Evaluating Rules in the Fed's Report and Measuring Discretion

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Abstract

In recent Monetary Policy Reports the Federal Reserve has been reporting and discussing specific monetary policy rules. This paper evaluates the monetary policy rules reported by Fed in these Reports. We define the rules in Section 2—three from the Report and one alternative. In Section 3 we calculate the performance of these rules in seven well-known macroeconomic models—a small new Keynesian model, a small old Keynesian model, a larger policy-oriented model, and four other models from the Macro Model Data Base.

Each model has an optimal rule, that by construction outperforms any of these simple model-independent rules. But good rules should not produce outcomes substantially worse than model-specific optimal rules. In Section 4 we compute optimal policies and the inflation-output variance tradeoff curves for two models, and we compare the economic performance under model-specific optimal policies with performance under the 4 policy rules.

Central banks value discretion, which we model as residuals or deviations from policy rules. Such deviations can in principle improve performance, by reacting to variables and shocks excluded from simple rules. If they do, then the actual volatility of inflation and output, produced by rule plus deviation, will be less than the volatility produced by the rule without deviations. To this end, in Section 5 we compare the interest rate prescriptions that result from these rules with the actual path of the federal funds rate.

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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? (Federal Reserve Board, 2019.) These counterfactual questions must be answered with models. We examine the Fed's rules, 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 tradeoff curve of output vs. 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. They defend this practice as a response to other events. What are the benefits and costs of such discretion? If it is beneficial, the actual outcome, which is produced by the rule plus residuals, should be better than the outcome under the rule with no residuals. The relative variation of output and inflation when residuals are included or excluded provides a measure of the benefits of discretion. More deeply, in any model the optimal policy responds to all variables and all shocks of the model. But can a real-world central bank implement such an optimal-control response? The relative performance of the rule with and without residuals according to a model answers this question and is an approach we are researching. However, even this measure leaves out the additional question whether discretion is harmful to transparency, communication, and the formation of 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' semi-annual Monetary Policy Report, and they have been published on the Fed's Monetary Policy Principles and Practices web page. These rules include the Taylor (1993) rule, a so-called balanced 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 (1993) rule and the price level rule.

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 models using the approach of Rotemberg and Woodford (1999), a simple old Keynesian models 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 Smet-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.

We find that the rules in the Fed's Report work well though some are not very robust. We also find that the Fed's reported rules are close to the inflation-output volatility curve of optimal rules.

Next, we take policy rules and models to the historical data. The first step is to calculate the prescriptions of the rules given the observed data to illustrate periods with large or small deviations from the particular rules. We find that one period of large deviations from the rules reported by the Fed occurred in the 1970s, and that these discretionary actions were likely responsible for the poor economic performance during that period. 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.

These period-specific results suggest the high value of a model-based evaluation of the costs and benefits of discretion with actual shocks rather than shocks effectively drawn from an estimated variance covariance matrix. With such an approach, which we are pursuing in our research, one could simulate a model with actual shocks to policy during different historical periods, and thereby better assess the costs and benefits of discretion.

1.1 Literature

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 based 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 φ_y= .5, φ_π =1.5 (as in Taylor (1993)), φ_y = 1.0, φ_π = 1.5 (the balanced rule) and φ_y and φ_π estimated. π 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 π^*, 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 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 rules-based periods—was 3.17, 1.85, and 1.70 for the three rules, respectively. Terryoshin (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 φ_y and φ_π each taking 20 different values. They find with very few exceptions that the loss ratio is greater than one. They find 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 such rules.

Another approach is to use economic models to evaluate rules versus discretion. This is the approach taken in Taylor (1979) where an optimal money growth rule for a specific model is compared 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) also report some model-based calculations with the Smets-Wouters (2007) model drawn from the Macroeconomic Model Data Base and with the FRB-US model as described in Tetlow (2015). They simulate policy rules of the above form using 100 different values of the φ_y and φ_π parameters each taking 10 different values. The results are completely opposite in the two models: For the Smets-Wouters model, the rule with the lowest loss (not loss ratio) has φ_y = 0.3 and φ_π = 2.0. For the FRB/US model, the rule with the lowest loss is at the other end of the range: φ_y = 1.0 and φ_π = 1.1. This result is suggestive of an underappreciated large difference between models used for policy making.

2. The Rules

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 1.

Table 1: The Rules in the Monetary Policy Report

Taylor (1993) 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*	$i_t^{FD} = i_{t-1} + 0.5(\pi_t - \pi^*) + (u_t^* - u_t) - (u_{t-4}^* - u_{t-4}) + r_t^*$
Taylor (1993) 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 to Table 1: i_t is the nominal federal funds rate, π_t is the inflation rate, for which the Fed uses core PCE inflation, u_t is the unemployment rate, π^* is the Fed's longer-run inflation objective of 2%, r_t^* is the Fed's estimate level of the neutral real federal funds rate in the longer-run, u_t^* is the Fed's estimate of rate of unemployment in the longer run. 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.

The Taylor (1993) 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 (1993) 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 (1993) rule and the balanced-approach rule then correspond to the specifications of equation (1) with $\varphi_y = 0.5$, $\varphi_\pi = 1.5$ and, $\varphi_y = 1.0$, $\varphi_\pi = 1.5$, respectively, 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.

An extended four-parameter version of the equation (1) also nests the first-difference rule,

$$i_t = \varphi_\pi \pi_t + \varphi_y y_t + \varphi_{yl} y_{t-4} + \varphi_i i_{t-1} + \mu \qquad (2)$$

with φ_y= 0.5, φ_π =0.5, φ_{yl}= -0.5, φ_i =1.

The adjusted Taylor (1993) 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 (1993) 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 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 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.

We do not include the adjusted Taylor (1993) rule and the price level rule in our comparison because we abstract for now from a zero bound or effective lower bound constraint. The separate 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. We leave these important questions for another day, and our calculations apply for "normal times" when the interest rate is well above zero.

We take up a suggestion from Nikolsko-Rzhevskyy, Papell, and Prodan (2018), to include an inflation-tilting rule, that is a rule with a higher response coefficient concerning inflation than the Taylor (1993) rule. Specifically, they propose a rule that is nested in equation (2) with φ_y= 0.5, φ_π =2, φ_{yl}= 0, φ_i =0. We call this the NPP rule.

3. Evaluating the Fed's Rules in Macroeconomic Models

We evaluate the performance of the four policy rules in several macroeconomic models. 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):

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

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

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

Here r_t^* is the natural real interest rate. It follows a serially correlated process. The innovations η_t, are independent and identically distributed with a standard deviation of 3.72. ε_t is a cost-push shock which is independent and identically distributed with standard deviation of 2.25.[1]

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 U.S. inflation and output dynamics quite well without taking recourse to serially correlated errors.[2]

Small Old-Keynesian Model (OK):

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

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

The super-script^{4q} denotes the four-quarter average of the federal funds rate and super-script^{q} denotes the quarterly inflation rate. The disturbances η_t and ε_t are i.i.d. with zero mean and standard deviations of 0.89 and 1.009, respectively.

Medium-Scale Policy Model (SW):

[1] 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 deviation of the i.i.d. cost-push shock so that the unconditional variance of inflation under their benchmark estimated policy rule matches the sample variance of U.S. quarterly inflation over the period 1983:1-1999:4. The model is available for download at www.macromodelbase.com.

[2] 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 had a p-value of 0.42 and was imposed in estimation. Estimation errors were serially uncorrelated. They also conducted sub-sample stability tests that did not uncover a lack of stability.

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 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).[3]

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).

3.1 Performance of the Four Rules

Table 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, 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.

Table 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

[3] 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.macromodeldatabase.com. The website also provides a replication package that reproduces the original analysis by Smets and Wouters.

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 to Table 2: 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 balanced approach rule (BA), the inflation-tilting Taylor rule proposed by Nikolsko-Rzhevskyy, Papell, and Prodan rule (NPP), 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.[4]

The standard deviations of inflation and the output gap differ across models in **Table 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 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 towards inflation relative to T93, while BA tilts towards 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, 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. This is denoted by the ∞ symbol. Ideally, the central bank should avoid

[4] OK Model: Rudebusch and Svensson did not provide an estimated rule, but they report sample standard errors for 1961 to 1996 which are reported here. NK: 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: 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.

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 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 backwards-looking economy. Overall, therefore, the FD rule is not as robust as the other rules. (The FD rule may also be geared towards a slowly time-varying natural rate that the central bank cannot observe. Our models do not include this feature.)

3.2 More Models

In in addition to the 3 models (NK, OK, SW) considered in Table 1, we consider 4 more models:

- TMCM: A multi-country model due to Taylor (1993), 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 including 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-Rostagno (2014), which adds financial frictions and considers post-crisis data.
- IN10: A model of Iacoviello and Neri (2010), which adds a housing market as well as financial frictions.

Detailed descriptions of these models and the equations which define the models can be found on the Macro Model Data Base web page.

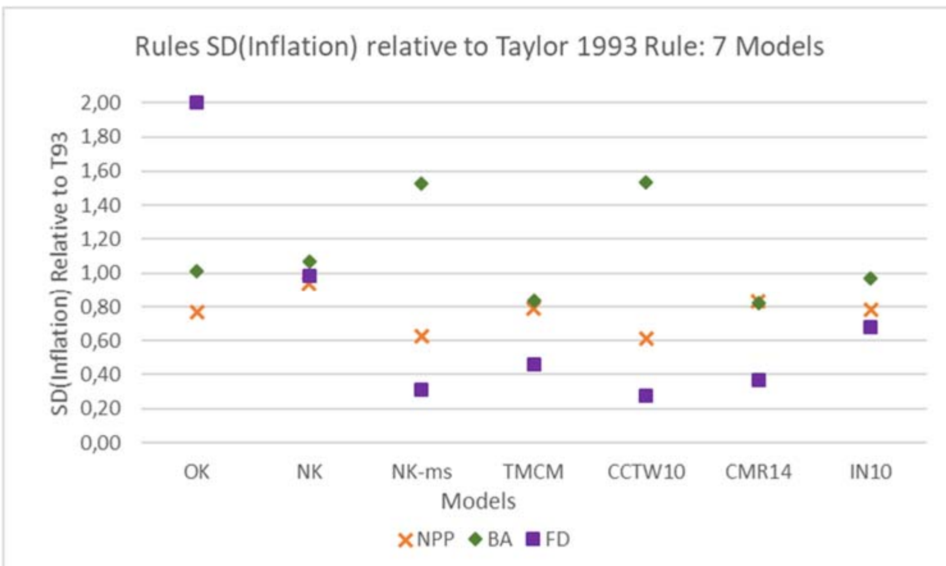
We report the *relative* standard deviations of inflation and output gap for the rules compared with the T93 rule. For each of the 8 models, we divide outcomes under BA, NPP and FD with the outcome under the T93 rule. A value of 1, for example, for the standard deviation of inflation indicates that inflation 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 1** for the 7 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.

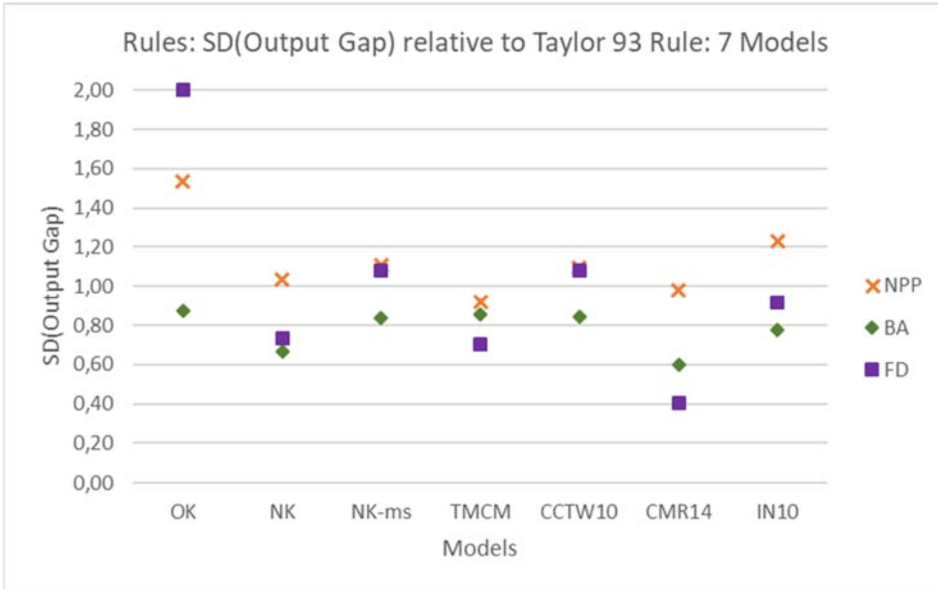
The FD rule delivers the lowest degree of inflation variability in the four additional models, and the lowest output gap volatility in two of them. For the forward-looking models, the unit root in the FD rule seems to be a positive feature, while it causes dynamic instability in the models of the type 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 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 2. The models that performed the worse with the first difference rules were the backward-looking models, again as in Table 2.

Figure 1. Standard deviation of inflation and output gap



[5] In Figure 1, a value of 2 is chosen to indicate the case of dynamic instability in the OK model.



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 7 different models. The rules shown are the balanced approach 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 (1993), (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).

4. 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

$$\underset{\varphi}{Min} \; Var(\pi) + \lambda Var(y) + Var(\Delta i)$$

$$s.t. \quad i_t = \varphi_\pi \pi_t + \varphi_y y_t + \varphi_{yl} y_{t-1} + \varphi_i i_{t-1}$$

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 description of 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 λ on the output gap. As a result, we obtain an output-inflation variability tradeoff curve.

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 2 shows the output-inflation variability curves for the OK (upper panel) and SW (lower panel) models. The vertical axis 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 output for the three rules discussed in the previous section.

Figure 3 shows the optimal coefficients in the rule for different values of the output variance. For example, in all four panels, as the coefficient on output in the rule goes down the variance of output goes up.

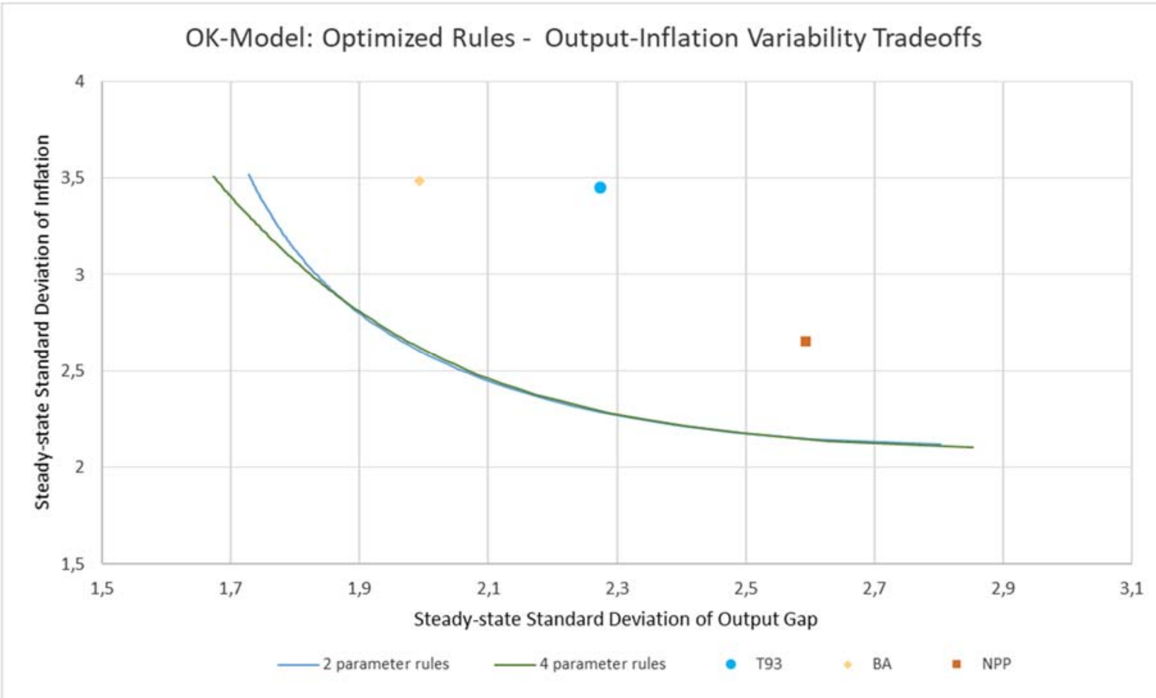
In the OK model, the trade-off curves for 2-parameter and 4-parameter rules are almost identical except for very large weights λ on output gap variance in the loss function. Even then, there is little to be gained from including the lag of the interest rate or the fourth lag of the output gap in the rule. The optimal coefficient on the lagged interest rate is close to zero, as can been seen in the top right-hand-side panel in **Figure 3**.

As the weight λ 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 3** 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 λ on output gap variability. As shown in **Figure 3**, lower right panel, the optimal coefficient on the lagged interest rate is slightly *above* unity for any choice of weight λ.

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

Figure 2


OK-Model: Optimized Rules - Output-Inflation Variability Tradeoffs
Steady-state Standard Deviation of Inflation
Steady-state Standard Deviation of Output Gap
4
3,5
3
2,5
2
1,5
1,5
1,7
1,9
2,1
2,3
2,5
2,7
2,9
3,1
2 parameter rules
4 parameter rules
T93
BA
NPP

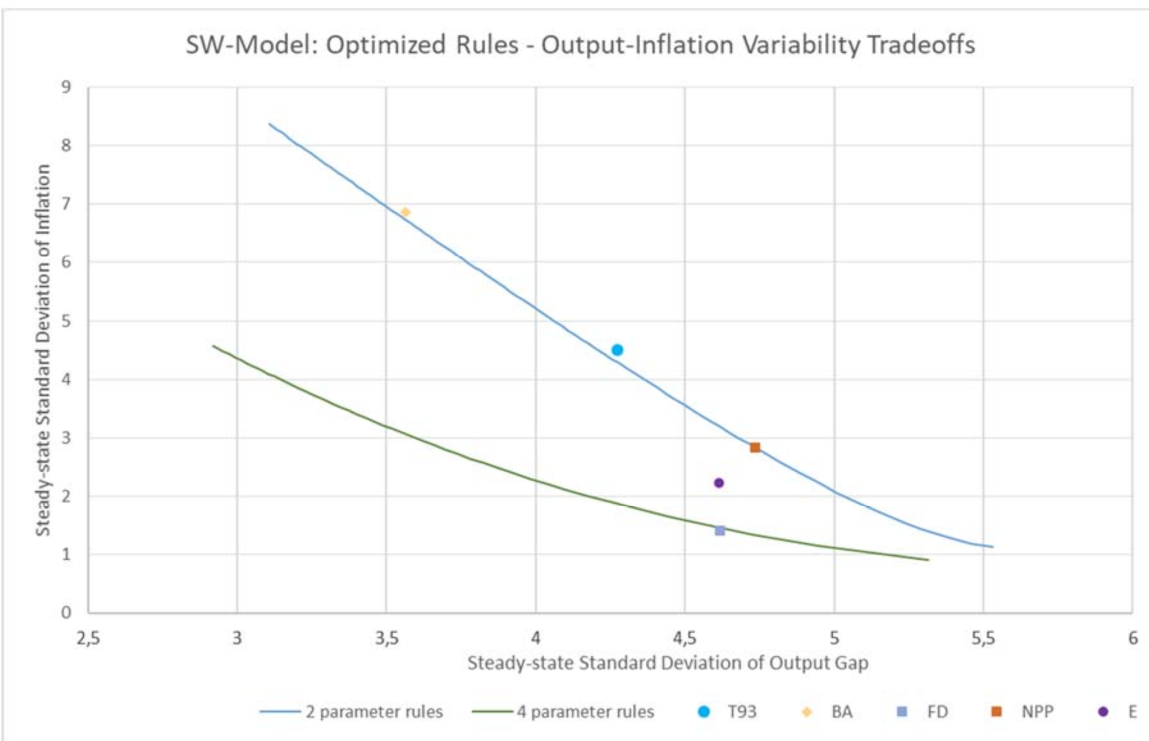
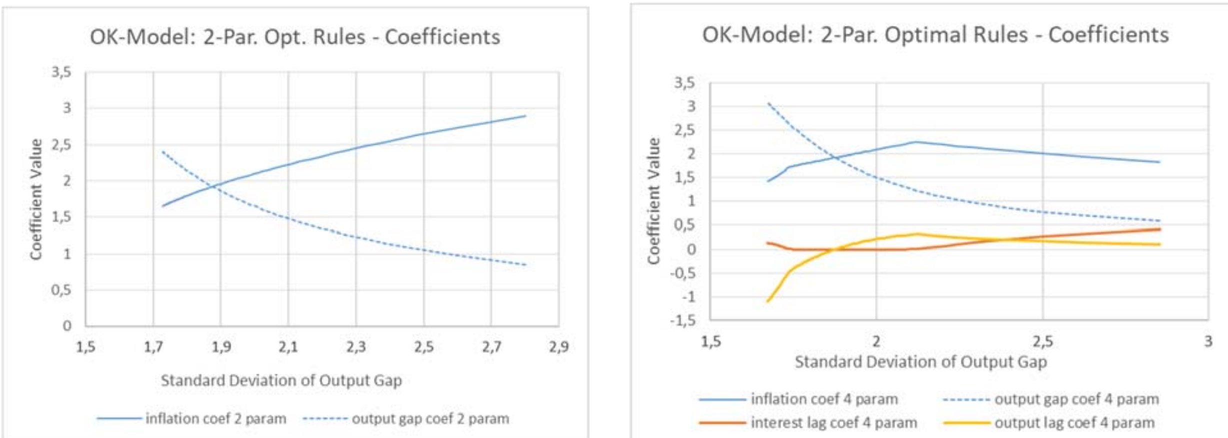
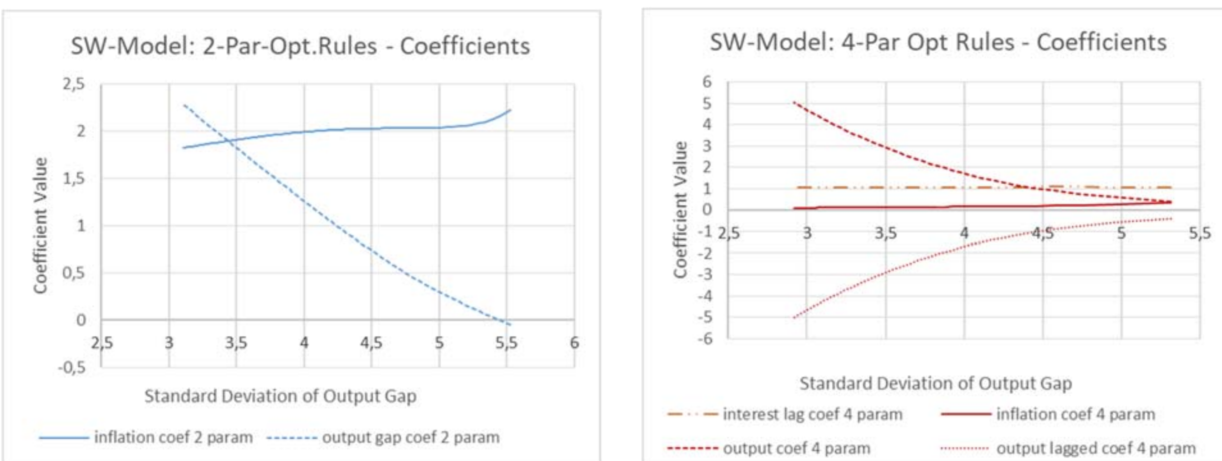

SW-Model: Optimized Rules - Output-Inflation Variability Tradeoffs
Steady-state Standard Deviation of Inflation
Steady-state Standard Deviation of Output Gap
9
8
7
6
5
4
3
2
1
0
2,5
3
3,5
4
4,5
5
5,5
6
2 parameter rules
4 parameter rules
T93
BA
FD
NPP
E

Figure 3

OK Model: Optimized Coefficients



SW Model: Optimal Coefficients



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.

5. Rules and Deviations: Measuring Discretion

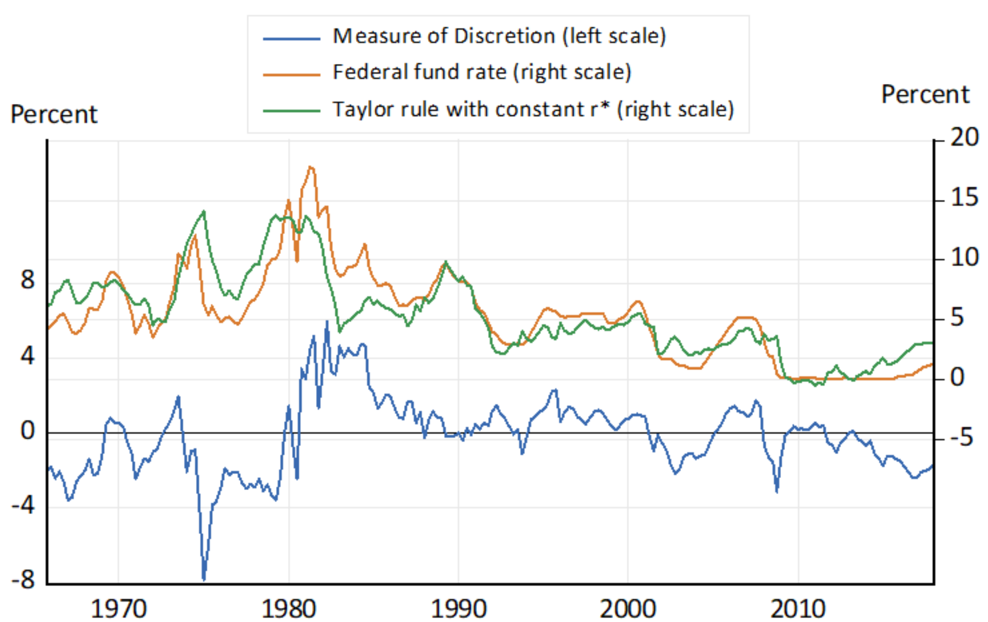
In this section we compare the rules with policies which are characterized by more discretion, and thereby are closer to actual policy than rules during some periods in the United States. This comparison leads to a natural definition of discretion in comparison with rules.

5.1. Real-Time Measures of Discretion: NPP

Nikolsko-Rzhevskyy, Papell and Prodan (2018) contrast actual interest rate policy with the Taylor rule. **Figure 4** shows the interest rate setting according for the Taylor rule (T93) along with the 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 4**. This is our "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 likely uninformative for us.

Figure 4



The measure of discretion in Figure 4 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. This was 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 4, this was not as large as the deviation in the 1970s, but it did 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.

5.2. An update with Other Rules and Deviations

We do the same calculations as in Figure 4 using current data (rather than real-time data) and all of the 4 policy rules. We use a constant equilibrium interest rate of $r^*=2$, an inflation target of $\pi^*=2$, and the CBO's measure of potential GDP. **Figure 6** shows the actual interest rate and the monetary policy rules T93, BA**,** FD and NPP. **Figure 7** shows the *difference* between actual interest rate and these rules which again is our measure of discretion.

Figure 7 shows that the T93, BA and NPP rules all show patterns of discretion similar to that shown in Figure 6 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 in the NPP calculations in Figure 5 compared with Figure 7 may be due to the use of real time data in Figure 5 compared with current data in the Figure 7.

The measure of discretion with the FD rule indicates 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 7, the standard deviation of the differences between the federal funds rate and first difference rule is $SD(i-i^{FD})=1.34$, while for the other three rules the standard deviations are $SD(i-i^{T93}) = 2.54$, $SD(i-i^{BA}) = 3.02$, and $SD(i-i^{NPP}) = 3.06$.

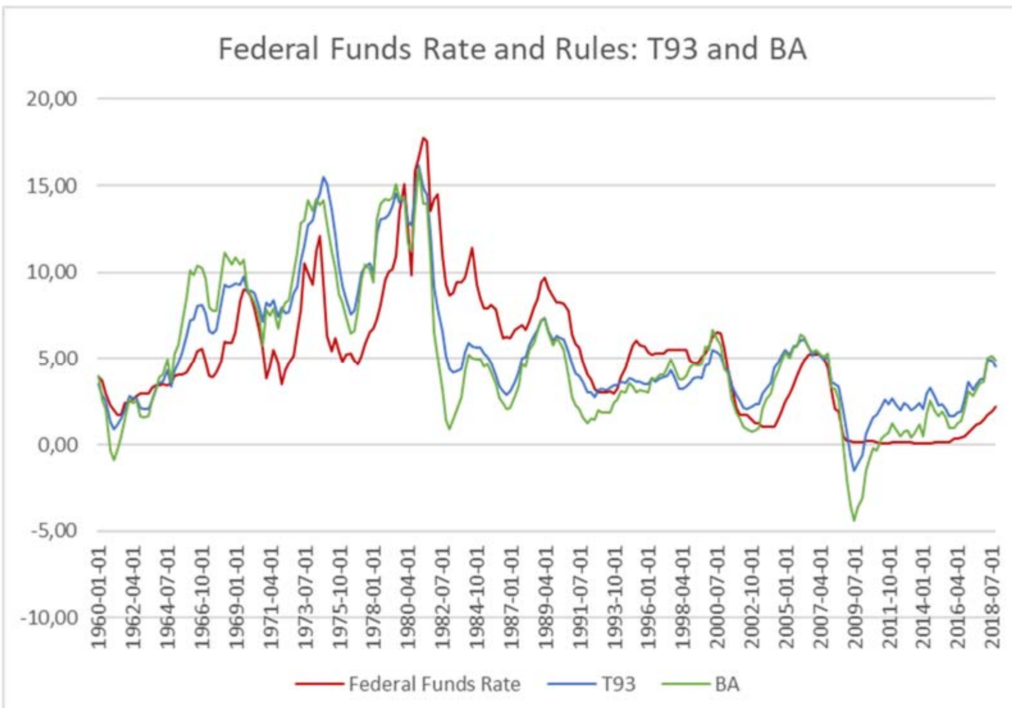
All of the other rules show persistent, highly serially correlated deviations. By putting the lagged interest rate in the rule (see Table 1), the first-difference rule counts yesterday's "deviation" as today's "rule." It mops up previous bouts of discretion and incorporates them in the rule. A rule "I won't eat any more than yesterday" is not a very effective diet when combatting discretionary donuts.

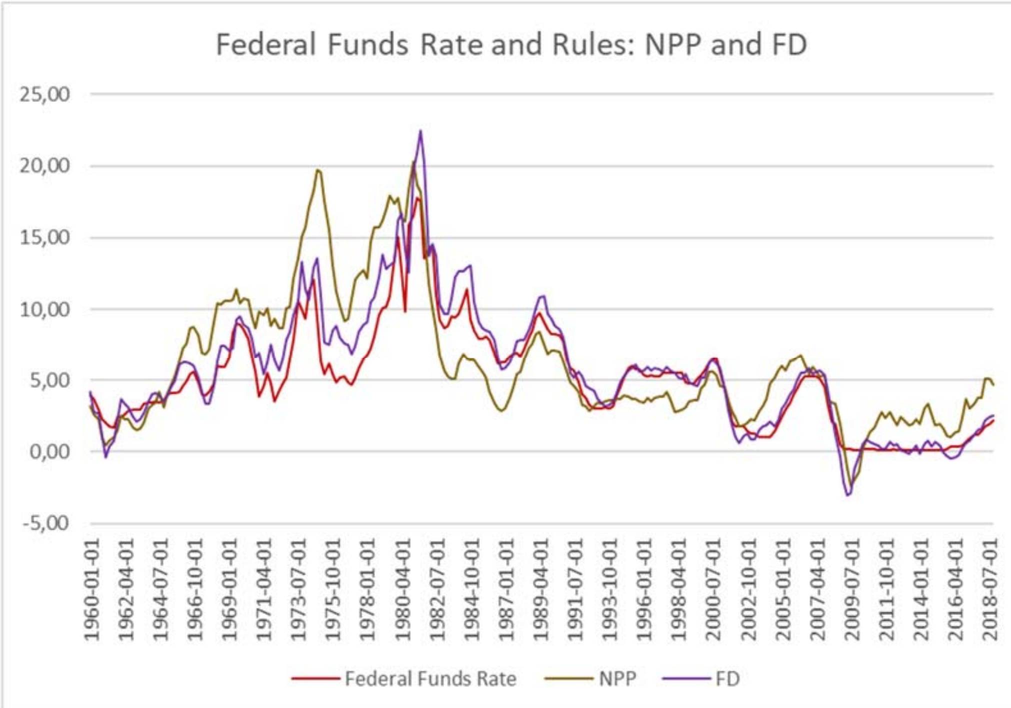
The rules in the Fed report (Table 1) do not include any residuals, deviations or errors, though they are reference points for actual interest rates that do deviate from the rules in a persistent way, so it is unclear just what the Fed intends by the difference rule. Does it really intend that the rule excuses anything done the previous period as part of the rule? Perhaps not, or perhaps it should not. With this in mind, we explore also a different interpretation of the first-differenced rule,

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

Here, v_t is a serially correlated disturbance, i.e. the discretionary component of the rule.

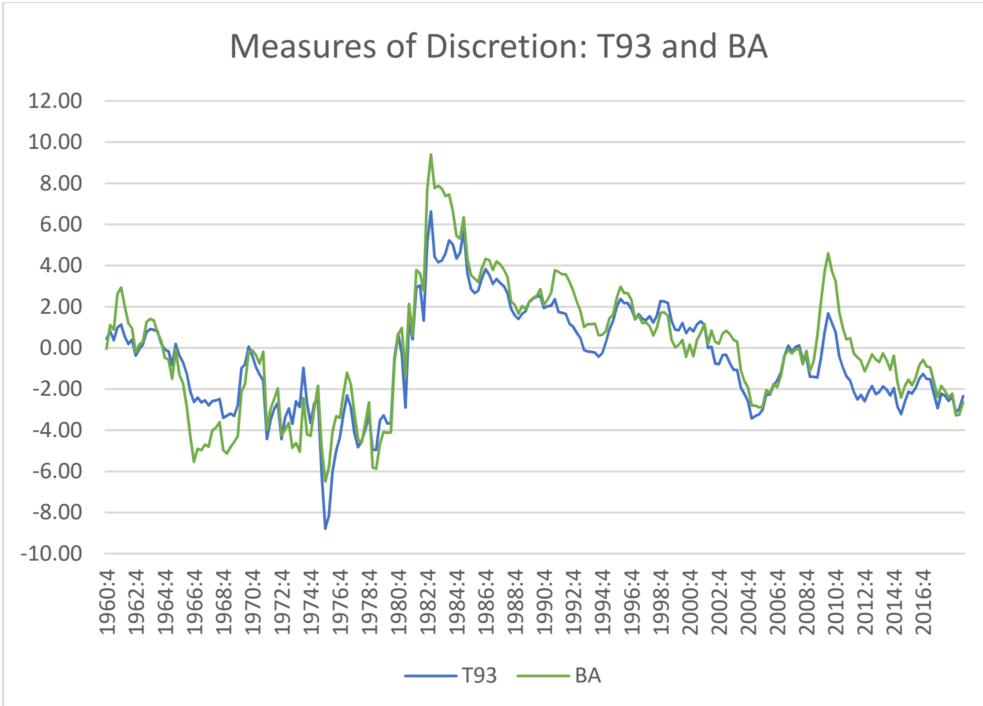
Figure 6

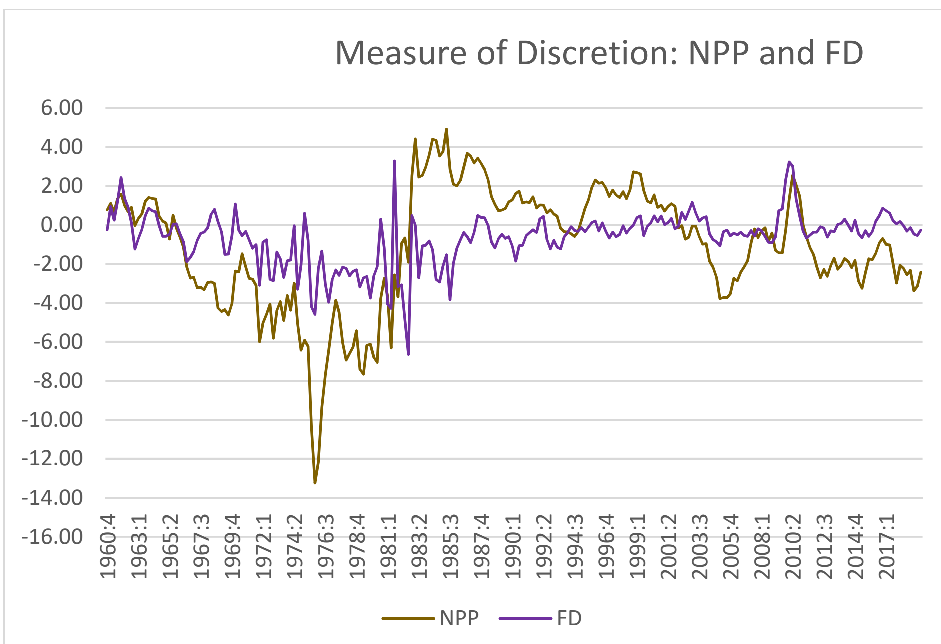




Federal Funds Rate and Rules: NPP and FD
25,00
20,00
15,00
10,00
5,00
0,00
-5,00
1960-01-01
1962-04-01
1964-07-01
1966-10-01
1969-01-01
1971-04-01
1973-07-01
1975-10-01
1978-01-01
1980-04-01
1982-07-01
1984-10-01
1987-01-01
1989-04-01
1991-07-01
1993-10-01
1996-01-01
1998-04-01
2000-07-01
2002-10-01
2005-01-01
2007-04-01
2009-07-01
2011-10-01
2014-01-01
2016-04-01
2018-07-01
Federal Funds Rate
NPP
FD

Figure 7





Note: In Figures 6 and 7 we use current data and not the real-time data that was available to Fed decision makers when they set the federal funds rate. Nikolsko-Rzhevskyy, Papell and Prodan (2019) 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.

6. Conclusions

To sum up, the purpose of this paper is to evaluate the rules now regularly considered by the Fed in the Monetary Policy Report and on the Fed's web page. To evaluate the rules, 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 new measure of discretion.

The results show that the rules in the Fed's Report would have worked well, though the first difference rule is not robust to different model assumptions. The results also show that the rules reported by the Fed are close to the optimal rules within a certain class.

The measures of discretion show that there was much discretion in the 1970s. The timing indicates that and that these discretionary actions led to 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. We find that the measures of discretion began to grow again in the early 2000s, though did not get as large as in the 1970s, and we noted that this occurred just prior to the great recession.

These results for different historical periods indicate that future research should endeavor to assess the costs and benefits of discretion in models with actual shocks, as computed in Section 5 in this paper, in addition to shocks drawn from an estimated variance covariance matrix, as in Sections 3 and 4 of this paper. 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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