Monetary Policy at the Zero Lower Bound: Revelations from the FOMC's Summary of Economic Projections

George A. Kahn and Andrew Palmer

In 2012, the Federal Open Market Committee (FOMC) added the federal funds rate to its quarterly Summary of Economic Projections (SEP). As a result, in addition to providing their individual projections of inflation, unemployment, and real GDP growth up to three years into the future, participants in FOMC meetings—including Federal Reserve Board governors and Bank presidents—also began providing their projections of the associated path for the target federal funds rate. These funds rate projections are not unconditional forecasts but rather reflect each participant's view of "appropriate" monetary policy. Thus, the projections reveal how participants expect the economy to evolve conditioned on their preferred future paths of the federal funds rate. While the federal funds rate remained at its effective lower bound from 2012 to 2015, FOMC participants repeatedly projected the funds rate would rise in conjunction with projected increases in inflation and declines in unemployment.

Although the SEP's various projections of liftoff from the zero lower bound did not materialize, the SEP still provides financial markets and the public valuable information about policymakers' outlook for the economy and their views about appropriate policy. In particular, the SEP can reveal information about Committee participants' policy

George A. Kahn is a vice president and economist at the Federal Reserve Bank of Kansas City. Andrew Palmer is a research associate at the bank. This article is on the bank's website at ***www.KansasCityFed.org.***

reaction function. In this article, we use the SEP to evaluate the projected response of monetary policy to expected economic developments, compare this response to past policy actions, and assess why the actual policy path persistently differed from the projected path. We find that the relationship since 2012 between the FOMC's projections of the target funds rate and its projections of inflation and unemployment is data dependent and systematic, meaning the funds rate projections were not on a preset path. Moreover, we find that the relationship is generally consistent with the FOMC's actual policy responses prior to the onset of the zero lower bound. That the funds rate remained stuck at the effective lower bound after 2012 mainly reflects unexpectedly low inflation which was offset to some extent by a faster-than-expected decline in the unemployment rate.

Section I describes the SEP and shows how the projections of real GDP growth, unemployment, inflation, and the federal funds rate evolved over time. Section II estimates a policy reaction function relating FOMC participants' projections of the federal funds rate to their projections of inflation and unemployment and compares it to the Committee's actions before the onset of the zero lower bound. Section III decomposes the deviation of the projected funds rate from its realized level at the zero lower bound into three parts—projection "misses" for inflation and unemployment and an unexplained component.

I. Getting to Know the SEP

The SEP has its roots in the FOMC's semiannual economic reports to Congress that started in July 1979 after the Full Employment and Balanced Growth Act (commonly referred to as the Humphrey-Hawkins Act) took effect. These reports included projections of inflation, economic growth, and unemployment over various horizons, although many features of the projections—including the indicators used to measure inflation and growth—have evolved over time.[1]

The FOMC released the first SEP in the minutes of its October 2007 meeting and has since provided participants' economic projections in conjunction with four of the eight regularly scheduled FOMC meetings each year. A compilation and summary of these projections (without attribution) is circulated to participants of FOMC meetings, and a detailed summary of the economic projections is included as an

addendum to the minutes released three weeks after each meeting. The summary includes the range of participants' projections of each variable and its central tendency—defined by excluding the top and bottom three projections. Since April 2011, an advance version of the SEP table presenting the range and central tendency of the participants' projections has been released in conjunction with the Federal Reserve Chair's post-meeting press conference.

The SEP reports participants' projections of real GDP growth, headline and core inflation, and unemployment. Inflation is measured by the personal consumption expenditure (PCE) price index. Growth rates for real GDP and the price indexes are computed on a fourth-quarter-to-fourth-quarter basis. Unemployment is the fourth-quarter average civilian unemployment rate. The forecast horizon is the current and subsequent two to three years.[2]

In addition, in April 2009, the FOMC began reporting the range and central tendency of the longer-run rates of real GDP growth, headline PCE inflation, and unemployment in the SEP.[3] These longer-run projections represent "each participant's assessment of the rate to which each variable would be expected to converge … in the absence of further shocks to the economy" (Board of Governors of the Federal Reserve System). Individual participants base their projections on their own view of appropriate monetary policy.

The FOMC further enhanced the SEP in January 2012, when it began reporting projections of the federal funds rate for the end of the current year, the next two to three years, and over the longer run. These projections are presented in the so-called "dot plot," which identifies without attribution each individual participant's judgment of the appropriate level of the target federal funds rate.[4] The dot plot can provide information about how Committee members view the appropriate stance of monetary policy as it relates to the outlook for inflation, unemployment, and growth. For example, since 2012, Committee participants have consistently projected a rising path for the funds rate based on projections that inflation would rise toward the FOMC's objective and unemployment would fall. Despite these projections, the FOMC ultimately continued to target the funds rate at the range of 0 to 25 basis points it established in December 2008 and maintained until December 2015.

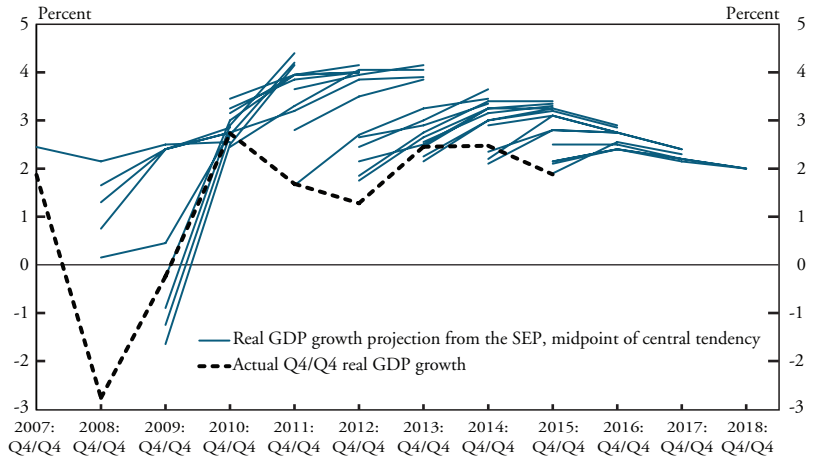
Examining the projections from the SEP shows how Committee members' outlook for growth, inflation, and unemployment led to overly optimistic projections that policy would lift off from the effective lower bound. Projections of real GDP growth, for example, have been too optimistic since the beginning of the SEP in 2007. Chart 1 shows the midpoint of the central tendency of the projections of real GDP growth over three- to four-year horizons made at FOMC meetings from 2007 to 2016.[5] Each solid line in the chart shows the projections made at a specific FOMC meeting, and the dashed line shows the actual real GDP growth rate as measured by current vintage data. For most of the period, the midpoints of the central tendencies projected faster real GDP growth than actually occurred. In general, the Committee participants missed the onset of the recession, underestimated its severity, and overestimated the speed of recovery. As the true depth of the recession was revealed in real time, many FOMC participants may have expected GDP growth to bounce back sharply as it had following previous deep recessions. Unfortunately, such a bounce back did not occur, and the Committee's optimistic projections were not realized.

With growth projected to be faster than its realization, the projections of unemployment were also too optimistic throughout the recession and early stages of recovery. As shown in Chart 2, projections of the unemployment rate made from 2007 to 2010 (solid lines) were consistently below the actual unemployment rate (dashed line). For example, in the January 2008 SEP, the midpoint of the central tendency of the unemployment rate projected for the fourth quarters of 2008, 2009, and 2010 was 5.25 percent, 5.15 percent, and 5 percent, respectively. The actual unemployment rate in those years turned out to be 6.9 percent, 9.9 percent, and 9.5 percent.

In contrast, as the recovery gained momentum, Committee participants' projections of unemployment became too pessimistic. From 2011 to 2015, the central tendencies of SEP unemployment projections were consistently above the actual realized unemployment rate (Chart 2). This divergence between the SEP's overly pessimistic outlook for unemployment and overly optimistic outlook for real GDP growth has been an ongoing conundrum for the FOMC, possibly reflecting low productivity growth, a sluggish cyclical rebound in labor force participation rates, and ongoing structural changes such as a decline in trend labor force participation.[6]

Chart 1

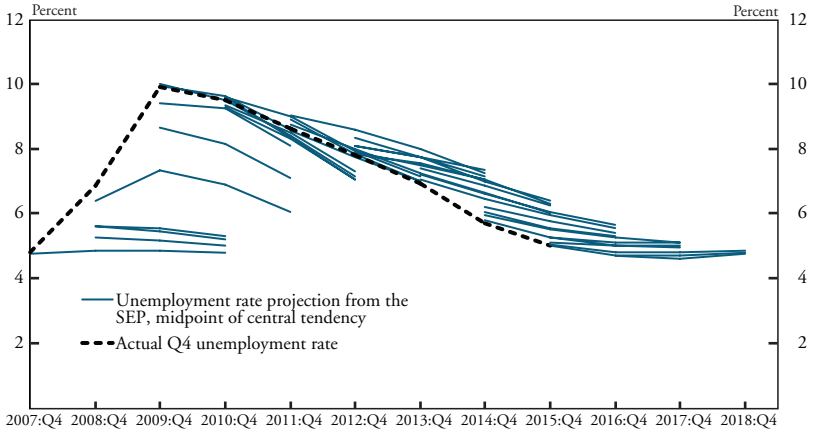
FOMC Projections of Real GDP Growth versus Actual



Sources: BEA, Federal Reserve Board, FRED, SEP, and Haver Analytics.

Chart 2

FOMC Projections of the Unemployment Rate versus Actual



Sources: BLS, Federal Reserve Board, FRED, SEP, and Haver Analytics.

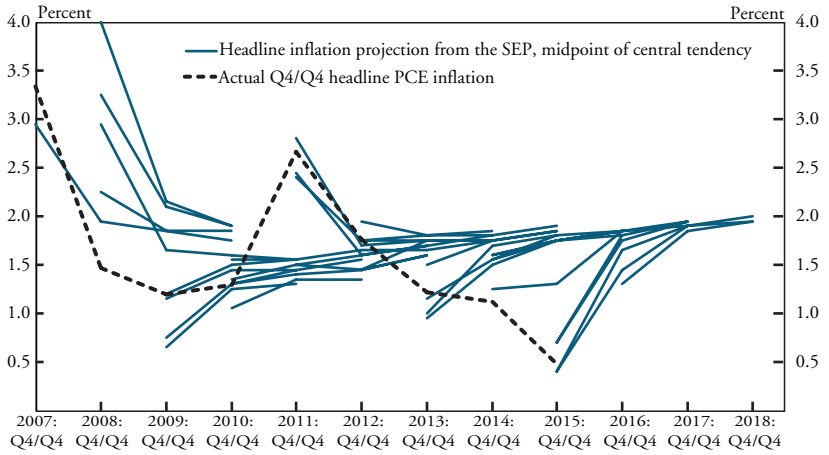
Projections of inflation have also consistently missed the mark, most likely due to unexpected fluctuations in energy prices. Chart 3 shows the midpoints of the central tendency of projected inflation, as measured by the headline PCE price index, were above the actual inflation rate in 2008 and 2009 as oil prices fell from $96 per barrel (for West Texas Intermediate) at the end of 2007 to $45 per barrel at the end of 2008. If the decline in oil prices was unexpected, it would not have been built into projections of headline inflation made in 2007 and 2008. In contrast, projected inflation was below actual inflation from 2010 to 2012 as oil prices rose from $45 per barrel at the end of 2008 to $99 per barrel at the end of 2011. Finally, projected inflation again rose above actual inflation from 2013 to 2015 as oil prices fell sharply from $99 per barrel at the end of 2011 to $37 per barrel at the end of 2015.

Projections of core PCE price inflation—which strips volatile food and energy prices from the headline measure—show a similar albeit more muted pattern. With the direct effects of oil price fluctuations removed from the headline price index, projected core inflation deviated from actual core inflation by less than the headline measures diverged (Chart 4). Nevertheless, because oil price increases to some extent pass through to the prices of other goods and services, the dramatic swings in oil prices over this period also likely contributed to the projection errors for core inflation. In addition, persistent movements in core import prices and an unusually muted response of core inflation to falling unemployment may have contributed to the overprediction of inflation.[7]

Since they were first reported in the SEP in 2012, the Committee's projections of the target federal funds rate appear to have reflected participants' projections of real GDP growth, inflation, and unemployment. Over this period, projections of real GDP growth suggested a stronger economic recovery than actually materialized. Projections of inflation generally suggested a relatively steady return to the FOMC's inflation objective of 2 percent. And while unemployment was not projected to fall as rapidly as actually occurred, the projections suggested a steady downward trajectory. As Committee participants expected inflation and labor market conditions to steadily converge on the FOMC's dual objectives of price stability and maximum employment, it is not surprising they would expect to lift the federal funds rate off its effective lower bound and move it toward its projected longer-run level. Indeed, Chart 5 shows FOMC participants repeatedly projected an upward trajectory for the funds rate

Chart 3

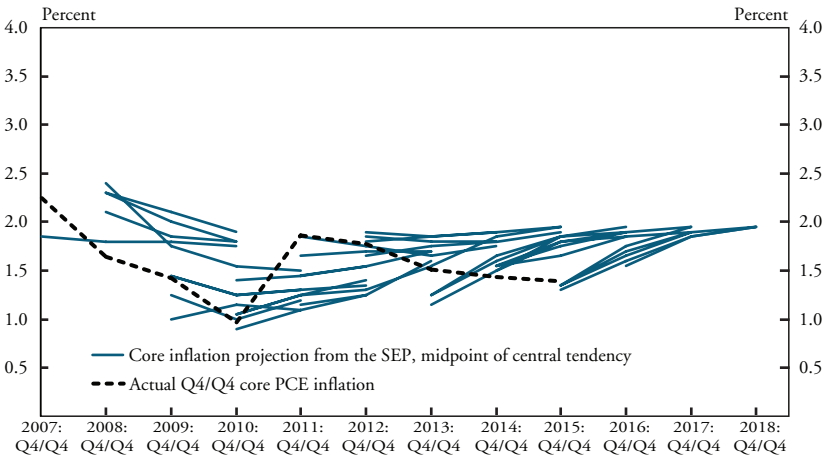
FOMC Projections of Headline PCE Inflation versus Actual



Sources: BEA, Federal Reserve Board, FRED, SEP, and Haver Analytics.

Chart 4

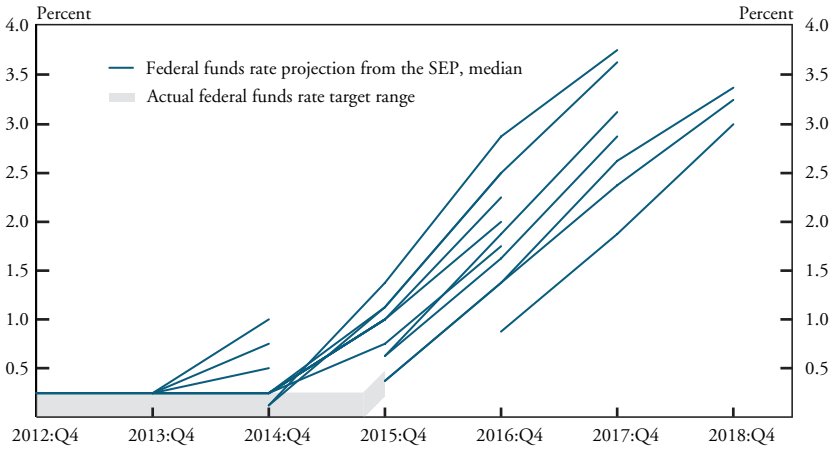
FOMC Projections of Core PCE Inflation versus Actual



Sources: BEA, Federal Reserve Board, FRED, SEP, and Haver Analytics.

Chart 5

FOMC Projections of Federal Funds Rate versus Actual



Sources: Federal Reserve Board, FRED, SEP, and Haver Analytics.

target (solid lines), while the actual funds rate remained in the 0 to 25 basis point range established in December 2008 and maintained until December 2015.

FOMC participants were not alone in projecting an upward sloping path for the funds rate. Private sector forecasts were also overly optimistic. For example, Bundick provides evidence from the federal funds futures market and the Blue Chip Economic Indicators showing that market participants and professional forecasters both expected short-term interest rates to rise after 2012. These projections, much like the Committee's, were associated with overly optimistic projections of growth and inflation.

II. Estimating the Policy Reaction Function Implied by the SEP

One way to more systematically determine the relationship between the FOMC participants' funds rate projections and their projections of inflation and unemployment is to estimate their implied policy reaction function. A reaction function provides a simple description of how policymakers generally move their policy instrument—in this case, the federal funds rate—in response to economic conditions. Although it is impossible to estimate such a reaction function from actual data over the period after 2012, as the funds rate target remained fixed at its

effective lower bound until December 2015, it is possible to estimate a reaction function based on FOMC participants' *projections* of the funds rate (which were not consistently fixed at the lower bound) and their associated projections of inflation and unemployment.[8]

Predicting the funds rate path projected in the SEP

We assume the reaction function is based on simple rules economists have proposed for setting the federal funds rate as a function of contemporaneous indicators of inflation and economic slack. However, in contrast to normative rules that spell out a prescription for monetary policy that theory would suggest best stabilizes macroeconomic activity, the reaction function used here is *estimated* and designed to describe how policymakers actually behaved. While the specification is similar to normative rules such as the Taylor rule, we estimate the parameters from projections policymakers provided in the SEP rather than deriving them from theory.[9]

We estimate the reaction function by regressing projections from the SEP of the median federal funds rate on the deviation of projected inflation from its projected long-run target and the deviation of the projected unemployment rate from its projected long-run rate (the unemployment gap).[10] The projected long-run inflation rate is a constant 2 percent, reflecting that all FOMC participants expected that, under appropriate policy, the Committee would over time achieve its stated longer-run 2 percent objective for inflation.[11] In contrast, the long-run projection for the unemployment rate fluctuated over time as the Committee reassessed the level of unemployment that would be associated with full employment and therefore consistent with its employment mandate.

The observations used in the analysis are the projections made at FOMC meetings associated with SEP reports of the median federal funds rate and the midpoints of the central tendencies of inflation and unemployment. In a number of these observations, the median projected funds rate is at or below 0.25 percent, which is taken to be the effective lower bound on nominal interest rates and a binding constraint on policymakers' ability to further reduce short-term rates.

The estimated reaction function takes the following form:

$$FFR_t^{t-i} = a + b(p_t^{t-i} - 2) + c(u_t^{t-i} - u_t^{LRt-i}) + \varepsilon_t,$$

where FFR_t^{t-i} is the projection from the SEP for the median federal funds rate in period t made in period $t-i$, p_t^{t-i} is the projected headline or core PCE price inflation in period t made in period $t-i$, u_t^{t-i} is the projected unemployment rate in period t made in period $t-i$, and u_t^{LRt-i} is the projected long-run unemployment rate made in period $t-i$.[12] Period t refers to the projection of the end-of-year funds rate, the Q4/Q4 inflation rate, and the fourth quarter unemployment rate. Period $t-i$ refers to the quarter in which the projection was made. For example, for projection horizon t = 2015:Q4, $t-i$ indexes quarterly SEP reports from the third quarter of 2012 to the fourth quarter of 2015.[13]

The coefficients, a, b, and c, are estimated using a statistical model that accounts for the censoring of observations at the effective lower bound.[14] The constant, a, represents the equilibrium nominal funds rate—that is, the funds rate projected to be consistent with inflation at its longer-run target and the economy at full employment. The coefficients on the other variables represent the projected response of the target federal funds rate to projected changes in inflation and the unemployment gap. The residual term, ε_t, captures all other influences on the projected funds rate and is assumed to have zero mean and finite variance.[15]

The estimated coefficients indicate that the median of federal funds rate projections responded strongly to projected increases in inflation and declines in unemployment. In Table 1, column 1 provides coefficient estimates for a reaction function with headline inflation as the measure of inflation, and column 2 provides estimates with core inflation. These coefficients are both statistically significant and above one, indicating that, other things equal, an increase in projected inflation—either headline or core—is associated with a greater than one-for-one increase in the projected nominal federal funds rate.[16] In most macroeconomic models, this property is critical for the stabilization of inflation around its longer-run target.

In addition, the coefficient on headline inflation is smaller than the coefficient on core inflation. This is not surprising. Policymakers likely projected a more subdued response to fluctuations in headline inflation because headline inflation is subject to more volatility from temporary energy price shocks than core inflation. Policymakers would likely have looked through this short-run volatility as they planned a trajectory for the federal funds rate.

Table 1

Estimated Policy Reaction Functions Using Projections from the SEP

	Baseline federal funds rate projection		"Dovish" federal funds rate projection		"Hawkish" federal funds rate projection	
	(1)	(2)	(3)	(4)	(5)	(6)
Reaction function with:	Headline inflation	Core inflation	Headline inflation	Core inflation	Headline inflation	Core inflation
Inflation gap projection	1.589***	3.829***	1.552***	3.723***	1.991***	4.516***
	(0.231)	(0.419)	(0.285)	(0.441)	(0.557)	(0.883)
Unemployment gap projection	-1.551***	-1.459***	-2.090***	-2.184***	-1.153***	-1.090***
	(0.162)	(0.138)	(0.393)	(0.219)	(0.181)	(0.0935)
Constant	2.376***	2.710***	2.142***	2.649***	2.886***	3.041***
	(0.130)	(0.128)	(0.112)	(0.136)	(0.120)	(0.135)
Regression standard error	0.600***	0.502***	0.468***	0.375***	0.771***	0.593***
	(0.0700)	(0.0574)	(0.0466)	(0.0264)	(0.103)	(0.0656)
Pseudo-R^2	0.5394	0.6393	0.6844	0.7971	0.3894	0.5340
Left-censored observations	24	24	28	28	16	16
Uncensored observations	38	38	34	34	46	46

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Notes: Standard errors are in parentheses. Estimates are from a Tobit regression using projections from the January 2012 to March 2016 SEPs, censoring observations for which the federal funds rate projection was at or below 0.25 percent. The baseline regressions use the median of the federal funds rate projection with the midpoints of the central tendency of projections of inflation, unemployment, and longer-run unemployment. The "dovish" regressions use the minimum of the central tendency of projections of the federal funds rate and inflation with the maximum of the central tendency of projections of unemployment and longer-run unemployment. The "hawkish" regressions use the maximum of the central tendency of projections of the federal funds rate and inflation with the minimum of the central tendency of projections of unemployment and longer-run unemployment.

Not only do the projections show a strong response of the funds rate to inflation, they also show a strong response to unemployment. The estimated coefficient on the projected unemployment gap is negative and significant, indicating the funds rate was projected to increase as the unemployment rate was projected to fall.[17]

Finally, the magnitude of the constant term—an estimate of the projected equilibrium federal funds rate—is consistent with the FOMC's policy statements indicating "the federal funds rate is likely to remain, for some time, below levels that are expected to prevail in the longer run." The constant is estimated at 2.4 percent for the specification with headline inflation and 2.7 percent for the specification with core inflation. In contrast, the median of the longer-run federal funds rate was projected to be 3.25 percent in the March 2016 SEP, down from 4.25 percent in the first two SEP reports in 2012. If FOMC participants lowered their estimates of longer-run productivity growth, their estimates of the longer-run federal funds rate may also have fallen (Laubach and Williams). Moreover, persistent headwinds—including ongoing adjustments from the financial crisis—may have kept the projected funds rate below its longer-run projection even when unemployment and inflation projections reached their mandate-consistent levels.

As a robustness check, Table 1 also provides estimates of the policy reaction function using the minimum (Columns 3 and 4) and maximum (Columns 5 and 6) of the central tendencies of the SEP projections of the federal funds rate instead of the midpoint. Specifically, we regress the maximum federal funds rate projection on the maximum inflation projection and the minimum unemployment projection under the assumption that the tightest policy projection—a "hawkish" policy—would be associated with the highest projected inflation and lowest unemployment. Similarly, we regress the minimum federal funds rate projection on the minimum inflation and maximum unemployment projection under the assumption that the most accommodative policy path—a "dovish" policy—would be associated with the lowest projected inflation and highest unemployment.

As the table shows, the coefficients in the policy reaction function are somewhat sensitive to whether the regression is based on the median, minimum, or maximum funds rate projections. For example, the coefficients on core and headline inflation are somewhat higher for the

hawkish projection relative to the baseline or dovish projections. In contrast, the coefficients on the unemployment rate are more negative in the regression for the dovish projection relative to the baseline or hawkish projection. This may suggest FOMC participants who are more dovish in the sense of preferring a lower projected path for the funds rate place more weight on unemployment in making their projections, whereas participants who are more hawkish in the sense of preferring a higher projected path for the fund rate place a greater weight on inflation.

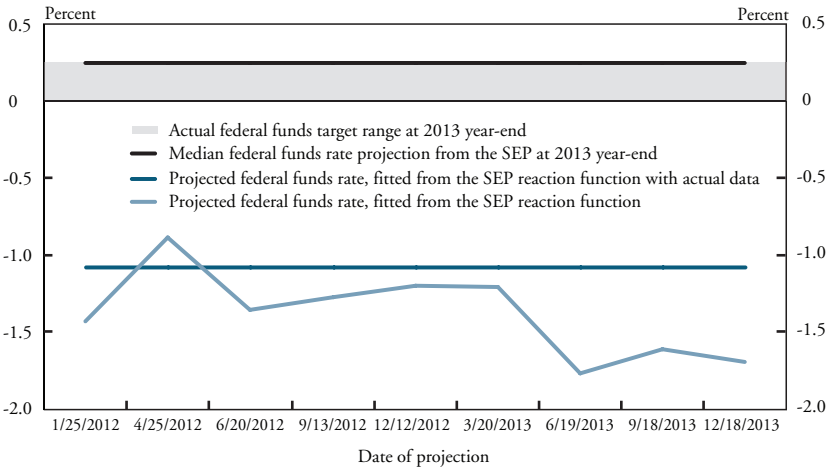
Comparing the projected funds rate path to prescriptions from the SEP reaction function

Comparing the median of the funds rate projected by FOMC participants to the federal funds rate predicted by the baseline SEP reaction function sheds additional light on how systematically the funds rate projection responded to economic conditions. Charts 6, 7, and 8 make this comparison using the reaction function with headline inflation. The black lines represent the median of the federal funds rate projected at various FOMC meetings for the end of 2013 (Chart 6), 2014 (Chart 7), and 2015 (Chart 8).[18] The light blue lines represent the predicted value of the funds rate at the end of the same years based on prescriptions from the SEP reaction function associated with each SEP meeting. For completeness, the gray bands show the range for the funds rate the FOMC actually targeted (which remained constrained by the effective lower bound until December 2015), and the dark blue lines show the end-of-year funds rate predicted by the SEP reaction function with the actual fourth-quarter inflation and unemployment rates substituted for their projected rates.

Chart 6 shows that the predictions from the SEP reaction function for the federal funds rate at the end of 2013 made at FOMC meetings in 2012 and 2013 (light blue line) were consistently negative. Moreover, as the outlook for inflation was revised down in 2013 and projections of unemployment indicated only gradual improvement, the SEP reaction function began predicting increasingly negative target funds rates. Based on the actual fourth-quarter inflation and unemployment rates, the SEP reaction function would have called for a somewhat higher funds rate target of about negative 1.1 percent (dark blue line). However, with the nominal funds rate constrained by the zero lower

Chart 6

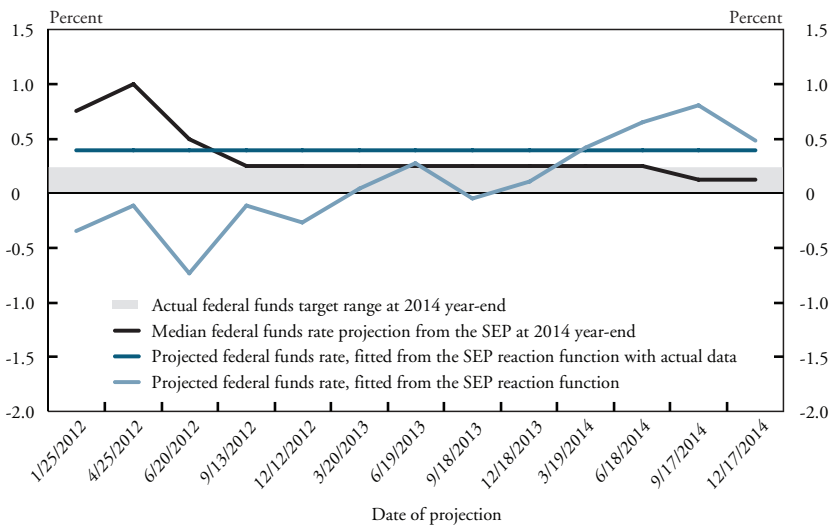
Projected, Fitted, and Actual Federal Funds Rate at the End of 2013



Notes: The light blue line shows the predicted federal funds rate from the estimated SEP reaction function using specification (1) from Table 1. The dark blue line shows the predicted federal funds rate from the same specification fitted with the actual Q4 unemployment rate and Q4/Q4 headline inflation for the projection year.
Sources: BEA, BLS, Federal Reserve Board, FRED, SEP, Haver Anaytics, and authors' calculations.

Chart 7

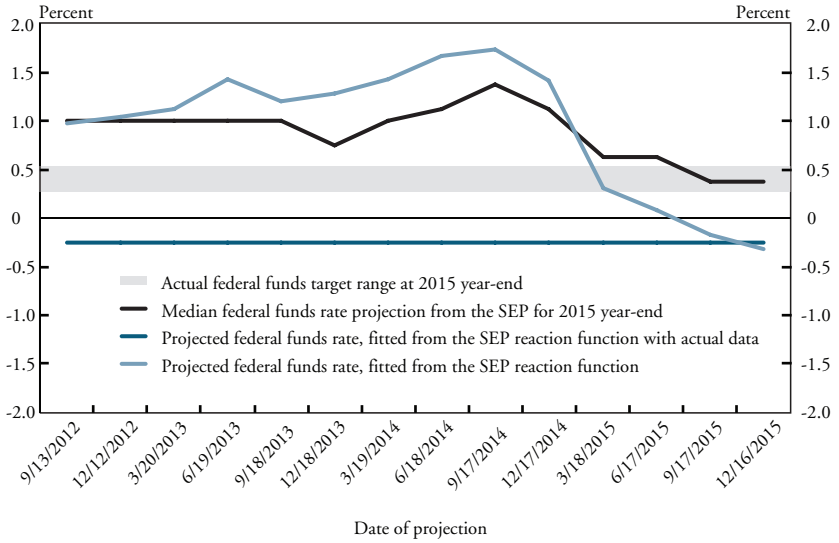
Projected, Fitted, and Actual Federal Funds Rate at the End of 2014



Notes: The light blue line shows the predicted federal funds rate from the estimated SEP reaction function using specification (1) from Table 1. The dark blue line shows the predicted federal funds rate from the same specification fitted with the actual Q4 unemployment rate and Q4/Q4 headline inflation for the projection year.
Sources: BEA, BLS, Federal Reserve Board, FRED, SEP, Haver Anaytics, and authors' calculations.

Chart 8

Projected, Fitted, and Actual Federal Funds Rate at the End of 2015



Notes: The light blue line shows the predicted federal funds rate from the estimated SEP reaction function using specification (1) from Table 1. The dark blue line shows the predicted federal funds rate from the same specification fitted with the actual Q4 unemployment rate and Q4/Q4 headline inflation for the projection year.
Sources: BEA, BLS, Federal Reserve Board, FRED, SEP, Haver Anaytics, and authors' calculations.

bound, the median projection of the funds rate remained fixed at 0.25 percent (black line). The same pattern (not shown) is observed if the funds rate is predicted on the basis of the SEP reaction function using core inflation rather than headline inflation, although the prescription for the funds rate falls much further to almost –3 percent.

Chart 7 shows that projections of the median funds rate at the end of 2014 differed significantly from what the SEP reaction function predicts. The median of the SEP federal funds rate projections (black line) rose from 75 basis points at the January 2012 FOMC meeting to 100 basis points at the April 2012 meeting. The median projection then fell in June and fell again in September 2012 as the funds rate hit its effective lower bound. It remained there through December 2014. In contrast, the SEP reaction function (light blue line) prescribes a gradual increase in the median funds rate from a low of –75 basis points at the June 2012 meeting to a high of +81 basis points at the September 2014 meeting before declining to 49 basis points at the end of 2014. Based on actual fourth-quarter data for inflation and unemployment, the SEP reaction function would have called for a funds rate of 43 basis points

at the end of the year. The version of the reaction function with core inflation (not shown) more closely captures the downward movement in the prescribed funds rate through December 2013 but then diverges. By the December 2014 meeting, the reaction function calls for a funds rate of roughly 1 percent compared with the SEP projection of 13 basis points.

Chart 8 shows the prescriptions from the SEP reaction function for the funds rate at the end of 2015 more closely match the midpoint of the SEP federal funds rate projections made at FOMC meetings from 2012 to 2015. While the SEP reaction function called for a somewhat higher funds rate than the SEP projections through September 2014, neither measure showed much movement. But in December 2014, both measures began to decline back toward the effective lower bound, with the prescriptions from the SEP reaction function falling faster than the median funds rate projection. Based on actual fourth-quarter inflation and unemployment, the SEP reaction function prescribed a funds rate of –0.25 percent. A similar pattern is apparent for the SEP reaction function based on core PCE inflation (not shown).

Comparing the SEP reaction function to a historical reaction function

A key question is whether the SEP reaction function represents a shift in the Committee's thinking about how it should respond to changes in the economic outlook as it contemplated liftoff from the effective lower bound. Perhaps surprisingly, the answer appears to be no. The estimated coefficients from the SEP reaction function are similar to coefficients from a reaction function estimated over the period before the constraint of the zero lower bound. Table 2 shows results from a regression of the target federal funds rate on real-time estimates of the inflation gap and the unemployment gap from 1987:Q1 to 2007:Q4. The inflation gap is measured as the difference between real-time estimates of headline inflation as measured by the PCE price index and an implicit 2 percent target. The unemployment gap is measured as the difference between the real-time unemployment rate and an estimate of its natural rate. Real-time estimates of the natural rate come from the Federal Reserve Board staff estimates of the natural rate published in the Greenbook—the briefing document Board staff used at the time to describe its macroeconomic forecast to the FOMC. Because these real-time estimates are only available starting in 1989:Q1, the natural

Table 2
Estimated Policy Reaction Function Using Real-Time Historical Data

Variables	Actual federal funds rate target 1987:Q1–2007:Q4
Real-time headline inflation gap	1.349*** (0.120)
Real-time unemployment gap	-1.728*** (0.277)
Constant	4.031*** (0.235)
R^2	0.7814
Observations	84

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Notes: Standard errors are in parentheses. The estimation uses Newey-West standard errors with a lag of 4. The federal funds rate is regressed on a constant, the deviation of real-time data on headline inflation—measured by the personal consumption expenditure price (PCE) index—from 2 percent and the deviation of the real-time unemployment rate from real-time estimates of the natural rate. Real-time estimates of the natural rate come from Federal Reserve Board staff estimates in the Greenbook. For the period before 1989, in which similar real-time estimates are not available, the natural rate is held at a constant 5.75 percent, the same as the estimate for 1989:Q1. Sources: BEA, BLS, Federal Reserve Board, FRED, Philadelphia Fed, Haver Analytics, and authors' calculations.

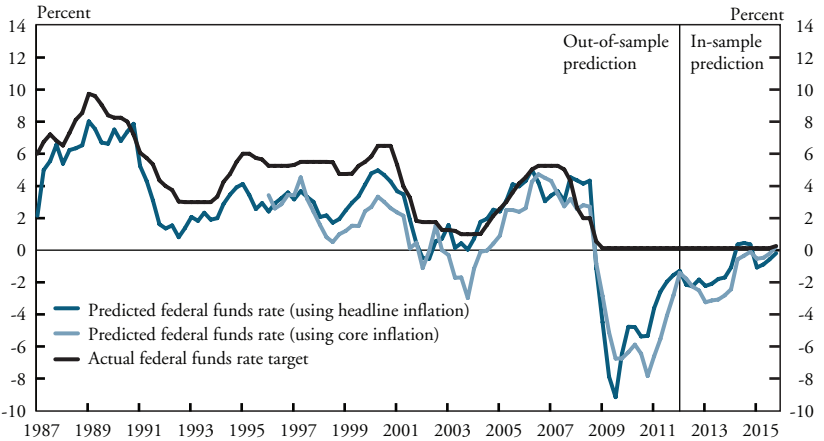
rate from 1987:Q1 to 1988:Q4 is assumed constant at its 1989:Q1 estimate of 5.75 percent.

Comparing the baseline SEP reaction function with the real-time historical reaction function shows that FOMC participants projected a trajectory for the federal funds rate in a manner not unlike their actual responses before the zero lower bound became a binding constraint. Table 2 shows the coefficient on the inflation gap in the historical policy reaction function (1.3) is close to the coefficient on inflation in the SEP reaction function (1.6). In addition, the coefficient on the unemployment gap is slightly more negative in the historical reaction function than in the SEP reaction function. Finally, the constant term of roughly 4 percent indicates a higher estimate of the historical equilibrium federal funds rate equal to the one John Taylor proposed in his original specification of the Taylor rule.[19]

One way to visualize the difference between the historical actions of the FOMC and the policy reaction function implied by the SEP is to consider a counterfactual scenario. In the counterfactual, we use the SEP reaction functions (using headline and core inflation) to "predict" the federal funds rate over the 1987 to 2008 period before the zero lower bound on interest rates became a constraint on policy. We can then compare the predicted funds rate with the actual funds rate. Chart

Chart 9

Federal Funds Rate Target: Actual versus Projections from the SEP



Notes: We generate the predicted federal funds rate paths using the reaction function coefficients estimated in specifications (1) and (2) from Table 1. These estimations use the median SEP projection for the federal funds rate and the midpoint of the central tendency for the unemployment rate, long-term unemployment rate, and both headline (dark blue line) and core (light blue line) inflation. The estimated regression is then fitted to the real-time historical data on unemployment and inflation. We piece together real-time estimates of the natural rate of unemployment from two sources. From 1989:Q1 to 2008:Q4, we use Federal Reserve Board staff estimates of the natural rate from the Greenbook; from 2009:Q1 to 2016:Q1, we use projections of the longer-term unemployment rate from the SEP. For the period before 1989, in which real-time estimates are not available from the Greenbook, the natural rate is held at a constant 5.75 percent, the same as the estimate for 1989:Q1. Predictions using core inflation begin in 1996, the first year for which real-time estimates of core inflation are available.
Sources: BEA, BLS, Federal Reserve Board, FRED, Philadelphia Fed, SEP, Haver Analytics, and authors' calculations.

9 shows the prediction from the SEP reaction function over the entire period using the same actual, real-time data for inflation and the unemployment gap used in Table 2. The dark blue line shows predictions based on the SEP reaction function with headline inflation, the light blue line shows predictions based on core inflation, and the black line shows the actual federal funds rate target. (The predictions based on core inflation begin in 1996, as that is the first year for which real-time estimates of the core PCE inflation rate are available.)

The SEP reaction function closely mirrors the actual federal funds rate target from roughly 2001 through 2015. Not surprisingly, for most of the in-sample period from 2012 to 2015, the SEP reaction function calls for a zero or negative funds rate. But the SEP reaction function also closely matches the actual funds rate in the out-of-sample period, at least from 2001 to 2012. During this period, the SEP reaction function prescribes a positive funds rate similar to the actual rate when the actual rate is above the effective lower bound and prescribes a negative

funds rate when the actual funds rate is at the effective lower bound. Of greater interest is the period from 2001 to 2007, when the SEP reaction function also traces the actual path of the funds rate (especially in the specification with headline inflation). This is a period in which the actual funds rate fell to 1 percent, well below the rate normative policy rules, such as the Taylor 1993 rule, prescribed. Some commentators have argued that monetary policy was overly accommodative during this period, especially from 2003 to 2006, and thereby contributed to the financial crisis and Great Recession.[20] If policy was indeed overly accommodative in this period, then it would be cause for concern that policy since 2012 as described by the SEP reaction function could also be too accommodative.

Over the period from 1985 to 2001, the projections from the SEP reaction function diverge from the actual target federal funds rate. For most of this period, the SEP reaction functions prescribe a lower federal funds rate than was realized. Given that this period—the so-called Great Moderation—is considered a period of good macroeconomic performance, it may again be cause for concern that the implied SEP reaction function does not more closely mimic the earlier response of policymakers to inflation and unemployment.[21]

III. Decomposing the Projection Errors in the SEP

Why did the FOMC repeatedly project a liftoff from the zero lower bound that failed to materialize? Using the estimated SEP reaction function, we decompose the missed projections into three components. The first component is the projection error for inflation times the coefficient on inflation in the estimated SEP reaction function. The second component is the projection error for the unemployment gap times the coefficient on the unemployment gap in the SEP reaction function. And the third component is the unexplained difference between the actual federal funds rate and the prescription from the SEP reaction function.

In determining the first two components, we compute the difference between the funds rate prescriptions from the reaction function based on "perfect foresight" of the future paths of inflation and unemployment and the funds rate prescriptions from the reaction function based on the SEP projections of inflation and unemployment. More technically, the perfect foresight prescription is defined under the assumption that the SEP reaction function represents the Committee's

systematic response to inflation and unemployment. It prescribes the funds rate the Committee might have chosen had it known the actual paths of future inflation and the unemployment gap. The resulting estimate of the perfect foresight funds rate target is determined as follows:

$$FFR_t^{PF} = \hat{a} + \hat{b}(p_t - 2) + \hat{c}(u_t - u_t^{LRt}) + \varepsilon_t,$$

where FFR_t^{PF} is the perfect foresight prescription for federal funds rate in period t, p_t and u_t are the actual inflation and unemployment rates in period t, ε_t is the residual term from the policy reaction function, and $\hat{a}$, $\hat{b}$, and $\hat{c}$ are the estimated coefficients from Table 1. The difference between the perfect foresight federal funds rate prescription and the projected federal funds rate is as follows:

$$FFR_t^{PF} - FFR_t^{t-i} = \hat{b}(p_t - p_t^{t-i}) + \hat{c}(u_t - u_t^{t-i} - u_t^{LRt} + u_t^{LRt-i}).$$

In addition, the difference between the actual funds rate and the perfect foresight funds rate is the component unexplained by the estimated policy reaction function. Thus, the difference between the actual federal funds rate target at time t, FFR_t, and the projected funds rate target at time $t–i$ can be decomposed as follows:

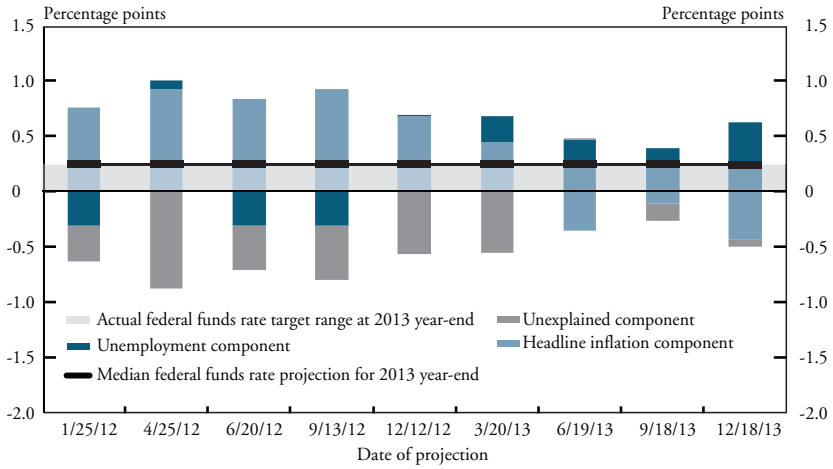
$$FFR_t - FFR_t^{t-i} = \hat{b}(p_t - p_t^{t-i}) + \hat{c}(u_t - u_t^{t-i} - u_t^{LR} + u_t^{LRt-i}) + \mu_t,$$

where μ_t is the unexplained component.

The decomposition shows that the repeated overestimation of inflation in the SEP was the primary contributor to projections that the federal funds rate would move off its effective lower bound. Missed projections of unemployment and unexplained deviations from the SEP reaction function played a smaller role. Charts 10, 11, and 12 show the decomposition of projection errors for the federal funds rate for 2013, 2014, and 2015, respectively. The decomposition is based on the SEP reaction function using headline inflation, but the results are qualitatively similar to those with the reaction function using core inflation. The light blue bars represent the inflation component of the projection error, the dark blue bars represent the unemployment gap component, and the gray bars represent the unexplained component. Together, these three components add up to the difference between the projected federal funds rate in the SEP—shown by the black lines—and the midpoint of the actual federal funds rate target range (13 basis points)—shown by the gray band.

Chart 10

Decomposition of 2013 Federal Funds Rate Projection Errors from the SEP



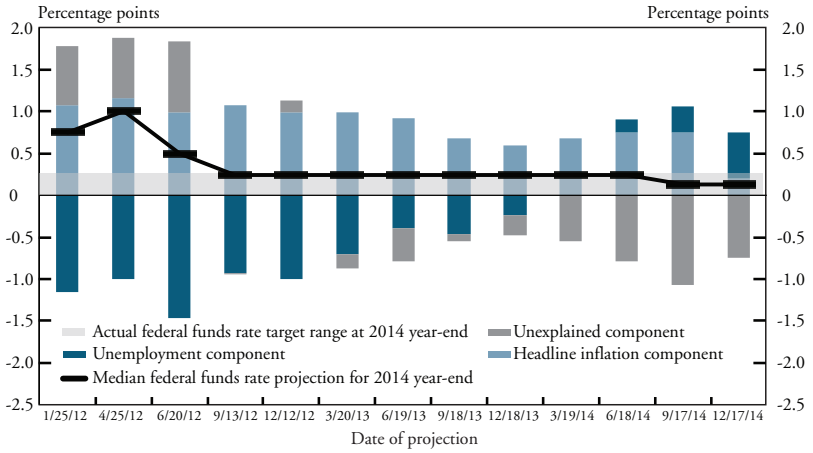
Note: We construct inflation and unemployment components as the difference between their projected and actual values multiplied by their respective coefficients in the estimated SEP reaction function (Table 1). The unexplained component is the difference between the actual federal funds rate and prescriptions from the estimated SEP reaction function with actual data (perfect foresight prescription).
Sources: BEA, BLS, CBO, Federal Reserve Board, FRED, SEP, Haver Analytics, and authors' calculations.

Chart 10 shows projections of the federal funds rate at the end of 2013 made at FOMC meetings from January 2012 to December 2013 at which the Committee issued a SEP report. At all of these meetings, the median funds rate projected in the SEP turned out to equal the upper end of the target range rate actually set by the FOMC at the end of 2013. Throughout 2012, overestimates of the inflation component were offset by underestimates of the unemployment component and a negative unexplained component. In contrast, in 2013, overestimates of the unemployment component were offset by underestimates of the inflation component and a negative unexplained component.

Chart 11 shows projections of the federal funds rate at the end of 2014 made at FOMC meetings from January 2012 to December 2014. For all of these projections, inflation was overestimated, tending to make the projected federal funds rate higher than otherwise would be the case. To a varying extent, these inflation projection errors were offset by projections of unemployment that proved to be too pessimistic from January 2012 to December 2013. These projection errors combined to lead to projected funds rates of 50 to 100 basis points

Chart 11

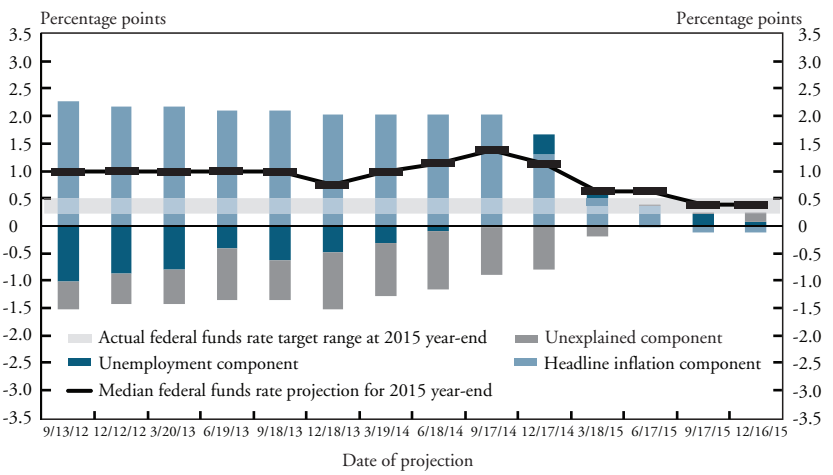
Decomposition of 2014 Federal Funds Rate Projection Errors from the SEP



Note: We construct inflation and unemployment components as the difference between their projected and actual values multiplied by their respective coefficients in the estimated SEP reaction function (Table 1). The unexplained component is the difference between the actual federal funds rate and prescriptions from the estimated SEP reaction function with actual data (perfect foresight prescription).
Sources: BEA, BLS, CBO, Federal Reserve Board, FRED, SEP, Haver Analytics, and authors' calculations.

Chart 12

Decomposition of 2015 Federal Funds Rate Projection Errors from the SEP



Note: We construct inflation and unemployment components as the difference between their projected and actual values multiplied by their respective coefficients in the estimated SEP reaction function (Table 1). The unexplained component is the difference between the actual federal funds rate and prescriptions from the estimated SEP reaction function with actual data (perfect foresight prescription).
Sources: BEA, BLS, CBO, Federal Reserve Board, FRED, SEP, Haver Analytics, and authors' calculations.

at FOMC meetings in January, April, and June 2012. However, by the September 2012 FOMC meeting, participants were correctly projecting the federal funds rate target within the range they ultimately targeted, with the various components of the projection error roughly offsetting each other.

Finally, Chart 12 shows projections of the federal funds rate at the end of 2015 made at FOMC meetings from September 2012 to December 2015. Again, for almost all of the projections, inflation was overestimated, contributing to the overestimate of the projected federal funds rate. The unemployment gap component played a relatively small role, while the unexplained component pushed the projected federal funds rate down over most of the period.

IV. Conclusions

The Summary of Economic Projections provides insights into FOMC participants' views on how the federal funds rate target should respond to inflation and unemployment. Although the projections in the SEP have proved to be consistently wrong—as have most projections of the future—they do provide information about the FOMC's implicit reaction function. For example, they show a systematic, planned response of the federal funds rate target to projected increases in inflation and projected declines in unemployment. Moreover, the estimated response function is similar to how policy responded to inflation and unemployment from 2001 to December 2008, when policy became constrained by the zero lower bound.

The estimated policy reaction function can also help explain why the SEP repeatedly got both the date of liftoff and the trajectory of the federal funds rate wrong. Taking into account not only projection errors for inflation and unemployment but also the SEP reaction function's estimate of the Committee's systematic response to inflation and unemployment, it is clear that the Committee's anticipated response to projected increases in inflation was the primary factor responsible for the missed projections.

Looking ahead, it will be interesting to see if the estimated SEP reaction function continues to describe the relationship between projections of the federal funds rate and projections of inflation and unemployment in future SEP reports. In any event, additional SEP reports will be useful in understanding how the Committee thinks about adjusting policy to achieve its dual mandate.

Appendix

Table A-1

Estimated Policy Reaction Functions Using Projections from the SEP by Forecast Horizon (OLS)

	One-year-ahead projections		Two-year-ahead projections		Three-year-ahead projections	
	(1)	(2)	(3)	(4)	(5)	(6)
Reaction function with:	Headline inflation	Core inflation	Headline inflation	Core inflation	Headline inflation	Core inflation
Inflation gap projection	1.177**	1.874	6.685***	4.516	6.216*	6.592
	(0.324)	(1.105)	(1.968)	(2.827)	(2.813)	(6.698)
Unemployment gap projection	-1.173***	-1.360**	-0.820***	-1.053***	-2.141***	-2.543***
	(0.272)	(0.463)	(0.191)	(0.215)	(0.378)	(0.414)
Constant	1.763***	1.871***	3.173***	2.816***	3.292***	3.208***
	(0.117)	(0.297)	(0.280)	(0.350)	(0.274)	(0.485)
R^2	0.810	0.590	0.850	0.763	0.934	0.890
Observations	9	9	16	16	8	8

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Notes: Standard errors are in parentheses. The estimation uses projections from the January 2012 SEP to the March 2016 SEP with Newey-West standard errors with a lag of 4 and excludes projections for which the median federal funds rate is at or below 0.25 percent. There is no regression for same-year projections, since there are not sufficient observations with the median federal funds rate projection above 0.25 percent. The estimation uses the midpoint of the central tendency of SEP projections for inflation, unemployment, and long-run unemployment, and the median projections for the federal funds rate.

Sources: The Federal Reserve Board, FRED, and authors' calculations.

Table A-2

Estimated Policy Reaction Functions Using Projections from the SEP by Forecast Horizon (Tobit)

	One-year-ahead projections		Two-year-ahead projections		Three-year-ahead projections	
	(1)	(2)	(3)	(4)	(5)	(6)
Reaction function with:	Headline inflation	Core inflation	Headline inflation	Core inflation	Headline inflation	Core inflation
Inflation gap projection	1.204***	1.922**	6.764***	3.697	6.216**	6.592
	(0.256)	(0.853)	(1.852)	(2.578)	(2.224)	(5.295)
Unemployment gap projection	-1.264***	-1.404***	-0.929***	-1.235***	-2.141***	-2.543***
	(0.151)	(0.299)	(0.173)	(0.187)	(0.299)	(0.327)
Constant	1.766***	1.881***	3.177***	2.715***	3.292***	3.208***
	(0.0944)	(0.233)	(0.264)	(0.322)	(0.217)	(0.384)
Regression standard error	0.130***	0.191***	0.382***	0.487***	0.280***	0.360***
	(0.0303)	(0.0446)	(0.0684)	(0.0872)	(0.0700)	(0.0901)
Pseudo-R^2	1.2587	1.0988	0.6708	0.5250	0.9026	0.7348
Left-censored observations	9	9	2	2	0	0
Uncensored observations	9	9	16	16	8	8

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Notes: Standard errors are in parentheses. The estimation uses a Tobit regression model, censoring projections for which the median federal funds rate forecast was at or below 0.25 percent. The estimation uses the midpoint of the central tendency of SEP projections for inflation, unemployment, and long-run unemployment, and the median projection for the federal funds rate.
Sources: The Federal Reserve Board, FRED, and authors' calculations.

Table A-3

Estimated Policy Reaction Functions Using Projections from the SEP by Forecast Horizon with Fixed Effects

	Baseline projection		"Dovish" projection		"Hawkish" projection	
	(1)	(2)	(3)	(4)	(5)	(6)
Reaction function with:	Headline inflation	Core inflation	Headline inflation	Core inflation	Headline inflation	Core inflation
Inflation gap (two-year horizon)	6.726*** (1.397)	3.724* (1.956)	2.873*** (0.659)	3.886*** (1.058)	2.664*** (0.898)	-4.591 (4.254)
d0*inflation gap	-6.637*** (1.437)	-4.066 (2.622)	-2.522*** (0.749)	-3.928 (2.465)	-2.554** (1.011)	4.751 (4.508)
d1*inflation gap	-5.450*** (1.505)	-1.514 (2.463)	-1.485* (0.761)	-2.140 (1.767)	-- --	8.272* (4.355)
d3*inflation gap	-0.510 (2.683)	2.868 (5.774)	0.789 (1.153)	1.184 (2.488)	-- --	-- --
Unemployment gap (two-year horizon)	-0.914*** (0.130)	-1.213*** (0.141)	-1.681*** (0.335)	-2.137*** (0.360)	-0.860*** (0.140)	-0.847*** (0.132)
d0*unemployment gap	-0.732 (0.731)	-0.686 (1.074)	-0.0395 (0.751)	0.505 (0.994)	-1.877 (1.195)	-1.870 (1.325)
d1*unemployment gap	-0.553* (0.318)	-0.408 (0.467)	0.162 (0.509)	0.533 (0.603)	0.0490 (0.185)	0.0578 (0.170)
d3*unemployment gap	-1.227*** (0.334)	-1.330*** (0.364)	-0.388 (0.435)	-0.403 (0.471)	0.0553 (0.387)	0.0420 (0.362)
Constant (two-year horizon)	3.172*** (0.199)	2.719*** (0.244)	2.507*** (0.191)	2.649*** (0.264)	3.118*** (0.126)	3.137*** (0.120)
d0*constant	-2.466*** (0.483)	-2.331** (1.097)	-1.633*** (0.523)	-2.292 (1.509)	-1.906*** (0.557)	-1.962** (0.804)

Table A-3 continued

d1*constant	-1.397*** (0.288)	-0.773 (0.485)	-0.871*** (0.287)	-1.006 (0.652)	-0.836*** (0.232)	-0.744*** (0.219)
d3*constant	0.120 (0.299)	0.489 (0.463)	0.490* (0.268)	0.412 (0.422)	0.332 (0.204)	0.313 (0.192)
Regression standard error	0.289*** (0.0333)	0.370*** (0.0427)	0.249*** (0.0303)	0.308*** (0.0374)	0.440*** (0.0464)	0.412*** (0.0432)
Pseudo-R^2	0.8988	0.7971	0.9673	0.8804	0.7042	0.7421
Left-censored observations	24	24	28	28	16	16
Uncensored observations	38	38	34	34	46	46

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Notes: Standard errors are in parentheses. Estimation uses projections from the January 2012 SEP to the March 2016 SEP in a Tobit regression model, censoring projections for which the median federal funds rate forecast was at or below 0.25 percent. The baseline projection uses the midpoint of the central tendency of projections of inflation, unemployment, and long-run unemployment, and the median of the federal funds rate projections. The "dovish" projection uses the minimum of the central tendency of the federal funds rate and inflation, as well as the maximum of the central tendency for unemployment and long-run unemployment. The "hawkish" projection uses the maximum of the central tendency of the federal funds rate and inflation, as well as the minimum of the central tendency for unemployment and long-run unemployment. Missing coefficients in the table were omitted by the model due to collinearity. The dummy variables d0, d1, and d3 correspond to the horizon of the SEP projections made for zero-years ahead (same year), one-year ahead, and three-years ahead. The "baseline" case is for projections made for two-years ahead. The regression specification takes the form:

$$FFR_t^{t-i} = a_2 + \sum_{(i=0,1,3)}(d_i a_i) + b_2(p_2^{t-2} - 2) + \sum_{(i=0,1,3)} d_i b_i (p_t^{t-i} - 2) + c_2(u_2^{t-2} - u_2^{LRt-2}) + \sum_{(i=0,1,3)} d_i c_i (u_i^{t-i} - u_i^{LRt-i}),$$

where

$$d_i = \begin{cases} 1 \text{ if projection was made for i=0,1, or 3 years ahead} \\ 0 \text{ otherwise} \end{cases}$$

Sources: The Federal Reserve Board, FRED, and authors' calculations.

Endnotes

[1]In its first reports, the FOMC provided ranges of projections from only the Federal Reserve Board Governors (Reserve Bank presidents were not included). The projections were for the four-quarter growth rates for nominal and real gross national product, the rate of GNP inflation, and the fourth-quarter unemployment rate, all for the current year (in the February and July reports) and the following year (in the July reports). In July 1980, all voting members of the FOMC (the Reserve Board Governors and the five voting Reserve Bank presidents) began providing projections. In February 1981, the FOMC adopted the current practice of including all FOMC participants' projections in the reported ranges. In 1983, the FOMC began reporting central tendencies of the projections along with their ranges. The central tendencies omitted high and low outliers, which were specified in 1987 as the top and bottom three projections. Projections for economic growth released through July 1991 were based on GNP. Starting the following year, projections for growth were for GDP. The consumer price index (CPI) replaced the GNP deflator as the measure of inflation starting in February 1989. The personal consumption expenditure (PCE) price index replaced the CPI in February 2000. The core PCE price index replaced the headline PCE price index from July 2004 to July 2007. In November 2007, the Committee began reporting projections for inflation as measured by both the headline and core PCE price indexes.

[2]The forecast horizon is the current and three subsequent years in the third and fourth-quarter SEP reports and the current and two subsequent years in the other two quarterly reports.

[3]No longer-run projection is provided for core PCE inflation because core and headline inflation are expected to converge over the longer run and the FOMC's longer-run inflation objective is broadly defined as price stability.

[4]The median federal funds rate projection, as well as the range and central tendencies of the projections, can be readily determined from the dot plot.

[5]Starting in September 2015, the FOMC began reporting the median of FOMC participants' projections as well as the central tendency and range. For consistency, we focus on the midpoint of the central tendencies for all meetings, including those for September and December 2015 and March 2016. In addition for robustness, we examine the maximum and minimum of the central tendencies.

[6]See, for example, Van Zandweghe (2012) on the labor force participation rate and Van Zandweghe (2010) on productivity growth.

[7]In particular, some FOMC participants may have overestimated the slope of the Phillips curve.

[8]Taking an alternative approach, Berriel, Carvalho, and Machado calibrate standard New Keynesian models subject to the zero lower bound under different assumptions about the degree of policy commitment. They then assess which specification best fits the SEP dot plots. By simulating policy responses to economic developments, they construct uncertainty bands around interest rate forecasts using

the best-fitting specification. They conclude that "the degree of Fed commitment to low rates for an extended period of time decreased in recent years."

[9]The Taylor rule (1993) recommends that the funds rate should be set equal to 1 plus 1.5 times inflation plus 0.5 times the output gap. For a discussion of the Taylor rule and its use in monetary policy, see Kahn (2012a). Carlstrom and Lindner examine how prescriptions from the Taylor rule describe the distribution of FOMC participants' views in 2012 about the appropriate timing of policy tightening. They find that such a rule "roughly captures many Committee participants' views of appropriate monetary policy."

[10]An important caveat is that the estimated reaction function is not necessarily that of the median FOMC participant since the median federal funds rate and the midpoints of the central tendencies of the explanatory variables likely reflect the views of different participants. Carlstrom and Jacobson explore this issue in the context of private sector forecasts from the Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters.

[11]In January 2012, the Committee adopted a numerical objective for the longer-run inflation rate of 2 percent as measured by the annual change in the PCE price index. Before that, the midpoints of the central tendency of longer-run projections of inflation from the SEP were slightly below 2 percent, varying from 1.8 to 1.85 percent. The SEP began including projections for the federal funds rate in January 2012. Thus, for the entire sample used in this analysis, the longer-run inflation projection is 2 percent.

[12]Theoretical and estimated policy reaction functions in the literature often also include a lagged federal funds rate on the right-hand side to reflect inertia or interest rate smoothing in the setting of monetary policy. Such smoothing is omitted here because of the end-of-year projection horizons. All projections are made for the end of the year based on projected Q4/Q4 inflation and Q4 unemployment. See Rudebusch for a discussion of interest rate smoothing and monetary policy inertia.

[13]The FOMC released five SEPs in 2012. After 2012, it released one SEP each quarter.

[14]Specifically, the estimation is by Tobit regression (Tobin).

[15]Because of the panel structure of the data set and the Tobit estimation procedure, correcting for possible serial correlation in the error term is problematic, at best. As a robustness check, we reestimate the reaction function separately for each forecast horizon from one to three years ahead using ordinary least squares (OLS) with Newey-West standard errors, omitting observations where the funds rate projection was at the effective lower bound. Hypothesis tests on the significance of regression coefficients are generally not affected. Appendix Table A-1 shows the OLS regression results. Appendix Table A-2 shows the comparable results from the Tobit regression for each forecast horizon.

In addition, to more fully exploit the panel structure of the data, we estimate a Tobit regression with fixed effects for each forecast horizon from the current year to three-years ahead, allowing the constant and slope coefficients to vary across forecast horizon. As shown in Appendix Table A-3, we find that the response of the projected federal funds rate to inflation in the model with headline inflation is strongest at the two- and three-year forecast horizons, while the response to unemployment gets increasingly strong as the forecast horizon is extended from the current year to three-years ahead. For the model with core inflation, we find no statistically different response of the projected funds rate to inflation across forecast horizons but an increased response to unemployment at the three-year horizon (in the baseline regressions).

Feroli, Greenlaw, Hooper, Mishkin, and Sufi estimate a policy reaction function from the SEP similar to the baseline regression reported here in Table 1, omitting observations at the effective lower bound. They present results for four specifications, using alternative measures of economic slack. The first measure is an estimate of the output gap based on Board staff estimates of the gap at the end of each calendar year and the subsequent deviation of projected real GDP growth from its long-run projected growth rate. The second measure is the projected change in the real GDP gap. The third measure is the projected unemployment gap. And the fourth measure is the change in the unemployment gap. Their results using the unemployment gap measure of slack are similar to those we report in this article.

[16]At 1.6, the estimated coefficient on headline inflation (as measured by the PCE price index) is very close to the coefficient on headline inflation (the GDP price deflator) in the 1993 Taylor rule.

[17]In addition to the specification of the policy reaction function given in the text, we estimate an alternative model that includes the deviation of projected real GDP growth from its longer-run level as an additional explanatory variable. Coefficients on this variable are not significantly different from zero except in the regressions using the core measure of inflation. However, the sign on the projected GDP growth variable is negative rather than the expected positive, suggesting a decrease in projected real GDP growth is associated with an increase in the projected federal funds rate. In retrospect, this result is not too surprising, as the SEP projected that growth would exceed potential in the near term as slack was gradually eliminated, then slow back to its long-run trend as policy was gradually tightened. Over this period of substantial economic slack, the FOMC would have been unlikely to lean against above-trend real GDP growth by raising the projected federal funds rate. See Coibion and Gorodnichenko (2011 and 2012) and Orphanides for a discussion of the role of real GDP growth in policy reaction functions estimated during the pre-zero lower bound period.

[18]Until June 2014, FOMC participants reported projections for the federal funds rate target at the upper end of the FOMC's prospective target range.

Starting in September 2014, they began reporting their projections as the midpoint of the target range. Thus for some of the sample, the effective lower bound is reported as 25 basis points while for the remainder, it is reported as 13 basis points.

[19]Bundick estimates the policy reaction function that private forecasters perceived the FOMC to have followed in the pre- and post-zero lower bound periods using a similar specification to ours and data from the Blue Chip Economic Indicators. He finds the coefficients on inflation and unemployment are similar across the two periods. In addition, for the zero lower bound period, he estimates a coefficient of 1.6 on inflation (the same as our estimate from the policy reaction function with headline inflation) and a coefficient of –6.8 on unemployment (somewhat larger than our estimate of –1.6).

[20]See Taylor (2007) for the view that monetary policy was overly accommodative and Bernanke for an opposing view.

[21]Kahn (2010, 2012b) discusses monetary policy during the Great Moderation in the context of normative and estimated policy rules.

References

Bernanke, Ben S. 2010. "Monetary Policy and the Housing Bubble," speech to the Annual Meeting of the American Economic Association, Atlanta, Georgia, January 3, available at http://www.federalreserve.gov/newsevents/speech/bernanke20100103a.htm.

Berriel, Tiago, Carlos Carvalho, and Octavio Machado. 2015. "Lift-Off Uncertainty: What Can We Infer from the FOMC's Summary of Economic Projections?" Society for Economic Dynamics 2015 Meeting Papers, no. 903, February.

Board of Governors of the Federal Reserve System. 2012–16. "Summary of Economic Projections," Minutes of the Federal Open Market Committee, available at https://www.federalreserve.gov/monetarypolicy/fomc_historical.htm#sep.

Bundick, Brent. 2015. "Estimating the Monetary Policy Rule Perceived by Forecasters," Federal Reserve Bank of Kansas City, *Economic Review*, vol. 100, no. 4, pp. 33–49.

Carlstrom, Charles T., and Margaret Jacobson. 2015. "Do Forecasters Agree on a Taylor Rule?" Federal Reserve Bank of Cleveland, *Economic Commentary*, no. 2015-10, September 2.

Carlstrom, Charles T., and John Lindner. 2012. "Monetary Policy and the FOMC's Economic Projections," Federal Reserve Bank of Cleveland, *Economic Trends*, May 17.

Coibion, Olivier, and Yuriy Gorodnichenko. 2012. "Why Are Target Interest Rate Changes So Persistent?" *American Economic Journal: Macroeconomics*, vol. 4, no. 4, pp. 126–62.

_____. 2011. "Monetary Policy, Trend Inflation, and the Great Moderation: An Alternative Interpretation," *American Economic Review*, vol. 101, no. 1, pp. 341–70.

Feroli, Michael, David Greenlaw, Peter Hooper, Frederic S. Mishkin, and Amir Sufi. 2016. "Language after Liftoff: Fed Communication Away from the Zero Lower Bound," report prepared for the 2016 U.S. Monetary Policy Forum, February 26.

Kahn, George A. 2012a. "Estimated Rules for Monetary Policy," Federal Reserve Bank of Kansas City, *Economic Review*, vol. 97, no. 4, pp. 5–29.

_____. 2012b. "The Taylor Rule and the Practice of Central Banking," in *The Taylor Rule and the Transformation of Monetary Policy*, Koenig, Evan, Robert Leeson, and George Kahn, eds., Hoover Institution Press: Stanford, CA, pp. 63–101.

_____. 2010. "Taylor Rule Deviations and Financial Imbalances," Federal Reserve Bank of Kansas City, *Economic Review*, vol. 95, no. 2, pp. 63–99.

Laubach, Thomas, and John Williams. 2015. "Measuring the Natural Rate of Interest Redux," Federal Reserve Bank of San Francisco, Working Paper 2015-16, October.

_____. 2003. "Measuring the Natural Rate of Interest," *Review of Economics and Statistics*, vol. 85, no. 4, pp. 1063–70.

Lindsey, David E. 2003. "A Modern History of FOMC Communication: 1975–2002," Board of Governors of the Federal Reserve System, June 24.

Orphanides, Athanasios. 2003. "Historical Monetary Policy Analysis and the Taylor Rule," *Journal of Monetary Economics*, vol. 50, no. 5, pp. 983–1022.

Rudebusch, Glenn D. 2002. "Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia," *Journal of Monetary Economics*, vol 49, no. 6, pp. 1161–1187.

Taylor, John. 2007. "Housing and Monetary Policy." Federal Reserve Bank of Kansas City *Economic Policy Symposium,* Jackson Hole, Wyoming, pp. 463–476.

_____. 1993. "Discretion versus Policy Rules in Practice," *Carnegie-Rochester Conference Series on Public Policy*, no. 39, pp. 195–214, North Holland.

Tobin, James. 1958. "Estimation of Relationships for Limited Dependent Variables," *Econometrica*, vol. 26, no. 1, pp. 24–36.

Van Zandweghe, Willem. 2013. "Interpreting the Recent Decline in Labor Force Participation," Federal Reserve Bank of Kansas City, *Economic Review*, vol. 97, no. 1, pp. 5–34.

_____. 2010. "Why Have the Dynamics of Labor Productivity Changed?" Federal Reserve Bank of Kansas City, *Economic Review*, vol. 95, no. 3, pp. 5–30.