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THE GRAVITATIONAL PULL OF INFLATION EXPECTATIONS

Inflation dynamics have changed, perhaps dramatically, over the past ten years due to the Federal Reserve's success at anchoring long-term inflation expectations at a low level. Policymakers seem to appreciate this development, as the FOMC has repeatedly pointed to well-anchored inflation expectations as a factor contributing to an expected moderation of core inflation. However, most empirical models of inflation fail to capture this change.

This commentary discusses some preliminary work at MA on directly incorporating a measure of long-term inflation expectations into our inflation modeling. The results convincingly show that inflation expectations exert a significant gravitational pull on realized inflation. While this result represents only a modest change to the empirical specification, it has very significant implications for the economy and monetary policy.

The new specification implies that inflation has a strong self-correcting nature as long as long-term inflation expectations hold steady. Under that condition, movements in inflation generated by a shock to the economy will tend to be transitory rather than persistent, with inflation returning towards its expected long-run level once the direct impact of the shock diminishes. This statistical property differs notably from the dynamics of inflation over much of the 1970s, 1980s, and early 1990s, when movements in inflation tended to become embedded in expectations, causing potentially transitory movements to become very persistent. Inflation expectations appear to have become much more anchored since the late 1990s, which has brought about this considerable change in the nature of inflation dynamics.

This change in inflation dynamics should be a principal consideration in the policy decisions of the Federal Reserve for at least two reasons. First, it highlights the benefits of patience by the central bank when long-term inflation expectations are stable and well aligned with the central bank's inflation objective. Under those circumstances, if inflation moves above the level of long-term inflation expectations, the central bank can achieve a given disinflation with less employment cost by exercising patience and allowing the pull of inflation expectations to do some of the work of moving inflation back to the desired level. Indeed, in this specification, the concept of a *sacrifice ratio* as a single statistic is obsolete, replaced by a *sacrifice function* in which the cost of disinflation (in terms of employment) depends on the horizon over which it is achieved and the proximity of inflation to inflation expectations. Second, the new specification implies that policymakers should be very concerned with keeping inflation expectations at an appropriate level, in addition to managing inflation itself.

The new specification provides a useful framework for understanding the recent policy decisions of the Federal Reserve and some of the disagreement across members of the FOMC in recent months. The FOMC has taken a very patient approach, pausing at a time when core inflation was near its cyclical peak and was expected to moderate only slowly. This strategy is appealing if one is confident that inflation expectations will hold steady, as those expectations

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would contribute to a moderation of inflation over time. In effect, the FOMC is using its credibility to achieve the disinflation at a lower employment cost. Some members, however, have been less convinced that inflation expectations are grounded at their current levels. Under that view, patience can involve substantial cost if it allows inflation expectations to rise. Those members have instead argued for a more aggressive policy approach to return inflation more quickly to a lower level, in order to ensure that the Federal Reserve's credibility is maintained.

It would be impossible to understand this discussion, or to quantify the associated risks, in the old paradigm of inflation models that do not include a forward-looking measure of inflation expectations. Overall, we believe that the new inflation model provides crucial insights into how inflation evolves and how the Federal Reserve thinks about its task of maintaining low inflation.

A Standard Price-Price Phillips Curve

We begin the analysis by considering a general specification for a "price-price Phillips curve." This framework attempts to predict inflation directly from measures of resource utilization, from changes in relative prices that may affect inflation in the short run (such as energy and import prices), and from the past history of inflation. A general equation of this form is as follows:

$$\Delta\pi_t = -\gamma_1(u_{t-1} - \tilde{u}_{t-1}) + \gamma_2 x_{t-1} - \gamma_3(\pi_{t-1} - \pi^e_{t-1}) + \sum_s \alpha_s \Delta\pi_{t-s} \,, \tag{1}$$

where $\Delta\pi_t$ is the quarterly change in inflation. The first term of the right-hand side of the equation is the unemployment gap (the unemployment rate relative to the NAIRU), the second term represents the relative price variables mentioned above, the third term is the expectations gap (lagged inflation relative to expected inflation), and the last term captures the momentum in inflation. This momentum arises because the structure of the economy may naturally impart some underlying persistence in inflation, for example through overlapping contract cycles, lags in recognition, and so on.

Equation (1) provides a general structure for determining inflation that emerges (roughly) out of some mainstream macroeconomic models. But to empirically implement this equation, one is immediately confronted with how to handle the expectations term in the equation. A typical practice is to assume adaptive expectations, where inflation expectations gradually move in the direction of realized inflation:

$$\Delta\pi^e_t = \beta(\pi_{t-1} - \pi^e_{t-1}) \,. \tag{2}$$

In this case, inflation expectations at time *t* will simply be a moving average of past inflation rates:

$$\pi^e_t = \sum_s \omega_s \pi_{t-s} \,, \tag{3}$$

where the weights, ω_s, sum to one. Substituting equation (3) into the baseline equation (1), one arrives at what we will refer to as a "standard price-price Phillips curve":

(4) $$\pi_t = -\gamma_1(u_{t-1} - \tilde{u}_{t-1}) + \gamma_2 x_{t-1} + \sum_s w_s \pi_{t-s} ,$$

where the coefficients on lagged inflation, w_s, are restricted to sum to one.

Note that there is nothing in the structure of this equation that intrinsically anchors inflation, because the variables on the right-hand-side of the equation predict *changes* in inflation (since the coefficients on lagged inflation sum to one). For example, suppose a rise in energy prices x_t led to an increase in inflation. If energy prices subsequently stabilized (so that x_t moved back to zero), inflation would simply stabilize at its new, higher level. It is up to the central bank to create enough economic slack (that is, push the unemployment rate above the NAIRU) to reverse the upward movement in inflation. Thus, it is the central bank's actions that provide the nominal anchor for the economy under this equation.

In the first column of Table 1, we present some results from estimating an equation of this form for core PCE inflation using quarterly data from 1967Q4 to 2006Q3. The estimates reveal that there is a significant role of lagged inflation in the determination of current inflation. Indeed, we find significant coefficients on eight quarters of lags for the inflation variable (not shown in the table), capturing the fact that core inflation has considerable inertia. That inertia reflects both the underlying persistence of inflation and the persistence induced by the assumption of adaptive expectations.

In addition to lagged inflation, the equation includes the unemployment gap, the change in the real price of energy (weighted by the share of energy in PCE), and the change in the real price of non-petroleum imports (weighted by the share of imports in non-farm business output). These enter with the expected signs, as a higher unemployment gap tends to lower inflation while higher energy or import prices tend to raise inflation.

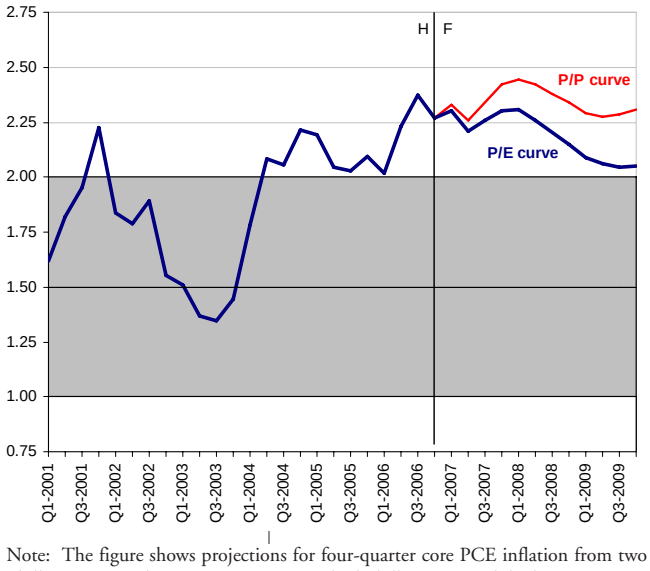
An important issue in the current outlook, and one that we will return to later, is the effects of energy prices on core inflation. Over the full sample, it appears that higher energy costs have been "passed through" to some extent to core prices. However, as we have discussed in the past, there appears to have been a dramatic decline in such pass-through effects over the past twenty years. If we split the sample to allow the coefficients on the energy variable to shift in 1987, we find that the coefficients are strongly significant in the earlier period but have fallen to zero in the more recent sample, as shown in the second column of the table.

TABLE 1
ESTIMATES OF A STANDARD PRICE-PRICE PHILLIPS CURVE
(EQUATION 4)

	(1)	(2)
Unemployment gap	-0.218	-0.234
	(3.80)	(4.21)
Real energy price inflation		
Full sample		
First lag	0.015	
	(2.77)	
Second lag	0.010	
	(1.82)	
Before 1987		
First lag		0.022
		(3.26)
Second lag		0.017
		(2.23)
Since 1987		
First lag		0.001
		(0.14)
Second lag		-0.002
		(0.25)
Real non-petro import price inflation		
First lag	0.091	0.090
	(3.57)	(3.65)
Second lag	-0.019	-0.013
	(0.70)	(0.50)
Sum of lagged inflation	1.000	1.000
Adjusted R-squared	0.86	0.86
Durbin-Watson	2.04	2.03

Note: Dependent variable is quarterly inflation rate for core PCE inflation. The equation is estimated over a sample from 1967Q4 to 2006Q3. Absolute t-statistics shown in parentheses.

Figure 1
The Effects of Inflation Expectations on Projections for Core PCE Inflation



Note: The figure shows projections for four-quarter core PCE inflation from two Phillips curves. The "P/P curve" is a standard Phillips curve, while the "P/E curve" is a Phillips curve that incorporates a forward-looking expectations measure. Shaded area represents the FOMC's implicit comfort zone.

For now, we will assume that there are no energy price pass-through effects by using the split-sample coefficient estimates. But this assumption is made purely for expositional purposes, in that it will allow us to more clearly highlight the role of inflation expectations in the next two sections. Instead, we believe that energy price pass-through did contribute to the run-up in core inflation last year, at least to some extent. We will provide more details on our assessment of the role of pass-through effects when we discuss the MA inflation forecast below.

Figure 1 shows the projection for core PCE inflation that arises from this equation (see the line labeled "P/P curve").[1] Core PCE inflation is expected to remain in the neighborhood of 2.3%, unchanged from the rate of inflation over the past four quarters. The reason is straightforward: Because the FOMC is not expected to generate any slack in the forecast, core inflation does not come down from that level. (Recall that the unemployment rate in our forecast rises to 5.1%, which is still slightly below our estimate of the NAIRU.) This projection highlights the inertial behavior of inflation in a standard price-price Phillips curve. In this framework, the FOMC would have to push the unemployment rate up further to produce a decline in core inflation back to its assumed comfort zone of 1% to 2%.

A Measure of Expected Inflation

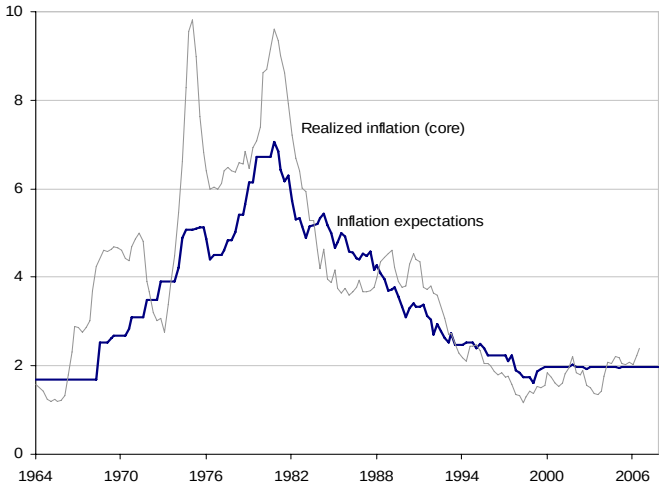
The above approach imposes the strong assumption that inflation expectations adjust in response to lagged inflation. Thus, it does not allow for the possibility that long-term inflation expectations have become better anchored in recent years. Of course, one reason for this assumption is that inflation expectations are difficult to measure. Nevertheless, the staff of the Federal Reserve Board (FRB) has constructed a measure for inflation expectations that could be used in this context. Here, we will make minor tweaks to this measure and then use it directly in our specification of the Phillips curve.

The FRB measure is derived from several sources over time. For the period since 1981, it is based on various surveys that ask about headline CPI inflation over the subsequent ten years. Most recently, it is taken from the Survey of Professional Forecasters compiled by the Federal Reserve Bank of Philadelphia. For the period before 1981, it is based on a research paper that developed an empirical proxy for how the private sector might have formed its expectations for PCE inflation over the subsequent ten years. The FRB staff splices these two series together, converting the survey responses for expected CPI inflation to a measure of expected PCE inflation by assuming a constant 55-basis-point spread between those inflation rates.

This last assumption ignores the fact that there have been methodological changes to the CPI that have presumably affected the average inflation spread between it and the PCE price index. Accordingly, we adjusted the FRB measure to more appropriately incorporate changes in the expected spread.[2] But this adjustment is fairly minor, leaving us with a series that is quite close to that constructed by the FRB staff.

The resulting measure of long-term inflation expectations is shown in Figure 2, along with realized core PCE inflation. Again, this measure is intended to capture the expected average level of headline PCE inflation over the subsequent ten years. In the results that follow, we will take it to be a proxy for the perceived long-run level of core PCE inflation, although this assumption raises some empirical questions that we will continue to pursue.[3]

Figure 2
Long-term Expectations for PCE Inflation



Note: The figure shows a measure of expectations of headline PCE inflation over the next ten years. This measure is a modification of a measure computed by the Federal Reserve Board staff, as discussed in the text.

As can be seen from the figure, long-term inflation expectations trended higher from the late 1960s to the early 1980s in response to the high and rising levels of realized inflation. In contrast, from the early 1980s to the mid-1990s, long-term inflation expectations declined notably, coinciding with the Federal Reserve's success at bringing realized inflation down to low levels. The most noteworthy shift, however, occurred in the late 1990s. Since that time, long-term inflation expectations have been remarkably steady at about 2%, no longer responding at all to current economic and policy conditions. In effect, the Fed has achieved remarkable credibility for keeping inflation low and stable in the long run. It is this shift in behavior that may have consequences for the dynamics of realized inflation, as explored next.

A Phillips Curve with Forward-Looking Expectations

An immediate question is whether long-term inflation expectations have any effect on realized inflation rates. To address this question, we incorporate the measure of inflation expectations described above directly into the Phillips curve framework. We return to equation (1), but now assume that inflation expectations are captured by the above measure, rather than assuming that they are governed by lagged inflation as in equation (3). The resulting equation to be estimated is then:

$$\pi_t = -\gamma_1(u_{t-1} - \tilde{u}_{t-1}) + \gamma_2 x_{t-1} + \gamma_3 \pi^e_{t-1} + \sum_s w_s \pi_{t-s} \ , \tag{5}$$

where now the coefficients on lagged inflation and the inflation expectations variables are restricted to sum to one—that is:[4]

$$\gamma_3 = (1 - \sum_s w_s). \tag{6}$$

The results from estimating the Phillips curve with a forward-looking expectation measure are shown in Table 2. The most important finding is that the measure of long-term infla-

TABLE 2
ESTIMATES OF A PHILLIPS CURVE WITH FORWARD-LOOKING EXPECTATIONS (EQUATION 5)

	(1)	(2)
Unemployment gap	-0.132	-0.135
	(2.39)	(2.51)
Real energy price inflation		
Full Sample		
First lag	0.014	
	(2.68)	
Second lag	0.009	
	(1.62)	
Before 1987		
First lag		0.022
		(3.15)
Second lag		0.015
		(1.97)
Since 1987		
First lag		0.001
		(0.07)
Second lag		-0.003
		(0.36)
Real non-petro import price inflation		
First lag	0.093	0.092
	(3.64)	(3.69)
Second lag	-0.029	-0.026
	(1.12)	(1.02)
LT inflation expectations	0.167	0.197
	(2.91)	(3.52)
Sum of lagged inflation	0.833	0.803
Adjusted R-squared	0.87	0.87
Durbin-Watson	2.02	2.01

Note: Dependent variable is quarterly inflation rate for core PCE inflation. The equation is estimated over a sample from 1967Q4 to 2006Q3. Absolute t-statistics shown in parentheses.

tion expectations enters the equation as one of the most significant variables. The positive coefficient on this variable suggests that long-term inflation expectations exert a strong "gravitational pull" on realized inflation.

The strong gravitational pull from well-anchored inflation expectations can be seen by comparing the projection for core PCE inflation from this equation (the line labeled "P/E curve" in Figure 1) to the one from the standard price-price Phillips curve. As noted above, the projection from the standard model had considerable inertia in inflation, with inflation lingering well above the FOMC's comfort zone, because the Federal Reserve is not expected to generate any slack to put downward pressure on inflation. However, under this new framework that allows a more direct role for expectations, core inflation moves towards the FOMC's comfort zone, even in the absence of slack. This effect arises from the gravitational pull of long-term inflation expectations.

Thus, while incorporating the inflation expectations variable appears to be a minor change in the specification, it has considerable implications for the dynamic behavior of inflation. It gives inflation an important self-correcting property, as long as inflation expectations remain anchored. Accordingly, one would expect the movements in inflation generated by various shocks to the economy to be more transitory than the persistent movements observed over much of the sample period before the late 1990s.

The rest of the equation is not significantly affected, though it is simplified considerably. We continue to find that energy prices affected core inflation in the earlier subsample but not in the latter subsample (see the second column of Table 2). We also continue to find that non-petroleum import prices have a significant effect on core inflation. However, the lag structure on actual inflation is quite different in this specification. Whereas we found that eight quarters of lagged changes were significant in the P/P specification, we need only two quarters of lags in the P/E specification. Thus, much of the significance of lagged inflation in the P/P equation, and particularly some of the longer lags, appears to have been serving as a proxy for long-term inflation expectations.[5]

NEW ISSUES FOR THE FEDERAL RESERVE

This specification for inflation highlights important new issues for the Federal Reserve—ones that were not present in the old Phillips curve framework. First, it presents an

increased role for patience on the part of the central bank in returning inflation to its desired level, provided that long-term inflation expectations are anchored near the desired level. And second, it places tremendous importance on the central bank's ability to keep long-term inflation expectations at a level close to the central bank's objective.

The role of patience is highlighted in the P/E curve projection presented above in Figure 1. In the situation in which inflation has moved above both long-term inflation expectations and the Fed's desired level, the Federal Reserve can achieve a gradual disinflation without having to make any sacrifice on the unemployment rate. Inflation will moderate on its own over time, even without the unemployment rate rising above the NAIRU, as a result of the gravitational pull of well-anchored inflation expectations.

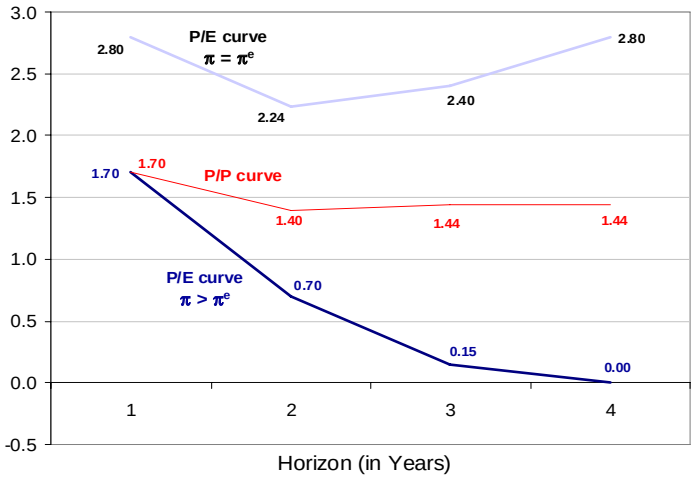
One key aspect of this specification is that it makes the notion of a sacrifice ratio obsolete. There is no single number capturing the total amount by which the unemployment rate must exceed the NAIRU to achieve a disinflation of a given size. The *sacrifice ratio* has instead been replaced by a *sacrifice function*, in which the cost of disinflation depends on the speed over which it is achieved and the proximity of inflation to long-term inflation expectations.

This point is illustrated in Figure 3, which shows the total employment sacrifice required to achieve a disinflation of 50 basis points.[6] (This total sacrifice is the amount by which the unemployment rate must exceed the NAIRU per year, summed across the number of years.[7]) For the standard P/P curve, the sacrifice does not depend importantly on the horizon over which the disinflation is achieved. The line is relatively flat around 1.4, suggesting that the Federal Reserve must create that much cumulative slack to achieve the disinflation.[8]

The situation is much different, however, for the P/E curve. The dark line assumes that inflation is currently running ½ percentage point above long-term inflation expectations. In that case, and assuming that long-term inflation expectations remain steady at that level, the required employment sacrifice is decreasing in the horizon over which the disinflation is achieved. Indeed, if the Federal Reserve were willing to wait four years, it could achieve the disinflation with no employment sacrifice whatsoever.[9]

These results highlight the merits of patience by the Federal Reserve in these circumstances. When inflation is elevated relative to its long-term expectations, the central bank can achieve any given disinflation with less employment cost if it is willing to wait and allow the gravitational pull of inflation expectations do some of the work. Of course,

Figure 3
Cumulative Unemployment Gap Needed to Reduce Inflation by 0.5 Percentage Point



Note: The figure shows the cumulative unemployment gap, or the amount by which the unemployment rate must exceed the NAIRU summed across the number of years, needed to reduce core PCE inflation by 0.5 percentage point. A reading of 1.5, for example, is consistent with the unemployment rate being 1.5 percentage points above the NAIRU for one year or 0.75 percentage point for two years. The red line shows the computation for the standard price-price Phillips curve, while the other two lines show the results for the Phillips curve that incorporates a forward-looking expectations measure. The dark blue line assumes that inflation begins 0.5 percentage point above long-term inflation expectations, and the light blue line assumes that inflation begins at the level of long-term inflation expectations.

these computations are conditioned on the assumption that inflation expectations remain steady.

This brings us to the second issue for the Federal Reserve in this framework, which is keeping inflation expectations at an appropriate level. The importance of this issue is highlighted by the light blue line in Figure 3. This line assumes that the central bank is attempting to achieve the same disinflation, only beginning from a situation in which inflation is equal to inflation expectations. Whereas in the previous case the gravitational pull of inflation expectations was helping the central bank, in this case it is working against it. As a consequence, it is much more challenging for the central bank to lower inflation, as implied by the much higher levels of the required employment sacrifice. Moreover, there is no longer any benefit to patience. Instead, patience is problematic because it gives the counterproductive gravitational pull more time to work, as indicated by the fact that the employment sacrifice begins to increase with the horizon.

Much of the debate on the FOMC about whether it was appropriate to pause can be well understood in the context of this chart. As discussed in the introduction, the FOMC paused at a time when core inflation was very elevated and when policymakers expected only a gradual moderation of inflation. This was a very patient approach, in that core PCE inflation was not expected to return to the FOMC's comfort zone until 2008.[10]

The advocates of this approach were effectively pointing to the dark P/E line in Figure 3. They argued that returning inflation more quickly to the comfort zone would involve too large of a sacrifice in terms of growth and employment. They felt that the disinflation could be achieved gradually over time at a much smaller cost by allowing the dissipation of temporary inflationary factors and well-anchored inflation expectations to pull inflation lower. Other FOMC members, most notably President Lacker, instead were more inclined to tighten further in order to return inflation more quickly to the comfort zone. Lacker argued that the strategy of allowing inflation to linger at an elevated level for an extended period would inappropriately raise the risk of dislodging inflation expectations. He emphasized that this would be a very costly mistake, essentially highlighting the risks associated with moving to the light blue line in Figure 3. As can be seen, the assumed behavior of inflation expectations—and specifically, the degree to which one believes those expectations are well anchored—played a critical role in this debate over the appropriate path of monetary policy.

The Behavior of Inflation Expectations

The elevated importance of inflation expectations suggested by the above results points to the importance of better understanding how inflation expectations are formed and what role the Federal Reserve can play in guiding those expectations. Indeed, the model of inflation presented here is incomplete until we add to it an equation for determining the behavior of inflation expectations.[11]

In much of the above discussion, we assumed that inflation expectations are completely anchored. Expectations certainly appear to be fixed to some degree, but they obviously would not remain anchored under all economic outcomes. Such an assumption would,

after all, imply a long run trade-off between inflation and employment—a perspective that nearly all macroeconomists find implausible. Instead, we believe that if inflation were pushed far enough above expectations for a long enough period of time, inflation expectations would eventually adjust (in which case the long-run neutrality between inflation and employment is restored).

We intend to conduct additional empirical work focused on the behavior of inflation expectations, which we will present in subsequent publications. Our preliminary work indicates that long-term inflation expectations over much of the sample responded significantly to current economic conditions, including realized inflation rates as assumed in equation (2). Over time, however, that sensitivity has diminished, and expectations have shown no such responsiveness since the late 1990s.[12] Nevertheless, as mentioned above, it is implausible to assume that expectations are completely anchored under all economic outcomes. These results therefore leave open the most relevant issue, which is finding the trigger point at which long-term expectations begin to adjust. It is this trigger point that will determine how much room policymakers have to count on the gravitational pull of those expectations.

It is also important to note that FOMC communications may also play a significant role in shaping long-term inflation expectations. In that regard, the above framework should be taken into consideration in the debate about whether the FOMC should move toward an explicit inflation objective.

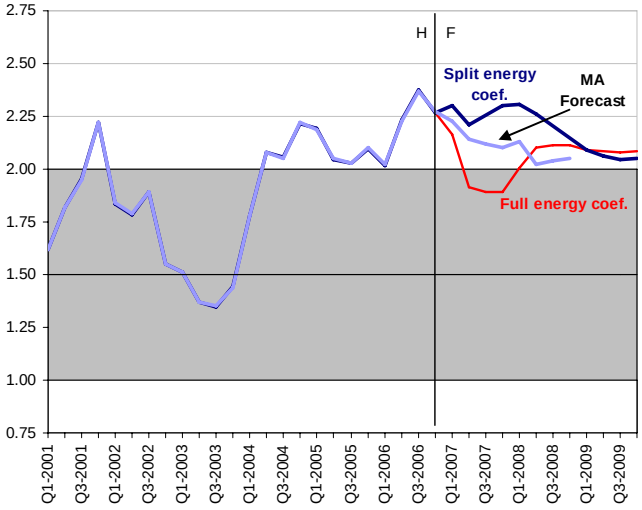
An important consideration in this respect is the divergence between the level of long-term inflation expectations today and the mid-point of what most observers take to be the FOMC's comfort zone. Expectations of PCE inflation are near 2% today under our measure, which is the upper end of the comfort zone. Thus, the gravitational pull from inflation expectations should help the FOMC lower inflation from its prevailing level to the upper end of the comfort zone. However, absent a change in those expectations, it may hinder any efforts to push inflation further inside the comfort zone, requiring the FOMC to accept very heavy employment cost for achieving this further disinflation.

The FOMC would have two choices in this case. First, it could be satisfied with inflation at the upper end of the comfort zone. In that case, core PCE inflation would tend to settle at 2%, which in turn would likely further cement the long-term inflation expectations at that level. Second, if it instead wanted to move inflation to the mid-point of the comfort zone, it could communicate explicitly that its inflation objective is centered on 1½%. This announcement of an explicit inflation objective would presumably encourage a decline in long-term inflation expectations towards this level, which in turn would allow the FOMC to achieve the further disinflation with less employment cost than would otherwise be the case.

The MA Forecast

The forward-looking Phillips curves estimated above are preliminary and are not yet incorporated into the MA model. Indeed, there are a number of empirical issues still to be resolved, and hence the results at this point should be taken only as suggestive.[13] But we see this approach as a promising direction for our model. Indeed, in recent forecasts we

Figure 4
The MA Inflation Forecast Relative to the Projections from the Forward-Looking Phillips Curve



Note: The figure shows the MA forecast for four-quarter core PCE inflation, along with the projections from the Phillips curve that incorporates forward-looking inflation expectations. Two versions of that curve are shown: one that allows the energy coefficient to shift in 1987 (giving no energy pass-through effects today), and one that uses the full sample energy coefficient (giving important pass-through effects today). Shaded area represents the FOMC's implicit comfort zone.

have been using these types of equations to informally guide our inflation forecast, overriding the inflation block in our formal model.

Figure 4 shows the MA forecast made in late December, compared to the forecasts from the P/E equation estimated with the full-sample and split-sample energy coefficients. These two equations produce markedly different projections of inflation, highlighting a key uncertainty in the near-term inflation outlook. The equation with the full sample coefficient attributes much of the run-up in core inflation last year to higher energy prices, and it now expects inflation to fall sharply in response to the decline in energy prices in the fourth quarter of last year. Indeed, the pass-through from lower energy prices results in a considerable dip in core inflation in the first two quarters of this year, after which inflation moves back to a higher level. The equation with the split-sample energy coefficient instead does not find energy price pass-through effects in the more recent sample (as discussed above). As a result, it does not produce a quick disinflation associated with the decline in energy prices. In this case, core inflation is expected to only gradually move down towards the FOMC's comfort zone.

Our forecast for inflation over 2007 lies between these two projections. We have implicitly attributed some of the increase in core inflation last year to energy price pass-through effects, though not as much as suggested by the full-sample coefficients. Thus, we get some immediate disinflation in the first half of the year from the reversal of those earlier increases. Beyond the first half, core inflation is relatively stable, edging down slightly towards the FOMC's comfort zone as a result of the pull of inflation expectations.

Concluding Thoughts

By making a simple modification to an estimated Phillips curve, we have been able to capture the important role of expectations in the determination of core inflation. The results suggest that expectations have played a key role in determining U.S. inflation over the past four decades, as realized inflation tends to gravitate towards the level of long-term inflation expectations.

It is very important to recognize this characteristic because the behavior of inflation expectations appears to have changed markedly in the late 1990s. The Federal Reserve seems to have achieved much greater credibility, in the sense that long-term inflation expectations have not responded to contemporaneous developments but instead have held steady at a relatively low level. That shift has importantly changed the dynamics of realized inflation. Various shocks to the economy have still caused movements in core inflation, but those movements have become more transitory, as core inflation tends to revert back towards the stable long-term expectations.

This new framework raises important considerations that the Federal Reserve seems to have already partially incorporated into its policy approach and its rhetoric. In particular, it emphasizes the role for patience by the central bank when core inflation has been pushed to uncomfortably high levels that are above long-term expectations. Moreover, it places tremendous emphasis on ensuring that long-term inflation expectations remain anchored at an appropriate level, raising the issue of whether Federal Reserve communications can play a significant role in facilitating that outcome.

ENDNOTES

1. The forecast jumps off from the fourth-quarter value of core PCE inflation, making an assumption for the December reading. Specifically, we assume a 0.16% advance that month, which brings the quarterly core PCE inflation rate to 2.1% for the fourth quarter. For the unemployment rate and import prices, we use the paths from our last forecast. For energy prices, we take the path from our last forecast but update it to account for the large downward shift in oil futures prices since then. All of these variables are extended through 2009 for expositional purposes, making relatively neutral assumptions for that year.

2. Specifically, we make this adjustment by using the CPI research series produced by the BLS. This series computes historical CPI numbers using the current methodology, so that the spread between it and the actual CPI at a given point in the past will show the cumulative effect of the methodological changes since that time. We identified five dates of major methodological changes in the CPI and used the average difference in these series between those dates to adjust the CPI expectations to what they would have been under current methods. Lastly, we assume that the expected differential between the CPI and the PCE under current methods is 50 basis points.

3. The primary issue here is whether the assumption that core inflation reverts to headline inflation expectations is appropriate, or whether the cointegrating vector may instead have a non-unitary coefficient or a constant term. Some additional empirical issues are listed in footnote 13.

4. It should be noted that equation (5) is the basic form of the Phillips curve, specifically with a weighted average of past inflation and forward-looking inflation expectations, that is the centerpiece of many modern theoretical models. The expectations in those models typically have a shorter horizon, but equation (5) may be able to approximate such expectations through a combination of the long-term expectations with lagged inflation.

5. The apparent shift in the behavior of inflation expectations in the late 1990s would, under this interpretation, imply that the coefficients on the lagged inflation terms in the P/P Phillips curve shifted at that time. Unfortunately, we do not have a long enough sample since then to definitively test this hypothesis.

6. This exercise assumes that the variables other than the unemployment rate follow paths that are neutral for inflation. Note that, under some scenarios, inflation asymptotes to the new level. To avoid the long tails in these situations, we require that the Fed only get within a tenth of the specified disinflation.

7. For example, a reading of 1.5 is consistent with the unemployment rate being 1.5 percentage points above the NAIRU for one year or 0.75 percentage point above the NAIRU for two years.

8. The only shape to this cost structure is that it bends up slightly at shorter horizons. This reflects the long lag structure in the equation. Because inflation is inertial, the Fed would have to push harder to achieve the disinflation within a year. If the equation had only one

lag, the curve would be perfectly horizontal at all horizons.

9. Of course, this is not a costless strategy to the Federal Reserve. While it allows no sacrifice on its employment objective, it involves a longer period over which the FOMC does not meet its inflation objective.

10. The FOMC forecasts presented in the summer of 2006 indicated that core PCE inflation would remain above the comfort zone through 2007, and Bernanke in the accompanying testimony said that core PCE inflation was expected to reach the top of the comfort zone in 2008.

11. That is, we should have a two equation system that simultaneously determines inflation and inflation expectations. Note that, implicit in the above equations, we have made an identifying assumption that these variables do not respond contemporaneously to one another.

12. Some initial work on this subject was presented at MA's Annual Model Meeting in June 2005. See the presentation "Issues in Inflation Modeling" by Joel Prakken, which is available on our website.

13. For example, is it appropriate to assume that core inflation moves to a survey measure of headline inflation, and is the cointegrating vector 1-for-1? In addition, should we be using an expectation of forward inflation rather than the ten-year average? Also, we should consider re-estimating the NAIRU, since the series we use was derived from the wage-wage Phillips curve currently in the model. Lastly, we need to see if a number of additional terms enter the equation, such as changes in the minimum wage or productivity accelerations.