurrently. A series that displays persistence in its autocorrelation function can (although it need not) exhibit a persistent relationship with other series. Thus, an important corollary to inflation's own persistence is that its relationships with other economic variables can also exhibit persistence.

The correlations among economic series over time display graphically the degree of persistence in relationships among economic series. Figure 4 displays the cross-time cross-correlations among inflation, interest rates, and the output gap.<sup>5</sup> The panels on the

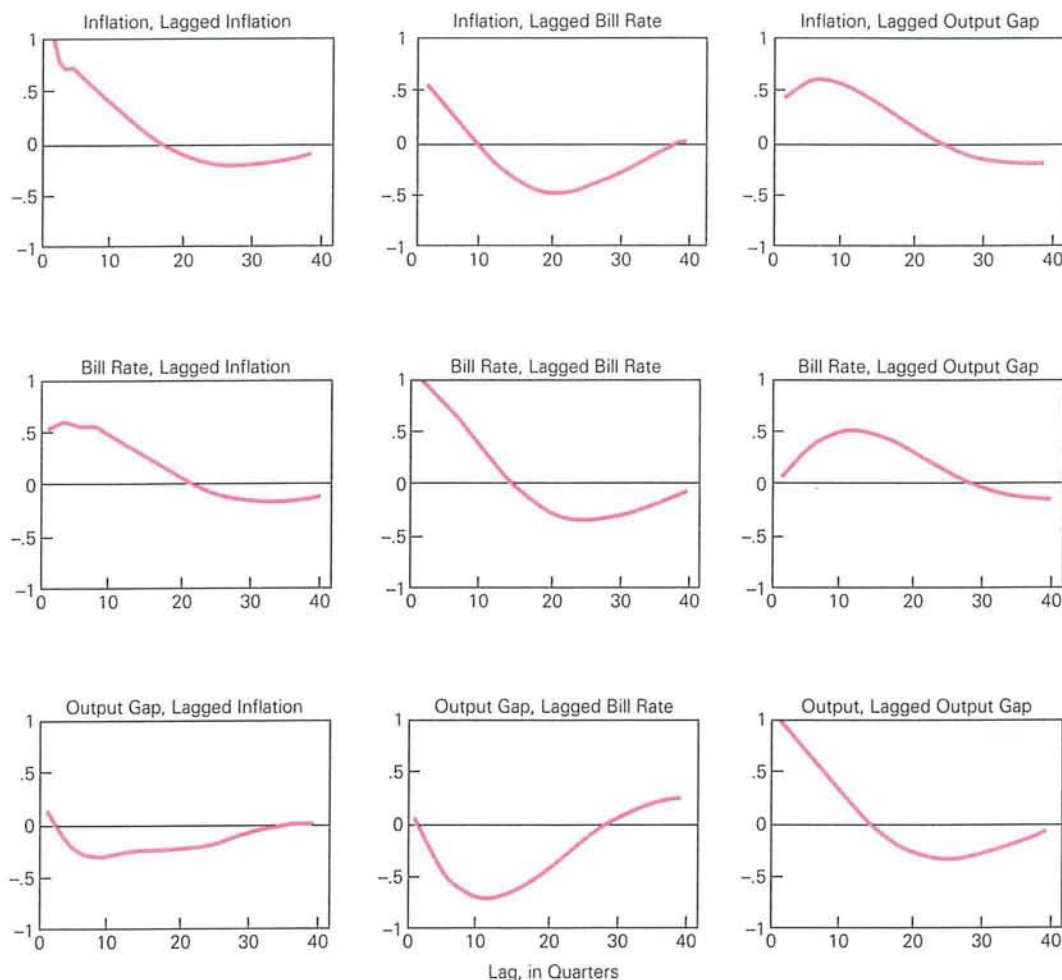
diagonal in the figure are the *autocorrelation functions* described above. All of the series exhibit considerable persistence; their autocorrelations die out slowly. The series also exhibit persistent correlations with one another, as the off-diagonal panels in the figure show. For example, the top right panel of the figure shows that when the output gap was high 8 to 12 quarters ago, inflation tends to be high today. Although no unique interpretation exists for the correlations in the figure, this pattern is consistent with a standard description of the monetary policy transmission mechanism: The Fed wishes to lower (raise) inflation, so it raises (lowers) interest rates, and contracts (expands) real activity. Inflation responds gradually to the negative (positive) output gap, falling (rising) over several years to its new, lower (higher) level.

<sup>5</sup> Inflation is defined as the four-quarter log change in the GDP deflator. The interest rate is the three-month Treasury bill rate. The output gap is the difference between real log per capita GDP and a linear trend. The autocorrelations are computed from the estimated

coefficients and error covariance matrix of an unconstrained vector autoregression. They are smoothed versions of the cross-correlations computed directly from the data.

Figure 4

### Vector Autocorrelation Function



Source: Author's calculations.  
 Inflation - Quarterly inflation rate of the GDP Deflator expressed at an annual rate.  
 Output Gap - Deviation of the log of per capita real GDP from a linear trend.  
 Bill Rate - Three-month Treasury bill.

A good model of inflation, interest rates, and output must capture (at least reasonably well) these persistent dynamic interactions. As we will show below, a model that misses the persistence in inflation bears dramatically different implications for the conduct of monetary policy.<sup>6</sup>

<sup>6</sup> Note that the measures of persistence in Figures 1 and 2 assume an "average" level for each of the variables; that is, they assume *stationarity* in the mean of the variables. If the variables were not mean-stationary or nearly nonstationary (as suggested by a number of authors), the degree of persistence that models would

## II. Models of Inflation

Two contrasting models highlight the importance of inflation inertia. The first builds no persistence into inflation, by making inflation depend only on the rational expectation of future inflation. The second builds persistence into the rate of inflation by making

have to produce would be even greater. Thus, a stationary representation of the behavior of inflation may understate the true persistence in inflation.



inflation depend on both expected and past inflation. The difference in the behavior of these two models in a disinflationary episode is striking.

### A Model of Flexible Inflation

In the discussion above, freely moving asset prices such as stock prices were contrasted with sticky or inertial prices such as the price of an automobile. The first model of inflation considered here implies a very flexible rate of inflation, for essentially the same reasons that stock prices were argued to be flexible above. In this model, inflation depends on expected inflation over the next period,  $E_t \pi_{t+1}$ , and on the "output gap,"  $y_t$ , the difference between actual and potential output:

$$\pi_t = E_t \pi_{t+1} + \gamma y_t. \quad (1)$$

The flexibility of inflation in this model arises from its dependence on the completely flexible expectation of inflation. When the output gap changes, expectations can adjust immediately to the new gap, so inflation can adjust immediately. In the long run, if the output gap is zero, inflation equals expected inflation. In the short run, when the output gap is positive (negative), current inflation will exceed (fall short of) expected inflation. This model is equivalent to a two-period version of the influential overlapping wage contract model found in Taylor (1980).<sup>7</sup> See the box for the relationship between these simple inflation models and their more sophisticated counterparts.

This flexible inflation model implies rather peculiar behavior during a disinflation.<sup>8</sup> If the Federal Reserve engineers a disinflation, it does so by pursuing a contractionary monetary policy that lowers output below potential ( $y_t < 0$ ). But the flexible inflation model of equation (1) says that when output falls short

<sup>7</sup> Taylor's model made a vital contribution to the literature on wage and price behavior. It allowed wage-setters to have rational expectations, but it imparted significant persistence to the level of prices. Previous models with rational expectations implied a perfectly flexible price level, which seemed clearly at odds with data on prices.

<sup>8</sup> In fact, its peculiar behavior arises when one assumes that inflation expectations are formed *rationally*, as the developers of the model do. If expectations are sufficiently persistent, then this model can also build in the persistence exhibited by the inflation data. This possibility will be explored below.

<sup>9</sup> An extended discussion of the points raised here appears in Fuhrer and Moore (1995a), especially sections I and II.D.

<sup>10</sup> To see this, substitute the definition of  $x_t$  from the equation (B1) ( $x_t = 2p_t - x_{t-1}$ ) into equation (B2), and simplify, using  $\pi_t = p_t - p_{t-1}$ , and  $\gamma y_{t-1} = x_{t-1} - (1/2)(x_{t-2} + E_{t-1}x_t)$ . This yields  $\pi_t = E_t \pi_{t+1} + \gamma(y_t + y_{t-1})$ . Equation (1) simplifies the  $y$  term to  $\gamma y_t$ . Note

### The Relationship between Wage Contracting Models and the Flexible/Persistent Inflation Models<sup>9</sup>

The "flexible inflation" model can be derived from a two-period version of John Taylor's (1980) overlapping wage contracting model. In that model, wage bargainers are assumed to negotiate contracts for their nominal wage,  $x_t$ , that remain in effect for a fixed period. They set contracts for their nominal wage so as to keep it in line with other wage contracts currently in effect (negotiated last period) and expected to be in effect next period, adjusted for excess demand conditions,  $y_t$ , in the labor market. For wage contracts that last two periods, this can be written as

$$x_t = (1/2)(x_{t-1} + E_t x_{t+1}) + \gamma y_t. \quad (B1)$$

Prices are determined by the average level of wage contracts in effect. For wage contracts that last two periods, prices will be the average of last period's and this period's wage contracts:

$$p_t = (1/2)(x_t + x_{t-1}). \quad (B2)$$

But equations (B1) and (B2) together imply that the equation for inflation is equation (1).<sup>10</sup>

Equation (4), below, may be shown to be equivalent to a similar two-period wage contracting model as well. In this model, the level of prices is determined by equation (B2); the difference is that wage contracts are set so that the real value of each wage contract,  $x_t - p_t$ , is in line with the real value of last period's and next period's wage contract, adjusted for excess demand conditions in the labor market:

$$x_t = (1/2)[(x_{t-1} - p_{t-1}) + E_t(x_{t+1} - p_{t+1})] + \gamma y_t. \quad (B3)$$

Combining equations (B2) and (B3) yields equation (4), below.

None of the qualitative results presented here depend on these simplifications. Multi-period wage contracting models exhibit the same properties as the simple models of equations (1) and (4).

that this model imparts tremendous persistence to the *level of prices*. In fact, this was the original motivation behind the model: to build a rational expectations model that did not imply perfectly flexible prices. This goal is clearly achieved by the model, but it brings with it the unintended implication of flexible inflation.



of potential, expected inflation in the next period must exceed current inflation. This does not sound like a disinflation. The only way for this to happen is for inflation to jump down immediately when output falls below potential, and then rise to its new, lower, inflation target from below! The extreme flexibility exhibited by inflation during the disinflationary episode illustrates its complete lack of persistence.

To display the behavior of the flexible inflation model graphically requires a description of the behavior of the output gap, which in turn depends on the behavior of interest rates, which in turn depends on the behavior of the Fed. A very simple characterization of these sectors includes a monetary policy *reaction function*. The Fed increases the federal funds rate when inflation,  $\pi_t$ , exceeds its target,  $\pi^*$ , or when the output gap is positive (output exceeds potential):

$$f_t - f_{t-1} = \alpha_\pi(\pi_t - \pi^*) + \alpha_y y_t. \quad (2)$$

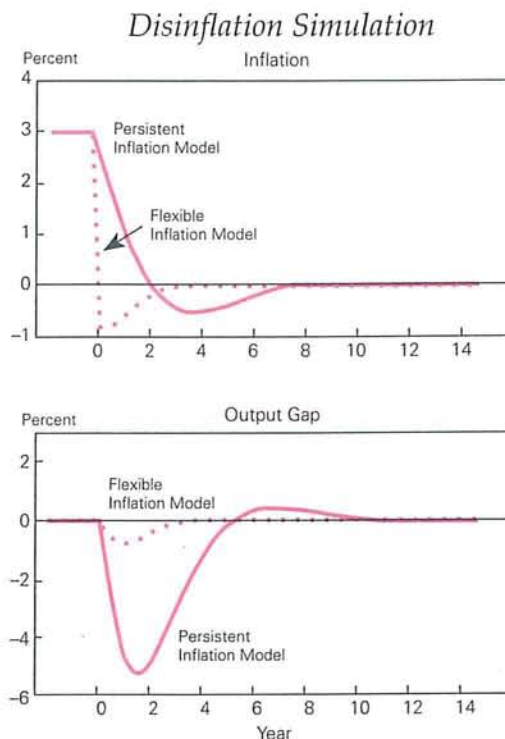
The coefficients  $\alpha_\pi$  and  $\alpha_y$  determine the vigor with which policy responds to inflation and output gap movements, respectively. Note that this description of monetary policy puts a degree of persistence into the federal funds rate. That is, the Fed is assumed to move the funds rate only by changing it incrementally relative to its level last period. While this behavior appears to be consistent with the behavior of the funds rate over the past 30 years, a policy of less gradual changes in the funds rate bears somewhat different implications for a disinflation, as will be shown below.

The Fed can raise (lower) short-term real rates, which will raise (lower) long-term real rates,  $\rho_t$ , which in turn will lower (raise) output gradually below (above) potential.<sup>11</sup> Equation (3) depicts the final link in this monetary transmission chain.

$$y_t = \lambda y_{t-1} + \beta \rho_{t-1}. \quad (3)$$

The dashed line in the top panel of Figure 5 displays the path of inflation during a disinflation as implied by the flexible inflation model. In this and all of the following simulations, inflation and expected inflation begin at their initial target rates of 3 percent; the output gap begins at zero (output equals potential output). At the beginning of the year labelled "0" on the figure, the Fed lowers its target rate of inflation from 3 percent to 0 percent. The inflation rate jumps down immediately below 0 percent and rises to it from below. The increase in real rates, which arises not because the funds rate rises but because the inflation

Figure 5



Source: Author's calculations.

rate drops precipitously, depresses output slightly. The "recession" associated with this disinflation is depicted in the dashed line in the bottom panel of Figure 5. Output falls slightly below potential, returning to potential after about 15 quarters.

One standard measure of the cost of a disinflation is the "sacrifice ratio"—the percentage shortfall of output below potential per percentage point decrease in the inflation rate. For the disinflation simulation in Figure 5, the flexible inflation model predicts a sacrifice ratio of 0.7, about one-sixth the size of the standard estimates presented in Gordon (1985), for example. By increasing the emphasis on the output gap, monetary policy can lower the sacrifice ratio to 0, making disinflation costless.

### A Model of Persistent Inflation

A different characterization of the inflation process implies considerably more persistence in the rate of inflation, and consequently implies considerably higher costs to disinflating. The model assumes that

<sup>11</sup> This description of monetary policy and its transmission to real output follows the discussion in Fuhrer and Moore (1995b).



inflation depends on expected future inflation and on lagged inflation and on the output gap.<sup>12</sup>

$$\pi_t = (1/2)[\pi_{t-1} + E_t\pi_{t+1}] + \gamma y_t. \quad (4)$$

As shown in the box, this model is equivalent to a two-period wage contracting model that is a variant of the Taylor (1980) model. Although both models are based on wage contracts, they bear very different implications for the persistence of inflation and for the costs of disinflation. When the output gap changes in the persistent inflation model, the rate of inflation cannot move as freely as in the flexible inflation model, because inflation depends both on what it was last period, which is fixed, and on expected inflation, which is flexible.

The difference between this specification and the flexible inflation specification can be seen in the solid lines in Figure 5, in which the same disinflation exercise is simulated for the persistent inflation model using the same description of monetary policy and the transmission mechanism. The simulation paths for the persistent inflation model are depicted by the solid lines in the figure. The inflation rate falls gradually to its new, lower target, as shown in the top panel. The output loss associated with the disinflation is shown in the bottom panel, and implies a sacrifice ratio of 4.1, about six times larger than that of the flexible inflation model and about in line with conventional estimates. Raising the emphasis on the output gap can lower the sacrifice ratio (as with the flexible inflation model), but it is difficult to lower the sacrifice ratio much below 2.0, even for a very vigorous output gap response. The difference in inflation behavior is striking, and the increase in implied costs is substantial.

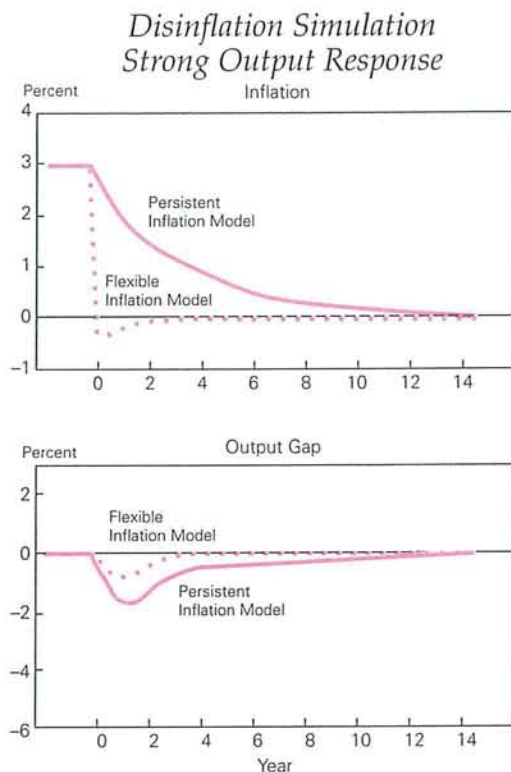
Note that the implication of the persistent inflation model for the flexibility of inflation does not depend on the exact specification of monetary policy and its transmission mechanism. We can rewrite equation (4) in terms of the change in inflation rates:

$$E_t\Delta\pi_{t+1} - \Delta\pi_t = \gamma y_t.$$

To see the implication using only the inflation equation, consider a disinflationary episode: Monetary policy tightens, lowering output below potential (making  $y_t$  negative). According to equation (4), the inflation rate will be falling, while the equation displayed above says that the expected *change* in the

<sup>12</sup> This model is a simplified version of the model used in Fuhrer and Moore (1995a).

Figure 6



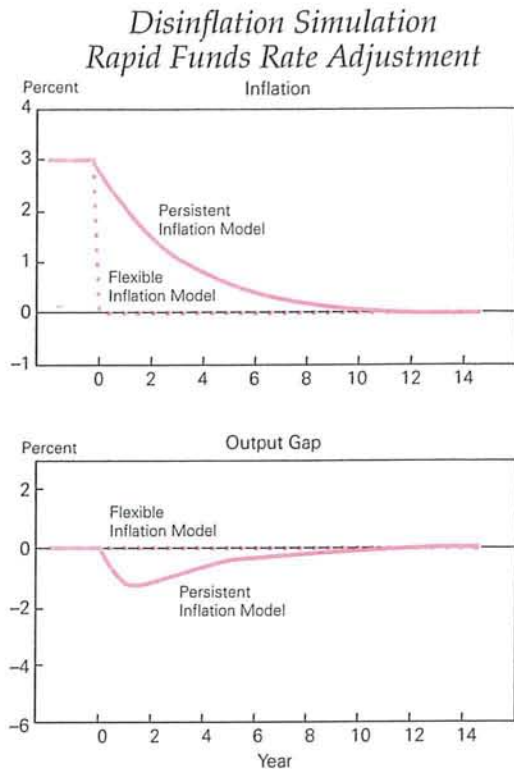
Source: Author's calculations.

inflation rate will be negative upon commencement of a disinflation. Figure 5 corresponds exactly to this description.

Figure 6 shows the extreme implications of the flexible inflation model under a disinflation in which the Fed places much more weight on stabilizing the output gap. Inflation jumps immediately to its new target, causing almost negligible disruption to output (the sacrifice ratio is 0.18 for this disinflation). In marked contrast, the inflation rate falls very gradually for the persistent inflation model, and output remains below potential for the duration of the simulation. The sacrifice ratio for the persistent inflation model is 1.8, ten times the size of the sacrifice ratio predicted by the flexible inflation model.

Finally, consider the effect on the estimated sacrifice ratio of removing the assumption that the Fed moves the funds rate incrementally. Suppose that the Fed were to move the federal funds rate more abruptly in response to deviations of its ultimate goals from their target values. Thus, it would alter the level

Figure 7



Source: Author's calculations.

of the funds rate without regard for its level in the previous period. A simple representation of this behavior is

$$f_t = f^* + \alpha_\pi(\pi_t - \pi^*) + \alpha_y y_t. \quad (5)$$

When inflation reaches its target and output equals potential, the funds rate settles to its "equilibrium" or natural resting place,  $f^*$ .<sup>13</sup>

Figure 7 depicts the disinflation simulations for modest policy responses using equation (5) to describe monetary policy. As the figure shows, the disinflation still incurs significant costs according to the persistent inflation model; the sacrifice ratio for this disinflation is about 2. For the flexible inflation model, however, the costs of disinflation completely disappear. The sacrifice ratio is exactly zero. Thus, the only reason for a nonzero sacrifice ratio in the flexible inflation model simulations above is that policy chooses to move the funds rate gradually. Removing this constraint makes inflation literally costless.

Figures 5 to 7 also show what the two models predict about the correlations between the inflation rate and other variables in the system. The correlations observed in the data are displayed in Figure 4. The dashed lines in Figures 5 to 7 suggest virtually no persistence in the correlations between inflation and the output gap, whereas the data show a long-lived positive correlation. Figure 7 in particular shows that inflation and the output gap move instantaneously from one resting point to another, with no transition time. This clearly stands at odds with the data on inflation and output.

Thus, the different characterizations of the behavior of inflation can have dramatic implications for the persistence of inflation and for the costs of disinflating. The notion that disinflation could be achieved with no disruption to the real economy stands in stark contrast to the experience of all economies around the world (see Ball 1994). One explanation for the high cost of disinflation is that the rate of inflation is persistent, and its persistence arises because of the way in which laborers and firms engage in multi-period wage and price contracts.

### III. Other Explanations for Costly Disinflation

Other explanations have been offered for the apparent costliness of disinflating. Two leading theories are as follows: (1) The flexible inflation model of equation (1) is correct, but price-setters' *expectations* exhibit more persistence than that model would imply; and (2) The flexible inflation model is correct, but the disinflations that have been conducted historically have not been *credible*, so that price setters did not

<sup>13</sup> In most descriptions of the economy,  $f^*$  would equal the equilibrium real interest rate plus the inflation target,  $\pi^*$ . Thus implementing this policy would, in principle, require knowledge of the equilibrium real interest rate for the economy. The lack of such knowledge is probably one reason that observed Federal Reserve behavior more closely resembles the smooth adjustments of equation (2), which require no such knowledge.

<sup>14</sup> Recall that the incremental policy rule of equation (2) suggests that the funds rate tends to move only gradually from its previous level. Because the inflation rate drops immediately to (or below) its new target in the flexible inflation model, this implies an immediate increase in the short-term real rate at the beginning of the disinflation. The increase in real rates depresses real activity, yielding a small, but positive sacrifice ratio. Contrast this with the persistent inflation model, in which inflation falls gradually, but only because the Fed raises the funds rate so as to increase real rates and depress real activity. This difference in the evolution of a disinflation in the two models does not depend on any particulars of the specifications.



believe that the Fed would go through with the measures necessary to lower the inflation rate. These two hypotheses are addressed in turn below.

### Adaptive Expectations

Laurence Ball (1991) has suggested that adaptive expectations may explain the absence of costless disinflations. The essence of the idea is that, if price-setters adjust their expectations slowly to changes in Federal Reserve policy, then their expectations will impart persistence to the inflation process, even if the other mechanisms of wage- and price-setting do not.

A common rendering of adaptive expectations makes the expectation of inflation next period a geometrically declining weighted average of current and previous inflation rates.<sup>15</sup>

$$\pi_t^e = (1 - \delta) \sum_{i=0}^{\infty} \delta^i \pi_{t-i}. \quad (6)$$

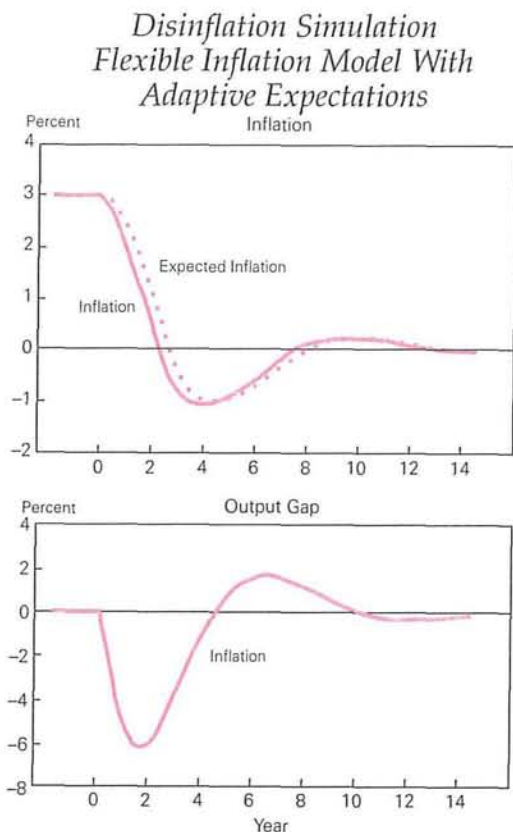
Imbedding this description of expectations into the flexible inflation model can, indeed, change the contours of the disinflation simulation. If equation (6) is substituted into equation (1), the result closely resembles a standard "Phillips curve": Inflation depends on lags of inflation and on the output gap.<sup>16</sup>

$$\pi_t = \sum_{i=1}^k a_i \pi_{t-i} + \gamma y_t.$$

Because this model also makes inflation depend on lags of inflation, it imparts considerable inertia to the inflation rate. Thus we expect the contours of a disinflation to be similar for the flexible inflation/adaptive expectations model and the persistent inflation models.

Figure 8 displays the disinflation with adaptive expectations. Inflation now recedes gradually towards its new, lower target level, and output falls well below

Figure 8



Source: Author's calculations.

potential for an extended period. The sacrifice ratio associated with this disinflation is 4.1.<sup>17</sup> In fact, the difference between Figures 8 and 5 is quite small, suggesting that the persistent inflation model with rational expectations and the flexible inflation model with adaptive expectations may be equivalent for all practical purposes.

Figure 8 also displays the persistence of *expected* inflation during the simulation. As the figure shows, expected inflation declines somewhat more gradually than actual inflation, as price-setters place significant weight on past inflation observations in forming their expectations of subsequent inflation movements.

<sup>15</sup> The classic definition of adaptive expectations makes the revision in expectations in the current period a function of the expectation error last period:  $\pi_{t+1}^e - \pi_{t+1}^e = \lambda (\pi_t - \pi_{t+1}^e)$ . It can be shown that this is equivalent to forming expectations as a geometrically declining weighted average of current and past inflation.

<sup>16</sup> The coefficients on lagged inflation would follow the geometric pattern of equation (6). It is more common to use the unemployment rate, rather than the output gap, to drive movements in inflation. In the models discussed here, however, the output gap and the unemployment rate move one-for-one, so that the distinction is not important. See Tootell (1994) for descriptions of standard implementations of the Phillips curve.

<sup>17</sup> The value of  $\delta$  in this simulation is 0.5. Note that, for the Phillips model, the total amount of output lost in a disinflation per point of inflation reduction does not depend on how the disinflation is conducted, quickly or slowly (it always equals  $1/\gamma$ ). The *timing* of output losses can vary, however, and thus the discounted sum of output losses will vary across faster or slower disinflations.



While it is the expectations-formation process that lends persistence to inflation in this model, if one were to look at the inflation process that comes from the model, one would be hard pressed to distinguish between expectations persistence and contract-derived persistence.

### *Imperfect Credibility*

An implicit assumption in the disinflation simulations conducted above is that price-setters knew that the Fed was contracting aggregate demand so as to lower the inflation rate and knew that it would continue to do so. Thus, price-setters saw the disinflation as perfectly credible: Policymakers were willing to inflict the costs of disinflation on the economy in order to lower the inflation rate. Expecting the real funds rate to remain high for an extended period, they bid up the real rates on long-term bonds, which lowered output below potential and decreased inflation.

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*The path that inflation and the output gap follow during a disinflation would likely depend upon the ways the Fed's and the public's views of the economy differed.*

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The scenario could look quite different if price-setters did not believe that the Fed would stick to its disinflationary policy. Three types of imperfect credibility, and their implications for disinflation, are discussed below. In each case, while the Fed may announce or begin a disinflationary program, the public (or some segment thereof) does not believe that the Fed will carry through with it.

*The possibility of regime shifts.* In this type of imperfect credibility, the Fed begins a disinflation intending to carry it through to completion. However, the public believes that there is a significant probability that the composition of the Federal Open Market Committee will change before the disinflation is completed. For example, FOMC members' terms may be expiring over the next several years, and the new appointees to the Committee could be less committed to the disinflation program.

In the simple framework described above, this type of imperfect credibility would manifest itself by an expected path for the federal funds rate that differs from the expectations implied by the policy rule (2) or (5). For example, the public might expect that with probability  $p$ , a new regime would dominate the FOMC at some time  $t$  in the future, with a much smaller emphasis on lowering inflation (much smaller  $\alpha_\pi$ ) or with a higher inflation target. If so, then long-term rates would not rise as much as in the perfect credibility case, because market participants would not be certain that short-term rates would remain elevated for the duration of the announced disinflation.

What effect would this type of imperfect credibility have on the path of inflation and output in a disinflation? If the fear is that the emphasis on inflation will be less than announced, this will not change the "overshooting" path that inflation follows in the perfect credibility simulations above. Inflation retained its perfect flexibility regardless of the policy rule followed in the disinflation simulations, so if the public believes that, on average, some mix of strong and weak inflation-fighting policies might obtain, this will not affect the behavior of inflation or the cost of disinflating.

If, however, the public expects that at some time in the future the Fed might raise its inflation target, this might give rise to quite different inflation behavior. The behavior of the economy could be quite complex to analyze in this case, as it would depend on how the public reconciled its observations of movements in the funds rate with its expectations based on an unchanged target, and how the public's expectations feed back into the determination of prices.

*Different views of the world.* Monetary policymakers who wish to disinflate will tighten monetary policy, contract aggregate demand, and lower inflation. How much they need to tighten and how long it will take for their actions to affect inflation are not unambiguous. The public may have a different assessment of the expected effect of a tightening on aggregate demand and inflation. Observing the Fed's actions, they may decide that, given their own assessment of the workings of the economy, the Fed's actions are not consistent with a falling inflation rate. If so, then they will find the Fed's attempts to disinflate not credible.

The implications of differences in economic frameworks for the outcome of an attempted disinflation are hard to know a priori. The path that inflation and the output gap follow during a disinflation would likely depend upon the ways the Fed's and the pub-



lic's views of the economy differed. As discussed in the regime shift case above, the dependence of the public's actions on its assessment of the impact of the Fed's actions, and vice versa, makes it particularly difficult to sort out the implications of this type of imperfect credibility. Whether either of these types of imperfect credibility can be modeled straightforwardly, and whether they might help the (otherwise) flexible inflation model match the basic properties of the data, is an interesting topic for further research.

*Cheating.* A third type of imperfect credibility is motivated by the work of Barro and Gordon (1983). Their work suggests that central banks that are not precommitted to stabilizing prices will always have the incentive to "cheat." This "time inconsistency" argument asserts that central banks under pressure from the electorate will consistently accept unexpected output gains at the cost of increased inflation, thus building in an inflationary bias. Central banks that have demonstrated this tendency in the past will find it difficult to persuade the public that they now intend to pursue a disinflation. They will have lost credibility and will have to convince the public by implementing consistent, pre-announced policy.

This argument seems particularly difficult to accept given the experience around the world during the past 15 years. Those who presided over the central banks of the United States, the United Kingdom, Germany, and Canada were widely viewed as extremely credible. Yet all of these countries paid a significant price for disinflation in lost output, as documented in Ball (1994). In addition, a recent comparison by DeBelle and Fischer (1994) shows that the extremely "hawkish" and credible Bundesbank actually paid a *higher* price in lost output in its recent disinflations than many other central banks. It would seem that this motivation for credibility has been put to the test and found lacking.

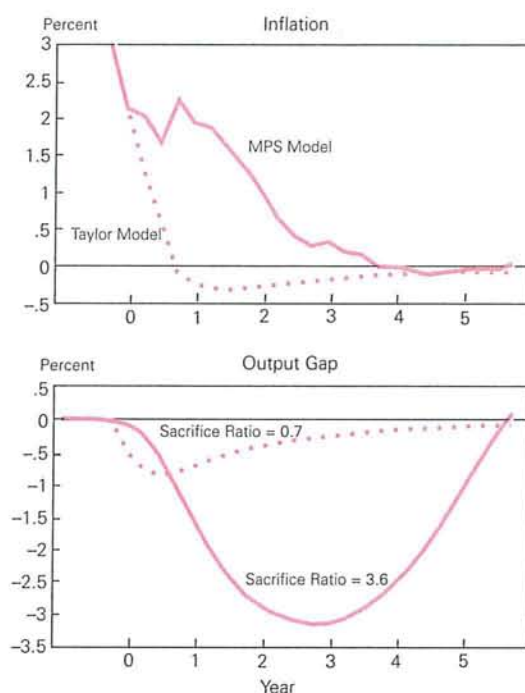
#### IV. Conclusions

How close a resemblance do the simple models of Section II bear to the models used by forecasters and policymakers for decision-making? For the broad patterns of inflation and the costs of disinflation, the simple models mirror the larger models closely.

John B. Taylor maintains a large macroeconomic model in which price behavior is based on his models of overlapping wage contracts, which have been presented here in simplified form as equation (1).<sup>18</sup> Figure 9 (dashed lines) displays the paths of inflation and the

Figure 9

#### Model Disinflation Simulation



Source: Solid Line - Author's calculations.  
Dashed Line - Taylor (1993); simulation provided by John Williams, Board of Governors, Federal Reserve System.

output gap for Taylor's disinflation simulation, conducted as in the preceding examples. The path of inflation and the output gap during the disinflation are roughly in accord with the simulations from the small flexible inflation model. Inflation drops rapidly, falling below its new target level, and then rising to it from below. The output gap is quite small in comparison to the large gaps for the small persistent inflation model and for the large persistent inflation model described below.

The MIT-PENN-SSRC (Social Science Research Council) or MPS model of the U.S. economy is a large (about 130 behavioral equations) model designed to capture the persistence in prices and inflation. Its price sector is a wage-price Phillips curve in which wage inflation depends on expected price inflation and

<sup>18</sup> A full description of the model used to produce this simulation may be found in Taylor (1993). The author thanks John Williams for providing the simulation results displayed in the dashed lines in Figure 9.

unemployment. Expected price inflation is formed adaptively. Prices move with unit labor costs, the difference between wages and productivity. Figure 9 (solid lines) displays the path of inflation and the output gap implied by this model for a disinflation like those in the preceding figures. The model clearly shows the same degree of inflation persistence as is exhibited by the persistent inflation model of equation (4) or the simplified Phillips curve of equations (6) and (1). The output loss associated with the disinflation is considerable; the model implies a sacrifice ratio of 3.6, compared to about 4 for the other persistent inflation models. Thus, this carefully designed, highly articulated macro model delivers essentially the same predictions for a disinflation as the simple persistent inflation models of this paper. Inflation is persistent, and disinflation is costly.

There appears to be little doubt that disinflations have been costly. Broadly speaking, the cost of disinflation arises because inflation has been persistent. The

question then turns to why inflation is persistent. This paper has examined several explanations of inflation's persistence, but much work remains in sorting out the explanation (or combination of explanations) that is most consistent with the data on prices and inflation.

Determining the source of inflation persistence is of much more than academic interest. If, for example, persistence arises through imperfect credibility of the Federal Reserve, then the Fed should be concerned about how to improve and maintain its credibility. On the other hand, if persistence arises because the public adjusts its expectations slowly to changes in the economic environment, or because inflation is inherently sticky because of the way in which wage and price contracts are negotiated, then monetary policy has to bear the costs of disinflation unless these behaviors change. Thus, the source of inflation persistence may be a reflection on the behavior of monetary policymakers, or it may be completely beyond their control.

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