SPECIAL REPORT
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Monetary Policy Report: Using Rules for Benchmarking

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Introduction

This special report highlights ongoing work to benchmark the stance of monetary policy using a range of policy rules that are widely employed in studies of monetary economics.[1] We perform the exercise with a specific, publicly available model of the macroeconomy developed by researchers at the Board of Governors of the Federal Reserve System. We then employ this model to explore the expected behavior of economic variables, including the policy rate, under alternative policy rules. The policy rules help to benchmark not only the current stance of the federal funds rate but also guidance on how the path of policy is likely to evolve in the context of the model. Such an exercise as part of a more comprehensive quarterly monetary policy report would enhance communication and promote a more systematic approach to monetary policy.

We begin with an overview of the economy and then discuss the benchmark model we use to generate our forecasts with different policy rules. The remainder of the report highlights the outcomes of different robust policy rules and discusses why policymakers might choose to deviate from the rules.

[1] The views expressed in this report are those of the authors and do not necessarily reflect those of the Federal Reserve Bank of Philadelphia or the Federal Reserve System. We thank Brie Coellner for her assistance.

Economic Overview

The U.S. economy continues to grow at a near-trend rate, with nowcasts of real GDP growth in the current quarter largely in the 1.0 percent to 2.0 percent range. Much of the recent and projected growth is due to healthy increases in consumption, although we are seeing signs of a modest recovery in manufacturing activity and some indications that business fixed investment will contribute as well. The labor market continues to generate new jobs at a healthy rate, and wage rates have been slowly trending upward. Economic conditions in the rest of the world appear to be improving, and there is substantial optimism among domestic consumers and firms alike. That optimism has yet to fully translate into hard data, so it is important not to place undue weight on it yet. Inflation continues to move slowly toward the Federal Open Market Committee's target, and the risks to the economy appear largely balanced. These factors have given the FOMC members a bit more confidence in the ongoing stability of the expansion, and they raised the federal funds rate by 25 basis points at their March meeting. The rate is intended to trade in the 75 to 100 basis points range, and the move was well anticipated. Market reaction has been positive, with both stock and bond prices rising following the move.

The most recent data on retail sales point to continued growth in consumption. Although February's core sales were flat, January's sales growth was revised upward to a healthy 0.9 percent, consistent with first quarter consumption growing at approximately a trend-like 2.0 percent. This pace represents a bit of a pullback from last year's growth despite very high levels of consumer confidence. There was substantial strength in building materials, indicating an increase in residential investment this quarter, and spending on autos remains at healthy levels.

The economy continues to add jobs at a robust pace, with 235,000 jobs added on net in February and 238,000 in January and the unemployment rate falling to 4.7 percent. Over the past 12 months, net gains have averaged almost 200,000 jobs per month. Labor force participation ticked up a tenth of a percent to 63.0, its highest reading since early last year. Thus, the participation rate remains above its demographically induced downward trend, largely due to some cyclicality of prime-age male workers who previously had reported themselves as disabled. Wages continue to rise slowly, with average hourly earnings increasing 2.8 percent over the past 12 months. The upward trend in wage growth is also seen in the Atlanta Fed's Wage Growth Tracker, which has risen 3.5 percent over the same period. Additionally, the job openings rate remains high, the quits rate jumped to a cyclical high in January, and the layoffs rate remains close to its historical low. Contacts in our region continue to express difficulty in finding workers, especially skilled workers. The healthy labor market is supporting strong income growth, with personal income growing 4.0 percent over the past 12 months to January and a healthy 0.4 percent in the first month of this year.

The housing sector continues to grow and may be picking up a bit of steam, although recent signals are mixed. Housing starts increased 3.0 percent in February, while housing permits declined 6.2 percent. However, the decline in overall permits was more than accounted for by the multifamily segment. In the more important single-family segment, starts and permits both grew, by 6.5 percent and 3.1 percent, respectively. Starts are now at a cyclical high of 872,000 at a seasonally adjusted annual rate. Single-family starts and permits both remain on an upward trend, which has fueled an average 15.5 percent increase in residential investment over the three months through January. New home sales rebounded in February to a healthy 6.1 percent, and January 's growth was revised upward to 5.3 percent , while existing home sales retreated in February from January's cyclical high. Overall, the housing sector is benefiting from solid income growth and improvements in household balance sheets.

The biggest disconnect between soft and hard data is occurring in the manufacturing sector, where we are beginning to see some improvement. The survey data have been extremely upbeat and reflect what we are hearing from numerous business contacts, but the hard data, while showing signs of improvement, do not measure up to the strength in the surveys. The February Institute for Supply Management manufacturing index rose to 57.7, its highest reading since August 2014, and the Philadelphia Fed's manufacturing index attained a robust 32.8 reading in March. This value followed a 43.3 reading in February, the highest in 20 years. Details of the Philadelphia survey were also robust, with strong numbers for new orders, shipments, employment, and prices, both paid and received. Additionally, the future activity index increased to 59.5, indicating a high degree of optimism among the participating firms.

In the hard data, it appears that industrial production is gaining some traction, with gains of 0.5 percent in both January and February, representing an annualized growth rate of roughly 6.0 percent. And core shipments in February surprised to the upside. Over the past three months, they are up 9.8 percent at a seasonally adjusted annual rate, their strongest growth since September 2014. Core capital goods orders have been a bit softer, declining 0.1 percent in February, indicating that some of the strength in shipments is likely to be transitory. Although the trend in orders remains positive, it in no way reflects the optimism expressed in surveys and anecdotes. That said, any improvement in manufacturing and equipment investment is welcome news.

Inflation continues to firm, albeit at a very slow pace, with the core CPI rising 2.2 percent and the headline CPI 2.7 percent over the past year. The latter rate represents the largest increase in five years. There also has been some momentum, with the three-month change accelerating to 3.0 percent in the core index and 3.8 percent in the headline index. In January, the three-month change in the core PCE price index increased 1.9 percent, which is very close to the FOMC's 2 percent target, but some of that increase appears to be transitory. Meanwhile, inflation

expectations, as measured by the spread between nominal Treasury yields and Treasury Inflation-Protected Securities (TIPS), have remained at approximately the target. They are now in line with survey measures of longer-run inflation expectations, such as those reported in the Survey of Professional Forecasters. Given the accommodative stance of monetary policy and the recent run-up in energy prices, we continue to believe that inflation will slowly converge with the target.

The latest revisions to fourth quarter growth show that output expanded at a roughly trend-like rate, though the first quarter is generally forecast to be a bit weaker. However, there may still be some residual seasonality in the first quarter data. Employment growth remains solidly above the rate that would imply no change in the unemployment rate. Most forecasts, including those made by FOMC participants, continue to anticipate around-trend economic growth and a gradual return of inflation to target. This view seems to be held more confidently than it was a few months ago.

The economic forecasts in March's Summary of Economic Projections were little changed from December and indicate that the majority of FOMC members expect the economy to grow at a roughly trend-like rate of 2.0 percent and for inflation to gradually return to target. Notably, there was a greater consensus for three rate hikes in the coming year, and the federal funds rate is expected to reach 3.0 percent by the end of 2019. That would leave the funds rate at the median projection for the long-run neutral funds rate, which is similar to what members had thought in December.

The Benchmark Model

To create our forecasts and to carry out our monetary policy benchmarking exercises, we use a structural forecasting model called Estimated Dynamic Optimization (EDO) developed by researchers at the Board of Governors. This medium-scale model shares many features of standard New Keynesian Dynamic Stochastic General Equilibrium (NKDSGE) models that are at the forefront of macroeconomic modeling and forecasting. The EDO model features households and firms that are forward looking and that make decisions facing resource constraints. The model includes multiple sectors, a rich menu of shocks, and adjustment costs that make wages and prices less than fully flexible in responding to changes in economic conditions. Detailed documentation on the model structure and computer programs that implement model simulations can be found at the Board of Governors' website at www.federalreserve.gov/econresdata/edo/edo-models-about.htm. We generate forecasts from a version of this model using several different monetary policy rules to provide a sense of how the economy might perform under a reasonable set of policy paths, given current and expected economic conditions.

The key parameters that we change under the various policy alternatives are those that govern the response of the short-term interest rate to changes in economic conditions. The monetary policy response function is of the form

$$R_t = \rho R_{t-1} + (1-\rho)[\Psi_\pi(\pi_{t|t-4} - \pi^*) + \Psi_y ygap_t] + \varepsilon_t^R,$$

where R_t is the deviation of the effective federal funds rate from its long-run equilibrium value, $\pi_{t|t-4}$ is the four quarter change in core PCE inflation, and $ygap_t$ is a measure of the output gap.[2] We run forecast simulations under four different versions of the basic rule shown here:

Table 1

Rule	$\boldsymbol{\rho}$	$\boldsymbol{\Psi_\pi}$	$\boldsymbol{\Psi_y}$
Baseline	0.83	1.46	0.26
Taylor (1993)	0.0	1.50	0.50
Taylor (1999)	0.0	1.50	1.0
Inertial Taylor (1999)	0.85	1.50	1.0

The baseline rule uses parameter values that are estimated from the data using the full EDO model. That is, the baseline rule depicts the historical behavior of monetary policymakers. The Taylor rule alternatives are parameterizations of the policy rule taken from the economics literature and are widely used in simulations of macroeconomic models.

Model Forecasts Under the Baseline

We first generate forecasts assuming that monetary policy follows the baseline policy rule. The forecast is generated using observed data through the fourth quarter of 2016 and a nowcast for the first quarter of 2017. The forecast begins in the second quarter of 2017 and extends through the fourth quarter of 2019. The forecasts under the baseline and the alternative policy rules are shown in Figures 1 through 4. The baseline forecast is represented by the dark solid line. The colored bands around the baseline forecast represent 10 percent confidence intervals of the predictive distribution around the median of the baseline forecast.[3]

The key features of the baseline forecast are as follows:

- Real output is forecast to grow at about 2.7 percent (Q4/Q4) in 2017, 2.5 percent in 2018, and 2.6 percent in 2019.

[2] The model calibration implies that the long-run equilibrium value of the federal funds rate is 4.1 percent. The output gap is calculated using the Beveridge-Nelson decomposition, which decomposes a data series into stochastic trend and stationary cycle components. The gap is then measured by the cycle component. It is important to note that the output gap is computed as part of the model solution and is not an exogenous input into the simulations.

[3] The forecast simulations are generated using Bayesian methods. The fan charts show 10 percent quantiles around the median of the posterior predictive distribution.

- Core PCE inflation reaches 2.1 percent (Q4/Q4) in 2017, rising to 2.3 percent in 2018 and to 2.4 percent in 2019.
- The unemployment rate falls to 4.2 percent in the fourth quarter of 2018 and then edges up to 4.3 percent by the end of 2019.[4]
- The federal funds rate rises to 1.6 percent at the end of 2017, 2.6 percent at the end of 2018, and 3.2 percent at the end of 2019.
- Compared with the December forecast, real GDP growth is slightly weaker, inflation is about unchanged, the unemployment rate is about unchanged, and the federal funds rate path is slightly weaker over the forecast horizon (Figures 5 a, b).

The baseline forecast calls for output growth to accelerate from 2 percent in the first quarter of 2017 to 3.2 percent in the second quarter and then edge down to a 2.6 percent pace at the end of 2017. Quarterly growth then ranges from 2.4 percent to 2.7 percent in 2018 and 2019. The unemployment rate continues to decline, reaching 4.2 percent by the third quarter of 2018 and then edging up to 4.3 percent at the end of 2019. [5] Moderately strong growth and anchored long-run inflation expectations lead to an acceleration of core PCE inflation from 1.2 percent in the fourth quarter of 2016 to a sustained 2 percent by the second quarter of 2017. Core inflation then overshoots the FOMC target of 2 percent, reaching 2.3 percent by mid-2018 and 2.4 percent by the end of 2019. Under the baseline policy parameterization, the output growth and inflation outcomes correspond to a gradually rising federal funds rate over the next three years. The model predicts that the federal funds rate rises to 1.6 percent at the end of 2017 and then increases on a modest path to 2.6 percent at the end of 2018 and 3.2 percent at the end of 2019.

The baseline forecast remains somewhat stronger than the median projections from the first quarter 2017 SPF. In that survey, the respondents expected real output growth of 2.3 percent in 2017, 2.4 percent in 2018, and 2.6 percent in 2019. (Note that the SPF reports GDP growth as annual average over annual average.) The SPF's core PCE inflation forecast is 1.9 percent (Q4/Q4) for 2017 and 2 percent for 2018 and 2019. The forecasters' path for the unemployment rate is a bit higher than in the baseline model: The median SPF forecast for the unemployment rate averages 4.6 percent in 2017 and 4.5 percent in 2018 and 2019.

The March 2017 SEP by FOMC participants shows the median projection for output growth at 2.1 percent in 2017, 2.1 percent in 2018, and 1.9 percent in 2019. The median forecast of the

[4] The baseline unemployment rate forecast is add-factored to more accurately reflect our views on the likely evolution of labor market conditions. The modifications to the baseline forecast are kept in place when the model is simulated under the alternative policy rules.

[5] The model estimates long-run real per capita output growth of about 2 percent. We then assume that population growth averages 1 percent per year over the forecast horizon.

unemployment rate in the fourth quarter of 2017 is 4.5 percent, where it stays in 2018 and 2019. Core PCE inflation is projected at 1.9 percent in 2017, rising to 2 percent in 2018 and 2019. Headline inflation is now projected to run at the same pace as core inflation over the forecast horizon. The forecast model's baseline forecast for the federal funds rate (Figure 4) lies within the central tendency of the March 2017 SEP over the forecast horizon and remains well above market expectations, which are below 2 percent for the fourth quarter of 2018. The model generally suggests a somewhat more rapid pace of policy normalization compared with market expectations to keep the output gap, inflation gap, and interest rate aligned as per the baseline rule parameterization.

Behavior Under Alternative Taylor Rules

To gauge the robustness of the model's benchmark prescription for monetary policy, we also generate forecasts assuming that the policymaker adopts one of the alternative Taylor rules shown in Table 1.[6]

The key features of the forecasts under the alternative policy rules are as follows:

- The policy rules continue to suggest that the federal funds rate should rise at a fairly rapid pace over the next three years — more rapidly than suggested by financial markets.
- The more accommodative monetary policies are associated with more rapid output growth, lower unemployment, and higher inflation.
- The major difference between the forecasts is in output growth and not in inflation or unemployment. The model estimates somewhat persistent inflation measures that respond sluggishly to shocks.
- By mid-2018, the forecasts for output, inflation, and the federal funds rate have largely converged across the policy alternatives. The entire future path of the interest rate — rather than the current rate — is key for the dynamics of the economy.
- The federal funds rate under all the alternative rules reaches about 2.7 percent by the end of 2018, which is well above current market expectations of what the federal funds rate will be at that time.

The alternative policy rules suggest different current levels of the appropriate federal funds rate. The baseline puts the funds rate at 0.84 percent in the second quarter of 2017, compared with 1.5

[6] When generating the forecasts under the alternative policy rules, we assume that the state of the economy up to and including the third quarter of 2014 is the same as that implied by the baseline rule calibration of the model. Given the state variable history, we then switch rules and forecast under the alternatives beginning in the fourth quarter of 2014. In this framework, the switch in policy rules is not anticipated by the model agents, and they expect the new rule to be in place for all future periods.

percent for the Taylor (1993) rule. The Taylor (1999) rule suggests a more accommodative policy, with the federal funds rate at 0.4 percent in the second quarter of 2017.[7] The inertial Taylor rule suggests a funds rate of 0.6 percent in the second quarter of 2017, a bit below the actual current target. At 0.88 percent, the current target lies within the range of the model rules, but all of the rules suggest gradual and ongoing tightening of policy over the next three years. For the fourth quarter of 2017, the funds rate stands at 2 percent for the Taylor (1993) rule, 1.8 percent for the Taylor (1999) rule, and 1.4 percent for the inertial Taylor rule. Thus, the rules see three to four additional tightenings this year. With ongoing normalization, all the rules suggest that the federal funds rate should be 2 percent or higher by mid-2018. So, even though the Taylor (1999) rule calls for a somewhat lower funds rate this quarter, the accommodation is fairly short lived.

The path of output growth is slightly weaker over the near term under the Taylor (1993) rule, which calls for the highest near-term interest rate, with output growth at 2.4 percent in the second quarter of 2017. The inertial Taylor (1999) rule, which over the forecast horizon is the most accommodative policy, has real output growth at 4.7 percent in the second quarter of 2017. Note, though, that the output growth forecasts largely converge by the second quarter of 2018. The alternative policy rules have little impact on the future path of inflation. Inflation adjusts gradually to shocks in the model and depends on the expected future path of the economy, which is similar across the policy rules in the medium and longer runs. Core inflation runs at about 2.1 percent (Q4/Q4) in 2017 and shows little dispersion over the forecast horizon across the alternative policies. Core inflation is slightly higher over the forecast horizon compared with the December projection. The inflation paths are all close to the baseline path and show relatively small differences across paths over the next three years.

Summary

The policy alternatives give mixed signals about the appropriate near-term stance of monetary policy, but the discrepancy remains short lived. The baseline rule suggests the current stance of policy is appropriate for the second quarter of 2017, while the Taylor (1993) rule suggests that the federal funds rate should average about 60 basis points higher than its current prevailing rate in the second quarter. The inertial Taylor (1999) rule suggests that current policy is slightly tight, while the Taylor (1999) rule suggests that policy should be more accommodative. However, the alternative policy rules agree that the federal funds rate should rise steadily over the next three years to about 3.3 percent at the end of 2019. This represents a more aggressive policy normalization compared with financial market expectations.

[7] We have not constrained the model to have a nonnegative interest rate in the estimation or simulation.

Economic conditions are consistent with a gradual tightening of policy, according to the various rules we analyze. Accompanying this gradual tightening, the economy remains slightly below full employment and inflation remains close to its long-run inflation target.

Figure 1: Real GDP Growth

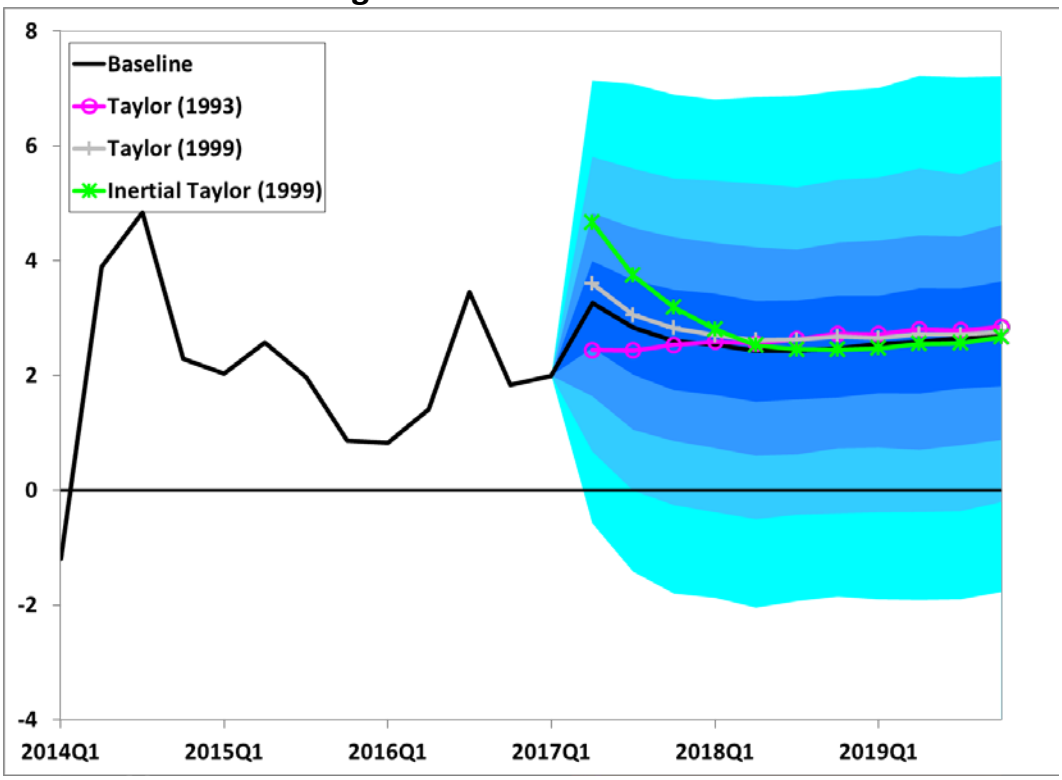

Figure 2: PCE Core Inflation

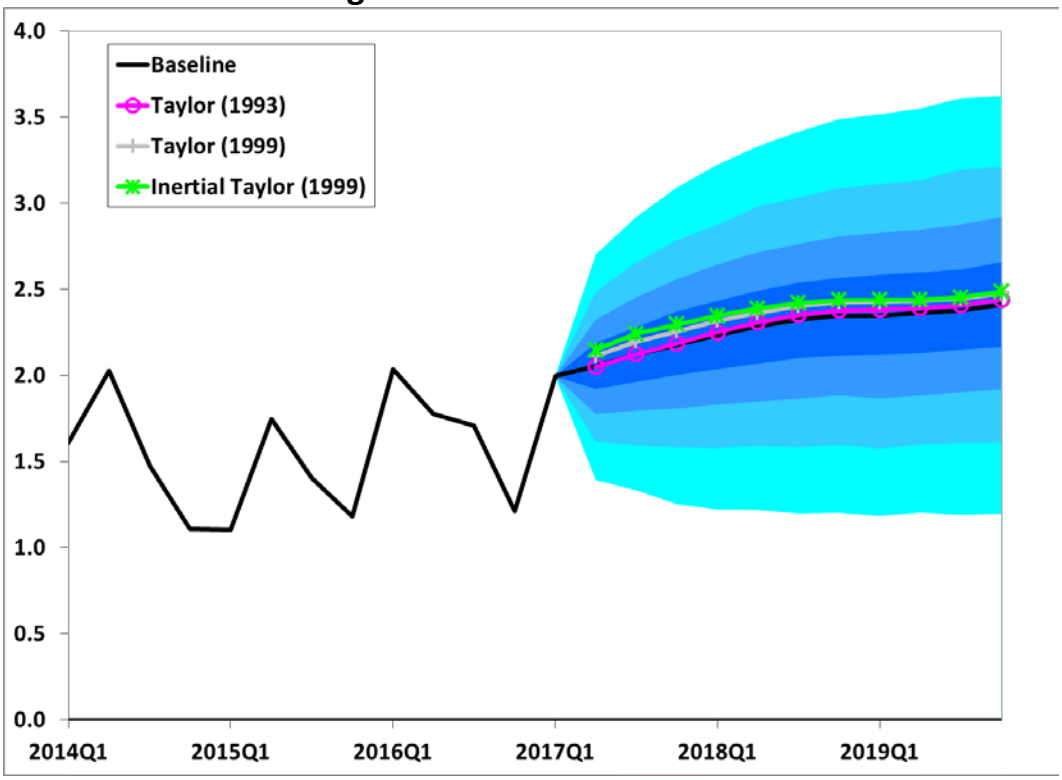

Figure 3: Unemployment Rate

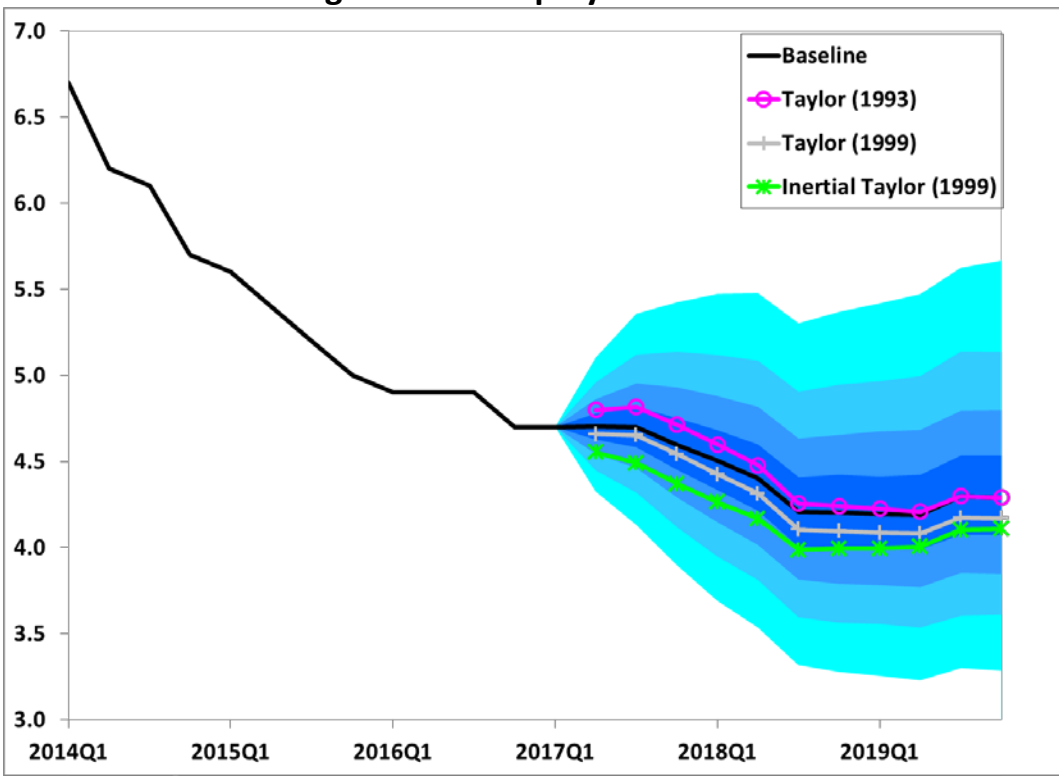

Figure 4: Federal Funds Rate

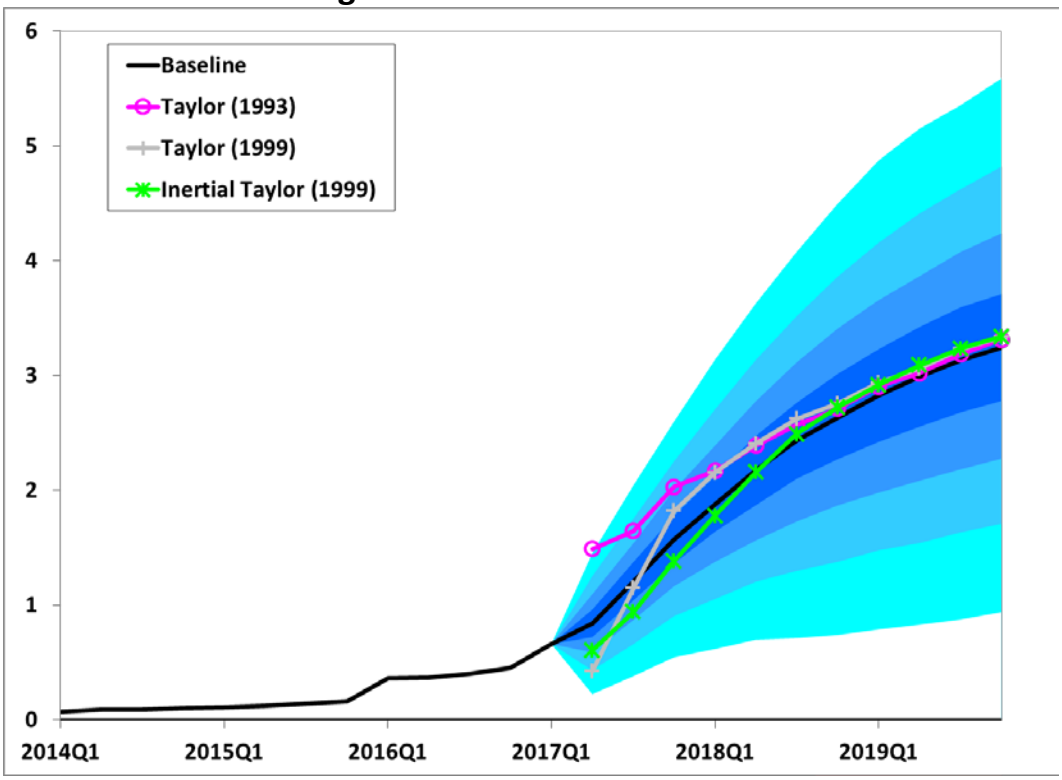

Figure 5: Baseline Forecast Comparisons

Figure 5a: Real GDP Growth

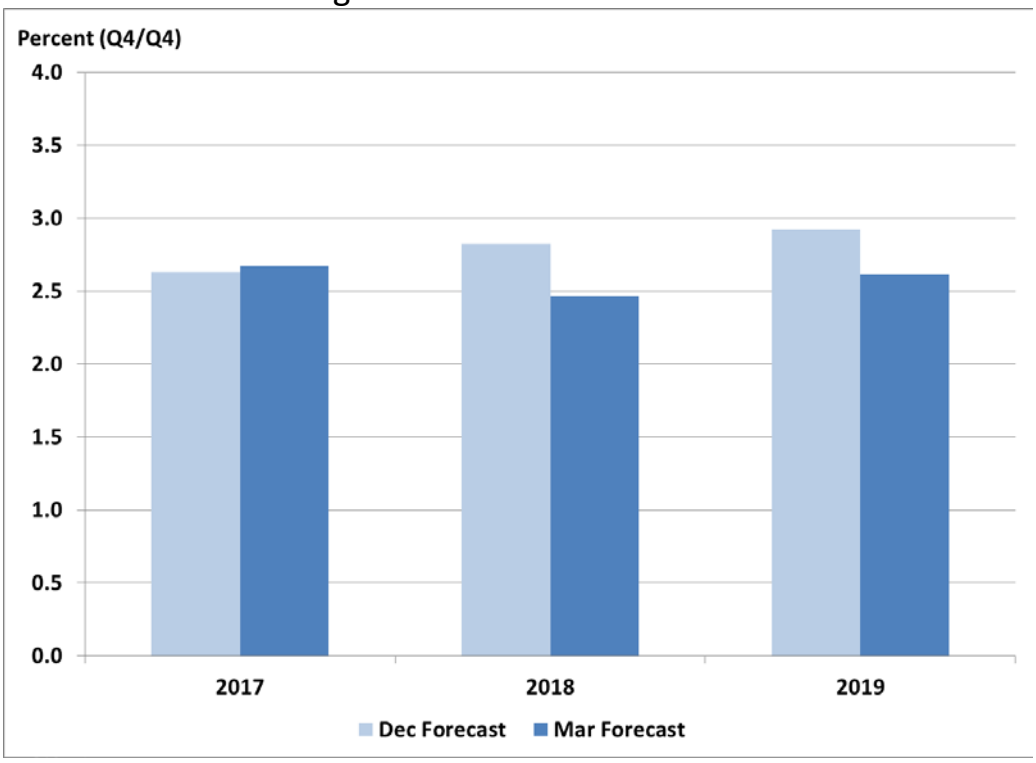

Figure 5b: PCE Inflation Growth

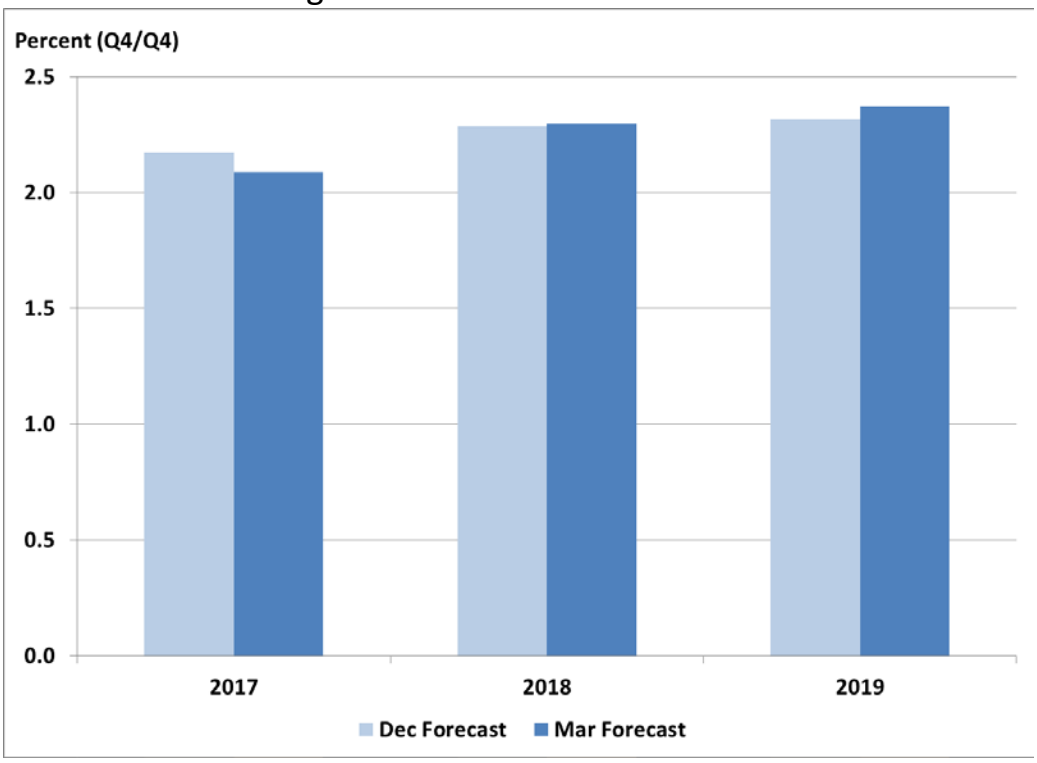

Figure 5c: Unemployment Rate

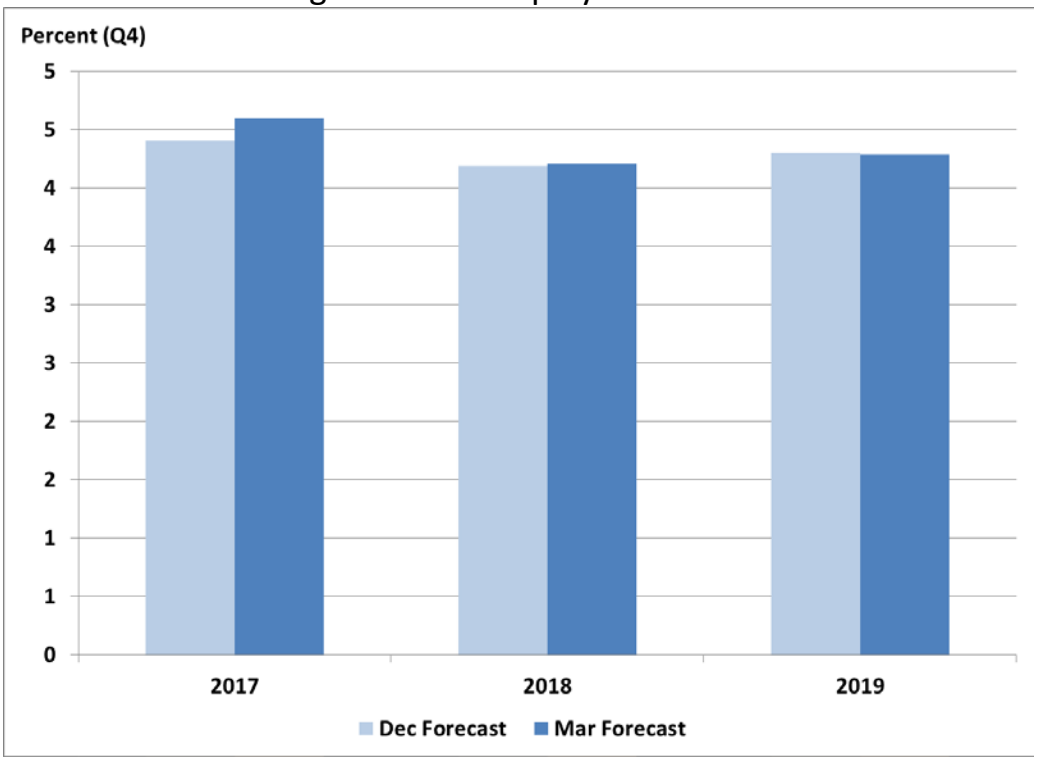

Figure 5d: Federal Funds Rate