The Fed's Policy Rules and the Neutral Real Interest Rate

Erika Callicott, David H. Papell and Ruxandra Prodan

University of Houston

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Abstract

The decline in the neutral real interest rate (r*) consistent with the Federal Reserve's maximum employment and longer-run inflation objectives over the past 30 years has had profound implications for monetary policymaking and monetary policy evaluation. While various measures of r* were presented to the Federal Open Market Committee (FOMC) between 2001 and 2012 and policy rules have been presented to the FOMC between 2004 and (at least) 2016 and have been included in the Monetary Policy Report since 2017, neither of the neutral real rates in the policy rules is consistent with the Fed's definition. We construct a measure of r*, which we call the single-equation measure, that is based on one of the measures presented to the FOMC and is consistent with the Fed's definition. Using Taylor and balanced approach rules, our single-equation measure produces federal funds rate (FFR) prescriptions that provide a closer fit to the FFR than the measures used in the Fed's policy rules.

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Correspondence to:

Erika Callicott, email: emcallicott@uh.edu, Department of Economics, University of Houston, Houston, TX 77204-5019

David Papell, tel. (713) 743-3807, email: dpapell@uh.edu, Department of Economics, University of Houston, Houston, TX 77204-5019

Ruxandra Prodan, tel. (713) 743-3836, email: rprodan@uh.edu, Department of Economics, University of Houston, Houston, TX
77204-5019

1. Introduction

The neutral real interest rate occupies center stage in U.S. monetary policy. In three highly publicized Jackson Hole Symposium speeches, Powell (2018, 2019) emphasized how a neutral real rate that is both low and uncertain causes difficulties for policymaking and, in Powell (2020), the decrease in the neutral real rate was the first reason provided for the FOMC's revised statement on longer-run goals and monetary policy strategy. With inflation close to the Fed's two percent target and output close to potential at the end of 2019, the long-run neutral real rate became the driving force for Taylor-type rule interest rate prescriptions. In response to the extreme economic dislocation caused by the COVID-19 pandemic, the Federal Open Market Committee (FOMC) lowered the federal funds rate (FFR) in March 2020 to the effective lower bound (ELB) and did not raise it until March 2022. With high inflation in 2022, the neutral real rate regained its importance for monetary policy evaluation. [1]

The Fed's semi-annual Monetary Policy Report's (MPR) describes "the level of the neutral real federal funds rate in the longer run that, on average, is expected to be consistent with sustaining maximum employment and inflation at the FOMC's 2 percent longer-run objective." Similar definitions go back to Laubach and Williams (2000) and have been used by numerous Federal Reserve Board Members and Regional Bank Presidents, including Williams (2015), Yellen (2017), Kaplan (2018), and Powell (2020).

Various measures of the neutral real rate were presented to the FOMC in the Bluebook (later Tealbook) between 2001 and 2012.[2] Five measures were in the May 2001 Bluebook, which were changed and expanded to nine measures in December 2004. These included six short-run measures and three medium-run measures from single-equation, small structural, and larger models. Starting in March 2012, all of the equilibrium real federal funds rate measures were dropped except for the estimate from the short-run Tealbook-consistent Federal Reserve Board/United States (FRB/US) model.

[1] At the current time, the target for the FFR is the range of 3.0 – 3.25 percent and, based on the September 2022 Summary of Economic Projections, is expected to rise to 4.25 – 4.5 percent by the end of 2022.
[2] The material in the Greenbook and Bluebook was combined into the Tealbook starting in June 2010. We will henceforth use "Tealbook" as a shorthand for "Bluebook/Tealbook" when it spans both periods.

Policy rules were presented to the FOMC in the Tealbook between 2004 and (at least) 2016 and rules using real-time data since 2000 have been included in the MPR since 2017.[3] While the neutral real rate in the policy rules has changed over time, it has never been consistent with the Fed's definition. Between 2004 and 2011, the neutral real rate for the policy rules in the Tealbook was two percent in accord with the Taylor (1993) rule. Between 2012 and 2016, it corresponded to the neutral real rate either "embedded" or "a value used" in the FRB/US model.[4] The neutral real rate in the MPR comes from surveys conducted by Blue Chip Economic Indicators. There is no particular reason to believe that either two, the number in the FRB/US model, or a number generated by a survey will sustain the FOMC's longer run inflation and employment objectives.

We propose to resolve this discrepancy by analyzing policy rules with a measure of the neutral real rate that is consistent with the Fed's definition. We use a measure that is based on one of the measures in Brayton and Reifschneider (BR) (2004 a,b) and reported to the FOMC in the Tealbook between December 2004 and January 2012. [5] Specifically, we use the BR single-equation model, which regresses the output gap on a constant, three lagged quarterly output gaps, and three lagged quarterly values of the real federal funds rate. We calculate the neutral real federal funds rate in the longer run from the coefficients of the estimated model by setting the output gaps to zero and equating the lagged federal funds rates.[6] We call our measure the "single-equation" measure because it is closely related but not identical to the BR single-equation medium-run measure. The resultant neutral real rate is consistent with the equilibrium real rate in the Taylor (1993) rule because, when inflation equals the Fed's target and the output gap is zero, the nominal federal funds rate equals inflation plus the neutral real rate.

The single-equation, Tealbook, and Monetary Policy Report measures of the neutral real interest rate (r*) are all close to two until mid-2008. During and following the Financial Crisis, all three measures fall and, while not monotonic, exhibit a pronounced downward trend. The single-equation measure, however, falls more sharply than either the Tealbook or the MPR measures. We then compare policy rule federal funds rate prescriptions between our single-equation measure and

[3] We do not know what was presented to the FOMC after December 2016 because the material is released with a five-year lag.
[4] The January 2016 Tealbook refers to the staff's "assumption for the longer-run equilibrium real rate." See Federal Reserve Board (2016). Fuentes-Albero and Wang (2016) describe a "judgmentally set value" based on Board staff econometric models, long-run growth assumptions, demographic characteristics, and long-term bond yields.
[5] The memoranda discussed in this paper were obtained by Freedom of Information Act request and are posted on the FOMC website.
[6] Brayton and Reifschneider use a different methodology to calculate short and medium-run measures.

the other measures. We use two well-known policy rules, the Taylor (1993) rule and the Yellen (2012) balanced approach rule, with the latter having twice as large a coefficient on the output gap. Differences among the measures of r* influence the prescribed FFR because they affect the intercept of both the Taylor and the balanced approach rules point-for-point. We compare the prescriptions with the effective FFR from 1991 to 2019 as well as the shadow FFR in Wu and Xia (2016) during the Effective Lower Bound period between 2009 and 2015.

We also consider a measure of r* that, while contained in the FOMC's Summary of Economic Projections (SEP), is not included in the Fed's policy rules. The SEP measure of r* can be calculated starting in 2012 by subtracting projected inflation in the longer run from the neutral nominal interest rate. Since the SEP measure is a median of the FOMC members' projections, there is no reason for it to be consistent with the Fed's definition. The SEP measure is similar to the Tealbook measure for the period where they overlap but is higher than the MPR measure and considerably higher than the single-equation measure. Finally, we consider a measure of r* from Laubach and Williams (2003). While not included in the Fed's policy rules, it is the best-known measure of r* and is featured prominently in Yellen (2015). This measure is both consistent with the Fed's definition and closer to our single-equation measure than the other measures.[7]

Our results can be summarized as follows. First, the two measures that are in accord with the Fed's definition of the neutral real federal funds rate, our single-equation measure and the Laubach and Williams (LW) measure, produce federal funds rate prescriptions that provide a closer fit to the effective and shadow FFR than the measures used in the Fed's policy rules. Second, it has been widely accepted since Yellen (2012) that the balanced approach rule is a better description of Fed policy than the Taylor rule following the Financial Crisis and the Great Recession. We show that this is an artifact of assuming that the neutral real interest rate is equal to two as in the Taylor (1993) paper. The Taylor rule is a better description of Fed policy with either our single-equation measure or the LW measure than the balanced approach rule.

2. The Neutral Real Interest Rate at the Fed

Measures of the equilibrium real federal funds rate were first presented to the FOMC in the May 2001 Bluebook. Five measures were included, as described by the memorandum by English and Bomfim (2001). Two of the estimates were from the FRB/US model in Horvath,

[7] There are many other measures of r*. Kiley (2020) develops an alternative using Bayesian methods. Yellen (2015) discusses four measures of r* from Dynamic Stochastic General Equilibrium models.

Mauskopf, and Williams (2001), two were from the statistical filter in Laubach and Williams (2000), and one from inflation-indexed Treasury securities in Bomfim (2001). Laubach and Williams (2000) define the equilibrium real rate to be "the real funds rate at which the output gap would gradually return to zero, barring further disturbances to aggregate demand and supply." This definition has remained consistent over time and, with the addition of the Fed's two percent inflation target, is the same as the definition of the neutral real interest rate used by the Fed today.[8]

The Bluebook measures of the equilibrium real interest rate r* were expanded in December 2004. As described in Brayton and Reifschneider (2004a,b), henceforth BR, these include short and medium-run measures from single-equation and small structural models, Greenbook-consistent and FRB/US short-run measures, and Treasury Inflation Protected Securities-consistent medium-run measures. As defined in BR (2004a,b), the short-run measure is the value of r* that would be projected to close the output gap three years in the future. The medium-run measure is the value of r* projected to prevail in seven years assuming that monetary policy closes the output gap in three years and keeps the gap closed.

We focus on their single-equation model medium-run measure, which we call the BR measure, because it is conceptually similar to the r* in the Taylor rule. To calculate the equilibrium real federal funds rate, they regress the current output gap on a constant, three lags of the output gap, and three lags of the real federal funds rate. Three lags were chosen because restriction that the coefficients on the fourth estimated lag were zero could not be rejected at the 10 percent level. In order to calculate the equilibrium real federal funds rate for December 2004, they estimate the equation for 1966:Q1 to 2004:Q3 where the output gap is the percentage difference between actual Gross Domestic Product (GDP) and staff estimates of potential GDP, and the real federal funds rate is the nominal funds rate minus the four-quarter moving average of core PCE inflation.[9] Figure 1 depicts the BR measure of the equilibrium real federal funds rate from December 2004 to January 2012. The value of r* starts at 2.2 percent in December 2004 and remains between 2.2 and 2.4 percent through June 2008. It starts falling with the financial crisis, dropping to 1.2 percent in December 2009 and 0.8 percent in January 2012.

[8] Following the Fed's parlance, we use "equilibrium" and "neutral" as synonyms. We do not consider the "natural" rate of interest, as in Woodford (2003), the real interest rate consistent with instantaneous market clearing in the absence of wage and price frictions.

[9] BR (2004b) report the model used to calculate the value of r* for December 2004. No subsequent estimates are available.

Policy rules were first presented to the FOMC in January 2004. The two rules with an equilibrium real federal funds rate were the "Baseline Taylor Rule" with a coefficient on the output gap of 0.5 as in Taylor (1993) and the "Aggressive Taylor Rule" with a coefficient on the output gap of 1.0 as in Taylor (1999).[10] The names of the rules were changed to the Taylor (1993) and Taylor (1999) rules in August 2006 through (at least) December 2016. Figure 1 illustrates the equilibrium real rate in the policy rules, which we call the Tealbook measure. In accord with Taylor (1993,1999) it was 2.0 percent from January 2004 through January 2012. It then increased to 2.25 percent in March 2012 before decreasing to 2.0 percent in March 2013, after which it steadily declined, reaching 0.75 in September 2016 before rising to 0.9 in December 2016.[11] Comparing the values of r* in the BR single equation model and in the policy rules when they overlapped, the former was above 2 percent from December 2004 through September 2008 and below 2 percent from December 2008 through January 2012 while the latter equaled 2 percent throughout the period.

The July 2017 Monetary Policy Report (MPR) was the first to include policy rules. It is notable that, in contrast to the Tealbook, the federal funds rate prescriptions from the rules are publicly available immediately instead of with a five-year lag.[12] The neutral real interest rates from 2000:Q1 to 2019:Q4 from the Monetary Policy Reports are shown in Figure 1. They are calculated as quarterly projections of longer-run values for the nominal federal funds rate from surveys conducted by Blue Chip Economic Indicators minus the Fed's two percent inflation target. They start at about 3 percent and don't fall below 2 percent until 2009. They then fall to 1.5 percent in 2012:Q2, below 1 percent in 2015:Q4, and below 0.5 percent in 2019:Q3 and 2019:Q4.

Another measure of the neutral real rate can be calculated by subtracting longer-run PCE inflation projections from the projected appropriate policy for the (nominal) FFR in the longer-run made by the members of the FOMC in the Summary of Economic Projections (SEP) released following the March, June, September, and December FOMC meetings starting in 2012.[13] The SEP measure of the neutral real rate is depicted in Figure 1. It starts at 2.3 percent and falls in steps

[10] There were also five rules that did not include an equilibrium real rate, a first-difference rule and four estimated rules.
[11] Between August 2006 and April 2008, a "Taylor (1999) rule with higher r*" of 2.75 percent was also reported in the Bluebook.
[12] Since the 2017 Tealbook won't be made public until January 2023, we do not know how closely the rules and prescriptions in the MPR correspond with those presented to the FOMC.
[13] We use PCE instead of core PCE projections because the latter are not collected in the longer run. The first two projections are from the January and April 2012 meetings.

to 1.3 percent in March 2016. Between June 2016 and March 2019, it fluctuates between 1.0 and 0.8 percent before falling to 0.5 percent in June 2019.

The most widely used time-varying measure of the neutral real interest rate is from Laubach and Williams (LW) (2003). While it has not been used in the policy rules presented to the FOMC in the Tealbook or the rules in the Monetary Policy Report, it is consistent with the definition in the MPR and was featured prominently by Yellen (2015). Real-time measures of the LW neutral real interest rate from 2005:Q1 – 2019:Q4 are illustrated in Figure 1.[14] They are above or equal to 2.0 percent from 2005:Q1 – 2008:Q1. Starting in 2008:Q2, they fall steadily until they reach -0.40 percent in 2013:Q2. Subsequently, they fluctuate between positive and negative and equal 0.14 in 2018:Q1. In May 2018, small revisions to the National Income and Product accounts caused large changes in the LW measure, which jumped to 0.87 in 2018:Q2 and remained close to that value through 2019:Q4.

3. A Proposed "New" Measure for the Neutral Real Interest Rate

There is a disconnect between the measures of the equilibrium/neutral real interest rate presented to the FOMC and the measures used in policy rules. The BR single-equation medium-run measure is consistent with the Fed's long-term definition of r* but was never incorporated into policy rules. The measures of r* in either the Tealbook or the Monetary Policy Reports are not consistent with the Fed's definition. In this section, we propose to resolve this discrepancy.

We propose a "new" measure of r* and analyze how it affects prescriptions from policy rules. We put quotation marks around "new" because, while it differs from the BR single-equation medium-run measure in several respects, it is largely based on the BR measure. The lag length is determined as in BR by choosing the largest lag j for which the coefficients on y_{t-j} and r_{t-j} are jointly significantly different from zero at the 10 percent level. Most of the selected lag lengths are three quarters. The equation that we estimate with three lags is as follows:

$$y_t = \mu + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-3} + \beta_1 r_{t-1} + \beta_2 r_{t-2} + \beta_3 r_{t-3}, \quad (1)$$

where y_t is the output gap and r_t is the real federal funds rate. We use real-time data that was available to the FOMC when making interest rate setting decisions. Our measure starts in 1991:Q1 when the Congressional Budget Office (CBO) first published vintages of potential GDP that, combined with GDP from the Philadelphia Fed's Real Time Data Set for Macroeconomists (RTDSM), can be used to calculate real-time output gaps. We follow both BR and the MPR by

[14] The data are available at https://www.newyorkfed.org/research/policy/rstar.

subtracting Personal Consumption Expenditure (PCE) inflation from the nominal federal funds rate to calculate the real federal funds rate.

In order to calculate the neutral real interest rate r*, we estimate Equation (1), set the current and lagged output gaps equal to zero, define r* by equating the lagged real interest rates, and solve for r* as $-\mu/(\beta_1+\beta_2+\beta_3)$. This is a long-run measure which, in contrast to the BR medium-run measure, is exactly the r* in the Taylor rule because, when the output gap is zero, inflation is at the 2 percent target and r = r*, the federal funds rate equals the neutral nominal rate, the neutral real rate plus the inflation target. We call this the single-equation r* to differentiate it from the BR medium-run r* measure.

The initial value for 1991:Q1 is calculated by estimating Equation (1) for 1966:Q1 - 1990:Q4 using the 1991:Q1 CBO and Philadelphia Fed vintage data for the real-time output gap. For each subsequent quarter, one observation is added through 2019:Q4.[15] The estimated neutral real rate averages 2.11 percent between 1999:Q1 and 2008:Q4 with a range of 1.5 to 2.5 percent. Starting in 2009, it falls almost monotonically, hitting zero in 2013 and negative 1.5 percent in 2016 before rising back to zero in 2019. Figure 2 compares our measure of r* with the BR measure from 2004:Q4 – 2012:Q1. Between 2004:Q4 and 2008:Q3 our measure is just below 2.0 and the BR measure is just above 2.0. Both measures fall following the financial crisis and, starting in 2010:Q1, our measure is again consistently below the BR measure. While our measure is mostly below the BR measure, the differences are small, averaging 0.23 percent in absolute value.

Figure 3 compares our measure of r* with the measures described above. Panel A illustrates the measure used to calculate policy rule prescriptions in the Tealbook from 2004:Q1 – 2016:Q4. Between 2004:Q4 and 2008:Q4, the Tealbook measure of r* equals 2.0 and our measure of r* is slightly below 2.0. Starting in 2009, the Tealbook measure stays at 2.0, and even rises to 2.25 for a few quarters, before falling from 1.75 to 0.75 between 2014:Q1 and 2016:Q3 before rising to 0.9 in 2016:Q4. Our measure falls much more sharply, equally zero from 2013:Q1 to 2014:Q1 and becoming negative from 2014:Q2 to 2016:Q4. Panel B depicts the measure used to calculate policy rule prescriptions in the Monetary Policy Report from 2000:Q1 – 2019:Q4. The two measures of r* are close from 2000:Q1 to 2009:Q1. Starting in 2009:Q2, our measure falls faster than the MPR

[15] We ended the sample in 2019:Q4 because of the very large GDP movements during and following the Covid-19 recession.

measure through 2016:Q1. It subsequently rises and, by 2019:Q4, the two measures are both close to each other and close to zero.

Panel C illustrates the SEP measure from 2012:Q1 – 2019:Q4. The SEP measure is approximately 2 percentage points higher than the single equation measure from 2012:Q1 – 2015:Q1. Starting in 2015:Q2, the gap widens to 2.75 percentage points in 2016:Q1, subsequently narrowing to zero in 2019:Q4. Panel D shows the LW measure from 2005:Q1 to 2018:Q1. The two measures are fairly close from 2005:Q1 to 2015:Q1. Starting in 2015:Q2, the LW measure rises slowly but stays around zero while the single equation measure falls sharply to almost -1.5 before rising to -0.74 in 2018:Q1.

4. Policy Rule Prescriptions with the Single-Equation Neutral Real Interest Rate

The best-known policy rule is the Taylor (1993) rule,

$$R_t = r_t^* + \pi_t + 0.5(\pi_t - \pi^{LR}) + 0.5y_t \quad (2)$$

where R_t is the level of the short-term federal funds interest rate prescribed by the rule, π_t is the inflation rate, π^{LR} is the 2 percent target level of inflation, y_t is the output gap, and r_t^* is the neutral real interest rate. While the neutral real interest rate equaled 2 percent in Taylor (1993), it is in general time-varying.[16] When inflation equals its 2 percent target and the output gap equals zero, the federal funds rate equals the neutral real interest rate plus the 2 percent inflation target.

Taylor (1999) and Yellen (2012) analyzed an alternative to the Taylor rule that, as described above, has been called the aggressive Taylor rule, the Taylor (1999) rule, and the balanced approach rule, where the coefficient on the inflation gap is 0.5 but the coefficient on the output gap is raised to 1.0.

$$R_t = r_t^* + \pi_t + 0.5(\pi_t - \pi^{LR}) + 1.0y_t \quad (3)$$

The balanced approach rule received considerable attention following the Great Recession because, with the then-conventional neutral real interest rate of two percent, it prescribed a negative FFR and thus provided a justification for quantitative easing and a longer period before exiting the Effective Lower Bound.[17]

How should we compare policy rule prescriptions with the FFR when the latter is at the ELB of between 0 and 0.25 percent from 2008:Q4 to 2015:Q4? Because the federal funds rate is

[16] Taylor (1993) estimated r* as 2.2 percent based on the steady-state growth rate, which he then approximated as 2 percent.
[17] See Rudebusch (2010).

constrained by the effective lower bound it is not a complete measure of Fed policy. The midpoint of the ELB of 0.25 percent is, however, the FFR used in the SEP and the Monetary Policy Report. Between 2009:Q1 and 2015:Q4 we focus on results with the shadow federal funds rate of Wu and Xia (2016) while also reporting some results with the midpoint of the ELB. 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.[18]

Using the Taylor and balanced approach rules, we compare policy rule prescriptions with the single-equation r* with the actual FFR, with r* = 2, and with the r* measures in BR, the Tealbook, the Monetary Policy Report, the SEP, and LW.[19]

4.1 Policy Rule Prescriptions with r=2*

We start by comparing policy rule prescriptions from the single-equation r* with prescriptions from r* = 2 and the actual federal funds rate in Figure 4 for 1991:Q1 – 2019:Q4. The Taylor rule prescriptions are depicted in Panel A. The prescriptions are similar between 1991:Q1 and 2009:Q4. Starting in 2010:Q1, the prescriptions diverge, with those from r*=2 consistently higher than those from the single-equation r*. For r*=2, the exit from the ELB occurs in 2013:Q3, more than two years before the actual 2016:Q1 exit and, by 2019:Q4, the prescribed FFR is more than two percentage points higher than the actual FFR. For the single-equation r*, the exit from the ELB occurs in 2017:Q3 and, between 2018:Q3 and 2019:Q4, the prescribed and actual FFR's are very similar.

Panel B shows the balanced approach rule prescriptions. As with the Taylor rule, the prescriptions from r* = 2 and the single-equation r* are similar until after the Great Recession. Between 2008:Q4 and 2009:Q4, both prescribed rates fell from about 2.5 percent to about -3.5 percent. Starting in 2010:Q1, however, the prescriptions diverge, with those from r*=2 again consistently higher than those from the single-equation r*. While the prescribed exit from the ELB with r*=2 is equal to the actual exit of 2016:Q1, the prescribed exit with the single-equation r* of 2017:Q3 is six quarters after the actual exit. Finally, the prescribed rate in 2019:Q4 is about one

[18] Bauer and Rudebusch (2015) 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.

[19] While other rules have been included in the Tealbook and Monetary Policy Report, these are the only rules that have been consistently included.

percentage point higher than the actual rate for the single-equation r* but about three percentage points higher for r* = 2.

*4.2 Policy Rule Prescriptions with the Brayton and Reifschneider measure of r**

Figure 5 compares policy rule prescriptions from the single equation r* with prescriptions from the BR medium-run measure and the actual federal funds rate for 2004:Q4 – 2012:Q1. The Taylor rule prescriptions are depicted in Panel A. The prescriptions using the single-equation and BR measures of r* are similar, which is not surprising since (1) the measures themselves in Panel A of Figure 3 are close and (2) the value of r* enters the Taylor rule prescriptions point-for-point. Both of the prescribed FFRs are lower than the actual FFR from 2005:Q2 to 2007:Q4, higher than the actual FFR from 2008:Q1 to 2009:Q1, and negative from 2009:Q2 to 2012:Q1.

The balanced approach rule prescriptions in Panel B are similar to the Taylor rule prescriptions in Panel A. Both of the prescribed FFRs are lower than the actual FFR from 2005:Q1 to 2007:Q4, higher than the actual FFR from 2008:Q1 to 2008:Q4, and negative from 2009:Q1 to 2012:Q1. The deviations between the prescribed and actual FFRs are similar than the deviations using the Taylor rule in 2005 – 2007 and similar in 2008. Starting in 2009, the prescribed FFRs with the balanced approach rule and considerably more negative than with the Taylor rule.

*4.3 Policy Rule Prescriptions with the Tealbook measure of r**

We compare policy rule prescriptions from the single-equation r* with prescriptions from the Tealbook measure and the actual federal funds rate in Figure 6 for 2004:Q1 – 2016:Q4. The Taylor rule prescriptions are depicted in Panel A. The prescriptions with the single equation r* and the Tealbook r* are virtually identical from 2004:Q4 to 2008:Q4, with both measures below the FFR from 2005:Q1 – 2008:Q1. Starting in 2009:Q1, the single equation prescriptions are lower than the Tealbook prescriptions and remain lower through 2016:Q4. The single-equation prescriptions are generally closer to the shadow FFR than the Tealbook prescriptions and the Teralbook prescriptions are generally closer to the effective FFR constrained by the ELB than the single-equation prescriptions.

Panel B shows the balanced approach rule prescriptions. The prescriptions with the single equation r* and the Tealbook r* are again virtually identical from 2004:Q4 to 2008:Q4, with both measures below the FFR from 2005:Q1 – 2008:Q1. The gap between the prescribed and actual FFR is larger with the balanced approach rule than with the Taylor rule because the output gap is negative throughout the period and the coefficient on the output gap is larger with the balanced

approach rule than with the Taylor rule. The single equation prescriptions are considerably lower than the Tealbook prescriptions from 2009:Q1 - 2016:Q4.

*4.4 Policy Rule Prescriptions in the Monetary Policy Report measure of r**

Policy rules have been included in the Monetary Policy Report since July 2017. The major difference between the rules in the MPR and those discussed above is that the unemployment gap $U_t^{LR} - U_t$ is used as the measure of real economic activity instead of the output gap y_t, where U_t^{LR} is the rate of unemployment in the longer run and U_t is the current unemployment rate.

The Taylor rule in the Monetary Policy Report is as follows,

$$R_t = r_t^{LR} + \pi_t + 0.5(\pi_t - \pi^{LR}) + (U_t^{LR} - U_t), \quad (4)$$

where R_t is the level of the short-term federal funds interest rate prescribed by the rule, π_t is the inflation rate, π^{LR} is the 2 percent target level of inflation, and r_t^{LR} is the neutral real interest rate that is consistent with inflation equal to the target level of inflation and unemployment equal to the rate of unemployment in the longer run. The Taylor rule has a coefficient on the inflation gap of 0.5 and a coefficient on the unemployment gap of 1.0. The coefficient of 1.0 on the unemployment gap is equivalent to a coefficient of 0.5 on the output gap with an Okun's Law coefficient of 2.0. The rate of unemployment in the longer run $U_t^{LR}$and the neutral real interest rate r_t^{LR} are from surveys conducted by Blue Chip Economic Indicators. The balanced approach rule in the MPR is,

$$R_t = r_t^{LR} + \pi_t + 0.5(\pi_t - \pi^{LR}) + 2(U_t^{LR} - U_t), \quad (5)$$

where the coefficient on the inflation gap is 0.5 but the coefficient on the unemployment gap is raised to 2.0.

Figure 7 compares policy rule prescriptions from the single equation r* with prescriptions from the MPR measure of r* and the federal funds rate for 2000:Q4 – 2019:Q4. The prescriptions with the MPR measure of r* are identical to those in the MPR. The effective FFR is reported for 2000:Q4 – 2008:Q4 and 2016:Q1 – 2019:Q4 and the shadow FFR for 2009:Q1 – 2015:Q4. The Taylor rule prescriptions are depicted in Panel A. The prescriptions with the two r* measures are similar through 2009:Q4. Starting in 2010:Q1, the prescriptions are consistently lower with the SE measure than with the MPR measure. While the prescribed FFR is closer to the shadow FFR with the MPR r* measure than with the SE r* measure from 2010:Q1 through 2011:Q2, the fit is closer with the SE r* measure from 2011:Q3 through 2019:Q4.

The balanced approach rule prescriptions are shown in Panel B. The FFR prescriptions from the MPR and SE measures of r* are similar and close to the effective FFR from 2000:Q1 – 2008:Q2. Starting in 2009:Q1, the prescriptions from both measures become both negative and considerably lower than the shadow FFR, with the SE measure of r* lower than the MPR measure of r* through 2019:Q4. While the prescribed FFR is closer to the shadow FFR with the MPR r* measure than with the SE r* measure from 2009:Q1 through 2013:Q3, the fit is closer with the SE r* measure from 2013:Q3 through 2019:Q4. The prescriptions from the SE r* measure closely track the actual FFR from 2016:Q4 – 2019:Q2.

*4.5 Policy Rule Prescriptions with the Summary of Economic Projections measure of r**

Policy rule prescriptions from the single-equation and SEP measures of r* are compared with the effective and shadow FFR from 2012:Q1 – 2019:Q4 in Figure 8. The Taylor rule prescriptions are illustrated in Panel A. The prescriptions with the single-equation r* are lower than those with the SEP r* for the entire sample, although the gap narrows at the end. Except for short periods in 2013 and 2019, the SEP prescriptions are above the effective FFR for the entire sample while the single-equation prescriptions are below the effective FFR except for a short period in 2018. Between 2012:Q1 and 2015:Q4, the single-equation prescriptions are fairly close to the shadow FFR while the SEP prescriptions are considerably above the shadow FFR.

Panel B depicts the prescriptions with the balanced approach rule. As with the Taylor rule, the prescriptions with the single-equation r* are lower than those with the SEP r* for the entire sample with the gap narrowing at the end. The SEP prescriptions are below or equal to the effective FFR from 2012:Q1 – 2016:Q2 and above or equal to the effective FFR from 2016:Q3 – 2019:Q4 while the single-equation prescriptions are below the effective FFR except for a short period in 2018. Between 2012:Q1 and 2015:Q4, the prescriptions from both rules are fairly close to the shadow FFR.

*4.6 Policy Rule Prescriptions with the Laubach and Williams measure of r**

We compare policy rule prescriptions from the single-equation r* with prescriptions from the Laubach and Williams (LW) measure and the federal funds rate in Figure 9 for 2005:Q1 – 2019:Q4. The Taylor rule prescriptions are depicted in Panel A. The prescriptions with the two measures are fairly close from 2005:Q1 – 2015:Q1. Starting in 2015:Q2, the prescriptions with the single equation r* are lower than those with the LW r* through 2019:Q4. The prescriptions with the two measures are lower than the effective FFR from 2005:Q3 - 2007:Q4 and higher than the

effective FFR from 2008:Q1 – 2009:Q1. The prescriptions from both measures are fairly close to the shadow FFR from 2009:Q3 – 2013:Q3. From 2015:Q3 – 2019:Q4, the prescriptions from the LW r* are mostly closer to the FFR than those from the single-equation r*.

The balanced approach rule prescriptions are shown in Panel B. As with the Taylor rule, the prescriptions with the two measures are fairly close from 2005:Q1 – 2015:Q1. Starting in 2015:Q2, the prescriptions with the single equation r* are lower than those with the LW r* through 2019:Q4. The prescriptions with the two measures are lower than the effective FFR from 2005:Q1 - 2007:Q4 and, as with the Tealbook measure, the gap between the prescribed and actual FFR is larger with the balanced approach rule than with the Taylor rule. In contrast with the Taylor rule, the prescriptions are far below the shadow FFR from 2009:Q1 – 2013:Q3. Starting in 2013:Q4, both prescriptions are closer to and increase with the shadow/effective FFR. The prescriptions with the LW measure are closer to the FFR than those with the single-equation measure from 2015:Q2 – 2018:Q2 but the prescriptions with the single equation measure are closer than those with the LW measure from 2018:Q3 – 2019:Q4.

Taylor and Wieland (2016) make an important point about the use of the LW measure of r* for policy rule analysis. The normal practice, as in Yellen (2015) and in this paper, is to calculate the output gap using Congressional Budget Office (CBO) measures. The CBO output gap, however, is not the measure that Laubach and Williams use to calculate their measure of r*. Our paper, in contrast, uses the CBO output gap to both construct the single-equation r* measure and to calculate the prescribed FFR.

5. Conclusions

The decline in the neutral real interest rate over the past 30 years has had profound implications for monetary policymaking and monetary policy evaluation. Starting with Taylor (1993), the neutral real interest rate affects the prescribed nominal interest rate point-for-point in the vast majority of monetary policy rules. The fall of r* from 2 percent in Taylor (1993) to 0.5 percent in the current Summary of Economic Projections lowers the neutral nominal interest rate from 4 percent to 2.5 percent, providing much less policy space to reduce the nominal interest rate in response to a recession without going below the near-zero Effective Lower Bound.

For the past 20 years, the Fed has defined the neutral real interest rate in terms of consistency with its maximum employment and longer-run inflation objectives, and various measures of r* were presented to the FOMC in the Tealbook between 2001 and 2012. Policy rules have been

presented to the FOMC between 2004 and (at least) 2016 and have been included in the Monetary Policy Report since 2017. Neither of the neutral real rates in the policy rules, however, is consistent with the Fed's definition.

We construct a measure of r*, which we call the single-equation measure, that is closely related to one of the measures in Brayton and Reifschneider (2004a,b). It is consistent with the Fed's definition and was reported to the FOMC in the Tealbook. We compare the single-equation measure to the Tealbook, and MPR measures used in the Fed's policy rules, as well as to measures from the Summary of Economic Projections and Laubach and Williams (2003). While all five measures fall over time, the single-equation measure falls more sharply than the others. The highlights of our findings are as follows.

a. The FFR prescriptions from the Taylor rule are very similar with the single-equation measure and with r* = 2 through 2008, including the "too low for too long" period discussed in Taylor (2007). Starting in 2009, the prescriptions are much closer to the shadow FFR through 2015 and the effective FFR from 2016 to 2019. The results with the balanced approach rule are less clear.
b. The single-equation and Tealbook measures of r* from the Taylor rule produce very similar FFR prescriptions through 2009. Between 2010 and 2016, the prescriptions with the Tealbook measure are much closer to the effective FFR than with the single-equation measure while the prescriptions with the single-equation measure are much closer to the shadow FFR than with the Tealbook measure. With the balanced approach rule, the prescriptions using both measures are consistently negative from 2009 to 2016.
c. The FFR prescriptions from the Taylor rule are very similar with the single-equation and Monetary Policy Report measures of r* through 2009. Between 2010 and 2018, the prescriptions with the single-equation measure are closer to both the effective and shadow FFR than with the MPR measure. Both measures converge to the effective FFR in 2019. The prescriptions with the balanced approach rule are closer to the shadow and effective FFR from 2013 to 2019 with the single equation measure than with the MPR measure.
d. The FFR prescriptions are consistently lower with the single-equation measure than with the Summary of Economic Projections measure of r* for both the Taylor and the balanced approach rule from 2012 to 2019. With the Taylor rule, the prescriptions with

the single-equation measure are closer to the shadow FFR for 2012 to 2015 and approximately the same distance away from the effective FFR for 2016 – 2019 than with the SEP measure. With the balanced approach rule, the prescriptions with the SEP measure are generally closer to the shadow and effective FFR than with the single-equation measure.

e. The single-equation and Laubach and Williams (LW) measures of r* from the Taylor rule produce very similar FFR prescriptions from 2005 through 2014. Starting in 2015, the single-equation prescriptions are consistently lower than the LW prescriptions. The FFR prescriptions are closer to the shadow FFR with the LW measure from 2015 to 2017 and closer with the single-equation measure in 2018 and 2019. The same pattern is observed with the balanced approach rule.

We conclude by summarizing our results across rules and measures. First, the two measures of r* that are in accord with the Fed's definition of the neutral real federal funds rate, our single-equation measure and the Laubach and Williams measure, produce policy rule federal funds rate prescriptions that provide a closer fit to the effective and shadow FFR than the measures that are used in the Fed's policy rules. Second, while the balanced approach rule is a better description of Fed policy than the Taylor rule following the Financial Crisis and the Great Recession when the neutral real interest rate is equal to two, the Taylor rule is a better description of Fed policy than the balanced approach rule with our single-equation measure or the LW measure of the neutral real interest rate.

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Figure 1. Measures of the Neutral Real Federal Funds Rate

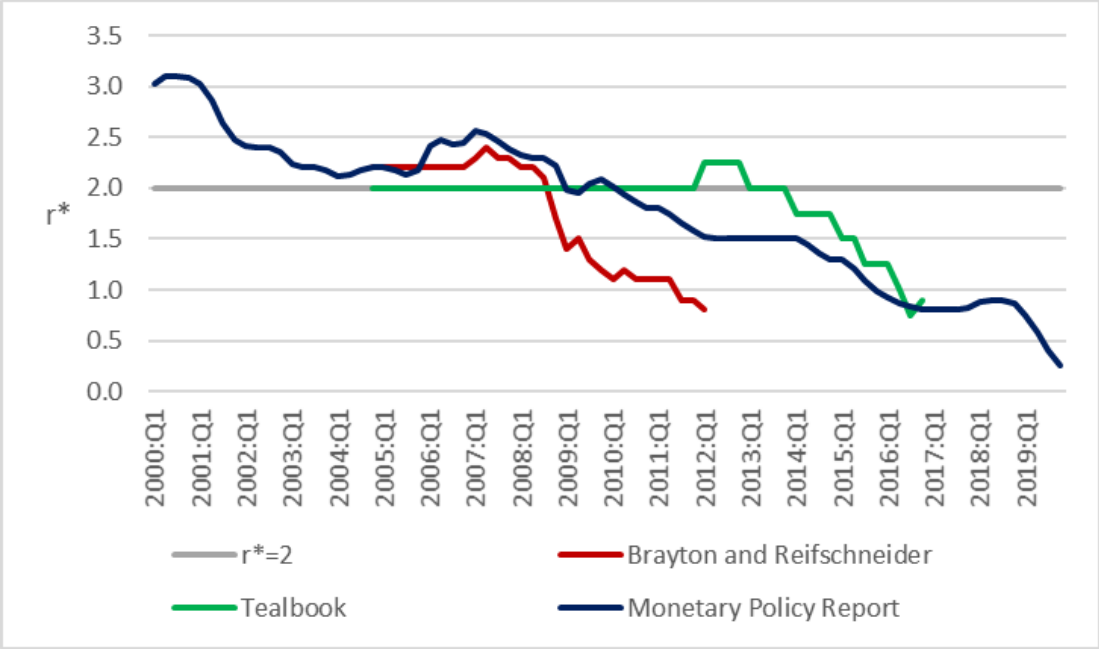


Figure 2. The Single Equation and the Brayton and Reifschneider Measures

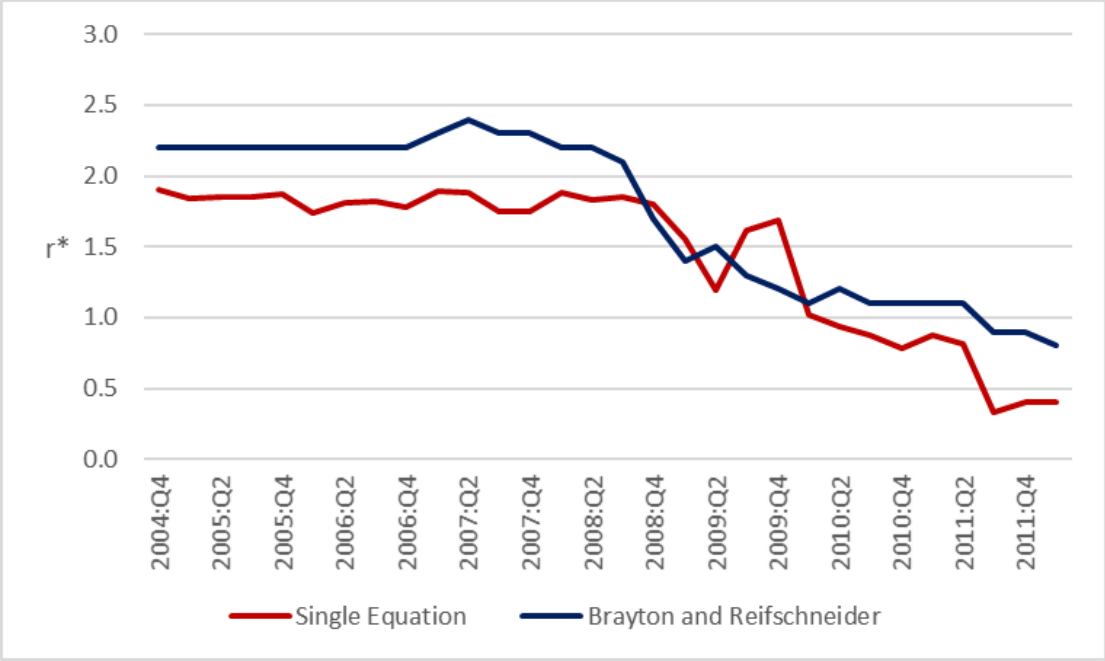
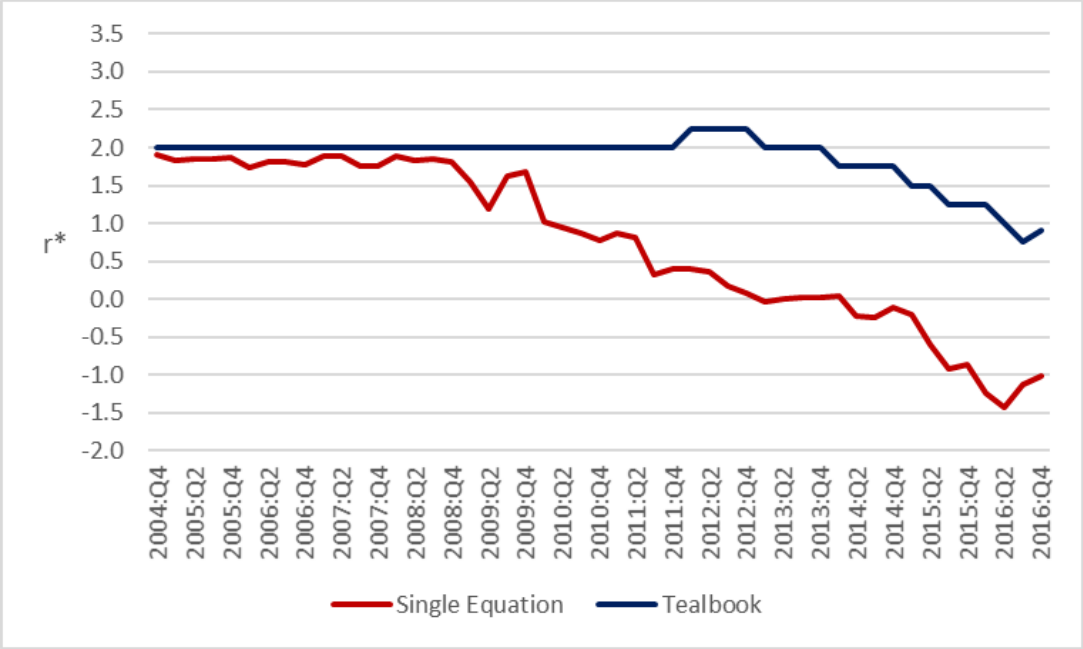


Figure 3.

A. The Single Equation and the Tealbook Measures



B. The Single Equation and the Monetary Policy Report Measures

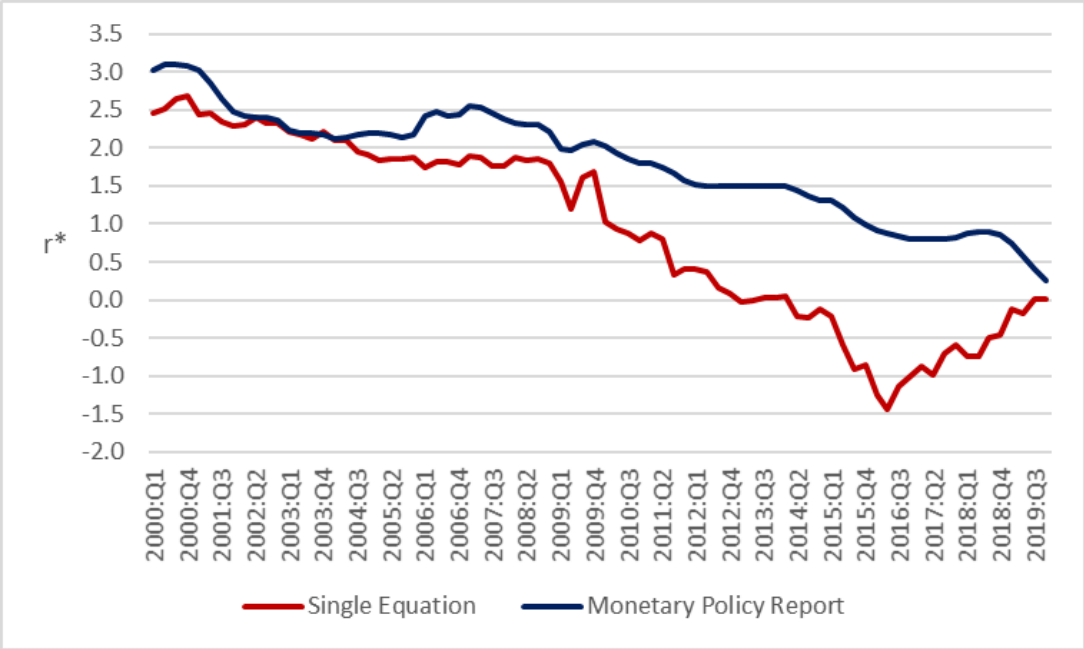
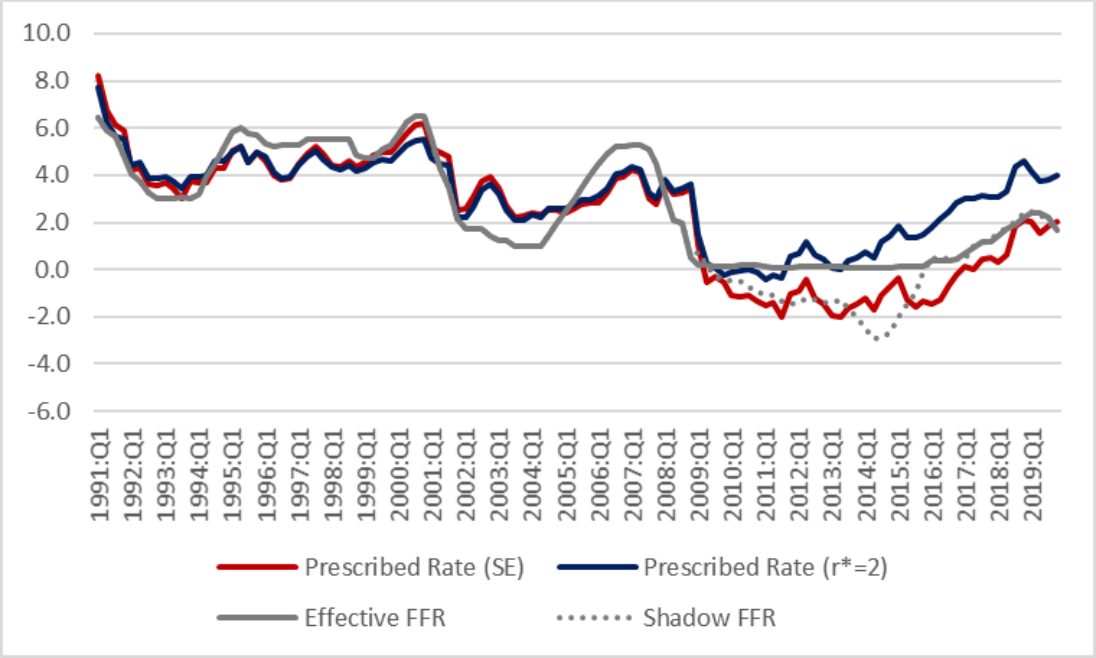


Figure 4. Policy Rule Prescriptions with the Single Equation r* and r*=2

A. Taylor Rule Prescriptions



B. Balanced Approach Rule Prescriptions

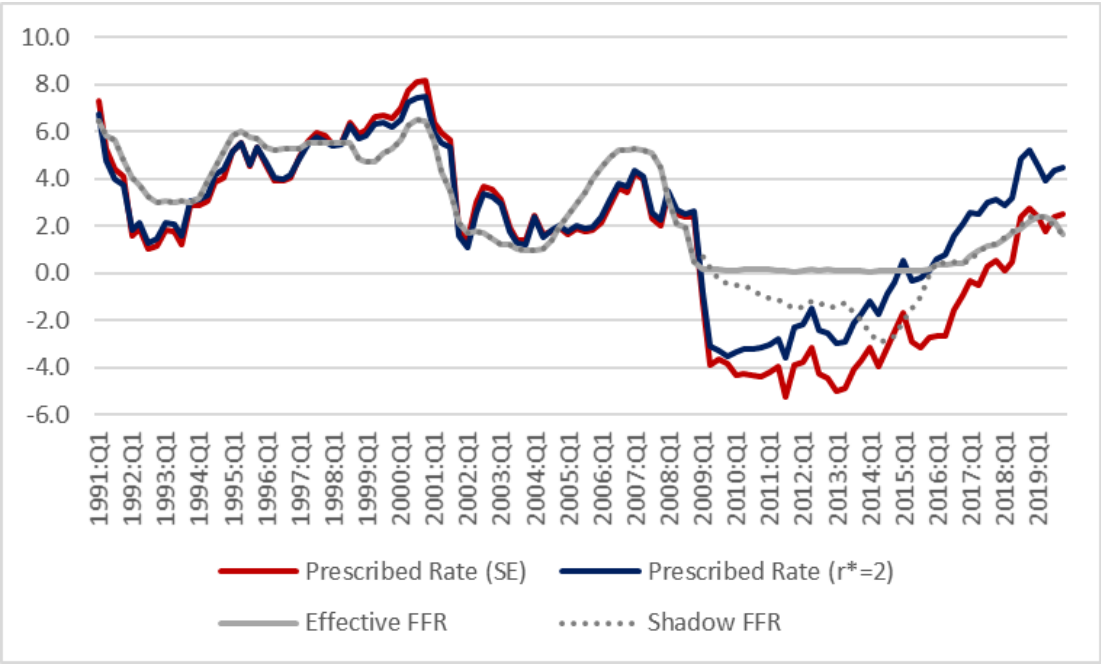
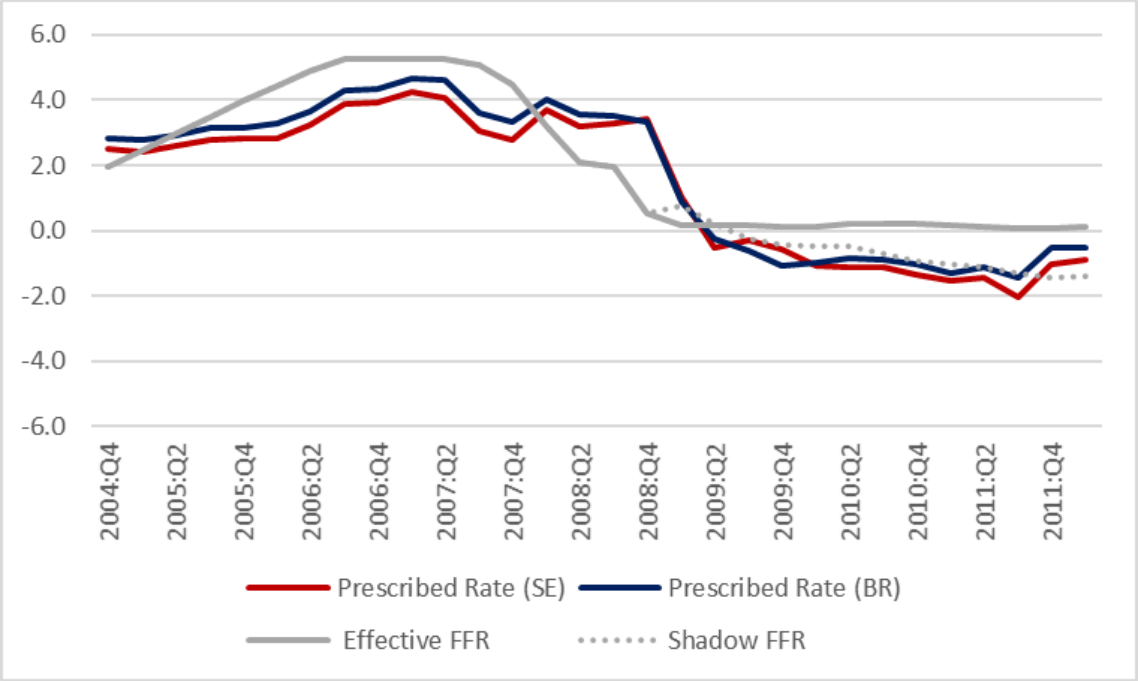


Figure 5. Policy Rule Prescriptions with the Single Equation and BR r*

A. Taylor Rule Prescriptions



B. Balanced Approach Rule Prescriptions

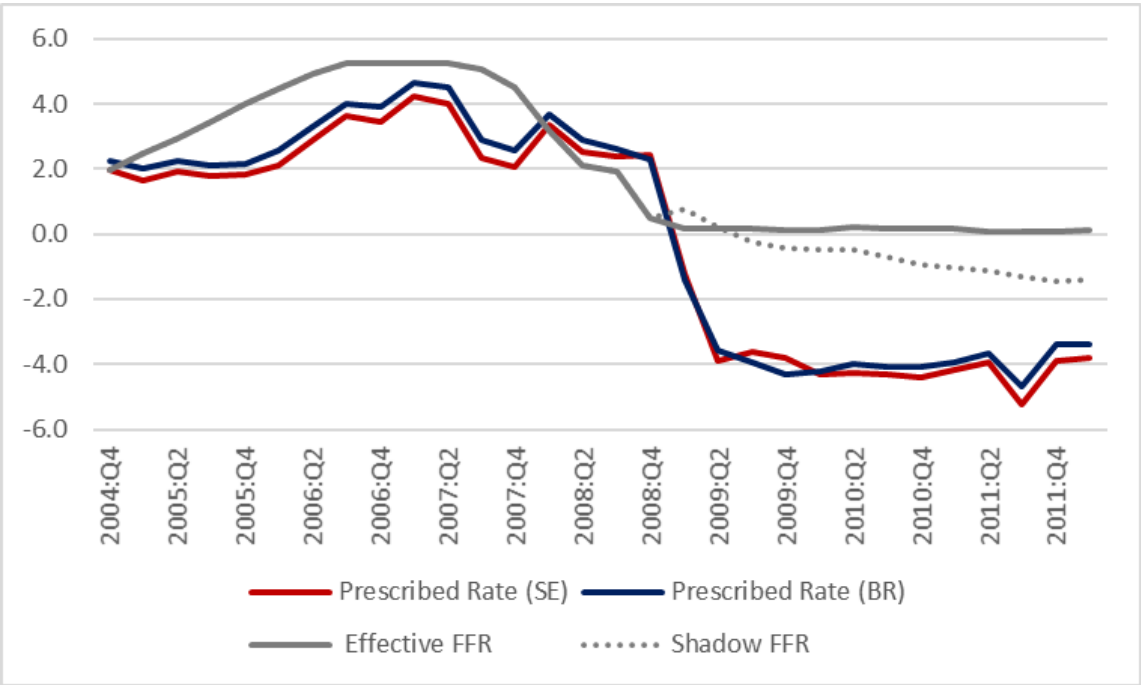
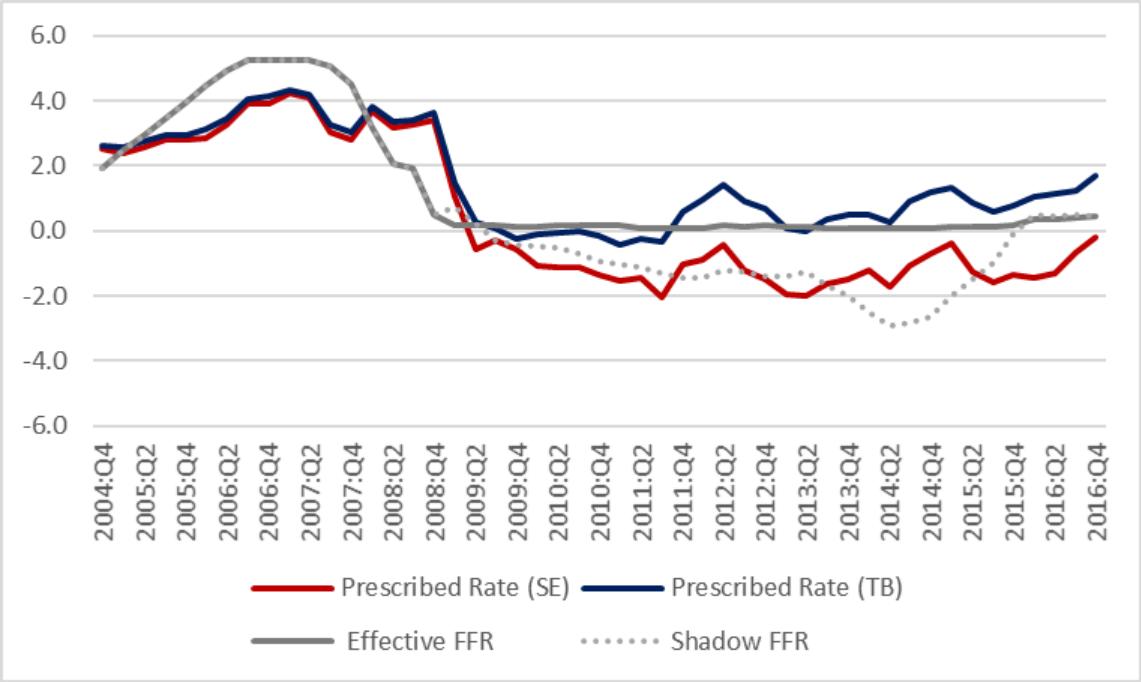


Figure 6. Policy Rule Prescriptions with the Single Equation and Tealbook r*

A. Taylor Rule Prescriptions



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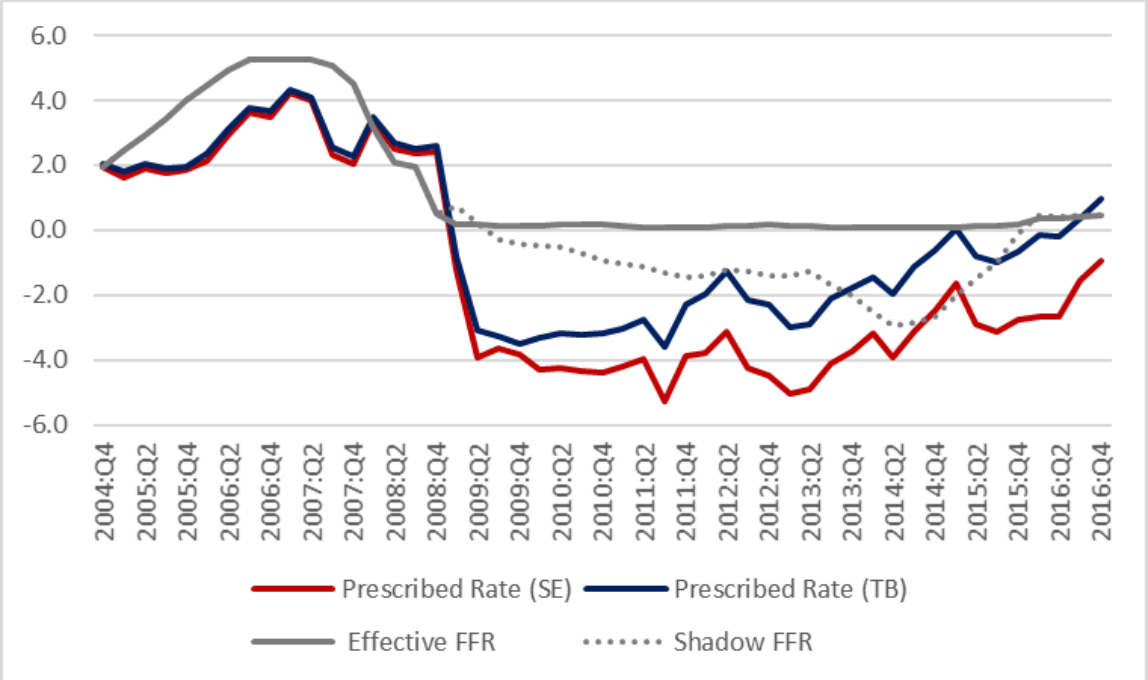
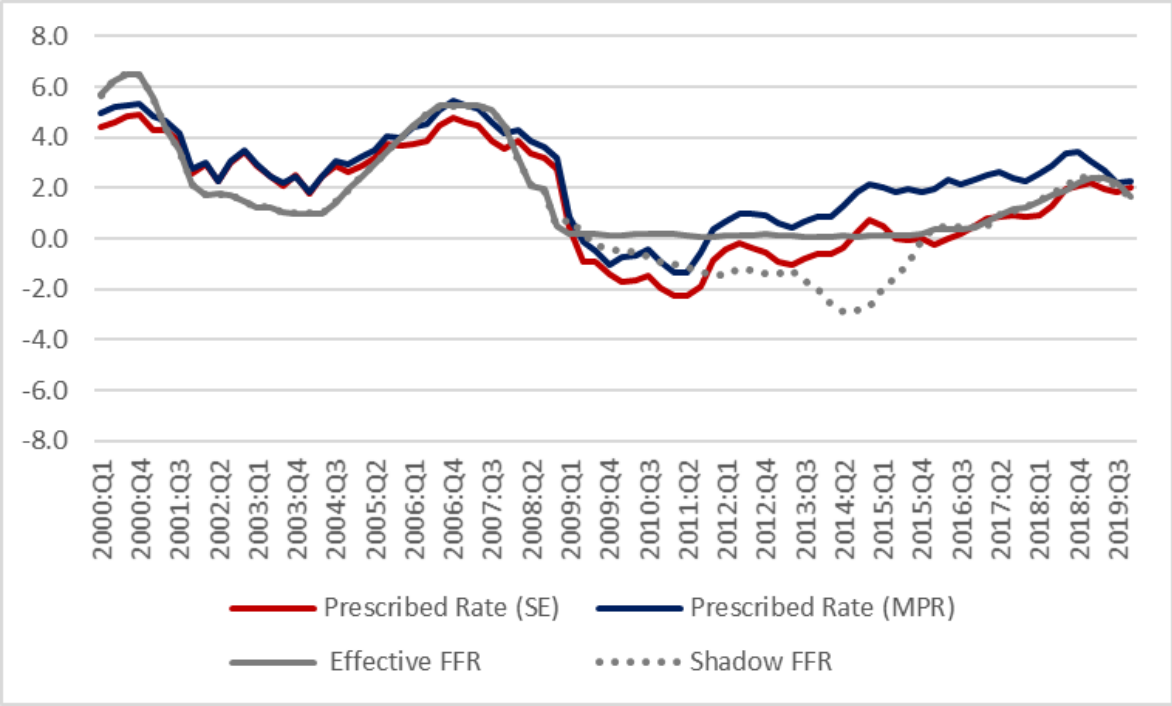
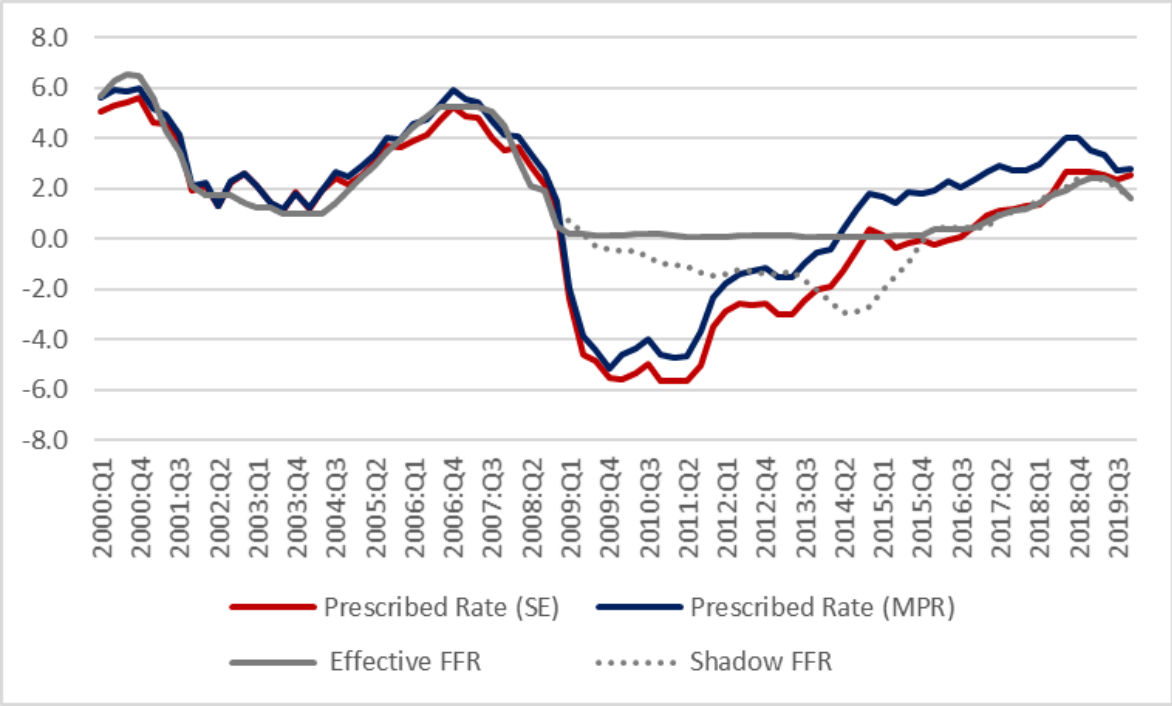


Figure 7. Policy Rule Prescriptions with the Single Equation and MPR r*

A. Taylor Rule Prescriptions



B. Balanced Approach Rule Prescriptions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2015:Q4
2016:Q3
2017:Q2
2018:Q1
2018:Q4
2019:Q3
Prescribed Rate (SE)
Prescribed Rate (MPR)
Effective FFR
Shadow FFR