Policy Rules and Economic Performance*

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Abstract

Debates about the conduct of monetary policy have evolved over time from "rules versus discretion" to "policy rules versus constrained discretion." We propose a metric to evaluate monetary policy rules that are consistent with constrained discretion by calculating quadratic loss ratios, the (inflation plus unemployment) loss in high deviations periods divided by the loss in low deviations periods, with policy rules with higher loss ratios preferred to rules with lower loss ratios. The central results of the paper are (1) economic performance is better in low deviations periods than in high deviations periods for the vast majority of rules, and (2) rules with larger coefficients on the inflation gap than on the output gap are preferred to rules with larger coefficients on the output gap than on the inflation gap. These results are robust to policy lags between one and two years, different weights on inflation loss than on unemployment loss, various definitions of high and low deviations periods, fixed and time varying neutral real interest rates, fixed and time-varying inflation targets, and measuring economic slack by either the output gap or the unemployment gap. We conclude that (1) the Fed should "constrain" constrained direction by following a rule that responds more strongly to inflation gaps than to output gaps, and (2) this type of rule should be added to the Fed's semi-annual Monetary Policy Report.

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1. Introduction

Is economic performance better under rules-based or discretionary monetary policy? This has been a central question in macroeconomics from the "rules versus discretion" debate among Friedman (1960), Council of Economic Advisors (1962), and Kydland and Prescott (1977) to the "policy rules versus constrained discretion" debate among Bernanke (2003), Mishkin (2017), and Taylor (2017). While money supply rules in the 1960s and 1970s had little effect on Fed policymaking, interest rate feedback rules following Taylor (1993a) have been much more influential. Interest rate rules have been presented to the Federal Open Market Committee (FOMC) since 2004, have been included in the Federal Reserve Board's semi-annual Monetary Policy Report since 2017, and have been posted on the Fed's Monetary Policy Principles and Practices web page since 2018. Variants of Taylor rules have been used by Kohn (2007) and Bernanke (2010) to justify Fed behavior between 2003 and 2006 and by Yellen (2012, 2015a, 2017) to explain Fed behavior following the financial crisis.

What is the relation between policy rules and constrained discretion? Consider a class of Taylor rules where the federal funds rate equals the inflation rate plus alpha times the inflation gap, the difference between the inflation rate and the target inflation rate, plus gamma times the output gap, the percentage deviation of Gross Domestic Product (GDP) from potential GDP, plus the neutral real interest rate that is consistent with the inflation and output gaps equal to zero.[1] In theory, alpha and gamma can take any value from minus to plus infinity. The Taylor (1993a) rule, where alpha and gamma equal one-half and the inflation target and the neutral real interest rate equal two, is an example of a "balanced" rule where equal changes to the inflation and output gaps cause equal changes in the real interest rate. Constrained discretion, as in Bernanke (2003), specifies that the Fed has an inflation target and respects the dual mandate, which restricts policy rules to those where alpha and gamma are both positive. While the Taylor (1993a) rule is consistent with constrained discretion, so are infinitely many other rules.

Suppose that the Fed were to adopt a policy rule. Which rule should it adopt? The standard way to answer this question is to estimate a model, simulate the model using the estimated coefficients and disturbances, and calculate the optimal policy rule that minimizes a loss function

[1] We use the term "neutral" real interest rate in accord with the terminology in the Monetary Policy Report. Neutral real rates are also called "equilibrium" or "natural", although the latter is sometimes used to denote the real rate of interest consistent with instantaneous market clearing in the absence of wage and price frictions.

that includes inflation, the output gap, and the change of the nominal interest rate. Several leading macro models for the U.S. are the Christiano, Eichenbaum, and Evans (2005) model (CEE), the Smets and Wouters (2007) model (SW), the Taylor (1993b) model, and the Federal Reserve Board/United States model (FRB/US). When the three variances are equally weighted, Taylor and Wieland (2012) show that the optimal policy rule in the CEE, SW, and Taylor models is "inflation gap tilting" with alpha > gamma and Tetlow (2015) shows that the optimal policy rule for the October 2007 vintage of the FRB/US model is "output gap tilting" with gamma > alpha. The choice of a policy rule cannot be definitively answered by models, as the values of alpha range from 0.53 to 2.00 and the values of gamma range from 0.26 to 1.17.

We propose a metric to evaluate monetary policy rules by comparing economic performance. It is standard practice to evaluate economic performance by calculating quadratic loss functions as the sum of inflation loss, the squared inflation gap, and unemployment loss, the squared unemployment gap (the unemployment rate minus the natural rate of unemployment), with smaller loss preferred to larger loss. We evaluate monetary policy rules by calculating quadratic loss ratios, the loss in high deviations periods divided by the loss in low deviations periods. Since the loss over the full sample is invariant to the policy rule, rules with higher loss ratios are preferred to rules with lower loss ratios because economic performance is relatively worse in high deviations periods than in low deviations periods.

Consider the 400 policy rules with alpha and gamma ranging from 0.1 to 2.0 in increments of 0.1, which span the optimal values from the various models. In order to measure the congruence between policy rules and Fed behavior, we calculate the "share in time" of the number of low deviations periods divided by the total number of periods. The preponderance of rules with the share in time in the upper quartile has both coefficients with an upper bound of unity. Since the set of rules that are consistent with Fed behavior is more restricted than the set of rules that are consistent with optimal policy, we calculate loss ratios for both the 100 rules with alpha and gamma ranging from 0.1 to 1.0 and the 400 rules with alpha and gamma ranging from 0.1 to 2.0.

The central results of the paper are (1) economic performance is better in low deviations periods than in high deviations periods for the vast majority of rules, and (2) rules with larger coefficients on the inflation gap than on the output gap have higher loss ratios, and are therefore preferred to, rules with larger coefficients on the output gap than on the inflation gap. Policy rules with larger coefficients on the inflation gap than on the output gap are preferable even if society places greater weight on unemployment loss than on inflation loss. The results are stronger for the larger set of rules.

The minimum criterion for a good policy rule is that the loss ratio be greater than one, so that economic performance is worse in high deviations periods than in low deviations periods. Otherwise, economic performance would improve by not adhering to the rule. We start with a variant of the Taylor (1993a) rule that is consistent with the rules posted on the Fed's Monetary Policy Principles and Practices web page, with real economic activity measured by the output gap, a two percent inflation target, and a time-varying neutral real interest rate, and proceed to consider three additional specifications with an unemployment gap, a two percent neutral real interest rate, or a time-varying inflation target.[2]

The benchmark model for all specifications has equal weight on inflation and unemployment loss, high (low) deviations periods defined by the absolute value of the deviation between the prescribed and actual federal funds rate being greater (less) than two percent, and the loss function calculated six quarters after the classification between low and high deviations periods to account for policy lags. Economic performance is better in low deviations periods than in high deviations periods. For the four benchmark specifications, the average loss ratio for the 100 policy rules is between 1.75 and 2.53, the loss ratios are greater than one for between 90 and 100 policy rules, and the loss ratios are greater than one for all 80 rules with a coefficient on the inflation gap of 0.3 and above. The Taylor principle that the coefficient on the inflation gap should be positive, so the federal funds rate is increased more than point-for point with inflation, is necessary, but not sufficient, for good policy. The strongest results are for the specification on the web page with an output gap, a time-varying neutral real interest rate, and a two percent inflation target. The results are even stronger when we consider all 400 policy rules.

Inflation gap tilting rules are preferred to output gap tilting rules. We divide the 100 policy rules into five quintiles of 20 rules, and the preponderance of rules in the top two quintiles, where the loss ratios are largest, are inflation gap tilting rules. The "relative loss ratio" of the inflation gap tilting rules to the output gap tilting rules is between 1.25 and 1.83 and significantly greater than 1.0 at the one percent level for all four benchmark specifications, showing statistical as well

[2] The rules in the Monetary Policy Report incorporate an unemployment gap instead of an output gap. The coefficients on the rules are consistent with those on the web page with an Okun's Law coefficient of two. The reports and web page also include effective lower bound adjusted, inertial, first-difference, and price level rules.

as economic significance. These results are robust to higher weight on inflation loss than on unemployment loss, higher weight on unemployment loss than on inflation loss, high and low deviations periods defined by 1.5 and 2.5 percent thresholds, and policy lags of four to eight quarters. The strongest results are for the specification in the Monetary Policy Report with an unemployment gap, a time-varying neutral real interest rate, and a two percent inflation target. The results are even stronger when we consider all 400 policy rules. We conclude that the Fed should "constrain" constrained direction by responding more strongly to inflation gaps than to output gaps.

We proceed to interpret our results in the context of other metrics. The preference for inflation gap tilting rules is consistent with theoretical results in Woodford (2003) and simulations of the Smets and Wouters (2007) and the Boehm and House (2014) models. It is not, however, consistent with simulations of the FRB-US model. It is also not consistent with Fed behavior. We calculate shares in time for the 100 policy rules for the specification (with a time-varying neutral real interest rate) that produces the strongest results, and Fed policy is more consistent with output gap tilting than with inflation gap tilting.

Orphanides and Williams (2007) and Laubach and Williams (2016) discuss the policy implications of uncertainty in real-time measures of the natural rate of unemployment and the neutral real interest rate, respectively. They advocate a strong response to inflation in order to reduce the importance of accurately measuring the natural rate of unemployment and the neutral real interest rate. Our result that inflation gap tilting rules are preferable to output gap tilting rules is consistent with their policy prescriptions.

Balanced and output gap tilting Taylor rules have been presented to the FOMC since 2004 and included in the Federal Reserve Board's Monetary Policy Report since 2017. While the balanced rule has a coefficient on both gaps of one-half, the output gap tilting rule has a coefficient on the inflation gap of one-half and a coefficient on the output gap of one. Our results suggest that the Fed should add an inflation gap tilting rule to the Taylor rules presented to the FOMC and included in the Monetary Policy Report. Based on the rules that are currently reported, an obvious choice would be a rule with a coefficient of one on the inflation gap and a coefficient of one-half on the output gap.[3]

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[3] For ease of exposition, we will use "Monetary Policy Report" as a shorthand for "Monetary Policy Report and Monetary Policy Principles and Practices web page".

2. Policy Rules

Taylor (1993a) proposed the following monetary policy rule,

$$i_t = \pi_t + \alpha(\pi_t - \pi^*) + \gamma y_t + R^* \tag{1}$$

where i_t is the target level of the short-term nominal interest rate, π_t is the inflation rate, π^* is the target level of inflation, y_t is the output gap, the percent deviation of actual real GDP from an estimate of its potential level, and R^* is the neutral real interest rate that is consistent with output equal to potential output and inflation equal to the target level of inflation. Combining terms,

$$i_t = \mu + \delta\pi_t + \gamma y_t, \tag{2}$$

where $\delta = 1 + \alpha$ and $\mu = R^* - \alpha\pi^*$. We define policy rule deviations as the difference between the actual federal funds rate and the interest rate target implied by various policy rules.

2.1 Real-Time Data

The implied Taylor rule interest rate is calculated from data on inflation and the output gap. Following Orphanides (2001), the vast majority of research on the Taylor rule uses real-time data that was available to policymakers at the time that interest rate setting decisions were made. The Real-Time Data Set for Macroeconomists, originated by Croushore and Stark (2001) and maintained by the Philadelphia Fed, contains vintages of nominal GDP, real GDP, and the GDP deflator (GNP before December 1991) data starting in 1965:Q4, with the data in each vintage extending back to 1947:Q1. The data ends in 2018:Q1.

While the policy rules in the Monetary Policy Report use core Personal Consumption Expenditure (PCE) inflation that excludes food and energy prices, it is only available in real time since 1996:Q1. We therefore construct inflation rates as year-over-year changes in the GDP deflator, the ratio of nominal to real GDP, from 1965:Q4 – 1995:Q4 and year-over-year changes in core PCE from 1996:Q1 – 2018:Q1. While PCE inflation is available for the entire period, it was not widely followed before 2000 and “headline” inflation produces implausible policy rule prescriptions when energy prices either rise or fall rapidly.[4]

The output gap, the percentage deviation of real GDP around potential GDP, is measured using real-time estimates of actual and potential GDP by the Congressional Budget Office (CBO) starting in 1991:Q1. In order to construct the output gap before CBO estimates are available, real GDP data needs to be detrended. We use real-time detrending, where the trend is calculated from

[4] This is discussed by Bernanke (2010). The results are robust to using the GDP deflator for the entire sample.

1947:1 through the vintage date. For example, the output gap for 1965:4 is the deviation from a trend calculated from 1947:Q1 to 1965:Q3 using the 1965:4 vintage, the output gap for 1966:Q1 is the deviation from a trend calculated from 1947:Q1 to 1965:Q4 using the 1966:1 vintage, and so on, replicating the information available to policymakers.[5]

The three leading methods of detrending are linear, quadratic, and Hodrick-Prescott (HP). Which real-time output gap best approximates the perceptions of policymakers before 1991? We can immediately rule out real-time linear detrending, as the output gap becomes negative in 1974 and stays consistently negative through 1990. Nikolsko-Rzhevskyy and Papell (2012) and Nikolsko-Rzhevskyy, Papell, and Prodan (2014) use Okun's Law to construct "rule-of-thumb" output gaps based on real-time unemployment rates, perceptions of the natural rate of unemployment, and perceptions of the Okun's Law coefficient. Focusing on the quarters of peak unemployment associated with the recessions in the 1970s and 1980s, the congruence between real-time Okun's Law output gaps and real-time quadratic detrended output gaps is fairly close while the real-time HP detrended output gaps are always too small. Real-time quadratic detrended output gaps for 1965:Q4 – 1990:Q4 and CBO output gaps for 1991:Q1 - 2018:Q1 are depicted in Figure 1.[6]

We use realized values for inflation and the output gap. While Federal Reserve policy is often characterized in terms of forecasts, the policy rules presented to the FOMC through 2012 and included in the Monetary Policy Report since 2017 all contain realized values.[7] In the context of comparing prescriptions from policy rules with the actual federal funds rate, the Fed would have to use realized values because, if the rule contained forecasts, it would cause credibility issues because of the temptation to alter the forecasts to minimize deviations from the rule.

Taylor rules are often written in terms of the unemployment gap, the difference between the natural rate of unemployment and the current unemployment rate. In the Monetary Policy Report, the estimated unemployment rate in the longer run starting from 2000:Q1 is calculated from Blue Chip Economic Indicators. Prior to 2000, we use the methodology of Koenig (2004) to construct the natural rate of unemployment from various editions of Robert Gordon's

[5] The lag reflects the fact that GDP data for a given quarter is not known until after the end of the quarter.

[6] The results are robust to using real-time quadratic detrending throughout. They are also robust to using internal Fed (Greenbook) output gaps from 1987-2012 (when they are publicly available), quadratic detrended gaps from 1965-1987, and CBO gaps from 2013-2018.

[7] The policy rules presented to the FOMC are only publicly available through 2012.

macroeconomics textbook. The values of U* from 1965 to 1999 are from Gordon (1978) and subsequent values come from each new edition. While this is not exactly a real-time measure of U*, it is a good approximation. The unemployment gaps are shown in Figure 2. [8]

The policy rate is the effective (average of daily) federal funds rate for the quarter. The federal funds rate is constrained by the zero lower bound starting in 2009:Q1 and is therefore not a good measure of Fed policy. Between 2009:Q1 and 2015:Q3 we use the shadow federal funds rate of Wu and Xia (2016). The shadow rate is calculated using a nonlinear term structure model that incorporates the effect of quantitative easing and forward guidance. It is a "quasi-real-time" estimate because, while the calculation does not involve any *ex post* data, the parameters of the term structure model were estimated in December 2013. The shadow rate is consistently negative between 2009:Q3 and 2015:Q3.The federal funds/shadow rates are shown in Figure 3.[9]

In Taylor (1993a), the neutral real interest rate R* equals 2.0. Following the theory developed by King (2000) and Woodford (2003), there has been much discussion of the policy implications of time-varying neutral real interest rates.[10] In the Monetary Policy Report, the estimated neutral real interest rate in the longer run is calculated since 2000:Q1 as the three-month Treasury bill rate projected in the long run deflated by the long-run projected annual change in the price index for gross domestic product from Blue Chip Economic Indicators. Between 1965:Q4 and 1999:Q4, we calculate real-time neutral real interest rates as the 10 year average growth rate of real GDP. This is in the spirit of Taylor (1993a), who based his choice of R* = 2.0 on the average growth rate of 2.2 percent over the previous 35 quarters. The time-varying neutral real interest rates are depicted in Figure 4.[11]

Taylor (1993a) assumes that the inflation target π^* equals two. While this has been the Fed's published target since 2012 and is generally regarded as its implicit target during the Great Moderation and beyond, is seems too low for the Great Inflation and Volcker Disinflation years of the 1970s and early 1980s. As an alternative measure of the inflation target, we also use the

[8] The results are robust to using Gordon's values through 2008 and the longer-run normal rate of unemployment from the Summary of Economic Projections from 2009 - 2018.
[9] Bauer and Rudebusch (2016) estimate a variety of shadow short rates. The Wu and Xia rate is near the middle of the Bauer and Rudebusch rates for their model with three risk factors during most of the period. The results are robust to using the effective federal funds rate throughout the sample.
[10] Hamilton et al. (2015) contains an extensive discussion of the neutral real federal funds rate.
[11] The results are robust to using trend growth rates throughout and using either trend growth rates or R*=2 through 2004 and Laubach and Williams (2003) real-time neutral real interest rates starting when they become available in 2005.

time-varying inflation goal calculated by Fuhrer and Olivei (2017) which, along with actual inflation, is shown in Figure 5.[12]

The estimated inflation goal starts at about 2 percent, rises to about 3 percent during the 1973 – 1975 inflation, and then increases steadily to almost 7 percent in 1980 before falling back to about 4 percent by 1983 and close to 2 percent by 1999. The large increase in the inflation goal in the late 1970s and early 1980s is difficult to reconcile with contemporary accounts. Measuring from trough to peak, the inflation goal rose by 2.9 percentage points from 3.8 percent in 1977:1 to 6.7 percent in 1981:1 while actual inflation rose by 4.8 percentage points from 4.6 percent in 1977:1 to 9.4 percent in 1981:1, meaning that over half of the Great Inflation in the late 1970s and early 1980s can be attributed to the Fed's desire for higher inflation. For these reasons, we impose a maximum of 4 percent on the time-varying inflation target.

2.2 Constrained Discretion

Bernanke (2003) describes the conduct on monetary policy in the U.S. as "constrained discretion," defined as (1) "the central bank must establish a strong commitment to keeping inflation low and stable" and (2) "subject to the condition that inflation be kept low and stable,…,monetary policy should strive to limit cyclical swings in resource allocation." He argues that this policy framework is consistent with Congresses mandated objectives for monetary policy of maintaining price stability, maximum employment, and moderate long-term moderate interest rates.

In the context of the policy rules described by Equation (1), constrained discretion imposes two restrictions. First, in order to maintain low and stable inflation, it is necessary to establish an inflation target, which the Fed has done at two percent, and conduct policy in accord with the target. This requires that the Taylor principle be satisfied so an increase in inflation raises the nominal interest rate more than point-for-point, thus raising the real interest rate. Algebraically, this requires $\alpha > 0$ so that $\delta > 1$. This condition is both necessary and sufficient for inflation to be stationary in "backward-looking" New Keynesian models such as Taylor (1999b) and sufficient, but not necessary, for inflation to be determinate in "forward-looking" New Keynesian models such as Woodford (2003).[13] Second, in order to limit cyclical swings in resource allocation, the

[12] Inflation is measured as the quarterly percent change at an annual rate of the GDP deflator.
[13] The only exception to "necessary and sufficient" in these models is if the coefficient on the output gap is very large and the long-run New Keynesian Phillips curve is non-vertical.

interest rate needs to be raised (lowered) when the output gap is positive (negative), so that $\gamma > 0$ in Equation (1). Thus, constrained discretion limits the class of Taylor rules to those where $\alpha > 0$ and $\gamma > 0$.

2.3 Policy Rule Deviations

Our metric to evaluate policy rules involves dividing the sample into high and low deviations periods, where policy rule deviations are defined by the absolute value of the difference between the actual federal funds rate and the rate prescribed by a particular rule. Figure 6 depicts the deviations for the rule in Taylor (1993) with real-time data. Inflation is year-over-year changes in the GDP deflator, the output gap is quadratic detrended real GDP, the policy rate is the federal funds rate except for 2009:Q1 to 2015:Q3, where we use the shadow rate, the coefficients on the inflation and output gaps are both 0.5, and $\pi^* = R^* = 2.0$. We choose coefficients and data in accord with the Taylor (1993) rule in order to provide a quantitative illustration of well-known qualitative findings. The only difference is that, for the reasons described above, we use quadratic instead of linear detrending to construct the output gap. In general, the deviations will depend on both the choice of data and the coefficients of the rule.

In Nikolsko-Rzhevskyy, Papell, and Prodan (2014), we use statistical methods to identify high and low deviations periods. Since this would be impractical for the thousands of policy rules studied in the paper, as a first approximation we define high (low) deviations periods when the policy rule deviations are greater than (less than) two percentage points. This is illustrated in Figure 6 where the high deviations periods are depicted by the shaded areas. The Great Inflation and Volcker disinflation are periods of high deviations, the Great Moderation is characterized by low deviations, and the periods before 1974 and after 2000 are mixed. These results are robust to defining deviations by either 1.5 or 2.5 percentage points.[14]

2.4 Candidates for Fed Policy Rules

While all rules with coefficients on the inflation and output gaps between zero and infinity are consistent with constrained discretion, they are not all candidates for Fed policy rules. First, we turn to economic theory, which is not much help, as both Ball (1999) and Boehm and House (2014) show that, if there is no uncertainty about inflation and the output gap, the optimal coefficients are infinite. Second, we turn to simulation. Taylor and Wieland (2012) show that the

[14] We also estimated Markov switching models to calculate deviations. The correlation between these deviations and the deviations with two percentage points is 0.76.

optimal values of α and γ are 2.00 and 0.52 in the Taylor (1993b) model, 1.58 and 0.45 in the Christiano, Eichenbaum, and Evans (2005) model, and 1.04 and 0.26 in the Smets and Wouters (2007) model. Boehm and House (2014) report optimal values of α and γ of 1.00 and 0.61 while Tetlow (2015) reports optimal values of α and γ of 0.44 and 0.33 for the December 1998 and 0.53 and 1.17 for the October 2007 vintages of the FRB/US model. Third, we turn to estimation. Choosing four out of the hundreds of estimated Taylor rules, the estimated values of α and γ are 0.53 and 0.77 in Taylor (1999a), 1.15 and 0.93 in Clarida, Gali, and Gertler (2000), 0.33 and 1.29 in Rudebusch (2006), and 0.49 and 0.47 in Nikolsko-Rzhevskyy, Papell, and Prodan (2014).[15]

We propose an additional metric to restrict the coefficients of policy rules based on Fed behavior. Consider the set of 400 policy rules with α and γ between 0.1 and 2.0 with increments of 0.1, which includes the coefficients of the five optimal rules described above. For each rule, we want to calculate the number of periods between 1965:4 and 2017:3 where the policy rule deviations, the absolute value of the difference between the actual and prescribed federal funds rates, are low. The "share of time" the Fed adhered to a rule, i.e. the number of periods with low policy rule deviations divided by the total number of periods, is illustrated in Figure 7 for the 400 policy rules with a threshold of two for the deviations, a time-varying R*, and π* = 2.0. It can immediately be seen that the overwhelming preponderance of policy rules with the largest share in time of low deviations periods are for rules with coefficients on inflation and the output gap between 0.1 and 1.0.[16] Among these 100 rules, 76 are in the top quartile and 24 are in the second quartile. The average share in time for these 100 rules is 62 percent, while for the other 300 rules, it is only 44 percent. We therefore consider both the 100 policy rules with α and γ between 0.1 and 1.0 and the 400 policy rules with coefficients between 0.1 and 2.0. The larger set of rules are in accord with constrained discretion and optimal Taylor rules while the smaller set are also in accord with the share in time results and estimated Taylor rules.

[15] The estimates for Rudebusch (2006) and Nikolsko-Rzhevskyy, Papell, and Prodan (2014) are for their full samples, while the estimates for Taylor (1999a) and Clarida, Gali, and Gertler (2000) are for the sub-samples where the Taylor principle holds.
[16] This result is robust to every choice of data that we have tried.

3. Economic Performance

We evaluate economic performance based on a quadratic loss function with most recent historical values of GDP deflator inflation and unemployment gaps, where

$$Loss = \Sigma\,((\pi - \pi^*)^2 + (U - U^*)^2). \quad (3)$$

π is inflation, π* is the inflation target, U is unemployment, and U* is the natural rate of unemployment. The objective of policy is to minimize the loss function. The quadratic loss function has the property that, for combinations of inflation and unemployment gaps that produce the same linear loss, equal inflation and unemployment gaps are preferred to unequal gaps. The inflation target is taken at two percent and the natural rate of unemployment is calculated using current data from the CBO.

One way to proceed would be to estimate a model and simulate loss under various policy rules. As described in the Introduction, however, different models produce very different optimal policy rules. We propose instead to evaluate monetary policy rules based on economic outcomes. We cannot, however, choose a rule to minimize the loss function, for the loss over the entire period is given by history and is independent of the policy rule.[17] We therefore calculate loss ratios, the average loss in high deviations periods divided by the average loss in low deviations periods. For example, with the original Taylor rule depicted in Figure 6, this is the average loss in the shaded regions divided by the average loss in the unshaded regions. A good policy rule will have a loss ratio greater than one so that periods of large deviations have worse economic performance than periods of small deviations. The optimal policy rule will be the one with the largest loss ratio. We calculate loss ratios with increments of 0.1 for the set of 100 policy rules with α and γ between 0.1 and 1.0 and for the set of 400 policy rules with α and γ between 0.1 and 2.0.

The first specification discussed below includes a time-varying neutral real interest rate, measures real economic activity with an output gap, and specifies a two percent inflation target. We then replace the output gap with an unemployment gap, replace the time-varying R* with a constant R* = 2, and replace $\pi^* = 2$ with a time-varying inflation target. For each specification, the benchmark model has equal weights on inflation and unemployment loss, a threshold for low and high policy rule deviations of two percentage points, and a policy lag of six quarters. We also

[17] The average quadratic loss from Equation (3) is 10.58. If all deviations were positive and the loss was distributed evenly between inflation and unemployment loss, average inflation would be 4.33 percent and average unemployment would be 2.33 percent above the natural rate.

allow for policy lags of 4 and 8 quarters, thresholds of 2.5 and 1.5 percent, and higher weights on inflation loss than unemployment loss (and vice versa).

3.1 Output Gap, Time-Varying R, π^* = 2*

We first calculate loss ratios for the set of 100 policy rules with α and γ between 0.1 and 1.0 with increments of 0.1. Real economic activity is measured by the output gap, the neutral real interest rate is time-varying, and the inflation target equals two percent. The benchmark specification has equal weights on inflation and unemployment loss and a threshold for low deviations periods of two percent. Because changes in interest rates are generally considered to have their maximum effect in between one and two years, we incorporate a six-quarter policy lag so that the economic loss in high and low deviations periods is calculated based on inflation and unemployment gaps six quarters in the future.

The discretion-to-rules loss ratios are depicted in Panel A of Figure 8. Economic performance is better in low deviations periods than in high deviations periods for all policy rules. For the benchmark specification, the average discretion-to-rules loss ratio for the 100 policy rules is 2.53. Inflation gap tilting rules are preferred to output gap tilting rules. As shown in Figure 8, the loss ratios are larger for "inflation gap tilting" rules above and to the left of the upward-sloping diagonal than for "output gap tilting" rules below and to the right of the diagonal. We illustrate this with several metrics. The first is visual. Figure 8 divides the 100 rules into five quintiles of 20 rules. The preponderance of rules in the top two quintiles, where the loss ratios are largest, are inflation gap tilting rules above and to the left of the diagonal where the inflation gap coefficient α is greater than the output gap coefficient γ. The second is numerical. The first column of Table 1 reports the "relative loss ratio", the average loss ratio of the inflation gap tilting rules above and to the left of the diagonal divided by the average loss ratio of the output gap tilting rules below and to the right of the diagonal. The relative loss ratio is 1.37, showing that the loss ratios are larger for inflation gap tilting rules than for output gap tilting rules.

While a relative loss ratio of 1.37 indicates economic significance, we also test for statistical significance. In order to bootstrap model-specific critical values for the relative loss ratios of the above and below diagonal discretion-to-rules loss ratios, we conduct Monte-Carlo simulations. We first save the actual 10x10 matrix of loss ratios that correspond to different combinations of alpha and gamma. We then generate 5,000 artificial 10x10 matrices of losses that consist of the elements of the original matrix, and calculate the resultant relative loss ratios. These are sorted in ascending order to construct the critical values. The null hypothesis is that the relative loss ratio is equal to one, while the (conservative) two-sided alternative hypothesis is that the relative loss ratio is different from one. For the benchmark specification with the ratio of 1.37, the null hypothesis can be rejected at the one percent level, showing that the loss ratios for inflation gap tilting rules are significantly greater than for output gap tilting rules.[18]

Table 1 also reports results for a number of changes in the benchmark specification. The result that inflation gap tilting rules are preferred to output gap tilting rules is robust to incorporating alternatives that change one aspect of the benchmark specification. First, we tried policy lags of four and eight quarters. The loss ratios continue to be larger for the inflation gap tilting rules than for the output gap tilting rules, with the relative loss ratio 1.35 with four quarter lags and 1.46 with eight quarter lags. Second, we varied the threshold. With a larger 2.5 percent threshold, the results are stronger, with a relative loss ratio of 1.44. With a smaller 1.5 percent threshold, the results are weaker, with a relative loss ratio of 1.26. Third, we varied the weights on inflation gap and unemployment gap loss. With weights of 1.25 and 0.75 on the inflation and output gaps the results are stronger, with a relative loss ratio of 1.51 and, with weights of 1.5 and 0.5, they are even stronger with a relative loss ratio of 1.65. It is not, of course, surprising that the relative loss ratios increase with higher weights on inflation than on unemployment loss. It is, however, more surprising that, even with higher weights on unemployment loss than on inflation loss, the loss ratios are still larger for the inflation gap tilting rules than for the output gap tilting rules. With weights of 1.25 and 0.75, the relative loss ratio is 1.21 and, even with weights of 1.5 and 0.5, the relative loss ratio is 1.04. All of the relative loss ratios are significantly greater than unity at the five percent level or higher except for the loss function with a weight of 1.5 on unemployment loss and 0.5 on inflation loss.

The discretion-to-rules loss ratios for the set of 400 policy rules with α and γ between 0.1 and 2.0 with increments of 0.1 are depicted in Panel B of Figure 8. The evidence that economic performance is better in low deviations periods than in high deviations periods is stronger for the 400 rules than for the 100 rules, as the average discretion-to-rules loss ratio for the benchmark specification is 3.50 compared with 2.53. The loss ratios are greater than one for all 400 rules. The

[18] The results are robust to using a “thick” diagonal which includes the upward-sloping lines just above and below the diagonal. This divides the 100 rules into two groups of 36 and one group of 28, which is as close as one can get to equal groups.

evidence that inflation gap tilting rules are preferred to output gap tilting rules is also stronger for the 400 rules than for the 100 rules. This can be seen in Panel B of Figure 8, where the preponderance of rules in the first and second quintiles are above and to the left of the upward-sloping 45 degree line. It can also be shown statistically. Comparing the first and second columns of Table 1, the relative loss ratio with the 400 rules is larger than the relative loss ratio with the 100 rules and significantly greater than unity at the one percent level for all nine specifications.[19]

3.2 Unemployment Gap, Time-Varying R, π* = 2*

The Monetary Policy Report incorporates a policy rule with an unemployment gap instead of an output gap,

$$i_t = R_t^* + \pi_t + 0.5(\pi_t - \pi^*) + 2.0(U_t^* - U_t) \quad (4)$$

where i_t is the level of the federal funds rate, π_t is the core PCE inflation rate, π^* is the FOMC's two percent target for inflation, U_t is the unemployment rate, U_t^* is the longer-run normal rate of unemployment, (U_t^* - U_t) is the unemployment gap, and R_t^* is the neutral real interest rate. The rule is an unemployment gap tilting rule because the coefficient 2.0 on the unemployment gap is consistent with a coefficient of 1.0 on the output gap with an Okun's Law coefficient of 2.0.[20]

We first calculate loss ratios for the set of 100 policy rules with α and γ between 0.1 and 1.0 with increments of 0.1. The coefficients on the unemployment gap are between 0.2 and 2.0 with increments of 0.2. The results are depicted in Panel A of Figure 9 with the coefficients on the unemployment gap multiplied by 0.5 to construct an "implied" output gap so that the upward-sloping 45 degree line divides the results between inflation gap tilting and unemployment gap tilting rules. They are for the specification with a time-varying R*, π^*=2, a policy lag of six quarters, a threshold of two percent, and equal weights on inflation and unemployment loss. The result that economic performance is better in low deviations periods than in high deviations periods with the unemployment gap in Figure 9 is not as strong as with the output gap in Figure 8. The average discretion-to-rules loss ratio is 2.02 and, for the benchmark specification, the loss ratios are greater than one for 91 out of 100 rules. Economic performance is better in low deviations

[19] Policy rules with higher coefficients above and to the right of the downward-sloping diagonal line in panel B of Figure 8 are also preferred to rules with lower coefficients below and to the left of the downward-sloping 45 degree line. As shown in Figure 7, however, these rules are much less in accord with Fed behavior than the lower coefficient rules, with most of the shares in time less than 50 percent and in the bottom two quartiles.

[20] Rudebusch (2010), Reifschneider (2016) and Yellen (2016) discuss rules with a coefficient of 2.0 on the unemployment gap.

periods than in high deviations periods for all policy rules with a coefficient on the inflation gap of 0.3 or higher.

Inflation gap tilting rules are strongly preferred to unemployment gap tilting rules. The preponderance of rules in the top two quintiles, where the loss ratios are largest, are inflation gap tilting rules above and to the left of the diagonal where the inflation gap coefficient α is greater than the implied output gap coefficient γ. The relative loss ratio for the benchmark specification, reported in the first column of Table 2, is 1.83, higher than for the same specification with the output gap. Table 2 reports the results for the same changes in the benchmark specification in order to test for robustness. The results are stronger than those with the output gap, a time-varying R*, and $\pi^*=2$, as the coefficients in the first column of Table 2 are larger than the corresponding coefficients in the first column of Table 1 and all of the relative loss ratios are significantly greater than unity at the one percent level. With a two percent inflation target and a time-varying neutral real interest rate, the result that economic performance is better in low deviations periods than in high deviations periods is stronger with the output gap while the result that inflation gap tilting rules are preferred to unemployment gap tilting rules is stronger with the unemployment gap.

The discretion-to-rules loss ratios for the set of 400 policy rules with α and γ between 0.1 and 2.0 with increments of 0.1 are depicted in Panel B of Figure 9. The evidence that economic performance is better in low deviations periods than in high deviations periods is stronger for the 400 rules than for the 100 rules, as the average discretion-to-rules loss ratio is 3.08 compared with 2.02. While the evidence is very strong, it is weaker for the unemployment gap than for the output gap, as the average loss ratio is 3.08 compared with 3.50 and the loss ratios are greater than one for 387 out of 400 rules with the unemployment gap compared with all 400 rules for the output gap. The loss ratios that are less than one, so that economic performance is better in high deviations periods than in low deviations periods, are all for rules with low inflation gap coefficients. The evidence that inflation gap tilting rules are preferred to output gap tilting rules is again stronger for the 400 rules than for the 100 rules. This can be seen in Panel B of Figure 9, where the preponderance of rules in the first and second quintiles are above and to the left of the upward-sloping 45 degree line, and by comparing the first and second columns of Table 2, where the relative loss ratio with the 400 rules is larger than the relative loss ratio with the 100 rules and significantly greater than unity at the one percent level for all nine specifications.

3.3 Output Gap, R = 2, π* = 2*

We proceed to analyze policy rules with an output gap, π* = 2, and R* = 2 as in the original Taylor (1993a) rule. First, we calculate loss ratios for the set of 100 policy rules with α and γ between 0.1 and 1.0 with increments of 0.1. The results with the benchmark specification of a six-quarter policy lag, two percent threshold, and equal weights on inflation and unemployment loss are depicted in Panel A of Figure 10. The result that economic performance is better in low deviations periods than in high deviations periods is weaker with R* = 2 than with a time-varying R*. The average discretion-to-rules loss ratio is 1.75 and, for the benchmark specification, the loss ratios are greater than one for 90 out of 100 rules. The 10 rules for which the loss ratio is less than one all have coefficients α on the inflation gap of 0.1 or 0.2.

Inflation gap tilting rules are also preferred to output gap tilting rules with R* = 2, as the preponderance of rules in the top two quintiles, where the loss ratios are largest, are inflation gap tilting rules above and to the left of the diagonal. The relative loss ratio, reported in the first column of Table 3, is 1.30, lower than the value of 1.37 with a time-varying R*. Table 3 reports the results for the same changes in the benchmark specification in order to test for robustness. The results with R* = 2 are similar to those with a time-varying R*, as the relative loss ratios in the first column of Table 3 are comparable to the corresponding loss ratios in the first column of Table 1. All of the relative loss ratios are significantly greater than unity at the five percent level or higher except for the loss function with a 1.5 weight on unemployment loss and 0.5 on inflation loss.

The discretion-to-rules loss ratios for the set of 400 policy rules with α and γ between 0.1 and 2.0 with increments of 0.1 are depicted in Panel B of Figure 10. The evidence that economic performance is better in low deviations periods than in high deviations periods is stronger for the 400 rules than for the 100 rules, as the average discretion-to-rules loss ratio is 1.95 compared with 1.75. It is weaker for the rules where R* = 2 than for the rules with a time-varying R*, as the average loss ratio is 1.95 compared with 3.50 and the loss ratios are greater than one for 331 out of 400 rules compared with all 400 rules with a time-varying R* = 2. The loss ratios that are less than one, so that economic performance is better in high deviations periods than in low deviations periods, are all for rules with low inflation gap and/or high output gap coefficients. The evidence that inflation gap tilting rules are preferred to output gap tilting rules is again stronger for the 400 rules than for the 100 rules. This can be seen in Panel B of Figure 10, where the preponderance of rules in the first and second quintiles are above and to the left of the upward-sloping 45 degree line, and by comparing the first and second columns of Table 3, where the relative loss ratio with the 400 rules is larger than the relative loss ratio with the 100 rules and significantly greater than unity at the one percent level for all nine specifications.

3.4 Output Gap, Time-Varying R, Time-Varying Inflation Target*

We now analyze policy rules where π*=2 is replaced by a time-varying inflation target. We use the inflation target calculated by Fuhrer and Olivei (2017), capped at a maximum of 4 percent. We analyze policy rules with the output gap and a time-varying R*. The results with the benchmark specification of a six-quarter policy lag, two percent threshold, and equal weights on inflation and unemployment loss are depicted in Panel A of Figure 11. Economic performance is clearly better in low deviations periods than in high deviations periods. The average discretion-to-rules loss ratio is 1.78 and, for the benchmark specification, the loss ratios are greater than one for 99 out of 100 rules. The results, however, are not as strong as with the output gap, a time-varying R*, and π*=2, where the average discretion-to-rules loss ratio is 2.53 for the benchmark specification and the loss ratios are greater than one for all 100 rules. Economic performance is better in low deviations periods than in high deviations periods for all policy rules with a coefficient on the inflation gap of 0.2 or higher.

Inflation gap tilting rules are strongly preferred to output gap tilting rules, as the preponderance of rules in the top two quintiles are inflation gap tilting rules. The relative loss ratio, reported in the first column of Table 4, is 1.25. Table 4 reports the results for the same changes in the benchmark specification in order to test for robustness. The results are weaker than those in Table 1 with the output gap, a time-varying R*, and π*=2, as six, one, and one of the nine relative loss ratios are significantly greater than unity at the one, five, and 10 percent levels, the exception being the loss function with a weight of 1.5 on unemployment loss and 0.5 on inflation loss.

The discretion-to-rules loss ratios for the set of 400 policy rules with α and γ between 0.1 and 2.0 with increments of 0.1 are depicted in Panel B of Figure 10. The evidence that economic performance is better in low deviations periods than in high deviations periods is weaker for the 400 rules than for the 100 rules, as the average discretion-to-rules loss ratio is 1.62 compared with 1.78. While the evidence is very strong, it is weaker for the time-varying inflation target than for π*=2, as the average loss ratio is 1.62 compared with 3.50 and the loss ratios are greater than one for 377 out of 400 rules with the time-varying inflation target compared with all 400 for π*=2. The loss ratios that are less than one, so that economic performance is better in high deviations periods than in low deviations periods, are almost all for rules with high output gap coefficients. The evidence that inflation gap tilting rules are preferred to output gap tilting rules is again stronger for the 400 rules than for the 100 rules. This can be seen in Panel B of Figure 11, where the preponderance of rules in the first and second quintiles are above and to the left of the upward-sloping 45 degree line, and by comparing the first and second columns of Table 4, where the relative loss ratio with the 400 rules is larger than the relative loss ratio with the 100 rules for all nine specifications and significantly greater than unity at the one percent level except for the loss function with a weight of 1.5 on unemployment loss and 0.5 on inflation loss, which is significantly greater than unity at the five percent level.

We conclude by summarizing the findings in this section. The results that (1) economic performance is better in low deviations periods than in high deviations periods and (2) inflation gap tilting rules are preferred to output gap tilting rules are robust across a wide variety of models. The results are stronger with a time-varying R* than with R*=2 and with π*=2 than with a time-varying π*. The strongest results that economic performance is better in low deviations periods than in high deviations periods are for the specification in Table 1 and Figure 8 consistent with the rules posted on the Fed's web page with an output gap, a time-varying R*, and π*=2 and the strongest results that inflation gap tilting rules are preferred to output gap tilting rules are for the specification in Table 3 and Figure 10 consistent with the rules in the Monetary Policy Report with an unemployment gap, a time-varying R*, and π*=2. While both results are stronger for the 400 rules with alpha and gamma ranging from 0.1 to 2.0 than the 100 rules with alpha and gamma ranging from 0.1 to 1.0, this comparison should be interpreted with caution because the congruence between the rules and Fed behavior is much larger for the smaller set of 100 rules than the larger set of 400 rules.

4. Perspectives

In the context of monetary policy evaluation based on economic performance, we have shown that economic performance is better in low deviations periods than in high deviations periods and inflation gap tilting policy rules are preferred to output gap tilting rules. These results are robust to fixed versus time-varying neutral real interest rates and/or inflation targets, different policy lags, weights on inflation and unemployment loss, and delineation of high and low deviations periods. We now proceed to use theory, simulations, and Fed policy to provide some perspective on the results.

4.1 Theory

Woodford (2003) is the definitive reference for optimal policy rules. In general, optimal policy depends on all of the parameters in the model and, in the context of Taylor rules, not much can be said about the magnitude of the coefficients except that optimality generally requires that the Taylor principle be satisfied. An exception, however, is contained in his discussion of implementation of a targeting rule, where the optimal rule has the property that the coefficient on the inflation gap is greater than the coefficient on the output gap in the Taylor rule if and only if the coefficient on expected inflation is greater than the coefficient on the output gap in the New Keynesian Phillips curve.[21] Some empirical support for the latter proposition can be found in Mavroeidis, Plagborg-Moller, and Stock (2014) who survey various estimates of hybrid New Keynesian Phillips Curves and find that, for the vast majority, the coefficient on expected inflation is greater than the coefficient on the proxy for real marginal cost which, in turn, is proportional to the output gap.

4.2 Simulations

Among the three models studied by Taylor and Wieland (2012), Smets and Wouters (2007) is the only one for which the coefficient on the inflation gap in the optimal Taylor rule is close to the top quartile of the share in time results in Figure 7 that are congruent with Fed behavior. Smets and Wouters (2007) estimate a model of the US economy with data from 1966:1 to 2004:4 using a Bayesian method to fit the dynamic properties of various key variables in response to a full set of shocks. Taylor and Wieland (2012) compute the optimal policy rule by minimizing a loss function which includes the unconditional variances of inflation, the output gap, and the change in the nominal interest rate, equally weighted, where

$$Loss = Var(\pi) + Var\ (y) + Var(\Delta i) \tag{5}$$

Taylor and Wieland (2012) show that the coefficients for the optimal policy rule for the SW model has alpha = 1.04 and gamma = 0.26. Using the same loss function, we evaluate economic performance for 100 policy rules with values of α and γ between 0.1 and 1.0 with increments of 0.1.[22] The results are shown in Figure 12. The quintile with the lowest loss, and thus best

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[21] See Woodford (2003), page 531.

[22] In order to simulate the model for various coefficients we use the Macroeconomic Model Database which is an interactive collection of macroeconomic models that can be estimated and optimized. More details can be found in Wieland et al (2012). This platform relies on the DYNARE 3 software for model solution and can be used with Matlab. Software and models are available for download from http://www.macromodelbase.com/.

performance, is in the upper left triangle where the coefficient on inflation α is larger than the coefficient on the output gap γ, with the loss increasing as α becomes smaller and/or γ becomes larger. These results are in accord with our results that inflation gap tilting rules are preferred to output gap tilting rules. Boehm and House (2014) simulate optimal Taylor rules in a New Keynesian model when inflation and the output gap are observed with error. For their baseline calibration, $\alpha = 1.0$ and $\gamma = 0.61$, which is in accord with our results that inflation gap tilting/high coefficient rules are preferred to output gap tilting/low coefficient rules.

The FRB/US model is the principal macro model used by the Fed since July 1996 and publicly available since April 2014. Using the FRB/US model and 46 vintages between July 1996 and October 2007, Tetlow (2015) examine how the model specification, coefficients and stochastic shock sets changed from vintage to vintage.[23] The optimal policy rule is computed by minimizing the expected value of a quadratic loss function with the inflation gap, the unemployment gap and the change in the nominal interest rate, equally weighted, where

$$Loss = \sum_{t=0}^{T} 0.99^{t}((\pi_t - \pi^*)^2 + (u_t - u^*)^2 + (\Delta i_t)^2) \qquad (6)$$

π_t is the inflation rate in quarter t (the four-quarter percent change of the PCE deflator), π^* is the two percent inflation target, u_t is unemployment, u^* is the natural rate of unemployment and Δi_t is the first difference of the federal funds rate. In addition, future losses are discounted at a quarterly rate of one percent.[24] Minimizing the above loss function, Tetlow (2015) shows that the optimal policy rule for the October 2007 vintage of the FRB/US model has alpha = 0.53 and gamma = 1.17.

Using the same loss function and the June 2015 vintage data, we evaluate economic performance for 100 policy rules with values of α and γ between 0.1 and 1.0 with increments of 0.1[25]. The results with R* = 2, π^* = 2, and a zero bound on the nominal interest rate are shown in Figure 13. The results are completely opposite to those with the Smets and Wouters (2007) model. The quintile with the lowest loss, and thus best performance, is in the lower right triangle where the coefficient on the output gap γ is larger than the coefficient on inflation α, with the loss

[23] Tetlow (2015) uses the VAR-based expectations version of the model rather than the model-consistent expectations version.
[24] The assumption is that the economy converges over time to a long-run equilibrium in which the inflation rate is two percent, the unemployment rate settles at its natural rate value, and the federal funds rate remains constant at its longer-run value (T in the above summation), so expected losses are zero. The loss function is evaluated for 20 quarters into the future, sufficient time for the economy to settle back into its long-run equilibrium.
[25] The data spans from1968:Q1 to 2015:Q2 and projected observations on all variables are available from 2015:Q3.

increasing as α becomes smaller and/or γ becomes larger. The preference for output gap tilting policy rules over inflation gap tilting rules is obviously not in accord with our results for economic performance that inflation gap tilting rules are preferred to output gap tilting rules.[26]

4.3 Uncertainty and Misperception

Inflation gaps are much less subject to revision than output and unemployment gaps because, while revisions to inflation gaps only depend on revisions to inflation, revisions to output and unemployment gaps depend on revisions to potential output and the natural rate of unemployment as well as to revisions in output and unemployment. Orphanides (2003) has emphasized underestimation of the natural rate of unemployment as an important cause of the rise of inflation in the 1970s and Orphanides *et al*. (2000) and Orphanides and Williams (2007) recommend that policymakers increase the responsive of the federal funds rate to inflation and reduce its responsiveness to measures of slack such as output and/or unemployment gaps. Our result that inflation gap tilting rules are preferred to output gap tilting rules is in accord with this research.

Yellen (2015a) uses the decline in the neutral real interest rate to justify Fed policy following the financial crisis and the Great Recession. One issue with using time-varying neutral real interest rates to conduct monetary policy is that, as discussed by Laubach and Williams (2003), Clark and Kozicki (2005), Yellen (2015b), and Taylor and Wieland (2016), they are measured with uncertainty and subject to revision. Laubach and Williams (2016) discuss the implications of uncertainty in the measurement of the neutral real interest rate. In the context of the Taylor rules in Equation (1), they advocate a strong response of the federal funds rate to inflation gaps in order to reduce the influence of the intercept, which changes one-for-one with changes in the neutral real interest rate, on the setting of the policy rate. This is in accord with our results for economic performance that the Fed should respond strongly to the inflation gap.

Powell (2018) discusses the difficulty of “navigating by stars” when the fundamental features of the economy – potential output, the natural rate of unemployment, and the neutral real interest rate, are both unobservable and shifting. In contrast, the two percent inflation objective has been chosen by the FOMC. While he doesn’t discuss policy rules, the same logic would dictate

[26] The results are robust to not imposing a zero lower bound on the nominal interest rate and/or to incorporating a time-varying neutral real interest rate.

placing more weight on the gap from the known inflation "star" relative to the gaps from the unknown output and unemployment "stars".

Erceg *et al*. (2018) revisit the conventional argument that, in the presence of mismeasurement of the output and/or the unemployment gap, policymakers should reduce the response to these measures and increase the response to inflation. Using a small version of the FRB/US model, they find that an "inflation-averse" rule performs worse than a "balanced approach" or an "unemployment-averse" rule.

Their inflation-averse rule has a coefficient α on the inflation gap of 1.5 and a coefficient γ on the output gap of 0.31, making it an "inflation gap tilting" rule in our terminology.[27] Their balanced approach rule has a coefficient α on the inflation gap of 0.5 and a coefficient γ on the output gap of 0.93, making it an "output gap tilting" rule in our terminology and their unemployment-averse rule has a coefficient α on the inflation gap of 0.17 and a coefficient γ on the output gap of 2.78, also making it an "output gap tilting" rule in our terminology.

Using the share in time results from Figure 7, the deviation between the prescribed and the actual federal funds rate from their balanced approach rule is within the two percent threshold 68 percent of the time, placing it in the first quartile and the deviation from their inflation-averse rule is within the two percent threshold 53 percent of the time, placing it in the third quartile. The output gap coefficient γ for their unemployment-averse rule, however, is 2.78, placing outside the bounds of the figure. If we decrease γ to equal 2.0, the deviation is within the two percent threshold only 32 percent of the time, placing it in the bottom quartile. We therefore restrict attention to their balanced approach and inflation-averse rules.

We now analyze how their rules perform according to our subsequent economic performance metric. Using their specification with the output gap, a time-varying R*, and $\pi^* = 2$, the loss ratio from their inflation-averse rule is in the second quintile of Panel B of Figure 8 while the loss ratio from their balanced approach rule is in the fourth quintile. The results from the Smets and Wouters (2007) model are even stronger, as the loss ratio from their inflation-averse rule is in the first quintile of Figure 11 while the loss ratio from their balanced approach rule is in the fourth quintile.[28] The results from the FRB/US model, however, are completely opposite, as the loss ratio

[27] Their policy rules are written in terms of the unemployment gap, so we do the same Okun's Law conversion as above to write them in terms of the output gap.
[28] We set α in the inflation-averse rule to 1.0 to keep it in the bounds of Figure 11.

from their balanced approach rule is in the first quintile of Figure 12 while the loss ratio from their inflation-averse rule is in the fifth quintile.

Bullard (2018) proposes a "modernized" policy rule with a time-varying R*, a coefficient of 0.5 on the inflation gap, and a coefficient of 0.1 on the output gap. The rationale for the low coefficient on the output gap comes from the weakening, and arguably disappearing, of the Phillips curve so that there is very little feedback from the real economy to inflation. This rule is in accord with our result that inflation gap tilting rules are preferred to output gap tilting rules. It is not, however, a well-performing rule, as it is in the fourth quintile of Figure 8. It should, however, be noted that the preponderance of our results come from periods where the slope of the Phillips curve was steeper than it is today. In addition, a modification of the rule with a coefficient of 1.0 on the inflation gap and a coefficient of 0.2 on the output gap, so that the magnitude of the coefficients is doubles but the proportion remains the same, is in the second quintile of Figure 8.

4.4 Optimal Policy Rules

While the focus of the paper is on types of policy rules rather than on optimal rules, we report the "best" rule in order to compare our results with other studies. For each of our specifications, we identify the policy rule in Figures 8-11 that maximizes the loss ratios for a six quarter policy lag, a two percent threshold for deviations, and equal weights on inflation gaps and unemployment gaps.

For the set of 100 rules with alpha and gamma ranging from 0.1 to 1.0, the coefficient on the inflation gap $\alpha = 1.0$ for all four specifications, which is the maximum allowed. In contrast, the coefficient on the output gap γ ranges from 0.6 to 0.9. In all four cases, the coefficient on the inflation gap is larger than the coefficient on the output gap. The coefficients on the inflation and output gaps that maximize the loss ratios are most consistent with the optimal Taylor rule in the Boehm and House (2014) model.

For the set of 200 rules with alpha and gamma ranging from 0.1 to 2.0, the coefficient on the inflation gap α ranges from 1.7 to 2.0 while the coefficient on the output gap γ ranges from 0.7 to 1.0, so the coefficient on the inflation gap is considerably larger than the coefficient on the output gap in all four cases. The coefficients on the inflation and output gaps that maximize the loss ratios are consistent with optimal Taylor rules in the Taylor (1993) and Christiano, Eichenbaum, and Evans (2005) models. Neither set of coefficients are consistent with optimal Taylor rules in the FRB/US model.

4.5 Fed Policy

We now consider how well our results accord with actual Fed behavior. Figure 14 depicts the share of time with low deviations, the number of periods with policy rule deviations less than two divided by the total number of periods, for the 100 policy rules with values of α and γ between 0.1 and 1.0 for the model with an output gap, a time-varying R*, and $\pi^*=2$. The set of 100 policy rules was chosen for congruence with Fed behavior in Figure 7.[29] Fed policy does not respond strongly to inflation. For the top quintile of the shares, the coefficient on the inflation gap α is less than or equal to 0.4 in 19 out of 21 cases and less than or equal to 0.5 in all cases. These results are robust to other specifications, showing a clear tilt towards policy rules with a low response to inflation within the class of rules where $\alpha > 0$ so that the Taylor principle is satisfied.

The Fed responds much more strongly to output gaps than inflation gaps. For the top quintile of the shares, the coefficient on the output gap γ is greater than or equal to 0.5 in all cases. The result that Fed policy responds strongly to output gaps and does not respond strongly to inflation gaps has a striking implication. With an output gap, a time-varying R*, and $\pi^*=2$, 16 of the 21 policy rules in the top quintile of the share-in-time results in Figure 14 and, therefore, most congruent with Fed policy, have loss ratios in the bottom two quintiles of Panel A of Figure 8.

5. Conclusions

Should the Fed specify a numerical policy rule, or should it follow constrained discretion by announcing an inflation target and respecting the dual mandate, but not specifying a particular rule? Despite decades of research and increased transparency by the Fed, the question seems no closer to resolution than the "rules versus discretion" debates of the 1960s and 1970s.

This paper takes a different perspective. Instead of evaluating "policy rules *versus* constrained discretion," we consider "policy rules *and* constrained discretion." This is consistent with the large increase in transparency from including policy rules in the Monetary Policy Report in addition to the Tealbook, as the former is publicly available immediately while the latter is only publicly available with a five year lag. For the first time, it is possible to see the prescriptions of the various policy rules that the Fed is presenting and compare them with the current Federal Funds Rate.

[29] The numbers in Figure 14 are identical to those in the lower left quadrant of Figure 7.

Starting with the universe of Taylor (1993a) rules with coefficients on the inflation and output gaps ranging from positive and negative infinity, we first show that constrained discretion restricts both coefficients to be positive. We then use optimal policy results, previous estimates of Taylor rules, and an original metric for Fed behavior to further restrict attention to two sets of rules. The first constrains both coefficients to be between 0.1 and 1.0 and is consistent with Fed behavior while the second constrains both coefficients to be between 0.1 and 2.0 and is consistent with the range of optimal policy results.

We propose a metric to evaluate monetary policy rules by comparing economic performance. We calculate quadratic loss ratios, the (inflation plus unemployment) loss in high deviations periods divided by the loss in low deviations periods, with policy rules with higher loss ratios preferred to rules with lower loss ratios. Rather than focusing on a single "optimal" rule, we examine the set of 100 rules with both coefficients between 0.1 and 1.0 and the set of 400 rules with both coefficients between 0.1 and 2.0 with increments to the inflation gap and output gap coefficients of 0.1.

The central results of the paper are that (1) economic performance is better in low deviations periods than in high deviations periods for the vast majority of rules, and (2) rules with larger coefficients on the inflation gap than on the output gap are preferred to rules with larger coefficients on the output gap. These results are robust to policy lags between one and two years, different weights on inflation loss than on unemployment loss, various definitions of high and low deviations periods, time-varying and constant neutral real interest rates, time-varying and constant inflation targets, and measuring real economic activity with either an output gap or an unemployment gap. The results receive support from theory and simulations of the Smets and Wouters (2007) model, but are not in accord with either Fed behavior or simulations of the FRB-US model.

Taylor rules with time-varying neutral real interest rates have, following Yellen (2015a), taken center stage in monetary policy debates. Williams (2015) and Yellen (2015b) have emphasized both the importance of the decline of various measures of neutral real rates since the Great Recession and the uncertainty in measuring neutral real rates on the conduct of monetary policy. Our result that the Fed should respond strongly to inflation gaps is in accord with the policy prescriptions in Laubach and Williams (2016) when the neutral real interest rate is uncertain.

The debate between proponents of policy rules and constrained discretion has focused on the adherence of Fed policy to one or more specific rules. Instead of examining a particular rule, we evaluate economic performance between two classes of rules, inflation gap tilting versus output gap tilting, all of which are consistent with constrained discretion. We conclude that the Fed should "constrain" constrained direction by responding more strongly to inflation gaps than to output gaps. This type of rule should be added to the Fed's semi-annual Monetary Policy Report. Since the Report already contains a balanced rule where the coefficients on both the inflation gap and the output gap equal one-half and an output gap tilting rule where the coefficient on the inflation gap equals one-half and the coefficient on the output gap equals one, an obvious choice would be to add an inflation gap tilting rule where the coefficient on the inflation gap equals one and the coefficient on the output gap equals one-half. This inflation gap tilting rule is in the top quintile for all four of our specifications, where the balanced rule is in the top quintile for one and the second quintile for three specifications and the output gap tilting rule is in the fourth quintile for all four specifications.

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Table 1. Relative Loss Ratios for R*=Time-Varying, π*=2%, Output Gap

	Inflation Gap Tilting Rules/Output Gap Tilting Rules Ratio	
Inflation α and Output Gap γ Coefficients Range	[0, 1]	[0, 2]
Equal Weights on Inflation and Unemployment Loss. Threshold = 2%		
Policy Lag = 6 quarters	1.37***	2.78***
Policy Lag = 4 quarters	1.35***	2.58***
Policy Lag = 8 quarters	1.46***	3.13***
Equal weights on Inflation and Unemployment Loss. Policy Lag = 6 quarters		
Threshold = 2.5%	1.44***	2.74***
Threshold = 1.5%	1.26**	2.65***
Threshold = 2%. Policy Lag = 6 quarters		
1.25:0.75 Inflation and Unemployment Loss Weights	1.51***	3.41***
1.5:0.5 Inflation and Unemployment Loss Weights	1.65***	4.16***
0.75:1.25 Inflation and Unemployment Loss Weights	1.21**	2.24***
0.5:1.5 Inflation and Unemployment Loss Weights	1.04	1.74***

** ,**, and *** denote test statistics significant at 10, 5, and 1% level, respectively, based on critical values for the two-sided test.*

Table 2. Relative Loss Ratios for R*=Time-Varying, π*=2%, Unemployment Gap

	Inflation Gap Tilting Rules/Output Gap Tilting Rules Ratio	
Inflation α and Output Gap γ Coefficients Range	[0, 1]	[0, 2]
Equal Weights on Inflation and Unemployment Loss. Threshold = 2%		
Policy Lag = 6 quarters	1.83***	2.92***
Policy Lag = 4 quarters	1.66***	2.48***
Policy Lag = 8 quarters	2.04***	3.26***
Equal weights on Inflation and Unemployment Loss. Policy Lag = 6 quarters		
Threshold = 2.5%	1.95***	2.61***
Threshold = 1.5%	1.51***	2.66***
Threshold = 2%. Policy Lag = 6 quarters		
1.25:0.75 Inflation and Unemployment Loss Weights	2.05***	3.52***
1.5:0.5 Inflation and Unemployment Loss Weights	2.26***	4.18***
0.75:1.25 Inflation and Unemployment Loss Weights	1.58***	2.38***
0.5:1.5 Inflation and Unemployment Loss Weights	1.30***	1.86***

** ,**, and *** denote test statistics significant at 10, 5, and 1% level, respectively, based on critical values for the two-sided test.*

Table 3. Relative Loss Ratios for R*=2%, π*=2%, Output Gap

	Inflation Gap Tilting Rules/Output Gap Tilting Rules Ratio	
Inflation α and Output Gap γ Coefficients Range	[0, 1]	[0, 2]
Equal Weights on Inflation and Unemployment Loss. Threshold = 2%		
Policy Lag = 6 quarters	1.30***	2.15***
Policy Lag = 4 quarters	1.32***	2.25***
Policy Lag = 8 quarters	1.50***	2.20***
Equal weights on Inflation and Unemployment Loss. Policy Lag = 6 quarters		
Threshold = 2.5%	1.41***	2.21***
Threshold = 1.5%	1.22**	2.10***
Threshold = 2%. Policy Lag = 6 quarters		
1.25:0.75 Inflation and Unemployment Loss Weights	1.44***	2.42***
1.5:0.5 Inflation and Unemployment Loss Weights	1.57***	2.67***
0.75:1.25 Inflation and Unemployment Loss Weights	1.14**	1.85***
0.5:1.5 Inflation and Unemployment Loss Weights	0.96	1.51***

** ,**, and *** denote test statistics significant at 10, 5, and 1% level, respectively, based on critical values for the two-sided test.*

Table 4. Relative Loss Ratios for R*=Time-Varying, π*=Time-Varying, Output Gap

	Inflation Gap Tilting Rules/Output Gap Tilting Rules Ratio	
Inflation α and Output Gap γ Coefficients Range	[0, 1]	[0, 2]
Equal Weights on Inflation and Unemployment Loss. Threshold = 2%		
Policy Lag = 6 quarters	1.25***	1.61***
Policy Lag = 4 quarters	1.22***	1.63***
Policy Lag = 8 quarters	1.40***	1.78***
Equal weights on Inflation and Unemployment Loss. Policy Lag = 6 quarters		
Threshold = 2.5%	1.33***	1.66***
Threshold = 1.5%	1.10*	1.72***
Threshold = 2%. Policy Lag = 6 quarters		
1.25:0.75 Inflation and Unemployment Loss Weights	1.38***	1.85***
1.5:0.5 Inflation and Unemployment Loss Weights	1.49***	2.07***
0.75:1.25 Inflation and Unemployment Loss Weights	1.10**	1.35***
0.5:1.5 Inflation and Unemployment Loss Weights	0.94	1.09**

** ,**, and *** denote test statistics significant at 10, 5, and 1% level, respectively, based on critical values for the two-sided test.*

Figure 1. Real-Time Quadratic Detrended and CBO Output Gaps

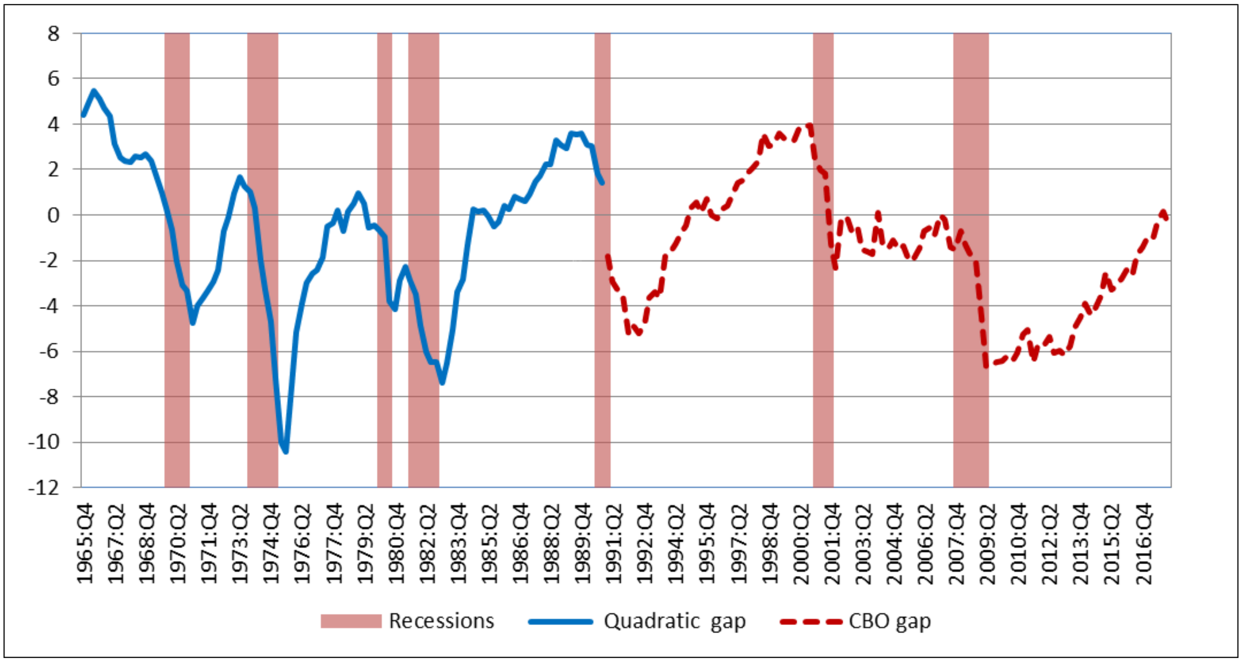

Figure 2. Natural Rate of Unemployment from Gordon and the Monetary Policy Report

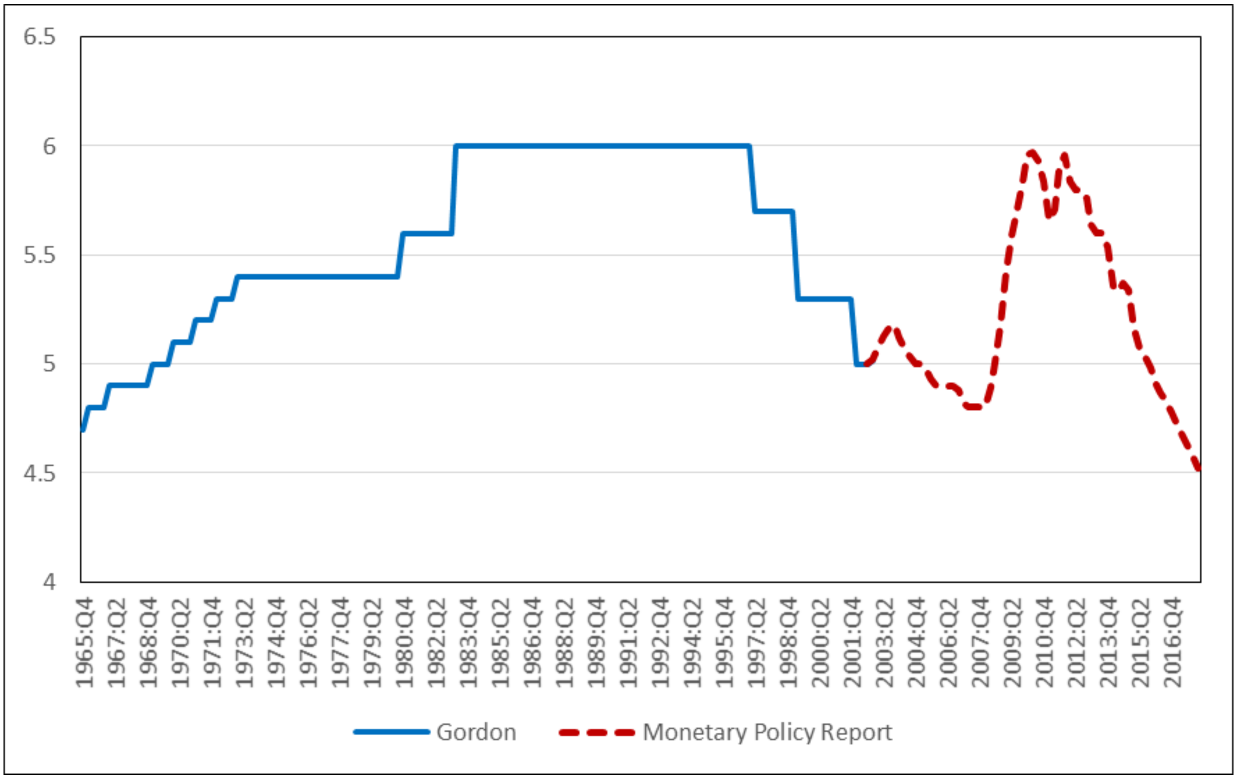

Figure 3. The Federal Funds Rate and the Shadow Rate

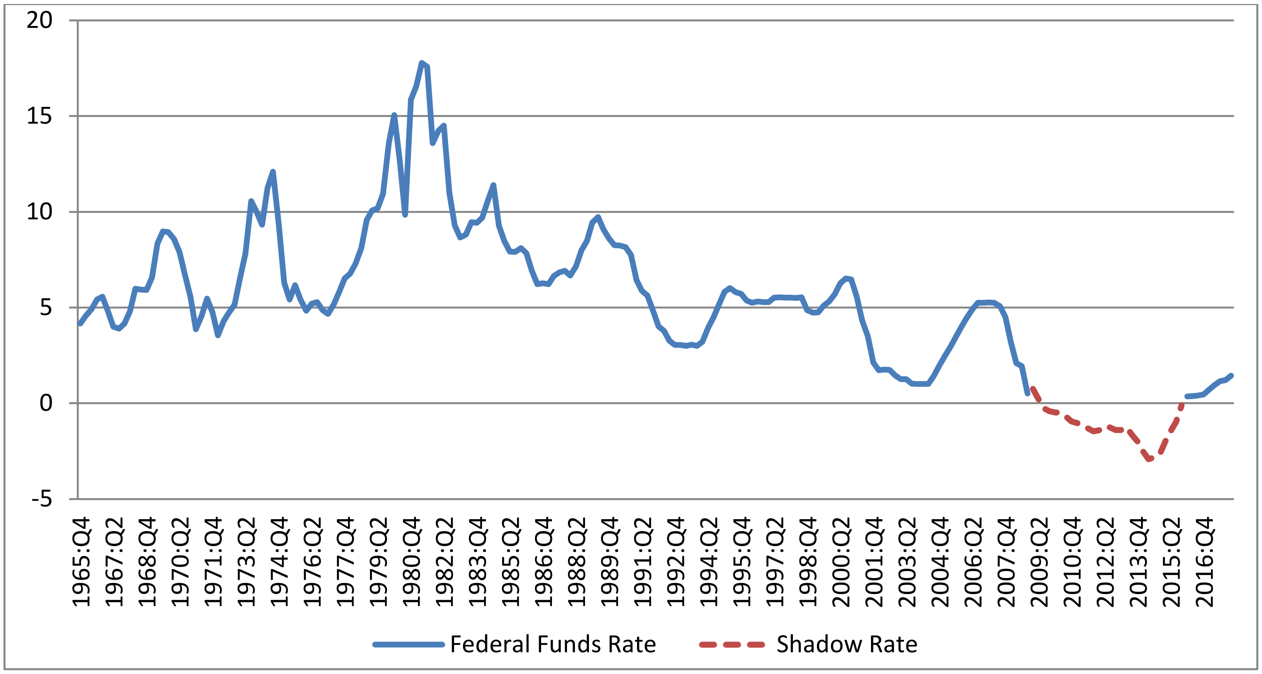

Figure 4. Trend Growth and Monetary Policy Report Neutral Real Interest Rate

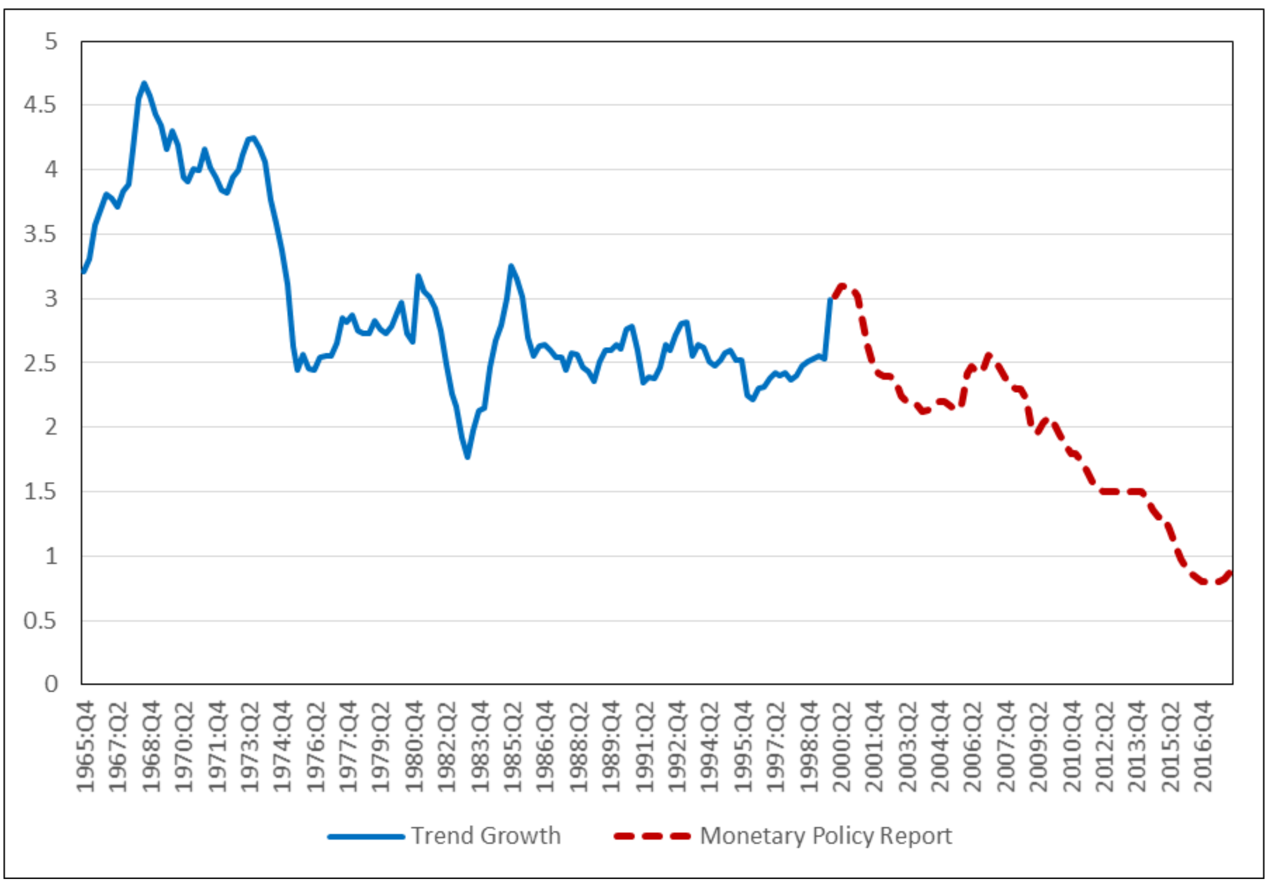

Figure 5. Time-Varying Inflation Goal and Actual Inflation (GDP Deflator and Core PCE)

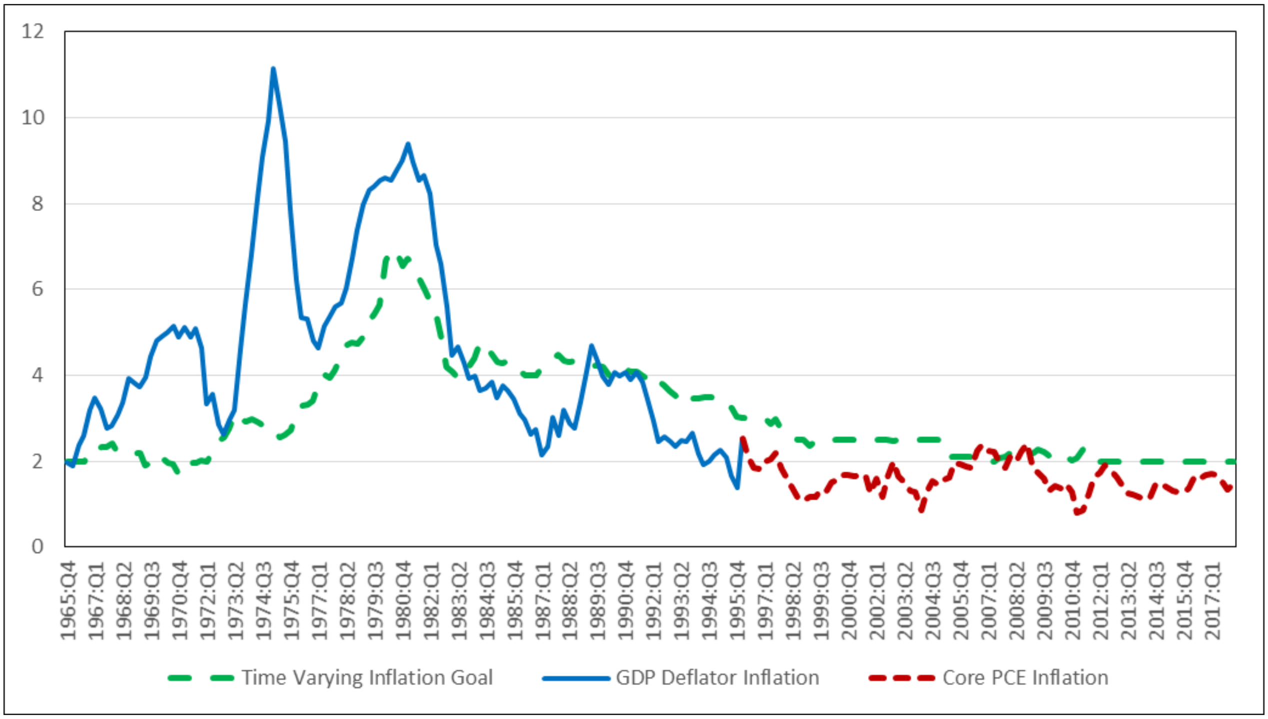

Figure 6. Deviations from the Original Taylor Rule

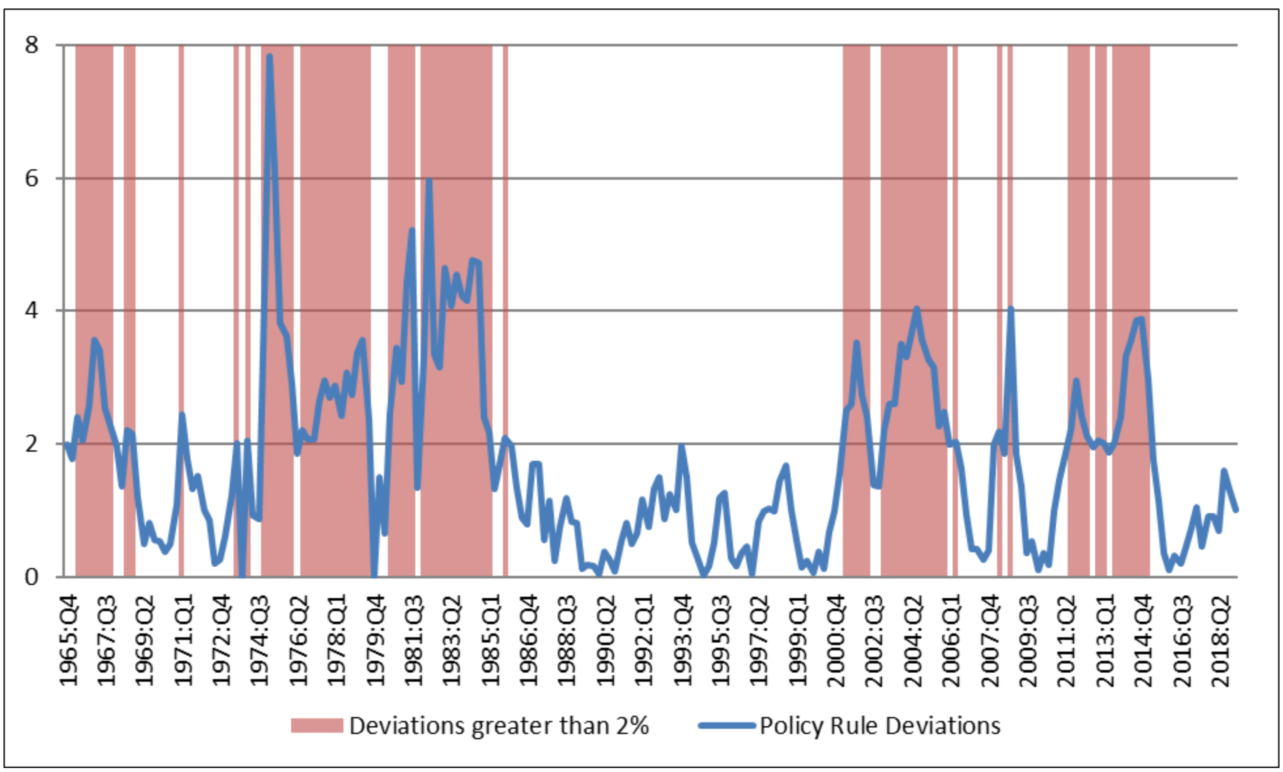

Figure 7. Share in Time in the Rules Regime: 400 Policy Rules

Inflation gap coefficient, α

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	
2.0	0.40	0.47	0.50	0.53	0.55	0.57	0.56	0.51	0.49	0.46	0.42	0.40	0.36	0.33	0.34	0.30	0.28	0.27	0.27	0.27	2.0
1.9	0.40	0.48	0.51	0.54	0.56	0.56	0.56	0.51	0.50	0.46	0.42	0.40	0.36	0.34	0.33	0.31	0.29	0.30	0.28	0.28	1.9
1.8	0.42	0.49	0.52	0.54	0.56	0.56	0.56	0.52	0.51	0.47	0.41	0.39	0.37	0.35	0.34	0.31	0.31	0.30	0.29	0.31	1.8
1.7	0.41	0.50	0.51	0.54	0.56	0.56	0.56	0.53	0.51	0.48	0.42	0.40	0.37	0.36	0.35	0.33	0.32	0.32	0.32	0.31	1.7
1.6	0.43	0.51	0.53	0.56	0.57	0.55	*0.57*	0.53	0.51	0.49	0.42	0.41	0.38	0.37	0.36	0.35	0.33	0.35	0.33	0.33	1.6
1.5	0.44	0.52	0.53	0.56	0.56	0.57	0.57	0.54	0.52	0.49	0.43	0.41	0.38	0.37	0.36	0.35	0.34	0.37	0.36	0.34	1.5
1.4	0.44	0.52	0.55	*0.58*	*0.58*	*0.58*	*0.57*	0.57	0.53	0.50	0.45	0.42	0.38	0.38	0.36	0.36	0.38	0.37	0.35	0.33	1.4
1.3	0.46	0.54	*0.57*	*0.58*	*0.58*	*0.58*	*0.59*	*0.58*	0.53	0.50	0.45	0.43	0.40	0.39	0.38	0.39	0.40	0.36	0.35	0.33	1.3
1.2	0.47	0.56	*0.59*	*0.59*	*0.60*	*0.59*	*0.59*	*0.60*	0.52	0.51	0.45	0.44	0.40	0.40	0.39	0.41	0.40	0.38	0.34	0.32	1.2
1.1	0.49	0.57	*0.59*	*0.62*	*0.61*	*0.62*	*0.59*	*0.59*	0.53	0.51	0.46	0.44	0.42	0.41	0.42	0.41	0.40	0.38	0.34	0.33	1.1
1.0	0.51	0.56	*0.59*	*0.60*	*0.62*	*0.62*	*0.61*	*0.59*	0.54	0.52	0.48	0.46	0.44	0.44	0.42	0.41	0.40	0.39	0.34	0.33	1.0
0.9	0.53	0.55	*0.59*	*0.60*	*0.63*	*0.64*	*0.63*	*0.62*	0.56	0.54	0.49	0.49	0.47	0.44	0.42	0.42	0.39	0.38	0.35	0.34	0.9
0.8	0.55	*0.57*	*0.60*	*0.62*	*0.65*	*0.64*	*0.63*	*0.61*	0.56	0.54	0.53	0.49	0.48	0.44	0.43	0.42	0.40	0.39	0.37	0.34	0.8
0.7	0.55	0.56	*0.60*	*0.62*	*0.64*	*0.64*	*0.63*	*0.62*	*0.60*	*0.60*	0.54	0.51	0.48	0.45	0.44	0.43	0.42	0.40	0.38	0.35	0.7
0.6	0.55	0.56	*0.61*	*0.63*	*0.64*	*0.64*	*0.65*	*0.64*	*0.65*	*0.61*	*0.57*	0.53	0.48	0.47	0.45	0.44	0.43	0.40	0.38	0.35	0.6
0.5	0.56	*0.57*	*0.62*	*0.62*	*0.65*	*0.65*	*0.67*	*0.69*	*0.68*	*0.63*	*0.57*	0.54	0.51	0.47	0.45	0.44	0.42	0.41	0.37	0.33	0.5
0.4	0.55	0.57	*0.60*	*0.62*	*0.65*	*0.68*	*0.70*	*0.71*	*0.69*	*0.63*	*0.59*	0.54	0.51	0.50	0.46	0.45	0.42	0.40	0.37	0.33	0.4
0.3	0.53	0.55	*0.60*	*0.63*	*0.68*	*0.70*	*0.72*	*0.72*	*0.72*	*0.65*	*0.59*	0.55	0.52	0.50	0.47	0.44	0.42	0.37	0.35	0.32	0.3
0.2	0.53	0.55	*0.60*	*0.64*	*0.69*	*0.72*	*0.73*	*0.74*	*0.72*	*0.65*	*0.61*	0.55	0.52	0.49	0.47	0.45	0.41	0.37	0.35	0.32	0.2
0.1	0.54	0.55	*0.62*	*0.67*	*0.72*	*0.75*	*0.76*	*0.77*	*0.72*	*0.66*	*0.61*	0.54	0.50	0.50	0.48	0.44	0.39	0.36	0.32	0.30	0.1
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	

Output gap coefficient, γ

Figure 8. Loss Ratios: R*=Time-Varying, π*=2%, Output Gap

Panel A: Inflation Gap α and Output Gap γ Coefficients Range [0,1]

Inflation gap coefficient, α

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
1.0	*3.29*	*3.17*	*3.33*	*3.46*	*3.44*	*3.87*	*3.84*	*4.33*	*5.59*	*4.79*	1.0
0.9	*3.04*	*3.11*	*3.11*	*3.30*	*3.29*	*2.96*	*3.39*	*3.33*	*3.63*	*3.50*	0.9
0.8	2.53	2.54	2.63	*2.76*	*3.16*	*3.10*	*3.10*	*3.31*	*4.12*	*3.46*	0.8
0.7	2.54	2.56	2.67	*2.92*	*3.10*	*3.27*	*3.54*	*2.93*	*3.06*	2.62	0.7
0.6	2.27	2.37	2.54	2.73	*3.03*	*3.06*	*3.12*	*2.76*	2.25	2.06	0.6
0.5	1.93	2.00	2.07	2.56	*2.82*	*2.93*	*3.01*	2.39	2.15	1.82	0.5
0.4	1.88	2.08	2.11	2.36	2.47	2.40	2.36	2.26	2.23	1.85	0.4
0.3	1.98	1.87	1.82	1.96	1.99	1.97	2.09	1.99	1.95	1.48	0.3
0.2	1.65	1.74	1.75	1.83	1.79	1.80	1.67	1.80	1.75	1.43	0.2
0.1	1.13	1.21	1.26	1.26	1.39	1.38	1.28	1.37	1.58	1.31	0.1
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	

Output gap coefficient, γ

Panel B: Inflation Gap α and Output Gap γ Coefficients Range [0,2]

Inflation gap coefficient, α

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	
2.0	*6.66*	*5.68*	*6.56*	*7.14*	*7.53*	*7.06*	*7.41*	*7.97*	*7.68*	*8.20*	*7.96*	*7.91*	*7.19*	*6.67*	*5.08*	*4.65*	*4.31*	3.00	2.38	2.09	2.0
1.9	*7.04*	*5.84*	*6.62*	*7.25*	*7.50*	*7.00*	*7.38*	*7.91*	*7.90*	*8.10*	*8.38*	*7.91*	*7.19*	*6.23*	*5.01*	*4.08*	*3.41*	2.68	2.30	2.12	1.9
1.8	*4.98*	*6.08*	*6.75*	*7.11*	*7.41*	*7.03*	*7.18*	*8.07*	*7.87*	*8.24*	*8.36*	*7.80*	*5.86*	*5.05*	*4.42*	*3.59*	2.77	2.51	2.21	2.16	1.8
1.7	*5.14*	*4.75*	*6.47*	*6.90*	*7.30*	*6.96*	*7.05*	*8.03*	*7.87*	*8.43*	*7.35*	*6.41*	*5.91*	*4.40*	*3.95*	3.16	2.96	2.51	2.07	2.10	1.7
1.6	*5.34*	*4.87*	*5.22*	*7.24*	*7.47*	*6.86*	*7.16*	*8.19*	*7.27*	*6.76*	*6.92*	*6.64*	*4.82*	*4.32*	*3.73*	2.81	2.40	2.32	2.08	1.73	1.6
1.5	*5.33*	*4.91*	*5.13*	*7.24*	*6.95*	*7.00*	*6.45*	*7.60*	*6.97*	*6.78*	*6.17*	*5.79*	*4.18*	*3.70*	2.92	2.53	2.49	2.09	1.78	1.61	1.5
1.4	*4.35*	*5.10*	*5.39*	*5.46*	*6.50*	*6.64*	*6.77*	*7.34*	*5.77*	*5.66*	*5.49*	*5.04*	*4.18*	3.17	2.79	2.30	2.21	1.95	1.82	1.72	1.4
1.3	*3.47*	*3.45*	*5.23*	*5.59*	*5.27*	*5.96*	*5.64*	*6.01*	*5.78*	*5.66*	*5.49*	*4.85*	3.25	2.80	2.38	2.46	2.14	1.93	1.82	1.80	1.3
1.2	*3.38*	*3.62*	*3.65*	*4.25*	*4.91*	*5.58*	*5.64*	*6.22*	*5.79*	*5.17*	*4.87*	*3.86*	3.13	2.76	2.75	2.14	2.14	2.05	1.87	1.79	1.2
1.1	3.24	*3.43*	*3.59*	*3.64*	*3.91*	*4.07*	*5.66*	*5.59*	*5.36*	*4.91*	*4.54*	*3.87*	3.01	2.84	2.22	2.06	1.96	2.09	1.75	1.61	1.1
1.0	3.29	3.17	*3.33*	*3.46*	*3.44*	*3.87*	*3.84*	*4.33*	*5.59*	*4.79*	*3.86*	*3.51*	2.67	2.24	2.29	1.97	1.86	1.71	1.65	1.64	1.0
0.9	3.04	3.11	3.11	3.30	3.29	2.96	*3.39*	*3.33*	*3.63*	*3.50*	*3.40*	2.75	2.42	2.16	2.04	1.81	1.87	1.86	1.61	1.54	0.9
0.8	2.53	2.54	2.63	2.76	3.16	3.10	3.10	3.31	*4.12*	*3.46*	2.55	2.20	2.24	2.04	1.98	2.02	1.96	1.68	1.55	1.44	0.8
0.7	2.54	2.56	2.67	2.92	3.10	3.27	*3.54*	2.93	3.06	2.62	2.29	1.91	1.70	1.61	1.63	1.51	1.44	1.41	1.29	1.17	0.7
0.6	2.27	2.37	2.54	2.73	3.03	3.06	3.12	2.76	2.25	2.06	2.03	1.78	1.53	1.44	1.34	1.28	1.55	1.39	1.32	1.18	0.6
0.5	1.93	2.00	2.07	2.56	2.82	2.93	3.01	2.39	2.15	1.82	1.92	1.83	1.51	1.43	1.33	1.33	1.29	1.20	1.40	1.27	0.5
0.4	1.88	2.08	2.11	2.36	2.47	2.40	2.36	2.26	2.23	1.85	1.47	1.63	1.56	1.33	1.23	1.15	1.27	1.17	1.10	1.01	0.4
0.3	1.98	1.87	1.82	1.96	1.99	1.97	2.09	1.99	1.95	1.48	1.36	1.25	1.43	1.39	1.36	1.31	1.25	1.13	1.08	1.02	0.3
0.2	1.65	1.74	1.75	1.83	1.79	1.80	1.67	1.80	1.75	1.43	1.23	1.10	1.06	1.34	1.47	1.35	1.26	1.08	1.01	1.05	0.2
0.1	1.13	1.21	1.26	1.26	1.39	1.38	1.28	1.37	1.58	1.31	1.22	1.13	1.06	1.20	1.20	1.17	1.12	1.18	1.18	1.21	0.1
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	

Output gap coefficient, γ

Figure 9. Loss Ratios: R*=Time-Varying, π*=2%, Unemployment Gap

Panel A: Inflation Gap α and Output Gap γ Coefficients Range [0,1]

Inflation gap coefficient, α	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
1.0	3.15	3.15	3.07	2.96	3.10	3.08	3.15	2.97	2.80	2.56	1.0
0.9	2.88	2.88	2.96	2.64	2.82	2.87	2.73	2.82	2.40	2.15	0.9
0.8	2.30	2.61	2.67	2.75	2.80	2.92	2.85	2.70	2.28	2.03	0.8
0.7	2.38	2.68	2.70	2.52	2.56	2.64	2.63	2.13	1.98	1.69	0.7
0.6	2.16	2.45	2.67	2.49	2.68	2.44	2.19	1.95	1.67	1.62	0.6
0.5	1.84	2.04	2.34	2.30	2.47	2.14	1.91	1.68	1.67	1.43	0.5
0.4	1.83	2.10	2.21	2.12	1.81	1.67	1.65	1.47	1.48	1.42	0.4
0.3	1.84	1.62	1.68	1.44	1.34	1.26	1.29	1.14	1.23	1.19	0.3
0.2	1.44	1.42	1.01	0.96	0.99	1.07	1.08	1.00	0.97	0.96	0.2
0.1	0.94	0.89	0.90	0.89	0.96	1.06	1.02	1.02	1.01	1.06	0.1
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	

Output gap coefficient, γ

Panel B: Inflation Gap α and Output Gap γ Coefficients Range [0,2]

Inflation gap coefficient, α	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	
2.0	6.15	6.06	6.35	6.86	7.32	7.78	8.56	8.88	8.94	9.39	9.02	7.89	6.69	6.28	5.57	5.11	3.79	2.76	2.49	2.21	2.0
1.9	4.51	6.13	6.40	6.96	7.32	7.74	8.43	8.88	8.94	8.74	9.31	7.45	5.75	5.64	4.84	3.79	2.99	2.55	2.17	2.25	1.9
1.8	4.68	4.89	5.04	6.90	7.27	7.88	8.32	8.91	8.94	8.83	6.75	6.16	5.81	4.34	3.80	3.34	2.73	2.34	2.46	2.08	1.8
1.7	4.85	5.05	5.14	5.53	5.54	7.57	8.32	8.80	7.96	6.94	6.26	4.86	4.64	3.96	3.35	2.96	2.57	2.36	2.15	2.01	1.7
1.6	4.93	4.99	5.14	5.53	5.66	5.93	7.55	7.86	7.35	6.14	4.98	4.86	4.19	3.61	3.02	2.57	2.37	2.08	2.19	2.12	1.6
1.5	5.00	5.13	5.02	5.47	5.37	5.59	5.78	5.18	6.13	4.96	4.66	4.49	4.02	2.87	2.66	2.53	2.32	2.19	2.08	2.11	1.5
1.4	4.48	4.37	4.48	5.19	5.52	5.18	5.18	4.72	4.06	4.56	4.57	4.00	3.19	2.74	2.86	2.25	2.17	2.31	2.30	2.26	1.4
1.3	3.60	3.41	3.51	4.18	4.51	4.47	4.22	4.07	3.94	3.50	3.46	3.73	3.25	2.91	2.40	2.42	2.47	2.35	2.13	2.04	1.3
1.2	3.36	3.13	3.37	3.55	3.78	3.90	4.00	3.38	3.29	3.16	3.21	2.89	2.58	2.60	2.55	2.58	2.50	2.23	2.04	1.99	1.2
1.1	3.13	3.36	3.34	3.10	3.34	3.10	3.05	2.90	3.45	3.29	2.64	2.66	2.21	2.12	2.54	2.38	2.38	1.97	1.89	1.76	1.1
1.0	3.15	3.15	3.07	2.96	3.10	3.08	3.15	2.97	2.80	2.56	2.16	2.27	2.09	1.98	1.81	1.65	1.81	1.76	1.85	1.95	1.0
0.9	2.88	2.88	2.96	2.64	2.82	2.87	2.73	2.82	2.40	2.15	2.10	1.96	1.78	1.65	1.77	1.64	1.54	1.73	1.74	1.32	0.9
0.8	2.30	2.61	2.67	2.75	2.80	2.92	2.85	2.70	2.28	2.03	2.19	1.80	1.60	1.55	1.36	1.23	1.22	1.24	1.27	1.40	0.8
0.7	2.38	2.68	2.70	2.52	2.56	2.64	2.63	2.13	1.98	1.69	1.64	1.59	1.55	1.44	1.28	1.23	1.16	1.10	1.04	1.15	0.7
0.6	2.16	2.45	2.67	2.49	2.68	2.44	2.19	1.95	1.67	1.62	1.58	1.52	1.56	1.32	1.23	1.14	1.15	1.09	1.11	1.12	0.6
0.5	1.84	2.04	2.34	2.30	2.47	2.14	1.91	1.68	1.67	1.43	1.39	1.40	1.46	1.32	1.22	1.20	1.18	1.05	1.25	1.07	0.5
0.4	1.83	2.10	2.21	2.12	1.81	1.67	1.65	1.47	1.48	1.42	1.39	1.31	1.22	1.12	1.09	1.07	1.04	1.06	1.03	0.97	0.4
0.3	1.84	1.62	1.68	1.44	1.34	1.26	1.29	1.14	1.23	1.19	1.23	1.22	1.13	1.06	1.02	0.98	0.98	1.01	0.93	1.10	0.3
0.2	1.44	1.42	1.01	0.96	0.99	1.07	1.08	1.00	0.97	0.96	1.03	1.18	1.31	1.19	1.22	1.15	1.15	1.14	1.15	1.11	0.2
0.1	0.94	0.89	0.90	0.89	0.96	1.06	1.02	1.02	1.01	1.06	1.19	1.11	1.23	1.16	1.18	1.10	1.18	1.21	1.11	1.10	0.1
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	

Output gap coefficient, γ

Figure 10. Loss Ratios: R*=2, π*=2%, Output Gap

Panel A: Inflation Gap α and Output Gap γ Coefficients Range [0,1]

Inflation gap coefficient, α \ Output gap coefficient, γ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
1.0	1.69	1.82	2.10	2.15	2.39	2.50	2.76	2.77	2.63	2.66	1.0
0.9	1.54	1.89	2.11	2.20	2.38	2.48	2.66	2.56	2.64	2.23	0.9
0.8	1.65	1.87	2.02	2.31	2.27	2.41	2.57	2.55	2.11	1.93	0.8
0.7	1.52	1.60	1.85	2.04	2.19	2.21	2.21	2.25	2.09	1.77	0.7
0.6	1.51	1.67	1.59	1.82	2.04	2.22	2.08	2.04	2.02	1.71	0.6
0.5	1.38	1.53	1.72	1.98	2.21	1.98	1.86	1.92	1.91	1.67	0.5
0.4	1.30	1.34	1.63	1.79	1.81	1.80	1.70	1.57	1.63	1.40	0.4
0.3	1.30	1.19	1.26	1.42	1.47	1.46	1.47	1.57	1.59	1.24	0.3
0.2	0.91	0.94	0.82	0.84	0.88	1.01	1.15	1.14	1.23	1.18	0.2
0.1	0.84	0.88	0.91	0.88	0.97	1.11	1.21	1.24	1.32	1.28	0.1
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	

Output gap coefficient, γ

Panel B: Inflation Gap α and Output Gap γ Coefficients Range [0,2]

Inflation gap coefficient, α \ Output gap coefficient, γ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	
2.0	2.37	2.48	2.64	2.89	3.33	4.35	4.44	4.56	4.24	3.78	3.65	3.41	3.27	3.21	2.89	2.58	2.35	2.11	1.96	1.82	2.0
1.9	2.40	2.46	2.67	3.07	3.40	3.75	3.71	4.35	4.24	3.78	3.63	3.17	2.99	2.63	2.76	2.36	2.07	1.82	1.89	1.69	1.9
1.8	2.40	2.41	2.69	3.16	3.60	3.64	3.73	3.65	3.22	3.66	3.41	3.19	2.94	2.46	2.13	2.28	1.91	1.64	1.54	1.59	1.8
1.7	2.45	2.42	2.67	3.26	3.59	3.68	3.67	3.35	3.08	2.95	2.84	3.18	2.74	2.34	1.98	2.10	1.81	1.66	1.30	1.29	1.7
1.6	2.53	2.47	2.78	3.29	3.48	3.51	3.45	3.38	3.07	2.95	2.52	2.37	2.16	2.28	2.06	1.66	1.67	1.41	1.40	1.31	1.6
1.5	2.46	2.50	2.83	3.24	3.45	3.52	3.32	3.14	2.73	2.64	2.54	2.38	2.21	1.79	1.57	1.56	1.35	1.50	1.48	1.41	1.5
1.4	2.37	2.43	2.96	3.32	3.37	3.22	3.22	3.03	2.71	2.60	2.44	2.29	2.01	1.74	1.61	1.27	1.23	1.14	1.48	1.48	1.4
1.3	2.30	2.43	2.81	3.14	3.33	3.06	3.09	3.02	2.57	2.52	2.38	2.26	2.02	1.62	1.46	1.39	1.25	1.18	1.35	1.29	1.3
1.2	2.20	2.48	2.80	2.98	3.11	2.92	3.05	2.92	2.62	2.61	2.44	2.27	1.79	1.66	1.48	1.48	1.35	1.22	1.11	1.26	1.2
1.1	1.88	1.98	2.38	2.77	3.04	2.96	2.92	3.03	2.79	2.66	2.55	2.03	1.76	1.59	1.44	1.35	1.26	1.12	0.98	0.93	1.1
1.0	1.69	1.82	2.10	2.15	2.39	2.50	2.76	2.77	2.63	2.66	2.37	1.91	1.73	1.61	1.48	1.28	1.22	1.08	0.97	0.93	1.0
0.9	1.54	1.89	2.11	2.20	2.38	2.48	2.66	2.56	2.64	2.23	2.25	1.92	1.74	1.51	1.38	1.28	1.17	1.06	0.84	0.80	0.9
0.8	1.65	1.87	2.02	2.31	2.27	2.41	2.57	2.55	2.11	1.93	1.78	1.44	1.29	1.27	1.12	1.10	0.99	0.91	0.86	0.79	0.8
0.7	1.52	1.60	1.85	2.04	2.19	2.21	2.21	2.25	2.09	1.77	1.65	1.41	1.21	1.11	1.01	0.89	0.88	0.92	0.85	0.80	0.7
0.6	1.51	1.67	1.59	1.82	2.04	2.22	2.08	2.04	2.02	1.71	1.52	1.36	1.18	1.08	0.95	0.94	0.84	0.81	0.73	0.69	0.6
0.5	1.38	1.53	1.72	1.98	2.21	1.98	1.86	1.92	1.91	1.67	1.40	1.12	1.07	0.98	0.89	0.87	0.91	0.84	0.75	0.70	0.5
0.4	1.30	1.34	1.63	1.79	1.81	1.80	1.70	1.57	1.63	1.40	1.20	1.16	1.02	0.87	0.80	0.80	0.83	0.77	0.72	0.62	0.4
0.3	1.30	1.19	1.26	1.42	1.47	1.46	1.47	1.57	1.59	1.24	1.08	1.04	0.92	0.88	0.86	0.83	0.81	0.78	0.70	0.65	0.3
0.2	0.91	0.94	0.82	0.84	0.88	1.01	1.15	1.14	1.23	1.18	1.12	1.02	0.93	0.85	0.86	0.82	0.83	0.80	0.75	0.65	0.2
0.1	0.84	0.88	0.91	0.88	0.97	1.11	1.21	1.24	1.32	1.28	1.14	1.06	0.87	0.70	0.73	0.74	0.74	0.71	0.66	0.57	0.1
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	

Output gap coefficient, γ

Figure 11. Loss Ratios: R*=Time-Varying, π*= Time-Varying, Output Gap

Panel A: Inflation Gap α and Output Gap γ Coefficients Range [0,1]

Inflation gap coefficient, α \ Output gap coefficient, γ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
1.0	1.74	1.95	2.07	2.22	2.36	2.46	2.17	2.13	1.95	1.79	1.0
0.9	1.67	1.74	1.88	2.21	2.36	2.36	2.21	2.17	1.98	1.67	0.9
0.8	1.76	1.89	2.07	2.25	2.28	2.17	2.20	2.25	1.96	1.63	0.8
0.7	1.60	1.61	1.96	2.30	2.33	2.18	2.26	2.13	1.80	1.71	0.7
0.6	1.60	1.76	1.90	2.05	2.18	2.27	2.22	1.96	1.86	1.72	0.6
0.5	1.76	1.79	1.91	1.95	2.09	1.91	1.68	1.61	1.62	1.51	0.5
0.4	1.59	1.56	1.79	1.67	1.71	1.71	1.63	1.63	1.58	1.51	0.4
0.3	1.66	1.52	1.50	1.51	1.72	1.69	1.52	1.60	1.61	1.66	0.3
0.2	1.22	1.20	1.16	1.23	1.42	1.74	1.59	1.56	1.53	1.33	0.2
0.1	0.97	1.09	1.07	1.19	1.40	1.44	1.34	1.37	1.30	1.21	0.1
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	

Output gap coefficient, γ

Panel B: Inflation Gap α and Output Gap γ Coefficients Range [0,2]

Inflation gap coefficient, α \ Output gap coefficient, γ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	
2.0	1.97	1.99	2.16	2.60	2.85	2.73	2.82	2.80	2.82	2.29	2.42	2.24	1.75	1.78	1.65	1.22	1.02	0.95	0.92	0.90	2.0
1.9	1.92	1.98	2.09	2.23	2.91	2.77	2.88	2.57	2.45	2.33	2.20	2.05	1.78	1.77	1.43	1.23	1.02	1.05	0.94	0.92	1.9
1.8	1.84	1.92	2.17	2.43	2.46	2.24	2.58	2.65	2.59	2.44	2.13	1.96	1.66	1.75	1.34	1.21	1.12	1.05	0.94	0.95	1.8
1.7	1.84	1.95	2.21	2.25	2.31	2.17	2.19	2.62	2.59	2.48	1.93	1.78	1.82	1.66	1.31	1.29	1.17	1.07	0.98	0.96	1.7
1.6	1.75	1.84	2.24	2.30	2.23	2.27	2.36	2.19	2.57	2.21	1.83	1.94	1.72	1.69	1.50	1.27	1.22	1.11	1.06	0.98	1.6
1.5	1.79	1.83	2.17	2.22	2.31	2.38	2.36	2.12	1.98	2.23	1.98	2.10	1.61	1.69	1.49	1.29	1.28	1.22	1.09	1.07	1.5
1.4	1.83	1.78	2.09	2.25	2.31	2.34	2.14	2.08	1.93	1.87	1.67	1.94	1.61	1.25	1.45	1.29	1.13	1.10	1.10	1.10	1.4
1.3	1.70	1.94	2.17	2.18	2.23	2.28	2.04	2.06	1.80	1.76	1.61	1.35	1.53	1.40	1.42	1.32	1.21	1.22	1.21	1.19	1.3
1.2	1.59	1.87	1.92	1.96	2.12	2.18	2.10	1.99	1.86	1.94	1.62	1.41	1.28	1.38	1.42	1.46	1.34	1.28	1.23	1.17	1.2
1.1	1.60	1.82	1.94	2.09	2.23	2.23	2.26	2.21	2.09	2.01	1.62	1.35	1.37	1.21	1.36	1.50	1.19	1.23	1.17	0.98	1.1
1.0	1.74	1.95	2.07	2.22	2.36	2.46	2.17	2.13	1.95	1.79	1.50	1.28	1.26	1.21	1.16	1.11	1.20	1.16	1.11	0.96	1.0
0.9	1.67	1.74	1.88	2.21	2.36	2.36	2.21	2.17	1.98	1.67	1.43	1.22	1.11	1.16	1.16	1.16	1.06	1.13	1.05	0.97	0.9
0.8	1.76	1.89	2.07	2.25	2.28	2.17	2.20	2.25	1.96	1.63	1.46	1.26	1.13	1.16	1.19	1.09	1.03	0.95	1.09	1.07	0.8
0.7	1.60	1.61	1.96	2.30	2.33	2.18	2.26	2.13	1.80	1.71	1.49	1.18	1.03	1.06	1.15	1.12	1.03	1.01	0.98	0.95	0.7
0.6	1.60	1.76	1.90	2.05	2.18	2.27	2.22	1.96	1.86	1.72	1.42	1.21	1.10	1.09	1.11	1.05	0.99	0.98	0.98	0.91	0.6
0.5	1.76	1.79	1.91	1.95	2.09	1.91	1.68	1.61	1.62	1.51	1.38	1.22	1.11	1.07	1.21	1.17	1.15	1.11	1.00	0.87	0.5
0.4	1.59	1.56	1.79	1.67	1.71	1.71	1.63	1.63	1.58	1.51	1.42	1.24	1.13	1.15	1.35	1.21	1.11	1.07	0.97	0.85	0.4
0.3	1.66	1.52	1.50	1.51	1.72	1.69	1.52	1.60	1.61	1.66	1.18	1.09	0.95	1.18	1.37	1.24	1.13	1.05	0.91	0.90	0.3
0.2	1.22	1.20	1.16	1.23	1.42	1.74	1.59	1.56	1.53	1.33	1.09	1.02	0.98	0.93	1.22	1.28	1.27	1.12	1.19	1.17	0.2
0.1	0.97	1.09	1.07	1.19	1.40	1.44	1.34	1.37	1.30	1.21	0.99	0.97	0.95	1.00	1.19	1.12	1.06	0.98	1.04	1.04	0.1
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	

Output gap coefficient, γ

Figure 12. Smets and Wouters (2007) model

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	
1	*29.97*	*29.45*	*29.40*	*29.76*	*30.46*	*31.45*	*32.69*	*34.15*	35.80	37.61	1
0.9	*29.94*	*29.48*	*29.58*	*30.14*	*31.08*	*32.36*	*33.91*	35.70	37.68	39.84	0.9
0.8	*29.95*	*29.60*	*29.89*	*30.72*	*32.00*	*33.64*	35.59	37.79	40.20	42.78	0.8
0.7	*30.03*	*29.83*	*30.41*	*31.62*	*33.34*	*35.47*	37.94	40.67	43.62	46.73	0.7
0.6	*30.23*	*30.27*	*31.28*	*33.02*	*35.36*	38.16	41.31	44.74	48.38	52.18	0.6
0.5	*30.62*	*31.07*	*32.72*	*35.27*	38.49	42.22	46.32	50.68	55.23	59.90	0.5
0.4	*31.38*	*32.56*	*35.26*	39.05	43.59	48.66	54.07	59.69	65.44	71.23	0.4
0.3	*32.95*	35.51	40.06	45.87	52.45	59.49	66.76	74.10	81.41	88.62	0.3
0.2	36.69	42.21	50.23	59.51	69.35	79.32	89.17	98.76	107.99	116.84	0.2
0.1	48.82	61.39	76.24	91.45	106.16	120.02	132.92	144.85	155.85	165.99	0.1
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	

Inflation gap coefficient, α

Output gap coefficient, γ

Figure 13. FRB-US Model: Zero bound on the nominal interest rate and R*=2%

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	
1	70.54	68.39	66.60	65.14	63.97	63.05	62.36	61.88	61.57	61.44	1
0.9	70.04	67.86	66.05	64.58	63.40	62.49	61.80	61.33	61.04	60.92	0.9
0.8	69.57	67.36	65.52	64.04	62.85	61.95	61.27	*60.81*	*60.53*	*60.42*	0.8
0.7	69.13	66.88	65.02	63.52	62.33	61.43	*60.76*	*60.31*	*60.04*	*59.95*	0.7
0.6	68.72	66.42	64.53	63.02	61.83	60.93	*60.28*	*59.83*	*59.58*	*59.50*	0.6
0.5	68.34	65.99	64.08	62.55	61.36	*60.46*	*59.82*	*59.39*	*59.15*	*59.09*	0.5
0.4	67.99	65.59	63.65	62.10	*60.91*	*60.02*	*59.39*	*58.97*	*58.75*	*58.70*	0.4
0.3	67.67	65.22	63.25	61.69	*60.50*	*59.61*	*58.98*	*58.58*	*58.37*	*58.33*	0.3
0.2	67.39	64.88	62.88	61.31	*60.11*	*59.23*	*58.61*	*58.22*	*58.02*	*58.00*	0.2
0.1	67.14	64.58	62.54	60.96	*59.76*	*58.88*	*58.27*	*57.89*	*57.71*	*57.69*	0.1
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	

Inflation gap coefficient, α

Output gap coefficient, γ

Figure 14. Share of Time in the Rules Regime: 100 Policy Rules

Inflation gap coefficient, α

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
1.0	0.51	0.56	0.59	0.60	0.62	0.62	0.61	0.59	0.54	0.52	1.0
0.9	0.53	0.55	0.59	0.60	0.63	0.64	0.63	0.62	0.56	0.54	0.9
0.8	0.55	0.57	0.60	0.62	0.65	0.64	0.63	0.61	0.56	0.54	0.8
0.7	0.55	0.56	0.60	0.62	0.64	0.64	0.63	0.62	0.60	0.60	0.7
0.6	0.55	0.56	0.61	0.63	0.64	0.64	0.65	0.64	0.65	0.61	0.6
0.5	0.56	0.57	0.62	0.62	0.65	0.65	0.67	0.69	0.68	0.63	0.5
0.4	0.55	0.57	0.60	0.62	0.65	0.68	0.70	0.71	0.69	0.63	0.4
0.3	0.53	0.55	0.60	0.63	0.68	0.70	0.72	0.72	0.72	0.65	0.3
0.2	0.53	0.55	0.60	0.64	0.69	0.72	0.73	0.74	0.72	0.65	0.2
0.1	0.54	0.55	0.62	0.67	0.72	0.75	0.76	0.77	0.72	0.66	0.1
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	

Output gap coefficient, γ