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POLICY BEHAVIOR OF THE FEDERAL RESERVE SYSTEM: AN ALTERNATIVE TAYLOR RULE

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Policy Behavior of the Federal Reserve System

An Alternative Taylor Rule

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April 1, 2014

Abstract: Taylor's Rule was designed to be a suggestion to the Federal Reserve System as to where to set the federal funds rate. The dynamic equation used in this study is built off the original Taylor Rule and variations of the Taylor Rule created by other economists, such as Judd and Rudebusch (1998) and Fair (2001). However, this model uses monthly data rather than quarterly data, and uses slightly different measures of the economic indicators used as the explanatory variables in the equation. The main objective of this study is to test for structural changes in the Federal Reserve's policy behavior across various Fed Chairmen since 1960 (Martin, Burns, Miller, Volcker, Greenspan, and Bernanke) using the CHOW test.

Introduction

Several studies have dealt with Taylor's Rule. For the most part, the Federal Reserve System (Fed) has followed the rule relatively closely over the years, as Figure 1 illustrates. The original Taylor's rule was a simple equation, $FFR_t = \pi_t + 0.5(\pi_t - \pi^*) + 0.5y_t + FFR^*$, where FFR is the effective federal funds rate, π is the one-year inflation rate (GDP inflator), π^* is the target inflation rate, y is the output gap as a percent of potential gross domestic product (GDP), and FFR^* is the equilibrium real federal funds rate. The coefficients of 0.5 on both the inflation and the output parameters suggest that the Fed should place equal weights, or emphasis, on the two economic indicators (Taylor, 1993).

Some economists, such as Nikolsko-Rzhevskyy and Papell (2011), argue that the Fed should have followed the original Taylor Rule more closely during recessions. For example, the economy was experiencing an inflationary period during the early 1970's. During this time, the Fed set the federal funds rate lower than Taylor's rule suggested. Nikolsko-Rzhevskyy and Papell argue that if the Fed set a higher federal funds rate, inflation would not have been as high.

Other economists, such as the current Fed Chairman Janet Yellen, argue that an alternative rule would have been more optimal. She stressed using a rule that gave more weight to the output gap. Her rule, much like Taylor's, suggested a higher federal funds rate than the Fed set during the early 1970's, as shown in Figure 2 (Yellen 2012).

The main objective of this study is to use statistical and econometrical means to test the null hypothesis of no structural change in the Fed policy behavior across different Federal Reserve Chairmen. I will combine and expand upon previous studies. My model will include more observations and the data will include monthly observations from January 1960 to August 2007. The variables in my model will be slightly different than what was used in previous studies, yet are still mentioned by the Fed in their statements when they discuss the statutory mandate of stabilizing prices and maximizing employment. For example, I will use the personal consumption expenditure (PCE) measure of inflation rather than the GDP deflator measure of inflation and I will use the unemployment gap in place of the output gap.

My results will provide insight on historical Fed behavior, which can be used as a benchmark as to where to set future federal funds target rates. This can be useful for policy makers because they will be able to see how their behavior changed over time and better analyze their current situation to make wiser choices when implementing monetary policies. For example, analyzing where the federal funds rate should be set can provide justification for the various rounds of quantitative easing, which began in 2009. If rules suggest that the federal funds rate should be lower than they currently are, then more stimulus monetary policy will be needed, which can help explain why the large-scale asset purchasing has been necessary.

The first round of quantitative easing (QE1) included purchases primarily of agency mortgage backed securities. In October of 2010, the second round (QE2) was implemented. The Fed purchased long term government bonds, and was considered a smaller version of QE1 (Gertler 2012). Finally in September of 2012, the third round (QE3) began, in which the Fed initially purchased $45 billion each month of treasury securities and $40 billion each month of mortgage back securities (Federal Reserve Press Release, September 2012). Currently, the Fed has begun the tapering process of QE3 and reduced the size of their purchases of treasury and mortgage back securities to $30 billion and $25 billion each month respectively (Federal Reserve Press Release, March 2014).

Policy makers can use information regarding the federal funds rate as they decide how quickly they should bring the third round of quantitative easing (QE3) to an end. Additionally, they can use this information in the future when determining if additional nontraditional monetary policies are needed to help the economy recover from a recession.

Literature Review

Many economists have revised Taylor's original equation. Janet Yellen (2012), for example did not believe Taylor's Rule suggested a high enough weight on the output gap. She modified the rule to be twice as responsive to the gap in output. The equation she used is as follows: $FFR = \pi + 0.5(\pi - \pi^*) + 1.0y_t + RFF^*$. This alternative rule reflects the reactions of the Fed in regards to their dual mandate. Figure 2 illustrates the differences in Yellen's Rule and Taylor's Rule. The rates are relatively close during the time period, except Yellen's Rule suggested a slightly higher rate during the late 1960's, from 1972 to 1973, and the late 1990's. Her rule suggests lower rates during recessions, such as the early 1980's, and after the financial crisis of 2008. Her rule currently suggests the target federal funds rate be continuously below the zero-lower bound, whereas Taylor's rule only suggested the rate be negative between the first quarter of 2009 through the third quarter of 2010.

Taylor and Yellen formulated their equations using judgment on appropriate values of the coefficients. Other economists, such as Judd and Rudebusch (1998) and Fair (2001), used econometrics to estimate the coefficients based on past behavior of the Fed. Judd and Rudebusch, and Fair and suggested a dynamic version of the Taylor Rule. The Federal Open Market Committee (FOMC) does not adjust the interest rates over night; it is a gradual effect. Therefore they included lagged terms of the explanatory variables, including values of the target rate. Judd and Rudebusch used the change in the federal funds rate as their dependent variable, while Fair used the 3-month Treasury bill rate. Each ran regressions to estimate the historical coefficients on the explanatory variables.

The overall purpose of the Judd and Rudebusch, and Fair studies were to estimate the Fed's policy behavior, or their reaction function. Unlike Judd and Rudebusch, Fair omitted the quarters 1979Q4 through 1982Q3. The Fed focused on monetary growth targets during this time period significantly more than during any other period. Fair refers to this period as the "early Volcker" period. In 1978, Congress passed the Humphrey-Hawkins (or the Full Employment and Balanced Growth) Act. This act essentially created the Fed's dual mandate in which their objectives to maximize employment and keep prices stable (i.e. low inflation) were explicitly stated. When Paul Volcker became the Fed Chair in August 1979, inflation was 9.2%, as seen in Figure 3. To combat the problem of high inflation, the Fed focused primarily on reducing money growth; however, in October of 1982, Volcker announced they were changing their focus back to interest rates, which was their main objective before 1979 (Ball 2012). When Fair omitted these 10 quarters, he found no evidence of a structural change within the FOMC policy behavior.

Judd and Rudebusch, on the other hand, did not omit the "early Volcker" period from their study; however they did omit Chairman G. William Miller's term (1978Q2 – 1979Q2) due to his short tenure. Overall, they ran four regressions: one full sample (1970Q1 – 1997Q4), and three subsamples for the chairmen, Arthur Burns, Paul Volcker, and Alan Greenspan. Judd and Rudebusch compared the three subsamples using the Chow test to test for breaks in the period corresponding to the different terms. When they tested for the Burns/Volcker period, they were able to reject the null hypothesis of no structural change at the 1% significance level. For the Volcker/Greenspan period, Judd and Rudebusch were able to reject the null hypothesis at the 10% significance level. In other words, they found evidence of structural change in the policy behavior of the Fed. Their results were not surprising to Judd and Rudebusch, nor were they surprising to me considering the fact the FOMC has explicitly changed their policy decision making several times since their creation.

Economic behavior has changed several times in respect to both monetary and fiscal policy. Taylor (2011) explains that policies swung from being discretionary to rule-based, and unfortunately back to discretionary in recent years. In the 1970's, monetary policy changed several times as inflation reached new heights. There was no strategy to keeping inflation under control; the Fed's behavior towards controlling inflation was erratic. As mentioned earlier, the Humphrey-Hawkins Act was passed in the late 1970's, and the FOMC began to use "rules" as guidelines in their policy. To meet the prongs of their dual mandate, they began to specifically target inflation, particularly during Volcker's term as Fed Chair. When Volcker's term ended, inflation had fallen 5.5 percentage points to 3.3%. While Alan Greenspan was Chair, he followed Volcker's commitment to maintaining stable prices. Although Taylor did not use econometrics to determine statistically if there was any structural change, he used historical evidence to reach his conclusion.

The different rounds of quantitative easing have been interpreted by Taylor as the FOMC returning to the use of discretionary policy. It could be argued that discretionary policy was needed after the financial crisis in 2008, especially if the federal funds rate was being constrained by the zero-lower bound. Janet Yellen wanted to use a higher accommodative policy, which is why she suggested using a rule, like Taylor's original rule, but twice as responsive to the gap in output. However, Taylor argues that the shift away from rule-based policies began even before 2008. He believed the shift began when interest rates dropped in 2003, which only aided the growth of the asset bubble. This shift back towards discretion lead to disruptions in the markets and aided to the onset of the crisis.

Nikolsko-Rzhevskyy and Papell (2011) found that Taylor's original rule was the best guideline after recessions. Currently the federal funds rate is between zero and one quarter of a one percent, the lowest range it can go. If the zero-lower bound is acting as a constraint, more monetary policy would be needed to offset this shortfall. Taylor's Rule suggested the federal funds rate should have been -0.3% in the third quarter of 2009, the lowest level since the financial crisis of 2008. This is virtually the same rate as the current rage suggesting the zero-lower bound is not a constraint.

Rudebusch (2009), however, found a different result. Rudebusch used a similar equation to the Taylor rule except he used the unemployment gap instead of the output gap as an explanatory variable. With his calculations, he found the federal funds rate should have been fallen below -5.0% by the end of 2009, with forecasts of it staying negative for several years to come. Rudebusch argued that the drastic difference between the actual and the prescribed federal funds rate is a major shortfall in monetary policy. To partially counter this shortfall, the FOMC expanded their use of nontraditional tools, such as implementing quantitative easing and the use of forward guidance. Forward guidance refers to the communication with the public as to how long the FOMC intends to keep the targeted federal fund rate low (Federal Reserve System 2014).

While Rudebusch justified quantitative easing, Nikolsko-Rzhevskyy and Papell, and Taylor found the various rounds of quantitative easing to be unnecessary. They argued that the Fed should have followed a more "rule-based" policy. Ben Bernanke, according to Taylor, defends the FOMC by arguing that interest rates fell in the early 2000's, not because they were deviating from rule-based policies, but because they were following a modified rule; the FOMC was using forecasted data rather than historical data. However, Taylor counters the argument by saying that their forecasts were too optimistic which therefore made the rule ineffective. If they had followed a rule like the original Taylor's Rule more closely, the financial crisis would not have been as severe. Nikolsko-Rzhevskyy and Papell compared alternative rules to the Taylor Rule and found that after each recession, a policy that closely followed Taylor's original rule was the optimal policy to use.

Studying how the Federal Reserve reacts to various economic indicators, and whether they follow Taylor's Rule, or a similar rule, is important because of the disagreements among economists. A goal of this study is provide a better understanding about the Fed's reaction function over time and across different Chairmen which can lead to more appropriate monetary policies in the future.

Empirical Model

Overall, I will combine the ideas from the Fair (2001) and Judd and Rudebusch (1998) studies to modify the equation with more appropriate variables and updated data. The main purpose of this study is to illustrate the Fed's policy behavior over time and to test for structural breaks between the Fed Chairmen. The monthly time-series observations will begin in 1960, the earliest data[1] available for all my explanatory variables, and continue through August 2007, the last month before the FOMC first began to decrease the federal funds rate. In September 2008, Lehman Brothers, one of the largest investment banks in the United States, failed, which helped fuel the financial crisis of 2008 (Bernanke, 2010). The Fed continued to lower the federal funds rate through December of 2008 to between zero and 25 basis points, the range where it is currently. My sample size will include 572 monthly observations. The sample period will be split into six subsamples for each of the Fed Chairmen: William Martin (1960M01 – 1970M01),

[1] All data used in this study came from the Federal Reserve of St. Louis Economic Data (FRED).

Arthur Burns (1970M02 – 1978M01), G. William Miller (1978M02 – 1979M07), Paul Volcker (1979M08 – 1987M07), Alan Greenspan (1987M08 – 2006M01), and Ben Bernanke (2006M02 – 2007M08). Because data for particular explanatory variables was only available beginning in 1960M01, the subsample for Martin will begin in 1960M01, rather than 1951M02 when his regime began. Also, the model will not include Bernanke's full regime, which ended in January 2014, for the reasons explained above.

Fair used the 3-month Treasury bill rate as his dependent variable; however Taylor (1993) and Judd and Rudebusch used the change in the federal funds rate. Since the Fed focuses on setting a target for the federal funds rate, I will be using a model more along the lines of what Judd and Rudebusch used, and use the change in the federal funds rate (FFR) as my dependent variable. Both Fair and Judd and Rudebusch used inflation as one of their explanatory variables, as I will too. There a couple different measure of inflation; Fair did not say which measure he used, but Judd and Rudebusch used the GDP deflator measure, which is also the measure Taylor used in his original model. I, however, will be using the total personal consumption expenditure (PCE) measure of inflation, since this is the measure the Federal Reserve refers to most often when discussing economic indicators (Meyer, 2001).

I used Taylor's original equation as the foundation for developing my model, similar to what Judd and Rudebusch did. Taylor's original rule can be written as equation 1

$$FFR_t = \pi_t + 0.5(\pi_t - \pi^*) + 0.5y_t + FRF^* \qquad \text{(eq. 1)}$$

where FFR_t is the recommended federal funds rate, π_t is the current rate of inflation (GDP deflator), π^* is the inflation target rate, y_t is the current output gap, and FFR^* is the equilibrium real federal funds rate,. This equation can be replaced using the PCE inflation, the unemployment gap, and the appropriate number of lagged variables. Taylor used judgment, rather than econometrics, to determine the coefficients on the inflation and output. Since I will be using econometrics, I will replace his coefficients of 0.5 with λ.

$$FFR_t^* = PCE_t + r^* + \lambda_1(PCE_t - PCE^*) + PCE_{t-1} - \lambda_2 UG_t - \lambda_3 UG_{t-1} - \lambda_4 UG_{t-2} \qquad \text{(eq. 2)}$$

This study looks at the dynamics of adjusting the actual federal funds rate, which is why my dependent variable is the change in the federal funds rate, rather than the recommended level of the federal funds rate. Equation 3 illustrates the dynamics of adjusting the rate, where γ is the adjustment factor, and ρ partially corrects for the over adjustment from one period to the next.

$$\Delta FFR_t = \gamma(FFR_t^* - FFR_{t-1}) + \rho_1 \Delta FFR_{t-1} + \rho_2 \Delta FFR_{t-2} + \rho_3 \Delta FFR_{t-3} + \rho_4 \Delta FFR_{t-4} \qquad \text{(eq. 3)}$$

The second equation needs to be substituted into the third equation in order to actually calculate the dynamic equation, equation 4. The equilibrium real federal funds rate (FFR*) and the inflation target rate (PCE*) cannot be estimated simultaneously. Therefore, I combined the terms into a single parameter, which will be denoted as α, and be used to calculate the intercept of the equation. Above each parameter of the equation is the expected sign according to the economic theory.

$$\Delta FFR_t = \overset{(+/-)}{\gamma\alpha} + \overset{(+)}{\gamma(1+\lambda_1)}PCE_t + \overset{(+)}{\gamma}PCE_{t-1} - \overset{(+)}{\gamma\lambda_2}UG_t - \overset{(+)}{\gamma\lambda_3}UG_{t-1} - \overset{(+)}{\gamma\lambda_4}UG_{t-2} - \overset{(+)}{\gamma}FFR_{t-1}$$

$$+ \overset{(+/-)}{\rho_1}\Delta FFR_{t-1} + \overset{(+/-)}{\rho_2}\Delta FFR_{t-2} + \overset{(+/-)}{\rho_3}\Delta FFR_{t-3} + \overset{(+/-)}{\rho_4}\Delta FFR_{t-4} \qquad \text{(eq. 4)}$$

Equation 4 is my primary equation; however I will also be using two dummy variables (DCC, and DV) for the full sample period. For the Volcker period, the credit control and the "early Volcker" dummy variables will be included. Therefore, the dummy variables need to be included in the dynamic equation. This is equation 5. Just as in equation 4, the expected sign of each variable, according to economic theory, is indicated above the parameter.

$$\Delta FFR_t = \overset{(+/-)}{\gamma\alpha} + \overset{(+)}{\gamma(1+\lambda_1)PCE_t} + \overset{(+)}{\gamma PCE_{t-1}} - \overset{(+)}{\gamma\lambda_2 UG_t} - \overset{(+)}{\gamma\lambda_3 UG_{t-1}} - \overset{(+)}{\gamma\lambda_4 UG_{t-2}} - \overset{(+)}{\gamma FFR_{t-1}} \quad \text{(eq. 5)}$$

$$+ \overset{(+/-)}{\rho_1 \Delta FFR_{t-1}} + \overset{(+/-)}{\rho_2 \Delta FFR_{t-2}} + \overset{(+/-)}{\rho_3 \Delta FFR_{t-3}} + \overset{(+/-)}{\rho_4 \Delta FFR_{t-4}} + \overset{(-)}{\beta_1 DCC} + \overset{(+)}{\beta_2 DV^{*}PCE_t} + \varepsilon_t$$

Based on Taylor's Rule, inflation is positively related to the change in the federal funds rate. When inflation rises above the target, the Fed should respond with an even greater increase in the federal funds rate so that the real interest rates increase and prices fall back toward the target. Therefore inflation is expected to have a positive sign in the regression. Due to information lags, we assume the Fed does not focus on just the current level of inflation; they also look at the joint effect of where the rate was in the previous month relative to its current rate. To account for this inertia, I have included the one-month lag of inflation, which is also expected to have a positive sign on the federal funds rate.

The unemployment gap (UG)[2] is another explanatory variable included in my model. The change in the federal funds rate should be inversely related to the unemployment gap. As the unemployment rate increases relative to the natural rate of unemployment (NROU), the Fed should decrease the federal funds rate in an attempt to reduce the unemployment rate back towards the natural rate. This means, in the model, unemployment is expected to have a negative sign. Similar to the inflation, the Fed does not focus on just the current rate of unemployment; they also focus on where the unemployment rate has been compared to NROU in recent months. For this reason, I have included two months' lag values of the unemployment gap, which are also expected to have negative signs.

[2] The unemployment gap is found by subtracting the Natural Rate of Unemployment (NROU) at time *t* from the unemployment rate at time *t*. NROU is only available as quarterly data; however, since it barely fluctuates between quarters, I have adjusted the data to be monthly.

Finally, I included the one-month lag of the level of the federal funds rate along with four lags of the change in the federal funds rate as additional explanatory variables. The Fed looks at where the federal funds rate was the previous month and how it's changed over the past several months. The lagged level of the rate, for given levels of inflation and unemployment gap, should have an inverse relationship with the change in the federal funds rate. If the Federal Reserve responds slowly to the economic indicators – inflation and unemployment – we would expect the lags in the change of the rate to be positively correlated with the current change; i.e. they will adjust the rate similar to how they adjusted it in previous months. However, if the FOMC responds quickly to incoming information, the current change could be negatively related to past changes. In other words, if the Fed was aggressive with recent changes in federal fund rate, they may be less aggressive with the current change.

I have also included a few dummy variables in my model. The first dummy variable is for the credit controls in the early 1980's. In March of 1980, President Carter authorized the Federal Reserve to enact restraints on credit based spending in the country to slow the economic growth and inflation. A sharp drop in the demand for credit led to large declines in market interest rates and the federal funds rate in April of 1980. The Fed first reacted to enabling the restrictions in May 1980. Chairman Paul Volcker said, "…we are not interested in fostering any impression that credit allocation…can be any part of…monetary policy" (Schreft, 1990) and the federal funds rate fell 6.63 percentage points from May to April. Therefore, in my model, the credit control dummy variable (DCC) will be equal to 1.0 for May 1980, and zero for the other months.

I agree with Fair when he says the "early Volcker" period, in which the Fed focused more on monetary growth to reduce inflation more so than they did during any other period, must be taken into consideration when testing for structural breaks. To account for this, I included a dummy variable (DV) where DV is equal is 1.0 for the months August 1979 through September 1982, and zero for all other months. This is an interaction term, which means I multiplied the dummy variable with the level of inflation at that time.

<u>Data Analysis</u>

Before calculating estimates of the equations, it is important to get to know the data. The summary statistics (Table 1) of each variable is a quick way to double check no errors were made in collecting the data, along with easily finding the range of the observations and the average for each variable.

The effective federal funds rate was above 10% nearly every month from December 1978 to October 1982 (Figure 4). The highest the federal funds rate ever reached was in January 1981 when it reached 19.10%. Around this time, inflation was consistently above 10%, reaching a peak of 11.58% (Figure 3) in March of 1980, when President Carter invoked the credit controls in attempts to slow the economy. From April to May of that year, the federal funds rate fell by its largest percentage point decrease, of 6.63%, but still remained relatively high.

The Phillips Curve Theory states that inflation and unemployment are inversely related; the early 1980's support this theory. After rising oil prices pushed inflation and unemployment up, the high unemployment brought inflation back down. The largest gap in the unemployment rate between 1960 and 2007 was in December of 1982. The natural rate of unemployment was 6.10%, but the unemployment rate was at 10.8% for the second consecutive month (Figure 5). That left an unemployment gap of 4.70%. At this time, inflation fell 6.77 percentage points and reached 4.81% by December 1982.

Unfortunately, none of the variables are normally distributed. The mean and median are not statistically equivalent and the distribution of the observations are skewed. A perfectly normal distribution will have a skew of zero and a kurtosis equal to three. The Jarque-Bera (JB) statistic uses the skew and kurtosis to statistically test for normality. A normal distribution will result in a JB-statistic less 5.99, at the 5% significance level. Each variable in my model, however, provides very strong evidence against the null hypothesis of normality. Although this poses potential problems, this is not uncommon for time-series data. Therefore, the variables should not be omitted from the model; however, their abnormalities should kept in mind. More important is the normality of the distribution of the error terms from the regressions, which will be tested for once we run the regressions.

Generally the explanatory variables are correlated with and the dependent variable, as shown in Table 2 of the appendix. The change in the federal funds rate is positively related to inflation and negatively related to the current and lagged values of the output gap.

The correlation between the explanatory variables and the dependent variable could potentially lead to problems. At the 1% level of significance, the unemployment gap and the one-month lag in the gap are correlated with the change in the federal funds rate, with correlation coefficients of -0.143 and -0.112 respectively. The two-month lag is correlated at the 10% significance level with a correlation coefficient of -0.72. As the negative sign indicates, the change in the federal funds rate and the unemployment gap has an inverse relationship.

Taylor used the effective federal funds rate as his dependent variable. Every explanatory variable is highly correlated with the effective federal funds rate (except the credit control dummy variable). Inflation has a correlation coefficient of 0.737 and is significant at the 1% level. The correlation for the one-month lag in the inflation rate is 0.738 which is also significant at the 1% level. The correlation coefficient for the unemployment gap at time *t* is 0.110 and is significant at the 1% level. The one-month lag in the gap has a correlation coefficient of 0.091

and the two-month lag correlation has a correlation of 0.078, which are significant at the 5% and 10% significant levels, respectively.

Multicollinearity occurs when there is a significant correlation amongst the explanatory variables. The correlations between the unemployment gap at time *t* and the unemployment gap at *t*–*1* and *t*–*2* are obviously very high; the correlation coefficient is approximately 0.99 for each. The current unemployment gap, in fact, is statistically significantly correlated with every variable at the 1% level of significance.

Similarly, there is a very high correlation between the current inflation rate and the lagged rate. The correlation coefficient between the two is approximately 0.995. Inflation is also highly correlated with the unemployment gap. The correlation coefficient between the rates at time *t* is 0.159. Unfortunately, this is not the sign we would expect to see. The Phillips Curve suggests that inflation and unemployment are inversely related. However, this can be explained by high oil prices. Periods of highest inflation, specifically the 1970's, resulted from the quickly rising oil prices and other supply shocks that contributed to the increase in unemployment. Inflation and the one-month lag of the inflation rate are significantly correlated with most variables at the 1% significance level. The four-month lag changes in the federal funds rate are the only variables inflation is not correlated with.

The current level of inflation is also correlated with the dependent variable (0.019) at the 10% significance level, although the one-month lagged term (0.005) is not correlated with the change in the federal funds rate.

Of course the lagged change in the federal funds rate is highly correlated with the change in the rate at time *t*. The correlation coefficient is 0.382, which is significant at the 1% significance level. The two-month lag, however, is not correlated with the dependent variable even at the 10% significance level. The three and four month lags, on the other hand, are correlated at the 1% and 5% significance level with correlation coefficients of -0.091 and -0.130, respectively. The negative signs suggest that the Fed responded relatively quickly to incoming economic information, such as inflation and unemployment.

<u>Econometric Results</u>

As mentioned earlier, I use slightly different explanatory variables than other economists regarding Taylor rules. Not only did I use theory to explain which variables to include, I also used econometrics. I ran several regressions to test for the appropriate variable and the correct number of lags to include.

First, I used an ordinary least squares (OLS) regression to test which measure of inflation to use. The GDP deflator and the consumer price index (CPI) measures of inflation did not provide as much explanatory power as the PCE measure did. PCE can be measured using the total inflation, or the core inflation, which excludes food and energy prices. Although core is more stable over time, I found that total PCE provided more explanatory power. To determine how many lags to include in the model, I used sequential lag testing. I first included six months lags and then dropped the ones that were insignificant. This left me with the current and one-month lag for inflation.

Judd and Rudebusch (1998), and Taylor (1993) used the output gap in their models. However, Fair (2001) and Rudebusch (2009) used the unemployment gap. In the OLS model, I tested for both the output gap and the unemployment gap. The unemployment gap provided more explanatory power, which was not surprising considering one of the prongs of the Fed's statutory mandate is maximizing employment. Using the unemployment gap as opposed to output gap has two advantages. First, it is more widely understood and easier to interpret. Secondly, data is available monthly for unemployment whereas the output gap is only available quarterly. This allowed me to have three times as many observations, which increased my degrees of freedom, and can therefore provide more reliable results.

As with inflation, I determined how many lags to include for the unemployment gap based on sequential lag testing. Again, I began with six lags and then dropped those that were insignificant, leaving me with the current value and two lags. The same process was applied for the change in the federal funds rate, and I found that four lags were needed to capture the dynamics.

The OLS equation of the full sample can be written, with their expected signs, using the equation below.

$$\Delta FFR_t = \beta_1 + \overset{(+)}{\beta_2(PCE_t+PCE_{t-1})} + \overset{(--)}{\beta_3 UG} + \overset{(--)}{\beta_4 UG_{t-1}} + \overset{(--)}{\beta_5 UG_{t-2}} + \overset{(--)}{\beta_6 FFR_{t-1}} + \overset{(+/--)}{\beta_7 \Delta FFR_{t-1}}$$

$$+\overset{(+/--)}{\beta_8 \Delta FFR_{t-2}} + \overset{(+/--)}{\beta_9 \Delta FFR_{t-3}} + \overset{(+/--)}{\beta_{10} \Delta FFR_{t-4}} + \overset{(--)}{\beta_{11} DCC} + \overset{(+)}{\beta_{12} DV^* PCE_t} + \varepsilon_t \quad \text{(eq. 6)}$$

The estimates of the coefficients, their corresponding standard errors, and the significance level of each explanatory variable along with the adjusted R-squared, the standard error of the regression, and the Durbin-Watson statistic from each regression[3] are shown in Table 3 in the appendix. Newey-West correction for heteroskedacity and autocorrelation (HAC) for time-series data results in more reliable significance levels. Therefore I will report my results of the full sample period based on the OLS regressions with HAC corrections.

The estimated coefficient on inflation has the expected positive sign with a value of 0.023, which is significant at the 1% significance level. This means that for every percent increase in inflation, the Fed will adjust the federal funds rate by 2.3 basis points in the short run.

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[3] All regressions were run using the statistical software eViews.

This was the direction of the impact we expected, and the high confidence level provides strong evidence that this effect is significantly different than zero. In other words, we can say with 99% confidence that inflation has a positive effect on the change in the federal funds rate.

In general we expect a negative sign on the unemployment gap in the Fed's reaction function. The estimated coefficient for the current unemployment gap was -0.570 and was significant at the 1% significance level. The estimated coefficient for the one-month lag in the unemployment gap was -0.154. The estimated coefficient for the two-month lag was 0.658, which was significant at the 1% level. To capture the short-run impact of the unemployment gap on the federal funds rate, the coefficients would be added together, which would be approximately -0.066. This tells me that the Fed does react negatively to a change in the unemployment gap, in that they decrease the federal funds rate to bring unemployment back towards full employment. For every one percent the unemployment deviates above NROU, the Fed lowers the federal funds rate by 6.6 basis points in the short run. This impact is more than three times the magnitude as the Fed's reaction to inflation, suggesting the Fed put a much stronger emphasis on the unemployment.

We expect a negative sign on the lagged level of the federal funds rate. The estimated coefficient was -0.043 and was significant at the 1% level. This suggests very strong evidence that the federal funds rate adjusts back towards equilibrium when it's out of balance. For every percentage point the federal funds rate was above the target in the previous month, the Fed changes the rate in the current month by -4.3 basis points in the short run.

In regards to the lagged changes in the federal funds rate, the estimated coefficient could be either positive, negative, or have no effect on the current changes in the federal funds rate. In chronological order, the estimated coefficients for each lag is 0.319, -0.038, 0.074, and -0.125.

This two-tailed test was significant at the 1% significance level, for the one-month lag, and significant at the 5% level for the fourth month lag, which provides strong evidence that the lagged federal funds rate has an impact on the change in the federal funds rate. The impact appears to alter between positive and negative with each month lag value, which is probably caused by the fact the FOMC typically meets every 6 weeks and not every month. In other words, the FOMC likely addressed the issue at the previous meeting.

My dummy variables also proved to be significant. The first dummy variable is for the credit controls for May 1980. The estimated coefficient was -6.339 and was significant at the 1% level. This provides very strong evidence that the Federal Reserve decreased the federal funds rate by approximately 6.4 percentage points in response to the credit controls. The second dummy variable, the "early Volcker" period, is an interaction term with the current level of inflation at that time. The estimated coefficient was 0.066 and was significant at the 1% significant level.

The long-run coefficients can be calculated from the OLS regression. The change in the federal funds rate is equal to the previous month's federal funds rate subtracted from the current level of the federal funds rate. The estimated coefficient of the lagged federal funds rate is approximately 0.043. To calculate the long-run effects, the estimated values of the explanatory variables will essentially be divided by 0.043. The coefficient of the long run effect of inflation was found to be approximately 1.07. The long run effect of unemployment on the federal funds rate is approximately -1.46. In the long run, the change in federal funds rate and the dummy variables are zero. Therefore, long-run equation can be written as equation 7.

$$FFR_t = 1.83 + 1.073PCE_t - 1.464UG_t \qquad \text{(eq. 7)}$$

This equation can be used to determine where the federal funds rate should be set. Figure 6 illustrates Binning's Rule. After the recent financial crisis, Binning's Rule suggested the federal funds rate to be below zero primarily from December 2008, until January 2011. Therefore, Binning's Rule provides justification for the first two rounds of quantitative easing, but not the third round. Recall that Taylor's Rule provided justification for the first round of quantitative easing, and Yellen's Rule provided justification for all three rounds.

The regression showed no signs of problems with autocorrelation. The Durbin-Watson statistic for the full sample period was approximately 1.942, which is close to the optimal value of 2.0. Each of the subsamples also showed no signs of autocorrelation. All reported Durbin-Watson statistics were close to 2.0. The "goodness-of-fit" calculations also proved to be somewhat promising. The adjusted R^2 for the full sample was 0.509, which suggested about 50% of the squared changes in the federal funds rate were explained by the model. The standard error of the regression was relatively low, with a value of 0.402, so the 95% confidence interval ranged by 0.80% around the predicted value. The Bernanke subsample had even better results. Nearly 74% of the variation was explained by the model, and the regression had a standard error of 0.055. The Volcker period, on the other hand, was not as well explained by the model. Although the adjusted R^2 was 0.601, the standard error, which is a better measure of "goodness-of-fit" was 0.761 and the standard deviation of the dependent variable was approximately 1.205.

Linear regressions have an assumption that the error terms are normally distributed. However, the residuals of five of my seven regressions are not normal. The skew of the full sample is approximately 0.136 and has a kurtosis approximately equal to 13.056. Therefore the distribution of the errors is pulled in the positive direction, or is a left-tailed distribution, and most of the values are concentrated closely around the mean. The JB-statistic for the full sample is 2386.442, which is larger than the critical value of 5.99 at the 5% significance level. This provides very strong evidence that the error terms of the regressions are not normally distributed. The outliers of the residuals occur in the late 1970's and the early 1980's. Despite the fact the errors are not normal, my model is still a good model to use; however, we must proceed with caution.

The Bernanke period (2006M02 – 2007M08) and the Miller period (1970M02 – 1978M07) are the only samples where the error terms are normally distributed. The Bernanke period had a skew of -0.218 which is not statistically different than zero and the kurtosis of 2.298 which is not statistically different than three. The calculated JB-statistic is 0.542, which is less than 5.99, suggesting the null hypothesis of normality cannot be rejected at the 5% significance level. Table 4 presents the statistics of the residuals, testing for normality, for each sample.

As mentioned earlier, I am using a dynamic equation (equation 5) where there is an adjustment factor involved with the explanatory variables. The dynamic equation I will be estimating for the full sample period can be written using the formula below, where γ is the adjustment factor, α is the equilibrium real federal funds rate and the inflation target, and ρ partially corrects for the over adjustment for the change in the federal funds rate at time *t*. (Note that the negative effect of the unemployment gap and the one-month lag of the federal funds rate is already built into the equation, therefore the actual coefficients are expected to be positive.)

$$\begin{aligned}\Delta FFR_t = &\overset{(+/-)}{\gamma\alpha} + \overset{(+)}{\gamma(1+\lambda_1)PCE_t} + \overset{(+)}{\gamma PCE_{t-1}} - \overset{(+)}{\gamma\lambda_2 UG_t} - \overset{(+)}{\gamma\lambda_3 UG_{t-1}} - \overset{(+)}{\gamma\lambda_4 UG_{t-2}} - \overset{(+)}{\gamma FFR_{t-1}} \\ &+ \overset{(+/-)}{\rho_1\Delta FFR_{t-1}} + \overset{(+/-)}{\rho_2\Delta FFR_{t-2}} + \overset{(+/-)}{\rho_3\Delta FFR_{t-3}} + \overset{(+/-)}{\rho_4\Delta FFR_{t-4}} + \overset{(-)}{\beta_1 DCC} + \overset{(+)}{\beta_2 DV^*PCE_t}\end{aligned} \quad \text{(eq. 5)}$$

Similar to the standard OLS equation, the dynamic equation did not show signs of problems with autocorrelation. The Durbin-Watson statistics for each sample period was statistically close the optimal value of 2.0. Approximately 50% of the variance was explained by the model. The adjusted R^2 for the full sample period was 0.508 and the standard error was approximately 0.405.

The adjustment factor, γ, was estimated to be approximately 0.042, which suggests the federal funds rate typically adjusts each month enough to eliminate 4.2% of the difference between the actual lagged value and what the rule suggests. The full sample equation, with the estimated coefficients can be written as follows:

$$\Delta FFR_t = 0.071 + 0.005PCE_t + 0.042PCE_{t-1} - 0.574UG_t - 0.157UG_{t-1} + 0.663UG_{t-2} - 0.042FFR_{t-1} + 0.319\,\Delta FFR_{t-1} - 0.038\,\Delta FFR_{t-2} - 0.074\,\Delta FFR_{t-3} + 0.125\,\Delta FFR_{t-4} - 6.33DCC + 0.063DV^{*}PCE \quad \text{(eq. 8)}$$

To test for changes in the Fed policy behavior as it relates to the federal funds rate, I tested for structural breaks between the regimes of the chairmen using the Chow Breakpoint Test. I ran six regressions: one for the Martin/Burns period (1960M01 – 1978M01), one for the Burns/Miller period (1970M02 – 1979M07), one for the Miller/Volcker period (1978M02 – 1987M07), one for the Burns/Miller/Volcker period[4] (1970M02 – 1987M07), one for the Volcker/Greenspan period (1979M08 – 2006M01), and one for the Greenspan/Bernanke period (1987M08 – 2007M08). The estimates of the coefficients, their corresponding standard errors, and the significance level of each explanatory variable along with the adjusted R-squared, the standard error of the regression, and the Durbin-Watson statistic from the regression are shown in Table 5 in the appendix. Similar to the OLS regression, the coefficients show the appropriate signs according to the economic theory, and most coefficients are highly significant, providing

[4] Previous studies excluded Miller's term because of his short tenure. To compare to previous studies, I combined the Burns and Miller period and ran a regression to test for a break between the regimes of Burns and Volcker.

strong evidence that each economic indicator in the model does have an impact on the change in the federal funds rate.

The null hypothesis is that there is no break at the specified breakpoint. The alternative, therefore, is that there is evidence of a break. For the Martin/Burns period (1960M01 – 1978M01), I tested for a breakpoint at February of 1970. This was the first month Arthur Burns became the Fed Chair. The reported F-statistic was approximately 4.353 with a p-value less than 0.001. This provides very strong evidence against the null hypothesis and suggests there was a structural break between Chairmen William Martin and Arthur Burns.

For the Burns/Miller/Volcker period (1970M02 – 1987M01), I tested for a break at the start of Volcker's regime – August 1979. The reported F-statistic was approximately 1.917 with a corresponding p-value of 0.035. This means we reject the null hypothesis at the 5% significance level. In other words, there is relatively strong evidence that there was a structural break between the regimes of Arthur Burns and Paul Volcker. Judd and Rudebusch found evidence at the 1% significance level of a structural break between the regimes of Burns and Volcker.

The breakpoint date used to test between the Volcker/Greenspan period (1979M08 – 2006M01) was August of 1987, the first month Alan Greenspan became the Fed Chair. The calculated F-statistic was reported as approximately 2.304 with a p-value of 0.008. This provides very strong evidence that there was a structural change in Federal Reserve policy behavior between the regimes of Paul Volcker and Alan Greenspan. It is important to remember that the model for this subsample used a dummy variable to account for the "early Volcker" period, which was an era where the Fed conducted policy unlike any other period. Therefore, evidence of a break suggests that even without that unusual period, there was a still a change in the way the Federal Reserve conducted policy between the end 1979 and the beginning of 2006. This result contradicts Fair's results, but is similar to results found by Judd and Rudebusch.

The Greenspan/Bernanke period (1987M08 – 2007M08), on the other hand, showed different results. The break date tested was February 2006 when Ben Bernanke took the Chair. The F-statistic was approximately 0.478 with a p-value of 0.903. This high p-value suggests there was no breakpoint at that specified date. It is important to keep in mind that the sample size ends in 2007, although Bernanke remained in office until 2014. In 2008, the Fed implemented nontraditional tools and the federal funds rate dropped virtually to zero. Therefore any results found reflect the Fed policy behavior between Chairmen Greenspan and Bernanke before the financial crisis of 2008, and no conclusions can be drawn for the reaction function after the crisis.

Similar to the residuals from the OLS regressions, the errors in these subsamples are non-normal. The full sample period has a skew of 0.148 and a kurtosis of 13.108. This resulted in a JB-statistic of approximately 2415.643, which strongly suggests rejecting the null hypothesis of normality. The residuals from the Greenspan/Bernanke period would be considered the closest to being normal compared to the other regressions, however there is still strong evidence to reject normality. The error terms had a skew of -0.376 and a relatively high kurtosis of 4.934. This resulted in a JB-statistic of approximately 43.244. The calculated JB-statistic is larger than the critical value of 5.99, which provides strong evidence that the residuals do not have a normal distribution. Table 7 provides details of the residual diagnostics from the dynamic regressions.

Conclusion

My study primarily combined the ideas of Judd and Rudebush, and Fair. The equation I used was built using Taylor's original rule as a foundation, similar to the way Judd and

Rudebusch created their equation. However, I used monthly rather than quarterly data, a wider sample period and slightly different explanatory variables. I used the PCE measure of inflation instead of the GDP-deflator, the unemployment gap instead of the output gap, and used several lagged values of the variables. Like Fair, I also included an interaction dummy term for the "early Volcker" period.

Since my study included more years, I was able to perform tests for the Martin and the Bernanke periods. In my study, I found that the Fed changed their behavior between each Fed Chairman since 1960, except between Alan Greenspan and Ben Bernanke's regime before the financial crisis of 2008.

Overall, my results were consistent with the results of Judd and Rudebusch. Fair argued that if Judd and Rudebusch had used a dummy variable for the "early Volcker" period, they would have likely found evidence for the null hypothesis of no structural break. I did include a dummy variable, yet I still found moderate evidence of a structural break between the Burns/Volcker period and strong evidence of a break between the Volcker/Greenspan period. So in contrast to Fair, I found evidence of a break before and after the Volcker regime.

In contrast to Taylor's original equation, I found a higher coefficient on the unemployment gap. This suggests that the Federal Reserve is quicker to react to the gap in unemployment compared to their reaction to inflation. The impact of their short run reaction to the unemployment is approximately –0.68, whereas Taylor suggested only a 0.5 coefficient. The impact of the short-run response to inflation is approximately 0.05, which is what Taylor suggested in his original model.

Unfortunately my research contains limitations, but that allows room for expansion on this topic. For example, a dummy variable could be added to account for the FOMC meeting times which could occur at the beginning of a month, in the middle, or at the end of a month. When their meeting is held will affect how they react to incoming information. Including such a dummy variable may help explain the non-normal pattern of the error terms. Using real-time data rather than historical data may also improve the model. Additionally, further analysis should be done on the differences between the long-run effects I found and the long-run effects Taylor found.

Despite my limitations, my research still improves the field of economics as we look at how the Fed has changed over the years. As the Federal Reserve System grows older, they mature in how they conduct monetary policy. Over the years, and through recessions, the Federal Reserve can learn what they did right and what they did wrong and use that information when conducting current policies in order to produce the correct amount of stimulus in the economy. My studies can help provide insight on how the Fed changed their policy behavior over time. Some changes were explicitly stated, such as which goal they focus on; however some changes may not be as apparent at that time. My model can be used to compare the Fed's response to inflation and unemployment on the federal funds rate across the different chairmen. Hopefully policy makers will then be able to keep a stable reaction function in the future as they continue to mature.

Appendix

Figure 1: Taylor's Rule vs. Effective Federal Funds Rate

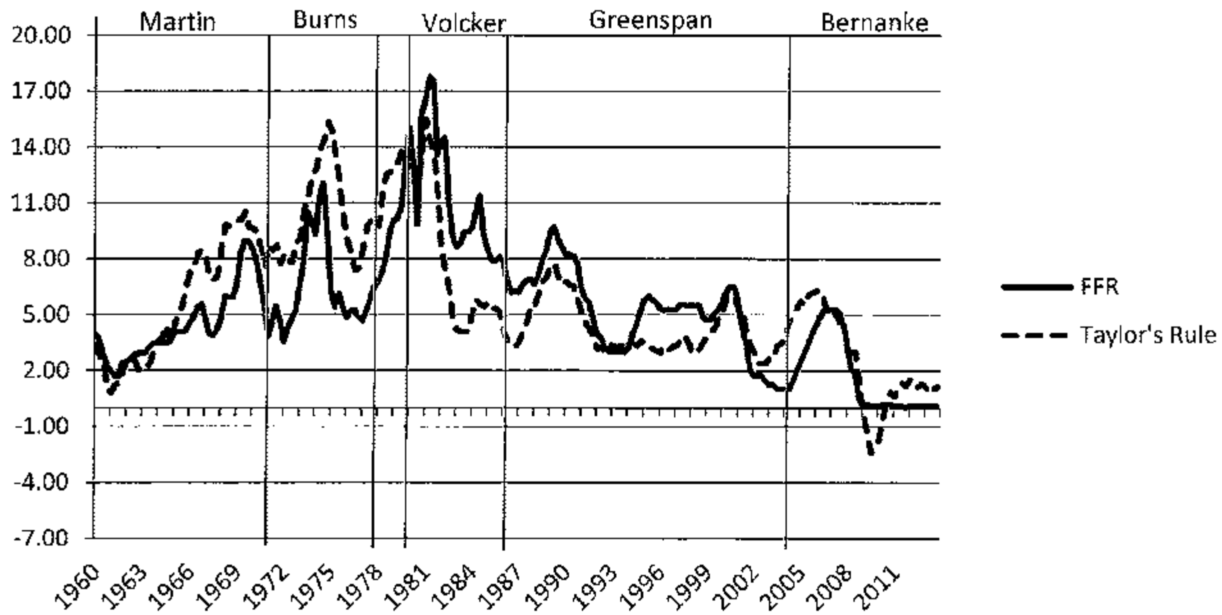

Figure 2: Yellen vs Taylor vs. Effective Federal Funds Rate

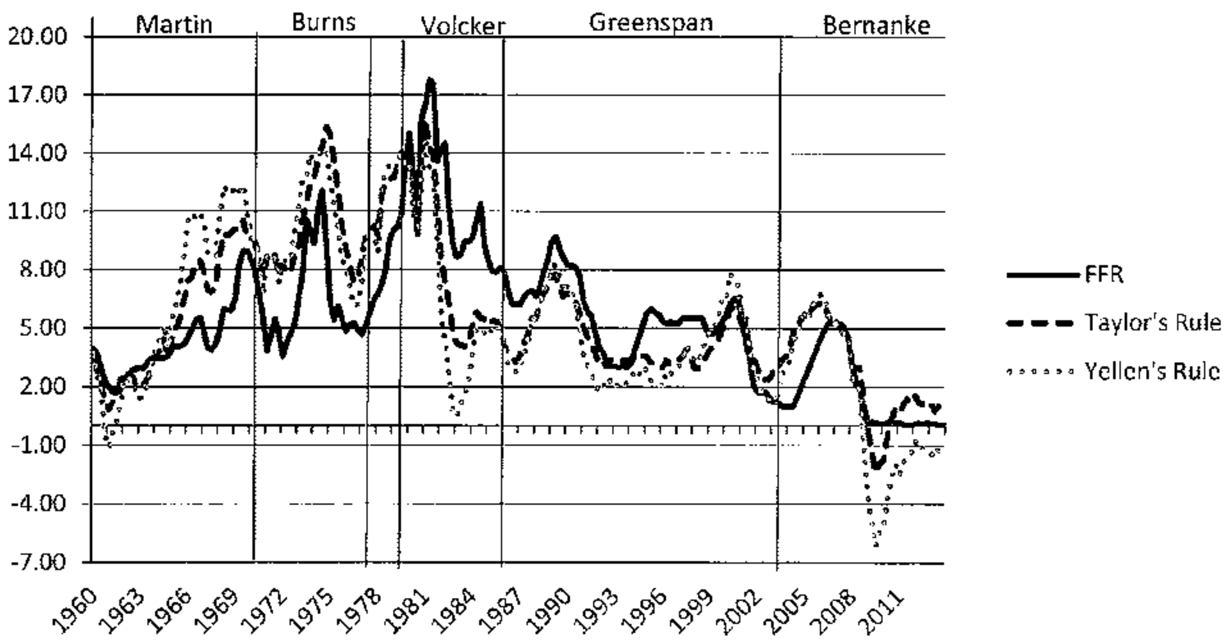

Figure 3: PCE Inflation

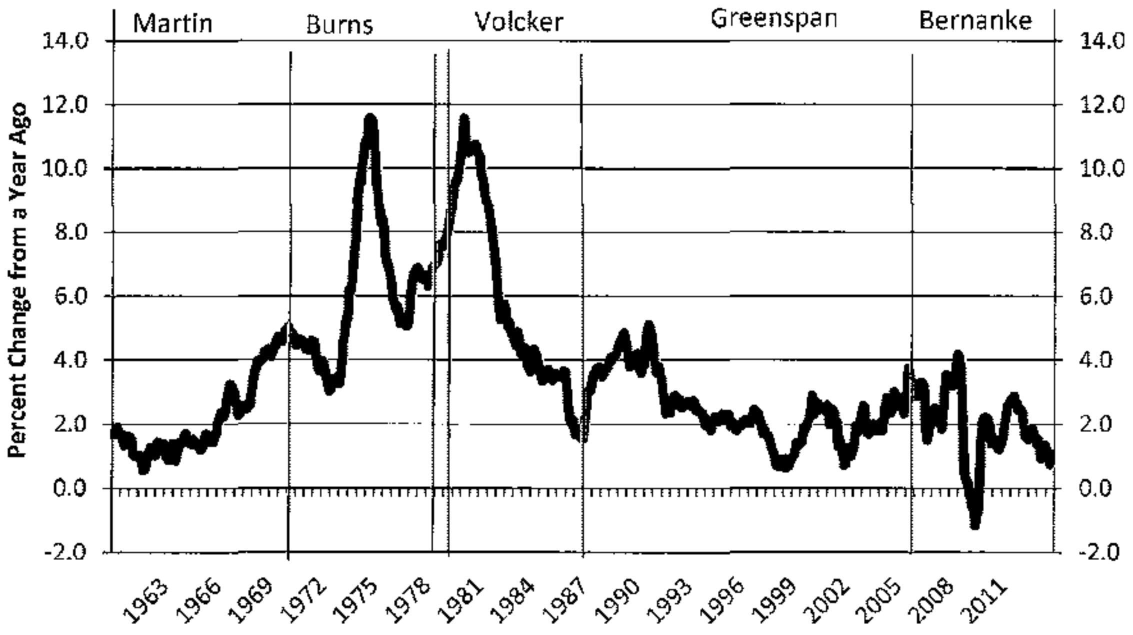

Table 1: Statistical Summary (1960M01 – 2007M08)

	ΔFFR_t	FFR_t	PCE_t	UG_t	DCC	DV
Minimum	-6.63	0.98	0.50	-2.44	0.00	0.00
Maximum	3.06	19.10	11.58	4.70	1.00	1.00
Mean	0.00	6.09	3.70	0.18	0.00	0.07
Median	0.01	5.45	3.00	0.04	0.00	0.00
Std. Dev.	0.57	3.30	2.51	1.30	0.04	0.25
Skewness	-2.14	1.22	1.35	0.50	23.83	3.48
Kurtosis	41.53	5.12	4.25	3.84	569.00	13.10
Jarque-Bera	35755.46	249.1749	209.204	40.68606	7675905	3577.129
Probability	0	0	0	0	0	0

Figure 4: Effective Federal Funds Rate

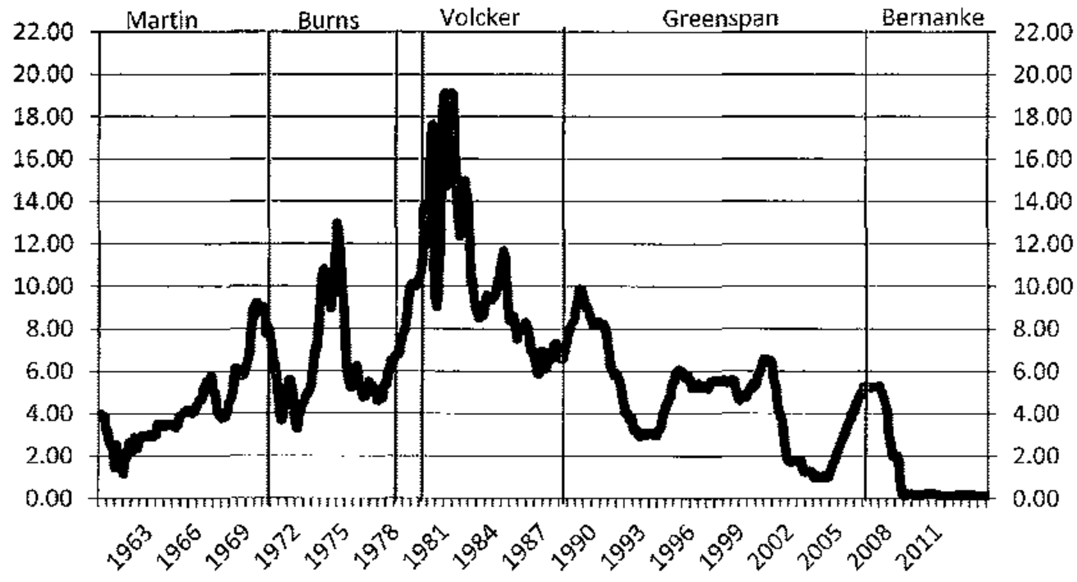

Figure 5: Unemployment Rate

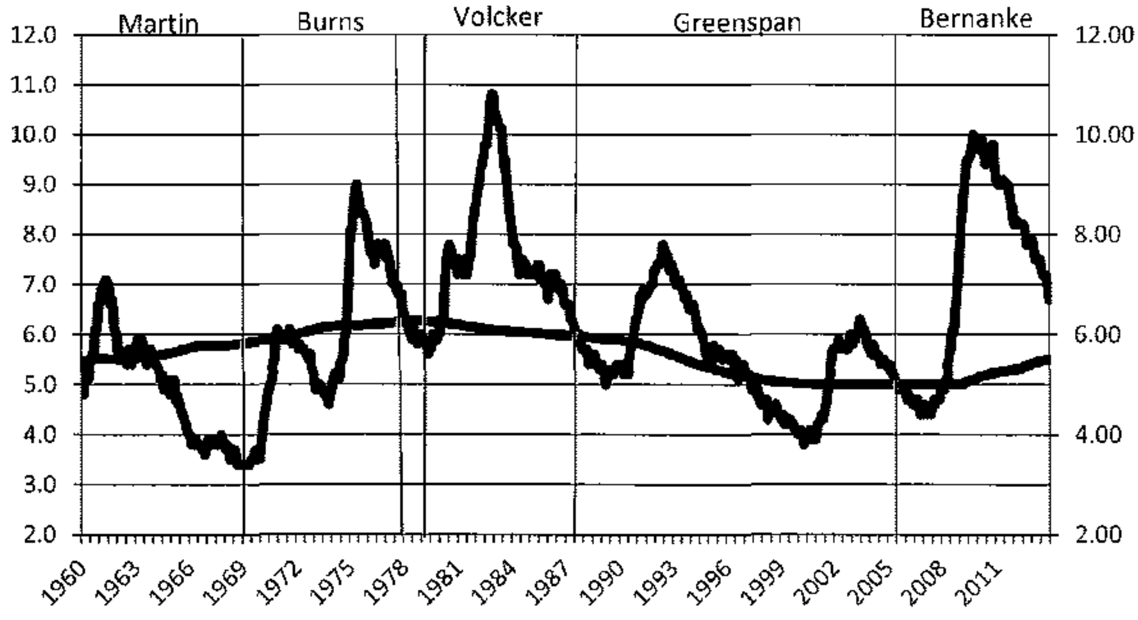

Table 2: Correlation Coefficients

	ΔFFR_t	FFR_t	PCE_t	PCE_{t-1}	UG_t	UG_{t-1}	UG_{t-2}	FFR_{t-1}	ΔFFR_{t-1}	ΔFFR_{t-2}	ΔFFR_{t-3}	ΔFFR_{t-4}	DCC	DV
ΔFFR_t	1.000													
FFR_t	0.085 *	1.000												
PCE_t	0.019 +	0.737 **	1.000											
PCE_{t-1}	0.005	0.738 **	0.995 **	1.000										
UG_t	-0.143 **	0.110 **	0.159 **	0.186 **	1.000									
UG_{t-1}	-0.112 **	0.091 *	0.132 **	0.159 **	0.991 **	1.000								
UG_{t-2}	-0.072 +	0.078 +	0.107 *	0.132 **	0.981 **	0.991 **	1.000							
FFR_{t-1}	-0.089 *	0.985 **	0.734 **	0.737 **	0.135 **	0.110 *	0.091 *	1.000						
ΔFFR_{t-1}	0.382 **	0.151 **	0.031	0.019	-0.158 **	-0.143 **	-0.112 **	0.085 *	1.000					
ΔFFR_{t-2}	-0.002	0.151 **	0.042	0.031	-0.171 **	-0.158 **	-0.143 **	0.151 **	0.382 **	1.000				
ΔFFR_{t-3}	-0.091 *	0.135 **	0.052	0.042	-0.187 **	-0.171 **	-0.158 **	0.151 **	-0.001	0.381 **	1.000			
ΔFFR_{t-4}	-0.130 **	0.113 **	0.066	0.052	-0.190 **	-0.187 **	-0.171 **	0.135 **	-0.091 *	-0.011	0.381 **	1.000		
DCC	-0.486 **	0.062	0.117 **	0.122 **	0.035	0.016	-0.004	0.146 **	0.031	0.224 **	0.023	0.003	1.000	
DV	-0.003	0.656 **	0.548 **	0.559 **	0.271 **	0.246 **	0.223 **	0.657 **	-0.003	0.028	0.050	0.053	0.157 **	1.000

Table 3: OLS Regression Results with HAC Standard Errors

Coefficient (Std. Error)	Full Sample ('60:1 - '07:8)	Martin ('60:1 - '70:1)	Burns ('70:2 - '78:1)	Miller ('78:2 - '79:7)	Volcker ('79:8 - '87:7)	Greenspan ('87:8 - '06:1)	Bernanke ('06:2 - '07:8)
C	0.078165 *	0.149996 *	0.325955 *	-0.9754	0.5807 +	0.030067	0.558091 *
	(0.036819)	(0.060584)	(.150831)	(1.664170)	(0.390374)	(.034099)	(0.267883) +
$PCE+PCE_{t-1}$	0.022916 **	0.073866 *	0.078487 **	0.249681 +	0.072529 **	0.01276 *	0.058066
	(0.006805)	(0.032409)	(0.020832)	(0.170415)	(0.040564)	(.006294)	(0.031992)
UG	-0.57038 **	-0.20316	-0.57494 **	-0.86535 +	-0.46847	-0.24953 **	-0.01098
	(0.111751)	(.163980)	(.209137)	(0.555439)	(0.341016)	(.090324)	(0.148520)
UG_{t-1}	-0.1543	-0.11932	-0.01242	-0.32398	-0.46482	-0.1339	-0.27831 **
	(0.149932)	(.238553)	(.254817)	(0.248456)	(0.559145)	(.113338)	(0.218717)
UG_{t-2}	0.658186 **	-0.28663 *	0.42656 **	0.56655	0.910898 *	0.354855 **	-0.46092 *
	(0.141246)	(.139869)	(.161959)	(0.454542)	(0.498978)	(.079443)	(0.250139)
FFR_{t-1}	-0.04273 **	-0.11639 **	-0.18741 **	-0.35652 **	-0.14187 **	-0.01921 **	-0.23166 **
	(0.100759)	(.035180)	(.043399)	(0.098875)	(0.051416)	(.005833)	(0.061373)
ΔFFR_{t-1}	0.318765 **	0.12174	0.378518 **	0.501989	0.328584 **	0.33711 **	-0.57068 +
	(0.071020)	(.137625)	(.095185)	(0.319760)	(0.107875)	(.062850)	(0.349107)
ΔFFR_{t-2}	-0.0375	-0.07751	0.288205 **	0.508975	-0.02741	0.073189	0.278647 *
	(0.084097)	(.089980)	(.089229)	(0.361320)	(0.121154)	(.097351)	(0.499906)
ΔFFR_{t-3}	-0.07404	0.430767 **	-0.14112	0.118264	-0.08558	0.159732 *	0.691102 **
	(0.071875)	(.106410)	(.121186)	(0.271057)	(0.105732)	(.081688)	(0.213327)
ΔFFR_{t-4}	-0.12495 *	0.015646	-0.01374	0.36317 **	-0.11449	-0.00815	0.198915
	(0.051354)	(.091389)	(.113043)	(0.099966)	(0.089672)	(.08688)	(0.199864)
DCC	-6.33661 **	--	--	--	-6.06101 **	--	--
	(0.362063)	--	--	--	(0.571531)	--	--
DV*PCE	0.063687 **	--	--	--	0.056418	--	--
	(0.015288)	--	--	--	(0.067024)	--	--
Adj. R^2	0.509142	0.222962	0.452286	0.387176	0.601071	0.424817	0.736043
SER	0.402531	0.264672	0.392204	0.174044	0.761098	0.155113	0.055182
D.F	554	104	86	8	84	212	9
DW	1.94231	2.001441	2.06241	2.144254	1.872205	2.034466	1.916119

** 1% Signficance Level

* 5% Significance Level

+ 10% Signifiance Level

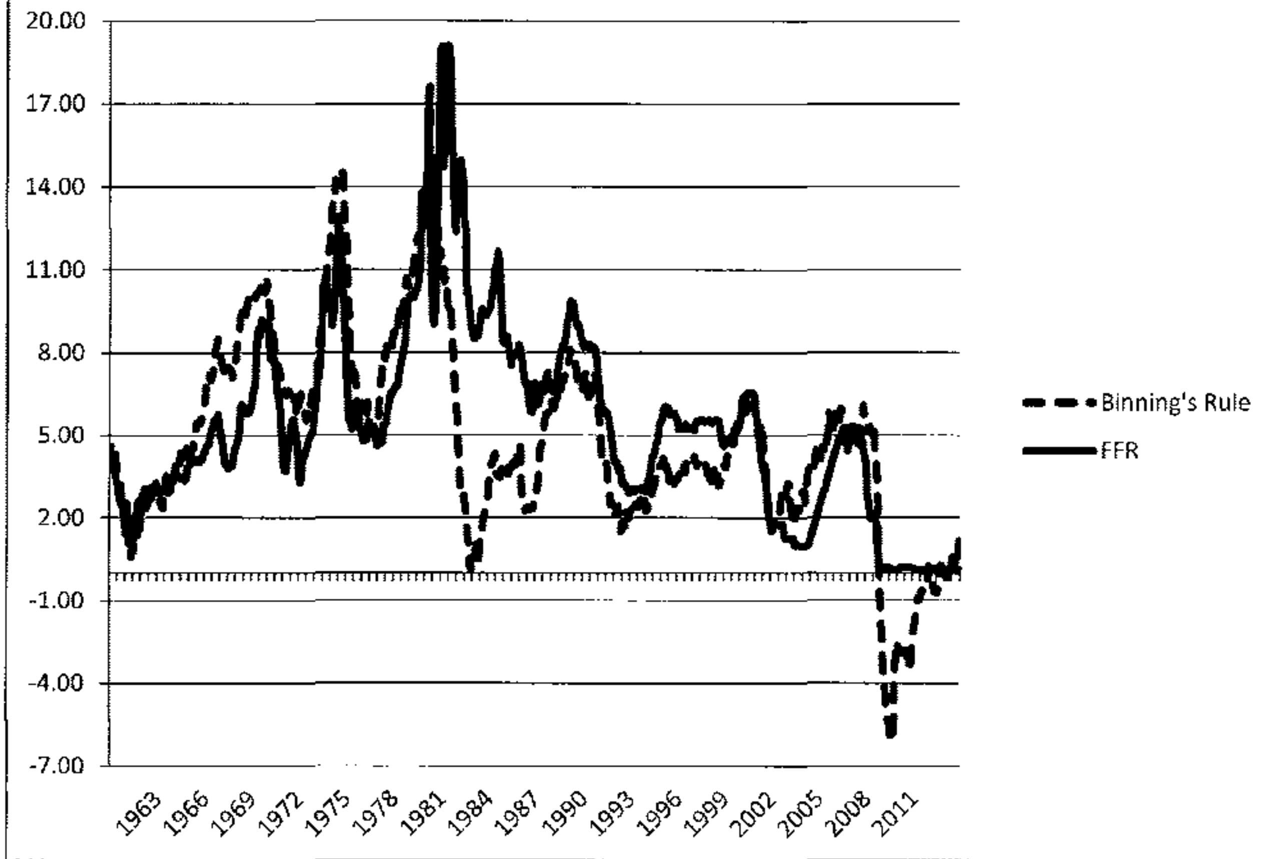

Figure 6: Binning's Rule vs. Effective Federal Funds Rate

Table 4: Residual Diagnostics – OLS Regressions

	Full Sample ('70:1 - '07:8)	Martin ('60:1 - '70:1)	Burns ('70:2 - '78:1)	Miller ('78:2 - '79:7)	Volcker ('79:8 '87:7)	Greenspan ('87:8 - '06:1)	Bernanke ('06:2 - '07:8)
Minimum	-2.796	-0.501	-1.066	-0.260	-2.355	-0.679	-0.071
Maximum	2.205	1.030	1.499	0.287	2.068	0.421	0.063
Mean	3.00E-17	-5.60E-17	8.38E-17	6.02E-16	4.63E-17	-1.53E-17	-5.11E-18
Median	-0.015	0.000	-0.001	0.007	-0.008	0.001	0.003
Std. Dev.	0.399	0.254	0.373	0.119	0.716	0.152	0.039
Skew	0.136	1.104	0.654	0.017	0.119	-0.364	-0.219
Kurtosis	13.056	6.390	5.418	4.024	4.760	4.756	2.298
JB-statistic	2386.442	79.138	30.241	0.788	12.621	33.431	0.542
[p-value]	[< 0.001]	[< 0.001]	[< 0.001]	[0.674]	[< 0.001]	[< 0.001]	[0.763]

Table 5: Dynamic Estimation

Coefficient [Std. Error]	Full Sample ('60:1 - '07:8)	Martin/Burns ('60:1 - '78:1)	Burns/Miller ('70:2 - '79:7)	Miller/Volcker ('78:2 - '87:7)	Burns/Miller/Volcker ('70:2 - '87:7)	Volcker/Greenspan ('79:8 - '06:1)	Greenspan/Bernanke ('87:8 - 2007:8)
γ	0.041772 **	0.1084 **	0.15809 **	0.14086 **	0.04827 **	0.05802 **	0.01912 **
	[0.010670]	[0.024537]	[0.040651]	[0.044723]	[0.019952]	[0.013998]	[0.005638]
α	1.695571 **	1.7072 **	1.32388 *	4.73979 **	2.94026	0.19579	1.21987
	[0.662578]	[0.458701]	[0.711064]	[0.908666]	[2.899665]	[0.864479]	[1.549221]
λ_1	-0.89016 **	-1.191 **	-1.0689 **	-1.2895 **	-1.0901 *	-0.0276	-0.5531
	[0.223619]	[0.125855]	[0.108303]	[0.185275]	[0.518318]	[0.333063]	[0.643420]
λ_2	13.73446 **	3.5987 *	4.06944 **	3.61156 +	14.5737 *	10.4105 **	11.867 *
	[4.016648]	[1.871966]	[1.398148]	[2.453807]	[8.362178]	[2.729425]	[5.837891]
λ_3	3.755708	1.0571	0.84636	2.82495	5.73698	4.40364	7.69244
	[3.627304]	[1.636788]	[1.413593]	[3.787849]	[6.915293]	[4.431580]	[5.389610]
λ_4	-15.8771 **	-3.574 **	-3.2378 *	-6.4051 +	-18.451 *	-13.437 **	-18.132 **
	[4.721866]	[1.415382]	[1.417974]	[4.169813]	[9.482621]	[4.243245]	[6.186241]
ρ_1	0.31877 **	0.3026 **	0.3775 **	0.33627 **	0.3043 **	0.30722 **	0.3386 **
	[0.071428]	[0.077797]	[0.087517]	[0.106028]	[0.056064]	[0.091396]	[0.061967]
ρ_2	-0.03774	0.128	0.28192 **	-0.0261	-0.0287	-0.0692	0.07611
	[0.084114]	[0.082821]	[0.079664]	[0.115940]	[0.060156]	[0.098833]	[0.095704]
ρ_3	-0.07436	0.1149	-0.1497	-0.0849	-0.1331 *	0.1016	0.16222 *
	[0.071738]	[0.124719]	[0.115180]	[0.103920]	[0.057955]	[0.083769]	[0.080140]
ρ_4	0.124822 *	-0.063	-0.025	-0.1094	-0.1237 *	-0.1406 *	-0.0103
	[0.051428]	[0.090705]	[0.123171]	[0.083500]	[0.054860]	[0.061090]	[0.085986]
β_1	-6.33388 **	--	--	-6.0420 **	6.1704 **	6.1643 **	--
	[0.363459]	--	--	[0.534526]	[0.649526]	[0.429598]	--
β_2	0.062545 **	--	--	0.08783 **	0.07446 **	0.02944	--
	[0.015236]	--	--	[0.024483]	[0.018344]	[0.019347]	--
Adj. R^2	0.508308	0.2854	0.46656	0.60608		0.58707	0.42484
SER	0.4058	0.3554	0.3658	0.69794	0.5549	0.43797	0.15084
D.F	554	201	103	101	197	305	230
DW	1.943131	2.0425	2.07485	1.86462	1.88778	1.88202	2.03398
Break Date	--	1970:2	1978:2	1979:8	1979:8	1987:8	2006:2
F-stat	--	4.3529	0.23351	0.1379	1.91742	2.30439	0.47833
[p-value]	--	[<0.001]	[.9922]	[0.9997]	0.0346	[0.0081]	0.903
Break?	--	Yes	No	No	Yes	Yes	No

** 1% Signficance Level

* 5% Significance Level

+ 10% Signifiance Level

Table 7: Residual Diagnostics – Dynamic Regressions

	Full Sample ('60:1 - '07:8)	Martin/Burns ('60:1 - '78:1)	Burns/Miller ('70:2 - '79:7)	Miller/Volcker ('78:2 - '87:7)	Burns/Miller/Volcker ('70:2 - '87:7)	Volcker/Greenspan ('79:8 - '06:1)	Greenspan/Bernanke ('87:8 - '07:9)
Minimum	-2.792	-1.081	-1.1939	-2.374336	-12.34081	-2.533151	-0.679322
Maximum	2.219	1.731	1.430794	2.156909	2.1702	2.119596	0.42423
Mean	-4.79E-16	-1.30E-15	-1.42E-13	2.76E-11	-5.88E-02	-1.37E-09	-1.29E-13
Median	-0.012	-0.201	0.003193	-0.004578	-0.021647	-0.018963	0.002218
Std. Dev.	0.398	0.348	0.350928	0.663096	1.03006	0.4303	0.147981
Skew	0.148	0.961	0.384605	0.09874	-8.057272	0.080133	-0.375803
Kurtosis	13.108	7.048	5.750029	5.600891	97.84807	12.41374	4.934307
JB-statistic	2415.643	177.333	38.73315	32.31724	80988.56	1174.537	43.24397
(p-value)	[< 0.001]	[< 0.001]	[<0.001]	[<0.001]	[< 0.001]	[< 0.001]	[< 0.001]

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