ISSUES PERTAINING TO THE SPECIFICATION OF A NUMERICAL PRICE-RELATED OBJECTIVE FOR MONETARY POLICY

Michael Kiley, Eileen Mauskopf, and David Wilcox*

Division of Research and Statistics
Board of Governors of the Federal Reserve System

March 12, 2007

*We gratefully acknowledge the assistance of many colleagues, including but not limited to Ellen Dykes, Thomas Laubach, David Lebow, Deborah Lindner, David Reifschneider, John Roberts, David Stockton, Robert Tetlow, and our colleagues in the International Finance Division.

In this paper we analyze the major questions that the FOMC will have to address if it decides to specify a numerical price-related objective for monetary policy.[1] As a prelude to that analysis, in section 1 we discuss the main benefits and costs associated with a low inflation objective. In section 2, we note that the Committee could pursue low inflation by adopting either a price-level objective or an inflation objective; but we conclude that, although a price-level objective has some attractive features relative to an inflation objective, the Committee is more likely to prefer an inflation objective, at least for the near term. Accordingly, to simplify the exposition, we confine our attention in section 3 to issues that the Committee would have to address if it decides to adopt an inflation objective. Specifically, we analyze the choice of a basic measure of inflation; whether the Committee should specify a timeframe over which it intends to achieve its stated inflation objective; whether the objective should be specified as a point or a range, the level of the point or range; the width of the range if the Committee decides to go that route; and how frequently the Committee should revisit the setting of the objective.

1. The Relation between Inflation and Economic Performance

Inflation influences economic performance in many ways. Some considerations suggest that inflation can be too high for optimal economic performance, and others that it can be too low.

Mechanisms through which medium or high inflation imposes costs

Inflation imposes economic costs by interacting with several structural features of the economy. Chief among these features are the following.

Nominal illusion

Some households and firms appear to suffer from "nominal" or "money" illusion—that is, an inability to distinguish between real and nominal prices, wages, and interest rates. Survey evidence shows that many households have a poor understanding of inflation and its financial implications. Such difficulty in understanding the drift in nominal values caused by inflation probably impairs the financial planning of affected households and firms. Despite its probable ubiquity, nominal illusion has not been modeled extensively, perhaps partly because it involves behavior that has traditionally been deemed to be irrational; as a result, no numerical estimates exist of the welfare losses associated with nominal illusion.

[1] The subcommittee on communications issues has directed us not to address in this paper the question of whether the FOMC should articulate such an objective; this question was discussed at the October 2006 meeting. For a discussion of the pros and cons of articulating a specific price-related objective, see Elmendorf and others (2005).

The non-indexation of the tax code

The fact that many aspects of the tax code are not fully inflation-indexed is typically viewed as one of the most important distortions in terms of its implications for economic efficiency. With respect to business income, a principal source of the distortion is due to the requirement that depreciation allowances be based on the historical cost of assets rather than on their replacement cost; as a result of this requirement, an increase in the rate of inflation reduces the value of depreciation allowances and, hence, boosts the effective rate of taxation and the real cost of capital.[2] A second distortion that affects business income, but works in the opposite direction, is the fact that firms are allowed to deduct nominal (rather than only real) interest payments from their income. The higher the rate of inflation, the greater is the tax benefit from the deductibility of nominal interest payments and, hence, the lower is the real cost of capital. For households, the interaction of the tax code with inflation introduces three common distortions.[3] Households pay tax on their nominal interest income; they pay tax on nominal capital gains; and they are allowed to deduct nominal interest payments associated with their mortgages and home equity loans from their income.[4]

Relative price distortions associated with sluggish nominal price adjustment

Recent research on nominal price adjustment has emphasized the likelihood that general inflation distorts relative prices because the timing and frequency of price changes differ across firms. These distortions of relative prices lead to an inefficient pattern of purchases by consumers and firms, lowering economic efficiency.[5]

Redistribution of wealth between borrowers and lenders

Unexpected variation in the price level causes unanticipated redistributions of wealth between debtors and creditors. For example, an unexpected jump in the price level confers windfall gains on debtors (and windfall losses on creditors) who are involved in long-term nominal fixed contracts. Furthermore, the uncertainty associated with these redistributions increases the risk premiums attached to such financial products, lowering efficiency indirectly.

---

[2] This distortion is presently less acute than it has been in the past: In the 1986 reform of the tax code, a more-accelerated writeoff schedule was introduced with the explicit purpose of compensating for the failure to index depreciation allowances to replacement cost. Nevertheless, as the rate of inflation rises, any understatement of true expenses increases, and consequently, the real cost of capital for a given real rate of interest becomes higher.

[3] The introduction in 1985 of inflation-indexing of personal tax rates, exemptions, and standard deductions eliminated a major source of the distortionary effects of the tax code in the presence of inflation. In addition, the 1997 and 2003 reductions in the long-term capital gains tax rate reduced the distortions induced by the tax code in the presence of inflation.

[4] A subtle—but nonetheless important—question is whether Congress takes account of the prevailing inflation environment when designing the tax structure, and thus would tend to offset the economic implications of any change in the inflation objective.

[5] These effects are most clearly discussed in the literature on sticky nominal prices. Inflation alters price setting along two margins in these models. First, it distorts relative prices and hence the pattern of transactions. Second, it can affect the average markup over costs. The first channel is typically the more important one in these models (for example, King and Wolman, 1999).

The "inflation tax" on money balances

Inflation imposes a cost on non-interest-bearing money balances; this cost is comparable to a proportional tax or a negative interest rate, with the size of the tax increasing as the nominal interest rate increases, and hence as the expected rate of inflation increases. Because of this tax, higher inflation causes households to expend more resources economizing on real cash balances.

The efficiency of the price system in allocating productive resources

Variability in inflation (and especially unanticipated variability) can obscure the rationale for changes in relative prices. In particular, a change in a nominal price could reflect a change in the scarcity of the item in question, or it could be purely a consequence of generally rising prices. Confusion regarding these possibilities can lead to an inefficient allocation of resources (see Lucas, 1972).

Mechanisms through which very low inflation imposes costs

Several other considerations suggest that inflation can be too low as well as too high.

The zero lower bound on nominal interest rates

Very low inflation might place the equilibrium nominal interest rate at a level that would occasionally limit the Federal Reserve's scope for cutting interest rates as much as it would like.[6] The quantitative implications of the zero bound depend on various factors, including the responsiveness of output and inflation to changes in the real funds rate, the magnitude and persistence of economic shocks, the level of the equilibrium real interest rate, and the conduct of monetary policy. Results based on simulations of the FRB/US model were presented in the 2005 report by Elmendorf and others.[7] According to these simulation results, inflation and the output gap become increasingly difficult to control as the Federal Reserve sets progressively lower inflation objectives because the zero lower bound on nominal interest rates becomes a progressively more important impediment to the conduct of monetary policy. Moreover, the deterioration in performance is nonlinear, with each downward step in the inflation objective causing a greater erosion in performance. In our view, the adverse effect from the zero lower bound is modest for inflation objectives at or above 1½ percent, though we recognize that "modest" in the eye of one beholder may be either "*de minimis*" or "significant" in the eyes of others.

[6] Indeed, in 2003, with inflation close to 1 percent and the funds rate at 1 percent, some observers were concerned that the Federal Reserve would not be able to counteract effectively an additional adverse demand shock.

[7] These estimates were based on stochastic simulations of the FRB/US model, under the assumption that expectations are formed in a model-consistent manner. The results we discuss in the text are based upon simulations in which monetary policy follows a Taylor rule linking the federal funds rate to inflation and the output gap. (A large literature shows that policy rules other than the one originally specified by Taylor can be more effective in stabilizing the economy (see, for example, Reifschneider and Williams, 2000). As mentioned in a later section, rules that have the funds rate react to the price level as well as to inflation and the gap in resource utilization can prove especially effective when expectations are forward-looking.

Downward nominal wage rigidity

Wage earners appear to resist reductions in nominal compensation even more than can be explained by their dislike for the associated reduction in real compensation. Consequently, very low inflation may be associated with a higher equilibrium rate of unemployment. Although such resistance by wage earners is evident in microeconomic data, downward nominal wage rigidity has left little imprint on macroeconomic outcomes. In particular, low inflation over the past fifteen years has not been associated with elevated levels of unemployment, perhaps because firms have been able to trim nonwage elements of compensation, such as health insurance coverage or bonuses, or because firms have been able to stretch the necessary adjustments to the real wage over several years. That said, downward nominal wage rigidity might have mattered more for equilibrium unemployment in recent years if low inflation had not been accompanied by relatively rapid increases in productivity and, hence, relatively rapid increases in equilibrium (real) compensation. Moreover, downward rigidity may have sharply nonlinear effects (as suggested by Akerlof, Dickens, and Perry, 1996), and if inflation had persisted at the rates it briefly reached in 2003, the consequences for unemployment could have been more noticeable.

The loss in government revenue associated with lower inflation

Higher inflation, at least over some range, generates additional government revenue on an inflation-adjusted basis (through both seigniorage revenue and the non-indexed aspects of the tax code discussed earlier). As a result, lower inflation opens up a gap in the government budget, all else being equal; closing that gap requires either an increase in other taxes or a decrease in government expenditures. But increasing other taxes and cutting spending also have adverse welfare consequences. On balance, therefore, this consideration tends to mitigate the desirability of lower inflation (see, for example, Phelps, 1973).

Debt deflation

If inflation runs at a lower rate than borrowers expected when they took out fixed nominal loans, the real value of required payments on principal and interest will be greater than expected. All else being equal, the greater the shortfall of inflation from expectations, the greater will be the strain on borrowers. In an extreme case, the net worth of borrowers will be severely stressed, and widespread defaults will ensue, potentially compromising the solvency of financial intermediaries. The erosion of the creditworthiness of borrowers as well as the increased fragility of financial intermediaries leads to a reduction in the credit available and a rise in the cost of such credit, triggering a downward spiral in economic activity. This mechanism probably played an important role in the Great Depression and more recently in Japan's prolonged period of recession and subpar growth over the 1990s.

2. Incremental Benefits and Costs of a Price-Level Objective

Under a price-level objective, the Committee would respond to high inflation outcomes by aiming for below-trend inflation, on average, in subsequent periods, with the goal of bringing the price level gradually back to a predetermined trajectory. In other words, the Committee would not allow "base drift" in the price level. (The Committee could choose to make the predetermined price trajectory either flat or upward-tilting.) By contrast, under an inflation objective, the Committee would let bygones be bygones and would aim for the same inflation rate going forward regardless of recent inflation experience.[8] The macroeconomic implications of these two basic forms of price-related objective are similar in many respects, but they are not identical. Therefore, a key question—and the topic of this section—is whether net incremental benefits could be reaped by going beyond an inflation objective and pursuing a price-level objective.

Several of the theories that we have highlighted do, indeed, suggest that pursuing a price-level objective would generate incremental net benefits beyond those that could be expected to accrue under an inflation objective. For example, the undesirable effects of nominal illusion would be reduced by forcing the general price level back to a predetermined trajectory. (In fact, to minimize the costs of nominal illusion, a central bank should aim to hold the general price level literally flat over time.) Similarly, the redistributions of wealth associated with long-term debt contracts that are set in nominal terms would generally be lower under a price-level objective. Models that feature sluggish nominal price adjustment often (though not always) point to a price-level objective as the best way to minimize the associated relative price distortions (where the appropriate definition of the price level depends on the relative sluggishness of the different prices). As highlighted by Svensson (1999), Wolman (2005), and many others, these models also suggest that adjusting the funds rate in response to undesired movements in output, inflation, and the price level might enable a central bank to reduce the volatility of *both* inflation and real activity relative to the volatility that can be achieved under a policy that ignores the price level. The possibility of better volatility performance arises because current inflation is assumed to depend on expected future inflation, and the public is assumed to understand the implications of the central bank's determination to control the price level. Thus, the public expects an inflationary shock to be followed by a period of below-trend inflation. This expectation, in turn, prevents current inflation from rising as much as it otherwise might in the event of a positive shock to the price level. In other words, the policy focus on the price level serves as an "automatic stabilizer" for inflation expectations. The result is confirmed by simulations of the FRB/US model under the assumption of rational expectations. Price-level targeting can also mitigate the problems associated with the zero-lower-bound issue, through the same automatic-stabilizer-type mechanism that helps reduce volatility more generally.

Other considerations, however, suggest that pursuit of a price-level objective may generate incremental net costs relative to an inflation objective. For example, models

[8] The Committee could also adopt an intermediate approach under which it would aim to gradually return the price level part of the way back toward the trajectory that had been anticipated before the surprises.

that presume that prices are set mostly or entirely in a backward-looking manner imply that the volatility of inflation and output would be greater under a price-level objective than under an inflation objective (see, for example, the discussion in Fischer, 1994). The greater volatility occurs because expectations in backward-looking models do not play the stabilizing role that they play in models that emphasize rational or forward-looking expectations. Another cost associated with the pursuit of a price-level objective operates through fiscal policy: In the presence of shocks to its fiscal position, a government might want to revalue its outstanding liabilities (up in response to good news, down in response to bad news). When government debt is fixed in nominal terms, inflation offers an immediate means of accomplishing this revaluation, but a price-level objective forestalls recourse to that means and implies that gaps in the government budget position must be closed by other, possibly less-efficient actions.[9] Finally, a price-level objective may be difficult to explain to the public and would mark a more significant departure from recent practice than would an inflation objective.[10] The more significant shift in the behavior of policymakers implied by a price-level objective might sow some confusion and impose sizable costs in the transition to the new regime.

We read the balance of considerations as supporting an inflation objective. Several considerations suggest that a price-level objective may improve economic efficiency relative to an inflation objective, but there are some potential downsides. We think that much more analysis is required before a confident determination can be made that significant net gains would result from pursuing a price-level objective. Moreover, no other central bank has adopted a price-level objective. In light of the unique role of the United States in the world economy, the Committee might wish to allow other nations to be the laboratories for monetary experimentation.[11] Even if the Committee views a price-level objective as a desirable ultimate outcome, it might see an inflation objective as putting the country on a sensible transition path toward that outcome.

3. Choices Associated with the Specification of an Inflation Objective

This section analyzes the major issues that the Committee will have to address if it decides to specify an inflation objective.

What measure of inflation?

The Committee will have to decide which basic index and which form of the index to use. Over the long term, the choice of a particular measure of inflation may be of only limited importance because most major inflation measures have broadly tracked one another over the past six decades. (In the appendix, we present formal statistical evidence that the major measures of inflation have been co-integrated—that is, have

[9] See Chari, Christiano, and Kehoe (1991, 1995) and Schmitt-Grohe and Uribe (2004).

[10] An intermediate objective would probably be even more difficult to explain to the public.

[11] Price-level objectives are not without historical precedent. For example, Sweden operated under such a regime in the 1930s (see Berg and Jonung, 1999).

tended roughly to track one another—since 1950.) This co-integration suggests that, if the Committee chooses to control one such measure, it could expect to control the others as well.[12] Even so, the various measures of inflation do depart from one another by noticeable amounts in the shorter run, so the choice of a particular gauge is a matter of some consequence.

The Committee may wish to link its choice of inflation measure to its analysis of the costs that it is trying to minimize through its conduct of monetary policy. For example, if the Committee believes that households' nominal illusion is a predominant source of the cost of deviations from price stability, then it may wish to specify its inflation objective in terms of a broad measure of consumer price inflation, such as the overall CPI or the overall PCE price index. Alternatively, a number of the other considerations discussed in section 1—for example, the inflation tax on money balances and the possible confusion regarding relative price signals associated with inflation variability—assign an important role to the market transactions of both households and firms. These considerations may point toward broader measures of inflation, such as the price index for GDP, or to a yet-broader index that would factor in the prices of intermediate goods and raw materials. The Committee might want to focus on an inflation gauge that excludes imputed non-market prices if it is concerned about the implications of measurement error and data revisions, given that the measurement error in the non-market components is plausibly greater than the measurement error in the components in which market transactions can be observed and given that substantial revisions of these components have occurred in the past.

The recent literature on sluggish nominal price adjustment points toward yet a different type of index as the optimal focus for monetary policy. In general, the models in this literature imply that economic welfare can be improved through the stabilization of a weighted average of nominal prices and wages, with the "stickiest" prices or wages being given the greatest weight in the constructed aggregate (see, for example, Mankiw and Reis, 2003).[13] To date, no central bank has framed its inflation objective in terms of a customized weighted average of this type.[14]

---

[12] In contrast, price *levels* have diverged from one another since World War II. Therefore, if the Committee decided to pursue a price-*level* objective, the choice of a particular measure of prices could be more consequential.

[13] The intuition for this result is as follows: Some prices and wages exhibit great sluggishness (or stickiness) because there may be direct costs of adjustment or because the information that a price- or wage-setter would like to have in order to set the price or wage may be costly to acquire. General inflation causes distortions in the structure of relative prices because relatively flexible prices adjust freely, whereas sticky prices are slow to move. Targeting the sticky prices reduces or even eliminates the need for them to adjust, and allows flexible prices to do all the adjusting. The shift in the burden of adjustment toward flexible prices improves overall economic efficiency.

[14] Some effort has been expended on measuring the degree of nominal rigidities in various prices both to assess the empirical importance of "sticky-price" distortions and to gauge which prices and wages should be included in any "sticky-price" index that would be the focus of monetary policy in these models. For example, Mankiw and Reis (2003) suggest that nominal wages are relatively sticky and should receive a large weight in an index constructed as the monetary policy objective. Some researchers have attempted to

Beyond choosing from among the basic families of indexes (PCE, CPI, GDP, and so forth), the Committee must also choose which *form* of the basic index to use. One possibility would be to focus on a core measure (that is, a measure that excludes the prices of food and energy). A reason for choosing a member of this class of indexes is that core measures are less variable, and our analysis in a later section suggests that the Committee could expect a core measure to lie within a pre-specified range more frequently than an overall measure—a characteristic that could help preserve the credibility of the FOMC. Also, a core measure may provide a better sense of the likely course of inflation in the near term and hence may be a useful indicator in FOMC communications even if it is not the explicit objective. Separately, the theories of nominal price adjustment that were discussed earlier could be interpreted somewhat loosely and seen as justifying a decision to express an inflation objective in terms of a core measure on the rationale that core measures toss out some prices that adjust very frequently. However, such a justification could be only approximate at best because some food prices (for example, the price of food consumed away from home) are not adjusted very frequently, whereas some prices that are included in traditional "core" measures are adjusted frequently.[15] At a more practical level, core measures are widely discussed and have been the focus of the Committee's semiannual forecasts since July 2004; if the Committee perceives a material communication challenge to be associated with a switch in index, it may prefer to stick with the core index.

On the other hand, the Committee has been criticized from time to time for what some observers have interpreted as indifference to movements in the prices of food and energy; presumably, the perception of this alleged indifference could be reduced or eliminated by designating an overall rather than a core measure of inflation as the focus of Committee communication. Also, several of the theoretical considerations discussed earlier point more naturally toward an overall measure of inflation. For example, a central bank attempting to minimize the costs of nominal illusion would focus on stabilizing an index of the overall cost of living, which would, of course, include the prices of food and energy. Similarly, the costs due to the inflation tax on money balances and to the degradation of the quality of relative price signals probably bear a closer relationship to overall inflation than to core inflation. Moreover, measures of overall inflation may be more familiar to the public; for example, the overall CPI is very familiar to many senior citizens because it is used as the basis for the annual escalation of Social Security benefits. As a result of this familiarity, an overall measure may therefore present fewer communication challenges than would arise under an objective expressed in terms of a core index—though the Committee seems not to have encountered any substantial communication problems on this front during the three years that it has been framing its inflation forecasts in terms of the core PCE index. Finally, an overall index may be more

---

directly measure the frequency with which various nominal prices are adjusted (for example, Bils and Klenow, 2004, and Nakamura and Steinsson, 2006).

[15] Bils and Klenow (2004) and Nakamura and Steinsson (2006) document these properties for food and energy prices and find that some apparel items, airfares, and a variety of other categories of prices are adjusted about as frequently as food and energy prices.

immune to suspicions—however groundless—that the government was somehow manipulating the situation to suit its convenience by picking an "obscure" index that excludes such crucial necessities as food, gasoline, and heating oil.

Yet another possibility would be to designate a trimmed mean or a median index as the focus of Committee attention. The Federal Reserve Banks of Cleveland and Dallas calculate and publish indexes of this type—in the former case, a median CPI and a trimmed-mean CPI and, in the latter case, a trimmed-mean PCE inflation rate. These indexes are intended to address, among other things, the fact that averages of the type used in constructing the official indexes provide poor estimates of the central tendency of the distribution of prices when many of the individual components lie far from the center of the distribution. Median and trimmed-mean measures address this shortcoming by dropping outliers. As a result, such measures may be useful indicators of current inflation trends and likely future inflation developments and have been the focus of some research and even some policy attention by foreign central banks. For example, the Reserve Bank of Australia publishes a weighted median and a trimmed mean of the CPI as proxies for underlying inflation. However, they are surely less familiar to the public than the traditional measures, even including the core measures, are.

The Committee may wish as well to take measurement error into account in choosing a focus for its policy. All else being equal, the Committee should focus on the measure of inflation that suffers the least contamination due to measurement error.[16] We defer until later a detailed discussion of the estimated magnitude of the upward bias that contaminates each of the candidate measures of inflation and simply note here that the overall PCE and core PCE price indexes suffer from upward biases estimated at 0.5 percentage point, the chained CPI and the GDP price index from an upward bias estimated at 0.6 percentage point, and the official CPI from an upward bias estimated at 0.9 percentage point. Such ongoing, steady biases are probably not much of a problem if the magnitude of the bias can be estimated: The Committee could simply adjust its objective one for one so as to hit the desired rate of true inflation. However, measurement error that varies significantly over time—and so potentially generates misleading signals about the direction inflation is headed—could lead to important challenges for policy. In that regard, the inclusion of nonmarket prices within PCE deserves mention. These prices vary from quarter to quarter and year to year, with large enough magnitude to be evident in overall core PCE inflation. Although these price

[16] Measurement error arises from many different sources. For a comprehensive review of measurement error in the consumer price index, see Lebow and Rudd (2003). In part, measurement error in the CPI stems from the substitutions that purchasers make across goods and services within the product bundle. The CPI fails to account for such substitutions because it prices a fixed basket of goods and services. (The price indexes for PCE and GDP use an aggregation formula that, in principle, should properly correct for such substitution.) Measurement error also results from the fact that some goods and services represented in some inflation measures are not traded in markets; many services produced by the nonprofit sector and governments fall into this category. Still another source of measurement error is that some observable prices do not pertain exactly to the relevant item; for example, the transactions price for residential and nonresidential structures includes the price of the land underneath the structure as well as the price of the building itself. Finally, the inability of economists accurately to adjust for quality change and the introduction of new goods and services infects every broad measure of inflation.

indexes may, for all we know, capture well the prices they are trying to measure, it is hard to be confident that this is so.

A related issue is whether the Committee should prefer an inflation gauge that is susceptible to revision. Most empirical measures of inflation are, in fact, revised from time to time, the only exception among broad measures of U.S. price inflation being the not-seasonally-adjusted version of the CPI.[17] Given our presumption that the Committee will choose an inflation objective rather than a price-level objective, susceptibility to revision probably should not greatly influence the Committee's choice of index. To see why not, consider the question of how the Committee would react to new information that would, all else being equal, cause the recent history of the focal measure of inflation to be revised up. Under an inflation objective, the Committee would respond to such news only to the extent that it affects the *outlook* for inflation as measured by this gauge, regardless of whether the history of the series is revised or not. Put differently, so long as the Committee is letting bygones be bygones, and can judge the implications of the news for the *future* of the series, the question of whether the *history* of the series may be revised is of relatively little consequence.[18]

Should the Committee provide guidance about how quickly it intends to achieve its objective?

In enunciating a specific inflation objective, the Committee could leave unspecified the timeframe over which it intends to achieve the objective. ("We intend inflation as measured by the *y* gauge to average *x* percent.") Such a statement would presumably clarify the direction in which the Committee would be pushing the specified measure of inflation at any given moment but would not reveal the speed with which the Committee would seek to attain the goal. One possible advantage of leaving speed unspecified is that fewer questions might be raised about whether the Federal Reserve had given the inflation objective priority within the dual mandate.

Alternatively, the Committee could specify a timeframe within which it intends to achieve its objective. ("We intend to return inflation as measured by the *y* gauge to our preferred rate of *x* percent over the next *M* to *N* years.") One advantage of an approach along these lines is that the mere announcement of the inflation objective might favorably influence the formation of inflation expectations and thereby help the Committee attain its objective. How strong this influence on expectations might be is difficult to know; no professional consensus exists on this issue. However, a disadvantage of a fixed policy horizon is that it is inconsistent with a literal interpretation of standard economic models of policymaker behavior; such models generally imply that the Committee should aim to approach both legs of its dual mandate gradually and should not aim to achieve either leg within a fixed timeframe. The Committee could assume that its statement would not be

[17] The seasonally adjusted version of the CPI is revised annually with the estimation of updated seasonal factors.

[18] By contrast, if the Committee were operating under a price-level objective, the Committee could be compelled to change its policy stance in response to a revision to history even if the outlook were unchanged.

taken so literally, or it could alternatively inform the public about something like the expected half-life of the inflation gap. ("We intend to close *z* percent of the gap between inflation as measured by the *y* gauge and our preferred rate of *x* percent within the next *N* years.") Even the latter statement might be too specific in that the Committee would want to preserve the flexibility to close the inflation gap at different speeds depending on the factors that caused the gap to open. In this case, the Committee might prefer to emphasize that the timeframe for returning inflation to the desired level varies according to circumstances and in a manner consistent with the dual mandate. The Committee might also stress that, under some circumstances, it is prepared to be quite patient, closing the gap only over a substantial number of years.

If the Committee chooses to specify a timeframe, two interactions are worth noting. First, if the objective is framed as a commitment to cause the *forecast* of inflation at the stated horizon to hit the stated goal, then choosing a longer horizon reduces the motivation for choosing a smoothed form of an index. Thus, for example, a policymaker in some models might be apprehensive about aiming to cause its forecast of overall PCE price inflation to average *x* percent over the next twelve or twenty-four months; if the Committee were intent on using such a short policy horizon, the motivation for using a smoother index, such as the core, might be more compelling. The Committee might be more comfortable about designating overall PCE price inflation as the object of its policy given a longer horizon. Second, choosing a longer horizon reduces the ability of outsiders to monitor and discipline the actions of the Federal Reserve; judging whether today's actions will deliver the stated inflation performance over the next twelve months is hard enough, but nowhere near as difficult as judging whether today's actions are the optimal choice for delivering the stated outcome four or five years down the road.

Should the inflation objective be framed as a point or a range?
For a variety of reasons, the Committee may prefer to frame an inflation objective in terms of a range rather than as a point estimate; we present four such rationales. These rationales have different implications for how the Committee would respond to deviations of inflation from its inflation objective.

- *Signal of nonlinear reaction function.* The Committee might announce a range to signal that it is close to indifferent among rates of inflation within certain limits but that it strongly prefers those rates to ones outside the limits. Even in this case, the Committee will generally aim for the center of the range (to reduce the probability of inflation later moving outside the range), but will press much more aggressively against rates of inflation falling outside the range. Articulation of a range under this rationale could present significant challenges related to communicating exactly how the Committee would respond to rates of inflation inside versus outside the range.

- *Intrinsic variability of inflation and the dual mandate.* Expressing the price objective as a range might help communicate that unpredictable "shocks" to inflation are inevitable and that inflation is not wholly under the control of the central bank in the short run. Moreover, a central bank with a dual mandate will generally choose to let inflation deviate from any chosen point objective for the sake of achieving greater

stability in real activity. These two considerations might argue for specifying the inflation objective as a point objective with a surrounding range that is wide enough to encompass inflation outcomes most of the time. Again, the Committee generally would aim for the midpoint of the range but in this case would presumably change the federal funds rate linearly in response to deviations of inflation from the midpoint of the range.

- *Uncertainty about the appropriate numerical value.* As we discuss below, considerable uncertainty surrounds the benefits and costs associated with small differences in the steady-state rate of inflation. Setting a range might reduce the risk of suggesting a false sense of precision about the central bank's ability to identify the appropriate rate of inflation. Setting a range might also allow the central bank to fine-tune the objective less frequently. In addition, a range might be motivated as reflecting uncertainty about the choice of price index and the extent and variation in measurement bias in that index. This set of considerations motivating a range does not have unambiguous implications for policymaker behavior. For example, if the Committee operates under this rationale but only announces a range and not its point estimate of the most appropriate rate of inflation, the public will be left to guess both whether the point estimate is the center of the range and whether the Committee will settle for anything within the range or will press to attain the point estimate.

- *Divergent views.* A range might reflect heterogeneous views among FOMC members about the appropriate inflation objective. If the members cannot agree on a point objective for inflation, the Committee could announce a range, as it does for the members' inflation forecasts in the Monetary Policy Report. Were this to be the overriding rationale for specifying a range, the policy response to movements in inflation would presumably depend on the distribution of members' preferences and the tenacity with which members were prepared to defend their preferences.

As discussed in the companion piece by Doyle, Kole, and Wood (2007), most central banks that have articulated an explicit numerical price objective have adopted a point objective while emphasizing a range about this point objective that reflects, in part, the degree of variation deemed inherent to inflation and necessary to meet their other objectives. However, some foreign central banks seem to have in mind something closer to a "zone of indifference." For example, Australia's and New Zealand's zones appear to reflect no preference for the midpoint of the zone, and the European Central Bank's preference for inflation below but close to 2 percent has been criticized for lacking more specificity. In any event, if the Committee opts for a range, explaining its motivations would be important.

If a point, what should that point be? If a range, what should the center of that range be?

The numerical value for a point objective or midpoint of a range should reflect an assessment of the implications of measurement error for the appropriate goal for measured inflation as well as the various costs and benefits associated with alternative values of the true rate of inflation (that is, abstracting from measurement error).

Measurement error

A large literature shows that the main inflation measures in the United States are likely biased upward, suggesting that if the Committee wishes to aim for zero true inflation, it will need to aim for positive reported inflation. The Board's staff estimates that the CPI currently overstates changes in the cost of living by 0.9 percentage point per year, with a subjective 90 percent confidence interval ranging from 0.3 percentage point on the low side to 1.4 percentage points on the high side.[19] Other commonly used price indexes are less biased than the CPI because they are derived using so-called "superlative" aggregation formulas and better weights. For example, the chained CPI (which uses Tornquist aggregation to capture shifts in spending patterns following relative price changes) is biased upward an estimated 0.6 percentage point per year, whereas the PCE price index (which uses more-accurate spending weights and Fisher aggregation to capture shifting spending patterns) is biased upward about 0.5 percentage point; this latter measurement error feeds directly into the GDP price index.[20] With far less information to go on than in the consumer area, the Board staff assumes that mismeasurement of prices for investment, government, and net exports contributes ¼ percentage point to bias in GDP prices, bringing the overall bias in the GDP price index to an estimated 0.6 percentage point per year.

The benefits and costs of alternative rates of inflation

The guidance that can be gleaned from the academic literature regarding the magnitude of the costs of inflation is limited. Most of this research has confined its attention to the inflation tax on money balances and the non-indexation of the tax code and has ignored other factors (such as nominal illusion) that are much more difficult to incorporate into a formal model.[21] In addition, the academic literature has focused mostly on the potential

[19] See Lebow and Rudd (2003) for a comprehensive examination of measurement error in the CPI (which, besides being one of the most visible price indexes, serves as an important input to other measures of price change).

[20] Importantly, these bias estimates for the CPI and the PCE price index do not take into account the different scopes of the two indexes. The scope of the PCE index is broader than the scope of the CPI and includes, for example, all expenditures on medical care (not just the portion paid by consumers out of pocket), expenditures by nonprofit institutions, and the consumption of unpriced financial services. (Many of the items in PCE that are outside the CPI's scope are among the non-market components of PCE prices.) If we were to assume that the scope of one or both of these indexes were not appropriate for the purposes of monetary policy, then the bias estimates cited in the text would have to be adjusted. For example, if we thought that the CPI had the appropriate scope and that PCE therefore should not include the extra weight on medical expenditures or the nonmarket items (both of which have above-average rates of price increase), then there would be an additional "scope bias" in the PCE price index that might boost that index's overall bias by about another 0.2 percentage point. Note as well that our estimate of bias for the PCE price index assumes, for lack of any information one way or the other, that the nonmarket components of the index have no bias on average.

[21] There are some exceptions to this characterization, but they are of limited use because the quantitative exercises make extreme assumptions about the nature of the economy. For example, there has been a burst of interest in using calibrated models that incorporate frictions in nominal price adjustment to examine the effects on economic welfare of alternative rates of inflation or different stabilization policies. Several unpalatable assumptions pervade this research. First, it is common to assume that other distortions from

gains from setting the inflation objective at zero (in terms of measured, not true, inflation). But in light of the problems associated with too-low inflation discussed in section 1, the Committee may not choose to aim for zero measured inflation. Because some of the mechanisms through which inflation erodes efficiency are nonlinear, the typical result in the literature cannot be extrapolated to nearby rates of inflation in any straightforward manner.

As a result, we review the range of estimates for the costs of inflation that have been provided by research and provide some illustrative calculations of our own using a modified version of a small general equilibrium model presented in Abel (1997, 1999). Like the bulk of the earlier research, this model focuses on the costs of inflation associated with the tax code and money balances. Our rough calculations may lowball the benefits to lower inflation because they abstract from a number of distortions (including those associated with nominal illusion and relative prices) that are minimized by aiming for very low rates of inflation. However, our formal model also ignores at least three distortions that underscore the desirability of at least a modest ongoing rate of inflation (the zero lower bound on nominal interest rates, downward nominal wage rigidity, and debt deflation). How these omissions balance out is impossible for us to judge given the current state of knowledge.

The increment to GDP associated with price stability. The middle column of table 1 presents the range of estimates that have been advanced in the literature of the long-run increment to GDP per year associated with an inflation rate of 0 percent instead of 2 percent; in this table, the costs associated with moving from 2 percent to 0 percent are not taken into account. The range is sizable, spanning essentially 0 percent to 1½ percent of current GDP. We should emphasize that much of this range comes from a single study—Feldstein (1997)—which considers a number of alternative assumptions regarding the magnitude of various channels.

As shown in the first row, the increased output associated with a reduction in the tax on money holdings is small or even negative; the reason is that, if the long-run government budget constraint is to be respected, the seigniorage that is lost due to the reduction in inflation must be recouped by higher taxes elsewhere, and those other taxes could be more distortionary than seigniorage, depending on where they are imposed. In contrast, the gain from the reduction in the effective tax rate on capital (row 2) is estimated to be

---

inflation are not present. Second, fiscal policy offsets distortions from monopoly power through lump-sum taxes, an assumption that can radically affect the estimated magnitude of welfare gains compared with alternative assumptions about the type of tax imposed (for example, see the discussion in Woodford, 2003, of "distorted" and "undistorted" steady states; see also the contrast between King and Wolman, 1999, and Levin, Lopez-Salido and Yun, 2006). Finally, the empirical characterization of alternative stabilization policies is sometimes performed in models in which a nearly optimal policy can almost perfectly stabilize inflation (for example, Schmitt-Grohe and Uribe, 2006)—an unrealistic assumption in our view. Another example focuses on the effects of wealth redistributions from unanticipated shifts in inflation: Recently, Doepcke and Schneider (2006) have argued that an unanticipated burst in inflation would, at the current time, result in a notable welfare gain to U.S. households through the associated redistribution of wealth. These types of gains are, quite obviously, not the type that can be achieved through a systematic policy strategy, as the gains reflect the effect of a large unanticipated jump in inflation.

potentially quite sizable in the long run. In these calculations, the reduction in revenue from capital taxation associated with lower inflation is typically assumed to be offset through an increase in the statutory tax rates applied to labor and capital income; because the tax on labor income is less distortionary than the one on capital income in the type of models generally considered, the shift boosts output.[22]

According to Feldstein (1997, 1999) and Abel (1997, 1999), the increase per year associated with 0 percent steady-state inflation rather than 2 percent inflation is most likely in the neighborhood of 1 percent of GDP. Our rough calculation (reported in the right-most column of the table) suggests an increase on the order of 1¼ percent of GDP per year, close to the value deemed most likely by previous researchers.

Table 1
Gain or loss to annual GDP when steady-state inflation is 0 percent rather than 2 percent
(Percent per year)

Source of gain or loss	Range from academic literature	Model-based estimate
Money holdings	-.2 to .5	-.2
Fiscal/capital accumulation	-.1 to 1.6	1.3
Total	-.1 to 1.6	1.2

From GDP to net welfare. For two reasons, the change in economic welfare that results from lower rates of inflation is not given by the long-run effect on GDP. First, in the analytical framework used by the Board staff, the Committee can bring inflation down only by opening up a gap in resource utilization. Thus, there is a loss in output during the transition to the new steady-state that should be netted against the higher GDP attainable in the new steady state. Second, the larger capital stock spurred by the lower effective tax rate associated with lower steady-state inflation can be achieved and maintained only by boosting the investment share of output. In a closed economy, this increased share of investment comes at the expense of a lower share of consumption. Because welfare depends on consumption rather than output, the reduction in the consumption share may offset a substantial portion of the welfare gain that would otherwise be implied by the increase in output.[23] (Fischer, 1999, emphasized this point.) Some research has ignored the second effect in evaluating the gain from lower inflation. For example, Feldstein compares the annual gain in output (given in table 1) to the loss in output associated with the gap in resource utilization over the transition path (not shown in table). With his estimated gain of about 1 percent per year in GDP, the steady-state gains to GDP from

[22] This result is closely related to the findings in Chamley (1986) and Judd (1985) that the long-run optimal tax rate on capital in simple general equilibrium models is typically zero; Atkeson, Chari, and Kehoe (1999) provide a review of related research.

[23] In an open economy, capital flows may offset some of this cost; however, this offset would imply that the income gain would accrue to foreign investors rather than to domestic households.

lower inflation easily dwarf the loss to GDP over the transition period; as a result, Feldstein (1997, 1999) argues forcefully for near-zero inflation.

Table 2 presents some rough calculations to illustrate the opposing effects on consumption and, hence, welfare associated with different steady-state rates of inflation. The middle column of the table focuses on the gains and losses to consumption associated with a shift from a steady state with 2 percent inflation to one with 0 percent inflation; the right-hand column presents the gains and losses associated with a shift to a steady state with 1½ percent inflation. The entries in the table give the per-year increments or decrements to consumption that can be sustained forever as a result of each consideration listed in the left-hand column. We have assumed a discount rate of 1 percent per year in the computation.[24] As shown in the first row, we estimate that the increase in investment required to achieve and maintain the larger desired capital stock negates (in consumption terms) much of the gross benefit (in GDP terms) of the move to lower inflation shown in Table 1; we estimate that the consumption dividend associated with moving from a 2 percent inflation steady state to a 0 percent inflation steady state is only ¼ percent, not counting the output that must be sacrificed during the transition to reduce inflation.

Table 2
Gain or loss to consumption from reducing steady-state inflation from a 2 percent baseline
(Percent per year in perpetuity)

Source of gain or loss	Inflation objective	
	0 percent	1½ percent
Capital accumulation	.25	.05
Sacrifice ratio	-.17	-.04
Net gain (row 1 plus row 2)	.08	.01

The second row presents the loss (hence the negative sign) to consumption via the sacrifice ratio. In line with values implied by the models used in the staff's near-term projection for the Committee, we assume a sacrifice ratio of 4 in unemployment/inflation space, which translates into a sacrifice ratio of 10 in terms of output and, by assumption, of consumption; as a result, the consumption effect of a shift from 2 percent inflation to 0 percent equals about 0.17 percent of current consumption in perpetuity terms. On net,

[24] The perpetuity value (PV) is computed using the following formula: $PV = \rho \int_0^\infty c(s) e^{-\rho s} ds$, where c(s) is consumption in period s and ρ is the discount rate. Note, for example, if $c(s)$ were constant over time and if we could instantaneously move to the new steady state, then the perpetuity value in row 1 of the table would identically equal $c(s)$.

therefore, as reported in row 3, we estimate that a welfare gain equivalent to 0.08 percent of one year's worth of consumption is associated with a reduction of steady-state inflation from 2 percent to 0 percent. (Regarding the small size of the perpetuity values, it is important to remember that these are per-year effects and that the discount rate is 1 percent—implying that the present value of the gain to consumption is around 8 percent of current consumption).

For 1½ percent inflation, we estimate a gross benefit in terms of consumption equivalent to 0.05 percent of current consumption per year (row 1). The costs arising from the sacrifice ratio (row 2) are estimated at -0.04 percent of each year's consumption forever, implying a very small net gain of 0.01 percent of per-year consumption forever (row 3).

To be sure, the uncertainty surrounding these calculations is enormous. One source of uncertainty involves the sacrifice ratio. The calculations in table 2 assume a sacrifice ratio of 10 in output gap/inflation space, in line with some reduced-form Phillips curves. Some research has employed a sacrifice ratio of 3 (as in Feldstein, 1997, following Ball, 1994). Nonetheless, the net gain from a permanent shift in inflation from 2 percent to 1½ percent would remain quite modest regardless of the value of the sacrifice ratio. Variations in other parameters could result in a welfare *loss* in consumption terms from inflation below 2 percent, but again, the magnitude would likely be quite small.[25]

Summary

Our analysis suggests that the gains in economic performance from steady-state rates of inflation below 2 percent would probably be modest. In particular, we have presented illustrative calculations in which the long-run benefits from a shift of core PCE inflation from its current level of about 2 percent down to 1½ percent outweigh the transition costs by only a very small amount. While we find the model to be a useful analytical tool as far as it goes, we also hasten to reiterate its shortcomings—namely that it incorporates only two of the costs of inflation from among the many that have been identified in the literature, it ignores several factors that militate against adopting too *low* an objective for inflation, and it inevitably suffers from unknown errors of specification.

Finally, we note a dilemma involving possible interactions between the public's inflation expectations and the Committee's choice of an inflation objective. One branch of this dilemma points toward ratifying the public's current inflation expectations, and the other branch points toward aiming for something lower. The logic in favor of the first view runs as follows: Survey readings and financial market data indicate that the public may see the Federal Reserve as willing to settle for something like 2 percent inflation in the long run. Furthermore, our analysis using the general equilibrium model suggests that

[25] The small net size of any gains or losses from modest, permanent changes in the inflation rate appears robust to a range of sensitivity tests including variations in the discount rate and variations in the size of the investment and output responses to lower capital taxes. Abel (1997) finds that his estimates of the benefit from lower inflation are not very sensitive to the choice of parameter values in his model. This sensitivity analysis was limited to varying only one parameter value at a time. Of possible concern is that the production function underlying the model is a Cobb-Douglas production function, implying a unit elasticity of the capital stocks in the model to the cost of capital; the benefits and costs associated with the capital accumulation channel may be sensitive to that assumption.

the net welfare gain associated with driving inflation below the level implicit in current expectations would be modest. Taken together, these considerations suggest that the Committee may wish to ratify current inflation expectations by setting the inflation objective at or very near the current rate of inflation. The logic in favor of the second view runs as follows: Several members of the Committee have indicated in public that they prefer an inflation rate somewhere below 2 percent; for example, some members have referred to a "comfort zone" extending from 1 percent to 2 percent inflation as measured by the core PCE price index. In that context, a downside risk associated with setting the inflation objective at the current rate is that, in the worst case, the public might conclude that whenever actual inflation differs from the Committee's objective, the Committee will move the objective to the actual rate rather than drive the actual rate to the objective. The welfare consequences of such a conclusion on the part of the public would be adverse. We do not think the public would draw this conclusion from just one action of that type by the Committee; but if the Committee took similar actions on a regular basis, the risk could become much greater.

All told, our view is that economic science cannot sharply distinguish the merits of a 1½ percent inflation objective from a 2 percent or a 1 percent inflation objective.

If a range, how wide should it be?

We noted earlier that the Committee might want to quantify its objective in terms of a range rather than a point in order to communicate that inflation is inherently variable. If the Committee deems this to be the most compelling reason for setting a range, then it may wish to tie the width of the range to the variability and controllability of inflation. Simulations of the FRB/US model suggest that the Committee could maintain overall PCE inflation measured on a four-quarter basis within ±1 percentage point of its point objective between 60 and 70 percent of the time, the precise fraction depending on the volatility of the shocks hitting the economy and on the behavior of expectations. Table 3 shows that, under the vector-autoregressive (VAR) assumption regarding expectations used in FRB/US, inflation measured on a four-quarter basis could be held within ±1 percentage point of a point objective about 64 percent of the time if the shocks hitting the economy are similar to those experienced over the past twenty years, but only 59 percent of the time if the shocks are more representative of a somewhat longer period extending back to 1968. These fractions are somewhat higher for core inflation.

Table 3
The influence of economic volatility on the percentage of time that inflation could be held within ±1 percentage point of desired inflation rate: FRB/US stochastic simulation results
(Percent)

Measure of inflation and period over which averaged	Low volatility (1986 to 2005)[1]	High volatility (1968 to 2005)[1]
Total PCE inflation		
Four quarters	64	59
Eight quarters	68	63
Twelve quarters	71	66
Core PCE inflation		
Four quarters	72	66
Eight quarters	72	67
Twelve quarters	73	67

Note. In the FRB/US simulations, the funds rate is set using a Taylor rule with coefficients of 1.0 and 0.5 on the output gap and inflation gaps, respectively. Expectations are derived from forecasts of a small VAR model in which projected inflation is constrained to converge to the public's perception of the FOMC's target rate of inflation. Monetary policy does not enjoy perfect credibility, and the perceived target drifts in response to movements in actual inflation.
1. Historical period from which stochastic shocks drawn.

In addition, success in controlling inflation would also depend importantly on the nature of expectations in the inflation process. As shown in table 4, FRB/US simulations indicate that inflation control could be somewhat more precise if expectations are formed in a model-consistent, or rational, manner than if they are formed in the more backward-looking manner represented by VAR-based expectations.

Table 4
The influence of expectations formation and credibility on the percentage of time that inflation could be held within ±1 percentage point of desired inflation rate: FRB/US stochastic simulation results
(Percent)

Measure of inflation and period over which averaged	VAR-based expectations with imperfect credibility	Rational expectations with perfect credibility
Total PCE inflation		
Four quarters	64	68
Eight quarters	68	74
Twelve quarters	71	79
Core PCE inflation		
Four quarters	72	75
Eight quarters	72	79
Twelve quarters	73	82

Note. In the FRB/US simulations, the funds rate is set using a Taylor rule with coefficients of 1.0 and 0.5 on the output gap and inflation gaps, respectively. Stochastic shocks are drawn from the 1986-2005 historical period. Under VAR-based expectations, expectations are derived from forecasts of a small VAR model in which projected inflation is constrained to converge to the public's perception of the FOMC's target rate of inflation. Under rational expectations, expectations are derived from the full FRB/US model.

International experience can also shed some light on the likely precision with which inflation could be controlled. Although the economies of Canada and the United Kingdom are in some ways quite different from the economy of the United States and are subject to different shocks, it is nonetheless instructive that they have been able to keep their target inflation indexes within ±1 percent most of the time.[26] Other countries have had somewhat less success, but typically these economies are quite small and open, implying potentially more uncontrollable fluctuations in inflation than may be the case in the United States.

How often should the setting of the objective be revisited?
Were the Committee to set an inflation objective, it might wish to make clear that the objective would not be fixed for all time, in light of the fact that several factors bearing on the choice of an objective vary over time—as does our understanding of how the economy operates. One example is measurement bias in the CPI. Since 1994,

[26] Since January, 1993, the twelve-month headline rate of inflation has been either above 3 percent or below 1 percent slightly less than 25 percent of the time, while the core measure has been outside the same range 3 percent of the time. In the United Kingdom, the targeted measure of inflation has been within 1 percentage point of its target since the Monetary Policy Committee was created in May, 1997; as a result, the MPC has not had to write an open letter to the Chancellor. See Doyle and others, 2007.

methodological improvements introduced by the BLS have reduced CPI bias about ½ percentage point. Variations in measurement bias and other factors suggest a potential benefit from periodic adjustments to an inflation objective.

Other considerations, however, suggest that the Committee might wish to approach the question of adjustments with caution. First, because our understanding of the economy is constantly evolving, the analytical basis for any such adjustments would be incomplete at best, suggesting that frequent adjustments could be difficult to defend and could even exact a toll of reduced credibility. Second, because the public has only limited ability to process information regarding long-run monetary policy objectives, the Committee might risk sowing confusion if it made frequent adjustments to the objective. In foreign countries, adjustments of inflation objectives are infrequent but not unheard of; by and large, the experience seems to have been that with careful attention to clear communication, occasional adjustments can be made without either damage to credibility or increased confusion. Finally, it would seem very important to ensure that revisions to the inflation objective are undertaken for scientific reasons pertaining to measurement issues or a reconsideration of the inflation-related distortions that monetary policy is trying to reduce. If the public came to believe that the Committee would adjust its objective opportunistically in light of recent inflation outcomes, the damage in terms of lost credibility and unmooring of inflation expectations could be significant. In particular, a critical element of instability could be introduced into inflation expectations and hence into inflation itself.

Appendix: Co-movements among Inflation Rates

A number of key inflation rates appear to exhibit the statistical properties that are characteristic of nonstationary time series. Therefore, we can employ standard statistical procedures to test whether these inflation rates tend to track each other over broad periods of time (in which case they are said to be co-integrated) or to drift apart (in which case they are said not to be co-integrated). The answer is that these measures of inflation generally appear to be cointegrated. As summarized in table A.1, we found long-run relationships between most major inflation rates with the exception of GDP price inflation, which may not be co-integrated with the core consumer price inflation measures (core CPI, core PCE, and core market-based components of PCE).[27] This divergence between the GDP and core consumer price inflation measures may reflect differences in productivity growth in the production of capital equipment versus the production of consumer goods and services; it may also reflect large and persistent oil shocks that have driven wedges between these inflation rates. The relevant price levels are shown in figure 1, and associated inflation rates in figure 2. Simple visual inspection of figure 2 confirms the statistical finding that these series move together over long periods of time. Similar tests for co-integration among the various price *levels* tend not to find long-run relationships among these series even though they have not diverged greatly during the sample period we inspect.

Table A.1
Do inflation rates drift apart over long periods?
Summary of statistical analysis results

Measure	CPI	CPI ex. food and energy	PCE	PCE ex. food and energy	GDP
CPI	. . .	No	No	No	No
CPI ex. food and energy	No	. . .	No	No	Possibly
PCE	No	No	. . .	No	No
PCE ex. food and energy	No	No	No	. . .	No
PCE ex. food and energy, market-based components	No	No	No	No	Possibly
GDP	No	Possibly	No	Possibly	. . .

Note: Sample period runs from 1960:Q1 to 2004:Q3. Tests were performed using the augmented Dickey-Fuller test.

[27] The results of the test for co-integration between GDP price inflation and core CPI inflation, core PCE price inflation, or market-based core PCE price inflation are sensitive to the number of lags included in the augmented Dickey-Fuller tests.

Since most of the inflation rates of interest appear to move together over the long run, it may be useful to look at the spreads between key inflation rates. As indicated in figures 3 and 4, the *average* spreads between key inflation rates since 1950 are very small, but these spreads are quite variable and have occasionally taken on large values. For example, in the top panel of figure 3, the spread between the four-quarter changes in the CPI and PCE chain price index has been about zero on average since 1950, but four-quarter CPI inflation has deviated from PCE price inflation as much as 1.2 percentage points on both the upside and downside. The variances of the other spreads are larger. For example, the average spread between the CPI and CPI excluding food and energy since 1960, shown in the top panel of figure 4, is also close to zero, but CPI inflation has exceeded core CPI inflation as much as 4.8 percentage points and has fallen below core CPI inflation 2.6 percentage points.

In contrast to the averages over the full post-World War II period, the spreads between broad inflation rates have not been zero on average in recent years. Over the past ten years, CPI inflation has exceeded both PCE price inflation and GDP price inflation between ¼ percentage point and ½ percentage point on average. However, the variation in these spreads has declined over the same period.

In summary, if CPI or PCE price inflation were targeted, the other inflation rates, in general, would also remain anchored over time. However, the nontargeted inflation rates would likely have different average values from the targeted rate, and those inflation rates could vary considerably from quarter to quarter.

References

Abel, Andrew B. (1997). Comment on Martin Feldstein, "The Costs and Benefits of Going from Low Inflation to Price Stability," in Christina D. Romer and David H. Romer, eds., *Reducing Inflation: Motivation and Strategy.* Chicago: University of Chicago Press, pp. 156-66.

Abel, Andrew B. (1999). Comment on Hasan Bakhshi, Andrew G. Haldane, and Neal Hatch, "Some Costs and Benefits of Price Stability in the United Kingdom," in Martin Feldstein, ed., *The Costs and Benefits of Price Stability*. Chicago: University of Chicago Press, pp. 180-91.

Akerlof, George A., William T. Dickens, and George L. Perry (1996). "The Macroeconomics of Low Inflation," *Brookings Papers on Economic Activity, 1:1996,* pp. 1-76.

Atkeson, Andrew, V.V. Chari, and Patrick Kehoe (1999). "Taxing Capital Income: A Bad Idea," *Federal Reserve Bank of Minneapolis Quarterly Review,* vol. 23 (Summer), pp. 3-17.

Ball, Laurence (1994). "What Determines the Sacrifice Ratio?" in N. Gregory Mankiw, ed., *Monetary Policy.* Chicago: University of Chicago Press, pp. 155-93.

Berg, Claes, and Lars Jonung (1999). "Pioneering Price Level Targeting: The Swedish Experience 1931-1937," *Journal of Monetary Economics*, vol. 43 (June), pp. 525-51.

Bils, Mark, and Peter J. Klenow (2004). "Some Evidence on the Importance of Sticky Prices," *Journal of Political Economy*, vol. 112 (October), pp. 947–85.

Chamley, Christophe (1986). "Optimal Taxation of Capital Income in General Equilibrium with Infinite Lives," *Econometrica,* vol. 54 (May), pp. 607-22.

Chari, V.V., Lawrence J. Christiano, and Patrick J. Kehoe (1991). "Optimal Fiscal and Monetary Policy: Some Recent Results," *Journal of Money, Credit, and Banking,* vol. 23 (August), pp. 519-40.

Chari, V.V., Lawrence J. Christiano, and Patrick J. Kehoe (1995). "Policy Analysis in Business Cycle Models," in Thomas F. Cooley, ed., *Frontiers of Business Cycle Research.* Princeton: Princeton University Press, pp. 357-411.

Doepcke, Matthias, and Martin Schneider (2006). "Inflation as a Redistribution Shock: Effects on Aggregates and Welfare," CEPR Discussion Paper 5939, Centre for Economic Policy Research, November.

Doyle, Brian, Linda Kole, and Paul Wood (2007). "Foreign Experience with the Formulation and Discussion of Inflation Objectives," paper prepared for the meeting of the Federal Open Market Committee, Washington, D.C., March 20-21.

Elmendorf, Douglas, Deborah Lindner, David Reifschneider, John Roberts, Jeremy Rudd, Robert Tetlow, and David Wilcox (2005). "Considerations Pertaining to the Establishment of a Specific, Numerical, Price-Related Objective for Monetary Policy," unpublished paper, Board of Governors of the Federal Reserve System, Washington, D.C.

Feldstein, Martin (1997). "The Costs and Benefits of Going from Low Inflation to Price Stability," in Christina D. Romer and David H. Romer, eds., *Reducing Inflation: Motivation and Strategy*. Chicago: University of Chicago Press, pp. 123-156.

Feldstein, Martin (1999). "Capital Income Taxes and the Benefit of Price Stability," in Martin Feldstein, ed., *The Costs and Benefits of Price Stability*. Chicago: University of Chicago Press, pp. 9-40.

Fischer, Stanley (1994). "Modern Central Banking," in Forrest Capie and others, eds., *The Future of Central Banking*. Cambridge, England: Cambridge University Press, pp. 262-308.

Fischer, Stanley (1999). Comments on "Capital Income Taxes and the Benefit of Price Stability," in Martin Feldstein, ed., *The Costs and Benefits of Price Stability*. Chicago: University of Chicago Press, pp. 40-43.

Judd, Kenneth L. (1985). "Redistributive Taxation in a Simple Perfect Foresight Model," *Journal of Public Economics,* vol. 28 (October), pp. 59-83.

King, Robert G., and Alexander L. Wolman (1999). "What Should the Monetary Authority Do When Prices Are Sticky?" in John B. Taylor, ed., *Monetary Policy Rules*. Chicago: University of Chicago Press. pp. 349-98.

Lebow, David E., and Jeremy B. Rudd (2003). "Measurement Error in the Consumer Price Index: Where Do We Stand?" *Journal of Economic Literature,* vol. 41 (March), pp. 159-201.

Levin, Andrew, David Lopez-Salido, and Tack Yun (2006). "Strategic Complementarities and Optimal Monetary Policy," unpublished paper, Board of Governors of the Federal Reserve System, Washington, D.C.

Lucas, Robert E., Jr. (1972). "Expectations and the Neutrality of Money," *Journal of Economic Theory,* vol. 4 (April), pp. 103-24.

Mankiw, N. Gregory, and Ricardo Reis (2003). "What Measure of Inflation Should a Central Bank Target?" *Journal of the European Economic Association*, vol. 1 (September), pp. 1058-86.

Nakamura, Emi, and Jon Steinsson (2006). "Five Facts about Prices: A Reevaluation of Menu Cost Models," unpublished paper, Harvard University, Cambridge, Mass.

Phelps, Edmund (1973). "Inflation in the Theory of Public Finance," *Swedish Journal of Economics,* vol. 75 (1), pp. 67-82.

Reifschneider, David, and John C. Williams (2000). "Three Lessons for Monetary Policy in a Low-Inflation Era," *Journal of Money, Credit, and Banking,* vol. 32 (November), pp. 936-66.

Schmitt-Grohe, Stephanie, and Martin Uribe (2004). "Optimal Fiscal and Monetary Policy under Imperfect Competition," *Journal of Macroeconomics,* vol. 26 (June), pp. 183-209.

Schmitt-Grohe, Stephanie, and Martin Uribe (2006). "Optimal, Simple, and Implementable Monetary and Fiscal Rules," unpublished paper, Duke University, Chapel Hill, N.C.

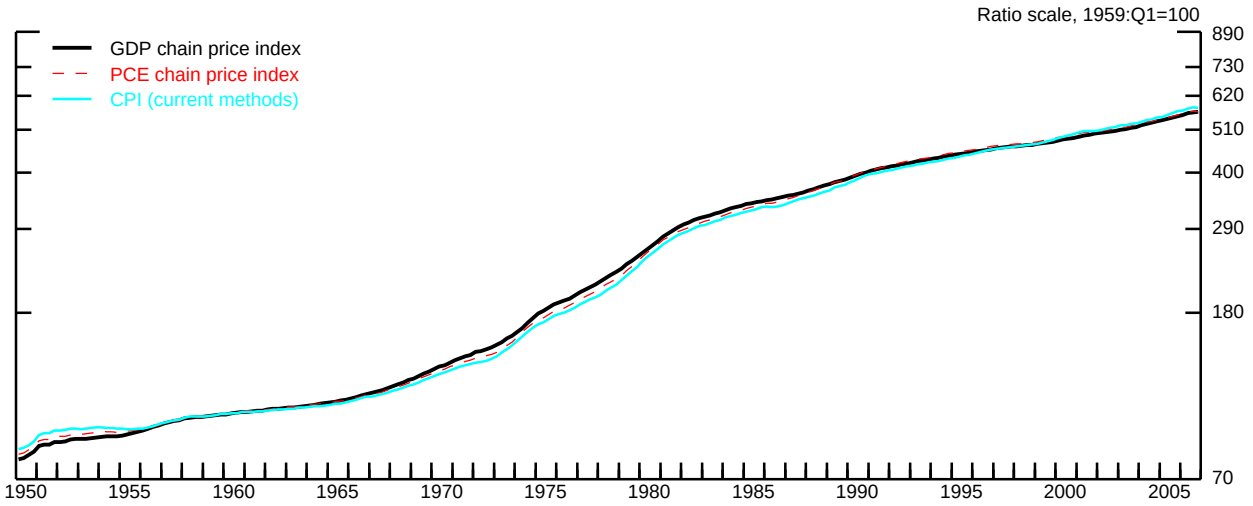
Svensson, Lars E.O. (1999). "Price-Level Targeting versus Inflation Targeting: A Free Lunch?" *Journal of Money, Credit, and Banking*, vol. 31 (August), pp. 277-95.

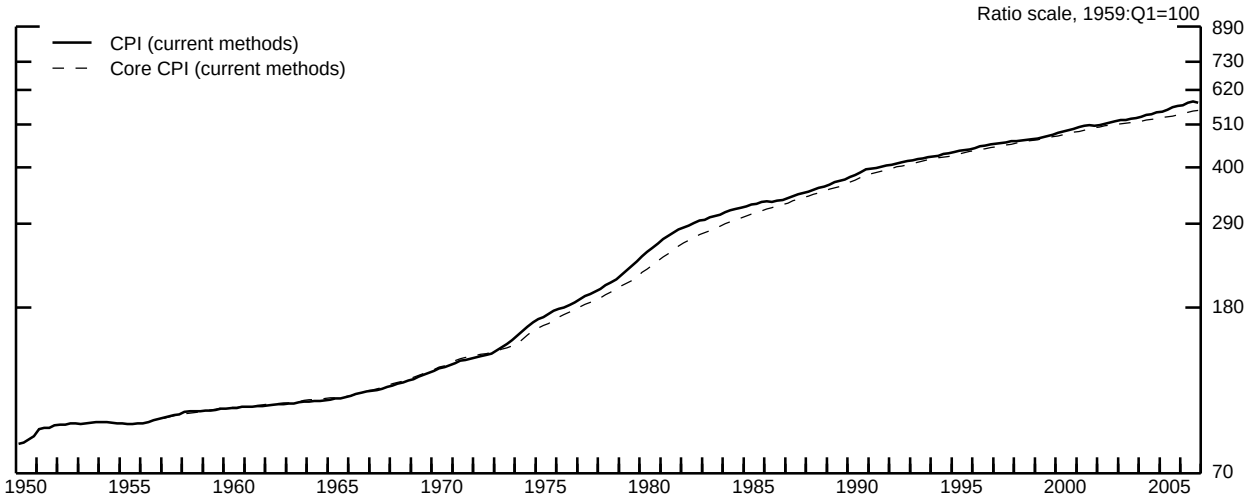
Wolman, Alexander L. (2005). "Real Implications of the Zero Bound on Nominal Interest Rates," *Journal of Money, Credit, and Banking*, vol. 37(April), pp.273-96.

Woodford, Michael (2003). *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton: Princeton University Press.

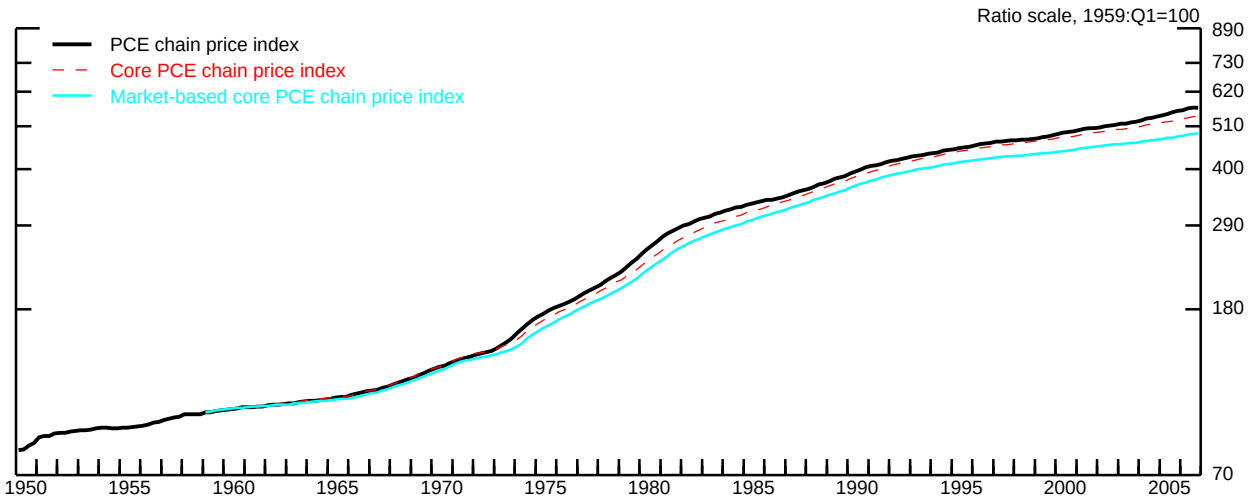
Figure 1

Price Levels





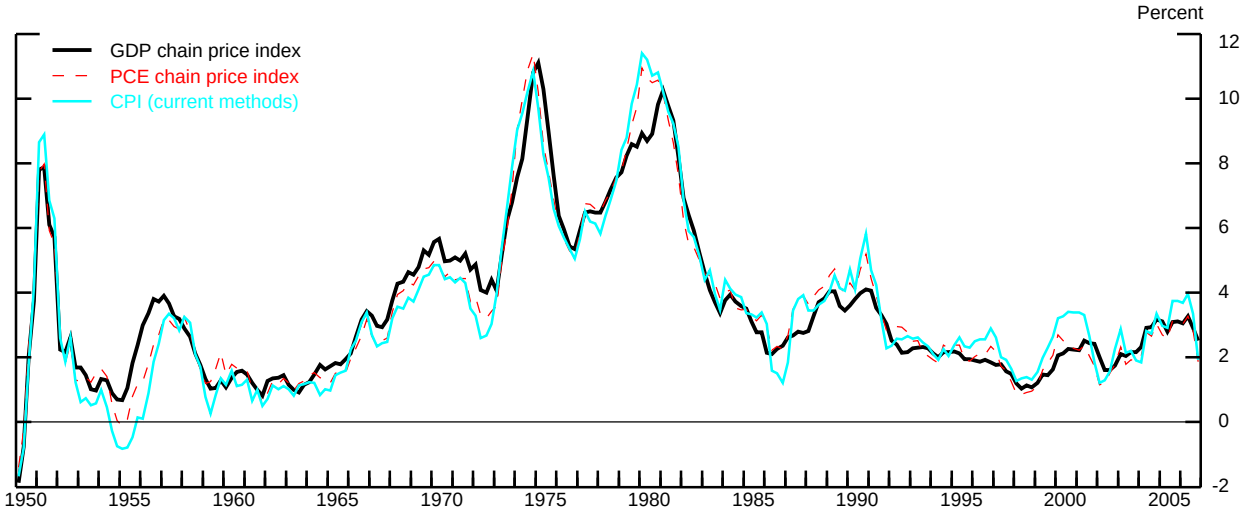
The core CPI is available beginning in 1957:Q1.

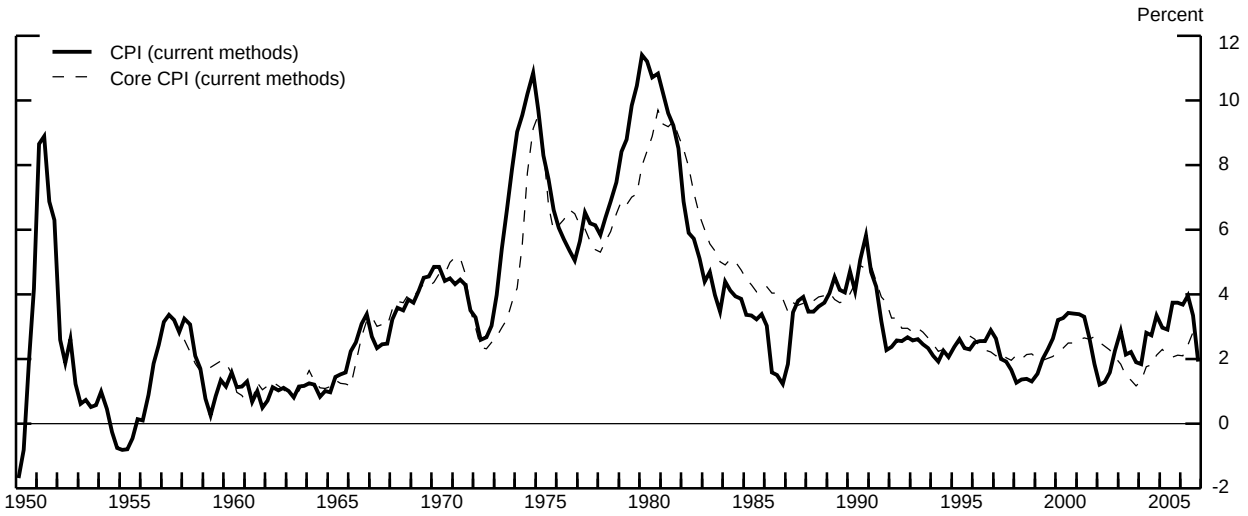


The core PCE and market-based core PCE chain price indexes are available beginning in 1959:Q1.

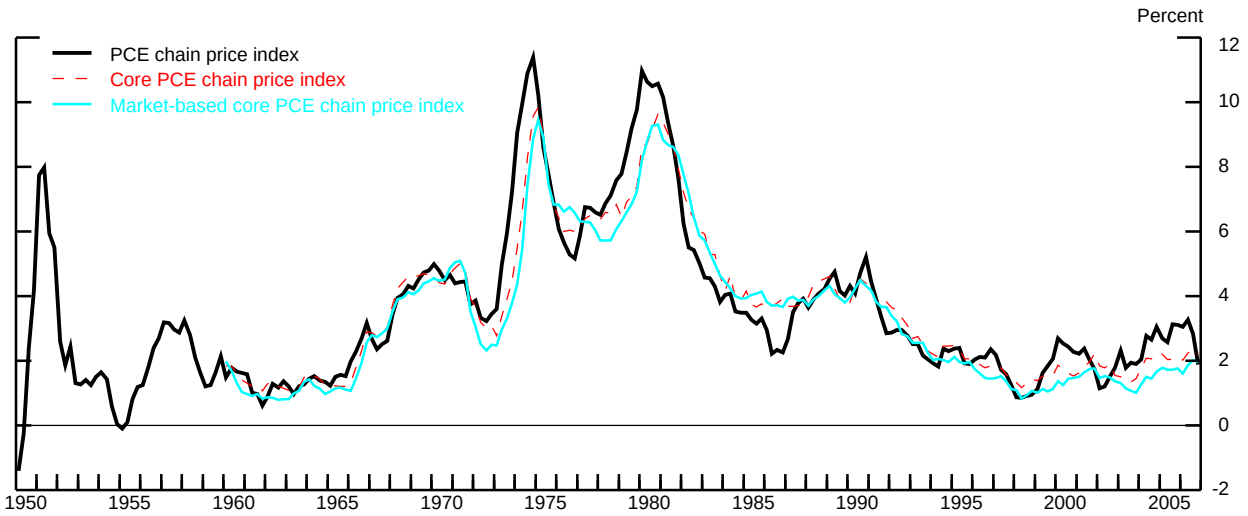
Figure 2

Inflation Rates
(Four-Quarter Percent Changes)





The four-quarter change in the core CPI is available beginning in 1958:Q1.



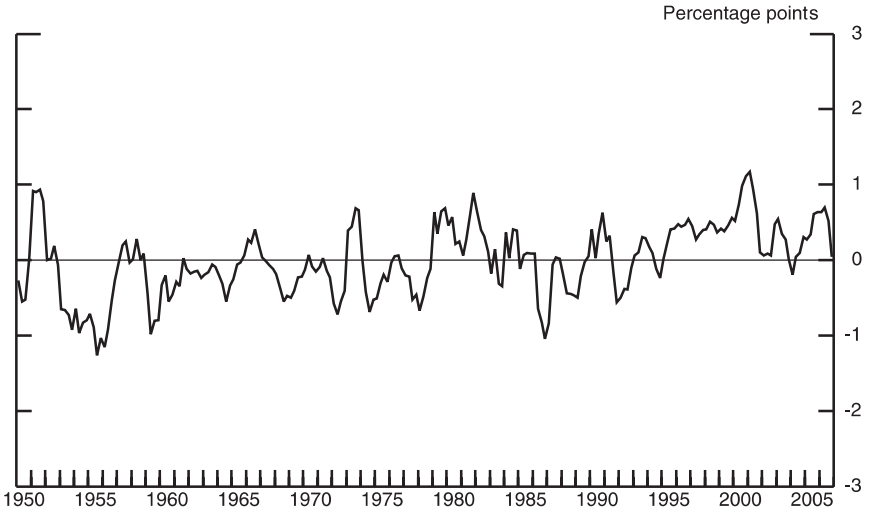
The four-quarter changes in the core PCE and market-based core PCE chain price indexes are available beginning in 1960:Q1.

Figure 3

Spreads Between Inflation Rates

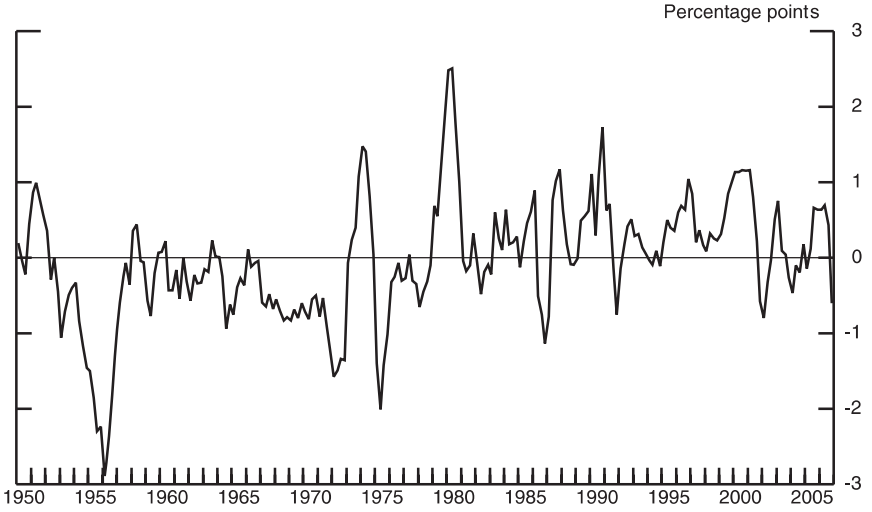
(Differences Between Four-Quarter Percent Changes)

CPI - PCE chain price index



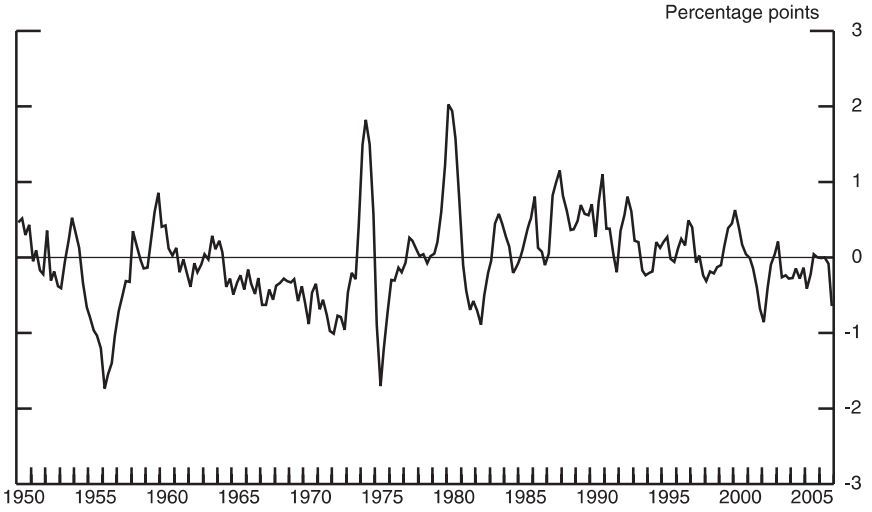
1950:1 – 2006:4	1997:1 – 2006:4
Mean -.02	Mean .43
Standard Deviation .5	Standard Deviation .3
Minimum -1.3	Minimum -.2
Maximum 1.2	Maximum 1.2

CPI - GDP chain price index



1950:1 – 2006:4	1997:1 – 2006:4
Mean -.05	Mean .33
Standard Deviation .8	Standard Deviation .5
Minimum -2.9	Minimum -.8
Maximum 2.5	Maximum 1.2

PCE - GDP chain price index



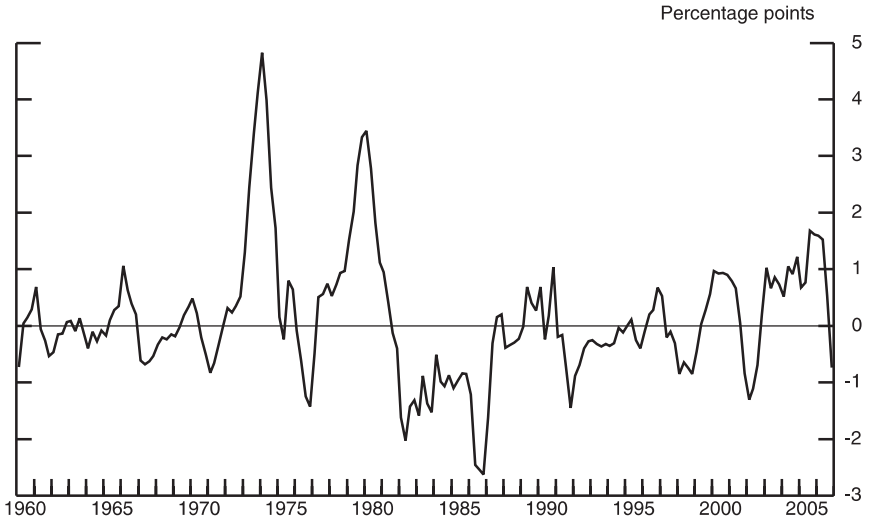
1950:1 – 2006:4	1997:1 – 2006:4
Mean -.03	Mean -.10
Standard Deviation .6	Standard Deviation .3
Minimum -1.7	Minimum -.9
Maximum 2.0	Maximum .6

Figure 4

Spreads Between Inflation Rates

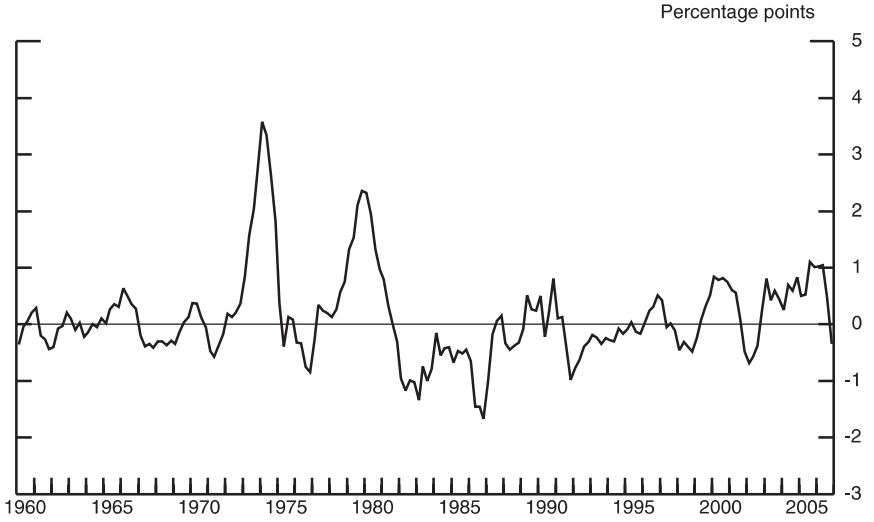
(Differences Between Four-Quarter Percent Changes)

CPI - core CPI



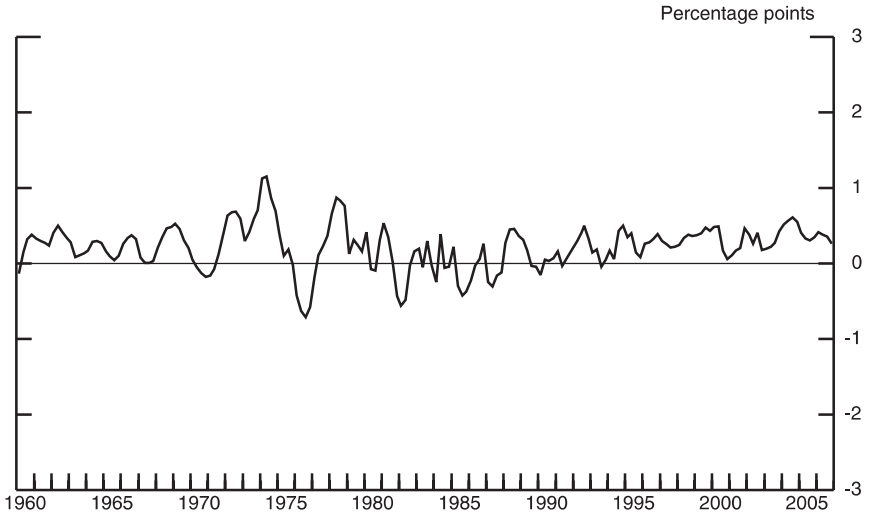
1960:1 – 2006:4	1997:1 – 2006:4
Mean	Mean
.12	.33
Standard Deviation	Standard Deviation
1.1	.8
Minimum	Minimum
-2.6	-1.3
Maximum	Maximum
4.8	1.7

PCE - core PCE chain price index



1960:1 – 2006:4	1997:1 – 2006:4
Mean	Mean
.12	.30
Standard Deviation	Standard Deviation
.8	.5
Minimum	Minimum
-1.7	-.7
Maximum	Maximum
3.6	1.1

Core PCE - market-based core PCE chain price index



1960:1 – 2006:4	1997:1 – 2006:4
Mean	Mean
.22	.34
Standard Deviation	Standard Deviation
.3	.1
Minimum	Minimum
-.7	.1
Maximum	Maximum
1.2	.6