Taylor’s Rule versus Taylor Rules*

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Abstract

Does the Taylor rule prescribe negative interest rates for 2009-2011? This question is important because negative prescribed interest rates provide a justification for quantitative easing once actual policy rates hit the zero lower bound. We answer the question by analyzing Fed policy following the recessions of the early-to-mid 1970s, the early 1990s, and the early 2000s in the context of both Taylor’s original rule and latter variants of Taylor rules. While Taylor’s original rule, which can be justified by historical experience during and following the recessions, does not produce negative prescribed interest rates for 2009-2011, variants of Taylor rules with larger output gap coefficients, which do produce negative interest rates, cannot be justified by the same historical experience. We conclude that the Taylor rule does not provide a rationale for quantitative easing.

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1. Introduction

Over the past two decades, Taylor (1993) rules have become the dominant metric for analyzing and evaluating monetary policy. Estimated Taylor rules are used for positive analysis of what policies the Fed and other central banks have followed, while prescribed Taylor rules are used for normative evaluation of what the Fed should have done. While no central bank would exactly follow a simple Taylor rule at all times, they provide an extremely useful benchmark for monetary policy evaluation.\(^1\)

The original Taylor rule states that the Fed set its policy rate (the federal funds rate) at one plus 1.5 times the inflation rate plus 0.5 times the output gap, the percentage deviation of GDP from potential GDP. In Taylor (1993), this simple rule is primarily prescriptive, based on simulations of a range of estimated monetary models, although it is also descriptive, as a close approximation of Fed policy between 1987 and 1992. In Taylor (1999), the rule is explicitly normative, with large deviations from baseline rules identified as policy mistakes.

At the height of the financial crisis in December 2008, the Fed lowered its target for the federal funds rate to between 0 and 0.25 percent, and it anticipates holding it at this level until at least 2015. While this ended (at least temporarily) the use of Taylor rules for positive analysis, the use of Taylor rules for normative analysis continued unabated.

Normative Taylor rule analysis for 2009 - 2011 centered on the following question: If it was not constrained by the zero lower bound, should the federal funds rate be negative? If the answer is yes, this provides a justification for the Fed’s quantitative easing in 2009 (QE1) and 2010-2011 (QE2). If the answer is no, then the Taylor rule rationale for both QE1 and QE2 becomes questionable.\(^2\)

There has been a lively debate on this topic. The debate started with an article by Guha (2009), which cited a confidential Fed staff study that placed the implied Taylor rule rate at negative 5 percent.

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\(^1\) Kydland and Prescott (1977) provide the seminal justification for rules-based monetary policy.

\(^2\) A rationale for QE1 was to provide liquidity to financial markets. Analysis of this rationale outside of the context of the Taylor rule is beyond the scope of this paper.
Taylor (2009a) countered that the Fed got both the sign and the decimal point wrong and calculated the rate at 0.5 percent. Rudebusch (2009), in an article that (despite the usual disclaimer) was widely interpreted as reflecting the internal Fed position, argued for negative 5 percent and Meyer (2009) advocated close to negative 6 percent. Conversely, Taylor (2009b) countered that the rate should be zero. Rudebusch (2010) argued that the implied Taylor rule was between negative 5 and 6 percent while Taylor (2010a), depending on the size of the output gap, argued for between 0.75 and negative 0.75 percent, close to current Fed policy and far from negative 6 percent. Taylor (2010a) argued that QE1 and QE2 are examples of harmful deviations from rules-based economic policies. Bernanke claimed that Taylor picked a different rule in 1999 than in 1993, one that would be consistent with negative interest rates, while Taylor countered that he did not propose or prefer an alternative rule in his 1999 paper.3

What accounts for these very large differences? By far the most important factor is the coefficient on the output gap. Both Meyer and Rudebusch (explicitly) and Bernanke (implicitly) use coefficients that are double Taylor’s coefficient. With an output gap of minus 6.6 percent, as calculated by the Congressional Budget Office (CBO) for 2009, this alone would decrease the implied interest rate by 3.3 percent.4 In addition, Meyer and Rudebusch use the unemployment gap, the difference between the unemployment rate and the natural rate of unemployment, instead of the output gap. With very low inflation, differences in the inflation coefficients were unimportant although, with forecasts of higher or lower inflation, the use of forecasted, rather than realized, inflation would either raise or lower the implied Taylor rule rate.

Another important policy debate conducted in terms of normative Taylor rules involves whether the Fed lowered interest rates too much in 2003–2005. Taylor (2007), using his original rule as a benchmark, argues that the federal funds rate was as much as three percentage points below the implied Taylor rule rate, causing the housing bubble and, in later writings, the financial crisis and the Great Recession. He calls this experience the Great Deviation. While most subsequent commentary has agreed

3 Bernanke’s quote and Taylor response are in Taylor (2011b).
4 This is the average of the quarterly CBO output-based gaps, as reported by Weidner and Williams (2011).
with Taylor’s conclusion, the agreement has not been universal. Kohn (2007) argued that Fed policy closely followed a Taylor rule if the core personal consumption expenditure (PCE) deflator, rather than the consumer price index (CPI), is used to measure inflation and Bernanke (2010) countered that Fed policy was appropriate in the context of a Taylor rule if forecasted, rather than realized, inflation is used.

Do QE1 and QE2 represent deviations from appropriate rules-based economic policies? Was the Federal Funds rate too low in 2003 – 2005? The use of some variant of the Taylor rule as a benchmark to answer these questions has become ubiquitous, but which variant should be used? An obvious choice is what we call Taylor’s rule, the original rule from Taylor (1993) with realized inflation and a coefficient of 0.5 on the output gap. Alternative Taylor rules include specifications with forecasted inflation and/or a larger output gap coefficient.

We answer the question using the simplest possible methodology. There is widespread agreement that Fed policy was too stimulative following the recession in the mid-1970s, leading to the Great Inflation later in the decade. There is also widespread agreement that Fed policy following the recession in the early 1990s produced strong growth without causing high inflation. We take advantage of these natural experiments by plotting the interest rate implied by various Taylor rules with the actual path of the federal funds rate. Under the stipulation that Fed policy was too stimulative in the mid-1970s and about right in the early 1990s, alternative Fed policies with substantially lower interest rates would have produced worse outcomes. In order to replicate the policy choices actually faced by the Fed, we only use real-time data that was available to Fed researchers and policymakers when the interest setting decisions were made.

In order to put our results in perspective, it is useful at this point to discuss research strategies that we do not pursue. First, we do not estimate Taylor rules. Such estimates are an exercise in positive, not normative, economics and can only be informative regarding what the Fed should do if one is willing to assume that past Fed policy has been correct. Moreover, our focus is on Fed policy during and following recessions, not on policy over the business cycle. Second, we do not simulate the performance of various Taylor rules in the context of a Dynamic Stochastic General Equilibrium (DSGE) model. While such an
exercise could be potentially valuable, there is no agreement on the correct DSGE model and there is considerable research showing that policy rules which perform well in one model can perform badly in other models.\(^5\)

Suppose that Fed policy had followed Taylor’s original rule. The resultant interest rate would have been higher than the realized rate in the mid-1970s, about equal to the realized rate in the early 1990s, and above the realized rate in the mid-2000s. By following the same rule in the 1970s and 2000s that characterized policy in the late 1980s and 1990, the Fed would have avoided contributing to either the Great Inflation of the 1970s or the Great Deviation of the 2000s.

Now suppose that, instead of following Taylor’s original rule, Fed policy had followed alternative Taylor rules. We first consider a rule with a larger output gap coefficient. Fed policy much more closely followed a rule with an output gap coefficient of 1.0 than one with a coefficient of 0.5 in both the mid-1970s and mid-2000s. In contrast, a policy rule with a higher output gap coefficient would have produced a much lower interest rate following the recession of the early 1990s, under 1 percent compared with the actual 3 percent. Given the positive economic performance of the mid-to-late 1990s compared with the late 1970s and late 2000s, this does not auger for raising Taylor’s output gap coefficient.

Next, suppose that the Fed had followed a second alternative Taylor rule, this time with Taylor’s original output gap coefficient but with forecasted rather than realized inflation. The results for the mid-1970s and mid-2000s are similar to those with a higher output gap coefficient and realized inflation, as Fed policy more closely followed a rule with forecasted inflation than one with realized inflation in both periods. For the early 1990s, the implied rules with an output gap coefficient of 0.5 are similar whether realized or forecasted inflation is used. Given the dismal economic performance of the late 1970s and late 2000s, this does not auger for changing the Taylor rule to incorporate forecasted inflation.

Finally, suppose that the Fed had followed a third alternative Taylor rule, this time with both an output gap coefficient of 1.0 rather than Taylor’s original output gap coefficient of 0.5 and with forecasted rather than realized inflation. Under this rule, the federal funds rate would have been more than

\(^5\) Taylor and Williams (2010) use this argument to advocate for simple rather than optimal policy rules.
5 percentage points lower than actual Fed policy and would have hit the zero lower bound at the height of the 1975 recession. Since there is widespread agreement that too stimulative Fed policy in the mid-1970s was an important contributor to the Great Inflation of the late 1970s, it’s frightening to think about how high inflation might have been under this rule. A similar scenario characterizes the mid-2000s, with the federal funds rate implied by the rule one percentage point lower than actual Fed policy and hitting the zero lower bound in mid-2003. This would have added even more fuel to the housing boom and magnified the extent of the Great Deviation. Lastly, we consider the implications of this rule for the early 1990s. The federal funds rate would have fallen to about 0.5 percent in mid-1992. Since the actual policy rate of 3.0 percent followed by incremental upward adjustments in 1994, peaking at a 6.0 percent rate in early 1995, produced a recovery from the recession without undue inflation, it is difficult to see how a tremendously more expansionary policy would have been desirable.

If the Fed had followed Taylor’s rule, it would have avoided fueling both the Great Inflation of the 1970s and the Great Deviation of the 2000s, while closely following its successful policy of the 1990s. If it had followed Taylor rules with the “improvements” used in 2009 and 2010 to justify a negative implied federal funds rate, a higher output gap coefficient and forecasted rather than realized inflation, it would have contributed even more to the Great Inflation and Great Deviation while running overly stimulative policy in the 1990s. It is difficult to see why “improvements” to Taylor’s rule which would have produced worse historical outcomes should be expected to produce better outcomes in the 2010s, and so we fail to find any justification for changing the rule.

2. Taylor’s Rule and its Modifications

Following Taylor (1993), the monetary policy rule postulated to be followed by central banks can be specified as

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i_t = \pi_t + \phi(\pi_t - \pi^*) + \gamma y_t + r^*
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where $i_t$ is the federal funds rate, $\pi_t$ is the inflation rate, $\pi^*$ is the target level of inflation, $y_t$ is the output gap, or percent deviation of actual real GDP from an estimate of its potential level, and $r^*$ is the equilibrium level of the real interest rate. The inflation is the annualized rate over the previous year. It is assumed that the target for the short-term nominal interest rate is achieved within the period so there is no distinction between the actual and target nominal interest rate.

According to the Taylor rule, the central bank raises the target for the short-term nominal interest rate if inflation rises above its desired level and/or output is above potential output. The target level of the output deviation from its natural rate $y_t$ is 0 because, according to the natural rate hypothesis, output cannot permanently exceed potential output. The target level of inflation is positive because it is generally believed that deflation is much worse for an economy than low inflation. Taylor postulated that the output and inflation gaps enter the central bank’s reaction function with equal weights of 0.5 and that the equilibrium level of the real interest rate and the inflation target were both equal to 2 percent, producing the following equation,

$$(2) \quad i_t = 1.0 + 1.5\pi_t + 0.5y_t$$

Two modifications of Taylor’s original rule are often used for normative analysis. The first is to argue that, because Fed policymaking is forward-looking, inflation (and sometimes also output gap) forecasts should be used instead of realized values. The second is to conduct the analysis using an output gap coefficient of 1.0 instead of 0.5. The rationale for this adjustment is usually based on estimates of past Fed behavior, but sometimes it is also claimed that a larger coefficient is optimal in the context of DSGE models. Incorporating both modifications produces the following equation,

$$(3) \quad i_t = 1.0 + 1.5\pi^*_{r/\pi_t} + 1.0y_t$$
where $\pi_{t+h}$ is the expectation of inflation in quarter $t+h$ conditional on information available in time $t$. The number $h$ usually ranges from 0, where the “forecast” is actually a within-quarter “nowcast” to 4, where the forecast is for the next year’s inflation.

These modifications are by no means exhaustive. For the purpose of estimating Taylor rules, a lagged interest rate is almost always included to capture partial adjustment and improve the fit of the estimates. While this is important for positive analysis of Fed behavior, it is not appropriate for normative analysis because it requires an estimated coefficient. Meyer (2009) uses a rule with an equilibrium real interest rate of 2.5 percent and Rosenberg (2010) posits a rule with an inflation target of 1.5 percent. These changes will increase the postulated Taylor rule interest rate by 0.5 and 0.25 percent, respectively. If the equilibrium real interest rate is lower, this will decrease the postulated Taylor rule interest rate.

3. Taylor Rules with Real-Time Data

Following Orphanides (2001), it has become standard practice to use real-time data that was available to policymakers at the time that interest rate setting decisions were made for both positive and normative analysis. Data on nominal and real GNP/GDP (and therefore inflation measured by the GNP/GDP deflator) was published by the Commerce Department in the monthly publication, *Survey of Current Business*, starting in 1947:1, and real-time quarterly vintages starting in 1965:4 are available on the Federal Reserve Bank of Philadelphia web site. One-to-four quarter ahead internal Fed (Greenbook) inflation forecasts are available starting in 1966, 1969, 1973, and 1974, respectively. Although the forecast data is not publicly available after 2004:4, there is a close enough fit between the Greenbook and the Survey of Professional Forecasters (SPF) forecasts so that the data can be spliced together. Other real-time inflation measures are of shorter duration, with data on the Consumer Price Index (CPI) starting in 1994:3 and the core Personal Consumption Expenditure (PCE) deflator starting in 1996:1. Data on the Federal Funds Rate is available for the entire period. We used the (annualized) quarterly effective rate published by the Federal Reserve Board.
Calculating real-time output gaps is more problematic. The Greenbook output gap is currently available from 1987:3 – 2004:4. The Congressional Budget Office (CBO) publishes real-time potential GDP estimates that can be combined with real-time GDP to calculate real-time output gaps starting in 1991:1 and, since there is a fairly close fit between the Fed and CBO gaps during the overlap of 1991:1 - 2004:4, we use the Fed data for the 1990s and splice the series together starting in 2005. Each January, the CBO releases revised estimates and forecasts of potential GDP. We construct (for example) the real-time output gap for 2010:1 by using actual and potential GDP estimates for 2009:4, which constitute the latest available data. For 2010:2, 2010:3, and 2010:4, since updated potential GDP estimates are not available, we combine updated GDP estimates with potential GDP forecasts from the January, 2010 CBO release. For 2011:1, we use the January, 2011 CBO release and repeat the process.

There is no record of an internal Fed output gap prior to 1987:3. While Orphanides (2003a, b) uses real-time output gaps published by the Council of Economic Advisors (CEA), these gaps have been criticized by Taylor (2000) as being too large, and Cecchetti et al (2007) propose using real-time Hodrick-Prescott (HP) detrending. Real-time detrending involves calculating the percentage deviation of real GNP from its trend, using data from the start of the sample to the time that policy decisions were made, and updating the trend each quarter. In Nikolsko-Rzhevskyy and Papell (2012), we show that, using Okun’s Law with real-time natural rates of unemployment for various years in the 1970s as a benchmark, the CEA gaps are too large, the real-time HP filtered gaps are too small, but real-time linear and quadratic gaps are reasonable. Since linear detrending was the leading method used at the time, we use real-time linear detrending to calculate real-time output gaps for the 1970s.

4. Taylor’s Rule versus Taylor Rules following Five Recessions

Monetary policy following the end of recessions is a crucial determinant of subsequent economic performance. Even though the recession has officially ended, unemployment usually remains high and the output gap is negative. The Fed typically faces a series of decisions as it tries to avoid over-stimulating

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6 While the output gap was not included in the Greenbook, it was constructed and used by the Board staff in generating Greenbook forecasts. The data are available on the Federal Reserve Bank of Philadelphia web site.

7 This method was used by Poole (2007) to construct real-time output gaps.
the economy and causing subsequent inflation or under-stimulating the economy and prolonging the slowdown. The Taylor rule provides a benchmark for this situation, as the rule stipulates that the Fed should raise interest rates as the output gap closes and/or inflation rises.

4.1 Taylor Rules following the 1970s Recessions

There were two recessions in the 1970s. The smaller recession started in December 1969 and ended in November 1970. Unemployment, which was 3.6 percent in 1969:4, rose to 5.9 percent by 1970:4, peaked at 6.0 percent in 1971:3 and 1971:4, and didn’t come down below 5.0 percent until 1973:1. Inflation stayed at about 5.0 percent from 1970:1 to 1971:3. The recession from November 1973 to March 1975 was, at the time, the largest recession since the Great Depression of the 1930s. Starting at 4.8 percent in 1973:4, unemployment steadily rose, peaking at 8.9 percent in 1975:2. Inflation rose from 3 percent in 1973:1 to 11 percent in 1975:1 before falling to 6 percent in 1976:1. The fall in inflation, however, was short-lived, as it started rising again in 1977:1 and continue to rise for the rest of the decade.

Monetary policy during and following the 1970s recessions is widely regarded as being too stimulative. This is illustrated in Figure 1, which plots the actual interest rate and the interest rate implied by the original Taylor rule in Equation (3), with realized inflation and an output gap coefficient of 0.5, for 1969:1 – 1979:2. Inflation is the percentage rate of change of the GNP deflator, the output gap is the percentage deviation of GNP from potential GNP, measured by a linear trend, and the interest rate is the effective Federal Funds Rate, all measured using real-time data. The actual FFR fell below the implied Taylor rule rate from 1969:4 to 1972:4 and again from 1974:1 through 1979:2. The peak deviation occurred at the beginning of 1975, when the implied FFR was 8 percentage points below the implied Taylor rule rate. Taylor (1999) describes deviations from the baseline in the 1970s as the second most serious policy mistake in twentieth-century U.S. history (the Great Depression of the 1930s being the most serious). He argues that, while there is uncertainty regarding its causes, there is little doubt that it

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8 The results are similar if the output gap is constructed using real-time quadratic detrending.
was responsible for the Great Inflation of the 1970s and, if a policy closer to that implied by the Taylor rule was followed, the rise in inflation may have been avoided.

Could the Great Inflation of the 1970s also have been avoided or mitigated if the Fed had followed one or both modifications of Taylor’s rule? The first part of the answer is provided by Figure 1, which also plots the interest rate implied by a Taylor rule with realized inflation and an output gap coefficient of 1.0. Following a Taylor rule with a higher output gap coefficient would not have improved policy. For the period following the early 1970s recession, the interest rate implied by the modified Taylor rule is both lower and closer to the actual FFR than the rate implied by Taylor’s original rule. For the period following the mid-1970s recession, the situation is even worse, with an implied FFR below the actual FFR between 1975:2 and 1977:1. Given that monetary policy in the early 1970s did not succeed in bringing down inflation and policy in the mid-1970s let to subsequent higher inflation, following a Taylor rule with a higher output gap coefficient would not have lowered inflation in the early 1970s and would have further fueled inflation in the latter 1970s.

The second modification of Taylor’s original rule which we consider is to replace realized inflation with forecasts of future inflation. Figure 2 depicts the implications of this modification with linear detrended output gaps and Greenbook-one-quarter-ahead inflation forecasts. These forecasts are lower than the realized inflation rates for 1969 – 1971 and much lower than the realized rates in 1974 and 1975. With an output gap coefficient of 0.5, the interest rate implied by the Taylor rule fairly closely follows the actual rate in 1970 and 1971, and very closely follows the actual rate in 1974 and 1975. Starting in 1976, however, the actual rate is considerably lower than the implied rate. With an output gap coefficient of 1.0, the implied interest rate falls almost 4 percentage points below the actual rate in 1971 and as much as 6 percentage points below the actual rate in 1975, hitting the zero lower bound in 1975:2.

4.2 Taylor Rules following the 1990-1991 Recession

Monetary policy following the recession of 1990-91 is generally regarded as successful. The target level for the Federal Funds rate, which was 8 ¼ percent in the first half of 1990, was gradually

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9 The results for two-to-four quarter-ahead inflation forecasts, when available, are very similar.
lowered, starting in July 1990, to 3 percent in September 1992 in response to the recession. It was left unchanged until February 1994 when, based on the possibility of incipient inflation, it was gradually raised to 6 percent by February 1995. Inflation, which fell from over 6 percent in late 1990 to 3 percent in late 1991, stayed around 3 percent until 1997.

In contrast to the 1970s, monetary policy following the recession of 1990-91 is not regarded as being too stimulative. This is illustrated in Figure 3, which plots the actual interest rate and the interest rate implied by the original Taylor rule in Equation (3), with realized inflation and an output gap coefficient of 0.5, for 1987:1 – 1999:4. Inflation is the percentage rate of change of the GNP deflator, the output gap is the percentage deviation of GNP from potential GNP, measured by internal Fed (Greenbook) data, and the interest rate is the effective Federal Funds Rate, all measured using real-time data. The actual FFR fairly closely follows the rate implied by the original Taylor rule for the entire period and, where it differs, the actual FFR rate is always above the implied rate. The closest fit between the implied and actual rates occurs from 1991:1 to 1994:1, during and following the recession. The fit is close enough that we can characterize Fed policy as following Taylor’s rule.\textsuperscript{10}

Suppose that, instead of following Taylor’s original rule with an output gap coefficient of 0.5, the Fed had followed a Taylor rule with a coefficient of 1.0. The results of this modification are also depicted in Figure 3. The implied FFR falls below both the actual FFR and the implied FFR with Taylor’s original rule from 1991:1 to 1994:3. The maximum deviation occurs in 1992:3, where the interest rate implied by Taylor’s rule with a coefficient of 1.0 is under 1 percent, about 2 percentage points lower than the rate implied by Taylor’s original rule and more than 2 percentage points below the actual rate. Given that lowering the FFR to 3 percent succeeded in stimulating the economy as it emerged from the recession without causing inflation to increase, it seems likely that lowering the FFR to 1 percent during the same period would have overstimulated the economy, causing higher inflation and more difficult policy choices later in the decade.

\textsuperscript{10}Taylor (1993) reports an even closer fit for 1987 – 1992. The difference occurs because he uses revised linear detrended GDP to construct the output gap, while we use real-time Greenbook data, which was not publicly available when he wrote the paper.
A common rationale for normative analysis with an output gap coefficient of 1.0 is that, over periods where the Fed conducted good policy, so that positive and normative analyses coincide, the estimated coefficient is closer to 1.0 than to 0.5. While we are interested in Fed policy during and following recessions, not on average policy over the business cycle, we will consider the argument. Rudebusch (2006), for example, estimates Equation (1) for 1987:4 to 2004:4 and reports an output gap coefficient of 0.92. Since Rudebusch’s data includes the early 2000s when Fed policy was arguably too stimulative, we estimate Equation with the data from 1987:1 – 1999:4 used to construct Figure 3. The output gap coefficient is 0.57 with a standard error of 0.06, significantly different from 1.0 and not significantly different from 0.5.\footnote{In addition to the different spans, Rudebusch uses revised data with inflation measured by the core PCE deflator and we use real-time data with inflation measured by the GDP deflator.}

The implications of modifying Taylor rules by replacing realized inflation with forecasts of future inflation are depicted in Figure 4, which differs from Figure 3 only by using Greenbook one-year-ahead inflation forecasts. For Taylor’s original rule with an output gap coefficient of 0.5, the fit between the actual and implied interest rates is slightly worse in 1991 and 1992, although it is somewhat better in 1987-1988 and again starting in 1994. For the modified Taylor rule with an output gap coefficient of 1.0, falls even further below 1 percent in 1992. Overall, using forecasted inflation rather than realized inflation does not produce major changes in the results. Taylor’s original rule with an output gap coefficient of 0.5 provides a good description of actual Fed policy, while modifying the rule by raising the output gap coefficient to 1.0 would have produced much too stimulative policy following the recession of 1990-1991.

4.3 Taylor Rules following the 2001 Recession

Monetary policy following the 2001 recession has been a subject of much controversy. Poole (2007) first documented that the Federal Funds rate fell below the prescribed Taylor rule rate from mid-2002 to mid-2006. Taylor (2007) argued that this deviation from rules-based policy caused the housing price bubble and, in subsequent papers and speeches, including Taylor (2010b, 2011a), that the deviation
was on the order of magnitude of the deviations in the 1970s and was the root cause of the financial crisis and the Great Recession. The deviation is illustrated in Figure 5, which depicts the interest rate prescribed by Taylor’s rule with real-time data, with inflation measured by the CPI, the output gap from the Greenbook until 2004:4 and the CBO thereafter, and an output gap coefficient of 0.5.\textsuperscript{12} The actual Federal Funds rate fell below the Taylor rule prescribed rate from mid-2002 to mid-2006, with the deviation as large as three percentage points for a considerable period. Figure 5 also depicts the prescribed Taylor rule rate with an output gap coefficient of 1.0. While the prescribed rate with a coefficient of 1.0 is below the prescribed rate with a coefficient of 0.5, the difference is not large and the gap between the prescribed and actual rates remains.

Bernanke (2010) criticized Taylor’s use of CPI inflation in the prescribed Taylor rule, pointing out, as can be seen in Figure 5, that it produced unreasonably high values for the Federal Funds rate when oil prices spiked in 2008. He argued that forecasted, rather than realized, inflation should be used in the prescribed Taylor rule. He implemented the argument, however, by contrasting prescribed Taylor rule interest rates with forecasted PCE and realized CPI inflation, changing the inflation measure as well, and showed that the gap between the actual and prescribed interest rates narrowed considerably.\textsuperscript{13}

The difference between Bernanke’s and Taylor’s results depends more on the use of PCE instead of CPI inflation than on the use of forecasted instead of realized inflation. Figure 6 is identical to Figure 5 except that realized CPI inflation is replaced by forecasted one-year-ahead CPI inflation, with the forecasts from the SPF. The results are very similar to those in Figure 5. With an output gap coefficient of 0.5, the federal funds rate is below the prescribed Taylor rule rate from 2002:2 to 2006:1, with a maximum deviation of over three percent. With an output gap coefficient of 1.0, the difference is not as large, but the federal funds rate is below the prescribed Taylor rule rate in all but two quarters from 2002:2 to 2005:3.

\textsuperscript{12} The analysis in Figure 5 differs from that in Poole (2007) only because Poole did not have access to Greenbook output gap data after 2000, and therefore used CBO data starting in 2001.

\textsuperscript{13} Bernanke (2010) constructs PCE inflation forecasts from core PCE inflation forecasts, based on Fed staff calculations that rely on energy futures prices.
Kohn (2007) argued that Fed policy closely followed a Taylor rule if the core PCE deflator, rather than the CPI, is used to measure inflation. Figure 7 illustrates this by depicting the prescribed interest rate with inflation measured by the realized core PCE deflator, the output gap from the Greenbook until 2004:4 and the CBO thereafter, and an output gap coefficient of 0.5. While the actual Federal Funds rate is below the prescribed Taylor rule rate from 2002 to 2005, the gap is much narrower than with headline CPI inflation, typically around one rather than three percentage points. This is similar to Bernanke’s results with forecasted PCE inflation. An even closer fit can be found using core PCE inflation and an output gap coefficient of 1.0 where, with only minor deviations, the prescribed and actual rates nearly coincide from 2001:2 – 2004:4.

Another piece of evidence that the prescribed interest rate depends more on the use of PCE instead of CPI inflation than on the use of forecasted instead of realized inflation is provided by Figure 8, which identical to Figure 7 except that realized core PCE inflation is replaced by forecasted PCE inflation from 2000:1 – 2004:2 and forecasted core PCE inflation from 2004:3 – 2011:1. The inflation forecasts are from Orphanides and Wieland (2008) through 2006:4 and from the SPF thereafter. The prescribed Taylor rule interest rates with forecasted inflation in Figure 8 are very similar to the prescribed rates with realized inflation in Figure 7. With an output gap coefficient of 0.5, the gap between the prescribed and actual rates is narrow and, with a coefficient of 1.0, the prescribed and actual rates are very close between 2002:1 and 2004:4.

A problem with the use of core PCE and headline CPI inflation is that real-time data is not available for policy analysis following the 1970s and 1990s recessions. In order to compare Fed policy following the 2001 recession to its policies following the earlier recessions, Figure 9 depicts the interest rate prescribed by Taylor’s rule with real-time data, with inflation measured by the realized GDP deflator, the output gap from the Greenbook until 2004:4 and the CBO thereafter, and an output gap coefficient of 0.5. The actual Federal Funds rate is below the prescribed rate from 2003:1 – 2005:3, with the typical gap

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being around two percentage points. The fit is much closer with an output gap coefficient of 1.0. The deviation only occurs from 2004:1 to 2005:2 and, except for 2004:1, the gap does not exceed one percentage point.

Figure 10 depicts the prescribed interest rate with inflation measured by the forecasted one-year-ahead GDP deflator, with the forecasts from the Greenbook until 2004:4 and the SPF thereafter, and the CBO/Fed output gap. With an output gap coefficient of 0.5, the prescribed and actual Federal Funds rate move closely together until 2004:1, when the prescribed rate jumps from one to three percent while the actual rate is unchanged at one percent. After the Fed started raising rates in 2004:3, the gap narrows until it is eliminated by 2005:3. With an output gap coefficient of 1.0, the prescribed rate falls below the actual rate starting in 2003:1, hitting the zero lower bound in 2003:3. In 2004:1, the prescribed rate with the higher output gap coefficient also jumps to three percent, and the gap between the prescribed and actual rates is eliminated by 2005:1.

Monetary policy analysis for 2003 – 2005 has been obscured by the use of different measures of inflation by different authors. In order to make historical comparisons, we use real-time actual and forecasted inflation measured by the GDP deflator, as well as real-time inflation measured by headline CPI as in Poole (2007) and core PCE as in Kohn (2007). Focusing on the GDP deflator, for which the prescribed rates are below those with headline CPI and above those with core PCE, Fed policy clearly deviated from Taylor’s original rule with actual inflation and an output gap coefficient of 0.5, with the Federal funds rate below its prescribed rate from 2003:1 to 2005:3. With a variant of the Taylor rule incorporating either forecasted inflation or an output gap coefficient of 1.0, but not both, the fit is closer. With both forecasted inflation and an output gap coefficient of 1.0, policy was not sufficiently stimulative until 2003:4 and too stimulative starting in 2004:1. Interest rate setting by the Fed in 2003 – 2005 was much closer to what would be prescribed by variants of the Taylor rule that characterized the 1970s than to what would be prescribed by Taylor’s original rule that characterized the 1990s.

4.4 Taylor Rules following the 2007 – 2009 Recession
As the financial crisis and the Great Recession unfolded, the Fed steadily lowered its target for the federal funds rate from 5.25 percent in 2007:3 to between 0 and 0.25 percent in December, 2008, where it stayed through (at least) 2011:1. The prescribed and actual federal funds rates are depicted for the Fed/CBO output gap and various inflation measures in Figures 5 through 10. We first consider the period from 2007:3 to 2008:4. Except for realized and forecasted CPI inflation in Figures 5 and 6, where, as Bernanke (2010) emphasized, the oil price shock produced unreasonably high prescribed policy rates, the pattern is similar across specifications. For core PCE inflation, core PCE inflation forecasts, GDP deflator inflation, and GDP deflator inflation forecasts in Figures 7-10, the prescribed and actual policy rates fell in tandem, with the rules with an output gap coefficient of 1.0 tracking the actual rate better than the rules with an output gap coefficient of 0.5.\footnote{Taylor (2008) advocates that, during periods of financial stress, the interest rate should be adjusted below the rate prescribed by the original Taylor rule by a smoothed version of the spread between the term Libor rates and the overnight federal funds rate. This adjustment would lower the prescribed interest rate for early 2008 by about $\frac{1}{2}$ percentage point.}

The focus of the current debate has been the prescribed Taylor rule rate in 2009 and 2010 - once the federal funds rate hit its zero lower bound. It is clear from Figures 7 – 10 that the debate is primarily about the output gap coefficient, as the difference in the prescribed rates from changing the output gap coefficient from 0.5 to 1.0 is much larger than the difference in the rates from using forecasted rather than realized inflation. The results for realized versus forecasted inflation are mixed. Comparing Figures 7 and 8, the prescribed rates are slightly lower with forecasted than with realized core PCE inflation but, comparing Figures 9 and 10, the rates are slightly higher with forecasted than with realized GDP deflator inflation. The results for changing the output gap coefficient are unambiguous. Regardless of the inflation measure, the prescribed rates are zero or slightly negative between 2009:2 and 2010:4 with an output gap coefficient of 0.5 and close to negative four percent with an output gap coefficient of 1.0. In 2011:1,
however, the prescribed rates with an output gap coefficient of 1.0 become less negative as the CBO output gap narrows.\footnote{Taylor (2010a, 2011b) gets slightly positive prescribed federal funds rates by using the average output gap in Weidner and Williams (2011) instead of the CBO gap. Rudebusch (2009, 2010) gets more negative prescribed rates by using the unemployment gap instead of the output gap.}

The implications of different Taylor rule variants for the prescribed federal funds rate can be illustrated in the context of perceived economic conditions on November 3, 2010, when the Federal Open Market Committee authorized the purchase of an additional $600 billion of longer-term Treasury securities (QE2) by the end of the second quarter of 2011. The core PCE inflation rate for 2010:4, reflecting data through 2010:3, was 1.3 percent and the output gap was -6.5 percent. Using Taylor’s original rule with an output gap coefficient of 0.5, the prescribed federal funds rate is -0.3 percent, close to the Fed’s range of 0 to 0.25 percent. With an output gap coefficient of 1.0, the prescribed interest rate falls to -3.6 percent. Moreover, forecasted core PCE inflation was 1.0 percent, so that the prescribed interest rate falls even further to -4.0 percent. While the federal funds rate implied by Taylor’s original rule was slightly negative, it was close enough to zero to be consistent with Fed policy without further quantitative easing. The negative interest rate implied by a Taylor rule with a larger output gap coefficient, especially augmented by forecasts of declining inflation, was of sufficient magnitude to be used as justification for QE2. As in 2003 – 2005, Fed policy in 2009-2010 was much more consistent with variants of the Taylor rule that characterized the 1970s than with Taylor’s original rule that characterized the 1990s.\footnote{Neely (2012) estimated that QE1 was equivalent to a 5% decrease in the federal funds rate. If QE2 maintained the effect on long rates that QE1 established, this would be consistent with a Taylor rule with an output gap coefficient of 1.0, but not with Taylor’s original rule.}

\section*{4. Conclusions}

In an address before the joint luncheon session of the American Economics Association and the American Finance Association in January, 2011, John Taylor delineated the major trends in the balance between rules and discretion over the past 60 years – toward more discretionary policies in the 1960s and 1970s, toward more rules-based policies in the 1980s and 1990s, and again toward more discretionary
policies in the 2000s – and presented historical evidence that rules-based monetary and fiscal policies are beneficial to the economy.

While it would seem tautological to say that the Taylor rule is an example of a rules-based policy, this is not necessarily the case. With Taylor’s original rule, that the federal funds rate equal one plus 1.5 times the inflation rate plus 0.5 times the output gap, you can evaluate policy in terms of adherence to and deviations from a well-specified rule. Once you start changing the rule, as in variants of Taylor rules with different coefficients and/or variables, you run the risk of characterizing discretionary policy as adherence to a particular variant.

The purpose of this paper is to use historical normative analysis to differentiate among different versions of the Taylor rule in order to answer an important current policy question – is the prescribed Taylor rule interest rate for 2009 – 2011 negative? We use Taylor’s original rule and later variants of Taylor rules to analyze monetary policy following the recessions of the early and mid 1970s, the early 1990s, and the early 2000s. It is generally agreed that monetary policy was too stimulative following the recessions of the 1970s and 2000s, but about on target in the 1990s. With Taylor’s original rule, the prescribed interest rate is higher than the actual rate in the 1970s and the 2000s and about equal to the actual rate in the 1990s. Had the Fed followed Taylor’s rule, they would have avoided the too stimulative policies of the 1970s and 2000s while maintaining the appropriate policy of the 1990s. With variants of Taylor rules that incorporate higher coefficients on the output gap and/or inflation forecasts, the prescribed interest rate is lower than or equal to the actual rate in the 1970s and the 2000s and lower than the actual rate in the 1990s. Had the Fed followed these Taylor rule variants, they would have replicated or worsened the too stimulative policies of the 1970s and 2000s while conducting too stimulative policy in the 1990s.

What are the implications for current policy? With Taylor’s original rule, the prescribed federal funds rate for 2009 – 2010 is zero or slightly negative. With a variant of the Taylor rule that doubles the size of the output gap coefficient, it is about negative four percent. This is important because, with the constraint of a zero lower bound on the federal funds rate, large negative prescribed interest rates provide
a rationale for the Fed’s quantitative easing in 2009 (QE1) and 2010-2011 (QE2). Our paper does not say whether or not QE1 and QE2 were good policies, a topic that is beyond the scope of our research. It does say that, if you are going to use negative prescribed interest rates to justify quantitative easing, you need to use a rule that can be justified by historical experience. Taylor’s original rule, which can be justified by historical experience, does not produce negative prescribed interest rates for 2009-2011. Variants of Taylor rules with larger output gap coefficients, which do produce negative interest rates, cannot be justified by historical experience. The Taylor rule does not provide a rationale for quantitative easing.
References

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