# STRATEGIES *for* MONETARY POLICY

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CHAPTER FIVE

# Evaluating Rules in the Fed's Report and Measuring Discretion

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## 1. INTRODUCTION

How would the economy have behaved, and how will the economy behave, if one or another monetary policy rule is followed? In particular, what are the effects of the various rules that the Federal Reserve considers in setting policy and has listed in its *Monetary Policy Report*? (Federal Reserve Board 2019). These counterfactual questions must be answered with models. We examine the rules in the Fed's report, and a few others, in a battery of models. We evaluate the means and variances of inflation and output, as predicted by the models with varying rules. Each model generates an optimal set of rules, optimal combinations of interest rate responses to output and inflation. We summarize model-specific optimal rules by a trade-off curve of output versus inflation volatility. A good simple rule should not produce results too far from a model-specific optimum but should be robust across models.

Many central banks deviate from rules at certain times. Central bankers often defend this practice as a response to other events. What are the benefits and costs of such discretion? True, in any model the fully optimal policy responds to all variables and all shocks of the model. But can a real-world central bank implement

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such an optimal-control response? If it could, would the complexity and obscurity of such policy suffer because it is non-transparent, is hard to communicate, and hence leads to uncertain expectations?

The Board of Governors and the Federal Open Market Committee (FOMC) have formally discussed interest rate rules since the 1990s, according to the record documented by Kahn (2012). FOMC chairs Greenspan, Bernanke, Yellen, and Powell have all referred to interest rate rules in explaining FOMC decisions. Since 2017, the prescriptions of selected rules for the federal funds rate have been shown in the Board of Governors' semiannual *Monetary Policy Report,* and they have been published on the Fed's Monetary Policy Principles and Practices web page. These rules include the Taylor (1993a) rule, a so-called balanced-approach rule, and a difference rule. Additionally, there are two rules that take particular account of periods with near-zero federal funds rates and implement a forward-guidance promise to make up for zero bound periods with looser subsequent policy, the adjusted Taylor (1993a) rule and the price-level rule.

First, we take the policy rules to the data. We calculate the prescriptions of the rules given the data, and we calculate the deviations from each rule. We find that one period of large deviations from the rules reported by the Fed occurred in the 1970s, a period of poor macroeconomic performance. We also find that the measure of discretion with all the rules reported by the Fed was small in most of the 1980s and 1990s, a period of relatively good macroeconomic performance. We find that the measure of discretion began to grow again in the early 2000s, though not as large as in the 1970s, and note that this occurred prior to the Great Recession.

Next, we consider a range of macroeconomic models that are available in the Macroeconomic Model Data Base (Wieland, Afanasyeva, Kuete, and Yoo 2016). These models include a simple New Keynesian model using the approach of Rotemberg and Woodford (1999), a simple Old Keynesian model using the approach of Ball (1999) and Rudebusch and Svensson (1999), a medium-size policy model using the approach of Christiano, Eichenbaum, and Evans (2005) and Smets-Wouters (2007), and a few larger-scale macroeconomic models that include, among other ingredients, exports, imports, exchange rates, the term structure of interest rates, additional financial frictions, and other behavioral assumptions.

Next, we evaluate each rule in each model. What is the volatility of output and inflation in each model, if the Fed follows each of the rules? We find that the rules in the Fed's report work well, though some are not very robust. In particular, the first difference rule, described below, does very well in forward-looking New Keynesian models but leads to infinite output and inflation volatility in backward-looking Old Keynesian models.

Finally, we calculate for each model the optimal rules for varying weights on inflation and output, generating a frontier of the best attainable inflation versus output volatility under that model. We compare the Fed's simple rules to those optimal rules. We find that many of the Fed's reported rules are close to the inflation-output volatility curve of optimal rules.

## 2. SOME LITERATURE ON DISTINGUISHING RULES AND DISCRETION IN PRACTICE

Many economists have endeavored to test whether economic performance is better with a rules-based monetary policy than with a discretionary policy. A common approach is to look at actual economic performance during periods when policy rules were in place and compare that with performance when there was more discretion. Indeed, there are periods when policy seems to have been close to prescriptions from rules and other periods with large deviations. However, distinguishing between rules and discretion in practice is difficult with much disagreement and debate, as discussed by McCallum (1999). Moreover, often it is said that particular developments and risks called for discretionary decision making, and that such deviations have led to better economic performance.

Friedman (1982) and later Meltzer (2012) and Taylor (2012) use a broad historical approach to distinguish rules from discretion. This approach did not require specifying that rules-based policy was predicated on a specific algebraic formula. Rather, policy was deemed rules based if it was predictable and strategic, while policy was discretionary if it is was mostly tactical with few strategic elements. Using this approach, Meltzer (2012) and Taylor (2012) find that the period from 1985 to 2003 in the United States was rule-like while the years before and after that interval were discretionary, and they noted that economic performance was better in the 1985–2003 period.

Nikolsko-Rzhevskyy, Papell, and Prodan (2014) use a more specific statistical procedure. They define rules-based policy as a specific policy rule for the interest rate, and discretion as deviations of the actual interest rate from that policy rule, as we do. They employ real-time data and three rules of the form

$$i_t = \varphi_\pi \pi_t + \varphi_y y_t + \mu \qquad (1)$$

with $\varphi_y = .5$, $\varphi_\pi = 1.5$ (as in Taylor 1993a), $\varphi_y = 1.0$, $\varphi_\pi = 1.5$, and $\varphi_y$ and $\varphi_\pi$ estimated. $\pi$ denotes the four-quarter inflation rate (change from a year ago of the GDP deflator) and $y$ the output gap. The latter is the difference between the log of actual and potential GDP. The constant, $\mu = r^* - (\varphi_\pi - 1)\,\pi^*$. The inflation objective is given by $\pi^*$, while $r^*$ is the long-run equilibrium real interest rate. Discretion is defined as deviations of the actual interest rate from equation (1).

They find that economic performance in the United States was worse in periods of discretion relative to each of those rules. For example, using a quadratic loss function with equal weights on inflation and output, they find that the *loss ratio*—the ratio of the average loss during discretionary periods to the average loss during more rules-based periods—was 3.17, 1.85, and 1.70 for the three rules, respectively. Teryoshin (2017) obtains similar results for other countries. Nikolsko-Rzhevskyy, Papell, and Prodan (2018) perform similar calculations for four hundred rules of this form, with the coefficients $\varphi_y$ and $\varphi_\pi$ each taking twenty different values ranging from 0.1 to 2.0. They find with very few exceptions that the loss ratio is greater than one. They find that "inflation-tilting" rules, that is, rules with a higher response coefficient concerning inflation, result in better performance, and they thus conclude that the set of rules that the Fed publishes regularly in its *Monetary Policy Report* should be extended to include an inflation-tilting rule.

Another approach is to use economic models to evaluate rules versus discretion. This is the approach taken in Taylor (1979), where the output-inflation variance trade-off curve from an optimal money growth rule for a specific model is compared with the variances of output and inflation with actual policy and with suboptimal rules. An advantage of this approach is that it brings more economic theory into the calculation. A disadvantage is that it is model specific, but by doing the calculation with many different models, one can reduce this disadvantage (Levin, Wieland, and Williams 2003; Taylor and Wieland 2012).

Nikolsko-Rzhevskyy, Papell, and Prodan (2018) (NPP 2018 in the following) also report some model-based calculations with the Smets-Wouters (2007) model drawn from the Macroeconomic Model Data Base[1] and with the FRB-US model as described in Tetlow (2015). They simulate policy rules of the above form using one hundred different values of the $\varphi_y$ and $\varphi_\pi$ parameters, each taking ten different values from 0.1 to 1.0. The results are completely opposite in the two models: For the Smets-Wouters model, the

1. See www.macromodelbase.com for further details on the database and models as well as Wieland et al. (2016).

rule with the lowest loss (not loss ratio) has $\varphi_y = 0.3$ and $\varphi_\pi = 1.0$. For the FRB-US model, the rule with the lowest loss is at the other end of the range: $\varphi_y = 1.0$ and $\varphi_\pi = 0.1$. This result is suggestive of an underappreciated large difference between models used for policy making.

## 3. THE RULES IN THE FED'S REPORT

As stated, for example, in the most recent report by the Fed, "The prescriptions for the policy interest rate from these rules can provide helpful guidance to the FOMC" (Federal Reserve Board 2019). Accordingly, one guiding principle is that monetary policy should respond in a predictable manner to changes in economic conditions. Its effectiveness is higher, if it is well understood by the public. Another key principle emphasized by the Fed's report is that policy should be accommodative when inflation is below its longer-run objective and employment is below its maximum sustainable level, and vice versa. Yet another key principle in the report "is that, to stabilize inflation, the policy rate should be adjusted by more than one-for-one in response to persistent increases or decreases in inflation."

The specific interest rate rules considered by the Fed define systematic responses to the four-quarter rate of inflation and the unemployment gap. The five rules are summarized in table 5.1.

The Taylor (1993a) rule and many other rules are typically expressed in terms of the deviation of real GDP from potential GDP. The FRB report version of the Taylor (1993a) rule uses an Okun's law relationship with a factor of 2 to translate the output gap into an unemployment gap. We translate the rules back into a version with the output gap. Many of our models do not include the unemployment rate. The Taylor (1993a) rule and the so-called balanced-approach rule then correspond to the specifications of equation (1) with $\varphi_y = 0.5$, $\varphi_\pi = 1.5$ and $\varphi_y = 1.0$, $\varphi_\pi = 1.5$, respec-

TABLE 5.1. The Rules in the *Monetary Policy Report*

| | |
|---|---|
| Taylor (1993a) rule: *T93* | $i_t^{T93} = \pi_t + 0.5(\pi_t - \pi^*) + (u_t^* - u_t) + r_t^*$ |
| Balanced-approach rule (BA) | $i_t^{BA} = \pi_t + 0.5(\pi_t - \pi^*) + 2(u_t^* - u_t) + r_t^*$ |
| First-difference rule (FD) | $i_t^{FD} = i_{t-1} + 0.5(\pi_t - \pi^*) + (u_t^* - u_t) - (u_{t-4}^* - u_{t-4})$ |
| Taylor (1993a) adjusted (T93adj) | $i_t^{T93adj} = \max\{i_t^{T93} - Z_t, 0\}$ |
| Price-level rule (PL) | $i_t^{PL} = \max\{\pi_t + 0.5(PLgap_t) + (u_t^* - u_t) + r_t^*, 0\}$ |

Note: $i_t$ is the nominal federal funds rate; $\pi_t$ is the inflation rate, for which the Fed uses core PCE inflation; $u_t$ is the unemployment rate; $\pi^*$ is the Fed's longer-run inflation objective of 2%; $r_t^*$ is an estimate of the level of the neutral real federal funds rate in the longer run derived from long-run Blue Chip forecasts; similarly $u_t^*$ is an estimate of the rate of unemployment in the longer run derived from long-run Blue Chip forecasts. $Z_t$ is the cumulative sum of past deviations from the Taylor rule forced by the zero bound, and $PLgap_t$ is the price-level gap, defined as the percent deviation of the actual level of prices from a price level that rises 2 percent per year from its level in a specified starting period.

tively, abstracting from a possibly time-varying equilibrium real interest rate.

However, Okun's law does not hold perfectly in the models or the data, and this translation leaves out the important problem of defining the time-varying natural rate of unemployment, leaving in its place the equally important problem of defining and measuring potential GDP. The numerical comparisons may well be affected by this substitution, and rules that respond to the unemployment rate and capture the Fed's difficult job of estimating changes in the natural rate may perform differently.

With regard to inflation, the FRB report uses the PCE deflator excluding food and energy prices. Instead, we will use the GDP deflator, because the models we consider do not include core PCE inflation, and most of them also do not include the overall PCE deflator.

NPP (2018) as well as Papell (see Discussant Remarks following this chapter) refer to the Taylor (1993a) rule as a balanced rule, because it has the property that the same change in the inflation gap and the output gap implies the same effect on the real interest rate. Accordingly, they call rules of the type of the Fed's "balanced-approach" rule as output gap–tilting rule. Such rules imply a stronger response of the real rate to the output gap than to the inflation gap. We agree with the interpretation of NPP and Papell. For this reason, we put the term "balanced-approach" in quotation marks.

A major question of implementation haunts the first-difference FD rule. As defined in the Fed's report, the FD rule is the "rule suggested by Orphanides (2003)," and it is also the rule considered in robustness studies such as those in the volume summarized by Taylor (1999). The rules as presented in the Fed report (table 5. 1) do not include any residuals, deviations, or errors. In the data, of course, actual interest rates persistently deviate from the rule. The first-difference FD rule as stated in the Fed's report and in these earlier studies makes the previous period's actual interest rate, including its deviation, instantly part of the rule! A rule "I won't eat any more donuts than I ate yesterday" means that one donut turns into a permanent part of what will turn out not to be a very successful diet.

With this issue in mind, we explore a different type of first-difference rule,

$$i_t^{FD} = i_{t-1}^{FD} + 0.5(\pi_t - \pi^*) + (u_t^* - u_t) - (u_{t-4}^* - u_{t-4})$$

$$i_t = i_t^{FD} + v_t \qquad (2)$$

Here, $v_t$ is a serially correlated disturbance, which can be interpreted as the discretionary component of the rule. We refer to this rule as the "dynamic first-difference" rule, FDdyn.

The Fed's recent *Monetary Policy Report* includes rules in part to request comment on the rules, and our first major comment is that the Fed should consider the alternative FD rule in equation (2). It makes a very large difference to the interpretation of the data—what is a rule, and what is deviation or discretion—and it makes a potentially large difference to economic performance under the rule.

The adjusted Taylor (1993a) rule and the price-level rule are meant to account for periods when policy is constrained at the zero lower bound on nominal interest rates. They also include a forward-guidance promise to keep policy looser than it would otherwise be in the wake of a zero bound event. The adjusted Taylor (1993a) rule makes up for periods when the rule prescribes a negative federal funds rate, but the actual rate is constrained at zero. The rule keeps the funds rate lower for longer once the Taylor rule again prescribes a positive policy interest rate. The adjustment factor $Z_t$ is the cumulative sum of such past deviations. The price-level rule makes up for a period of below-target inflation by a period of above-target inflation in order to catch up with a price-level target that steadily increases with the target inflation rate. In some models promises of future looser-than-usual policy can stimulate output during the period of the zero bound.

Our second major comment is to take up a suggestion from NPP (2018) to include an inflation-tilting rule in the list of rules examined in the report, that is, a rule with a higher response coefficient concerning inflation than the Taylor (1993a) rule. Specifically, they propose a rule that is nested in equation (1) with $\varphi_y = 0.5$, $\varphi_\pi = 2$. We call this the NPP rule.

## 4. RULES AND DEVIATIONS: MEASURING DISCRETION

In this section, we compare the rules with actual policy, which is characterized by more discretion, and compute deviations. This comparison leads to a natural definition of discretion in the form of deviations from a particular rule.

### 4.1. Real-Time Measures of Discretion: NPP

Nikolsko-Rzhevskyy, Papell, and Prodan (2018) contrast actual interest rate policy with the Taylor rule. Figure 5.1 shows the interest rate setting according to the Taylor rule (T93) along with the

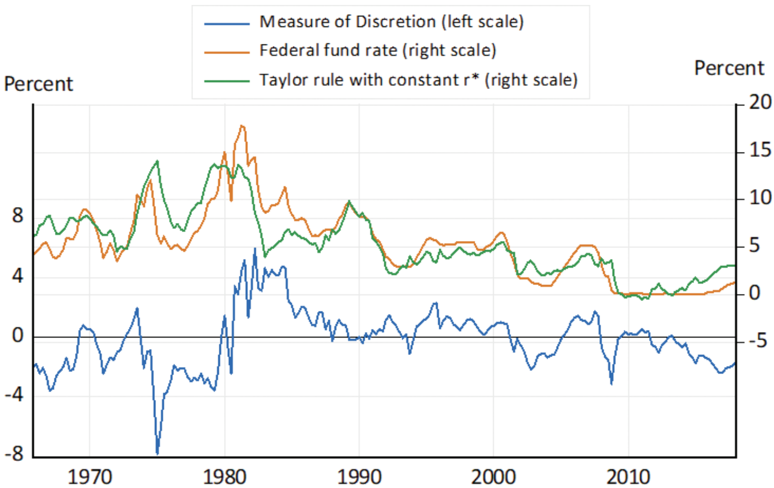


FIGURE 5.1. Federal Funds Rate, Taylor rule and Deviations
Source: Nikolosko-Rzhevskyy, Papell, and Prodan (2018) and the authors' own calculations.

actual interest rate. Nikolsko-Rzhevskyy, Papell, and Prodan (2018) use real-time data available to Fed decision makers at the time to construct the Taylor rule. The chart uses the actual federal funds rate for the interest rate throughout the sample period rather than a "shadow interest rate" during the 2009–2015 period as in Nikolsko-Rzhevskyy, Papell, and Prodan (2018).

The difference between the actual rate and the rule is plotted below the interest rate paths in figure 5.1. This deviation can be considered a measure of discretion. Discretion so defined captures any deviation from the posited rule, including different rules, time-varying rules, rules that respond to additional variables and shocks, perhaps in a time-varying way. The line between such generalized "rule" and discretion seems blurry, but the main point of rules is that people know them, expect them, and understand them, and a complex time-varying rule is indistinguishable from seat-of-the-pants discretion to observers, so it is likely uninformative for us.

The measure of discretion in figure 5.1 is large and negative in the 1970s, especially in the late 1970s. Inflation was high and variable, and output fluctuations were large during this period of generally poor economic performance.

Policy then changed. A positive deviation in the early 1980s was just as large as the negative deviation in the 1970s. We interpret this period as a transition to a new policy with less discretion. During the transition—a period of disinflation—the interest rate went above the rule as the Fed brought inflation down and established credibility.

Following this transition, there were nearly two decades during which there was virtually no discretion—from about 1985 to 2002—by this measure. Economic performance was very good during this period, which is frequently called the great moderation or the long boom.

However, one can see another bout of discretion during the 2003–2005 period. According to figure 5.1, this was not as large as the deviation in the 1970s, but it did suggestively precede the terrible performance during the Great Recession. To see what happened in recent years, we update the measures and include other policy rules in the next section.

## 4.2. Deviations from Rules in the Fed's Report

We do the same calculations as in figure 5.1 using current data (rather than real-time data) for all of the policy rules considered by the Fed's report. Additionally, we include the inflation-tilting rule with coefficients $\varphi_y = 0.5$, $\varphi_\pi = 2$, which we call the NPP rule. Since the numbers for $r_t^*$ used by the Fed are not made available in the *Monetary Policy Report,* we use a constant equilibrium interest rate of $r^* = 2\%$ together with an inflation target of $\pi^* = 2\%$, and the measure of potential GDP from the Congressional Budget Office (CBO). Figure 5.2 shows the actual interest rate and the monetary policy rules T93, BA, FD, and

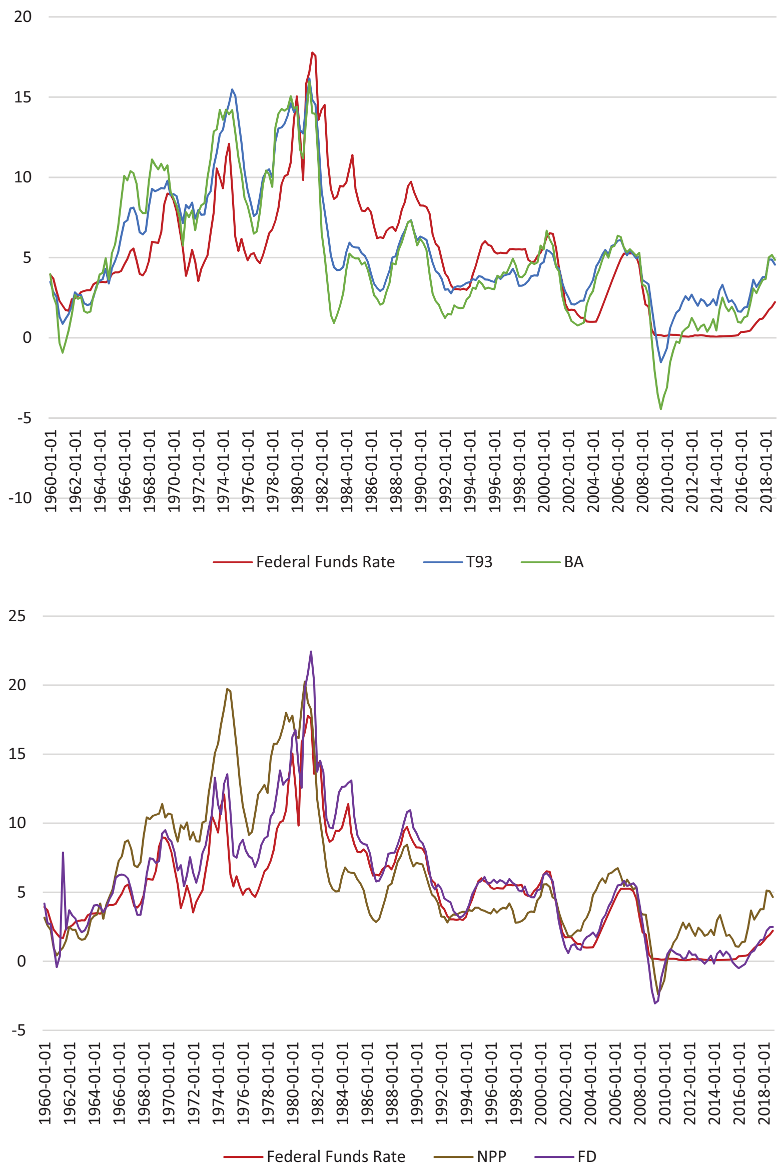


FIGURE 5.2. Federal Funds Rate and Rules: T93 and BA, NPP and FD

Note: We use current data and not the real-time data that were available to Fed decision makers when they set the federal funds rate. Nikolsko-Rzhevskyy, Papell, and Prodan (2018) use the real-time data for their analysis. On the basis of current data, we produce "ex-post" measures of discretion derived from the rules from the Fed's report.

NPP. Figure 5.3 shows the *difference* between the actual interest rate and these rules, which again is our measure of discretion.

Figures 5.2 and 5.3 show that the T93, BA, and NPP rules all display patterns of discretion similar to those in figure 5.1 for T93 with real-time data. There is a big deviation in the 1970s, a transition period, a period of less discretion, and a period of increased discretion. The deviations—especially in 1970s—suggest that policy could have improved outcomes substantially by more closely following the rules. The difference between the calculations in figure 5.1 and those in figure 5.2 may be due to the use of real-time data in figure 5.1 compared with current data in the figure 5.2.

The deviations from the FD rule suggest a much smaller degree of discretion. There is no noticeable deviation for the whole period, except possibly a small negative deviation in the 1970s. For the full sample period in figure 5.3, the standard deviation of the differences between the federal funds rate and first difference rule is $SD(i\text{-}i^{FD}) = 1.34$, while for the other three rules the standard deviations are $SD(i\text{-}i^{T93}) = 2.54$, $SD(i\text{-}i^{BA}) = 3.02$, and $SD(i\text{-}i^{NPP}) = 3.06$.

The adjusted Taylor (1993a) (T93adj) rule and the price-level (PL) rule are meant to account for periods when policy is constrained at the zero lower bound on nominal interest rates. Hence we follow the Fed's report and compute these rules for the recent period since the year 2000. The results are shown in figure 5.4.

Of course, the T93 rule and the T93adj rule result in the same interest rate prescriptions, unless the T93 rule calls for a negative setting. It turns out that the T93 rule only implies four quarters of negative rates, namely, 2009:Q2 to 2010:Q1. The T93adj rule makes up for the constrained period by keeping the policy rate at zero a bit longer, that is, until the first quarter of 2011.

The price-level target used by the PL rule has to be initiated in a particular period. From that period onward, it grows with a fixed rate of 2 percent. We follow the Fed's report and set the initial period for the price-level target in 1998:Q1. If the rate of inflation subsequently exceeds 2 percent, there will have to be a period

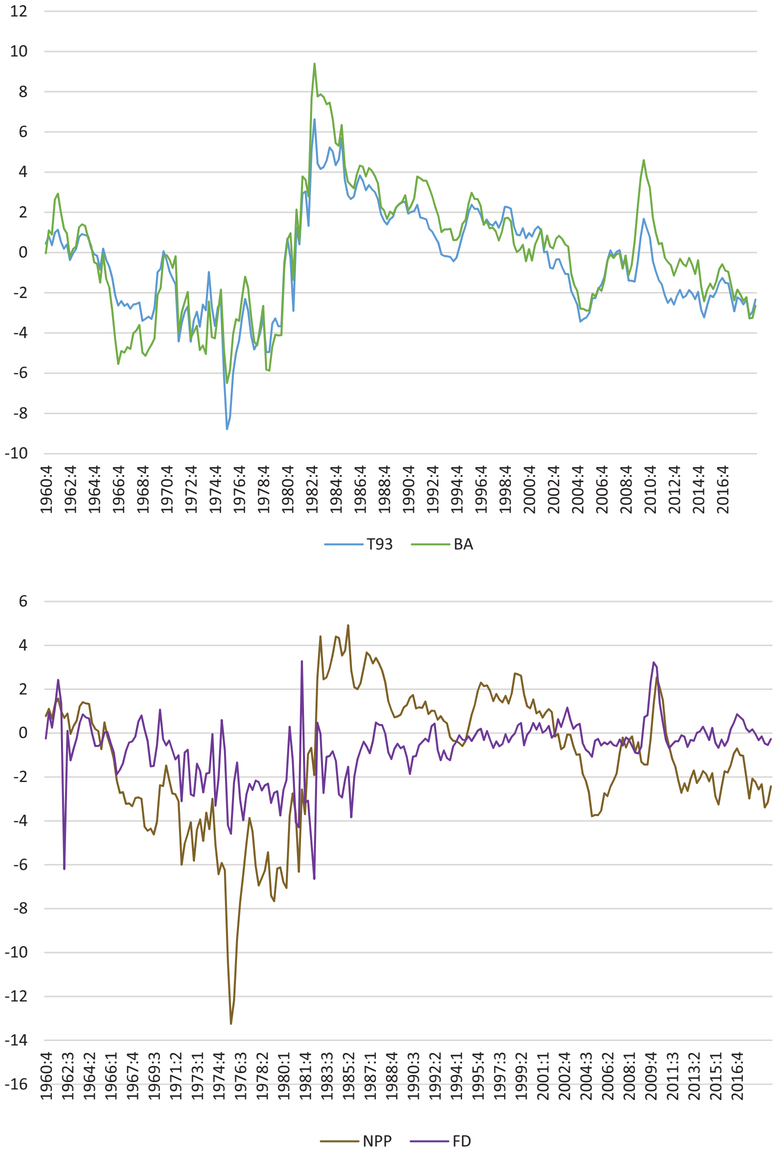


FIGURE 5.3. Measure of Discretion, T93 and BA, NPP and FD

Note: We use current data and not the real-time data that were available to Fed decision makers when they set the federal funds rate. Nikolsko-Rzhevskyy, Papell, and Prodan (2018) use the real-time data for their analysis. On the basis of current data, we produce "ex-post" measures of discretion derived from the rules from the Fed's report.

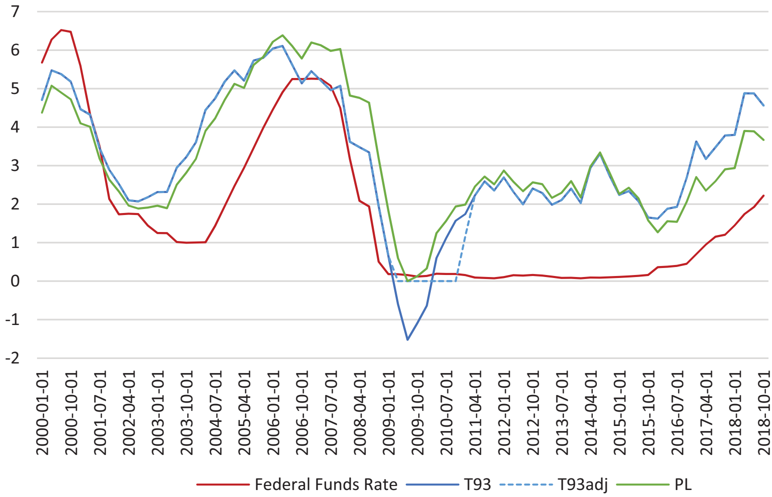


FIGURE 5.4. Federal Funds Rate and Rules: T93, T93adj, and PL based on GDP Deflator. We use current data and not the real-time data that were available to Fed decision makers when they set the federal funds rate. On the basis of current data, we produce "ex-post" measures of discretion derived from the rules from the Fed's report.

with inflation below 2 percent to bring the price level back to the price-level target path consistent with 2 percent growth. Similarly, if the rate of inflation falls short of 2 percent, there will have to be a period with inflation above 2 percent in order to bring the price level back to the price-level target path. It is this latter effect that helps push inflation expectations up during periods when the central bank is constrained at the zero bound. As shown in figure 5.4, the PL rule touches zero only in the second quarter of 2009.

It is remarkable that the interest rate under the PL rule is so close to the various Taylor rules. One would expect the cumulative inflation rate to drift away from 2 percent price-level growth. Apparently, over long time periods, the long periods of inflation below target have been just matched by equally long periods of above-target inflation. Yet there is nothing in an inflation-based policy rule to produce this outcome.

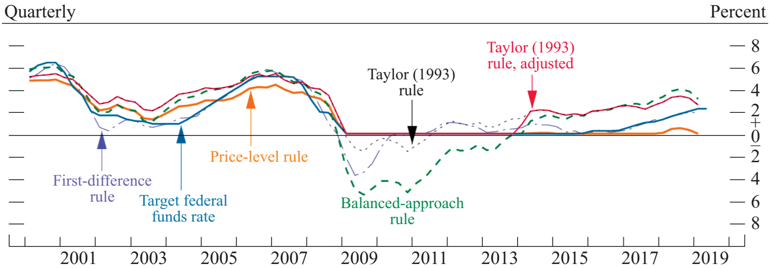


FIGURE 5.5. Historical Federal Funds Rate Prescriptions from Simple Policy Rules

Source: Federal Reserve Bank of Philadelphia, Wolters Kluwer, Blue Chip Economic Indicators, Federal Reserve Board Staff estimates.

Note: The rules use historical values of inflation, the federal funds rate, and the unemployment rate. Inflation is measured as the 4-quarter percent change in the price index for personal consumption expenditures (PCE) excluding food and energy. Quarterly projections of long-run values for the federal funds rate and the unemployment rate are derived through interpolations of biannual projections from Blue Chip Economic Indicators. The long-run value for inflation is taken as 2 percent. The target value of the price level is the average level of the price index for PCE excluding food and energy in 1998 extrapolated at 2 percent per year. The target federal funds rate data extend through 2019:Q2.

Actual fed funds rates stayed near zero for a much longer period, that is, from December 2008 until December 2015. Interestingly, the T93adj rule and the PL rules shown in the Fed's *Monetary Policy Report* also imply fairly long periods of prescriptions near zero. As shown in figure 5.5, taken directly from the 2019 report, the Taylor (1993a) rule in the Fed's report prescribes a near-zero fed funds rate for about five years. The PL rule prescribes a funds rate of (near) zero for about nine years.

There are several potential sources of the differences between figure 5.4 and figure 5.5:

(i) We use the GDP deflator (because it is the inflation variable in our models), while the Fed chart uses the PCE deflator excluding food and energy.

(ii) We use the CBO output gap, while the Fed uses an unemployment gap.

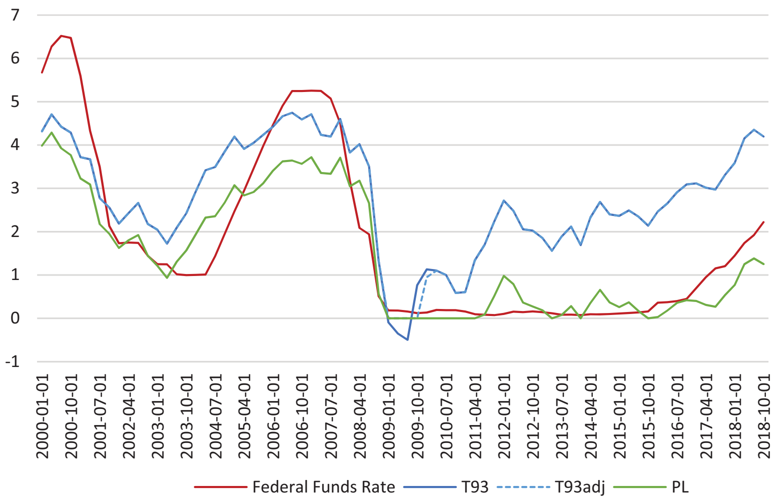


FIGURE 5.6. Federal Funds Rate and Rules: T93, T93adj, and PL based on PCE Deflator

Note: We use current data and not the real-time data that were available to Fed decision makers when they set the federal funds rate. On the basis of current data, we produce "ex-post" measures of discretion derived from the rules from the Fed's report.

(iii) We use a long-run equilibrium real rate ($r^*$) of 2 percent, while the Fed uses a variable $r^*$ that is derived by interpolating biannual projections from Blue Chip Economic Indicators. Similarly, the natural unemployment rate, $u^*$, that underlies the unemployment gap used in the Fed's report is derived by interpolating biannual projections from the Blue Chip Economic Indicators. Unfortunately, the values of $r^*$ and $u^*$ are not made available by the Fed.

Figure 5.6 shows the T93, T93adj, and the PL rules using the core PCE deflator rather than the GDP deflator. In this case, the PL rule provides much lower fed funds rate prescriptions. It stays near zero till 2011 and returns to zero several times afterward. The PCE deflator excluding food and energy increased less than the GDP deflator in recent years. As a result, its level falls behind the 2 percent price-level target more and more. Yet, the effect is still not as strong as in the rules chart reported in the Fed's report. As for the T93 and T93adj rules, they do not imply substantially longer periods near zero in figure 5.6, which uses the PCE deflator as measure of inflation than in figure 5.4, which uses the GDP deflator instead.

Thus, the use of the unemployment gap instead of the CBO output gap and the particular series for the long-run real interest rate, $r^*$, in the Fed's report must also be important factors pushing down the fed funds rate prescriptions. Unfortunately, we cannot check this as the Fed does not make the values it uses available. Moreover, time variation in $r^*$ has only really achieved such prominence in the Fed's deliberations in recent years.

Finally, all of the rules other than the FD rule show persistent, highly serially correlated deviations. By putting the lagged interest rate in the rule (see table 5. 1), the first-difference rule counts yesterday's "deviation" as today's "rule," so the "deviations" are no longer persistent. The dynamic first-difference rule, FDdyn, interprets the lagged interest rate as the lagged rule, not the lagged actual rate. As a reminder, this rule is defined by equation (2).

We implement this rule by dynamic simulation from a specific starting point. As in the case of the PL rule, we choose 1998:Q1 to initialize the rule. The resulting interest prescriptions are shown as FDdyn in figure 5.7.

The dynamic simulation of the FDdyn rule uses actual historical inflation and output data but does not reset to the actual lagged interested rate every period. As a result, it deviates much further from the actual federal funds rate path than the FD rule. It suggests that the small amount of discretion relative to the FD rule indicated in figure 5.3 is misleading. This interpretation of the FD rule, which we think is more sensible, also indicates substantial deviations over time.

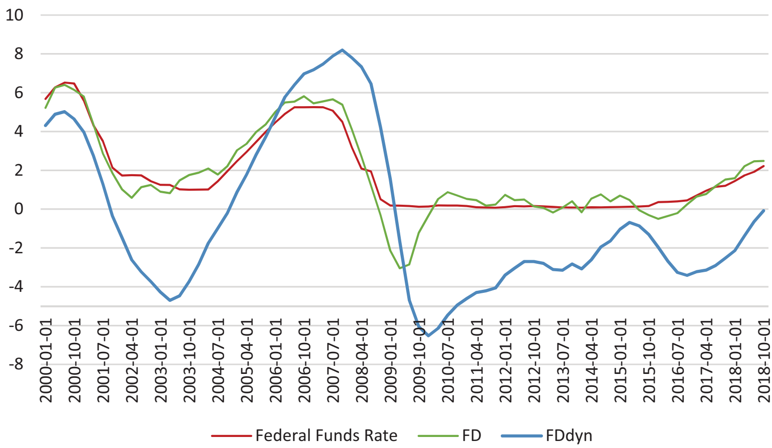


FIGURE 5.7. Federal Funds Rate and Rules: FD, FDdyn

Note: the dynamic simulation of the rule, FDdyn, is initialized in 1998:Q1. We use current data and not the real-time data that were available to Fed decision makers when they set the federal funds rate. On the basis of current data, we produce "ex-post" measures of discretion derived from the rules from the Fed's report.

## 5. EVALUATING THE FED'S RULES IN MACROECONOMIC MODELS

To make further progress on these questions, we simulate the different policy rules in macroeconomic models, which account for the endogenous response of output and inflation to the choice of policy rule.

We consider the T93, BA, FD, and NPP rules. These rules are nested by this extended four-parameter version of equation (1):

$$i_t = \varphi_\pi \pi_t + \varphi_y y_t + \varphi_{yl} y_{t-4} + \varphi_i i_{t-1} \tag{3}$$

This equation does not have an error term. Thus, in the model simulations the actual interest rate always corresponds exactly to the proposed policy rule. Thus, in the model simulations we conduct here, the FD and FDdyn rules are identical.

We do not include the adjusted Taylor (1993a) rule and the price-level rule in the model comparison because we abstract for now from a zero bound or effective lower bound constraint. The separate and nonlinear effects of the zero bound limit, and the forward guidance promise, are important questions and likely to differ greatly across models. Based on whether dominant eigenvalues are above or below one, some models have dramatic effects of zero bound episodes and forward-guidance promises, and some have very slight effects. (See Cochrane 2017.) We leave these important questions for another day, and our calculations apply for "normal times" when the interest rate is above zero.

To start, we consider two small models. While less realistic, they illustrate some lessons of the larger models. The first model is a version of the small New Keynesian model of Rotemberg and Woodford (1997) and Goodfriend and King (1997). It consists of purely forward-looking Phillips and IS curves. The dynamic behavior therefore is driven by serially correlated shocks. There are technology, government spending, and cost-push shocks. We use the empirical specification of this model from Levin, Wieland, and Williams (2003).

*Small New Keynesian Model (NK):*

$$y_t = E_t y_{t+1} - 1.59(i_t - E_t\pi_{t+1} - r_t^*)$$

$$r_t^* = 0.35 r_{t-1}^* + \eta_t$$

$$\pi_t = .99 E_t \pi_{t+1} + .096 y_t + \varepsilon_t$$

Here $r_t^*$ is the natural real interest rate. It follows a serially correlated process. The innovations $\eta_t$ are independent and identically distributed with a standard deviation of 3.72. $\varepsilon_t$ is a cost-push shock, which is independent and identically distributed with standard deviation of 2.25.[2]

2. Levin, Wieland, and Williams (2003) set the parameters of the aggregate demand equation and the inflation equation based on Woodford (2003) and calibrate the standard

The second model is a simple traditional Keynesian model with backward-looking dynamics. This model is similar to Ball (1999), Orphanides and Wieland (2000), and Rudebusch and Svensson (1999). We refer to it as the small Old Keynesian model. We use the empirical specification of Rudebusch and Svensson (1999). They show that the models with lagged dependent variables can explain US inflation and output dynamics quite well without taking recourse to serially correlated errors.[3]

*Small Old Keynesian Model (OK):*

$$y_t = 1.16 y_{t-1} - .25 y_{t-2} - .1(i_{t-1}^{4q} - \pi_{t-1}) + \eta_t$$

$$\pi_t^q = .7\pi_{t-1}^q - .1\pi_{t-2}^q + .28\pi_{t-3}^q + .12\pi_{t-4}^q - .14 y_{t-1} + \varepsilon_t$$

The superscript $^{4q}$ denotes the four-quarter average of the federal funds rate and the superscript $^{q}$ denotes the quarterly inflation rate. The disturbances $\eta_t$ and $\varepsilon_t$ are independent and identically distributed (i.i.d.) with zero mean and standard deviations of 0.89 and 1.009, respectively.

*Medium-Scale Policy Model (SW):*

We consider a medium-scale dynamic stochastic general equilibrium model using the approach of Christiano, Eichenbaum, and Evans (2005) as extended and estimated in Smets and Wouters (2007). The model contains a greater number of equations and

deviation of the independent and identically distributed (i.i.d.) cost-push shock so that the unconditional variance of inflation under their benchmark estimated policy rule matches the sample variance of US quarterly inflation over the period 1983:1–1999:4. The model is available for download at www.macromodelbase.com.

3. Rudebusch and Svensson (1999) estimate these two equations with ordinary-least squares for data from 1961:1–96:2. They report that almost identical estimates were obtained with seemingly unrelated regressions and system maximum likelihood methods. The hypothesis that the sum of the lag coefficients of inflation is equal to unity had a $p$-value of 0.42 and was imposed in estimation. Estimation errors were serially uncorrelated. They also conducted subsample stability tests that did not uncover a lack of stability. The model is available for download at www.macromodelbase.com.

macroeconomic shocks than the above small-scale models. It aims to explain more variation in key variables, and to also include other variables and to match data dynamics. The model is estimated with Bayesian methods that allow—and require, as some model parameters are poorly identified—priors on model parameters.

In the long run, the medium-scale model is consistent with a balanced steady-state growth path driven by labor-augmenting technological progress. The model assumes that firms index wages to a weighted average of lagged and steady-state inflation. It does not impose a delayed effect of monetary policy on other variables, and there is no so-called cost channel in the model. In the following, we use the specification of the model from Smets and Wouters (2007) and thus label this model SW, though it can be also traced to research by Christiano, Eichenbaum, and Evans (2005).[4]

To obtain measures of performance, we replace the model's specified policy rule with one of the alternative rules, and we assume there are no monetary policy shocks. We then compute the steady-state or unconditional distribution of the endogenous variables and report the standard deviations of the four-quarter inflation rate (growth in GDP deflator from prior year) and the quarterly output gap.

The steady-state distribution for any particular model depends on the parameters of that model, the policy rule, and the covariance matrix of the structural shocks of that model. The models are linear, or linear approximation of originally nonlinear models. Thus, we can calculate unconditional variances and covariances analytically, as in Levin, Wieland, and Williams (2003) and Taylor and Wieland (2012).

4. For more detail on the derivation of the model and model equations, the reader is referred to Smets and Wouters (2007). Model equations, parameters, and shock covariances are implemented for use with the Macroeconomic Model Database and available for download from www.macromodelbase.com. The website also provides a replication package that reproduces the original analysis by Smets and Wouters.

## 5.1. Performance of the Four Rules

Table 5.2 reports standard deviations of inflation and the output gap in the NK, OK, and SW models for the four different rules: T93, BA, NPP, and FD. When we have the model's estimated rule and the process and covariance matrix of its residuals, we use these to generate the model's variance of inflation and output.

The standard deviations of inflation and the output gap differ across models in table 5.2 for a number of reasons. First, of course, the models are different. Second, the data samples and estimation periods of the OK and SW models are quite different, and the NK model is calibrated and not estimated. Third, the output gap concepts are different: in the SW model the gap is between actual GDP and the modeled flexible-price level of GDP that varies with a number of economic shocks.

These differences enable us to examine the robustness of the different rules to alternative assumptions. A robust rule performs reasonably well across all models that would be considered as relevant for evaluating policy.

There are some obvious findings in terms of variation across rules within any given model. First, consider the interest rate–level rules: T93, BA, and NPP. The BA rule has the same response coefficient on inflation as T93, but it has twice as large a coefficient on the output gap (1 instead of 0.5). In all three models, the standard deviation of the output gap is smaller under the BA rule than under the T93 rule. The standard deviation of inflation is greater under BA than under T93, but except for the SW model the increase is small.

The NPP rule has a greater coefficient on inflation than the T93 rule, 2 instead of 1.5, but the same output gap coefficient. It tilts toward inflation relative to T93, while BA tilts toward output compared to T93. In all three models, the standard deviation of inflation under the NPP rule is smaller than under the T93 and BA rule,

TABLE 5.2. Steady-State Standard Deviation of Inflation and Output Gap in the Models

| Rules/ Models | OK | | NK | | SW | |
|---|---|---|---|---|---|---|
| | Inflation | Output Gap | Inflation | Output Gap | Inflation | Output Gap |
| T93 | 3.45 | 2.27 | 0.90 | 4.24 | 4.50 | 4.27 |
| BA | 3.49 | 1.99 | 0.96 | 2.83 | 6.87 | 3.56 |
| NPP | 2.65 | 2.59 | 0.84 | 4.38 | 2.83 | 4.74 |
| FD | ∞ | ∞ | 0.88 | 3.12 | 1.39 | 4.62 |
| E | 2.33 | 2.80 | 0.86 | 2.78 | 2.22 | 4.61 |

Note: The models are the small Old Keynesian (OK), small New Keynesian (NK), and the medium-size policy model (SW). The rules are the Taylor (1993) rule (T93), the so-called balanced-approach rule (BA), the inflation-tilting rule proposed by Nikolsko-Rzhevskyy, Papell, and Prodan rule (NPP), and the first-difference rule (FD). E refers to the outcome under the model's estimated rule with its residuals, when that rule and residual covariance matrix is available, or to sample standard deviations when not available.†

† OK model: Rudebusch and Svensson did not provide an estimated rule, but they report sample standard errors for 1961 to 1996 that are reported here. NK model: Levin, Wieland, and Williams (2003) estimated a benchmark interest rate rule and calibrated the standard deviation of the cost-push shock such that it replicates the unconditional variance of inflation in their sample under this benchmark rule. SW model: Smets and Wouters (2007) estimated a policy rule along with the model. The unconditional variance reported accounts for the standard error of serially correlated policy shocks.

while the standard deviation of the output gap is greater than under these two other level rules.

The first-difference rule, FD, delivers quite different outcomes. First, in the OK model it is dynamically unstable, so it produces infinite output and inflation variation. This is denoted by the ∞ symbol in the table. Ideally, the central bank should avoid pursuing a policy that is dynamically unstable! In the small NK model and in the SW model, however, the FD rule performs quite well. In the small NK model, it achieves the second-lowest standard deviations of inflation and the output gap among the four rules considered. In the SW model it achieves by the far the lowest standard deviation of inflation, but the second-highest standard deviation of the output gap.

The FD rule seems to be optimized to forward-looking models but performs poorly in a backward-looking economy. The Taylor rule achieves robustness across the two classes of models in a straightforward way. Old Keynesian models are unstable under an interest rate peg. The Taylor rule with an inflation coefficient greater than one renders those models stable. New Keynesian models are already stable under an interest rate peg but indeterminate; there are multiple equilibria. The Taylor rule renders them determinate, eliminating multiple equilibrium indeterminacy. The same rule has a different but beneficial effect in two quite different classes of models. As a result it is "robust." The FD rule does not have this property, as it does not cure the instability of Old Keynesian models under an interest rate peg.

Overall, therefore, the FD rule is not as robust as the other rules. The FD rule may also be geared to avoid having to account for a slowly time-varying natural rate that the central bank cannot observe. Our models do not include this feature.

## 5.2. More Models

In addition to the three models (NK, OK, and SW) considered in table 5. 2, we consider four more models:

- TMCM: A multi-country model due to Taylor (1993b), which is a first-generation New Keynesian model. It is a model with rational expectations, nominal rigidities based on staggered contracts, and an interest-rate policy rule.
- CCTW10: A model due to Cogan, Cwik, Taylor, and Wieland (2010), which extends the SW model. It includes Keynesian rule-of-thumb consumers. This modification affects, for example, the size of the fiscal multipliers and improves fit a little bit.
- CMR14: A model due to Christiano, Motto, and Rostagno (2014), which adds financial frictions and considers postcrisis data.
- IN10: A model of Iacoviello and Neri (2010), which adds a housing market as well as financial frictions.

Descriptions of these models and the equations that define the models can be found on the Macro Model Data Base web page.

We report the *relative* standard deviations of inflation and the output gap for the rules compared with the T93 rule. For each of the seven models, we divide outcomes under BA, NPP, and FD with the outcome under the T93 rule. A value of 1, for example, for the standard deviation of inflation indicates that inflation volatility is the same as under the T93 rule. A value above (below) 1 indicates that it performs worse (better) along that dimension than the T93 rule. We make this comparison because the raw standard deviations reflect different standard deviations of shocks as well as different performance. We do not want to say that model A produces smaller inflation variation simply because that model has smaller shocks, for example, if it was fit to a quieter data set.

The results are shown graphically in figure 5.8 for the seven models: NK, OK, SW, TMCM, CCTW10, CMR14, and IN10. We find that the BA rule reduces output gap variability relative to the T93 and the NPP rule in all seven models. In two models, inflation variability under BA is significantly higher than under the T93 and NPP rules. NPP, on the other hand, always reduces inflation variability relative to T93 and BA.

The FD rule delivers the lowest degree of inflation variability in the four additional models, and the lowest output gap volatility in two of them. For the forward-looking models, the unit root in the FD rule seems to be a positive feature, though it causes dynamic instability in the models of the type of the OK model.[5] This lack of robustness illustrates the important and strong differences between new and Old Keynesian models.

The results seem to be consistent with earlier model comparison studies. For example, in a review of one model comparison with

5. In figure 8, a value of 2 is chosen to indicate the case of dynamic instability in the OK model.

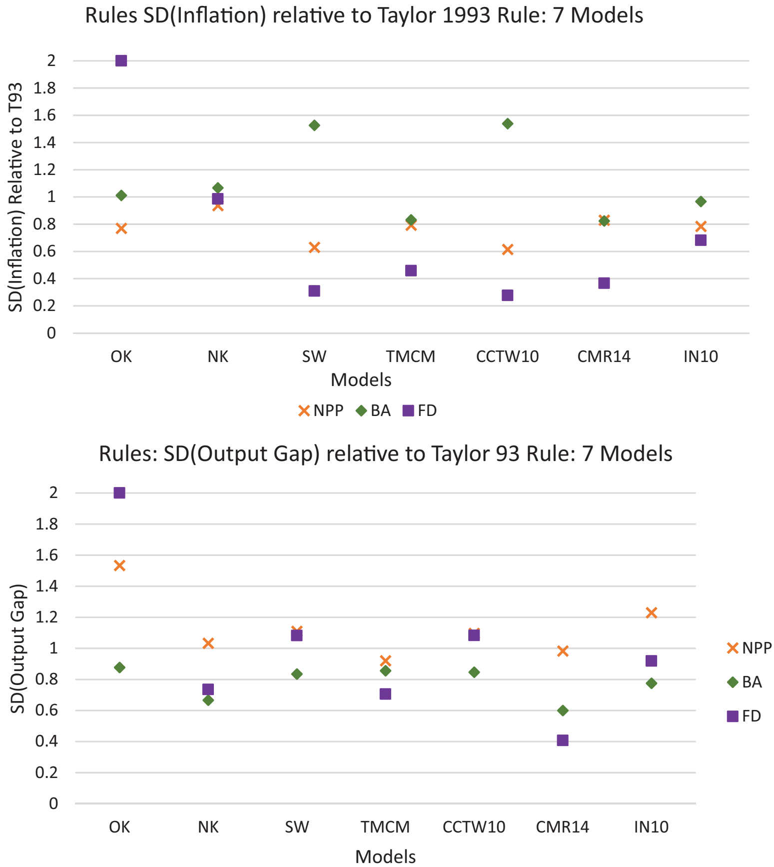


FIGURE 5.8. Standard Deviation of Inflation and Output Gap

Note: The figure shows the standard deviations of inflation and the output gap of each of the rules relative to the Taylor 1993 rule in seven different models. The rules shown are the c rule (BA), the first-difference rule (FD), and the inflation-tilting rule (NPP). The models are as follows: (1) OK model, specification from Rudebusch and Svensson (1999), (2) NK model, specification from Levin, Wieland, and Williams (2003), (3) SW model from Smets and Wouters (2007), (4) TMCM model from Taylor (1993a), (5) CCTW10 model from Cogan, Cwik, Taylor, and Wieland (2010), (6) CMR14 model from Christiano, Motto, and Rostagno (2014), and (7) IN10 model from Iacoviello and Neri (2010).

four rules and eight models, Taylor (1999) reported that rules with lagged dependent variables, such as first difference rules, resulted in large—even infinite—variances as in table 5. 2. The models that performed worse with the first-difference rules were the backward-looking models, again as in table 5. 2.

## 5.3. Comparison with Optimal Rules in Macroeconomic Models

How good are the four rules considered above relative to an optimal rule within a given model? By "optimal" we mean the best among rules that respond to inflation and output and the lagged interest rate, not to other variables including observable shocks. Specifically, we consider two classes of rules: (1) 2-parameter rules that respond to four-quarter inflation and the output gap, and (2) 4-parameter rules that also include the lagged interest rate and the lag of the output gap similar to the FD rule.

We find optimal response coefficients φ for these rules that solve in each model

$$\underset{\{\varphi\}}{Min} \quad Var(\pi)+\lambda Var(y)+Var(\Delta i)$$
$$s.t. \quad i_t = \varphi_\pi \pi_t + \varphi_y y_t + \varphi_{yl} y_{t-1} + \varphi_i i_{t-1}$$

We include the variance of interest rate changes in the objective. Without it, coefficients on inflation and output and the variance of the interest rate become unreasonably large. For a description of the methodology for minimizing the loss function of the variances, see, for example, Levin, Wieland, and Williams (1999).

We solve this problem for different values of the weight $\lambda$ on the output gap. As a result, we obtain an output-inflation variability trade-off curve as computed in Taylor (1979). We focus on two of the models considered so far, the OK model and the SW model. These two models deliver quite different policy implications, in particular concerning the possible benefits or costs of a first-difference rule relative to a level rule. Furthermore, both models have been estimated and include a full set of shocks.

Figure 5.9 shows the output-inflation variability curves for the OK (upper panel) and SW (lower panel) models. The vertical axis

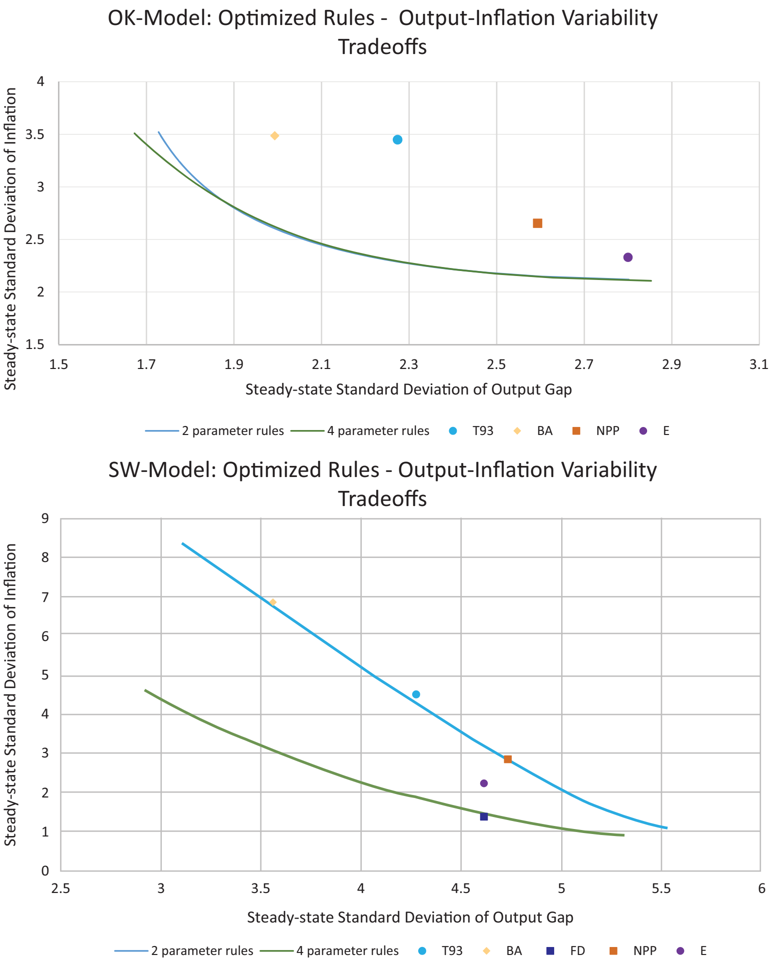


FIGURE 5.9. Output-Inflation Variability Trade-offs

Notes: The curves show the outcomes for the standard deviation of inflation and the output gap for rules, for which the response parameters have been optimized with respect to loss functions with different weights on output and inflation variability. The symbols report outcomes for particular rules such as the T93, BA, FD, NPP rules and estimated rules (E).

denotes the standard deviation of inflation, the horizontal axis the standard deviation of the model-consistent output gap. The trade-off curves are downward sloping through the relevant range. The panels also include outcomes for the standard deviation of inflation and the standard deviation of the output gap for the rules discussed in the previous section.

Figure 5.10 shows the optimal coefficients in the rule for different values of the output variance. For example, in all four panels, as the coefficient on the output gap in the rule goes down the variance of the output gap goes up.

In the OK model, the trade-off curves for 2-parameter and 4-parameter rules are almost identical except for very large weights $\lambda$ on output gap variance in the loss function. Even then, there is little to be gained from including the lag of the interest rate or the lag of the output gap in the rule. The optimal coefficient on the lagged interest rate is close to zero, as can be seen in the top right-hand-side panel in figure 5.10.

As the weight $\lambda$ on the variance of the output gap in the loss function is increased, the optimal coefficient on inflation declines and the optimal coefficient on output increases, and consequently, the resulting standard deviation of the output gap (inflation) declines (increases) (see figure 5.10 top left-hand-side panel).

In the SW model, however, the trade-off curve for 4-parameter rules is a good bit closer to the origin than the trade-off curve for 2-parameter rules. Thus, including the lagged interest rate and the fourth lag of the output gap significantly improves outcomes for any weight $\lambda$ on output gap variability. As shown in figure 5.10, lower right panel, the optimal coefficient on the lagged interest rate is slightly *above* unity for any choice of weight $\lambda$.

The outcome under the FD rule lies almost on the 4-parameter trade-off curve or frontier. Similarly, the three level rules, that is, T93, BA, and NPP, are close to the 2-parameter frontier. This means that there is some value of $\lambda$ for which any of these rules are near optimal within their specific class of rules. By contrast, the OK model indicates that outcomes could be improved substantially by changing the policy coefficients. In particular, it calls

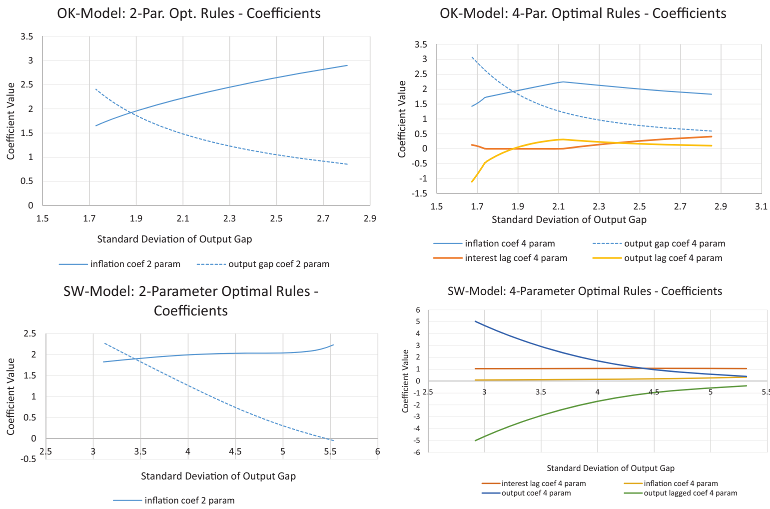


FIGURE 5.10. Optimal Coefficients: OK Model and SW Model. The coefficients shown are the response parameters in the respective rules that have been optimized with respect to loss functions with different weights on output and inflation variability. They correspond to the outcomes for the standard deviations of inflation and the output gap shown in figure 5.9

for higher coefficients on inflation and the output gap. Possibly, a higher weight on interest rate variability would shift the frontier out toward the three rules. The FD rule is not shown because the variance grows without bounds due to dynamic instability.

Given that the optimal coefficient on the lagged interest rate in the SW model is slightly above unity, these optimized rules would all generate dynamic instability in the OK model. Thus, they are not robust as discussed previously.

## 6. CONCLUSION

To sum up, the purpose of this paper is to examine the policy rules that the Fed has begun to regularly publish in its semiannual *Monetary Policy Reports* during of 2017, 2018, and 2019, as well as on Fed's web page. We address two main questions: Using each rule, how do we interpret the history of rules versus. deviations or discretion? Which rules produce better economic outcomes? For the latter question, we use seven different models: a simple New Keynesian model, a simple Old Keynesian model, a medium-sized policy model, and four models that are part of the Macroeconomic Model Data Base. We compare the policy rules in the Fed's report, plus one more, to each other, to optimal rules from those models, and to actual policy. We thereby create a measure of discretion.

The results show that most of the rules in the Fed's report would have worked well and roughly similarly. The results also show that the rules reported by the Fed are close to the optimal rules within a certain class. The first difference rule is an outlier. The Fed needs to clarify if indeed it means to accept yesterday's actual interest rate as today's "rule." The first difference rule also works very well but only in forward-looking models. It is disastrous in models with backward-looking expectations. We note that most policy discussion reflects such models, in which inflation stability rather than indeterminacy is the main concern of monetary policy.

The deviations from the rules show that there was much discretion in the 1970s. These discretionary actions coincided with poor economic performance. In contrast, the measures of discretion with all the rules reported by the Fed were small in most of the 1980s and 1990s, a period of relatively good macroeconomic performance. The measures of discretion began to grow again in the early 2000s, though they did not get as large as in the 1970s, and we noted that this occurred just prior to the Great Recession.

We close with a question that we are pursuing in follow-up research. Central bankers defend discretion, or adjusting interest rates in response to variables and shocks not included in these simple rules, as stabilizing. By responding to other events, they can, in principle, deliver lower output and inflation variance than these simple rules produce. If they are able to do so in practice, however, output and inflation volatility should be *lower* if one *includes* monetary policy disturbances than if one leaves them out. The observed monetary policy disturbances should, in effect, be negatively correlated with right-hand variables, in such a way as to produce less variance. The relative variation of output and inflation when residuals are included or excluded therefore can provide a measure of the benefits of discretion.

One can check this by computing perfect tracking residuals: Find the time-series of shocks that makes a model, with a given policy rule, exactly account for the data. Then, turn off the monetary policy shocks, simulate the model with the remaining historical shocks, and see if predicted inflation and output turn out to be less variable in this simulation than they were in history. Future research could also use the methods in this paper to evaluate policy rules in other countries that have been presented and discussed by other central banks.

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## DISCUSSANT REMARKS

*David Papell*

The paper by Cochrane, Taylor, and Wieland (which I will subsequently refer to as CTW) is about two subjects, evaluating rules in the Fed's *Monetary Policy Report* and measuring discretion. I will first discuss the two subjects and then combine the two by talking about evaluating rules by measuring policy rule deviations.

Figure 5.11 is a picture of a universe of policy rules of the form introduced by Taylor (1993a),

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

where $i_t$ is the target level of the federal funds rate, $\pi_t$ is the inflation rate, $\pi^*$ 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.

The inflation gap, the difference between inflation and target inflation, is on the vertical axis and the output gap is on the horizontal axis. The coefficients on the two gaps are between 0.1 and 1.0 with increments of 0.1, so the figure depicts one hundred rules. The coefficients on inflation are greater than one, so they satisfy the Taylor principle and provide a stable inflation target. The coefficients on the output gap are also positive, so they satisfy the dual mandate.

CTW analyze three of these rules in seven well-known macroeconomic models. (They also analyze a first-difference rule.) The rules are highlighted in figure 5.11. Two of the rules are in the

This paper is based on joint work with my two coauthors, Alex Nikolsko-Rzhevskyy and Ruxandra Prodan.

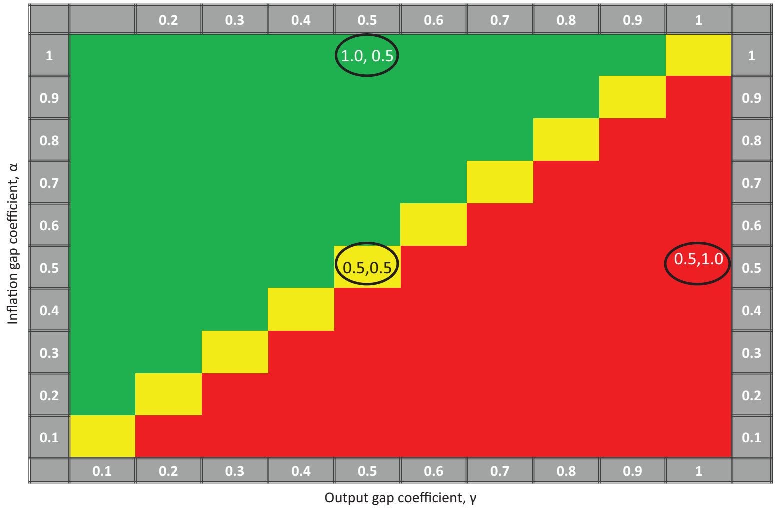


FIGURE 5.11. Policy Rules. The cells in the figure represent balanced policy rules on the 45-degree line as in Taylor (1993a), output gap–tilting rules below the 45-degree line as in Yellen (2012), and inflation gap–tilting rules above the 45-degree line as in Nikolsko-Rzhevskyy, Papell, and Prodan (2019).

*Monetary Policy Report*. The first rule is the Taylor (1993a) rule with $\alpha=\gamma=0.5$. We call this a balanced rule because it has the same coefficients on the inflation gap and the output gap and, maybe more important, it has the property that the same change in the inflation gap and the output gap produces the same effect on the real interest rate. It is not the only balanced rule, as all of the rules on the upward-sloping 45-degree line have the same coefficients on the two gaps.

The second rule in the *Monetary Policy Report* analyzed by CTW has $\alpha=0.5$ and $\gamma=1.0$. This is an example of an output gap–tilting rule because it has a higher coefficient on the output gap than on the inflation gap. Yellen (2012) called this rule the "balanced-approach rule," and that is the terminology used in the *Monetary Policy Report*. I think this is a brilliant marketing strategy, because what's the opposite of a balanced-approach rule? An unbalanced-approach rule, and we wouldn't want an unbalanced rule. It is not the only output gap–tilting rule, as all of the rules below and to the right of the 45-degree line have higher coefficients on the output gap than the inflation gap. CTW also analyze a rule with $\alpha = 1.0$ and $\gamma = 0.5$, which is not in the *Monetary Policy Report*. They call it the NPP rule following Nikolsko-Rzhevskyy, Papell, and Prodan (2019). It is an example of an inflation gap–tilting rule because the coefficients are above and to the left of the 45-degree line.

The first part of the CTW paper involves evaluating policy rules. They compute optimal policies and inflation-output variance trade-off curves and compare economic performance under model-specific optimal policies with performance under the four policy rules. As in Taylor and Wieland (2012), there is a lot of robustness across the models except for the first-difference rule.

Smets and Wouters (2007) present one of the models analyzed by CTW. Using this model, we ask the following question. Out of the one hundred rules, which are the twenty best, the next twenty, and so on? The answer is provided in figure 5.12. Inflation gap–tilting rules are clearly the best, followed by balanced and output gap–tilting rules. Among the three rules considered by CTW, the NPP (2019) rule is in the first (best) quintile, the Taylor (1993a) rule is in the third (middle) quintile, and the Yellen (2012) rule is in the fourth (second from worst) quintile. Similar results are found using the Christiano, Eichenbaum, and Evans (2005) and Taylor (1993b) models.

We then ask the same question using the Federal Reserve Board—United States (FRB-US) model, which is not analyzed by CTW. The results are shown in figure 5.13, and they are completely opposite from those using the Smets and Wouters (2007) model. The output gap–tilting rules are clearly the best, followed by the balanced and the inflation gap–tilting rules. Among the three rules considered by CTW, the Yellen (2012) rule is in the first quintile, the Taylor (1993a) rule is in the third quintile, and the NPP (2019) rule is in the fourth quintile.

| 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 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | |

Output gap coefficient, γ

FIGURE 5.12. Smets and Wouters (2007) Model. The cells in the figure depict quadratic loss functions for each policy rule with lower values preferred to higher values

Let's look at this more generally. Take the best twenty rules from the first quintile of the Smets and Wouters (2007) model and put them in the FRB-US model. Fifteen of the rules are in the fifth quintile while five are in the fourth quintile. Now take the best twenty rules from the first quintile of the FRB-US model and put them in the Smets and Wouters (2007) model. Sixteen of the rules are in the fifth quintile while four are in the fourth quintile. The message in CTW is one of robustness across models. Including the FRB-US model, which is very different from those considered by CTW, you end up with much less robustness. I think this should give you pause about making definitive conclusions from any one model, or even a class of models if it's not a wide enough class.

The second part of the paper involves measuring discretion by calculating deviations from the Taylor (1993a) rule with data that, except for using the actual federal funds rate instead of a shadow federal funds rate during the 2009–2015 period, are identical to the data in NPP (2019). The authors depict the well-known pattern of

| 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 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | |

Output gap coefficient, γ

FIGURE 5.13. FRB-US Model. The cells in the figure depict quadratic loss functions for each policy rule with lower values preferred to higher values

high deviations in the 1970s and early eighties, low deviations in the Great Moderation period, and an increase in deviations during the 2003–2005 period. Their visual evidence is supported by structural change tests on the absolute value of the deviations, as in Nikolsko-Rzhevskyy, Papell, and Prodan (2014). The deviations are very large in the Great Inflation and Volcker Disinflation periods, are very low during the Great Moderation, and increase starting in 2001, although not to the levels before 1985.

I will conclude by discussing evaluating policy rules by measuring deviations. In NPP (2019), we calculate deviations from the one hundred policy rules discussed above with coefficients on the inflation and output gaps from 0.1 to 1.0 and divide the sample into high- and low-deviations periods. We then evaluate the rules by calculating quadratic loss ratios with the two gaps for the high- and low-deviations periods, with a "good" rule having worse performance during high-deviations periods than during low-deviations periods so that the quadratic loss ratio is greater than one. The central results of the paper are (1) economic performance is better

| 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 | 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

FIGURE 5.14. Quadratic Loss Ratios. The cells in the figure depict quadratic loss ratios, the loss in high deviations periods divided by the loss in low deviations periods, for each policy rule. Higher values are preferred to lower values

in low-deviations periods than in high-deviations periods for the vast majority of rules and (2) inflation gap–tilting rules are preferred to output gap–tilting rules. This is illustrated in figure 5.14. Among the three rules considered by CTW, the NPP rule is in the first quintile, the Taylor (1993a) rule is in the second quintile, and the Yellen (2012) rule is in the fourth quintile. The policy recommendation from the paper is to put what CTW call the NPP rule in the Fed's *Monetary Policy Report* in addition to the Taylor (1993a) and Yellen (2012) rules.

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