March 4, 2016

# Longer-Term Inflation Expectations: Evidence and Policy Implications[1]

## 1. Introduction and Summary

Under the staff's interpretation of recent inflation dynamics, inflation in the United States over the past 20 years has fluctuated around a stable statistical trend, a situation that we attribute to anchored longer-term inflation expectations (LTIE). If LTIE are indeed anchored—meaning that they are relatively unresponsive to the state of the economy—and are anchored at levels consistent with the FOMC's 2 percent inflation objective, monetary policy will have to work less actively to return inflation to its objective; inflation will naturally return to 2 percent over time as shocks dissipate.[2] If, however, LTIE are anchored, but not at a level consistent with policy objectives, then policymakers will have to take active policy measures to move LTIE toward the desired level. And similarly, if LTIE are initially consistent with policymakers' objectives, but are not anchored, then policymakers will need to respond actively to shocks that would otherwise move LTIE in adverse ways.

Over the past couple of years, some indicators of LTIE have moved lower, calling into question the staff view that inflation expectations will help move inflation back toward 2 percent over time.[3] Prompted by this observation, in this memo, we first review survey- and market-based indicators of LTIE for the United States and summarize the international evidence. We subsequently turn to models that attempt to filter out some of the noise from recent movements in inflation and indicators of inflation expectations. Along the way, we re-examine the usual assumption that LTIE, however measured, serves as a suitable proxy for the "attractor" to which actual price inflation can be expected to converge over time. We then examine possible causes of recent movements in various indicators of inflation expectations, including inflation compensation, and we

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[2] Indeed, to the extent this is so, the Committee can pursue the employment half of its dual mandate at reduced cost in terms of inflation, so long as its policy actions do not cause LTIE to become unanchored. See, among other references, Kohn (2007).

[3] In fact, the staff's analysis has assumed that LTIE have been most consistent with PCE inflation eventually moving toward a level slightly below 2 percent (1¾ percent). In this memo we will elide that distinction between 1¾ percent and 2 percent.

discuss the implications for actual inflation of a decline in LTIE. The discussion recognizes both that LTIE may not always matter for actual inflation as much as we have assumed and that existing indicators of expected inflation may be imperfect proxies for the "true" expected inflation that, in our models, is relevant for inflation. A theme of all these analyses is that uncertainty regarding the movements in LTIE, their determinants, and their importance for inflation is pervasive. Accordingly, we conclude with some simulations intended to shed light on the implications for policymakers of that uncertainty.

To briefly summarize our findings:

- Survey measures of household inflation expectations have drifted down in recent years, as have measures of inflation compensation, while survey measures of professional forecasters' inflation expectations have remained fairly stable. Similar patterns are observed in other advanced economies.
- Estimates of trend inflation from models fitted to price data alone show a small but meaningful decline, on net, since the onset of the last recession, while estimates from models that combine price data with surveys of professional forecasters indicate a higher confidence in trend inflation remaining anchored around 2 percent.
- Possible reasons for the decline in some measures of domestic inflation expectations include not only observed low inflation itself—reflecting declining oil and gasoline prices—but also concerns about the outlook for global growth and inflation as well as the associated reassessment of the ability and willingness of central banks to achieve their inflation goals.
- Measures of inflation compensation have shown especially notable declines since mid-2014. Contributing factors include a lower inflation risk premium, as investors increasingly view nominal bonds as good hedges against adverse macroeconomic and financial outcomes accompanied by disinflation, as well as a higher TIPS liquidity premium reflecting the higher liquidity of nominal Treasury securities during periods of heightened financial market volatility.
- The relatively small movements in the Michigan survey measure that we have observed since the mid-1990s have had little predictive power for actual core PCE inflation. We are treating the recent decline similarly and have built in only a small effect of that decline on our inflation projection; however, if the recent decline proves larger and more persistent than the earlier movements, the implications for actual inflation also may be larger.
- Model simulations show that, if LTIE are unanchored and so move lower, monetary policy will need to be more accommodative than otherwise to bring inflation back to its target. We also discuss the implications of policymaker

uncertainty, and in particular, whether it would be more costly to assume that LTIE are fixed when they were actually responsive to economic conditions, or to assume that they were responsive to economic conditions when they were actually fixed.

## 2. What the Data Tell Us

*2.1 Recent behavior of survey-based and market-based measures for the United States*

The staff tracks a variety of survey measures of longer-term inflation expectations. A number of these measures are shown in Figure 1. Recently, the survey measures for different groups of respondents have behaved differently from one another. In particular, survey measures of professional forecasters and financial industry participants (the upper four panels of the figure) have remained fairly stable over the course of the recession and recovery and stand close to the levels seen just prior to the 2007–2009 recession. By contrast, survey measures of household inflation expectations (the lower-left panel) have drifted down over the past couple of years.[4] Indeed, readings at the bottom of the historical range have been frequent lately, including the February reading of the Michigan-survey measure.[5] Finally, the Atlanta Fed survey measure (the lower-right panel), which reflects expectations of businesses in the Sixth District for changes of their own overall unit costs, has moved down since its inception but remained about flat since 2014. However, the short history of this measure makes it difficult to interpret the significance of these movements.
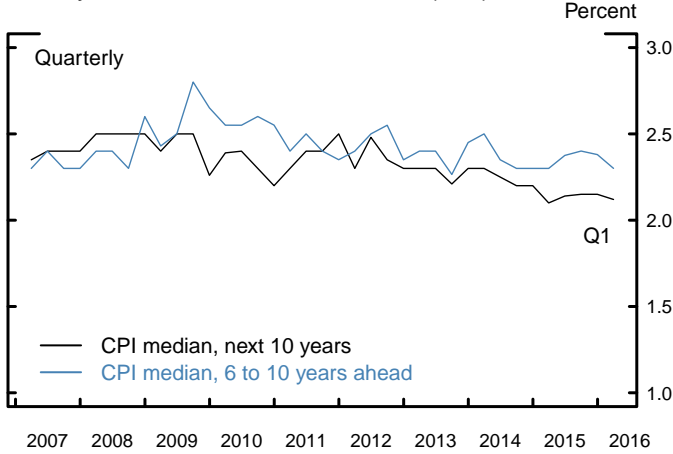
Drilling down into more details from individual responses, Figure 2 reveals noticeable downward revisions to the upper quartiles of the individual responses for expected longer-term inflation in both the Michigan Survey and the Survey of Professional Forecasters, whereas the lower quartiles have been generally stable or have revised down by less. In other words, fewer respondents now expect a high inflation outcome, but

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[4] Note that the Michigan survey asks about inflation between now and 5 to 10 years in the future, and is therefore likely influenced by respondents' expectations of inflation in the near term. An imputed Michigan forward measure for expected inflation from 1 to 5-to-10 years ahead shows a similar decline as the longer-term measure, though this may still largely reflect the consequences of current economic events on expected inflation over the next few years instead of the inflation rate expected to prevail in the more distant future.

[5] The downward trend in the New York Fed Survey of Consumer Expectations, shown in the lower-left panel of Figure 1, is much more pronounced. However, its interpretation is more difficult since it has a much shorter history and its scope is expected inflation at a three-year-ahead horizon, which may be more heavily influenced by current economic conditions than the inflation rate expected to obtain in the long run.
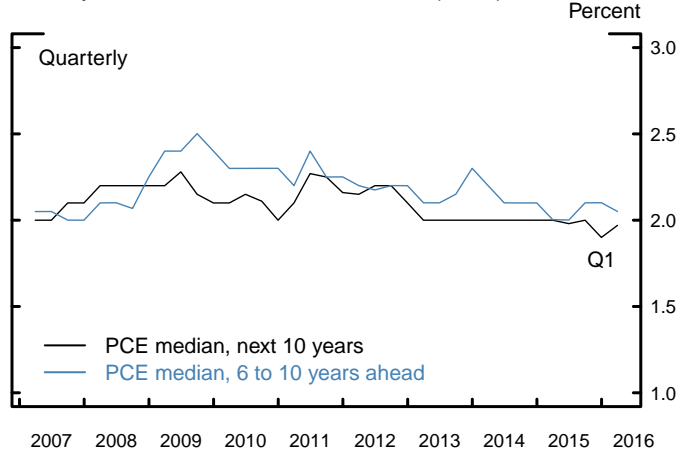
## Figure 1: Survey Measures of Longer–Term Inflation Expectations
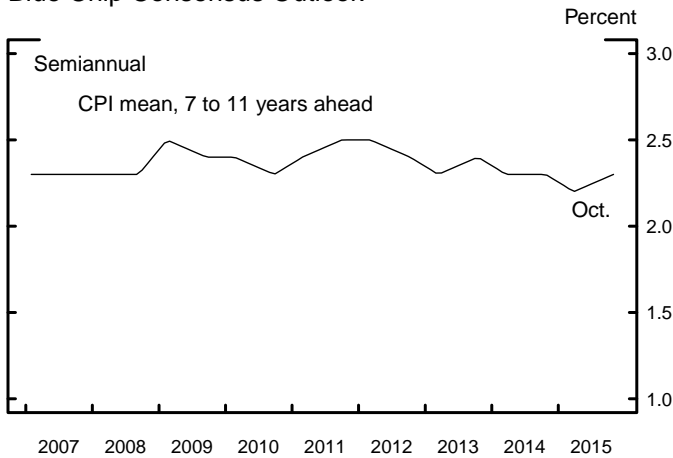
Survey of Professional Forecasters (CPI)

Percent

Quarterly

Q1

— CPI median, next 10 years
— CPI median, 6 to 10 years ahead

2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Source: Federal Reserve Bank of Philadelphia.

Survey of Professional Forecasters (PCE)

Percent

Quarterly

Q1

— PCE median, next 10 years
— PCE median, 6 to 10 years ahead

2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Source: Federal Reserve Bank of Philadelphia.

Blue Chip Consensus Outlook

Percent

Semiannual

CPI mean, 7 to 11 years ahead

Oct.

2007 2008 2009 2010 2011 2012 2013 2014 2015
Source: Blue Chip Economic Indicators.

Survey of Primary Dealers

Percent

FOMC frequency

CPI median, 5 to 10 years ahead

Jan.
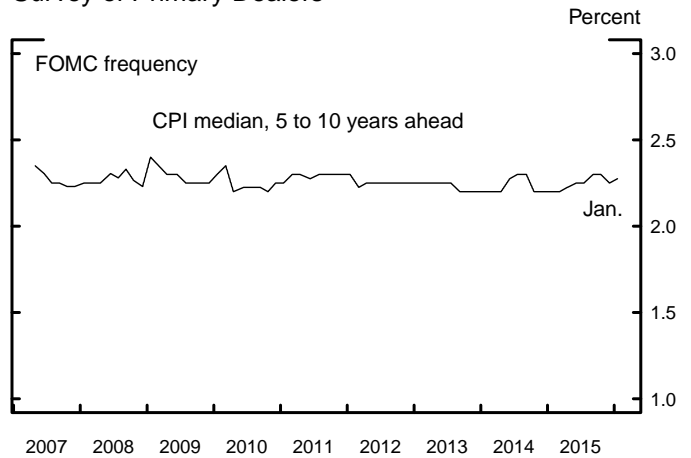
2007 2008 2009 2010 2011 2012 2013 2014 2015
Source: Federal Reserve Bank of New York.

Surveys of Consumers

Percent

Monthly

Jan.

Feb.

— Michigan median increase in prices, next 5 to 10 years
— NY Fed median increase in prices, 3 years ahead
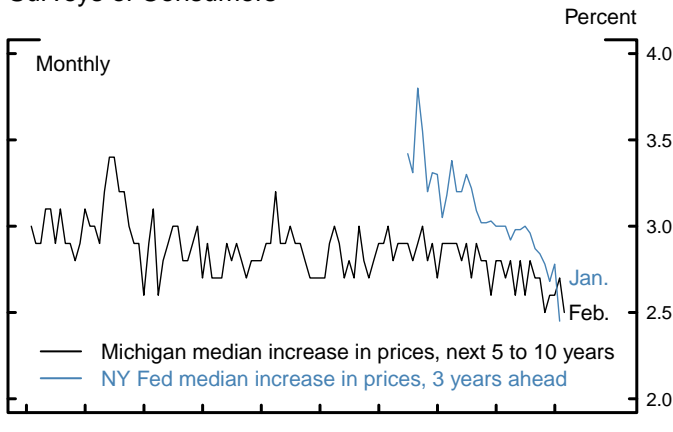
2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
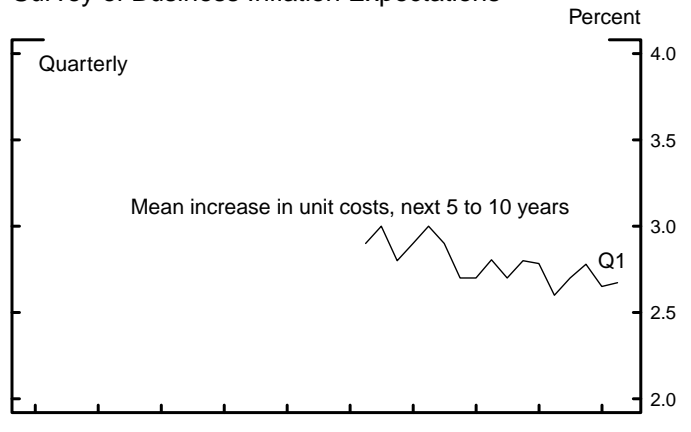Note: NY Fed Survey reports expected 12–month inflation rate 3 years
from the current survey date.
Source: University of Michigan Surveys of Consumers; Federal Reserve
Bank of New York Survey of Consumer Expectations.

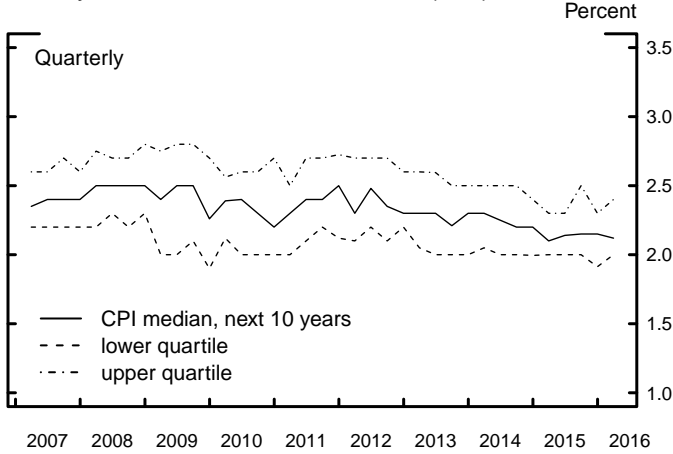Survey of Business Inflation Expectations

Percent

Quarterly

Mean increase in unit costs, next 5 to 10 years

Q1

2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Note: Survey of businesses in the Sixth Federal Reserve District. Data
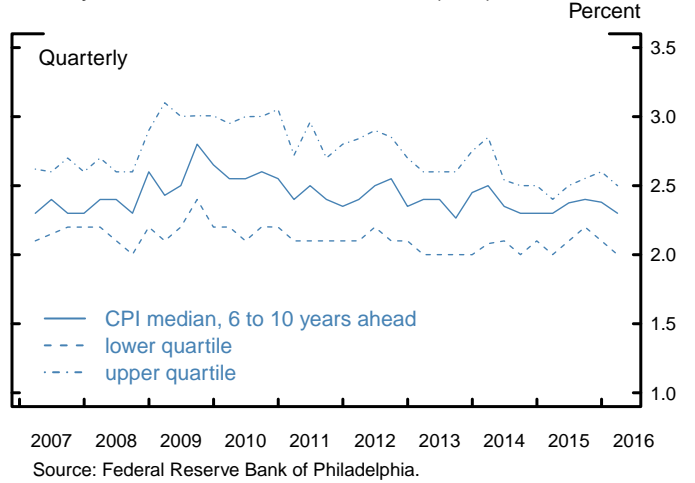begin in February 2012.
Source: Federal Reserve Bank of Atlanta.

# Figure 2: Quartile Distributions of Survey Measures of Longer–Term Inflation Expectations
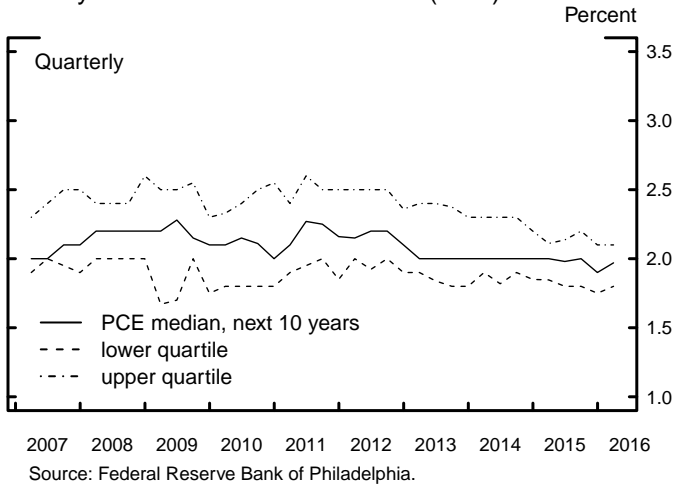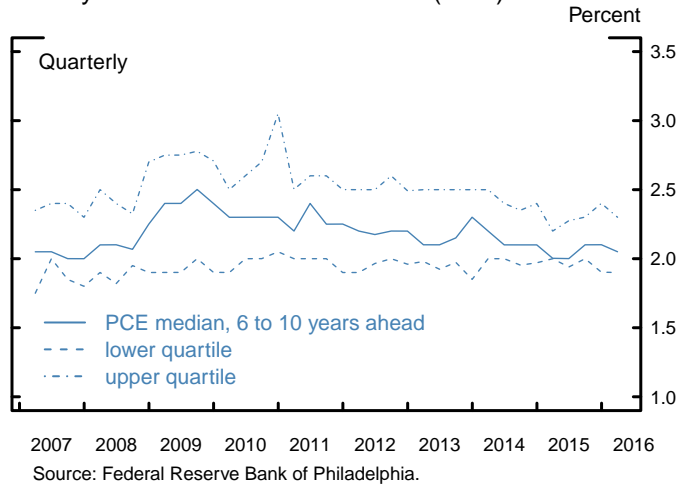
Survey of Professional Forecasters (CPI)

Percent

Quarterly

- CPI median, next 10 years
- - - lower quartile
- · - · upper quartile

2007  2008  2009  2010  2011  2012  2013  2014  2015  2016

Source: Federal Reserve Bank of Philadelphia.

Survey of Professional Forecasters (CPI)

Percent

Quarterly

- CPI median, 6 to 10 years ahead
- - - lower quartile
- · - · upper quartile

2007  2008  2009  2010  2011  2012  2013  2014  2015  2016

Source: Federal Reserve Bank of Philadelphia.

Survey of Professional Forecasters (PCE)

Percent

Quarterly

- PCE median, next 10 years
- - - lower quartile
- · - · upper quartile

2007  2008  2009  2010  2011  2012  2013  2014  2015  2016

Source: Federal Reserve Bank of Philadelphia.

Survey of Professional Forecasters (PCE)

Percent

Quarterly

- PCE median, 6 to 10 years ahead
- - - lower quartile
- · - · upper quartile

2007  2008  2009  2010  2011  2012  2013  2014  2015  2016

Source: Federal Reserve Bank of Philadelphia.

Michigan Survey of Consumers

Percent

Monthly

- Michigan median increase in prices, next 5 to 10 years
- - - lower quartile
- · - · upper quartile

2007  2008  2009  2010  2011  2012  2013  2014  2015  2016

Source: University of Michigan Survey of Consumers.

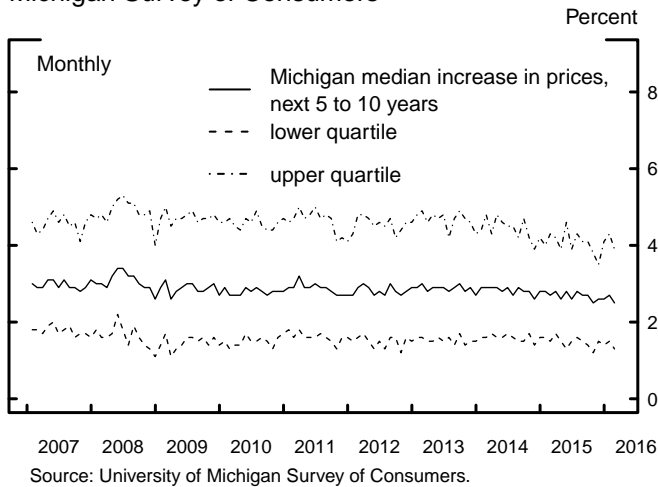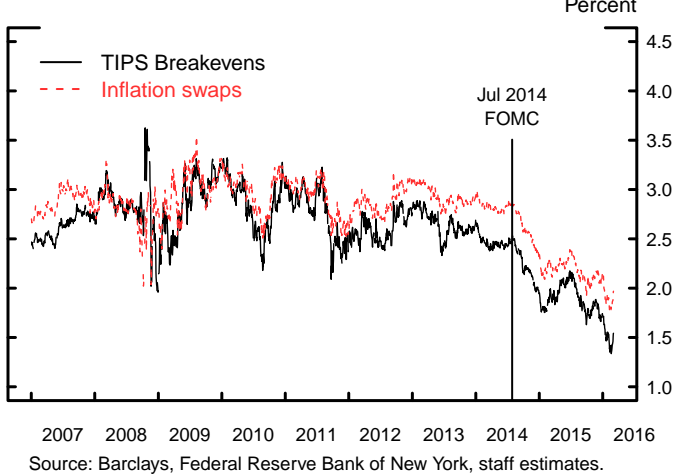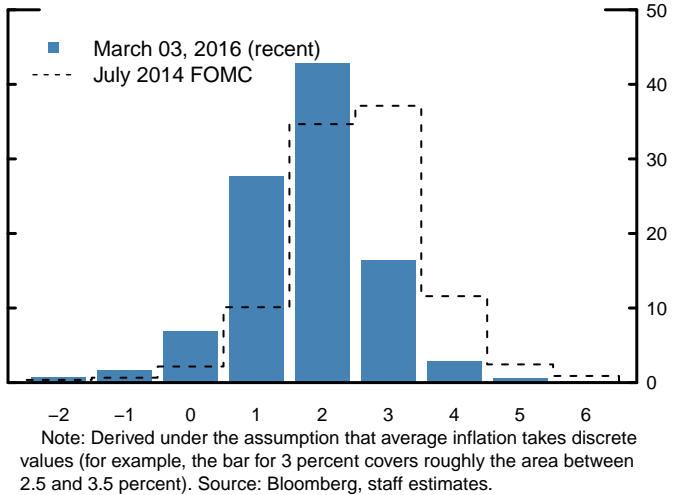# Figure 3: Market–Based Measures of Longer–Term Inflation Expectations

### 5–to–10–Year Forward Inflation Compensation

Percent

- TIPS Breakevens
- Inflation swaps

Jul 2014 FOMC

Source: Barclays, Federal Reserve Bank of New York, staff estimates.

### Implied One–Year Forward Inflation Compensation

Percent

- 03/03/2016
- Jul 2015 FOMC
- Jul 2014 FOMC

Years Ahead

Note: Forward one–year rates that mature at the end of the year shown on the horizontal axis are implied by the smoothed TIPS yield curve adjusted for the carry effect. Source: Barclays, staff estimates.
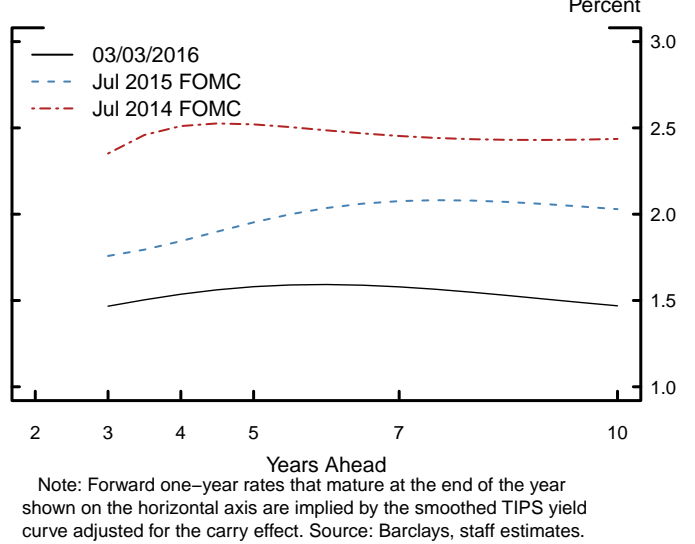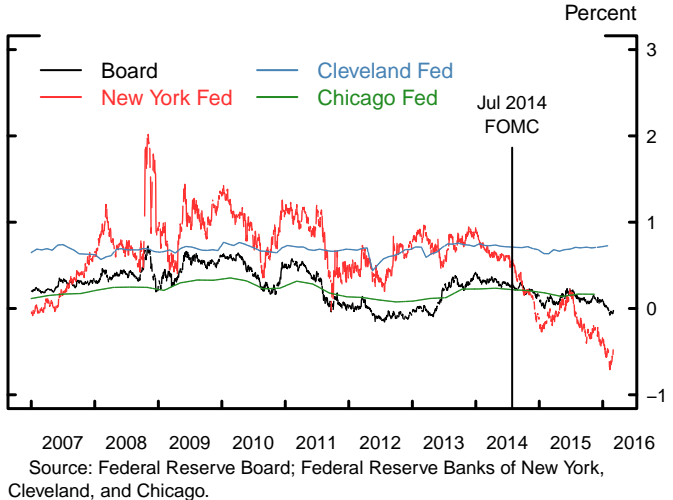
### Probability Distribution of Annualized Headline CPI Inflation over the next 10 years from Inflation Caps and Floors

Percent

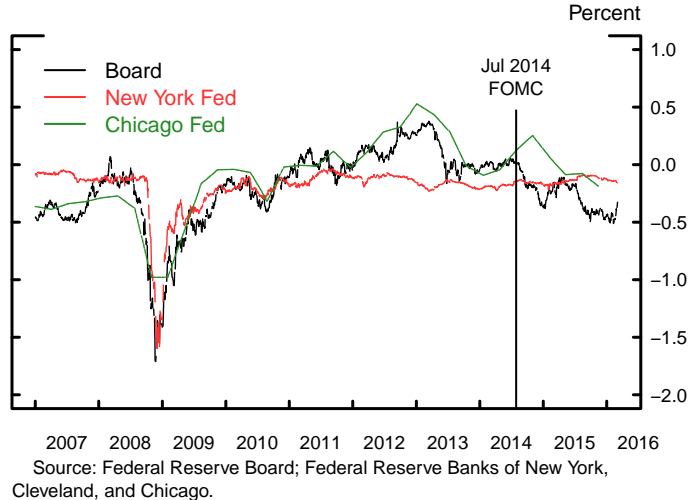- March 03, 2016 (recent)
- July 2014 FOMC

Note: Derived under the assumption that average inflation takes discrete values (for example, the bar for 3 percent covers roughly the area between 2.5 and 3.5 percent). Source: Bloomberg, staff estimates.

### 5–to–10–Year Inflation Expectations

Percent

- Board
- New York Fed
- Cleveland Fed
- Chicago Fed

Jul 2014 FOMC

Source: Federal Reserve Board; Federal Reserve Banks of New York, Cleveland, and Chicago.

### 5–to–10–Year Inflation Risk Premiums

Percent

- Board
- New York Fed
- Cleveland Fed
- Chicago Fed

Jul 2014 FOMC

Source: Federal Reserve Board; Federal Reserve Banks of New York, Cleveland, and Chicago.

### 5–to–10–Year Other Risk Premiums

Percent

- Board
- New York Fed
- Chicago Fed

Jul 2014 FOMC

Source: Federal Reserve Board; Federal Reserve Banks of New York, Cleveland, and Chicago.

there does not seem to be a substantial migration of respondents toward expecting lower inflation outcomes.

Similarly to the decline in inflation expectations of consumers, measures of longer-term inflation compensation from TIPS and from inflation swaps, such as 5-to-10-year inflation compensation, have dropped notably since the July 2014 FOMC meeting, to historical lows (Figure 3, top left panel). The decline is apparent in forward inflation compensation at all maturities (top right panel). Over the same period, TIPS yields and their forward rates at similar maturities were about unchanged. The interpretation of these declines in inflation compensation is discussed later.

The notable decline in inflation compensation was also reflected in a leftward shift of the risk-neutral probability distributions of future inflation inferred from inflation caps and floors (middle left panel).[6] Somewhat differently from the survey results, these distributions suggest that investors have become not only less concerned about higher inflation outcomes (above 3 percent), but also more concerned about lower inflation outcomes (below 1 percent) since the summer of 2014.[7] Nonetheless, the distributions remained largely symmetric, suggesting that investors still viewed the upside and downside risks to longer-term inflation as about balanced.

*2.2 International evidence*

The patterns described above for the United States are also found in the euro area and United Kingdom.[8] LTIE in the euro area, as measured by the semi-annual surveys by Consensus Economics, have moved down somewhat since 2014 but still remain close to levels seen early in the past decade (top panel of Figure 4). LTIE from similar surveys in the United Kingdom have declined more markedly over the past few years, but in contrast to the experience in the euro area and the United States, remain above levels observed prior to the global financial crisis. In addition, LTIE remain close to central bank targets in both cases, in line with the U.S. experience, which suggests that at least
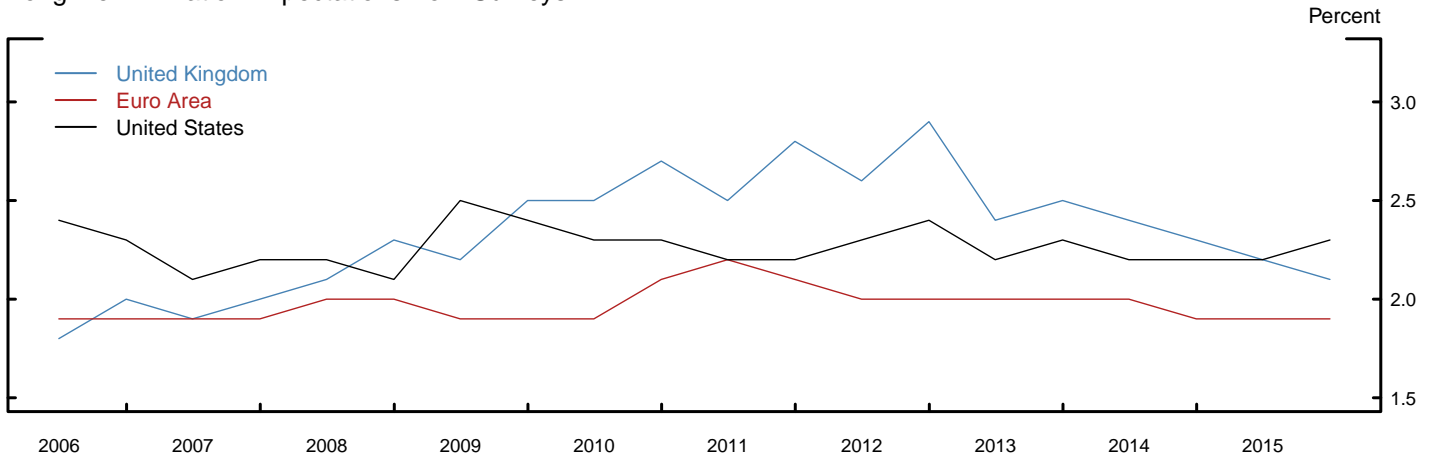
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[6] The mean of the distribution from inflation caps and floors has to be equal to the inflation swap rate by no arbitrage.

[7] The difference between option-implied and survey-based distributions could in part reflect increased investor concerns about, rather than higher perceived odds of, low inflation outcomes.
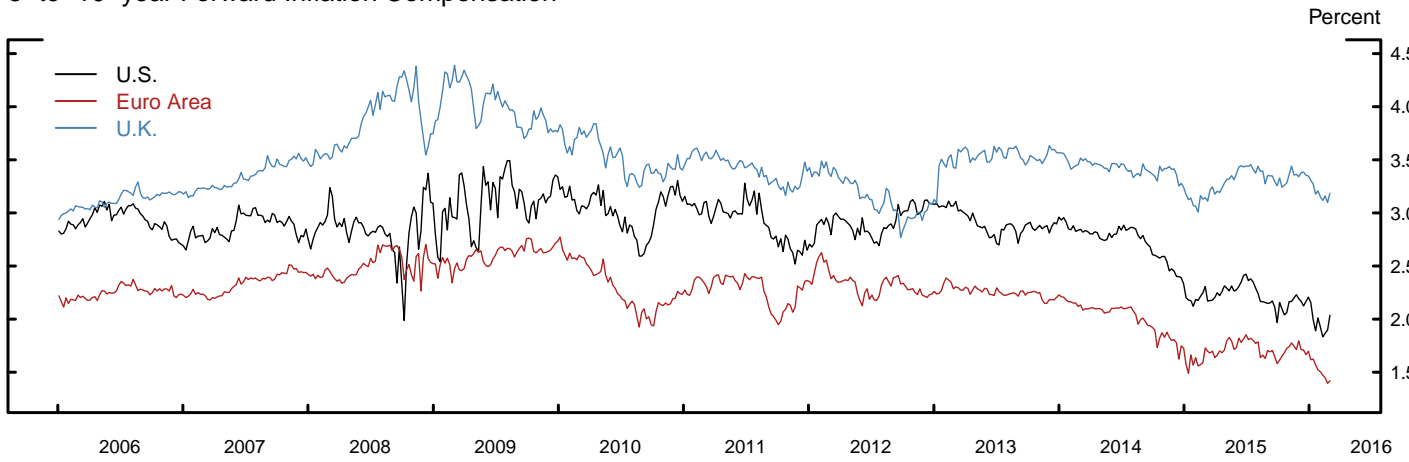
[8] For the euro area as a whole, inflation swaps are the only available market-based measure, so we concentrate on this measure, rather than inflation compensation computed from, for example, German or French government bond yields. Canada and Japan are not included in the analysis: there are no inflation swap data for Canada, and the inflation swaps market for Japan is less developed.
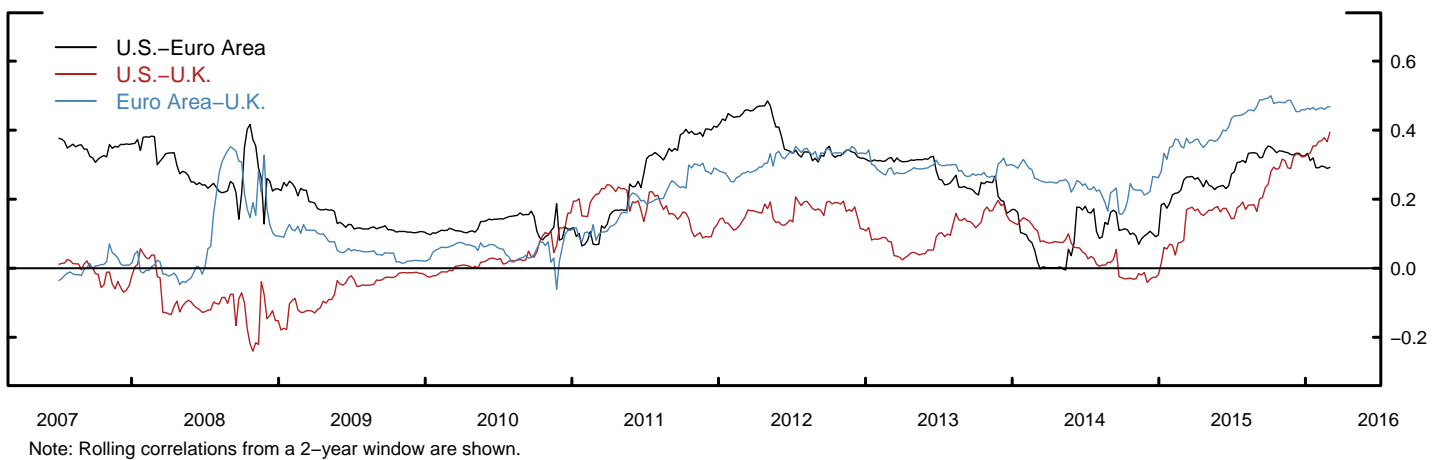
## Figure 4: International Evidence

Long−Term Inflation Expectations from Surveys

Percent

United Kingdom
Euro Area
United States

Note: Forecasts for 6−10 year ahead inflation from the semi−annual survey by Consensus Economics. Data end in Dec. 2015.

5−to−10−year Forward Inflation Compensation

Percent

U.S.
Euro Area
U.K.

Note: Based on inflation swap quotes. Data end on Mar. 02, 2016.

Inflation Compensation Correlations

U.S.−Euro Area
U.S.−U.K.
Euro Area−U.K.

Note: Rolling correlations from a 2−year window are shown.

the professional forecasters who furnish these forecasts still believe that these central banks are likely to come close to achieving their inflation objectives.[9]

Turning to market-based measures, 5-to-10-year inflation compensation in the euro area has declined markedly since mid-2014, as it has in the United States (middle panel). U.K inflation compensation also moved down, on net, over the same period but to a significantly lesser extent. Indeed, estimates based on rolling windows suggest that cross-country correlations have been trending higher since around mid-2014, and remain well above longer-run averages (bottom panel).[10] Overall, the evidence from market-based measures is consistent with a larger role for a common component perhaps reflecting increased global growth concerns.

*2.3 Model-based estimates of longer-term inflation expectations*

As discussed above, measures of consumer inflation expectations and inflation compensation have shown pronounced declines since the middle of 2014. However, these are volatile measures and at least part of their movement may be the result of idiosyncratic factors rather than true movements in underlying inflation expectations. This section discusses what signal we should take for LTIE from the declines in the data noted above.

Considering market-based measures, both TIPS- and swaps-based measures of inflation compensation capture not only expected inflation, but also an inflation risk premium as well as other premiums reflecting liquidity differences and shifts in the relative supplies of and demands for nominal versus inflation-indexed securities. Staff at the Board and the Federal Reserve Banks of Chicago, Cleveland, and New York maintain term structure models aiming to disentangle the various components of inflation compensation and to provide estimates of inflation expectations and risk premiums. As shown in the middle right panel of Figure 3, none of these models indicate notable declines in LTIE since the summer of 2014. Both the Board and the FRBNY models currently estimate longer-term expected CPI inflation to be around 2.4 percent, roughly corresponding to 2 percent for longer-term PCE inflation.[11] These models attribute most of the declines in inflation

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[9] There is no consumer survey in the euro area covering longer-term inflation expectations. In the United Kingdom, the Bank of England has been conducting a survey of consumers since 2009 asking about inflation expectations for a one-year period five years into the future. Similar to the surveys in the U.S., this survey indicates that consumer expectations are somewhat above those of professional forecasters and have declined notably over the past few years.

[10] An analysis based on Granger causality tests does not suggest a leading role for any of the three jurisdictions under consideration.

[11] The standard errors on 5-to-10-year inflation expectations from the Board model are in the range of 5 to 8 basis points in this sample period.

compensation to lower inflation risk premiums and changes in other risk premiums rather than to lower expected inflation.

All those models assume a constant terminal rate for inflation; therefore, shocks to inflation can have long-lasting, but not permanent, effects in those models. An alternative version of the Board staff's term structure model that allows some of the shocks to have permanent effects on inflation produces estimates of a much larger decline in longer-term inflation expectations since August 2014 of around 65 basis points. However, this version of the model also produces an increasingly positive inflation risk premium over the same period, which is difficult to reconcile with the high correlation observed in recent years between low inflation and weak economic performance.

Turning to consumer inflation expectations from the Michigan survey, we can filter out some of the noise in this series by using a statistical model to decompose expectations into a trend LTIE and transitory deviations from that trend.[12] The point estimates from this decomposition suggest that trend Michigan long-term inflation expectations were roughly constant from the middle of 2009 to the middle of 2014 before declining about ¼ percentage point since then; the current estimate of the level of LTIE from this model is 2.6 percent, with a 70 percent confidence interval ranging from 2.5 percent to 2.7 percent. The decline in this trend is roughly one-half the size of the decline that the raw data through February would indicate on their own; the smaller estimated decline in the trend is partly because the model interprets much of the swing from the 2.7 percent reading in January to the 2.5 percent reading in February to be random noise. A more worrisome possibility is that the latest readings reflect a sharper decline in inflation expectations than can be accommodated within the framework of this model.

*2.4 Estimates of trend inflation derived from inflation and expectations data*

An alternative to estimating potential changes in trend inflation from a single indicator series, such as the Michigan survey or a measure of realized inflation, is to identify a

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[12] The model is a member of a class of state-space models called local-level models (a well-known example is the model of Stock and Watson, 2007), with the particular version implemented here based on Clark and Doh (2014). The model characterizes trends and transitory movements as unobserved components with the former assumed to follow a random walk and the latter a white noise process. The model also allows for time-variation in the shock magnitudes—a process known as stochastic volatility. Michigan inflation expectations, with nearly the entire panel of respondents changing every month, are likely particularly well suited for a local level model. When estimating monthly Michigan inflation expectations over the short sample that begins in the late-1990s, allowing for stochastic volatility has almost no effect on the results.

common trend from several measures.[13] To determine the common trend, we use a methodology that extracts a monthly measure of trend inflation aligned with headline PCE, while drawing on a range of indicator variables that are, in part, sampled less often, such as GDP price inflation and inflation expectations from the Survey of Professional Forecasters (SPF), both quarterly, and the Livingston Survey and longer-horizons forecasts from Blue Chip Survey, both semiannually. Here, we focus on estimates from two broad sources of data, various measures of inflation itself, and measures from the aforementioned surveys of professional forecasters; more results are available elsewhere.[14]

The top panel of Figure 5 shows two estimates of trend inflation, one generated using actual price data (the red solid line), the other employing a combination of price data and survey forecasts (the black dashed line).[15] Temporary deviations aside, the trend measures track each other quite closely over the post-war sample, although the combined trend is notably smoother. The variability of the price-data-only trend measure reflects the higher volatility of shocks to trend inflation—a model-implied measure of how "well anchored" LTIEs are—shown in the bottom panel. According to the price-data-only trend estimate, there were large shocks to trend inflation in the 1970s; the volatility of shocks to the combined trend shows much less time variation. More recently, over the disinflationary periods of the 1980s and 90s, the combined trend estimate has fallen more

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[13] The common trend-inflation rate is defined as the infinite-horizon forecast of what PCE inflation is projected to be once the effects of all transitory shocks have dissipated. The common trend estimates are extracted from various inflation measures and survey inflation forecasts, assuming that the infinite-horizons forecasts of all variables move in lock-step with that for PCE headline inflation.

[14] See Mertens (forthcoming) and Garnier, Mertens, and Nelson (2015). Beyond the additional information from multiple sources at mixed frequencies, another improvement over the univariate setup of Stock and Watson (2007, 2010) is that this model allows for persistent, but not permanent, deviations of each variable from its trend. Results shown here are from the baseline model in Mertens (forthcoming) with stochastic volatility in trend shocks only. Results using either data set from an extended model that also allows stochastic volatility in shocks to deviations from the trend generate trend estimates similar to the price-data-only estimates shown here.

[15] In both cases the reported measure of trend inflation corresponds to the model's long-run estimate of PCE headline inflation. Survey forecasts used in the estimation include near- and longer-term forecasts from Blue Chip Economic Indicators, the SPF and the Livingston Survey. Actual inflation data include headline and core PCE, CPI, and GDP price inflation, PCE trimmed mean inflation as constructed by the Federal Reserve Bank of Dallas, CPI trimmed mean and median inflation as constructed by the Federal Reserve Bank of Cleveland. All data have been updated through the end of February 2016. Using survey forecasts alone generates estimates that are similar to those shown here for the combined data set.
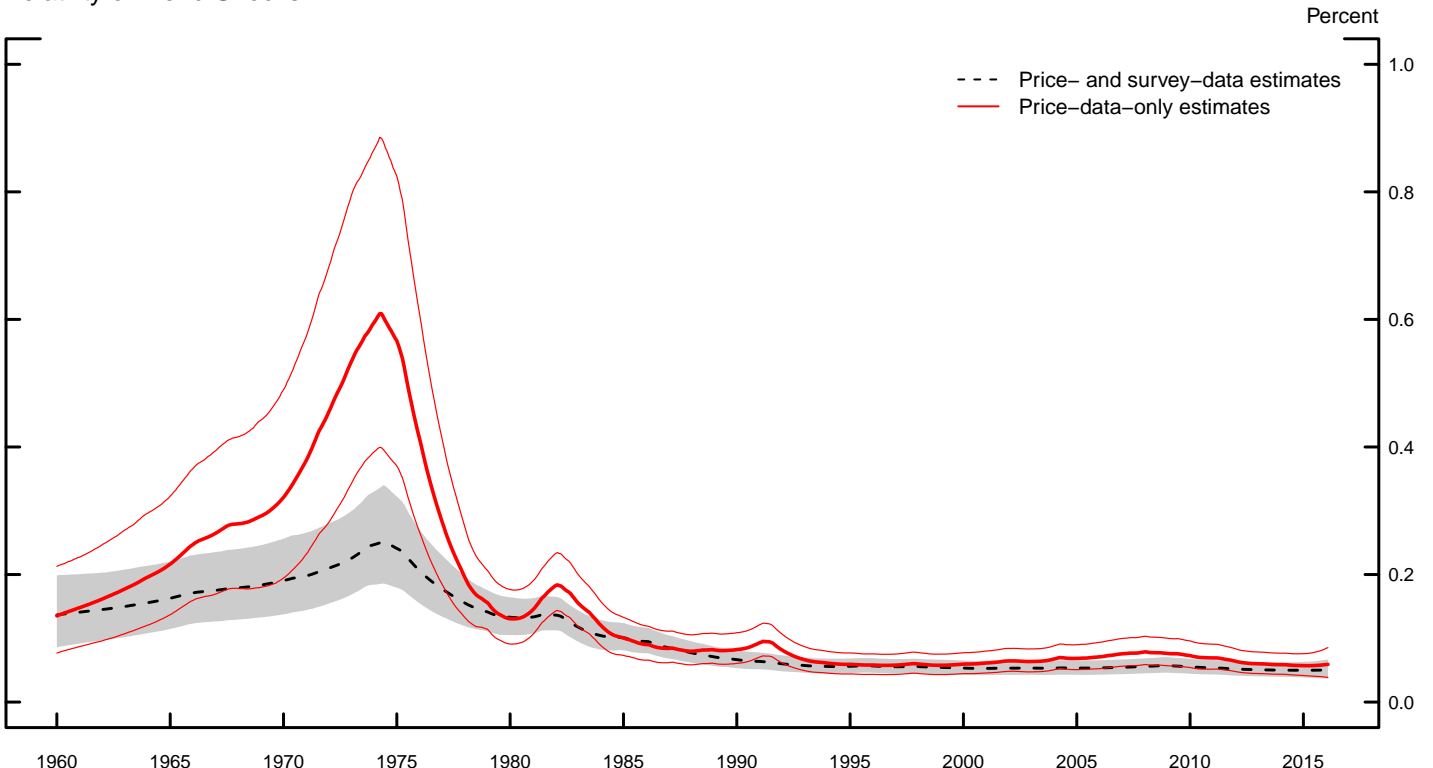
## Figure 5: Level and Uncertainty of Trend Inflation

Trend Estimates

Percent
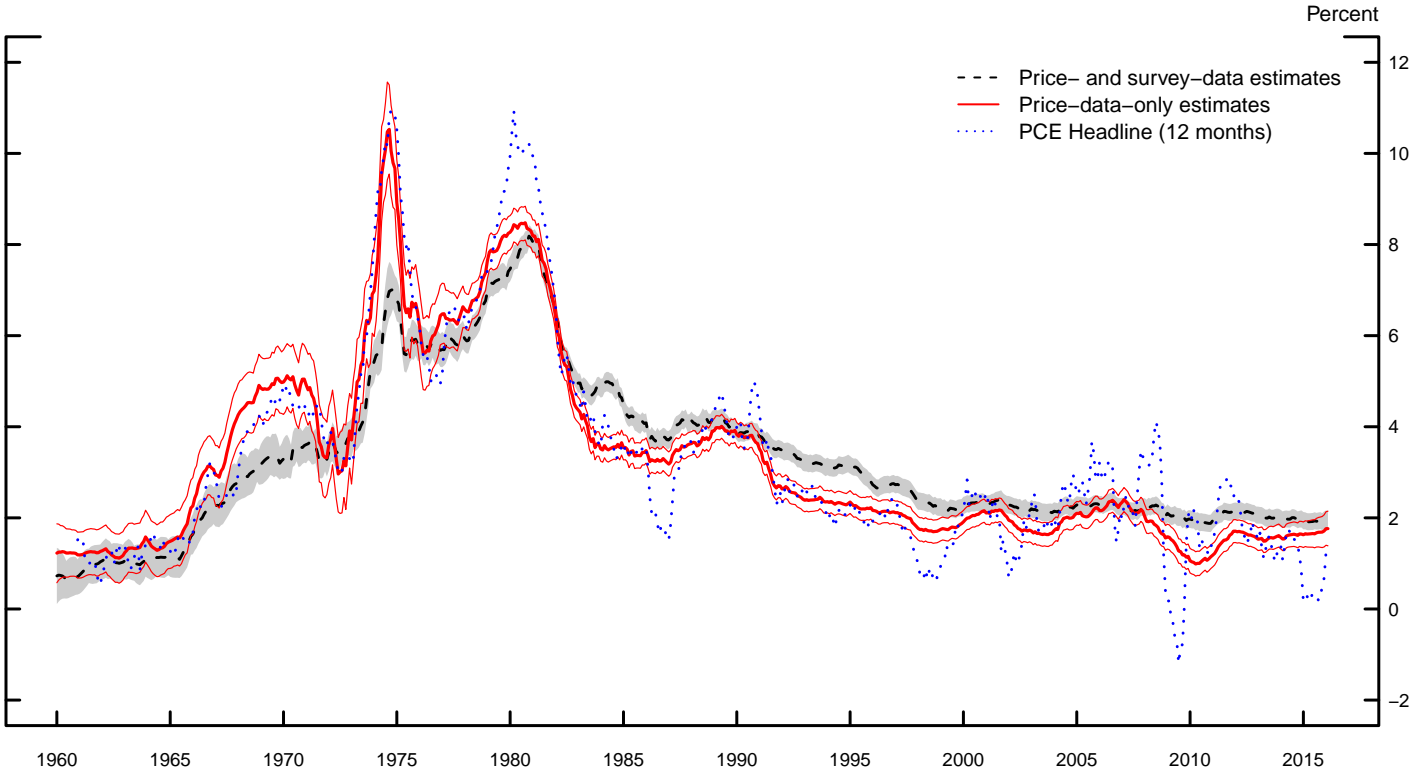


Note: Shaded areas and thin lines denote 90% uncertainty bands for trend estimates. All results reflect smoothed estimates derived from up to 19 indicator variables using all available observations from January 1960 through February 2016.

Volatility of Trend Shocks

Percent



Note: The volatility of trend shocks is measured by the monthly standard deviation of a shock to the trend level, where the trend level is measured as an annualized percentage rate. Shaded areas and thin lines denote 90% uncertainty bands. All results reflect smoothed estimates derived from up to 19 indicator variables using all available observations from January 1960 through February 2016.

gradually and often lags further behind the inflation-based estimate as well as inflation itself.[16]

Over the last 30 years shown in the top panel, the price-data-only trend has been almost universally lower than the combined trend. At the end of the sample in February 2016, the point estimate from the combined trend is 2.0 percent with a 90-percent uncertainty band that ranges from 1.8 to 2.2 percent. By contrast, the more volatile price-data-only trend stands at 1.8 percent, with a 90-percent range from 1.4 to 2.1 percent, after having dipped down to about 1.5 percent a few years earlier.[17] The recent upward drift in the price-data-only trend estimates results mostly from the latest more positive readings on trimmed-mean and core PCE. Based on the point estimate and the relatively tight uncertainty bands of the combined trend, one might feel "reasonably confident" that inflation will return to the Committee's objective of 2 percent; the slightly lower price-data-only trend estimate and the wider band surrounding that estimate might, however, temper that confidence somewhat.

*2.5 Potential Explanations for the Decline in LTIE*

As noted above, of the various indicators of inflation expectations, the largest declines occurred in survey measures of consumers' inflation expectations and in inflation compensation from financial markets. Possible reasons for the decline in inflation expectations include not only the observed low inflation itself—reflecting declining oil and gasoline prices—but also factors such as concerns about the outlook for global growth and inflation, including emerging views regarding asymmetric risks in the world economy along with associated reassessments of the power of monetary policy to

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[16] Consistent with these results, Coibion and Gorodnichenko (2015), for example, present evidence suggestive of informational frictions, such as sticky information or rational inattention, in the survey formation process. In particular, Mertens and Nason (2015) find that the sensitivity of survey responses to current information has varied positively with trend variability in U.S. post-war data on inflation and survey data from professional forecasters. Mertens and Nason are careful not to suggest that this interdependence between trend variability and the sluggishness of surveys is structural, but their evidence suggests that survey respondents may react more swiftly to incoming information should they come to perceive that the variability of trend inflation has risen.

[17] The uncertainty bands shown in the figure describe the model's confidence in the location of trend inflation, which, of course, contributes only to a small extent to the model's uncertainty about future inflation itself. The relative tightness of the confidence bands for trend inflation, in particular for estimates of the trend after 1980 that are conditioned on the combined data set, reflects the availability of additional data sources—notably several surveys but also the trimmed and median measures of inflation—over the later part of the sample.

achieve policymakers' goals or of the willingness of monetary authorities to use the instruments they have to achieve these goals.

The recent decline in long-term inflation expectations in the Michigan Survey of Consumers started in the second half of 2014, at about the same time as oil and gasoline prices began to fall sharply. To the extent that energy price declines are unlikely to continue to fall at the same rate as they have over the past year and a half, it may be reasonable to discount as ephemeral any shifts in LTIE that are associated with these shocks. And indeed, in a model that allows for a link between changes in gasoline prices and inflation expectations, the estimated trend in consumer LTIE has fallen by only about 5 basis points since the middle of 2014, versus a roughly 25 basis point decline for the model without energy prices (see the upper-left panel of Figure 5).[18] In this augmented model, as in the one without a direct role for gasoline prices, the latest observations are considerably lower than the model can explain. That said, if the model structure and parameter estimates remain valid, then the Michigan survey measure should rise gradually over the next few years.[19]

The effective lower bound on nominal interest rates, and its relation to other forces in the economy, is another possible reason why LTIE may have declined. At present, many commentators (including the staff) see a prevalence of downside risks for the U.S. economy, stemming from problems in overseas economies, fears of incipient financial instabilities, and a lack of capacity for fiscal policy to play a role in supporting aggregate demand. With the federal funds rate close to zero, and with doubts in the minds of many regarding the ability or willingness of the Federal Reserve to respond effectively to adverse shocks, the subjective distribution of expected future economic outcomes is likely skewed to the downside. To the extent this is the case, it imparts a downward bias to expected inflation.[20]

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[18] Roughly similar results are found in a simple regression of Michigan long-run inflation expectations on its own lag and lags of core, food, and energy PCE inflation estimated since 2000. Related to the decline in oil prices has been a decline in commodity prices, which has helped push food price inflation since the beginning of 2015 to a very low level. However, model results differ as to whether such movements in food prices have much effect on Michigan long-term inflation expectations. Note that the model here excludes stochastic volatility.

[19] This assumes the pass-through of the declines in gasoline prices to other items is small, and in line with historical averages since the late 1990s. Further, the model suggests that effect of the large gasoline price declines on consumer inflation expectations will not dissipate quickly and can last for a few years.

[20] The fact that major overseas countries face similar issues reinforces the point: adverse shocks to overseas economies, if they cannot be countered by monetary or fiscal policy in those countries, will result in larger effects than otherwise, with attendant effects on U.S. exports. Moreover, to the extent that such problems increase the perceived likelihood of tail events and induce a widening of risky spreads and a flight to safety, financial market outcomes will be distorted and deleterious outcomes will be magnified.

### 3. Declines in Inflation Compensation: The Role of Risk Premiums

Market-based measures of inflation expectations such as TIPS breakeven rates and inflation swap rates reflect not only market participants' expected rate of inflation, but also risk premiums investors require to hold assets that are exposed to inflation risk and other risk factors:

inflation compensation = expected inflation + inflation risk premium + other premiums

Several observations suggest that variations in risk premiums likely played an important role in the substantial decline in inflation compensation since mid-2014. First, the correlation between inflation compensation and the VIX, one common measure of investor risk aversion, turned significantly negative over the past year (upper-right panel of Figure 6). In addition, results from the various term structure models, shown in the bottom panels of Figure 3, suggest that lower risk premiums accounted for a significant portion of the decline in inflation compensation since mid-2014. [21] Finally, as widely noted by market participants, the correlation between inflation compensation and oil prices has risen sharply over the past year (lower-left panel). This elevated correlation is puzzling, as it seems unlikely that oil prices would continue to fall over the next five to ten years and lead to lower expected inflation at those distant horizons. One possibility is that the sharp decline in oil prices may have exacerbated investor concerns about the global economic outlook, and as explained below, reduced both the inflation risk premium and the other premium components in inflation compensation.

While the focus of this memo is primarily on expected inflation, the inflation risk premium may also be relevant for monetary policy considerations. For example, Kocherlakota (2014) argues that a decrease in inflation risk premiums signals that the public puts greater weight on the possibility that below-target inflation would be associated with weak economic outcomes, and therefore the FOMC should view the risk of below-target inflation with more concern.[22] Meanwhile, a lower "other premiums" component may be signaling increased financial market stress and/or deteriorating liquidity conditions as well as the associated macroeconomic implications. In this section, we examine the potential drivers of the declines in the inflation risk premium and other premiums.

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[21] Changes in other premiums played a slightly large role than lower inflation risk premiums in the Board and the Chicago model, whereas the reverse is true in the FRBNY model. The Cleveland model does not have an "other premiums" component.

[22] However, Bauer and Rudebusch (2015) argue that it is important to recognize the limitations of market-based measures. They point out that market prices may vary for a number of reasons that are unrelated to the fundamental factors of interest to policymakers.
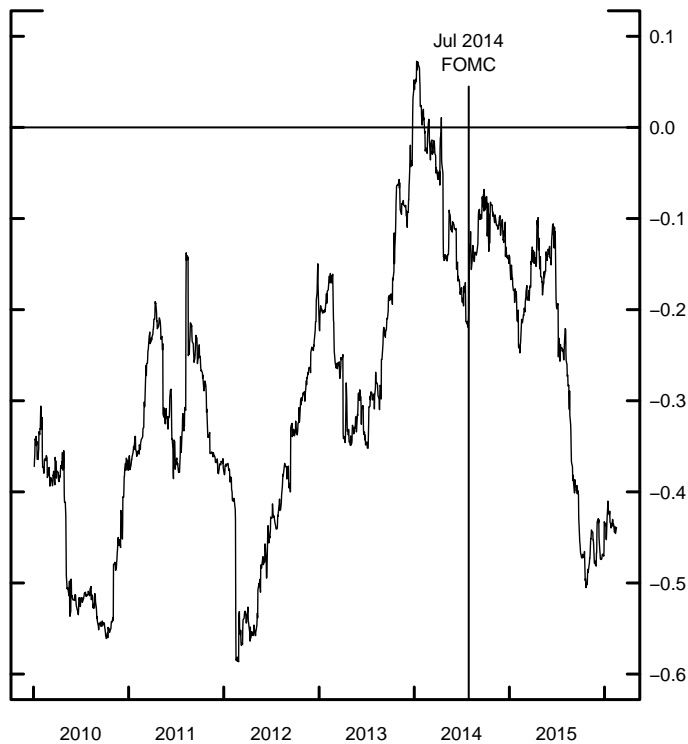
# Figure 6: Potential Explanations for Declines in Longer–Term Inflation Expectations and Inflation Compensation

Michigan Measure of Median Inflation Expectations and Trend Expectations
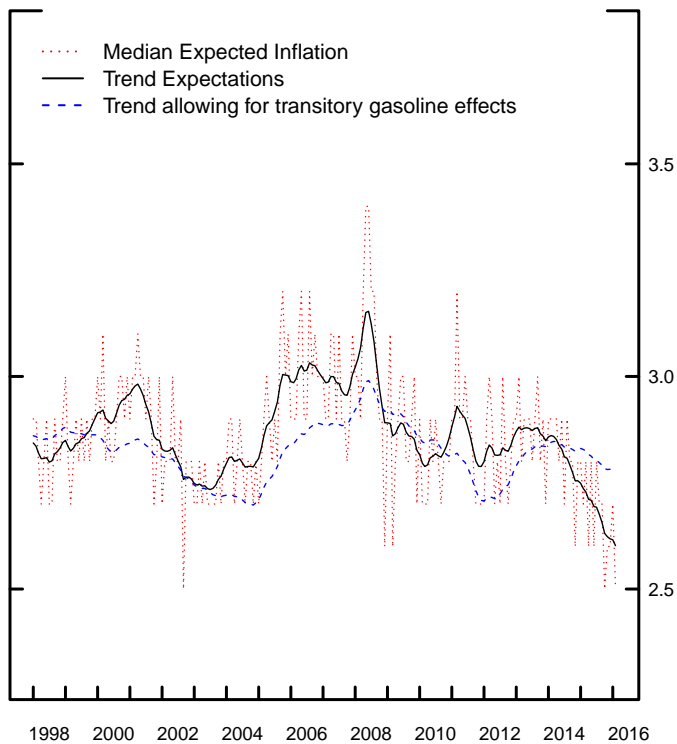


Source: Michigan for the median survey and staff estimates for the trends.

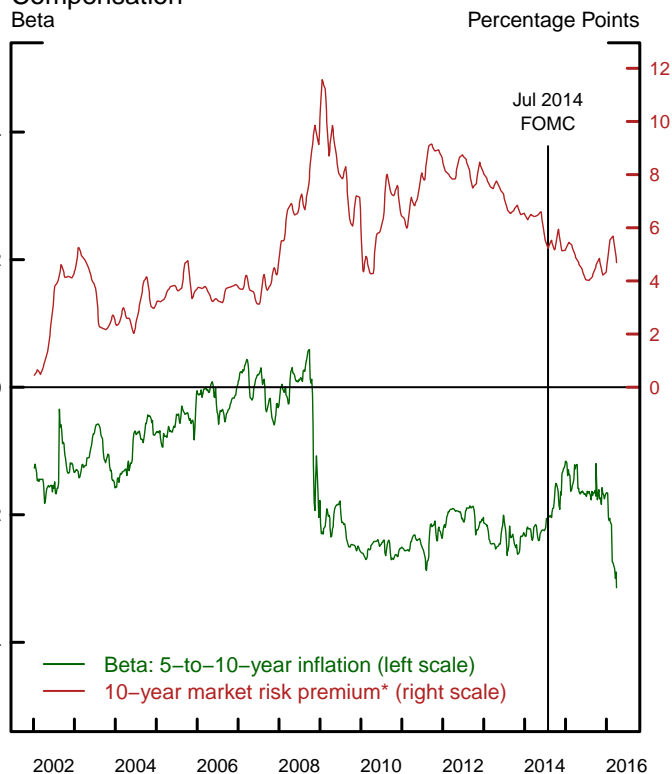Correlation of 5–to–10–Year Inflation Compensation with the VIX



Note: 6–month rolling sample correlation of daily changes in 5–to–10–year TIPS inflation compensation and log(VIX).

Correlation of 5–to–10–year Inflation Compensation with Oil Prices
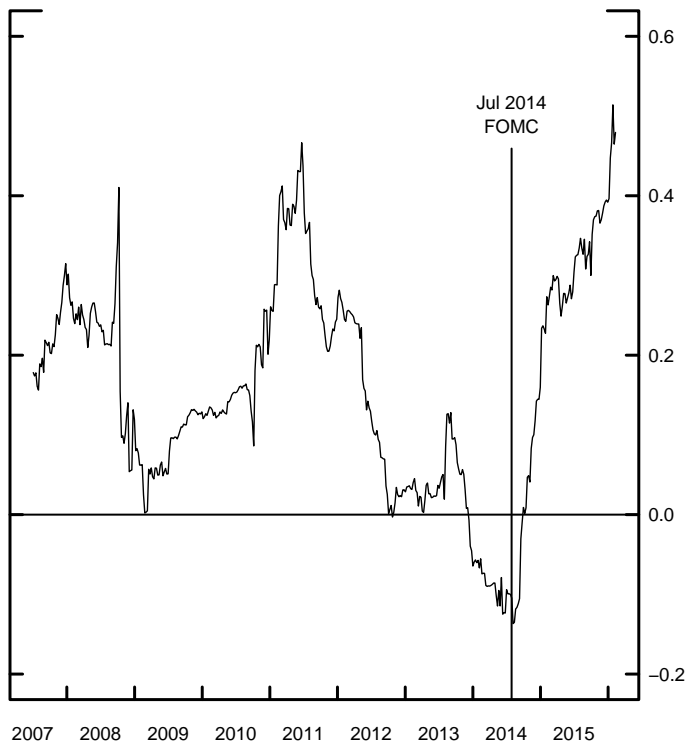


Note: Rolling correlations from a 2–year window are shown.

Comovement of Equity Returns and Inflation Compensation



* Staff estimate.

*3.1 The inflation risk premium*

Conventional asset pricing theory suggests that the risk premium for any asset depends in part on how the asset return is expected to covary with the typical investor's consumption or wealth. For example, equity returns require a high positive risk premium because equity prices tend to fall during recessions, precisely when consumption also declines. The theory thus suggests that the inflation risk premium will depend on the correlation between inflation and consumption or wealth.

One way to examine potential changes in the inflation risk premium is through the lens of the capital asset pricing model (CAPM). Under the CAPM, the risk premium associated with a position in inflation compensation is:

Inflation risk premium = equity market risk premium x β(inflation compensation)

where the function β measures the sensitivity of returns to inflation compensation to equity market returns.[23]

The estimated beta of 5-to-10-year inflation compensation, shown as the green line in the lower right panel of Figure 6, has remained negative after plummeting in late 2008 and has moved down further, one net, since mid-2014.[24] Over the same period, the staff estimate for the 10-year equity market risk premium, the red line, is little changed on net. Taken together, the CAPM would imply an inflation risk premium that is likely negative and has become more so over the past year.[25]

*3.2 Other premiums: Rising liquidity premiums on TIPS relative to nominal Treasuries*

As can be seen in the top left panel of Figure 3, 5-to-10-year TIPS inflation compensation displays a substantial amount of short-run variation. Part of this variation may reflect safe-haven flows into nominal Treasuries: At times of rising risk aversion and/or market uncertainly, investors tend to pile into assets that are perceived as safe and liquid, pushing yields on those assets below the levels that can be justified by the underlying risk profile of their cash flows. In light of the lower liquidity of TIPS relative to nominal Treasuries,

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[23] More generally, estimates of beta will capture exposure to both the inflation risk and any other risk factors that cause inflation compensation to covary with equity returns.

[24] We use a vector autoregression with time-varying parameters for this analysis. The endogenous variables include nominal Treasury and TIPS yields at the 5- and 10-year maturities, the VIX index, and returns on the S&P 500 index. Data are weekly from January 2010 – February 2016.

[25] To gauge the magnitude of the CAPM-implied inflation risk premium, we could use the following assumptions: We adopt the current staff estimate for the 10-year market risk premium of about 5½ percent per year, and assume that the current levels of the estimated betas for all maturities will persist over the next 10 years. These assumptions imply a risk premium on 5 to 10 year inflation compensation of about negative 90 basis points, a value about twice as large as what prevailed one year ago. One cautionary note is that the CAPM has a mixed record of explaining risk premiums across assets and over time,

these safe haven flows would be directed mainly to nominal Treasuries, thereby depressing nominal Treasury yields and TIPS-based measures of inflation compensation. Popular measures of risk aversion, such as corporate bond spreads and the VIX, are current significantly higher than before the onset of global market volatility in August 2015. Therefore, the safe haven flow effects may have played a significant role in driving down inflation compensation since then.

In addition, certain trading dynamics may also have contributed to the outsized decline in inflation compensation. Some market participants commented that, due to the higher liquidity of longer-maturity TIPS, investors may choose to trade in those assets even though their focus is on changes in near-term inflation outlook associated with movements in oil prices and import prices, causing far forward inflation compensation to decline in line with near-term measures. Investors also pointed to increased balance sheet pressures as a factor preventing dealers from absorbing the selling pressure from TIPS funds when those funds trimmed back their holdings following significant losses over past months, amplifying declines in inflation compensation.

## 4. The implications of inflation expectations that are not well anchored

If inflation expectations cannot be taken to be well anchored, two questions arise. The first question concerns whether the declines we have seen in measures of LTIE are likely to be followed by lower rates of actual core inflation. In addressing this question, we focus on the Michigan LTIE measure—as opposed to the surveys of professional forecasters or the measures derived from asset prices—because it is likely the best proxy for the LTIE of the general public, and as such, we suspect that it is the most relevant for price- and wage-setting decisions. If the answer to this question is yes, the second question concerns the implications for monetary policy that arise from such a conclusion.

*4.1 Inflation, inflation expectations, and causality*

As noted, LTIE play a key role in the staff's analysis of inflation.[26] To the extent that the apparent stability of inflation's long-run trend does in fact reflect the stability of LTIE, then we would expect a decline in LTIE to result in a lower level of actual inflation, all else equal. Nevertheless, the staff has typically chosen not to take signal from the relatively small movements that we have seen in the Michigan LTIE measure over the

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[26] We acknowledge, however, that theory suggests price setting should depend more on short-term expectations of inflation than on longer-term expectations. However, the staff has had little success in modeling or forecasting inflation with measures of short-term inflation expectations. For further discussion, see Detmeister et al. (2014).

past two decades—and we have thus far taken only a small signal for our baseline inflation projection from the more recent declines in the Michigan measure.

The empirical importance of the Michigan LTIE measure in our estimated expectations-based Phillips curves is driven by the persistent downward movement in that measure from the early to mid-1990s, which broadly coincided with a reduction in actual core inflation. When we estimate the same models using data from the mid-1990s to present, movements in expectations display little predictive power for actual core PCE inflation.[27] Since the mid-1990s, movements in the Michigan LTIE measure have been relatively small and largely transitory, and as such, we surmise that they may not have reflected movements in whatever true expectations influence pricing. As can be seen in the upper-left panel of Figure 6, the recent decline in the Michigan measure is roughly similar in magnitude to some other movements over that time period, such as the energy-driven upward drift in the years just prior to the Great Recession; and in those earlier episodes, actual inflation by and large did not follow. Accordingly, we are putting more weight on the likelihood that we are now seeing another transitory movement in LTIE rather than a persistent movement similar in nature to what we observed in the early to mid-1990s period, and we have made only a small revision to our inflation projection in response.[28]

Although the staff framework assumes that LTIE are a key driver of inflation, it also remains possible that the influence of even a persistent movement in LTIE on actual inflation would be considerably smaller than what is implied by the staff's interpretation of inflation dynamics. In that regard, it bears remembering that Japan saw a disconnect between measures of LTIE (in this case, from surveys of professional forecasters) and actual inflation during its deflationary period in the 2000s—though in that case, expectations were relatively stable while actual inflation moved lower and turned to deflation.

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[27] Similarly, Granger causality tests over that period show the Michigan measure predicts 12-month core PCE inflation over the next two years but with a negative sign, as might be expected if Michigan long-term expectations overreact to near-term transitory shocks.

[28] We also note that the Michigan LTIE measure has run above CPI and PCE price inflation over most of the period since the early 1990s. If the recent declines in the Michigan measure reflect a reduction in consumer misperceptions, they may have little effect on actual wage and price setting behavior. While Detmeister et al. (2015) found little influence of the FOMC's announcement of an inflation objective on consumer inflation expectations, it may be that the recent decline in these expectations is the result of consumers finally learning about, or giving credibility to, the FOMC's objective. That said, Michigan expectations may normally run higher than either CPI or PCE price inflation for understandable reasons: The Michigan survey does not ask about a particular price index, and perhaps respondents do not factor in quality change as the statistical agencies do.

*4.2 Some policy implications of unanchored long-term inflation expectations*

In this section, we consider the implications of unanchored LTIE for monetary policy. We first use formal model simulations to consider the case in which expectations are not anchored and policymakers fully understand how expectations will evolve going forward. However, as the preceding discussion highlights, our understanding of how inflation expectations are formed is limited. We therefore also consider, in a less formal setting, the implications of policymaker uncertainty, and in particular, which error would be more costly: to assume that LTIE are fixed when they were actually responsive to economic conditions, or to assume that they were responsive to economic conditions when they were actually fixed.

We begin our analysis with simulations of a version of the FRB/US model that allows for direct modeling of long-term inflation expectations. We ask how monetary policy would differ from the January Tealbook baseline if, instead of being well anchored as is assumed in the Tealbook, we assume that LTIE respond adaptively to the historical experience of inflation; under current conditions this would imply a persistent downward drift in LTIE.[29]

In these scenarios, we assume that LTIE evolve over time according to

$$\pi_t^e = \pi_{t-1}^e + \gamma(\pi_{t-1} - \pi_{t-1}^e)$$

where $\pi_t^e$ is the public's longer-term inflation expectations and $\pi_{t-1}$ is lagged four-quarter core PCE inflation. This law of motion allows the current LTIE to be influenced by the inflation rate over the past year. Under fully anchored expectations, $\gamma = 0$ and expectations do not react to the experience of inflation. Not surprisingly, simple regressions using survey data from the SPF or the Michigan survey over the past 15 years suggest $\gamma$ has been very low, in the range of 0.00 to 0.05. Consistent with the recent downward movements in inflation compensation and survey measures discussed above, a risk for policymakers is that $\gamma$ may have increased and expectations have become much less anchored. In our formal analysis, we consider an alternative that assumes $\gamma = 0.45$. This value is based on recent readings from a statistical model that allows for time variations in $\gamma$ and implies movements of expected inflation that are very responsive to

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[29] These simulations were carried out using the FRB/US model, taking as given the January 2016 Tealbook baseline outlook.

recent inflation and therefore a high degree of persistence in inflation.[30] Such a change in the behavior of LTIE would be a marked break from the staff's assessment of its recent behavior and would be, qualitatively, a return to the high persistence in inflation that prevailed in the 1970s and 1980s.[31]

Figure 7 compares outcomes under this alternative assumption about LTIE with those under our baseline assumptions. In both simulations, monetary policy is set using our usual "optimal control" procedure—that is, policymakers minimize a loss function that is given by the discounted, simple average of the squared values of the inflation gap, unemployment gap and changes in federal funds rate. The black line shows the standard optimal control exercise around the Tealbook baseline. In this simulation, LTIE do not respond to the economic conditions. The alternative, the blue line, assumes adaptive expectations with $\gamma$ set equal to 0.45.

The black line in the upper-right panel of Figure 7 shows that the path of 10-year inflation expectations in the baseline is consistent with "well anchored" inflation expectations. Consequently, despite the core and headline inflation rates undershooting the target at the moment, the 10-year inflation expectations show very little fluctuations. In contrast, the blue line shows LTIE that are affected by the recent history of the lagged four-quarter inflation rate. The sensitivity of LTIE to recent low inflation readings reinforces those lower expectations, which then feed through to lower actual inflation through the Phillips curve (the bottom-right panel).

To counter these self-reinforcing dynamics, the optimal control simulation prescribes lowering the funds rate to stimulate aggregate demand, as indicated by the decline in the unemployment rate below the natural rate (bottom left), which helps push up inflation toward target. While lowering the unemployment rate further below the staff's estimate
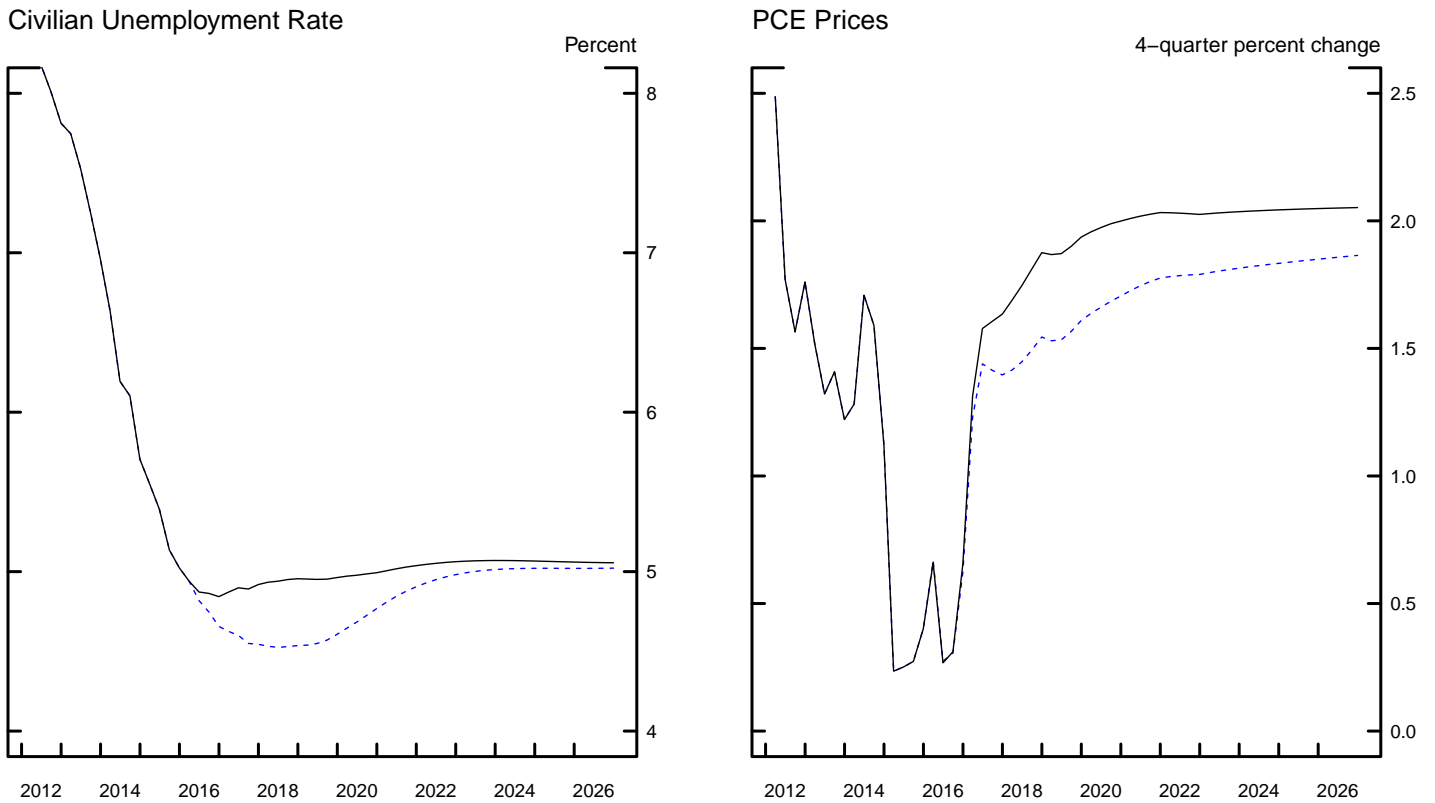
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[30] Mertens and Nason (2015) apply the statistical model of Stock and Watson (2007, 2010) to quarterly data on PCE headline inflation from 1960 to the end of 2015, allowing a time-varying dependence of trend inflation estimates on inflation data that is estimated to be 0.45 at the end of the sample. We adopt this value assuming LTIE follow similar dynamics as trend inflation.

[31] Recent work by Nalewaik (2015) attempts to assign a probability to such a shift in behavior. Nalewaik's model computes the probability that the economy is in a regime with high inflation persistence, as is implied by the higher $\gamma$. Based on the latest data on PCE inflation in 2015, the model puts that probability at 9 percent. While this estimate is up from 3 percent in 2014, it remains low and might overstate the risk substantially. Model results show the U.S. economy has not been driven into a high-persistence regime by *low* inflation in the post-WWII period, and probably not since the Great Depression, so it is unclear whether such a transition is possible outside of a severe recession. Still, whether recent economic conditions and policy responses to those conditions might lead to further climbs in the probability is an open question. Note, however, that if inflation were to remain near 1 percent for the next two years—a difference from the FOMC's 2 percent objective that policymakers would likely view as material—this model probability would not increase.

## Figure 7: Stronger Backward–Looking Inflation Expectations

Federal Funds Rate

10–Year Expected Inflation



Civilian Unemployment Rate

PCE Prices
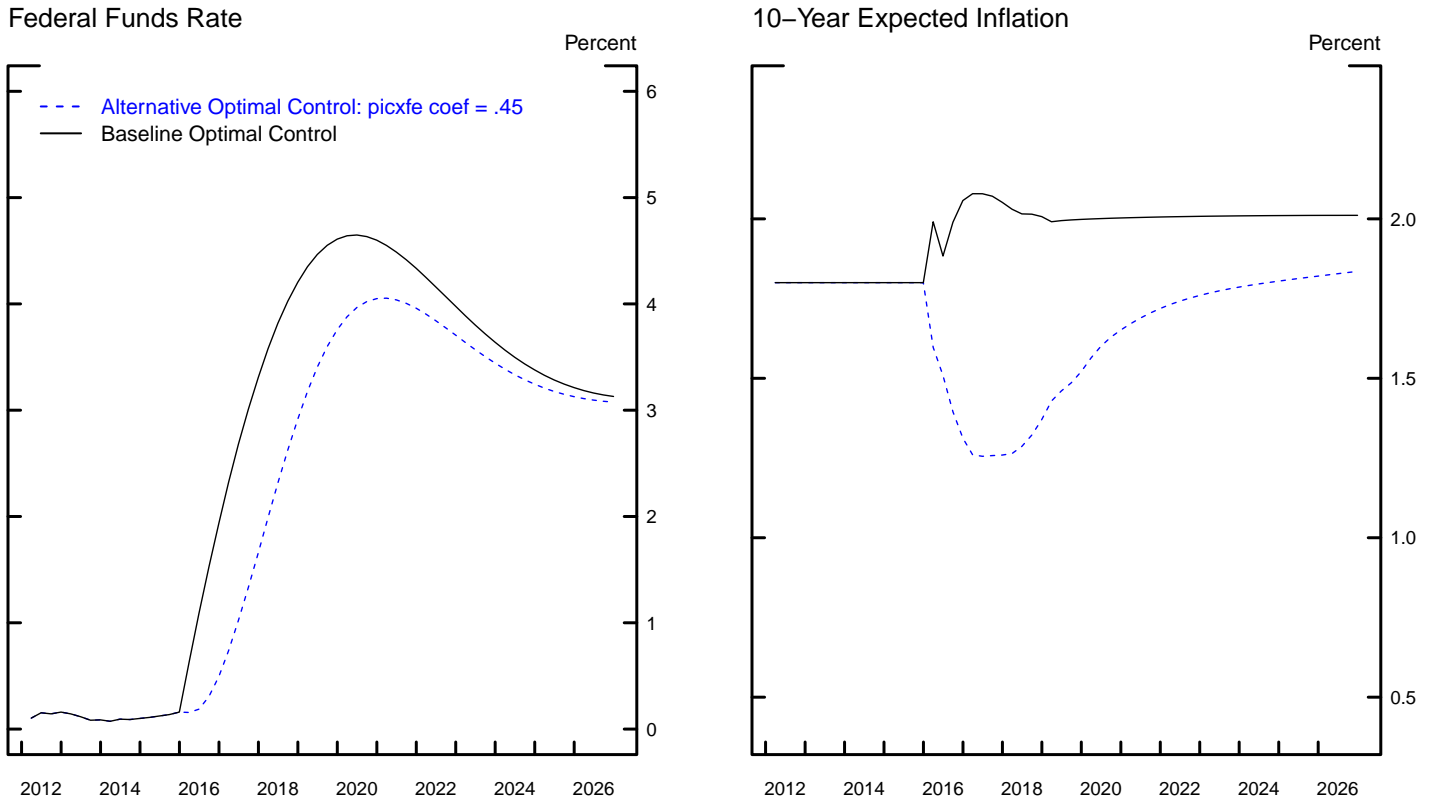


Note: The simulations begin in 2016Q1.

of the natural rate is costly, given the loss function, the policymaker has to strike a balance between the inflation gap and unemployment gap.

In this alternative simulation, policymakers correctly perceive the adaptive nature of LTIE. This is a strong assumption and given the limits of our understanding of LTIE, there could be significant misperception on the part of policymakers. We therefore next consider, in an informal way, the implications of choosing the wrong model for LTIE.

We first consider the case in which policymakers act on the assumption that longer-term inflation expectations are adaptive when they are in fact well-anchored. If policymakers believe that economic agents have adaptive expectations, they will expect inflation to fall and so will initially choose an accommodative monetary policy. Because it is based on an incorrect understanding of the LTIE process, such a policy is inappropriate and will run the risk of pushing inflation above its longer-run target. However, because inflation expectations are well-anchored, that overshooting of inflation will be temporary. Over time, policymaker perceptions will catch up with reality and policy will be tighter. Unemployment will eventually converge to the natural rate, and inflation will return to the 2 percent target.

Suppose, however, that policymakers set the fed funds rate in the belief that LTIE are well anchored, when, in reality, inflation expectations are drifting away from the Committee's target to the downside. In this case, policymakers will choose a monetary-policy stance that will turn out to be too tight. Because inflation expectations drift, the self-correcting mechanism in the first case will not be at work. At the same time, believing that expectations are well-anchored, policymakers will incorrectly ascribe the low realized inflation rate to transitory shocks. As long as this misperception continues, both LTIE and actual inflation will move down in a mutually reinforcing manner, and the effect will be persistent.

This discussion suggests that the potential costs of incorrectly assuming expectations are fixed are considerable, whereas the potential costs of assuming expectations are adaptive when they are fixed are fairly minimal. We should caution that while we gauge these conclusions to be appropriate in current circumstances, they would not be general. For example, policy implications would be different if LTIE were well-anchored at a rate that was far away from the Committee's objective. They would also be different if the recent history of inflation were directing LTIE up toward the 2 percent objective rather than away from it. We would further caution that formal modeling analysis to support the intuition summarized above is still a work in progress.

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