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A Phillips Curve with Anchored Expectations and Short-Term Unemployment

This paper examines the behavior of U.S. core inflation, as measured by the weighted median of industry price changes. We find that core inflation since 1985 is well-explained by an expectations-augmented Phillips curve in which expected inflation is measured with professional forecasts and labor-market slack is captured by the short-term unemployment rate. We also find that expected inflation was backward-looking until the late 1990s, but then became strongly anchored at the Federal Reserve's target. This shift in expectations changed the relationship between inflation and unemployment from an accelerationist Phillips curve to a level-level Phillips curve. Our specification explains why high unemployment during the Great Recession did not reduce inflation greatly: partly because inflation expectations were anchored, and partly because short-term unemployment rose less sharply than total unemployment.

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How does unemployment affect inflation? This question has been a controversial topic in macroeconomics since Phillips (1958) and Samuelson and Solow (1960). Since the Great Recession of 2008–9, economists have entered a new phase of research and debate about the unemployment-inflation relationship.

Recent research has been spurred by a puzzle: the "missing deflation" (Stock 2011). The accelerationist Phillips curve of textbooks says that a high level of unemployment causes inflation to fall over time. For common calibrations of this relationship, the high unemployment rates during the recession and subsequent weak recovery should have pushed the inflation rate well below zero. Yet in recent years, the rate of core

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inflation—inflation excluding the transitory effects of supply shocks—has been close to its level before 2008. Many observers have concluded that "we don't have a very good story about inflation and unemployment these days" (Krugman 2014).

Many economists have proposed resolutions of the missing-deflation puzzle, and two basic ideas have become popular. The first idea, emphasized by Fed officials (e.g., Bernanke 2010) and the IMF (2013), among others, is that inflation expectations have become anchored. According to this story, the Fed's commitment to a 2% inflation target has kept expected inflation near 2%, which in turn has prevented actual inflation from falling very far below that level.

The second explanation, proposed by Stock and by Gordon (2013), is that inflation depends not on the aggregate unemployment rate, as in textbook Phillips curves, but rather on the short-term unemployment rate. This variable is defined as the percentage of the labor force unemployed for 26 weeks or less. The story here is that the short-term unemployed put downward pressure on wages but the long-term unemployed do not, because their attachment to the labor force is weak. This idea helps explain why inflation has not fallen by more, because short-term unemployment rose less sharply than total unemployment over 2008–9, and then returned more quickly to prerecession levels.

Section 1 of this paper reviews the textbook Phillips curve and the puzzling behavior of inflation since 2008. We also present informal evidence that this puzzle may be explained by the behavior of expectations and of short-term unemployment.

In Section 2, we begin our econometric analysis of the behavior of core inflation. An important feature of our approach is that we measure core inflation with the weighted median of industry price changes, as constructed by the Federal Reserve Bank of Cleveland. In our view, this core-inflation measure is preferable to more traditional measures, such as inflation excluding food and energy prices, on both theoretical and empirical grounds.

We seek to explain core-inflation behavior with a simple Phillips curve. Following Friedman (1968), we assume that core inflation depends on expected inflation and the level of unemployment, with the twist that only short-term unemployment matters. To estimate this equation, we measure expected inflation with long-term forecasts from the Survey of Professional Forecasters (SPF). Our Phillips curve fits the data well from 1985 through 2015, with little evidence of instability during the Great Recession or any other period.

Section 3 examines the behavior of inflation expectations as measured by the SPF forecasts. We assume that expected inflation is a weighted average of a backward-looking term—an average of past inflation rates—and a fixed inflation target. Here, we find strong evidence of a regime shift in the late 1990s: the weight on the backward-looking term drops from approximately one to near zero. That is, expectations were fully backward-looking in the first part of our sample, but then became strongly anchored.

Section 4 again considers an expectations-augmented Phillips curve, but instead of measuring expected inflation directly we use our assumption that this variable is a mixture of a backward-looking term and a fixed target. Estimates of this equation are consistent with our other results: the effect of short-term unemployment on inflation appears to be constant, but the effect of past inflation falls sharply in the late 1990s. Overall, the data suggest a stable expectations-augmented Phillips curve with short-term unemployment, but a shift in the reduced-form relationship between unemployment and inflation resulting from the anchoring of expectations.

Section 5 returns to the motivation for our research, the missing deflation since 2008. We find that this anomaly disappears with our preferred specification of the Phillips curve.

Section 6 presents a caveat to our results: they weaken considerably if we change our measure of core inflation from weighted median inflation to inflation excluding food and energy prices. Section 7 concludes the paper and emphasizes another caveat: our success at explaining recent inflation behavior partly reflects the fact that our Phillips curve is designed for that purpose. Going forward, new data will allow us to judge how well our specification fits inflation behavior in general.

1. RECENT THINKING ABOUT THE PHILLIPS CURVE

Here we review the textbook Phillips curve, the puzzle of the missing deflation, and recent discussions of expectations anchoring and short-term unemployment.

1.1 The Phillips Curve and the Missing Deflation

In his Presidential Address to the American Economic Association, Friedman (1968) posited that the inflation rate depends on expected inflation and the deviation of unemployment from its natural rate. Friedman's theory can be expressed as

$$\pi_t = \pi_t^e + \alpha\left(u_t - u_t^*\right) + \epsilon_t, \qquad \alpha < 0, \tag{1}$$

where π_t is inflation, π_t^e is expected inflation, u_t is unemployment, u_t^* is the natural rate, and ϵ_t is an error term. This equation is commonly called the expectations-augmented Phillips curve.

Friedman went a step further by specifying the behavior of expectations. He said that "unanticipated inflation generally means a rising rate of inflation," or in other words, that expected inflation is well-proxied by past inflation. With this assumption, equation (1) becomes

$$\pi_t = \pi_{t-1} + \alpha\left(u_t - u_t^*\right) + \epsilon_t, \tag{2}$$

where π_{t-1} is past inflation. This equation is the accelerationist Phillips curve, a staple of undergraduate textbooks. It is often written with past inflation moved to left:

$$\pi_t - \pi_{t-1} = \alpha\left(u_t - u_t^*\right) + \epsilon_t. \tag{3}$$

As we see here, the textbook Phillips curve is a negative relationship between the level of unemployment and the change in inflation.

Equation (2) has guided much empirical research on U.S. inflation, including the work of Gordon (1982, 2013), Stock and Watson (1999, 2009), Ball and Mazumder (2011), and many others. Typically these researchers seek to explain quarterly data on core inflation, capturing past core inflation with four or more lags. Their equations often include lags of unemployment as well, and allow the natural rate u_t^* to vary over time.

As Stock and Watson (2010) discuss, the accelerationist Phillips curve has had enduring appeal because it captures "a broad historical regularity": since 1960, U.S. recessions have led to decreases in the inflation rate. The most salient example is the recession of the early 1980s, which pushed the unemployment rate above 10%. In this episode, core inflation fell by about 6 percentage points.

This history explains why recent inflation behavior has puzzled economists. During the Great Recession of 2008–9, the unemployment rate again exceeded 10%, and it returned to prerecession levels only at the end of 2015. Therefore, as shown formally below, an accelerationist Phillips curve that once fit the data predicts that inflation falls below zero in late 2010 and then continues to fall. In reality, from 2007Q4 to 2015Q4, the four-quarter rate of core inflation fell only from 2.3% to 2.0% if measured by the CPI excluding food and energy, and from 3.0% to 2.3% for median CPI. The disinflationary effect of recessions—"the essential empirical content of the Phillips curve," according to Stock and Watson—seems to have disappeared.[1]

1.2 *Anchored Expectations*

Why has inflation not fallen by more? Many policymakers and economists cite the anchoring of inflation expectations. For example, according to Janet Yellen (2013):

> Well-anchored inflation expectations have proven to be an immense asset in conducting monetary policy. They've helped keep inflation low and stable while monetary policy has been used to help promote a healthy economy. After the onset of the financial crisis, these stable expectations also helped the United States avoid excessive disinflation or even deflation.

According to this story, the expectations-augmented Phillips curve, equation (1), still holds, but the behavior of expectations has changed. In the past, expected inflation π_t^e may have depended on lagged inflation, but today it is close to a constant—specifically, the Fed's 2% inflation target. With a constant π_t^e, the Phillips curve becomes a relationship between unemployment and the level of inflation, not the change in inflation.

1. As the reader probably knows, much academic research has analyzed the "New Keynesian" Phillips curve (NKPC), in which inflation depends on expected future inflation and real marginal cost (e.g., Galí 2008). The empirical validity of the NKPC is disputed, and we are on the side that believes it does not fit inflation behavior in general or recent U.S. inflation in particular. We discuss this issue in our 2011 paper (Section 5), and have nothing to add here.

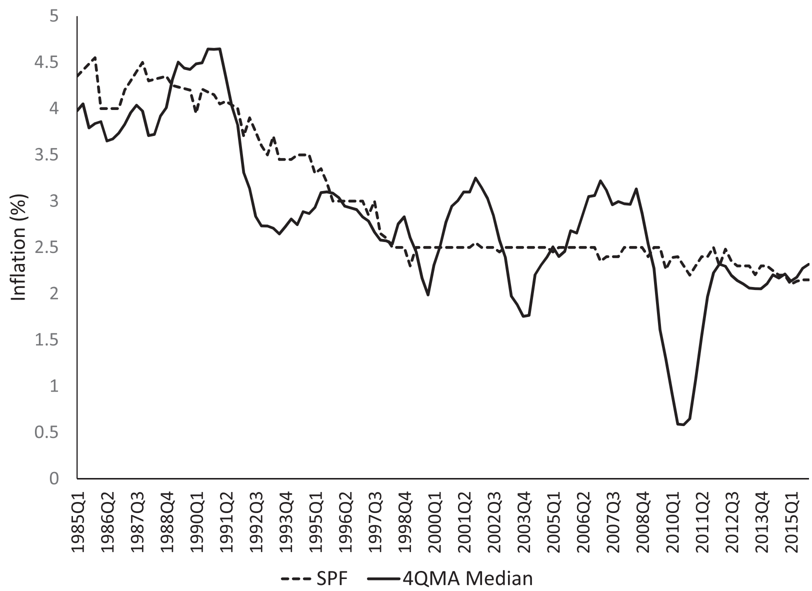

FIG. 1. Long-Term SPF Inflation Expectations versus Four-Quarter Moving Average of Median Inflation, 1985–2015.

This idea goes in the right direction for explaining the missing deflation. According to the accelerationist Phillips curve, a recession causes inflation to fall lower and lower as long as unemployment exceeds the natural rate. With anchored expectations, a period of high unemployment implies a low level of inflation but not an ever-falling level.

The idea of anchored expectations predates the Great Recession. The Fed announced a formal inflation goal of 2% only in 2012, but research as far back as Taylor (1993) finds that the Fed was implicitly targeting 2%. In the 2000s, Fed officials began to suggest that their commitment to stable inflation "in both words and actions" had produced "a strong anchoring of long-run inflation expectations" (Mishkin 2007).

An important detail: The Fed's target of 2% applies to inflation as measured by the PCE (personal consumption expenditure) deflator excluding food and energy. Since 1980, this measure of core PCE inflation has averaged about 0.5% less than core CPI inflation (for both the weighted-median and ex-food-and-energy measures of core CPI). We should expect, therefore, that expectations of core CPI inflation are anchored at a level near 2.5%.

As many researchers have pointed out, the idea of anchored expectations receives striking support from long-term inflation forecasts in the SPF. For the period from 1985 through 2015, Figure 1 shows the mean SPF forecast of CPI inflation over the next 10 years, along with a four-quarter moving average of weighted median inflation. From 1985 until the late 1990s, SPF forecasts drift down along with the

Fig. 2. Short-Term Unemployment versus Total Unemployment, 1985–2015.

realized levels of median inflation. Since the late 1990s, by contrast, SPF forecasts are almost constant at 2.5%, despite significant fluctuations in median inflation.

1.3 Short-Term Unemployment

The traditional Phillips curve includes the aggregate unemployment rate. A growing number of researchers replace this variable with the short-term unemployment rate—usually defined as the percentage of the labor force unemployed for less than 27 weeks—and argue that this modification helps explain the missing deflation.

The rationale for this specification is that the long-term unemployed “are on the margins of the labor force” (Krueger, Cramer, and Cho 2014). These workers are unlikely to find jobs because they are unattractive to employers and because they do not search intensively for work. As a result, only the short-term unemployed create an excess supply of labor and put downward pressure on wage growth and inflation.

Figure 2 shows how this reasoning helps explain the missing deflation. Long-term unemployment rose sharply over 2008–9, so the rise in total unemployment was unusually large compared to the rise in short-term unemployment. Long-term unemployment has continued to be unusually high relative to short-term unemployment even as total unemployment has returned to prerecession levels. Overall, labor-market slack since 2008 is less severe if it is measured by short-term rather than total unemployment, so the Phillips curve predicts a smaller fall in inflation in this case.

Phillips curves with short-term unemployment were introduced in the 1980s to explain experiences in Europe, where inflation rates were stable despite high long-term unemployment (e.g., Nickell 1987). Llaudes (2005) shows that this Phillips-curve specification fits the data for a number of countries.

Before the Great Recession, students of the U.S. Phillips curve rarely considered specifications with short-term unemployment. The reason is that short-term and total unemployment were highly collinear in U.S. data, making it difficult to separate their effects (as shown formally below). This collinearity problem has diminished substantially since 2008 because of the disproportionate rise in total unemployment.

2. AN EXPECTATIONS-AUGMENTED PHILLIPS CURVE

In our econometric work, we seek to explain the behavior of core inflation from 1985 through 2015. During this period, the level and volatility of inflation were fairly low, making it plausible that a stable Phillips curve fits the data. We do not examine the 1970s or early 1980s, when high and volatile inflation produced a different Phillips curve. (In particular, both theory and evidence suggest that changes in unemployment had larger effects on inflation before 1985; see Ball and Mazumder 2011).

In this section, we examine a Phillips curve in which core inflation is measured by the weighted median inflation rate; expected inflation is measured with forecasts from the SPF; and economic slack is measured with short-term unemployment. This equation fits the data well throughout the 1985–2015 period.

2.1 Measuring Core Inflation

The most common measure of core inflation is the growth rate of the price level (either the CPI or the PCE deflator) excluding food and energy prices. We choose, however, to use the weighted median of industry inflation rates, as constructed by the Federal Reserve Bank of Cleveland.[2] We will see that our results are not robust to measuring core inflation in the traditional way, but that finding does not trouble us greatly because we believe the weighted median is a better core-inflation measure.

As we discuss in Ball and Mazumder (2011), the weighted median is a good core-inflation measure because it filters out movements in headline inflation caused by large relative-price changes in any industry, not just food and energy. Our earlier paper finds that, since 2000, quarterly innovations in median inflation have been almost entirely permanent, whereas inflation in the CPI excluding food and energy (CPIX) has a substantial transitory component. Median inflation does a better job of capturing the underlying trend in inflation.

2. As in Ball and Mazumder (2011), we compute a quarterly series for weighted median inflation from the monthly series reported by the Cleveland Fed. We first cumulate the monthly median inflation rates to construct a monthly series for price levels, then average 3 months to get quarterly price levels. Quarterly median inflation is the annualized percentage change in the quarterly price level.

FIG. 3. Median CPI and CPIX Quarterly Inflation, 2000–15.

Figure 3 illustrates the appeal of the weighted median by plotting this variable and CPIX inflation over 2000–15. We can see that CPIX inflation is more volatile at the quarterly frequency. The standard deviation of the change in inflation is 0.44 for the median and 0.64 for CPIX.

2.2 Specification

We consider a version of Friedman's expectations-augmented Phillips curve, equation (1), in which labor-market slack is measured by the deviation of short-term unemployment from its natural rate. Following Staiger, Stock, and Watson (1997) and Gordon (2013), we specify an equation for quarterly data with four lags of the unemployment term:

$$\pi_t = \pi_t^e + \sum_{j=1}^{4} \alpha_j \left(u_{t-j}^s - u_{t-j}^{s*} \right) + \epsilon_t, \tag{4}$$

where π_t is the annualized rate of core inflation, π_t^e is expected inflation, u^s is the short-term unemployment rate, and u^{s*} is the natural rate of short-term unemployment.

For parsimony, we assume that the coefficients on the four unemployment lags are equal, that is, that inflation depends on average short-term unemployment over the previous four quarters. When we test this restriction, it is not rejected (p-value for Wald test = 0.53). We can now write equation (4) as

$$\pi_t = \pi_t^e + \alpha \left(\overline{u}_{t-1}^s - \overline{u}_{t-1}^{s*} \right) + \epsilon_t, \tag{5}$$

FIG. 4. Short-Term Unemployment and Estimates of Its Natural Rate.

where $\overline{u}^{s}_{t-1}$ and $\overline{u}^{s*}_{t-1}$ are the averages of u^s and u^{s*} from $t-4$ through $t-1$.

In our empirical work, we measure core inflation with weighted median inflation, as discussed above. We measure the other variables in equation (5) as follows:

Expected Inflation: In this section, we do not model the behavior of expectations; instead, we measure expectations directly with survey data. Specifically, following past work such as Fuhrer, Olivei, and Tootell (2009), we measure expected inflation with the long-term SPF forecasts of CPI inflation shown in Figure 1.[3]

Short-term Unemployment: As in Figure 2, we define the short-term unemployment rate as the fraction of the labor force unemployed for 26 weeks or less.

The Natural Rate of Short-term Unemployment: When we estimate Phillips curves that include total unemployment, we measure the natural rate u^* with estimates from the Congressional Budget Office (CBO). The CBO does not, however, produce a series for the natural rate of short-term unemployment, so we must create a proxy for this variable. We assume this natural rate is proportional to the CBO's natural rate for total unemployment: $u^{s*} = gu^*$. We estimate the constant g with the ratio of short-term to total unemployment at times when total unemployment is close to u^*. This procedure yields $g = 0.852$.

Figure 4 shows the series for u^{s*} that we construct. An online Appendix to this paper describes our procedure for estimating u^{s*}, and the rationale for our approach, in more detail.

3. The SPF forecasts are 10-year predictions of headline inflation, not median inflation. We assume, however, that expected median inflation is the same as expected headline inflation for a 10-year horizon. In our data, the levels of headline and median inflation over 10-year periods are usually close to each other, and it appears difficult to forecast the difference between the two.

TABLE 1

AN EXPECTATIONS-AUGMENTED PHILLIPS CURVE, 1985–2015

$\pi_t = \pi_t^e + \alpha(\overline{u}_{t-1}^s - \overline{u}_{t-1}^{s,*}) + \epsilon_t$	
α	−0.756
	(0.077)
DW	1.259
SE of Reg.	0.383
$\overline{R}^2$	0.824

NOTE: OLS with Newey–West (1987) standard errors in parentheses. π_t is median CPI inflation, π_t^e is the average forecast of long-term CPI inflation from the Survey of Professional Forecasters, $\overline{u}_{t-1}^s$ is the average of the short-term unemployment rate from $t-1$ to $t-4$, and $\overline{u}_{t-1}^{s*}$ is the average of the natural rate of short-term unemployment from $t-1$ to $t-4$.

2.3 Results

Table 1 presents estimates of the Phillips curve in equation (5) for our 1985–2015 sample. The estimated coefficient on short-term unemployment is −0.76, which means that a 1 percentage point rise in average short-term unemployment over the previous four quarters reduces core inflation by about three quarters of a percentage point.[4]

Our Phillips curve explains a large fraction of the variation in core inflation: the $\overline{R}^2$ is 0.82. The top panel of Figure 5 illustrates this good fit by plotting the actual and fitted values of core inflation.

This fit partly reflects the fact that actual inflation follows the trend in SPF expected inflation, which falls from 1985 to the late 1990s and then stabilizes. However, short-term unemployment also explains a substantial part of inflation behavior. To see this point, we move π_t^e to the left side of (5) and compute the $\overline{R}^2$ for this version of the equation. This statistic—the fraction of the variation in $\pi_t - \pi_t^e$ explained by short-term unemployment—is 0.61. The bottom panel of Figure 5 plots the actual and fitted values of $\pi_t - \pi_t^e$.

Notice that core inflation falls significantly during three parts of our sample: the early 1990s, the early 2000s, and 2008–10. These periods align with the last three U.S. recessions, when short-term unemployment was elevated. As a result, our Phillips curve mostly explains the inflation declines.

In Table 2, we examine the stability of the Phillips curve by splitting the 1985–2015 sample into three parts. The break dates are 1998, when the reduced-form Phillips curve changed (as shown below); and 2008, the onset of the Great Recession. There is no evidence of instability: the coefficient α is close to the full-sample estimate of −0.76 in all three subsamples, and a Wald test fails to reject a constant α ($p = 0.81$).

4. We have also estimated equation (4), our Phillips curve without the restriction of equal coefficients on the four lags of $u^s - u^{s*}$. The estimated coefficients on lags one through four, with standard errors in parentheses, are −0.193 (0.144), −0.219 (0.209), 0.089 (0.275), and −0.444 (0.173). The sum of these coefficients is −0.767, which is close to the estimated coefficient on $\overline{u}_{t-1}^s - \overline{u}_{t-1}^{s*}$ in Table 3.

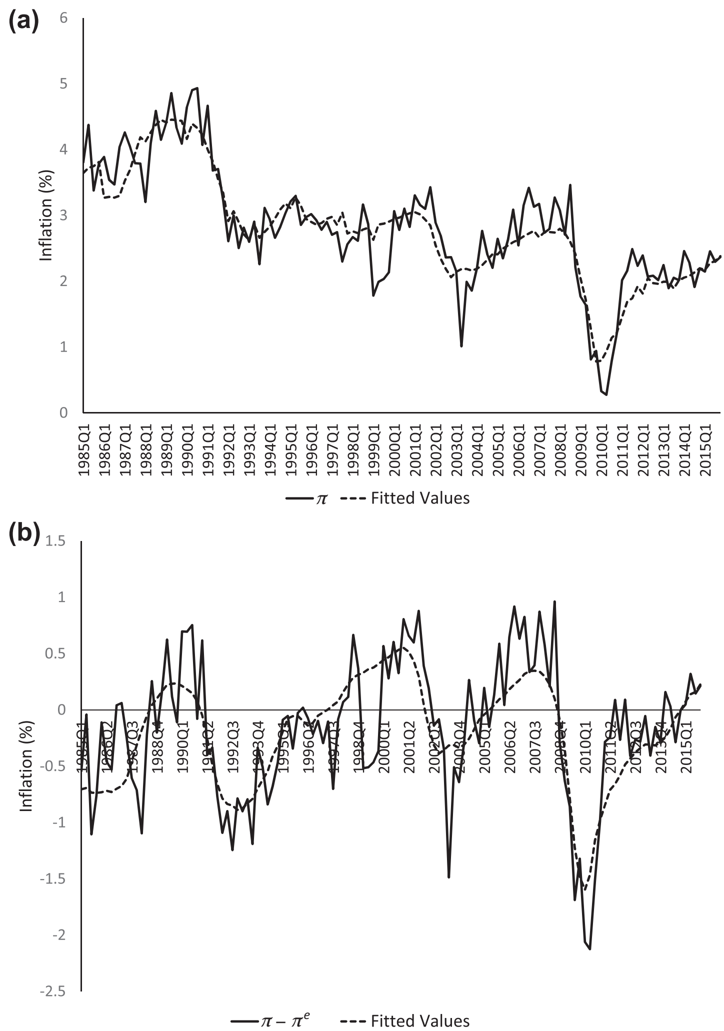

FIG. 5. The Fit of the Expectations-Augmented Phillips Curve.

2.4 Short-term versus Total Unemployment

We depart from most previous research by including short-term rather than total unemployment in our Phillips curve. Here we examine whether the data support this choice by comparing three equations: our preferred Phillips curve with short-term unemployment; a variation that includes total unemployment instead, with CBO estimates of the natural rate; and a horserace regression that includes both short-term and total unemployment. We estimate these equations for the entire 1985–2015 sample and for the three subsamples we examined before.

TABLE 2

Stability of the Expectations-Augmented Phillips Curve

	$\pi_t = \pi_t^e + \alpha(\overline{u}^s_{t-1} - \overline{u}^{s,*}_{t-1}) + \epsilon_t$ 1985Q1–1997Q4	1998Q1–2007Q4	2008Q1–2015Q4
α	−0.702	−0.781	−0.795
	(0.094)	(0.228)	(0.109)
DW	1.492	1.043	1.286
SE of Reg.	0.361	0.436	0.353
$\overline{R}^2$	0.764	0.316	0.755
p-Value for stability		0.813	

Note: OLS with Newey–West (1987) standard errors in parentheses. π_t is median CPI inflation, π_t^e is the average forecast of long-term CPI inflation from the Survey of Professional Forecasters, $\overline{u}^s_{t-1}$ is the average of the short-term unemployment rate from $t-1$ to $t-4$, and $\overline{u}^{s*}_{t-1}$ is the average of the natural rate of short-term unemployment from $t-1$ to $t-4$. The reported p-value is for a Wald test of the hypothesis that α is equal in the three subsamples.

The results, reported in Table 3, yield two clear conclusions. First, for the entire sample, the data say that short-term unemployment is the right variable in the Phillips curve. When we replace short-term with total unemployment, the $\overline{R}^2$ falls from 0.82 to 0.70. Most important, in the horserace regression, only short-term unemployment matters: the coefficient on total unemployment is insignificant and has the wrong sign.

Second, the strong results for the entire sample are driven primarily by the third subsample–the Great Recession period from 2008 to 2015. For this period, the difference between the $\overline{R}^2$s with short-term and total unemployment is huge (0.76 versus 0.28), and the horserace regression again yields a total-unemployment coefficient with the wrong sign. In contrast, for the first two subsamples, the fit of the Phillips curve is similar with short-term and total unemployment, and the horserace regressions are inconclusive. The results are similar when we pool the first two subsamples.[5]

These results reflect the collinearity between short-term and total unemployment before 2008, which we saw in Figure 2. In interpreting our finding that short-term unemployment belongs in the Phillips curve, we should bear in mind that it is driven by a single historical episode, the Great Recession and the subsequent recovery.

3. THE CHANGING BEHAVIOR OF EXPECTATIONS

We have seen that a stable expectations-augmented Phillips curve fits the data from 1985 through 2015. Yet this result masks a sharp shift in the behavior of expectations. Expected inflation, as measured by SPF forecasts, was backward-looking until the late 1990s but then became anchored by the Fed's inflation target.

5. A caveat is that the Newey–West (1987) standard errors in Table 3 may be unreliable for our short subsamples. We address this issue in footnote 6.

TABLE 3

PHILLIPS CURVES WITH SHORT-TERM AND TOTAL UNEMPLOYMENT

	1985Q1–2015Q4	1985Q1–1997Q4	1998Q1–2007Q4	2008Q1–2015Q4
(1) $\pi_t = \pi_t^e + \alpha(\overline{u}^s_{t-1} - \overline{u}^{s,*}_{t-1}) + \epsilon_t$				
α	−0.756	−0.702	−0.781	−0.795
	(0.077)	(0.094)	(0.228)	(0.109)
DW	1.259	1.492	1.043	1.286
SE of Reg.	0.383	0.361	0.316	0.353
$\overline{R}^2$	0.824	0.764	0.316	0.755
(2) $\pi_t = \pi_t^e + \alpha(\overline{u}_{t-1} - \overline{u}^{*}_{t-1}) + \epsilon_t$				
	1985Q1–2015Q4	1985Q1–1997Q4	1998Q1–2007Q4	2008Q1–2015Q4
α	−0.236	−0.503	−0.455	−0.179
	(0.068)	(0.051)	(0.140)	(0.074)
DW	0.768	1.595	0.922	0.512
SE of Reg.	0.500	0.350	0.461	0.604
$\overline{R}^2$	0.699	0.779	0.232	0.281
(3) $\pi_t = \pi_t^e + \alpha_1(\overline{u}_{t-1} - \overline{u}^{*}_{t-1}) + \alpha_2(\overline{u}^s_{t-1} - \overline{u}^{s,*}_{t-1}) + \epsilon_t$				
	1985Q1–2015Q4	1985Q1–1997Q4	1998Q1–2007Q4	2008Q1–2015Q4
α_1	0.061	−0.396	0.115	0.125
	(0.043)	(0.219)	(0.284)	(0.040)
α_2	−0.882	−0.158	−0.945	−1.150
	(0.123)	(0.368)	(0.481)	(0.109)
DW	1.285	1.602	1.051	1.768
SE of Reg.	0.380	0.352	0.440	0.304
$\overline{R}^2$	0.826	0.776	0.301	0.818

NOTE: OLS with Newey–West (1987) standard errors in parentheses. π_t is median CPI inflation, π_t^e is the average forecast of long-term CPI inflation from the Survey of Professional Forecasters, $\overline{u}^s_{t-1}$ is the average of the short-term unemployment rate from $t-1$ to $t-4$, $\overline{u}^{s*}_{t-1}$ is the average of the natural rate of short-term unemployment from $t-1$ to $t-4$, $\overline{u}_{t-1}$ is the average of the unemployment rate from $t-1$ to $t-4$, and $\overline{u}^{*}_{t-1}$ is the average of the natural rate of unemployment from $t-1$ to $t-4$.

3.1 Modeling Expectations

In Figure 1, we see visual evidence that expected inflation follows the downward trend in actual inflation in the first part of our sample, and then becomes anchored. To examine this behavior more formally, we first specify models of anchored and backward-looking expectations.

Our model of anchored expectations is simply:

ANCHORED EXPECTATIONS

$$\pi_t^e = 2.5 + \epsilon_t. \quad (6)$$

That is, expected inflation is constant except for a random error. The level of 2.5% is strongly suggested by the path of SPF expectations in Figure 1. As discussed earlier, this level of CPI inflation, the variable that the SPF forecasts, is consistent with the Fed’s target of 2.0% inflation in the PCE deflator.

In our backward-looking model, we assume that expected inflation depends on past levels of core inflation. Following Gordon (2013), we include a large number of lags, which allows expectations to adjust slowly to changes in actual inflation. We make the accelerationist assumption that the coefficients on the lags sum to one.

For parsimony, we also assume that the coefficients decline exponentially as the lag length rises. This assumption yields a single parameter to be estimated, and we find that it fits the data well. In principle, the exponential specification includes infinite lags, but we truncate them at 40 quarters. Our equation is

BACKWARD-LOOKING EXPECTATIONS

$$\pi_t^e = \frac{1}{1-\gamma^{40}}\left[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}\right] + \epsilon_t, \quad (7)$$

where γ determines the rate of decay of the lag coefficients. (The term outside the brackets makes the coefficients sum to one.)

We hypothesize that expectations shifted from backward-looking to anchored during our sample period. To test this idea, we examine a specification that nests the two models:

$$\pi_t^e = \lambda 2.5 + (1-\lambda)\frac{1}{1-\gamma^{40}}\left[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \cdots \right.$$
$$\left. + \gamma^{39}(1-\gamma)\pi_{t-40}\right] + \epsilon_t. \quad (8)$$

Here, expected inflation from the SPF is a weighted average of two terms, the 2.5% anchor and our backward-looking specification. We ask whether the coefficients λ and $1-\lambda$ have changed over time.

Specifically, we test for a change in λ at an unknown break date using the Andrews (1993) sup-Wald test. We then examine estimates of equation (8) before and after the date that yields the highest Wald statistic. In this exercise, we assume that the parameter γ in the backward-looking model is constant over time.

3.2 Results

The Andrews test rejects stability of λ and $1-\lambda$, the weights on backward-looking and anchored expectations. The sup-Wald statistic is 68.3, which greatly exceeds the 1% critical value of 12.4 (for 15% trimming of the data).

The break date that produces the highest Wald statistic is 1998Q1. The first column of Table 4 presents estimates of equation (8) with that break, and reveals a large change in λ. For 1985–97, the estimated λ is 0.07, and it is statistically insignificant; for 1998–2015, the estimate is 0.77. These results mean that expectations were backward-looking before 1998, but then became strongly (although not completely) anchored.

The second column of Table 4 presents estimates of (8) with the restrictions that $\lambda = 0$ before 1998Q1 and $\lambda = 1$ after 1998Q1, meaning that expectations shift from

TABLE 4

ANCHORED VS. BACKWARD-LOOKING EXPECTATIONS

$$\pi_t^e = \lambda 2.5 + (1-\lambda)\frac{1}{1-\gamma^{40}}[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}] + \epsilon_t$$

	1985Q1–2015Q4 (with 1998Q1 Break in λ)	
$\lambda^{prebreak}$	0.067	0
	(0.046)	
$\lambda^{postbreak}$	0.773	1
	(0.066)	
γ	0.875	0.859
	(0.018)	(0.017)
DW	0.357	0.312
SE of Reg.	0.189	0.203
$\overline{R}^2$	0.940	0.930

NOTE: NLLS with Newey–West (1987) standard errors in parentheses. π_t^e is the average forecast of long-term CPI inflation from the Survey of Professional Forecasters, and π_t is median CPI inflation. The break date of 1998Q1 is the quarter that produces the largest Wald statistic for the hypothesis that $\lambda^{prebreak} = \lambda^{postbreak}$.

fully backward looking to fully anchored. These restrictions do not substantially reduce the fit of the equation: the $\overline{R}^2$ falls by only 0.01, from 0.94 to 0.93.[6]

The estimate of the exponential parameter γ, which determines the adjustment speed of expectations in the backward-looking model, is 0.88, or 0.86 when we assume that λ switches from zero to one. These high values of γ support Gordon's view that long lags of inflation can influence expectations. With $\gamma = 0.88$, the sum of coefficients on the first four lags is only 0.41, and the sum of the coefficients on the remaining lags is 0.59.

Figure 6 illustrates the fit of our model of expectations. We show fitted values based on our estimates of λ before and after 1998Q1 (Table 4, first column), and when we assume that λ shifted from zero to one (Table 4, second column). The fitted values in both cases are consistently close to the actual path of SPF expectations.

Figure 7 illustrates the shift in expectations in a different way. We estimate equation (7), the pure backward-looking model, for the subsample 1985–97; the estimated γ is

6. The error term in our equation for π^e is highly serially correlated, as indicated by the very low Durbin–Watson statistics. The Newey–West (1987) standard errors reported in Table 4 are consistent, but may have significant small-sample bias. As a robustness check, we address serial correlation by modeling the error term as an AR-1 process and estimating the AR coefficient along with the parameters of the π^e equation by nonlinear least squares. The results are qualitatively similar to those in Table 4, except the standard errors are larger. The sup-Wald test again identifies a change in λ in 1998Q1. The estimate of λ prebreak is 0.115 (standard error of 0.075) and the estimate of λ postbreak is 0.799 (standard error of 0.129). With OLS and a Newey–West (1987) covariance matrix, we reject the joint hypothesis that $\lambda^{prebreak}=0$ and $\lambda^{postbreak}=1$ ($p = 0.002$). When we assume an AR-1 error, the evidence against the joint hypothesis is considerably weaker ($p = 0.095$). For the other equations in this paper, with π rather than π^e on the left side, serial correlation is less severe and modeling the errors as AR-1 has little effect on our results. The only exception is in Table 3, where we examine short subsamples and small-sample bias is presumably worse. In the horserace between short-term and total unemployment (Table 3, Line (3)), OLS and Newey–West (1987) standard errors suggest that short-term unemployment wins in the second as well as third subsample. In the second subsample, 1998–2007, total unemployment is insignificant and short-term unemployment is borderline significant ($t = 1.96$). With an AR-1 error, both slack measures are insignificant in the second subsample ($t = 1.31$ for short-term unemployment).

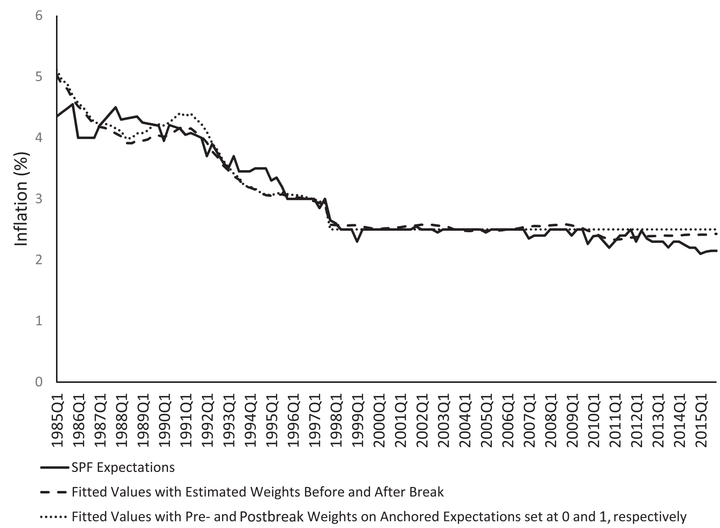

FIG. 6. Actual SPF Expectations versus Fitted Values with a Mix of Backward-Looking and Anchored Expectations, Break in Weights in 1998Q1.

0.86. We use this equation to produce out-of-sample forecasts of expected inflation, given the path of actual core inflation. These forecasts vary substantially, with a high of 3.0% in 2008Q4 and a low of 1.5% in 2011Q1. If we fail to account for the anchoring of expectations after 1997, we predict fluctuations in expected inflation that did not occur.

It is perhaps not surprising that our data identify 1998 as the point at which inflation expectations became anchored. Over 1998–2000, the Clinton/Internet boom pushed unemployment to very low levels (in 2000Q4, the total unemployment rate was 3.9% and the short-term rate was 3.5%). Yet inflation did not rise significantly, which puzzled many observers (e.g., Rosenblum 2000). An anchoring of expectations helps to explain the muted response of inflation to the late-1990s boom as well as to the post-2007 recession.

4. A REDUCED-FORM PHILLIPS CURVE

Here we combine the expectations-augmented Phillips curve presented in Section 2 with the model of expectations in Section 3. The result is a reduced-form Phillips curve that relates the inflation rate to its own lags, with coefficients that change when expectations become anchored, and to short-term unemployment. Our estimates of this equation are consistent with the two equations that underlie it.

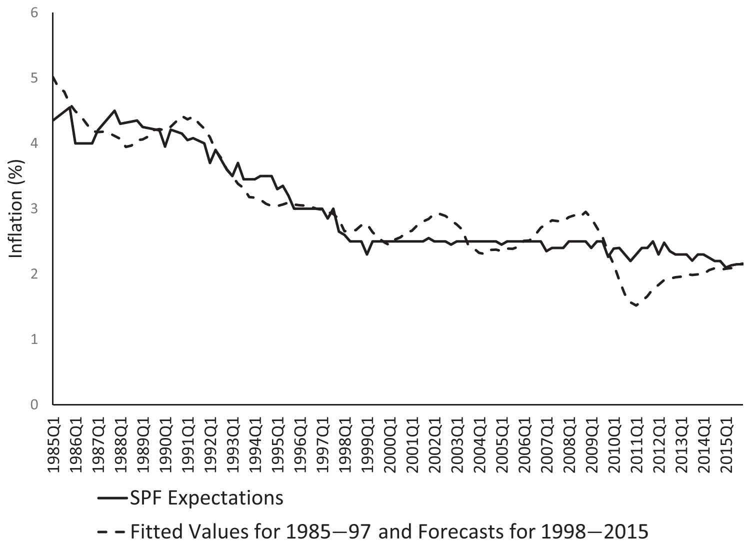

Fig. 7. Actual SPF Expectations versus Backward-Looking Expectations: Fitted Values from 1985 to 1997 and Out-of-Sample Forecasts for 1998–2015.

4.1 Deriving the Reduced Form

Equation (5) is our expectations-augmented Phillips curve, and equation (8) is our model of expected inflation. If we substitute (8) into (5), the expected inflation term is eliminated and we obtain:

$$\pi_t = \lambda 2.5 + (1-\lambda)\frac{1}{1-\gamma^{40}}\left[(1-\gamma)\pi_{t-1} + \cdots + \gamma^{39}(1-\gamma)\pi_{t-40}\right] + \alpha\left(\overline{u}^{s}_{t-1} - \overline{u}^{s*}_{t-1}\right) + \epsilon_t. \tag{9}$$

In this equation, inflation depends on short-term unemployment and on a weighted average of the constant 2.5 and an average of past inflation rates.

Equation (9) nests two common versions of the Phillips curve. If the parameter λ is zero, then the inflation rate depends on past inflation rates, with weights that sum to one, and on short-term unemployment. This case is similar to the accelerationist Phillips curve of textbooks. If λ is one, then the lagged inflation terms disappear and (9) becomes a relationship between the level of short-term unemployment and the level of inflation—what Blanchard (2016) calls a “back to the sixties” Phillips curve.

When we estimated our model of expected inflation, equation (8), we found that the parameter λ shifts sharply in the late 1990s, from near zero to approximately 0.8. This means that expectations shift from fully backward-looking to mostly anchored. The shift in equation (8) implies a corresponding shift in λ in equation (9): a change from an accelerationist Phillips curve toward a 1960s Phillips curve. We therefore test for such a shift.

TABLE 5

A REDUCED-FORM PHILLIPS CURVE

$$\pi_t = \lambda 2.5 + (1-\lambda)\frac{1}{1-\gamma^{40}}[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}] + \alpha(\overline{u}^{s}_{t-1} - \overline{u}^{s,*}_{t-1}) + \epsilon_t$$

	1985Q1–2015Q4 (with 1998Q1 Break in λ)	
$\lambda^{prebreak}$	0.036	0
	(0.054)	
$\lambda^{postbreak}$	1.020	1
	(0.193)	
γ	0.890	0.882
	(0.016)	(0.013)
α	−0.868	−0.865
	(0.081)	(0.082)
DW	1.263	1.267
SE of Reg.	0.390	0.388
$\overline{R}^2$	0.817	0.819

NOTE: NLLS with Newey–West (1987) standard errors in parentheses. π_t is median CPI inflation, $\overline{u}^{s}_{t-1}$ is the average of the short-term unemployment rate from $t-1$ to $t-4$, and $\overline{u}^{s*}_{t-1}$ is the average of the natural rate of short-term unemployment from $t-1$ to $t-4$.

4.2 Results

For equation (8), we identified a break in λ and dated it at 1998Q1 based on the sup-Wald statistic. For the Phillips curve (9), we test for a break in λ in that same quarter. Stability before and after 1998Q1 is strongly rejected: the t-statistic is 4.8. (Stability is also rejected again by the sup-Wald test for an unknown break date.)

Table 5 presents estimates of equation (9) with a break in λ in 1998Q1. The estimated λs are 0.04 before the break and 1.02 after the break. Based on these point estimates, the shift in λ is similar to, but a bit more extreme than, the shift in the expectations equation (8) (where λ shifts from approximately zero to 0.8). Here, we cannot reject the hypothesis that λ is zero before 1998Q1 and one after 1998Q1 ($p = 0.79$); that is, the data are consistent with a complete shift from an accelerationist Phillips curve to a 1960s Phillips curve. The second column of Table 5 presents estimates of (9) in which we impose the restriction that λ shifts from zero to one.

Like these results about λ, the estimates of the parameters γ and α in Table 5 are consistent with our earlier results. The estimate of γ, which governs the adjustment of expectations in the backward-looking case, is 0.89 (with no restrictions on the λs); this is close to the estimate of 0.88 in our equation for expectations. The estimate of α, the Phillips curve slope, is −0.87; this is fairly close to the estimate of −0.76 in the expectations-augmented Phillips curve, equation (5). In sum, our results are consistent with a stable expectations-augmented Phillips curve and a reduced form that shifts in the late 1990s because of a shift from backward-looking to anchored expectations.[7]

7. We can use our estimates of α and γ to compute short-run and long-run impacts of short-term unemployment on inflation. With either anchored or backward-looking expectations, a 1 percentage point rise in the average level of short-term unemployment over the previous four quarters, $\overline{u}^{s}_{t-1}$, reduces inflation in the current quarter by $-\alpha$=0.87 percentage points. With anchored expectations, there is no permanent

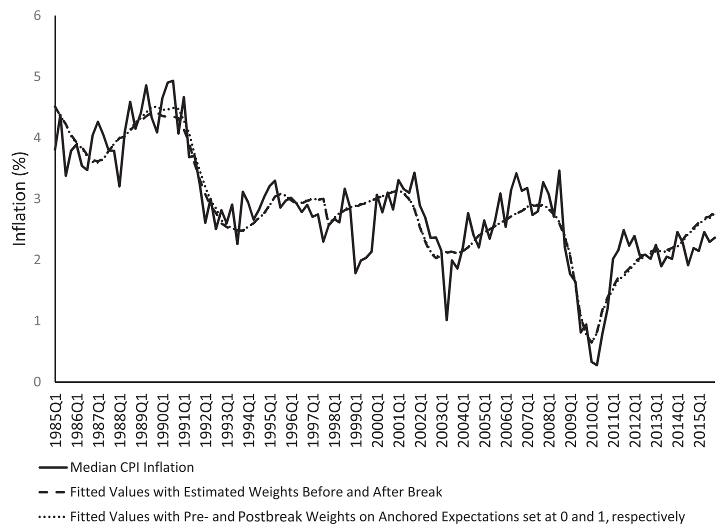

FIG. 8. Actual Median CPI Inflation versus Fitted Values from Reduced-Form Phillips Curve.

The fit of our reduced-form Phillips curve is good: in Table 5, the $\overline{R}^2$ is 0.82 (both with and without the restriction that λ shifts from zero to one). Figure 8 shows the fitted values of core inflation, which closely follow the medium-term path of actual core inflation. Only transitory movements at the quarterly frequency are left unexplained.

Our Phillips curve suggests a simple account of core inflation since 1985. As noted above, there have been three recessions in which high short-term unemployment caused inflation to fall: the early 1990s, the early 2000s, and 2008–10. In Figure 8, we see that inflation stayed roughly constant after its first decrease, but the second and third decreases were reversed. This history is consistent with a shift from backward-looking expectations, which cause changes in inflation to persist, to anchoring that pulls inflation back to its target level.

5. REVISITING THE MISSING DEFLATION

As we have discussed, recent debates about the Phillips Curve are motivated by the missing-deflation puzzle: the failure of the inflation rate to fall by more than it has since the recession of 2008–9. Here, we examine the puzzle by estimating Phillips

effect on inflation. With our formulation of backward-looking expectations, equation (7), a 1 percentage point fall in current inflation reduces expected inflation by $(1-\gamma)$=0.11 percentage points, and the decrease in expected inflation causes a permanent decrease in actual inflation of the same magnitude. Combining these facts, a one-point rise in $\overline{u}^s_{t-1}$ causes a permanent inflation decrease of $\alpha(1-\gamma) = 0.095$ points in the backward-looking case (see Ball, Chari, and Mishra 2016).

curves with pre-2008 data and then forecasting inflation over 2008–15. We see that a conventional Phillips curve predicts a deflation that did not occur, and that this anomaly is resolved with the specification proposed in this paper.

For this exercise, we estimate Phillips curves over the period 1985–97. We assume backward-looking inflation expectations, equation (7), because that assumption fits the data for 1985–97. We consider both short-term and total unemployment as measures of economic slack. We saw that those variables were highly collinear before 1998, so we expect the fit of the Phillips curve to be similar in the two cases. Our specifications are

$$\pi_t = \frac{1}{1-\gamma^{40}}\left[(1-\gamma)\pi_{t-1} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}\right] + \alpha\left(\overline{u}^{s}_{t-1} - \overline{u}^{s*}_{t-1}\right) + \epsilon_t \tag{10}$$

and

$$\pi_t = \frac{1}{1-\gamma^{40}}\left[(1-\gamma)\pi_{t-1} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}\right] + \alpha\left(\overline{u}_{t-1} - \overline{u}^{*}_{t-1}\right) + \epsilon_t, \tag{11}$$

where u^s is short-term unemployment and u is total unemployment. Note that equation (10) is a special case of our reduced-form Phillips curve, equation (9), with no anchoring of expectations ($\lambda = 0$).

Table 6 presents our estimates of (10) and (11). The fit is good ($\overline{R}^2 > 0.7$) with either short-term or total unemployment in the equation. The estimates of the parameter γ (0.88 and 0.87) are close to estimates in previous parts of our analysis.

In Figure 9, we use the results in Table 6 to produce alternative forecasts of inflation over 2008–15. In Panel A of the Figure, we present dynamic forecasts based on actual inflation through 2007 and our estimates of equation (11). In using (11), we make the conventional assumptions that expectations are backward-looking—we ignore the shift to anchored expectations—and that economic slack is measured by total unemployment. We confirm that this specification predicts deflation: the inflation rate is forecasted to fall from 3.3% in 2007Q4 to −2.9% in 2015Q4.

In Panel B, we present inflation forecasts based on our preferred specification of the Phillips curve. We measure slack with short-term unemployment, with the coefficient estimated in equation (10) (−0.86). We depart from (10), however, by replacing the lagged inflation terms with a constant of 2.5; that is, we account for the anchoring of expectations that occurred after the estimation period of 1985–97. The resulting forecasts are quite accurate, confirming the good fit of our preferred Phillips curve.

Our resolution of the missing-deflation puzzle involves both anchored expectations and the behavior of short-term unemployment. In Figure 9, Panels C and D isolate the roles of these two factors. Each one alone goes partway toward explaining recent inflation.

TABLE 6

A BACKWARD-LOOKING PHILLIPS CURVE, 1985–97

(1) $\pi_t = \frac{1}{1-\gamma^{40}}[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}] + \alpha(\overline{u}^s_{t-1} - \overline{u}^{s*}_{t-1}) + \epsilon_t$	
γ	0.882
	(0.015)
α	−0.863
	(0.132)
DW	1.548
SE of Reg.	0.368
$\overline{R}^2$	0.755
(2) $\pi_t = \frac{1}{1-\gamma^{40}}[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}] + \alpha(\overline{u}_{t-1} - \overline{u}^{*}_{t-1}) + \epsilon_t$	
γ	0.867
	(0.021)
α	−0.514
	(0.135)
DW	1.327
SE of Reg.	0.403
$\overline{R}^2$	0.707

NOTE: NLLS with Newey–West (1987) standard errors in parentheses. π_t is median CPI inflation, $\overline{u}^s_{t-1}$ is the average of the short-term unemployment rate from $t-1$ to $t-4$, $\overline{u}^{s*}_{t-1}$ is the average of the natural rate of short-term unemployment from $t-1$ to $t-4$, $\overline{u}_{t-1}$ is the average of the unemployment rate from $t-1$ to $t-4$, and $\overline{u}^{*}_{t-1}$ is the average of the natural rate of unemployment from $t-1$ to $t-4$.

In Panel C, the forecasts assume anchoring—we fix expected inflation at 2.5%—but slack is measured with total unemployment, with the coefficient estimated in equation (11). This specification underpredicts inflation during the high-unemployment period following the Great Recession. The gap between actual and forecasted inflation peaks at 2.1 percentage points in 2011Q3, when the unemployment rate is 9%. However, because of anchored expectations, forecasted inflation rises as unemployment returns to its natural rate.

In Panel D, the Phillips curve includes short-term unemployment, but we assume backward-looking expectations. This specification is simply equation (10). In this case, forecasted inflation falls over 2008–10 and then stabilizes. The forecasts remain positive, but we do not predict the rebound in inflation that actually occurred. Starting in 2011, forecasted inflation is about 1% while actual inflation exceeds 2%.

Our conclusions here differ from those in Ball and Mazumder (2011). In that paper, we argue that inflation behavior during the Great Recession was consistent with a conventional Phillips curve with backward-looking expectations and total unemployment. Our current findings differ for a simple reason: a longer sample period. The sample in our earlier paper ends in 2010Q4, which happens to be near the trough for inflation in its most recent cycle. In Panel A of Figure 9, we see that a conventional Phillips curve makes accurate predictions through 2010: forecasted and actual inflation fall in tandem. It is only after 2010 that the two series diverge, leading us to reject the conventional equation.

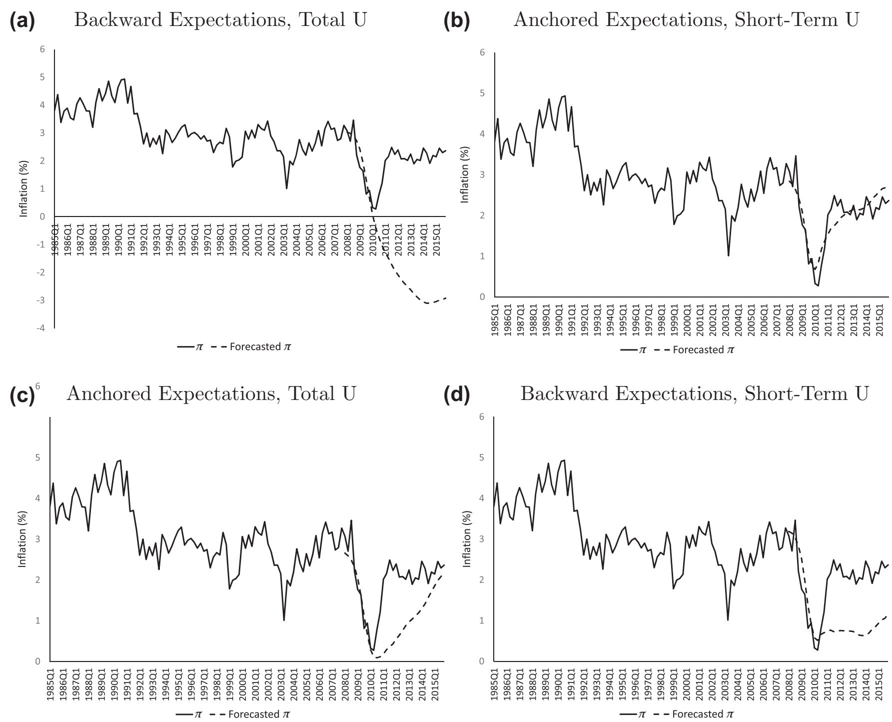

FIG. 9. Forecasts for Median CPI Inflation for 2008Q1–2015Q4 Based on Alternative Phillips Curves.

NOTES: π is median CPI inflation and Forecasted π is computed from Phillips curves estimated over 1985–97. The four panels show results for different combinations of expected inflation models (backward-looking or anchored) and measures of slack (total or short-term unemployment).

6. ALTERNATIVE MEASURES OF CORE INFLATION

So far we have studied the behavior of the weighted median inflation rate, which we believe is the best measure of core inflation. Here, as a robustness check, we redo some of our analysis with a more traditional measure of core inflation: the inflation rate excluding food and energy prices. We consider two versions of this variable, derived from the CPI less food and energy (CPIX) and the PCE deflator less food and energy (PCEX). The results are disappointing.

We focus on our reduced-form Phillips curve, equation (9), in which core inflation depends on short-term unemployment and on a weighted average of the Fed's inflation target and an average of past inflation. We again allow the weights on the target and past inflation to shift in 1998Q1, based on our finding that the behavior of SPF inflation expectations shifted at that point.

One detail concerns the level of the inflation target. In studying median CPI inflation, we assumed a target of 2.5%, for two reasons: SPF forecasts of CPI inflation

TABLE 7

REDUCED-FORM PHILLIPS CURVES WITH ALTERNATIVE MEASURES OF CORE INFLATION

$$\pi_t = \lambda(Anchor) + (1-\lambda)\frac{1}{1-\gamma^{40}}[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}] + \alpha(\overline{u}^s_{t-1} - \overline{u}^{s,*}_{t-1}) + \epsilon_t$$

	1985Q1–2015Q4 (with 1998Q1 Break in λ)		
Core inflation measure	Median CPI	CPIX	PCEX
$\lambda^{prebreak}$	0.036	−0.004	0.058
	(0.054)	(0.063)	(0.082)
$\lambda^{postbreak}$	1.020	0.330	0.237
	(0.193)	(0.114)	(0.159)
γ	0.890	0.686	0.725
	(0.016)	(0.086)	(0.100)
α	−0.868	−0.359	−0.136
	(0.081)	(0.124)	(0.085)
t-stat for $\lambda^{prebreak}=\lambda^{postbreak}$	4.8	2.3	1.0
DW	1.263	1.965	1.726
SE of Reg.	0.390	0.528	0.560
$\overline{R}^2$	0.817	0.782	0.698

NOTE: NLLS with Newey–West (1987) standard errors in parentheses. π_t is core inflation, $\overline{u}^s_{t-1}$ is the average of the short-term unemployment rate from $t-1$ to $t-4$, and $\overline{u}^{s*}_{t-1}$ is the average of the natural rate of short-term unemployment from $t-1$ to $t-4$. "Anchor" is the assumed inflation target of the Federal Reserve which we set to 2.5% for median CPI and CPIX, and 2.0% for PCEX.

appear anchored at that level; and it is consistent with the Fed's 2% target for PCE deflator inflation and a gap of 0.5% between CPI and PCE inflation. In this section, when we study CPIX inflation, we continue to assume a target of 2.5%. However, when we study PCEX inflation, we assume a target of 2.0% based on the Fed's announced policy.

Table 7 presents results. For reference, the first column reproduces our estimates of the reduced-form Phillips curve with core inflation measured by median CPI inflation (Table 5, column 1). Again, the results are consistent with a shift from fully backward-looking to fully anchored expectations: we can strongly reject the hypothesis that the weight λ on the 2.5% anchor is the same before and after 1998Q1, and we cannot reject the hypothesis that the λs before and after are zero and one, respectively.

The second column presents estimates of the same equation, but with core inflation measured with the CPIX (both on the left side of the equation and in the lagged inflation terms on the right.) These results are less supportive of a sharp shift in inflation behavior. We can still reject equality of the weight λ before and after 1998Q1 ($t = 2.3$). The estimated λ is close to zero before the break, as before, but it is only 0.33 after the break, and we strongly reject a value of one. In sum, the data suggest a regime change in 1998, but even after that the backward-looking term has a larger weight in our Phillips curve than the 2.5% anchor.

The third column of Table 7 presents results with core inflation measured with PCEX. Here, the estimated weight λ is small both before and after 1998, and we cannot reject the hypotheses that λ is the same in the two periods ($t = 1.0$), or that it is zero in both periods (p-value $= 0.17$). Thus the data are consistent with fully backward-looking expectations for the entire period from 1985 to 2015. Notice also that the coefficient on short-term unemployment is small, with borderline significance ($t = 1.6$): we lack strong evidence of an unemployment-inflation trade-off.

Our research has focused on the behavior of median CPI inflation because it is our preferred measure of core inflation. At this point, we have a poor understanding of the behavior of CPIX and PCEX inflation. The difficulty of explaining these variables may reflect their volatility at the quarterly frequency, illustrated above in Figure 3. For our sample period of 1985–2015, the standard deviation of the quarterly change in inflation is 0.65 percentage points for CPIX and 0.69 for PCEX, compared to 0.44 for median inflation.

7. CONCLUSION

One of Mankiw's (2014) 10 principles of economics is, "Society faces a short-run trade-off between inflation and unemployment." This trade-off, the Phillips curve, is critically important for monetary policy and for forecasting inflation. It would be extraordinarily useful to discover a specification of the Phillips curve that fits the data reliably.

Unfortunately, researchers have repeatedly needed to modify the Phillips curve to fit new data. Friedman added expected inflation to the specification in Samuelson and Solow (1960). Subsequent authors have added supply shocks (Gordon 1982), time variation in the Phillips-curve slope (Ball, Mankiw, and Romer 1988), and time variation in the natural rate of unemployment (Staiger, Stock, and Watson 1997). Each modification helped explain past data, but, as Stock and Watson (2010) observe, the history of the Phillips curve "is one of apparently stable relationships falling apart upon publication." Ball and Mazumder (2011) is a poignant example.

Nonetheless, because of the practical importance of the Phillips curve, researchers must continue to search for better specifications. This paper proposes a simple Phillips curve that fits the recent behavior of core inflation, at least when core inflation is measured by median inflation. Our key assumptions are that labor-market slack is measured by short-term unemployment, and that expected inflation has become anchored at a constant level.

Our two key assumptions have been proposed by a number of researchers, but others have questioned them. For example, Abraham (2014) reports that the job finding rates of the short-term and long-term unemployed do not differ dramatically, making it unclear why only short-term unemployment affects inflation. The apparent anchoring of inflation expectations also lacks a full explanation. The data suggest a sharp regime shift in the late 1990s, but it is not obvious why the Fed's inflation target became credible during that period.

Nonetheless, we believe that the Phillips curve proposed in this paper provides a plausible account of inflation behavior since 1985. Going forward, new data will help us determine the robustness of our conclusions. One risk is that expectations will become unmoored because the Fed changes its inflation target, or actual inflation deviates greatly from the target. If that happens, future Phillips curves will need to incorporate the new behavior of expectations.

While our Phillips-curve specification draws on recent research, we have ignored one idea that is prominent in recent work on inflation: downward nominal wage rigidity. We neglect downward rigidity primarily because our Phillips curve fits the data without it. Research will surely continue on the roles of short-term unemployment, anchored expectations, and downward wage rigidity in explaining recent inflation behavior.[8]

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