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The Role of Expectations and Output in the Inflation Process
An Empirical Assessment

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Executive Summary

In current discussions regarding the likely trajectory of inflation, two concepts loom large: (1) Whether "well-anchored" expectations will help to restrain inflation's decline, and perhaps whether an "un-anchoring" of expectations could lead to undesirably high inflation; and (2) to what extent output (or utilization) gaps are useful components of empirical models of inflation and, if so, to what extent current gaps might counter-balance the effect of expectations on inflation. This paper examines these issues from both theoretical and empirical perspectives, with the goals of articulating a reasonably coherent theoretical basis for the discussion, highlighting the key areas of uncertainty, and providing new empirical evidence that sheds some light on these areas.

On the theoretical side, the paper argues that in structural models of inflation that highlight the importance of expectations and monetary policy, the currently low level of real marginal cost—the primary driver of inflation in such models—acts as a powerful downward force on inflation, even when expectations are well-anchored in the sense that the public understands the central bank's firm commitment to a specific numerical inflation objective. The result is that, under conditions that approximate current economic conditions, inflation falls for a period in such models. The extent to which it falls, however, and the length of the period over which it returns to the Committee's inflation goal, depend importantly on the way in which expectations are formed.

The next section considers alternative ways of characterizing the expectations that may influence inflation. The alternatives include "rational" or model-consistent expectations, backward-looking expectations, and two survey measures of expectations that reflect shorter- and longer-horizon forecasts of inflation. Over the past thirty years, the evidence on the roles that these expectations alternative play in influencing inflation is far from air-tight. However, a few patterns emerge. First, putting exclusive weight on model-consistent expectations seems fairly strongly at odds with the data. Second, the role of simple backward-looking expectations appears to have declined in recent years. Third, the influence of the survey measures appears to have increased in recent years. All of these results should be taken with a grain of salt, because the period for which we have such data is also the "Great Moderation" period, and the relative tranquility of this period (the past two years notwithstanding) poses significant challengs for uncovering the determinants of inflation.

The paper considers the implications of the empirical results on expectations for current circumstances. Because the survey measures (both long- and short-horizon) adjust quite sluggishly to conditions, including recent inflation, a greater influence of these variables would

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act to damp the movements of inflation in both directions. That is, with marginal cost and output gaps both far from their norms, sluggish survey measures may act to slow the downward movement of inflation. However, this also implies sluggishness in the gradual upward recovery of inflation towards the FOMC's inflation goal.

Finally, we examine some evidence on the effects of output and unemployment gaps on inflation. Consistent with results in Stock and Watson (2009), we find that in more tranquil periods, the benefit provided by such measures to inflation forecasts is marginal at best. However, in periods characterized by larger gaps—for example, an unemployment rate that is more than 1.5 percentage points from its estimated (time-varying) NAIRU—the improvement afforded by including such measures is considerable.

Introduction

In almost all models of inflation, the expectations of private agents about future inflation play an important role in determining current inflation. In older-style Phillips curves of the type canonized in Robert Gordon's (1982) "triangle model," expectations were implicitly captured via the lags of inflation, which proxied for an autoregressive or (loosely speaking) adaptive expectations process. In more recent models, private agents form rational expectations of future inflation that are consistent with the model's structure. For example, in the so-called New-Keynesian Phillips curve, inflation π_t depends on the rational expectation of next period's inflation $E_t\pi_{t+1}$, discounted at rate $\beta < 1$, as well as the current value of an output gap $\tilde{y}_t$ (or marginal cost)[2]:

$$\pi_t = \beta E_t \pi_{t+1} + \gamma \tilde{y}_t$$

In this model, the role of expectations is at one level completely transparent. What may be less obvious is that the role of *inflation* expectations in the model is somewhat limited: Only the expectation of next period's inflation enters directly in the model. Other roles for expectations are less direct. To see how expectations of other aspects of the economy such as monetary policy may matter, consider re-writing the equation above by "iterating forward," i.e. by substituting for future values of inflation using the same equation but moving all the "t" subscripts forward a period or more. Successive substitutions of this sort result in an expression for inflation in which inflation is solely a function of the infinite expected future values of output gaps (or marginal cost):

$$\pi_t = \gamma E_t \sum_{i=0}^{\infty} \beta^i \tilde{y}_{t+i} \tag{1.1}$$

This formulation makes it clear that it is fundamentally the expectation of future output that matters in determining inflation.

But that begs the question: What determines (the expectation of) future output? In most conventional models of output and inflation, output is determined in a way that is remarkably similar to inflation. Output depends on the expectation of output next period, and (negatively) on the real rate of interest, defined as the difference between the nominal interest rate and the expected rate of inflation. That suggests in turn that output is a function of the expected path of all future real rates. The real rate in this simple depiction depends on the federal funds rate ff_t, set by the central bank according to a policy rule of the type made popular by John Taylor (1993), and the rate of inflation. Summarizing simply in equation form:

$$\begin{aligned} \tilde{y}_t &= \beta E_t \tilde{y}_{t+1} - \sigma(ff_t - E_t \pi_{t+1}) \\ ff_t &= a(\pi_t - \bar{\pi}_t) + b\tilde{y}_t \end{aligned} \tag{1.2}$$

[2] The literature on inflation modeling of the past twenty years provides many examples in which either an output gap—defined in many different ways—or real marginal cost is the "driving variable" for inflation. We consider both options in this memo.

An important addition in the equation determining the federal funds rate is the presence of an inflation goal or target $\bar{\pi}_t$, which has a time subscript because it can and likely does vary over time.[3]

If the path of expected output matters for determining inflation, then by implication so does the path of expected funds rates, which in turn depends on the path of future inflation (and output), as well as the path of the inflation target. This schematic model captures most of the focal points in the discussion about inflation and its determinants of the past 25 years. This memo examines the role of output, inflation expectations, rational or not, and of the time-varying inflation target in determining inflation.

The balance between “anchored” expectations and marginal cost pressures in a structural model

In recent discussions of the outlook for inflation, many have referred to the importance of “well-anchored” inflation expectations. Loosely speaking, if inflation expectations are well-anchored, this may act as an offset to the potential downward pressure on inflation from the formidable estimates of the output gap. Alternatively, for those who are less-inclined to put much emphasis on gap measures, well-anchored expectations will offset the downward pressure on inflation that arises from the very low levels of real marginal cost in recent quarters.[4]

In the context of this schematic model, what does it mean for private agents to have “well-anchored” inflation expectations? And how much anchoring can expectations provide in the face of substantial resource slack and rapidly declining marginal cost?

In order to answer this question, we consider a model in which the central bank’s inflation goal plays a central role, along the lines in Cogley and Sbordone’s (2009) recent work. Output and the funds rate are determined as suggested above. Inflation is modeled in a way similar to the New-Keynesian Phillips curve above, augmented for the presence of a time-varying inflation target. The time-varying target is assumed to follow a random walk—i.e. the level of the target is very persistent, but changes in the target are unpredictable

$$\bar{\pi}_t = \bar{\pi}_{t-1} + \varepsilon_t \quad (1.3)$$

In recent years, it would seem that the amount of time-variation in the inflation target has declined considerably.[5] This likely owes in part to the more transparent stance of the Fed in recent decades. In a simple case, if the inflation goal is fixed, then well-anchored expectations in such a rational expectations model simply means that the private agents know the fixed inflation goal, and understand the implications of monetary policy for the future course of output. This does not imply that inflation will be constant, nor that expectations will be constant. But it does imply that expectations will correspond directly to the underlying fundamentals in the model.

[3] This discussion abstracts for the moment from the important observation of Cogley and Sbordone, which alters the form of the Phillips curve in the presence of a time-varying target. We will return to this shortly.)

[4] Because of very rapid productivity growth and decelerating wage growth, the third-quarter reading for the four-quarter change in real unit labor cost for the nonfarm business sector is -4.4, the lowest reading since 1983, a period of substantial disinflation.

[5] See Stock and Watson (2007) for a timeseries model that documents a decline in the contribution to the variance of inflation from the permanent component.

Now consider a case in which the private agents do not know the Fed's inflation goal with metaphysical certainty, but instead have a *perceived* inflation goal $\bar{\pi}_t^{pub}$ which may differ from the actual goal. For simplicity, we posit that the perceived inflation goal is persistent, subject to shocks, but will ultimately respond to the smoothed history of realized inflation, so that it cannot drift indefinitely away from the true inflation goal. The simple equation describing the public's perceived inflation goal in this section is

$$\bar{\pi}_t^{pub} = \rho \bar{\pi}_{t-1}^{pub} + (1-\rho)\pi_t^{avg} + \upsilon_t \tag{1.4}$$

This augmentation allows us to consider expectations that are not perfectly well-anchored, in the sense that a shock υ_t that moves the public's perception away from the actual goal can last for some time. Now their expectations do not depend only on the true underlying fundamentals in the model. To close the model, we assume that the public sets its prices according to a Cogley-Sbordone augmented Phillips curve in which expectations about the inflation goal are determined by equation 1.4 above.[6]

$$\pi_t - \bar{\pi}_t^{pub} = \tilde{\rho}(\pi_{t-1} - \bar{\pi}_{t-1}^{pub} - g_t^{\bar{\pi}}) + b_1 E_t(\pi_{t+1} - \bar{\pi}_{t+1}^{pub}) + \gamma mc_t \tag{1.5}$$

Where *mc* is the standard proxy for real marginal cost, i.e. real unit labor cost, or real wages less productivity, and $g_t^{\bar{\pi}}$ is the innovation to the perceived inflation goal.[7] Note that as in Cogley and Sbordone (2009), this model allows for the effect of lagged inflation on current inflation when $\tilde{\rho} \neq 0$, perhaps reflecting the behavior of firms who at times index current prices to reflect recent inflation, or firms who always use a rule of thumb to set current prices with regard to lagged inflation. The size of the coefficient $\tilde{\rho}$ can bear significant implications for the dynamics of inflation in response to economic conditions. It is also a matter of current debate, so we examine the implications of the model for two different values of $\tilde{\rho}$, one which implies *no* lagged inflation effect ($\tilde{\rho} = 0$) and one which allows for a more substantial (and in our view generally more data-consistent) effect of lagged inflation.[8] The coefficient on marginal cost is set at 0.05, consistent with the relatively small values estimated in the literature, and with the values we obtain in our own estimates below. We impose the zero lower bound on the federal funds rate, and agents in the model understand this constraint on the conduct of monetary policy.

In this model in which expectations can become un-anchored, we can examine how much well-anchored expectations can offset the effect of declining marginal cost, and whether an adverse change in the public's view of the Fed's inflation goal could lead to undesirably high inflation. In the simulation of the model that follows, we start the economy at a quarterly level of real marginal cost that is well below its equilibrium, reflective of recent readings for this series (see footnote 3 above). The output gap begins at -2 percent, which is qualitatively consistent with such low readings for marginal cost, but is still a relatively modest gap given most current estimates, including the Greenbook's. The inflation rate begins at two percent, a bit above its current value, and the true inflation target is two percent. The output gap is zero initially, and the federal funds rate is at its long-run equilibrium, the sum of the long-run real interest rate and the inflation goal. Given these starting conditions, the model then determines the evolution of

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[6] We exclude some of the additional terms in the Cogley-Sbordone linearized Phillips curve (longer-term expectations of inflation and the discount rate), as both they and we find them to be of marginal significance in explaining inflation.
[7] Gali and Gertler (1999) show that, under certain assumptions, real unit labor cost is proportional to output.
[8] See Barnes, Lie and Olivei (2009) for empirical evidence bearing on this point.

inflation, the funds rate, marginal cost and output.[9] Of course, this is an optimistic starting point relative to current conditions, as inflation today is lower than the implicit goal of the Fed, and despite uncertainty about the size of the output gap, it is not likely that it is currently as small as negative two percent.[10] Lowering the initial value for inflation and the output gap would of course lower the trajectory for inflation and make the points below even more strongly.[11]

The simulations are revealing. In the baseline simulation, we assume a degree of indexation that is consistent with a standard "hybrid" model of inflation that mixes both forward-looking and backward-looking (indexation) influences.[12] In the baseline, there is no mis-perception about the Fed's inflation goal. Despite initially very well-anchored inflation expectations, the pull of depressed marginal cost on inflation is significant. Inflation drops well below zero, the federal funds rate is pinned at the zero lower bound for about two years, and inflation only gradually regains levels consistent with the Fed's target. Again, this simulation is decidedly optimistic, in the sense that it assumes that all of the decline in output is matched by a decline in potential, and the model reflects no financial disruption during the recession. Both would serve to further depress output, inflation, and the policy rate. But the simulation serves to illustrate an important qualitative point: Even if one places no faith in the gap, the enormous decline in (the proxy for) marginal cost acts as a powerful pull on inflation even in the presence of perfectly-anchored expectations.[13]

In the next simulation (figure 2), the public initially believes that the Fed's inflation target has risen to 3 percent, shown in the dotted red line in the figure. Over time, it will adjust its perception of the target down in line with observed inflation. But at first, this misperception keeps inflation from falling as much as it does in the baseline simulation, as price-setters expect a higher rate of trend inflation. As a consequence, the funds rate does not have to fall as far, but it is still the case that on net, inflation falls well below zero for an extended period, and the funds rate remains well below its equilibrium for several years. Thus, in the model with significant indexation, these unanchored expectations, while important, do not nearly offset the downward pressure on inflation that arises from depressed marginal costs.

The next figure considers a simulation in which there is no indexation in the economy, and thus no backward-looking inertia imparted to the inflation rate from this source. In this case, the overall disruption from the sharp drop in marginal cost is less severe: Inflation declines, to be sure, dropping below one percent for a while, but after about three years it has risen close to the Fed's goal. The required decline in the federal funds rate is noticeably less.

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[9] Marginal cost is linked to output in a way consistent with the simple derivation described in footnote 3, but allowing for a gradual adjustment to movements in output: $mc_t = \omega mc_{t-1} + b_1 \tilde{y}_{t-1} + b_2 \tilde{y}_{t-2}$. We set the parameters in the relationship to their full-sample estimates, obtaining the parameters $\omega = 0.96, b_1 = 0.45, b_2 = -0.33$.

[10] The data suggest a relationship between real marginal cost and the output gap that is described in the preceding footnote.

[11] The shocks to marginal cost and output at the beginning of the simulations do not persist into subsequent periods. The model's own propagation mechanisms account for the dynamics displayed in the figures.

[12] The coefficients $\tilde{\rho}$ and b_1 in equation 1.5 are estimated using conventional techniques over the post-1984 sample.

[13] While there are some differences in the paths of marginal cost across the four simulations, they are qualitatively similar, so we display the marginal cost path only for the first baseline simulation.

Under the same model assumptions, but allowing for the same misperception about the inflation goal as in figure 2, the inflation rate still declines, but is below target by less than a percentage point and only for a fairly short time. The federal funds rate dips below its long-run equilibrium for a bit, but because of the very forward-looking, flexible nature of the economy in this model, the increase in the perceived inflation goal offsets most of the downward pressure on inflation from marginal cost.

From these simulations, we offer the following conclusions:

- No matter the degree of indexation in the model, even with perfectly anchored expectations, inflation is likely to fall in a recession characterized by the decline in marginal cost (or the output gap) that we have seen to date.
- How much it falls, and how much monetary accommodation is required (and for how long) is critically dependent on the degree of indexation or "backward-lookingness" that characterizes inflation. In a very forward-looking model, the decline in inflation may well be modest—perhaps no more than what we have seen to date.
- The evidence on the persistence of inflation that bears on the degree of indexation in this model is still mixed to date. Fuhrer (2009) examines a wide array of evidence for recent samples and concludes that it would be risky to assume *no* persistence in inflation for the U.S., even in recent years. While persistence is likely to have declined relative to the 1970s and 1980s, it probably remains a feature of inflation in the U.S. Thus one should probably give some weight to a model with some indexation. In these circumstances, well-anchored expectations do not avoid serious downward pressure on inflation. Correspondingly, expectations that become un-anchored on the upside do not offset much of the downward pressure on inflation.

Because the way in which expectations are formed and the degree of backward-lookingness in the model matter importantly for how much expectations can offset the effects of marginal cost or output, the next section examines empirically the influence of various expectations concepts, including rational expectations, over the past 30 years.

What kind of expectations influence inflation? An empirical assessment

The expectations in the models described above are not observed in the way that the federal funds rate, inflation and output are. In the economics literature of recent decades, this unobservability has been circumvented by assuming "rational expectations:" The expectations of interest are in essence the forecasts of the model in which they are embedded.[14]

But if the model fails to capture important aspects of the economic environment, then the rational or model-consistent expectations may not represent well the expectations of real-world economic actors. Alternatively, economists may wish to examine more direct measures of inflation expectations to see how robust the conclusions from rational expectations models are to

[14] This poses some methodological complications, as the equations include the expectations themselves. We will leave this problem aside for the purposes of this memo.

different assumptions about expectations. Finally, much recent commentary has focused on the stability (or lack thereof) in more direct measures of inflation expectations, positing that "well-anchored" expectations may preclude a drop in inflation such as those that have followed other significant postwar recessions. For any of these reasons, one may turn to proxies for expectations such as the forecasts of professionals, surveys of households or businesses, or the expectations embedded in financial market prices.[15]

In this section, we use survey-based measures of inflation expectations to obtain another measure of the importance of expectations in determining inflation. We run a "horse race" in a simple inflation equation, allowing four different proxies for inflation expectations to determine inflation. In addition to output or marginal cost, inflation is allowed to depend on

1. Lagged inflation—here we employ the four-quarter moving average of inflation, denoted π_{t-1}^{avg} in equation 1.6 below;
2. The rational (model-consistent) expectation of inflation;
3. The four-quarter-ahead forecast of inflation from the Survey of Professional Forecasters (SPF);
4. The 10-year forecast of inflation from the SPF.[16]

Figure 5 displays the data for the two SPF forecasts, along with the core CPI and PCE inflation measures. Note that the 10-year SPF forecast has hovered very close to 2.5 percent since the late 1990s. This remarkable stability in the 10-year forecast is somewhat suspect to us. Recall that this is the median forecast for the *average* inflation rate over the ensuing ten years. Like a ten-year bond, its longer maturity implies that it will be less responsive to near-term conditions than a one-year forecast. But it would be unusual for a 10-year forecast (or a 10-year bond) to remain within 10 basis points of a single value for over a decade. If the Fed had persuaded the public that its inflation goal were 2.5 percent, then the one-year inflation expectation ten years hence could well remain fixed at 2.5 percent. But the rationale for a fixed median of 10-year average forecasts is much harder to come by. The 1-year SPF forecast which, like the 10-year is plotted *as of its forecast date*, fluctuates considerably and tracks current inflation reasonably well.

The contribution of these four measures to current inflation is constrained to sum to one, roughly in keeping with an accelerationist Phillips curve. We further allow for the influence of important changes in the relative price of oil. The estimating equation is thus

$$\pi_t = \mu_1\pi_{t-1}^{avg} + \mu_2 E_{t-1}\pi_{t+1} + \mu_3\pi_t^{S1} + (1-\mu_1-\mu_2-\mu_3)\pi_t^{S10} + \gamma\tilde{y}_t + d\Delta\frac{p_{t-1}^o}{p_{t-1}} + \varepsilon_t \qquad (1.6)$$

With this flexible specification, the data can allow the model to choose a completely forward-looking form ($\mu_1 = \mu_3 = 0, \mu_2 = 1$) or a New-Keynesian hybrid form ($\mu_3 = 0, \mu_1 + \mu_2 = 1$) or any

[15] Roberts (1997) provides one of the earliest examination of these inflation models with survey expectations.
[16] The University of Michigan 1-year ahead inflation expectation displays very similar properties to the SPF. In initial estimation testing, the differences between the Michigan and SPF forecasts were not qualitatively significant. The SPF 10-year expectation is the only consistently collected measure of longer-term inflation forecasts that is readily available. With more time, researchers will likely use the inflation expectations implied by the yields on TIPs, but at present, only a ten year sample is available.

number of other combinations. One should not think of this specification as reflecting "deep structure," as it combines elements of a structural model and a partially reduced-form model. But it seems a useful benchmark for assessing the empirical contributions of various expectations measures.[17]

We estimate the equation using a standard Bayesian estimator for rolling samples of ten years beginning in 1983 and extending through 1999:Q3.[18] The priors for the key parameters are as listed in the following table

Prior distributions			
Parameter	**Distribution**	**Mean, Std. deviation**	**Support**
μ_1	Beta	0.25, 0.18	[0,1]
μ_2	Beta	0.25, 0.18	[0,1]
μ_3	Beta	0.25, 0.25	[-0.5,1]
γ	Gamma	0.05, 0.03	[0,0.3]
d	Gamma	0.05, 0.03	[0,0.3]

These priors smooth the estimates somewhat in the presence of large shocks, but with relatively large standard errors, they allow the data to be the primary influence on the estimates. Note that the prior on μ_3 allows for some probability mass below zero, reflecting our somewhat more diffuse prior about the role of the one-year survey expectation in determining inflation. For example, the one-year survey could serve as a correction to the model-consistent expectation, which might entail a non-positive coefficient. Similarly, the implicit prior on the 10-year survey expectation spans a considerably larger region (from -2 to 1.5), reflecting the less theoretically-grounded role for this long-term expectation in the canonical inflation equation. The priors on the indexation and rational expectation terms are a bit tighter, as theory suggests they should fall between zero and one.

With the presence of rational expectations for inflation in period $t+1$, the model implicitly requires expectations of the output gap (and/or marginal cost), as well as expectations for the 1-year and 10-year SPF expectations. For output and the federal funds rate, we include unconstrained (VAR) equations in output, the funds rate and inflation. The intercepts for these equations are allowed to change for each sample period. We link marginal cost to output as in the section above. Finally, we model the 1- and 10-year inflation expectations as moving averages of recent inflation, with moving average parameters estimated from the data. That is, we specify the 1- and 10-year inflation expectations as

$$\begin{aligned} &\pi_t^i = \lambda_i \pi_{t-1}^i + (1-\lambda_i)\pi_{t-1} \\ &i = 1,10 \end{aligned} \tag{1.7}$$

This specification provides a reasonable one-step-ahead forecast for these measures, and also ensures that the expectations measures will converge to the inflation goal in the steady-state.[19]

[17] For example, the way in which many theories would suggest that the 10-year expectation should enter a structural inflation model, the overlap between the indexation term and the inertial 1- and 10-year surveys, and so on, are left as incompletely specified in the empirical specification.

[18] Increasing the sample window to 15 years produces somewhat smoother, but qualitatively similar results.

Note that the coefficients λ_i which index the degree of inertia in the survey expectations are estimated to be in the range of 0.8 to 0.96, implying significant inertia in these expectations, a feature to which we return below. Finally, we allow for an intercept shift in the SPF 10-year expectation, to reflect its stubborn insistence on remaining at 2.5% despite over the past ten years during which inflation averaged about two percent, and the Fed's not-official inflation goal was widely believed to be about two percent. This implies the following modification to equation 1.6, with the intercept shift denoted c_{10}:

$$\pi_t = \mu_1 \pi_{t-1}^{avg} + \mu_2 E_{t-1}\pi_{t+1} + \mu_3 \pi_t^{S1} + (1-\mu_1-\mu_2-\mu_3)(\pi_t^{S10} - c_{10}) + \gamma \tilde{y}_t + d\Delta \frac{p_{t-1}^o}{p_{t-1}}$$

We estimate the model for a variety of inflation, driving variable, and trend inflation alternatives. First, the inflation measure in equation 1.6 is either the core CPI or the core PCE. Second, the driving variable in the horserace Phillips curve is either marginal cost or the output gap.[20] Third, we either abstract from or allow for the presence of "trend inflation" in the model. In the latter case, all of the inflation variables in equation 1.6 are expressed as deviations from Cogley and Sbordone's estimated trend inflation measure, which we denote $\bar{\pi}_t^{CS}$. In this case, the estimating equation becomes

$$\hat{\pi}_t = \mu_1 \hat{\pi}_{t-1}^{avg} + \mu_2 E_{t-1}\hat{\pi}_{t+1} + (1-\mu_1-\mu_2)\hat{\pi}_t^{S1} + \gamma \tilde{y}_t + d\Delta \frac{p_{t-1}^o}{p_{t-1}} \qquad (1.8)$$

where each "hatted" variable represents the deviation of the original variable from $\bar{\pi}_t^{CS}$, i.e. $\hat{\pi}_t \equiv \pi_t - \bar{\pi}_t^{CS}, \hat{\pi}_t^{S1} \equiv \pi_t^{S1} - \bar{\pi}_t^{CS}, \hat{\pi}_{t+1} \equiv \pi_{t+1} - \bar{\pi}_{t+1}^{CS}$. The 10-year SPF forecast is assumed to have no significant effect on short-run movements in inflation for this variant.

Because we are interested in part in potential changes in the influence of expectations variables over the past thirty years, we estimate equation 1.6 or 1.8 for rolling ten-year samples beginning in the early 1980s and continuing through to the middle of 2009. For each sample, we estimate the values of the parameters in equations 1.6 or 1.8, as well as the intercepts in the VAR equations for output and the funds rate and the intercept shift for the 10-year SPF forecast. The parameters for the other equations are held constant over the 1983-2009 period.[21] For several points in the overall estimation sample, we estimate the posterior distribution of the parameters to assess the accuracy with which key parameters are estimated at various points in the sample

[19] These equations matter only to the extent that the weight on π_{t+1} differs from zero, in which case the model will compute expectations of the 1- and 10-year surveys in computing the solution for current inflation. In examining the determinants of the survey expectations in the data for the full sample, two clear features emerge: (1) Both the 1-year and 10-year expectations are well-modeled as slowly-moving moving averages of past inflation; and (2) The influence of other variables on the expectations is of marginal importance economically, and at best fleeting significance statistically.

[20] We use the CBO's estimate of potential output and define the gap as 100 times the log difference between real GDP and the CBO potential estimate. The level of the gap is adjusted to reflect the difference in the base years between the BEA's current real GDP estimates (2005) and the CBO's potential measure (2000).

[21] Fuhrer (2009) provides evidence that suggests that the dynamics for this output gap measure and for real marginal cost have changed little over the past 30 years, suggesting that this approximation is reasonable.

Figures 6-9 display the posterior distributions over the past three decades for the parameters μ_i that premultiply the expectations proxies.[22] [23] As the figures make clear, there is considerable uncertainty about the precise contributions to core inflation measures from lagged inflation, the model-consistent expectation of inflation, and the short- and long-term survey expectations proxies.[24] This likely reflects collinearity among the survey measures and lagged inflation, as well as the relatively low variability in inflation and marginal cost prior to the most recent recession. Nonetheless, the results suggest some broad patterns across measures and time periods.

1. The weight on lagged inflation, often associated with so-called "intrinsic persistence" of inflation, has been moderate over the past thirty years. For most measures, its weight appears to have declined in the most recent decade.
2. Note that in principle, the model could replicate a purely forward-looking rational expectations model by assigning weights of zero to lagged inflation and the survey expectations measures. However, the weight on the "rational expectation" of next quarter's inflation is estimated to be small and insignificantly difference from zero throughout the decades, across all inflation and driving variable measures. The vertical line in the top-right panel of each figure indicates the value that this parameter takes in the purely forward-looking simulation of the first section. In all cases, the estimate places a tiny probability on this value.
3. In the most recent decade, the weight on the 10-year SPF expectation has risen for some, but not all measures. The most noticeable increase arises for the core CPI with the output gap as the driving variable, figure 6. In prior decades, it would have been difficult to reject the hypothesis that the contribution from the 10-year expectation was zero. The core PCE model with real marginal cost as the driving variable shows a more modest increase in the weight on the 10-year SPF forecast in the most recent decade.
4. The weight on lagged inflation was particularly high for the core PCE/output gap model in the 1990s.
5. For the CPI models, the 1-year SPF forecast has a significant influence on inflation for all of the sub-samples. The influence of the 1-year forecast is much less evident for the PCE models.

While the shift towards some weight on the long-term expectation for some periods is of interest, it is also important to note that the weight rises precisely at the time that the 10-year forecast "flat-lines" at 2.5 percent. This could be taken as evidence that price-setters have "well-anchored" expectations, but as discussed above, one would not expect that well-anchored expectations would manifest themselves as a constant forecast for the 10-year average inflation rate.

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[22] These distributions are derived from estimates for rolling 10-year samples from 1983 to 2009, using the methods described in footnote 13.

[23] The posterior is estimated using the now-conventional Markov-chain Monte Carlo method, with a Random-walk Metropolis-Hastings step.

[24] In some cases, the posterior distribution differs little from the prior, suggesting that the likelihood (the data) offer little information about the parameter. In the text, we highlight those cases in which this is not true.

A key part of the debate over the determination of inflation is the role played by the output gap or marginal cost. Figure 10 provides some evidence bearing on this question. It displays the distribution of the estimated parameter on the output gap or marginal cost (γ) for the four models discussed above. In general, the estimated parameter is small, ranging from 0.02 to 0.06 across the decades, but in most cases, its accuracy has improved in the past decade. The data generally reject the null that the parameter is zero. Typically only about five percent of the estimated parameter's distribution lies to the left of 0.01.

For the periods in which the 10-year expectation is given near-zero weight, so that $1-\mu_1-\mu_2-\mu_3=0$, one can re-write the model of equation 1.6 so that it is approximately an "inflation gap" model in which trend inflation is proxied by the 10-year expectation:[25]

$$\pi_t-\pi_t^{S10}=\mu_1(\pi_{t-1}^{avg}-\pi_t^{S10})+\mu_2(E_{t-1}\pi_{t+1}-\pi_t^{S10})+\mu_3(\pi_t^{S1}-\pi_t^{S10})+\gamma\tilde{y}_t+d\Delta\frac{p_{t-1}^{o}}{p_{t-1}} \qquad (1.9)$$

Because the results overall suggest that this inflation gap representation may be a reasonable approximation, the next set of figures display parallel results for an "inflation gap" model, in which all of the inflation measures are expressed as deviations from Cogley and Sbordone's trend inflation estimate, and thus the estimating equation becomes equation 1.8. The results in these cases, figures 11-14, suggest a somewhat greater role for the one-year survey expectation for the core CPI, and a somewhat greater role for lagged inflation in the core PCE models. The role of the rational expectations term is relatively limited. While it is not precisely estimated, in the most recent decade (the green lines), its weight is typically low and usually not significantly different from zero.

<u>The balance of expectations and marginal cost pressures in a survey-expectations-based model</u>

The results in the preceding section suggest that inflation is not well-characterized by a purely forward-looking model, and appears to favor some weight on the survey expectations (as well as lagged inflation). Thus it is of interest to revisit the simulation of the first section for a model that uses survey expectations as the key expectation variable in an otherwise standard DSGE model. We conduct a simulation like that in the first section, but instead of rational expectations, we use a model that is consistent with the estimated influence of survey expectations from the preceding section.

In particular, we assume that the influence of the longer-term inflation expectation primarily reflects the influence of trend inflation, and model trend inflation as in the first section (it represents the very slow-moving inflation target of the Fed). We allow the one-year survey expectation to influence current inflation in lieu of the model-consistent expectation. Thus the inflation equation becomes

$$\pi_t-\overline{\pi}_t^{pub}=\mu_1(\pi_{t-1}-\overline{\pi}_{t-1}^{pub})+\mu_3(\pi_t^{S1}-\overline{\pi}_t^{pub})+\gamma mc_t \qquad (1.10)$$

[25] The model would be exactly an inflation gap model if the timing of the 10-year expectation terms corresponded to the inflation measures from which it is subtracted. Because the 10-year expectation is highly persistent, this difference is of little practical consequence. Clark and Davig (2008) find that the underlying trend inflation component appears to be closely correlated to the 10-year SPF survey measure.

To mimic the qualitative properties of the estimation results in the preceding section, we set $\mu_1 = 0.4$ and $\mu_3 = 0.6$--inflation depends somewhat on lagged inflation, but more importantly, it is strongly tied to the one-year (SPF) expectation of inflation. The equation for the one-year SPF expectation is also expressed in deviations form

$$\pi_t^{S1} - \bar{\pi}_t^{pub} = \omega(\pi_{t-1}^{S1} - \bar{\pi}_{t-1}^{pub}) + (1-\omega)(\pi_{t-1} - \bar{\pi}_{t-1}^{pub})$$

which simply makes the deviation of the one-year expectation from the inflation trend a moving average of past deviations of actual inflation from the inflation trend. As suggested in figure 5 and discussed in footnote 14, the one-year SPF forecast is well-modeled as a slowly moving average of current and recent inflation realizations. Thus for this exercise, we set ω to two-thirds, which implies a bit more rapid response to recent inflation than what we find in the data.[26]

Figure 15 shows the response to the same large marginal cost shock for this "survey expectations" model, with a shock to the public's perceptions of the Fed's inflation goal.[27] The significant downward pressure exerted by below-equilibrium marginal cost is partly offset by the rather slow downward progress of the one-year inflation expectation. That "anchoring" limits the decline in inflation to a minimum of 0.7 in the second year of the simulation. But that same anchoring also slows the progress of inflation upward towards its (unchanged) goal of two percent. While inflation has risen above 1.5 percent by the end of the simulation, it takes several more years to reach its goal. To be sure, monetary policy could act more aggressively with the funds rate in this simulation (if not in the real world). But the qualitative point of the simulation is clear: To the extent that inflation of late has become more closely associated with slow-moving expectations like those reflected in the SPF measures, this may limit the downward trajectory of inflation somewhat. But it will also likely slow the upward progress towards its long-run goal.[28]

Activity gaps and inflation dynamics

The inflation models and the related simulations considered in the previous section hinge on activity gaps (or real marginal costs) being the driving process for inflation. Absent such a link from activity to inflation, these models have no content. There is now a large literature on the performance of inflation forecasts based on activity gaps (that is, Phillips curve representations of inflation dynamics) relative to univariate benchmarks. Recent work by Stock and Watson (2009) surveys the literature and provides a comprehensive analysis of Phillips curve forecasts of inflation vis-à-vis good univariate benchmark models. The conclusion reached by Stock and Watson after examining a wide array of (backward-looking) Phillips curve

[26] The estimates of the process for the 1-year forecast are performed on the raw, rather than de-trended data. However, the trend inflation rate is presumed to move quite slowly, so that its contribution to the short-run movements of the 1-year forecast will generally be small.

[27] The simulation without the misperception of the inflation goal, not shown, leads to quite similar results. With the strong weight on the one-year inflation expectation, the effect of the temporary shift in the inflation goal is fairly muted.

[28] This feature would be qualitatively similar, although quantitatively exaggerated, with a 10-year expectation that mimicked the behavior of the SPF 10-year forecast. That variable is even more inertial, and would thus more forcefully limit the downward motion of inflation, and similarly slow even more inflation's progress towards its goal.

specifications is that the link from activity gaps to inflation is not always present. Inflation is difficult to forecast, and Phillips curve-based forecasts of inflation outperform univariate benchmarks only sporadically. Stock and Watson, however, note that the episodes when activity-based forecasts outperform univariate forecasts have in common a large activity gap, either positive or negative.

The point that large activity gaps may contain information for inflation forecasting is illustrated in Figure 16. The figure compares inflation forecast errors based on a standard backward-looking Phillips curve, with the forecast errors based on a random walk model of inflation. Specifically, the Phillips curve model takes the form

$$\pi_{t+4}^{4} = a(L)\pi_t - \gamma \tilde{u}_t + \chi z_t + \upsilon_{t+4}^{4}, \tag{2.1}$$

where π_{t+4}^{4} denotes the 4-quarter ahead rate of inflation, π_t is the 1-quarter (annualized) rate of inflation, $\tilde{u}_t$ is the unemployment rate gap, z_t is a vector of supply shocks, and υ_{t+4}^{4} is an error term. As usual, the sum of the coefficients on the lags of inflation is constrained to sum to unity. In the random walk model of inflation, the 4-quarter ahead rate of inflation is equal to the rate of inflation over the most recent four quarters plus an error term:

$$\pi_{t+4}^{4} = \pi_t^{4} + \upsilon_t^{4}. \tag{2.2}$$

The figure shows on the horizontal axis the difference between the absolute value of the forecast error for 4-quarter ahead core PCE inflation based on the Phillips curve, and the absolute value of the forecast error of 4-quarter ahead core PCE inflation when the inflation forecast is given by the most recent historical value of 4-quarter core PCE inflation. A negative value on the horizontal axis implies that the Phillips curve-based forecast is more accurate than the random walk univariate forecast, and vice versa. The variable on the vertical axis is the absolute value of the unemployment rate gap, i.e. the absolute value of the difference between the unemployment rate and an estimated measure of the NAIRU. Each dot in the figure represents a different quarter, and the period we consider is 1961:Q1 to present. It is apparent from the figure that when the unemployment rate gap is small, there is little suggesting that the Phillips curve inflation forecasts are better than the random walk forecasts, as there are roughly as many points to the left as there are to the right of the vertical axis. It is only when the gap starts to become large in absolute value that there is a tendency for the points to be located to the left of the vertical axis, implying that Phillips curve-based forecasts are more accurate than the random walk forecasts.

The Phillips curve based-forecasts embedded in Figure 16 are in-sample. Stock and Watson, instead, work with out-of-sample forecasts. Moreover, they consider a variety of activity gap-based specifications for modeling inflation, a different estimate for the time-varying NAIRU than the one we are using, and a more sophisticated univariate forecast -- though not materially different in terms of forecast outcomes -- than the simple random walk this exercise is based upon. Still, their evidence is broadly similar to the one depicted in the figure. Indeed, Stock and Watson sum up their results as indicating that that when the unemployment rate gap exceeds 1.5 percentage points in absolute value, the Phillips curve forecasts “improve substantially” (p. 146) upon the univariate model.

These findings are consistent with potential nonlinearities in the Phillips curve. Consider the following modification to a standard backward-looking Phillips curve

$$\pi_{t+4}^{4} = a(L)\pi_t - \gamma_L \tilde{u}_t I\left(\left|\tilde{u}_t \le \zeta\right|\right) - \gamma_H \tilde{u}_t I\left(\left|\tilde{u}_t > \zeta\right|\right) + \chi z_t + \upsilon_{t+4}^{4} \quad . \qquad (2.3)$$

The modification to the standard linear setup in (2.1) allows the tradeoff between inflation and unemployment to change as a function of the level of the unemployment rate gap. There are several ways of introducing this nonlinearity. In equation (2.3), we simply assume that the slope of the Phillips curve can change according to whether the absolute value of the unemployment rate gap lies below or above a threshold ζ, where $I(\cdot)$ is an indicator function that takes the value of one if the statement in parenthesis is true, and zero if the statement is false. Suppose, consistent with the findings in Stock and Watson, that the threshold ζ takes the value of 1.5 percent. Then γ_L in equation (1) denotes the slope of the Phillips curve when the unemployment rate gap is, in absolute value, below 1.5 percent, and γ_H denotes the slope of the Phillips curve when the absolute value of the unemployment rate gap is above 1.5 percent. Results from estimating (2.3) over the period 1961 to present for core PCE inflation at quarterly frequency are reported in column (A) of Table 1. The slope is statistically significant and economically relevant when the absolute value of the unemployment rate gap is above the threshold, and not significantly different from zero when the absolute value of the unemployment rate gap is below the 1.5 percent threshold. A formal statistical test rejects the null hypothesis of the linear model (2.1) in favor of the nonlinear model (2.3) with the 1.5 percent threshold. Searching over the threshold that provides the best fit to the nonlinear model in equation (2.1) yields an estimated value for the threshold ζ of 1.47 percent. Not surprisingly, estimates of the slope of the Phillips curve when the absolute value of the unemployment rate gap is above or below the optimized threshold are very similar to the estimates reported in column (A) of the table.

The Phillips curve models we consider in this section are based on the unemployment rate gap because much of the discussion in Stock and Watson about the usefulness of activity gaps in informing inflation forecasts focuses on the unemployment rate. Similar results, however, hold when the activity measure is given by the output gap. Consider the following nonlinear Phillips curve model

$$\pi_{t+4}^{4} = a(L)\pi_t + \gamma_L \tilde{y}_t I\left(\left|\tilde{y}_t \le \zeta\right|\right) + \gamma_H \tilde{y}_t I\left(\left|\tilde{y}_t > \zeta\right|\right) + \chi z_t + \upsilon_{t+4}^{4}, \qquad (2.3')$$

where the only difference with the model in (2.3) is that we have replaced the unemployment rate gap with the output gap. Estimates of the inflation-activity tradeoff and the threshold ζ are provided in column (B) of Table 1. The estimated threshold for the absolute value of the output gap is 2.9 percent. This value is consistent, from an Okun's law standpoint, with the estimated threshold for the unemployment rate gap in (2.3). The tradeoff is estimated to be statistically and economically significant when the absolute value of the output gap is above the threshold, but not so when the output gap is below the threshold. The null hypothesis of a linear specification is rejected in favor of the nonlinear specification at standard confidence levels. The similarity of findings when using the output gap in place of the unemployment rate gap also extends to the rest of the analysis in this section. For this reason, in what follows we only mention results concerning the unemployment rate gap.

It is possible to modify the model in (2.3) and proxy inflation expectations with a weighted average of past inflation and long-run inflation expectations. Estimation results are largely unaffected. The unemployment rate gap threshold is estimated at 1.51. Again, a formal test does reject the null hypothesis of a linear specification in favor of the threshold specification.

The result (not reported) that the slope of the Phillips curve is statistically significant and economically relevant when the absolute value of the unemployment rate gap is above the threshold but not when the absolute value of the unemployment rate gap is below the threshold continues to hold. Here, we briefly consider an alternative specification that treats inflation expectations as an unobserved component. The relationship we estimate now takes the form

$$\pi_{t+4}^{4} = \pi_t^e - \gamma_L \tilde{u}_t I\left(\left|\tilde{u}_t \leq \zeta\right|\right) - \gamma_H \tilde{u}_t I\left(\left|\tilde{u}_t > \zeta\right|\right) + \chi z_t + \upsilon_{t+4}^{4}, \qquad (2.4)$$

where

$$\pi_t^e = \pi_{t-1}^e + \nu_t .$$

In this setup, inflation expectations π_t^e are unobserved and follow a random walk, with ν_t denoting an i.i.d. shock. Results from this estimation exercise are reported in column (C) of Table 1. The absolute value of the unemployment rate gap threshold is now estimated at 1.6 percent. The estimates continue to be consistent with the view that the gap matters for determining inflation once the unemployment rate is sufficiently far from the NAIRU.

These in-sample findings, together with the out-of-sample forecasting results of Stock and Watson, provide some evidence that knowledge of a large unemployment rate gap contains useful information about inflation. The results can also be reconciled with the Atkeson and Ohanian (2001) findings that, from 1984 on, the random walk characterization of inflation provides better inflation forecasts than the forecasts obtained from a Phillips curve. Excluding the current recession, there have been few episodes when the unemployment rate gap was above or below the 1.5 percent threshold. To some extent, the enumeration of these episodes depends on the way in which the NAIRU is estimated. Starting in 1984 and excluding the present period, one can estimate with some confidence the unemployment rate to be sufficiently far away from the NAIRU at the beginning of the sample and during the recession of the early 1990s, and with much more uncertainty during a few quarters late in the 1990s expansion (when the unemployment rate bottomed at 3.9 percent) and after the 2001 recession (when the unemployment rate peaked at 6.1 percent in 2003). The proximity of the unemployment rate to the NAIRU for most of the post-1983 period could then explain the Atkeson and Ohanian results, and possibly also in-sample estimates of the slope of the Phillips curve (in standard linear settings) being not particularly significant statistically and/or relevant from an economic standpoint.

While there is uncertainty about the extent of activity gaps in many circumstances, the most recent reading of 10.2 percent in October 2009 for the unemployment rate should place the unemployment rate gap well above the 1.5 threshold that seems to make knowledge of the gap useful for forecasting inflation. More debatable is the extent of the downward pressure that such a gap will exert on inflation. As the previous section shows, this will depend importantly on how inflation expectations are formed. Too, it will depend on the size of the gap and the slope of the Phillips curve. In this respect, it is interesting to assess the performance of a simple threshold Phillips curve model of inflation in the current situation. Since the 4-quarter ahead inflation model in (2.3) leaves limited scope for considering the dynamics of inflation in the most recent quarters (the average unemployment rate for 2008:Q3 was 6.1 percent), we use a 1-quarter ahead inflation specification

$$\pi_{t+1} = a(L)\pi_t - \gamma_L \tilde{u}_t I\left(\left|\tilde{u}_t \leq 1.5\right|\right) - \gamma_H \tilde{u}_t I\left(\left|\tilde{u}_t > 1.5\right|\right) + \chi z_t + \upsilon_{t+1}^{1}, \qquad (2.5)$$

where we have imposed a 1.5 percent unemployment rate gap threshold. We estimate (2.5) on core PCE inflation over the period 1961 to 2004. We then perform a dynamic simulation over the subsequent period. In the simulation, we provide actual values for the unemployment rate gap $\tilde{u}$ and the supply shocks z, while only the projected values of inflation enter the simulation. Column (D) of Table 1 reports the estimates for the parameters γ_L and γ_H in (2.5). Again, the inflation-unemployment tradeoff is significant only when the unemployment rate gap is larger than 1.5 percent in absolute value.

Results for the dynamic simulation are shown in Figure 17. The figure reports actual and simulated values for 4-quarter core PCE inflation starting in 2005:Q4.[29] Predicted inflation tracks actual inflation reasonably well. Still, it is also apparent that over the past three quarters predicted inflation has been on a somewhat steeper downward trend than actual inflation. Given the estimates in column (D) of Table 1, an average unemployment rate gap of about 4 percent over the next four quarters implies a further drop in 4-quarter core PCE inflation of roughly 1.2 percent, other things equal. It is possible that the estimates reported in Table 1 when the unemployment rate gap lies above the threshold could underestimate the current sacrifice ratio. Some studies (see Tetlow and Ironside, 2007) provide evidence of a flattening of the Phillips curve in most recent years, with a consequent increase in the sacrifice ratio. As already mentioned, this could be the result of weak identification stemming from the very few instances of large unemployment rate gaps. But it could suggest also that inflation behavior at the very low levels of inflation we have been experiencing in the most recent years is fundamentally different from inflation behavior when the average level of inflation is comparable to the levels experienced during the ’70s, ’80s, and early ’90s.

What do these results imply for the interpreting the recent behavior of inflation, and for the current forecast?

Conclusions

Given the difficulties in modeling inflation, especially over the past decade when inflation has been relatively tranquil, and the economy—up until 2007—was similarly placid by historical standards, we should be hesitant to draw any conclusions too firmly.

That said, the analysis presented in this paper points to some tentative conclusions about inflation and its likely trajectory over the coming years:

1. For all of the models discussed in this paper, the current configuration of output gaps (however poorly estimated) and marginal cost suggest that inflation is likely to remain low, perhaps declining, and below the Committee’s implicit goal for several years.
2. Within more formal models of inflation, apart from the extreme position of a purely forward-looking model, there are significant downside risks to inflation, even if expectations are very well anchored.

[29] This is the first period in the simulation where only forecast values of inflation enter in (2.5).

3. Evidence on the influence of survey measures of inflation expectations on current inflation suggests that model-consistent expectations have not reflected well the expectations that influence CPI or PCE inflation over the past three decades. The effect of lagged inflation has been large at times, but appears to have declined in recent years.
4. Expectations that are well-proxied by slow-moving survey expectations appear to have had some influence over the decades, and for some models, that influence has increased recently.
5. In a model that substitutes slow-moving survey expectations measures for model-consistent expectations, the forecast for the near-term envisions a decline in inflation that is somewhat more muted. In this sense, the risks to more pronounced disinflation could be mitigated by "well-anchored" inflation expectations. Correspondingly, however, the time required for inflation to rise to its FOMC-determined goal will be quite long.
6. While there are numerous issues surrounding the measurement and definition of the output or unemployment gap that sits at the center of many inflation models, evidence in this paper is consistent with that of Stock and Watson (2009). Both they and we find that in periods characterized by what appear to be large output gaps (such as the current period), gaps are important predictors of inflation.
7. Altogether, these observations suggest that across a fairly wide array of inflation frameworks, one would expect inflation to decline in the near term. Precisely how much depends on key parameters of the model, about which we must admit a fair amount of uncertainty. But one extreme among the alternative inflation models—a purely forward-looking model with little effect from inertial variables, such as the one depicted in figures 3 and 4—appears to be significantly at odds with the data. It could be risky to count too much on the implications of such a framework.

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Figure 1

No shock to perceived inflation target, ρ=.47, b_1=.51

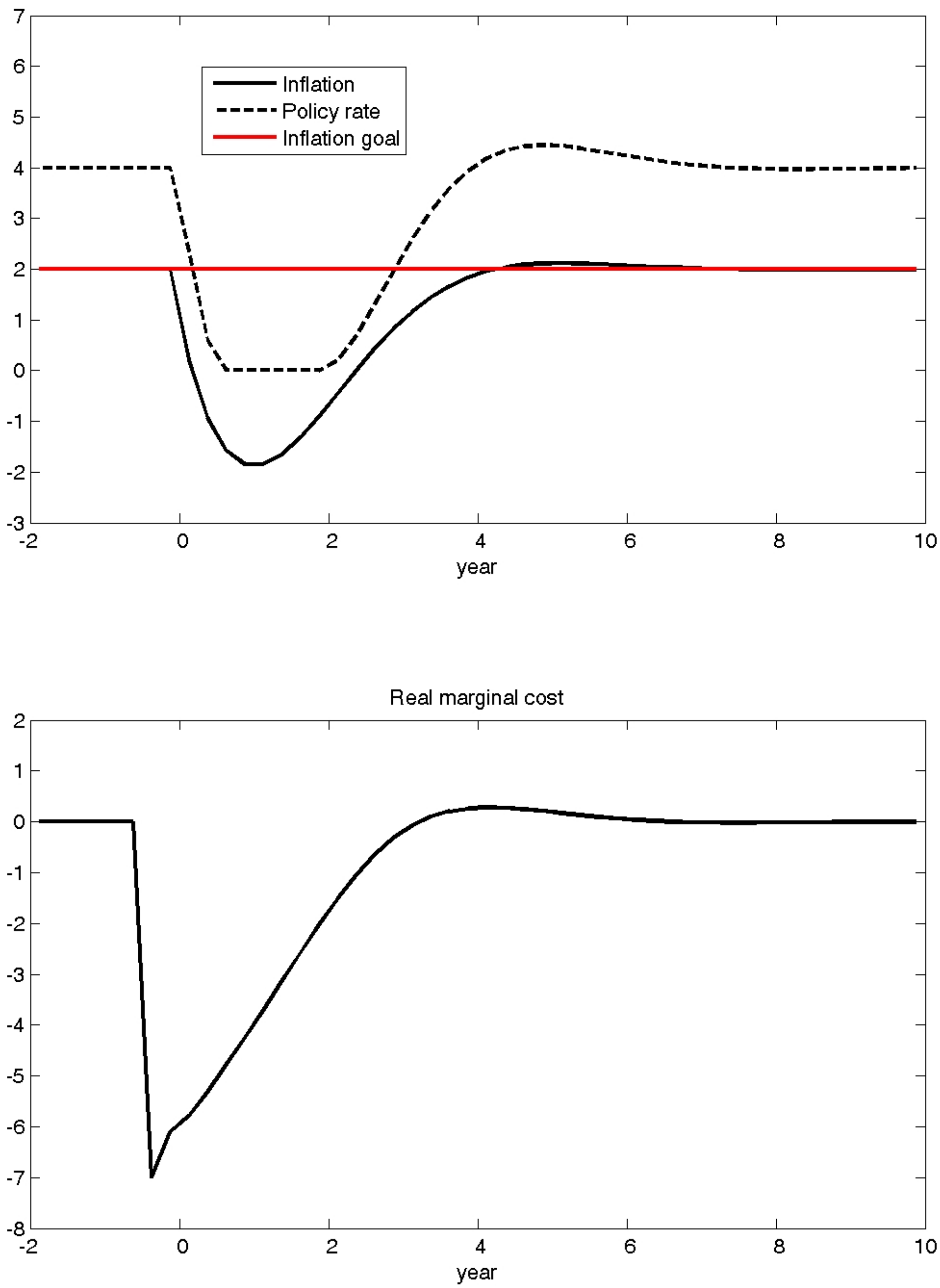


Figure 2

Shock to perceived inflation target, ρ=.47, b_1=.51

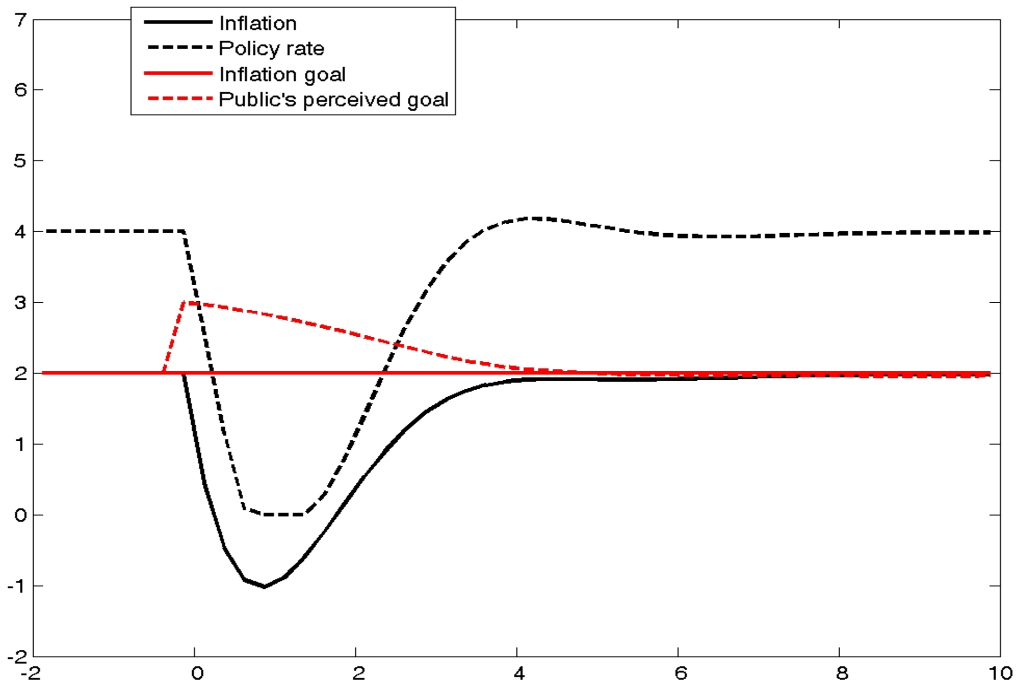


Figure 3

No shock to perceived inflation target, ρ=0, b_1=.85

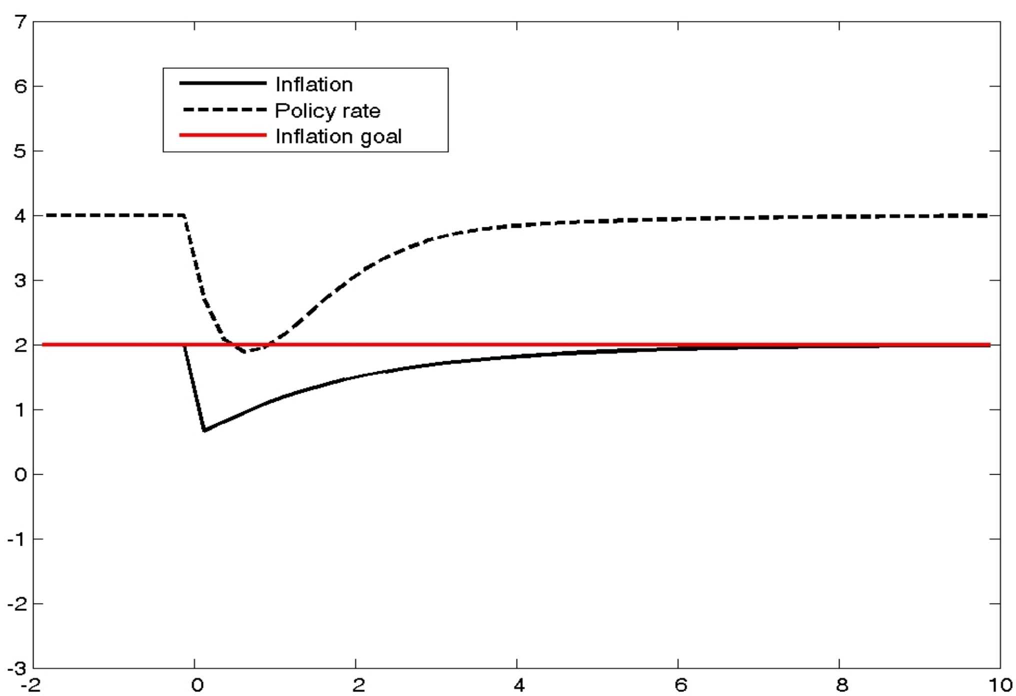


Figure 4

Shock to perceived inflation target, ρ=0, b_1=.85

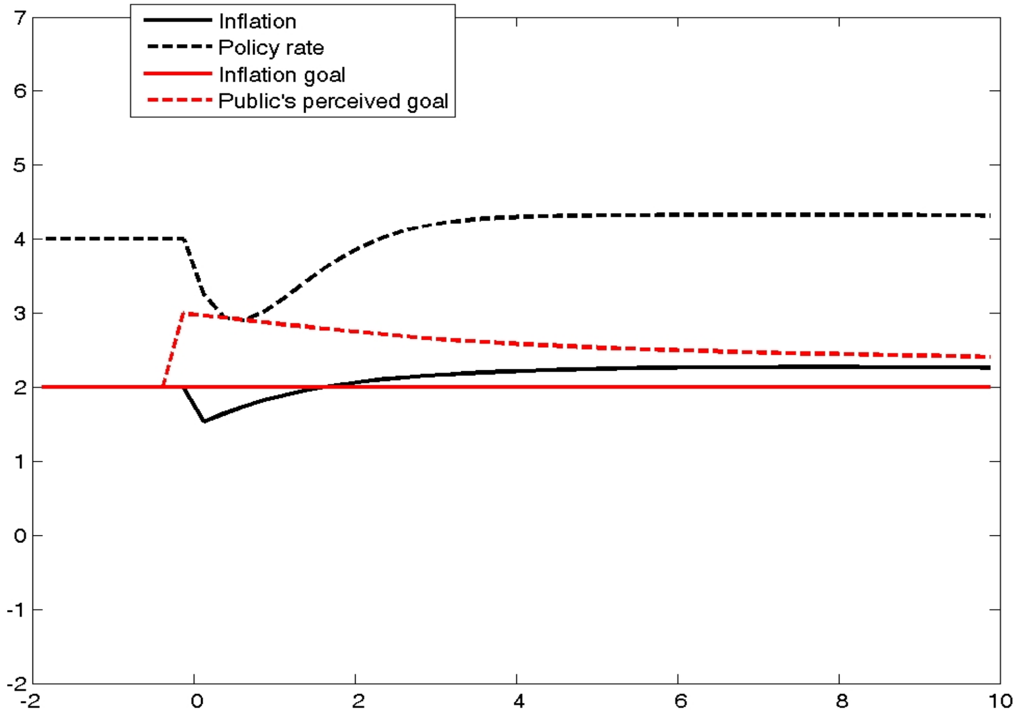


Figure 5

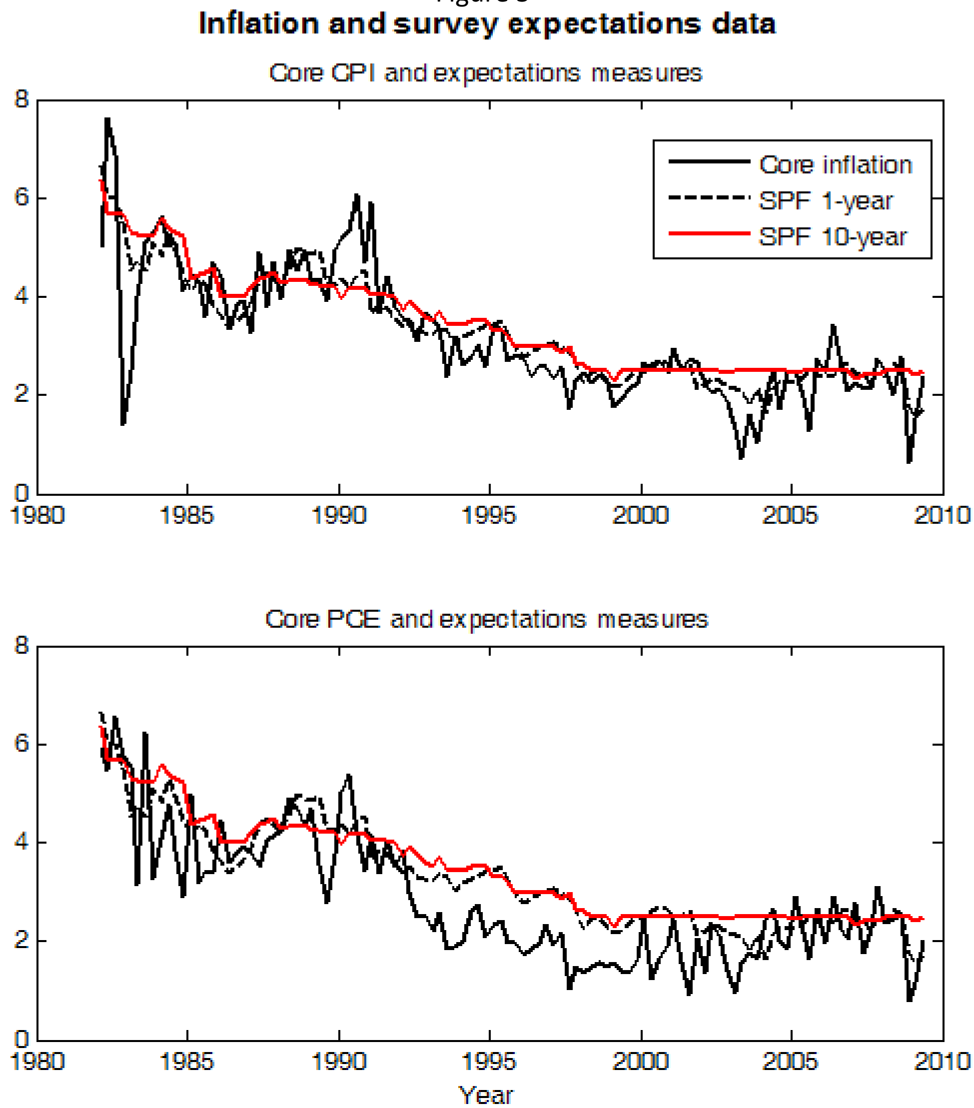

Inflation and survey expectations data
Core CPI and expectations measures
Core inflation
SPF 1-year
SPF 10-year
0
2
4
6
8
1980
1985
1990
1995
2000
2005
2010
Core PCE and expectations measures
0
2
4
6
8
1980
1985
1990
1995
2000
2005
2010
Year

Figure 6:
Distribution of parameter estimates
Core CPI, output gap model

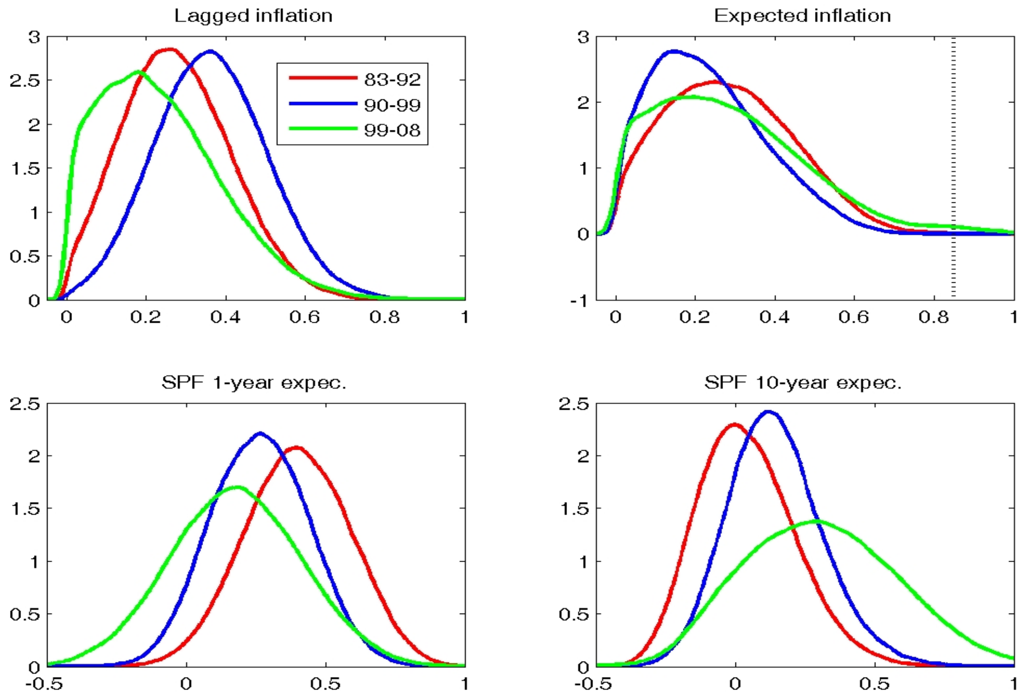


Figure 7:
Distribution of parameter estimates
Core CPI, marginal cost model

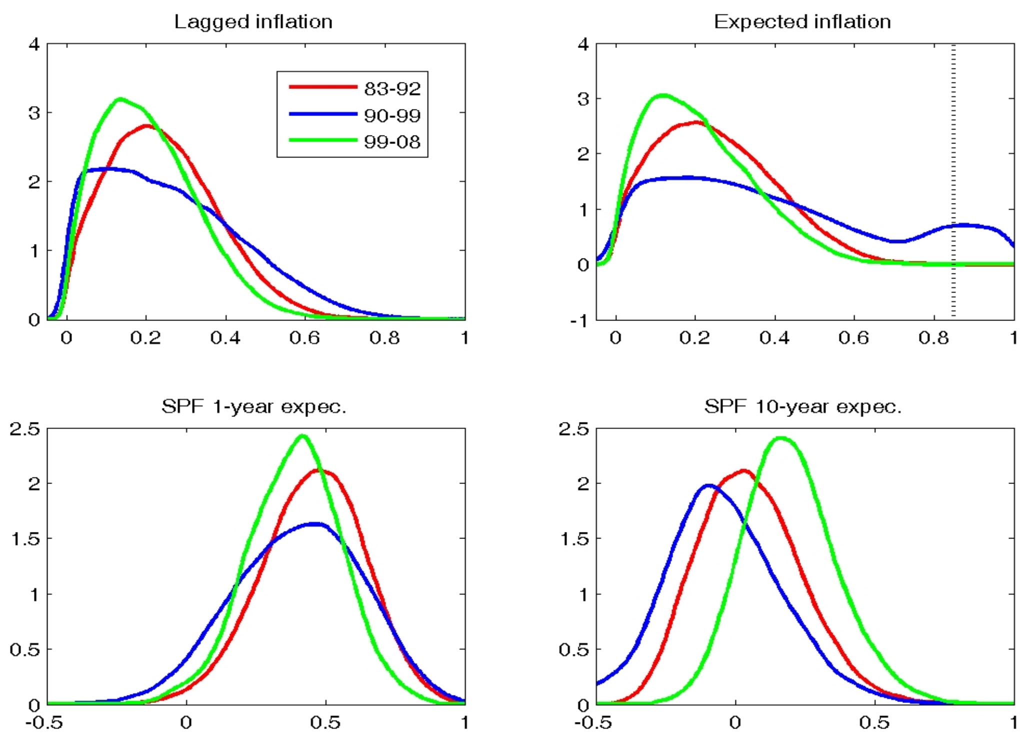


Figure 8:
Distribution of parameter estimates
Core PCE, output gap model

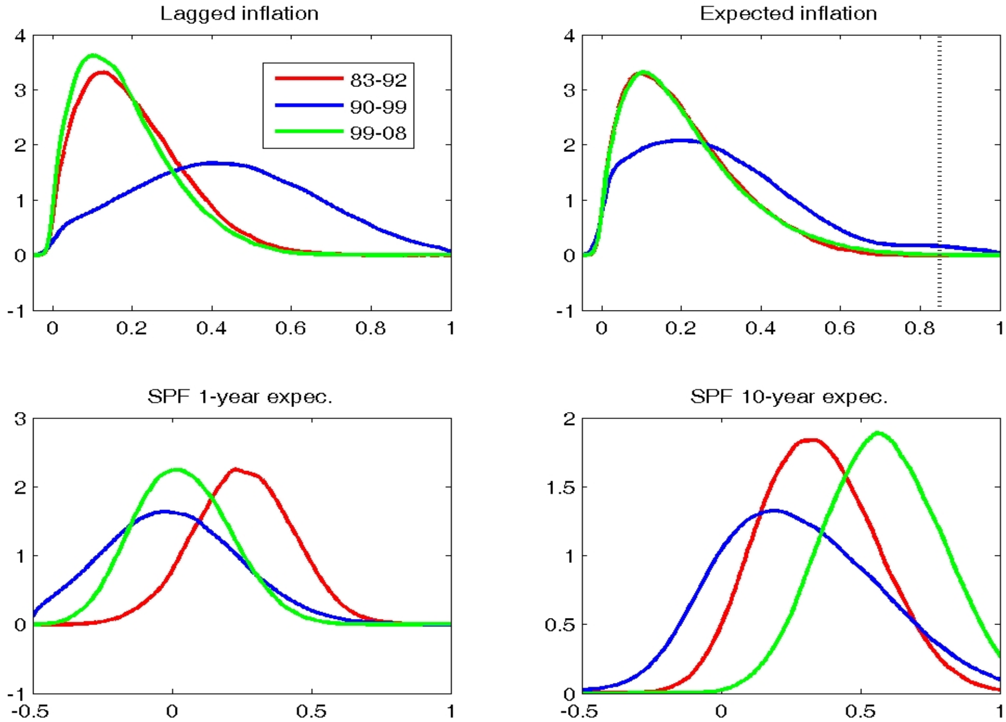


Figure 9:
Distribution of parameter estimates
Core PCE, marginal cost model

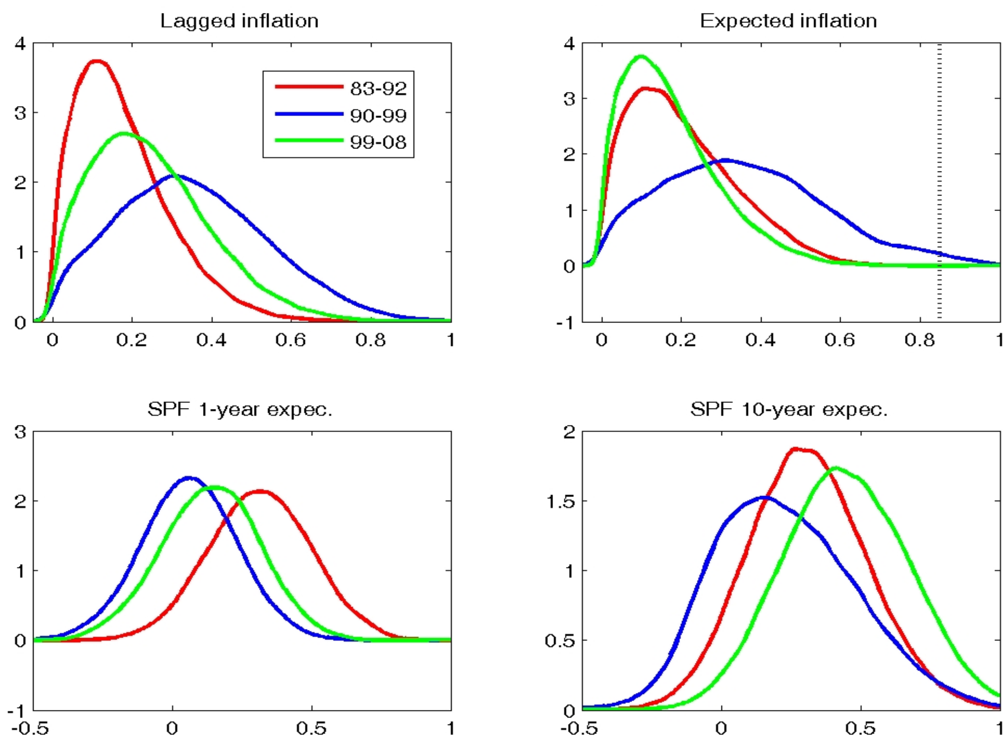


Figure 10

Distribution of output gap/marginal cost parameters

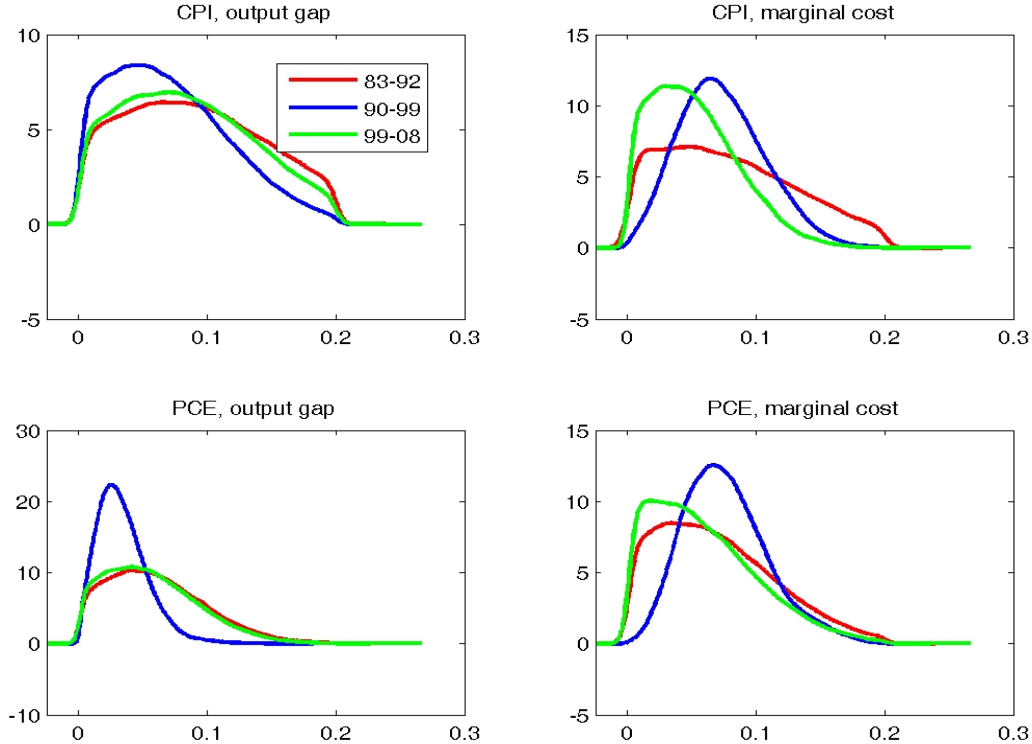


Figure 11

Distribution of parameter estimates

Core CPI, output gap, “trend inflation” model

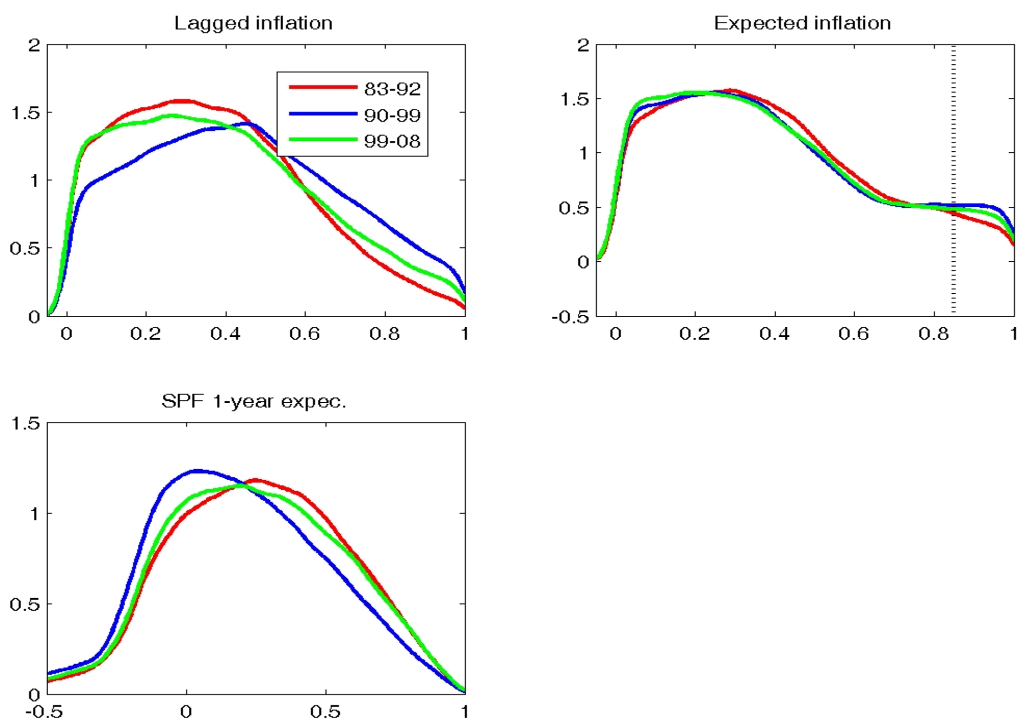


Figure 12
Distribution of estimated parameters
Core CPI/Marginal cost, "trend inflation" model

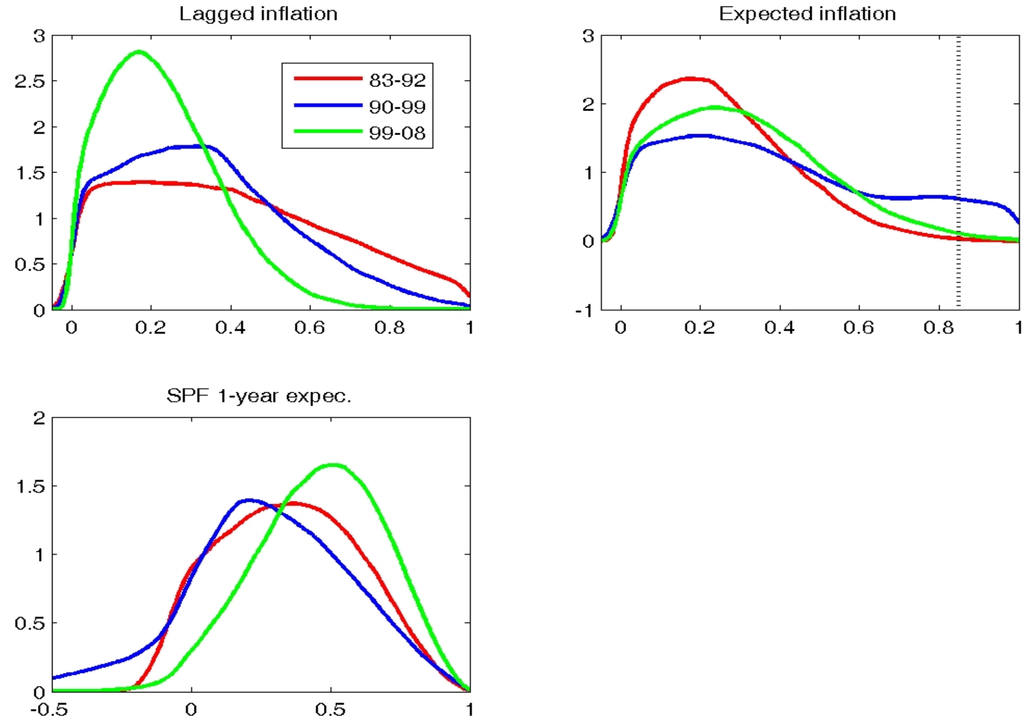


Figure 13
Distribution of estimated parameters
Core PCE/Output gap, "trend inflation" model

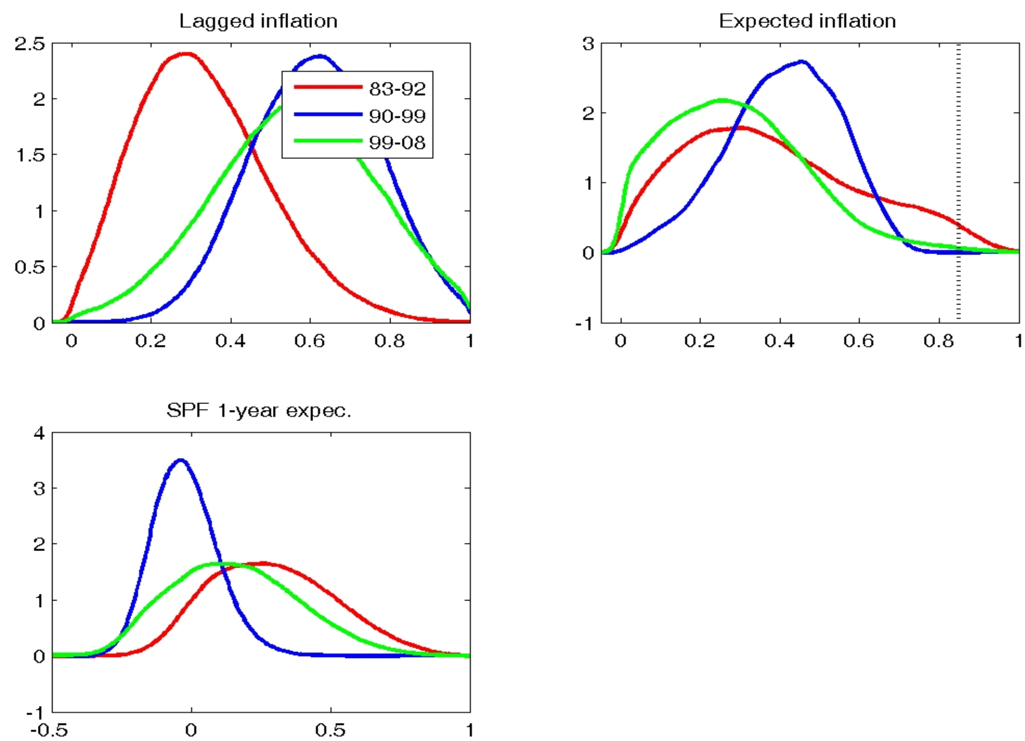


Figure 14
Distribution of estimated parameters
Core PCE/Marginal cost, "trend inflation" model

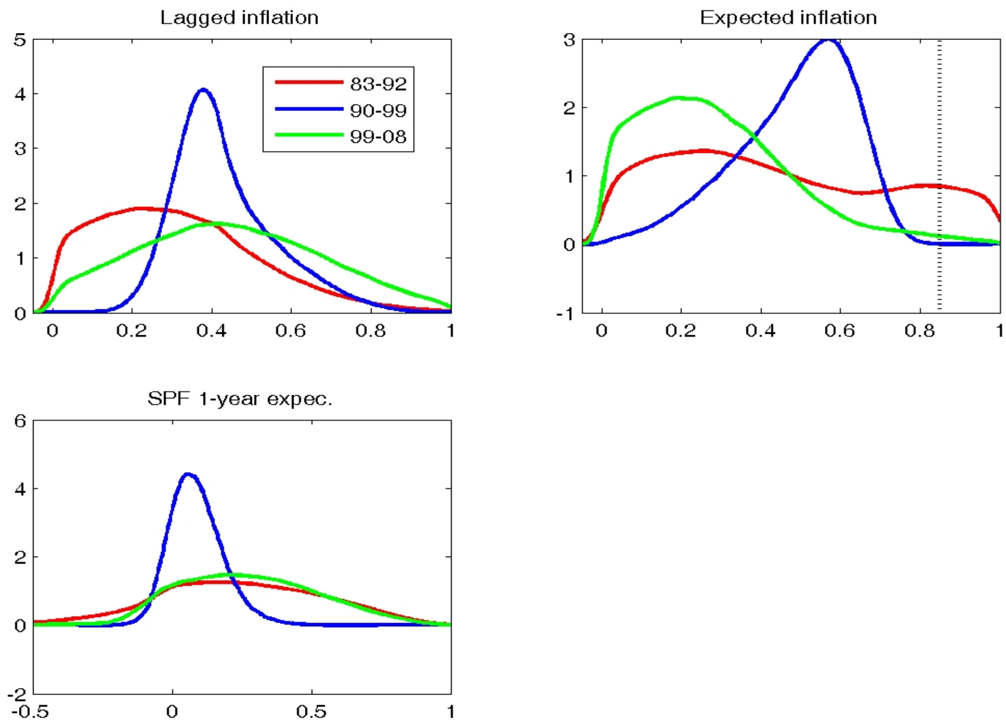
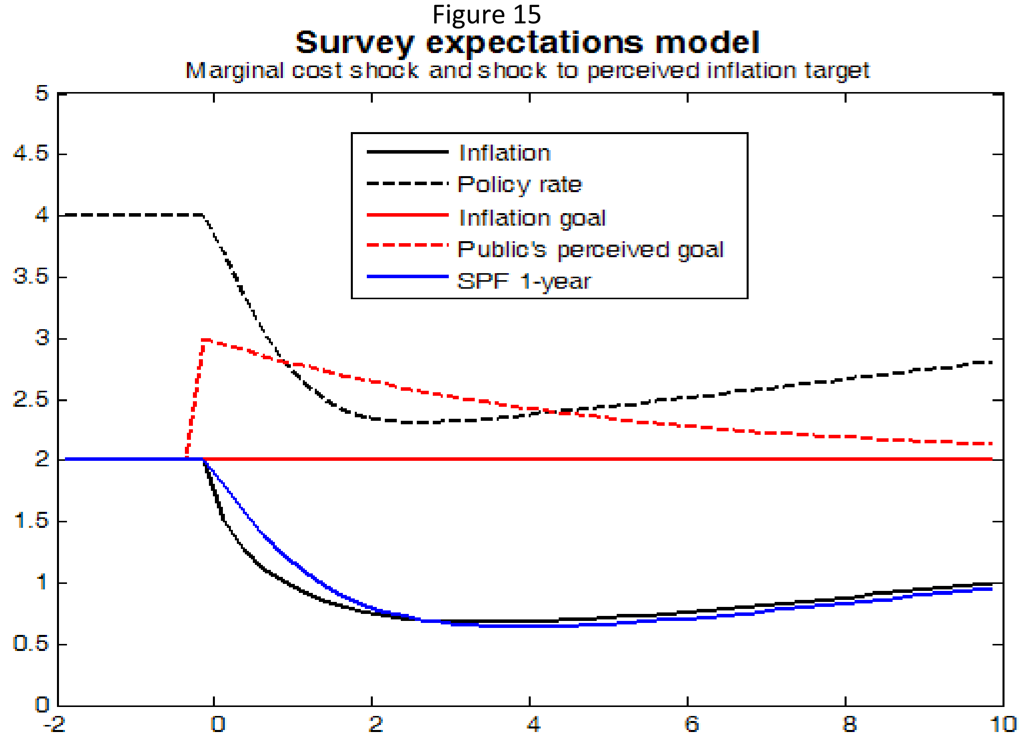


Figure 15



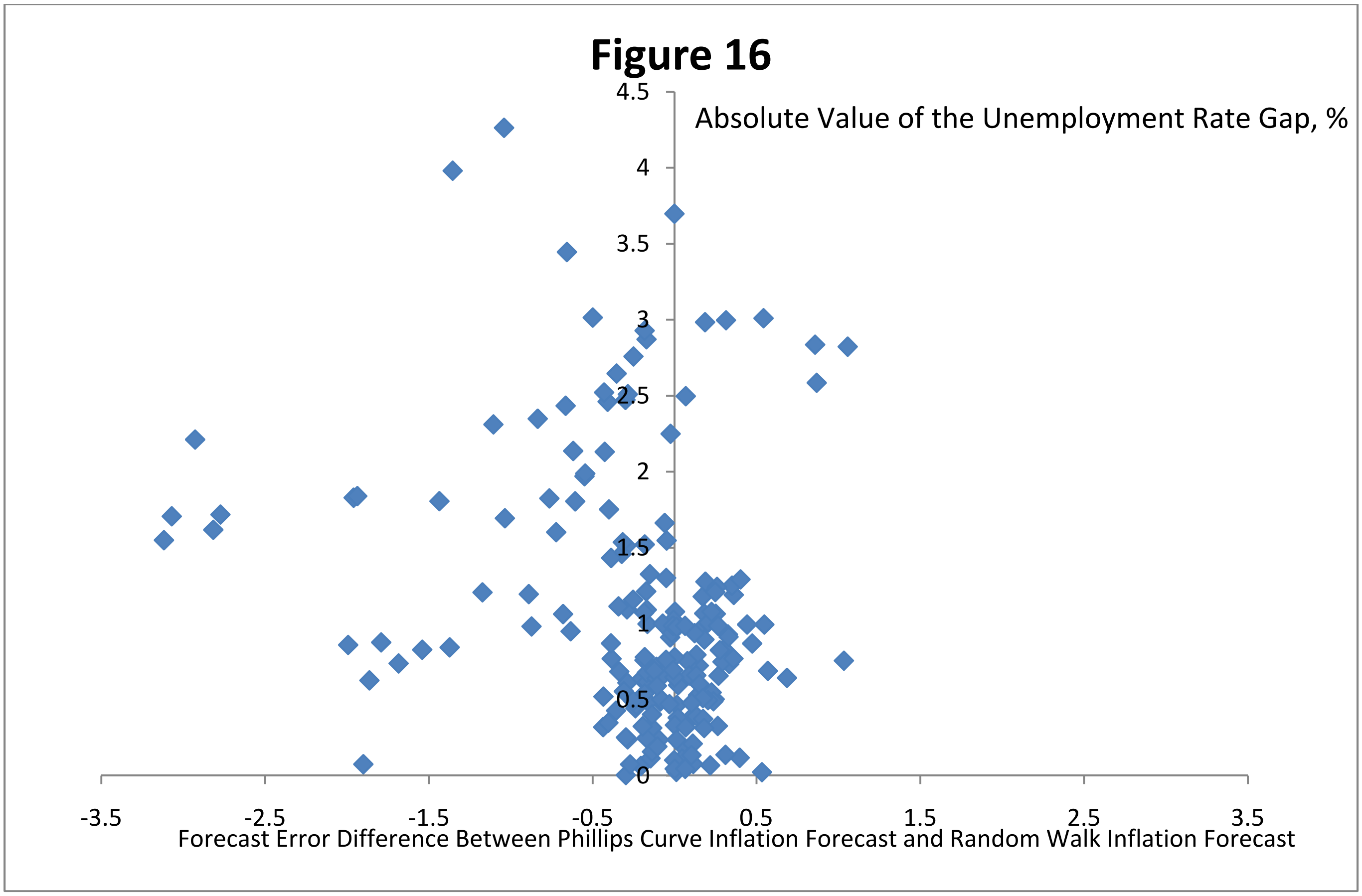


Table 1: Estimates of Phillips Curve Slopes

	(A) Equation (2.3) Unempl. Rate Gap	(B) Equation (2.3') Output Gap	(C) Equation (2.4) Unempl. Rate Gap	(D) Equation (2.5) Unempl. Rate Gap
	$\zeta = 1.5^*$	$\hat{\zeta} = 2.9$	$\hat{\zeta} = 1.6$	$\zeta = 1.5^*$
$\hat{\gamma}_L$:	0.05975	-0.00909	0.11470	0.03184
	(0.08303)	(0.04115)	(0.09073)	(0.08260)
$\hat{\gamma}_H$:	0.36436	0.17149	0.28065	0.22539
	(0.06633)	(0.02126)	(0.07251)	(0.04875)

* Imposed. Standard errors in parenthesis.

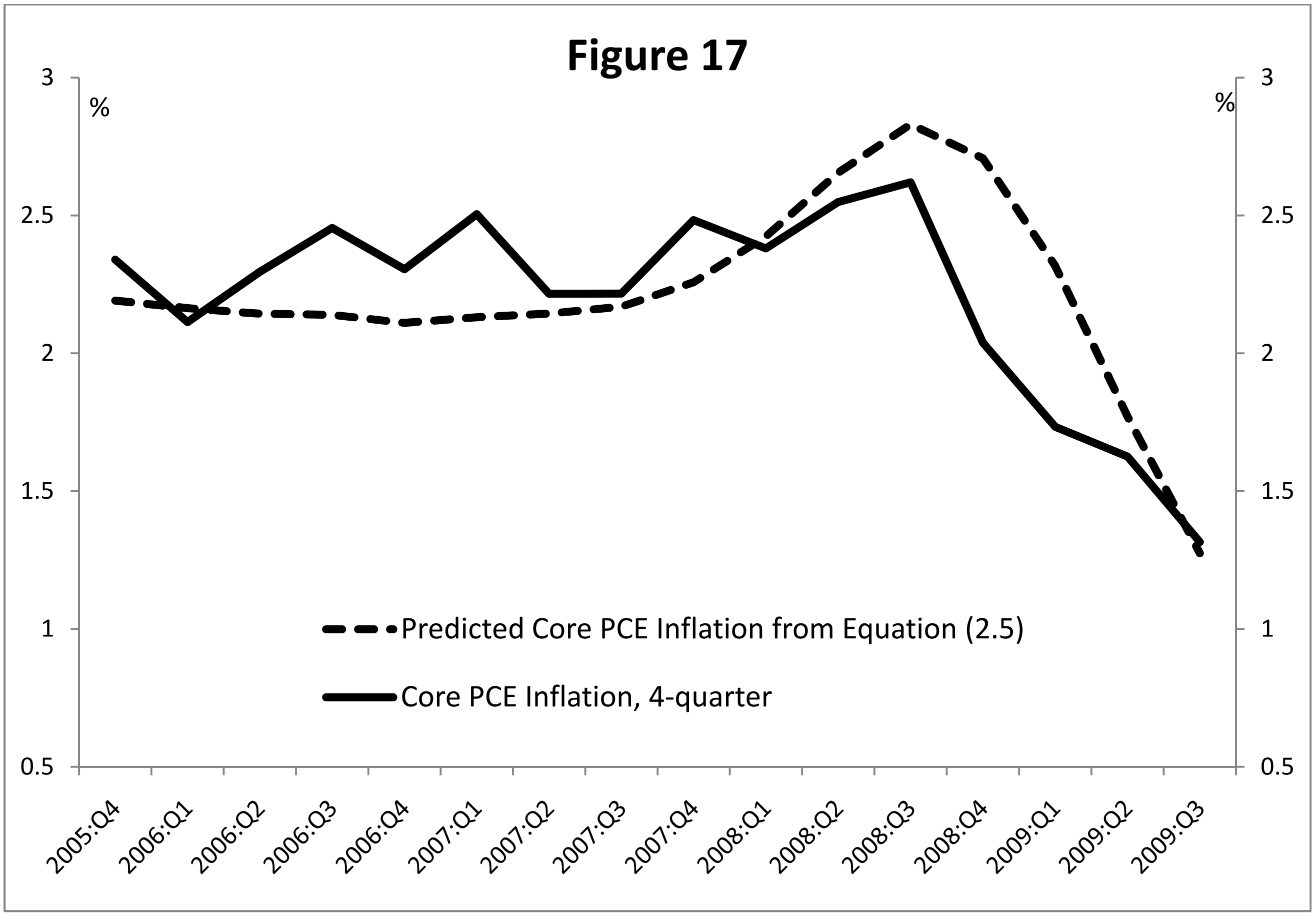


Figure 17
%
%
3
2.5
2
1.5
1
0.5
Predicted Core PCE Inflation from Equation (2.5)
Core PCE Inflation, 4-quarter
2005:Q4
2006:Q1
2006:Q2
2006:Q3
2006:Q4
2007:Q1
2007:Q2
2007:Q3
2007:Q4
2008:Q1
2008:Q2
2008:Q3
2008:Q4
2009:Q1
2009:Q2
2009:Q3