The evolving role and definition of the federal funds rate in the conduct of U.S. monetary policy

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In the Conduct of U.S. Monetary Policy

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ABSTRACT: The federal funds rate has become known conventionally as the Federal Reserve's "instrument" of policy. This fails to recognize that the funds rate is an endogenously determined price that can be influenced by shifts in the demand for reserves or other conditions in credit markets; indeed, recognizing just this possibility, Bernanke and Blinder (1992) chose to label the funds rate as an indicator variable, one that merely signaled the thrust of monetary policy actions. Because the Fed's ability to control the funds rate and the issue of endogeneity is central to modeling questions in monetary economics, we apply various statistical methods to offer evidence on whether the funds rate is best characterized as an instrument, intermediate target or indicator variable.

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Discussions of the federal funds rate over the past four decades have altered its definition within the hierarchy of the monetary policy mechanism and, in doing so, have suggested fundamentally different null hypotheses about relationships among macroeconomic time series. For example, in the classic debates between Keynesian and monetarist schools of thought in the 1960s and 70s, the funds rate was viewed conventionally as an *intermediate target* of monetary policy.[1] Later, in one of the most widely-cited papers of the early 1990s, Bernanke and Blinder (1992) referred to the funds rate as an *indicator variable* for monetary policy actions. By the end of the decade, however, it had become conventional wisdom to refer to the funds rate as the Fed's monetary policy *instrument* and, more important, to model the funds rate accordingly as an exogenously-determined variable. [2]

Whatever the proper denotation for the funds rate might be at any moment in time, the alternative designations given to the funds rate are not interchangeable. Each implies a very specific role within the structure of how monetary policy is conducted and, for empirical purposes, each implies specific null hypotheses about relationships between the funds rate and the behavior of other aggregate time series. Surprisingly, however, many of these relationships have been accepted on faith and have not been tested in any systematic way. This paper offers evidence on the alternatives and re-examines whether, at this moment in history, the funds rate is best classified as instrument, intermediate target or indicator variable of the Federal Reserve's monetary policy actions. The evidence suggests that the funds rate contains little unique information relative to its role as an indicator variable. Moreover, evidence of significant non-linearities among variables in a small VAR suggest that attempts to implement monetary policy through a Taylor Rule framework – beyond the conceptual difficulties already noted elsewhere [3] -- would complicate the task far beyond what has been implied to this point.

Terminology

Tobin (1969) identified three types of variables inherent in discussions of monetary policy: Instruments, targets and intermediate variables. In his taxonomy, instruments are variables controlled completely by actions of the central banker. Targets are variables that the central banker is trying to control, either to reach a particular level or to minimize variations around a desired level; because variables of this type came to be called “intermediate targets” in standard discussions, this paper uses the term “goal” in place of “targets” when referring to the objectives of monetary policy. Intermediate variables, in Tobin’s framework, are those that lie between the instrument(s) and the goal(s). Finally, one other type of variable not discussed by Tobin – *an indicator* – is a variable that may not be controlled by the Fed’s actions but is considered by the public to be informative about the thrust of monetary policy and its future impacts on the central banks goal variable(s). This nomenclature, relative to the funds rate, is investigated in this paper because Bernanke and Blinder (1992) among others have referred to the funds rate in this fashion.

Having drawn these distinctions, the conduct of monetary policy can follow one of two paths. The simpler alternative is one which eliminates the intermediate variable and exploits a direct link between the instrument and goal as in (a) below.

(a) Instrument => Policy Objective

One example is Boschen and Talbot (1981), which examined the association between the growth rate of the monetary base and the inflation rate; another example is the nominal GDP targeting plan developed by McCallum (1988).

The more complicated alternative is an intermediate targeting strategy in which the central bank’s instrument is used to influence the path of an intermediate target because the link between the instrument and ultimate goal of policy is imprecise. The path of the intermediate target variable, however, it believed to be connected closely with the desired path of the goal variable so, by influencing it, the central bank’s objective can be moved in the desired direction. This framework is shown in (b).

(b) Instrument => Intermediate Target => Policy Objective

In the case of monetary targeting, the Fed would use open market operations to determine a growth rate for bank reserves or the base (its instrument) to pursue a path for money growth (the intermediate target) it thought was consistent with a rate of inflation determined to be the ultimate goal of the Fed's policy actions. In the case of fed funds rate targeting, the Fed again would use open market operations to manipulate the supply of reserves to keep the funds rate at its targeted level. This level of the funds rate, through some economic model, would be connected to a desired outcome for the Fed's actions.

Other things the same, the choice between policy strategies (a) and (b) depends on the nature of the covariance between the two sources of error in the second mechanism – the "control error" between the actual and desired paths of the intermediate target and the "projection error" between the desired and actual paths of the policy objective. [4] A deeper argument, however, divided monetarists and Keynesians in the 1960s and the same argument still is germane to any current investigation of empirical properties of the funds rate. One criticism of the so-called monetarist approach was the assertion that the quantity of money was determined *endogenously* and, as such, its out-of-sample path could not be predicted reliably. Instead, holders of this position argued, the Fed could control short-term interest rates and, on that basis, should conduct monetary policy with the funds rate as its intermediate target. In the other camp, advocates for money as the Fed's intermediate target presented evidence that narrow aggregates, over periods of a quarter, were related closely to non-borrowed reserves and, by implication, whatever endogeneity of very short-run money growth might exist, it could be offset by use of the Fed's exogenous instrument (non-borrowed reserves) to keep the intermediate target (narrow money) on its desired path.

<u>Is the Funds Rate a Policy Instrument?</u>

Using Tobin's taxonomy as a guide and either (a) or (b) as strategies for the implementation of monetary policy, it seems clear that, for the federal funds rate to be designated as the *instrument* of monetary policy, it must satisfy at least one statistical condition: It must be strictly exogenous to other relevant economic time series. Superficially, if the period of observation is sufficiently short, there is little disagreement that the Fed can control the value of the funds rate by its ability to conduct open market operations and control the entire supply side of the reserves market. Monetary policy goals, however, typically are stated in terms of the inflation rate, unemployment or output, all variables that evolve over the cycle and, when evaluated over periods of months or quarters, it becomes less clear that the Fed has complete ability to control the funds rate. The reason to question the Fed's ability to control the funds rate is that, at lower frequencies, changes in the demand for reserves become a potential influence on their market price.

The market for reserves is depicted in Figure 1. The perfectly inelastic supply curve represents the quantity of reserves the Fed has supplied to the market, via open market operations, at time t. The demand for reserves is the banking system's demand and its position is influenced primarily by the private sector's demand for loans. Panel A depicts what is labeled as an "official interpretation" of changes in the funds rate: The demand for reserves is static and all changes in the funds rate occur only because of the Fed's open market operations and shifts in the supply of reserves provided to the banking system. Panel B depicts an "alternative interpretation" in which the private sector demand for loans moves cyclically with real income. [5] In this representation, the observed value of the funds rate would change because of changes in the public sector's demand for loans. Moreover, if changes in the private sector's demand for credit generally were changing, it should be observed that other short-term interest rates were moving in conjunction with the funds rate if Panel B is a better description of how the funds rate evolves over time.

To distinguish between the alternatives empirically, we first conduct tests of Granger causality between the following pairs of variables. The first pair is the funds rate and total loans and leases. Recalling that the funds rate must be strictly exogenous to other influences if it is to be called the Fed's instrument, a finding of unidirectional or bi-directional causality from total loans and leases to the funds rate would be damaging to this designation. In terms of economics, this statistical finding merely would indicate that movements in the demand for reserves are significant in determining the value of the funds rate, an observation counter to the conventional wisdom that the funds rate is strictly under the Fed's control

A second test of causality can be carried out between the funds rate and the three-month T-bill rate. Under this conjecture, changes in the market demand for credit will move market rates in general and, in particular, the short term market rate (the T-bill rate). If the Fed, as it has been implementing policy for most of the past four decades, is attempting to maintain the fed funds rate at a pre-determined target value and market rates change in response to a change in the demand for credit (and, presumably, a change in real income), the Fed may have to alter its target for the funds rate at some point to "catch up" with credit market conditions. In this case, causality will be found to run not from the funds rate to the T-bill rate but in the opposite direction. As in the previous case, this result will be damaging to claims that the funds rate is the Fed's monetary policy instrument.

Finally, the most direct test of the funds rate as policy instrument can be conducted by examining the relationship between it and bank reserves. Unlike the funds rate, which is a market-determined price, the quantity of reserves is product of the Fed's open market operations. Unidirectional causality running from reserves to the funds rate would establish reserves as the Fed's instrument of policy and relegate the funds rate to another role – perhaps indicator or intermediate target – as it was thought at the beginning of the decade.

<u>Results</u>

The three relationships discussed above were examined over two sample periods using monthly data. The sample periods are: 1960 – 1979 and 1985 – 2007. The first sample pre-dates the experiment with monetary targeting and the worst of the high inflation experience. This sub-sample, however, covers the period when the United States still was under the Gold Standard and during which it conducted some specific interest rate experiments such as "Operation Twist." The second sample begins after the experiment with monetary targeting had ended, inflation had been brought down substantially and the post-inflation recovery was well-established. Moreover, this latter period is one in which the Fed explicitly paid more attention to the funds rate as its target and the professional literature increasingly began to refer to the funds rate as the Fed's instrument of policy.

Prior to conducting these tests, however, each variable was tested for stationarity and results of these preliminary tests are reported in Table 1. The results indicate that funds rate, the three month T-bill rate and unemployment rate are stationary in first differences. The results for the remaining variables are mixed. The growth rate for the chained deflator for personal consumption expenditures is not stationary in either sub-sample. In the second period, the growth rates of non-borrowed reserves, total loans and leases made by commercial banks and real personal consumption expenditures also are non-stationary. The growth rate of real disposable personal income, the remaining variable to be considered, is stationary in both periods.

The upper panel of Table 2 reports the results of tests for Granger causality among these series for the pre-1979 sub-sample. Among the more interesting results is a finding of bi-directional causality between the T-bill rate and the funds rate. Strong unidirectional causation is found running from the funds rate to non-borrowed reserves as well as from total loans and leases to the funds rate. Whatever one is to make of these results – whether it is the influence of the Gold Standard on the Fed's operations or the identification of a Fed reaction function or some other phenomenon in the data – it is difficult to identify the federal funds rate as an exogenous policy instrument in the 1960 – 1979 period.

Results for the 1985 – 2007 sub-sample are reported in the bottom panel of Table 2 and only a few results differ from the earlier period. The growth rate of total loans and leases no longer Granger-causes changes in the funds rate and, unlike the earlier period, changes in the funds rate and the growth rate of non-borrowed reserves now are unrelated. Changes in the T-bill rate and the funds rate still exhibit strong bi-directional causality, however, with the T-bill rate, in terms of statistical significance, having the more dominant influence. Finally, although the specifics have changed in a few cases, the general results still seem to reject the specific proposition that the funds rate meets the exogeneity criterion required to be the Fed's monetary policy *instrument*.

For more insight on how these results might be interpreted, Granger (1980) offers these thoughts on the specific case of a policy variable where strong priors are held:

> "Some variables are such that prior beliefs will be strong that they are exogenous: An example is that weather is probably exogenous to the economy. However, other variables have often been considered to be exogenous yet need to be tested, the best examples being the control variables. One can argue that a government controlled interest rate is in fact partly determined by previous movements elsewhere in the economy, and so is not strictly exogenous. The true exogenous part of such a variable is that which cannot be forecast from other variables and its own past and it follows that it is only this part that has any policy impact. The theory of rational expectations is relevant here...........
>
> The effect of the presence of control variables on causality was considered by Sims (1977). It is certainly possible that the actions of a controller can lead to what appears to be a causal relationship between two variables. Equally, it is possible that two variables that would be causally related if no controls were used would seem to be unrelated in the presence of a control. It also may be worth pointing out that controllability is a much deeper property than causality, in my opinion, although some writers have confused the two concepts. If Y causes X, it does not necessarily mean that Y can be used to control X……It seems quite possible that some variables used in the past by governments to control may be so ineffectual that causation will not be found, so that testing is worthwhile. (p.) "

Finally, on another point crucial to the current discussion, Granger notes that "the possibility of 'instantaneous causation' obviously greatly complicates the problem of how to test for exogeneity." With the Fed typically conducting an Open Market Operation each day and the demand side of the fed funds market subject to changes in expectations as well as other influences within the monthly frequency of the data, this latter concern is very real.

In sum, testing for exogeneity remains a tricky proposition. When reviewing the economics of the reserves market, however, it seems clear that the funds rate is an endogenously-determined price and the supply of reserves an exogenously-determined quantity, even if its position is influenced by the desire of policy makers to engineer an intersection with the reserves demand curve such that a particular value for the funds rate prevails. With these priors about the economics of the federal funds market and the Granger causality tests in table 2, considering the federal funds rate as a policy "instrument" seems to be incorrect.

Is the Federal Funds Rate an Indicator Variable?

In their influential 1992 paper, Bernanke and Blinder labeled the federal funds rate as an *indicator* variable for monetary policy. Unlike any variable that is part of a monetary policy mechanism as described in either (a) or (b) earlier, an indicator variable is simply a variable that provides a reliable signal of the stance of monetary policy. The central bank is not presumed to control its behavior and is not presumed to be targeting a path for it but, if its behavior is monitored by the public, the signal in the funds rate will carry valuable information about the future behavior of the Fed's goal variables. Their study found the funds rate to be a strong indicator of monetary policy actions and in conjunction with negative empirical results for the Fed's official monetary aggregates, the funds rate began to receive more attention in both policy and academic circles as the 1990s progressed. [6]

By way of re-examining the influence of the funds rate on aggregate activity, bi-variate causality tests were conducted between the funds rate and four monthly data series likely to be consistent with the Fed's "dual mandate" to achieve goals for price stability and full employment: real disposable personal income (rdpi), real personal consumption expenditures (rpce), the aggregate price level (p, as measured by the Personal Consumption Expenditure Deflator) and the civilian unemployment rate (U). Prior to testing, all variables were differenced appropriately according to the ADF tests reported earlier. These results, for both sub-samples, are reported in Table 3.

For the pre-1980 sub-sample, the results indicate that changes in the funds rate had significant effects on both presumed goals of monetary policy: They led the inflation rate and changes in the unemployment rate. For proponents of a short-run Phillips Curve relationship and the Fed's ability to exploit the inflation-unemployment tradeoff by manipulating the funds rate, these results would be consistent with that story. A caution to this interpretation is that reverse causation also runs from changes in the unemployment rate to changes in the funds rate.

In the post-1984 period, when the Fed presumably focused more closely on an objective of price stability and announced specific targets for the funds rate in its implementation of monetary policy, changes in the funds rate no longer have a significant causal relationship with the inflation rate. Changes in the funds rate continue to show a causal influence on changes in the unemployment rate but, as in the earlier period, the causation is bi-directional. Changes in the funds rate also now show a significant influence on the growth in real disposable real income as well but strong reverse causation from growth in real personal consumption expenditures to changes in the funds rate not present in the earlier period now is found. Overall, in both sub-samples, changes in the funds rate do appear to contain information about future movements in aggregate variables likely to be the objectives of monetary policy actions and, as such, the funds rate can be thought of as an indicator variable. At the same time, movements in some of the candidate goal variables appear to contain information about future movements in the funds rate.

The results in Table 3, however, may overstate the influence, or information content, of changes in the funds rate if Granger's comments regarding innovations and the truly exogenous component of a series were to form the basis of testing. Accepting the notion that the part of the funds rate series that is relevant for discussions of policy is that part of the monthly changes which cannot be forecast from their own history and other variables, we estimate an equation of the form:

(1) $\Delta FF_t = a + b_1 * \Delta FF_{t-1} + b_2 * \Delta Tbill_{t-1} + b_3 * Release + e_t$

where Release is a dummy variable that takes a value of one beginning at 1994.02 to mark the point at which the Fed adopted a policy of announcing its policy change -- specifically, any change in its stated target value for the funds rate -- to the public immediately after FOMC meetings rather than with a 45-day lag as had been the case prior to this date. Although financial market participants had invested resources in trying to forecast what the Fed might do or, in fact, had done at a specific FOMC meeting before the February 1994 change in Fed practices regarding public release of its Directive, this date marks a fundamental change in the time series relationships between what the public believed to be true and what was formally announced to it in an official statement of what the Fed had decided to do.

Estimating the relationship in (1) produces an innovations series for the 1985.01 – 2007.12 period, which is shown in Figure 2. Experimenting with longer lags and inserting other variables, such as the reserves or loans series, did not add significant information to the results. And while the Release variable was not statistically significant, its inclusion was important for stability of the equation. Moreover, a Chow test found a significant breakpoint in the equation at 1994.02.

Perhaps the most interesting conclusion to be drawn from Figure 2 is that, after relatively large volatility in the period immediately following the abandonment of monetary targeting and, at least publicly, experimentation with the P-star model for inflation targeting, the fed funds innovations series has tended to vary within a symmetric 40 basis point band, centered on zero. A prominent deviation from this pattern, however, occurs in the slow-growth period of 2000 – 2002. Whether by accident or design, in the aftermath of its injections of liquidity prior to the Y2K phenomenon, the Fed engaged in highly contractionary reserves operations early in 2000; to some observers, the downturn in real activity that followed was a classical, monetary-induced recession. To others, the recession was the product of prior contractionary moves by Fed, as measured by increases in the federal funds rate from 4.75 percent in 1998 to 6.5 percent by early 2001. Data to support the alternative interpretations are shown in the upper and lower panels of Figure 3. Thus, while an economic downturn *did* occur (as designated by NBER) between March and November of 2001, the proximate cause – which transmission mechanism – linked a precise monetary policy action to the observed result is more a matter of accepted wisdom than by empirical testing.

Employing the innovations series for the funds rate allows us to re-estimate the causality relationships between measures of aggregate economic activity and a measure of monetary policy more in the spirit of rational expectations and more likely to meet the concept of exogeneity as discussed by Granger. The results of this experiment, for the 1985.01 – 2007.12 sub-sample, are reported in the top panel of Table 4.

When innovations in the funds rate replace actual changes in the funds rate, the results indicate that the significant information content of the funds rate disappears. Although there is a weak (prob. = 0.0_) association between innovations in the funds rate and the inflation rate, the only significant relationships in the table's top panel are reverse causation running from the growth rate of real personal consumption expenditures and changes in the unemployment rate to changes in the unemployment rate. Thus, at least for the measures of aggregate activity examined here, the exogenous component of changes in the funds rate appears to have a non-significant policy effect.

Repeating the same exercise for the growth rates of non-borrowed reserves indicates that innovations in reserves growth appear to have significant effects on two measures of real activity: Growth in real disposable personal income and real personal consumption expenditures. This finding is consistent with a traditional monetarist story that short-run deviations in quantitative variables (reserves, the monetary base or money) from the growth paths will have effects on real variables. The other significant finding, reverse causation from the inflation rate to innovations in the growth in non-borrowed reserves, could be interpreted as a result of inflation smoothing under a Taylor Rule environment: If the central bank responded to new information about inflation by changing its path for reserves growth, this behavior would explain this finding. This also is consistent with a feedback interpretation of the reverse causation running from real variables to the funds rate discussed above.

VAR Estimation

To this point, the funds rate has been examined in a piecemeal fashion, in bi-variate relationships with variables thought to have some potential to influence the behavior of the funds rate or variables commonly thought to be goals of monetary policy if the funds rate were the Fed's intermediate target variable. To examine the funds rate more systematically and allow for possible interactions among these variables, we estimated a VAR over the same two sub-samples and included in the model the eight variables that have been part of the foregoing analysis: the funds rate, the three-month T-bill rate, the unemployment rate, non-borrowed reserves, total loans and leases, real disposable personal income, real personal consumption expenditures, and the chained PCE deflator. As in the foregoing, each series is transformed and differenced appropriately prior to estimation. The results for the federal funds rate equation are shown in Table 5.

The first striking feature of this equation, for both sub-samples, is its relatively low explanatory power. In the pre-1980 period, lagged first differences in both the T-bill rate and the unemployment rate are significant in explaining changes in the funds rate, with a somewhat stronger effect coming from the unemployment rate. This finding is consistent with the earlier causality test results and the general idea that the Fed, prior to 1980, may have been implementing monetary policy with real activity as its primary objective. The results for the post-1984 sample indicate that, while both changes in the T-bill rate and unemployment rate still affect changes in the funds rate, the influence of the T-bill rate now is much stronger and its coefficient has more than doubled (from 0.20 to 0.46). As in the earlier causality test results, however, this closer association between changes in the T-bill rate and funds rate, leaves undetermined whether changes in the T-bill rate are the product of financial market conditions that subsequently cause the central bank to adjust the funds rate or whether the T-bill rate changes in response to changes in the funds rate. Whatever the case may be, the two interest rate series are linked more closely in the post-1984 sample and while the effect of changes in the unemployment rate on the funds rate remains.

<u>Testing for Nonlinearity</u>

The foregoing allowed more interactions among variables but maintained an assumption that relationships these series linear. The assumption of linearity may be tenuous in view of evidence to the contrary in regard to macroeconomic time series (see, e.g., Neftci (1984), Brock and Sayers (1988) and Valderrama (2007)). Moreover, when designing a feedback rule for monetary policy, such as a Taylor Rule, its success in implementation will depend on whether its assumptions of linearity are parsimonious with the behavior of the time series involved; evidence of significant non-linearities in the data would undermine an assumption of such rules and, at a minimum, call for a revision in them that would add a degree of complexity not currently displayed in their simple designs.

To test for nonlinearity in the series used in this paper, we utilize the research framework originally proposed in Hinich and Patterson (1995), which seeks to detect epochs of transient serial dependence in a discrete-time pure white noise process. [7] The procedure divides the full sample period into equal-length, non-overlapping, moving time windows of arbitrary length and then computes the portmanteau correlation, bi-correlation and tri-correlation test statistics (denoted as C, H and $H4$ statistics) for each window to detect linear and nonlinear serial dependence .

To understand the concept of the test, let the sequence $\{x(t)\}$ denote the sampled data process, where the time unit, t, is an integer. Because test procedure employs non-overlapped time windows, and we denote n as the window length, then the k-th window can be written as: $\{x(t_k), x(t_k+1), \ldots, x(t_k+n-1)\}$. The next non-overlapped window is

$\{x(t_{k+1}), x(t_{k+1}+1), \ldots, x(t_{k+1}+n-1)\}$, where $t_{k+1} = t_k + n.$ Define $Z(t)$ as the sequence of standardized observations obtained from:

$$Z(t) = \frac{x(t) - m_x}{s_x} \tag{1}$$

for each $t = 1, 2, \ldots, n$ where m_x and s_x are the sample mean and sample standard deviation of the window.

The null hypothesis for each time window is that the transformed data $\{Z(t)\}$ are realizations of a stationary pure white noise process. Thus, under the null hypothesis, the correlations $C_{ZZ}(r) = E[Z(t)Z(t+r)] = 0, \ \forall \ r \neq 0$, the bi-correlations $C_{ZZZ}(r,s) = E[Z(t)Z(t+r)Z(t+s)] = 0, \ \forall \ r, s$ except when $r = s = 0$, and the tricorrelations $C_{ZZZZ}(r,s,v) = E[Z(t)Z(t+r)Z(t+s)Z(t+v)] = 0, \ \forall \ r, s, \ and \ v$ except when $r = s = v = 0$. The alternative hypothesis is that the process in the window has some non-zero correlations, bicorrelations or tricorrelations in the set $0 < r < s < v < L$, where L is the number of lags that define the window. In other words, if there exists second-order linear or third- or fourth-order nonlinear serial dependence in the data generating process, then $C_{ZZ}(r) \neq 0, \ C_{ZZZ}(r,s) \neq 0, \ or \ C_{ZZZZ}(r,s,v) \neq 0$ for at least one r value or one pair of r and s values or one triple of $r, s \ and \ v$ values, respectively.

The r sample correlation coefficient is:

$$C_{ZZ}(r) = \frac{1}{\sqrt{n-r}} \sum_{t=1}^{n-r} Z(t)Z(t+r) \tag{2}$$

The C statistic is developed to test for the existence of non-zero correlations (i.e. linear dependence) within a window, and its corresponding distribution is:

$$C = \sum_{r=1}^{L} \left[C_{ZZ}(r)\right]^2 \approx \chi_L^2. \tag{3}$$

The (r, s) sample bicorrelation coefficient is:

$$C_{ZZZ}(r,s) = \frac{1}{n-s} \sum_{t=1}^{n-s} Z(t)Z(t+r)Z(t+s), \text{ for } 0 \le r \le s. \tag{4}$$

The H statistic is designed to test for the existence of non-zero bi-correlations (i.e. third-order nonlinear serial dependence) within a window, and its corresponding distribution is:

$$H = \sum_{s=2}^{L} \sum_{r=1}^{s-1} G^2(r,s) \approx \chi^2_{L(L-1)/2} \tag{5}$$

where $G(r,s) = \sqrt{n-s}\; C_{ZZZ}(r,s)$.

The (r, s, v) sample tri-correlation coefficient is:

$$C_{ZZZZ}(r,s,v) = \frac{1}{n-v} \sum_{t=1}^{n-v} Z(t)Z(t+r)Z(t+s)Z(t+v), \text{ for } 0 \le r \le s \le v. \tag{6}$$

The $H4$ statistic is designed to test for the existence of non-zero tri-correlations (i.e. fourth-order nonlinear serial dependence) within a window, and its corresponding distribution is:

$$H4 = \sum_{v=3}^{L} \sum_{s=2}^{v-1} \sum_{r=1}^{s-1} T^3(r,s,v) \approx \chi^2_{L(L-1)(L-2)/3} \tag{7}$$

where $T(r,s,v) = \sqrt{n-v} \times C_{ZZZZ}(r,s,v)$.

The autocorrelation structure in each window is removed by an autoregressive AR(*p*) fit, in which the number of lags is selected such that there is no significant C statistic at the specified threshold level. [8] It is worth highlighting that the AR fitting is employed purely as a pre-whitening operation, and not to obtain a model of best fit. The portmanteau bicorrelation and tricorrelation tests then are applied to the residuals of the fitted model of each data window such that any further rejection of the null hypothesis of pure white noise is due only to significant H or $H4$ statistics.

The number of lags L is specified as $L = n^b$ with $0 < b < 0.5$ for the correlation and bi-correlation test and $0 < b < 0.33$ for the tri-correlation test, where b is a parameter under the choice of the user. Based on the results of Monte Carlo simulations, Hinich and Patterson (1995, 2005) recommended the use of $b = 0.4$ (in relation to the bi-correlation test) which is a good compromise between: (1) using the asymptotic result as a valid approximation for the sampling properties of H statistic for moderate sample sizes; and (2) having enough sample bi-correlations in the statistic to have reasonable power against non-independent variates. In making a choice about the length of the windows for the test, a tradeoff is faced between increasing the power the test with longer lags increasing the uncertainty on the event time when the serial dependence occurs. The choice also is constrained by the number of available observations. In this study, the data are split into non-overlapping moving time windows of twenty four observations. [9] A small portion of the results of these tests for the pre-1980 sample are reported in Table 6; the results for the post-1984 sample period are reported in Table 7.

The general story of tables 6 and 7 is that the relationships among the variables in the eight variable VAR are subject to episodic non-linearities not captured within the framework of a simple feedback system such as a Taylor Rule. For example, in the pre-1980 sub-sample, the residuals from the rate equation and the non-borrowed reserves equation are revealed to share a non-linear relationship in two different frames (1961.03 – 1963.02 and 1975.03 – 1977.02) and to indicate several different types of significant relationships: significant 3rd order nonlinear bicovariance (xxy) and significant 3rd order nonlinear bicovariance of the covariance of y with the level of x (yyx). This same window appears to be important for other relationships as well, revealing significant non-linearities between the residuals from the funds rate and loans equations, the residuals from the non-borrowed reserves equation against the residuals from, respectively, the loans, inflation, and T-bill rate equations. The funds rate and inflation also are related in the second frame (1963.03 – 1965.02).

In the post-1984 sub-sample, only the particular results are changed but episodic non-linearity is again present among the VAR's key variables. Frame 1 (1985.01 – 1986.12) now appears to be the key window for significant results but the 1997.01 – 1998.12 window (frame 7) also produces evidence of non-linearity. As in the earlier period, residuals from the funds rate equation and the non-borrowed reserves equation again produce several significant statistics (yyx, yyy) but now, the funds rate residuals also are related to the residuals of the T-bill rate equation in a significantly non-linear way (yyx, yyy) in the seventh frame. As in the earlier sub-sample, the residuals from the non-borrowed reserves equation show a significant relationship with the residuals from the loans, inflation and T-bill rate equations. Over all, not only are the residuals from the eight equations in the foregoing VAR not independent but they share, at least for episodes in the data, complex non-linear relationships are inconsistent with the linear, time-invariant structure of simple feedback rules such as a Taylor Rule.

Conclusions

The federal funds rate is the centerpiece of monetary policy in the United States. For more than a decade, economists have referred to it as the central bank's *instrument* of policy, presuming that it is an exogenous variable that can be set by the Federal Reserve's actions without feedback from competitive market actions. Moreover, both economists and lay observers alike have monitored changes in the funds rate for indications about the likely future paths for inflation, output growth and other key economic variables. Finally, although a Taylor Rule has not been formally adopted by the Fed as a model to guide its policy decisions, monetary economists have come to it include as an equation in standard models of aggregate activity.

This paper has questioned each of these premises about the funds rate and the empirical evidence, across two sample periods, finds each to be in doubt. Although the usefulness of causality tests to resolve the question of exogeneity is a matter of debate, the results of these tests do indicate that the funds rate shares significant interactions with other variables suggested by alternative hypotheses about how the funds rate could be determined *endogenously* – as an intermediate target variable – rather than as an instrument of policy. While this may seem like a minor quibble to modern audiences, the issue between an exogenous money supply and one determined endogenously was among the key issues that formed the debate between those who supported interest rates v. money as intermediate targets in the 1960s.

With regard to the funds rate as an indicator variable, the results show that, once the funds rate is purged of the information contained in its own past, little significant information remains between changes in it and other variables. In contrast, innovations in non-borrowed reserves have significant effects real disposable income and personal consumption expenditures. Rather than offering leading signals for the paths of other variables of interest, innovations in the funds rate seem to be more likely tied to Fed responses to paths in potential goal variables of monetary policy. Estimation of an eight-variable VAR confirmed the results of the causality tests by revealing low explanatory power and changes in Fed operating procedures over time: Responding relatively more to real variables (unemployment) prior to 1980 and shifting relatively more to interest rate smoothing since 1985.

Finally, with Taylor's (1993) work playing a key role in standard monetary models, its assumptions of linearity and structural stability were examined. Test results for only a few residual pairs among the many possibilities within the estimated VAR revealed multiple examples of episodic non-linearity among the system's key variables: The federal funds rate, non-borrowed reserves, total loans and leases, the PCE deflator and the T-bill rate. Because implementation of a Taylor Rule presumes linearity in the data and an unchanged structure over time, these findings suggest that any attempt to use this type of interest rate rule in practice will lead to an unstable path for the central bank's chosen objective.

Table 1. Results of Unit Root Tests

	Time Period	
Variable	1960.01 – 1979.12	1985.01 – 2007.12
ΔFF	-7.21	-10.70
ΔTB	-12.00	-6.85
ΔU	-7.36	-7.61
ΔlnNBR	-4.56	-2.58*
		(-6.71)
ΔlnLoans	-3.48	-2.18*
		(-5.77)
Δlnrdpi	-3.22	-5.37
Δlnrpce	-3.23	-2.41*
		(-5.62)
ΔlnPCEDef	-0.77*	-1.71*
	(-4.04)	(-6.56)

NOTES: An asterisk next to a test statistic indicates the presence of a unit root in the series. Values in parentheses are test statistics applied to second differences of the series. -2.87 is the 0.05 critical value.

Table 2. Results for Tests of Granger Causality: Is the Funds Rate a Monetary Policy Instrument?

1960.01 – 1979.12 Sub-sample (n= 210)

Null Hypothesis:	F-statistic
ΔFF ≠> ΔTB	7.65*
ΔTB ≠> ΔFF	3.46*
ΔFF ≠> ΔdlnNBR	6.54*
ΔdlnNBR ≠> ΔFF	0.43
ΔFF ≠> ΔdlnLoans	1.89
ΔdlnLoans ≠> ΔFF	2.46*

1985.01 – 2007.12 Sub-sample (n=276)

Null Hypothesis:	F-statistic
ΔFF ≠> ΔTB	3.13*
ΔTB ≠> ΔFF	12.72*
ΔFF ≠> ΔΔdlnNBR	1.23
ΔΔdlnNBR ≠> ΔFF	1.63
ΔFF ≠> ΔΔdlnLoans	7.05*
ΔΔdlnLoans ≠> ΔFF	2.73*

Table 3. Results for Tests of Granger Causality: Is the Funds Rate an *Indicator* of Monetary Policy Actions?

1960.01 – 1979.12 Sub-sample

Null Hypothesis:	
ΔFF ≠> ΔΔlnp	3.50*
ΔΔlnp ≠> ΔFF	2.88*
ΔFF ≠> Δdlnrdpi	0.28
Δdlnrdpi ≠> ΔFF	1.56
ΔFF ≠> Δdlnrpce	0.97
Δdlnrpce ≠> ΔFF	2.65*
ΔFF ≠> ΔU	2.19*
ΔU ≠> ΔFF	4.67*

1985.01 – 2007.12 Sub-sample

Null Hypothesis:	
ΔFF ≠> ΔΔlnp	2.16
ΔΔlnp ≠> ΔFF	3.03*
ΔFF ≠> Δlnrdpi	2.47*
Δdlnrdpi ≠> ΔFF	1.41
ΔFF ≠> ΔΔlnrpce	4.07*
ΔΔdlnrpce ≠> ΔFF	2.60*
ΔFF ≠> ΔU	2.64*
ΔU ≠> ΔFF	3.81*

Table 4. The Effects of Innovations in the Funds Rate and Reserves on Economic Activity, 1985.01 – 2007.12

Null Hypothesis:	Innovations in the Funds Rate
ΔFF ≠> Δlnp	2.01
Δlnp ≠> ΔFF	0.69
ΔFF ≠> Δdlnrdpi	1.78
Δdlnrdpi ≠> ΔFF	1.38
ΔFF ≠> Δdlnrpce	0.45
Δdlnrpce ≠> ΔFF	3.46*
ΔFF ≠> ΔU	1.53
ΔU ≠> ΔFF	3.58*

Null Hypothesis:	Innovations in Growth of Nonborrowed Reserves
ΔR ≠> Δlnp	1.08
Δlnp ≠> ΔR	2.98*
ΔR ≠> Δlnrdpi	2.18*
Δdlnrdpi ≠> ΔR	1.79
ΔR ≠> Δlnrpce	4.37*
Δdlnrpce ≠> ΔR	0.29
ΔR ≠> ΔU	0.95
ΔU ≠> ΔR	1.72

Table 5. Results of VAR Estimation

Dependent Variable: First Difference of Federal Funds Rate

Variable	1960.01 – 1979.12	1985.01 – 2007.12
$\Delta lnNBR_{t-1}$	-0.00 (0.26)	0.00 (1.24)
$\Delta lnNBR_{t-2}$	0.02 (1.24)	0.00 (0.44)
$\Delta lnRDPI_{t-1}$	0.01 (0.18)	-0.01 (0.70)
$\Delta lnRDPI_{t-2}$	0.00 (0.04)	0.02 (0.80)
$\Delta lnLOANS_{t-1}$	0.00 (0.62)	0.01 (0.08)
$\Delta lnLOANS_{t-2}$	-0.02 (0.27)	0.02 (1.23)
$\Delta FedFunds_{t-1}$	0.12 (1.51)	0.02 (0.22)
$\Delta FedFunds_{t-2}$	0.10 (1.25)	-0.06 (0.80)
$\Delta lnRPCE_{t-1}$	-0.01 (0.32)	0.00 (0.50)
$\Delta lnRPCE_{t-2}$	0.02 (0.43)	0.02 (0.99)
$\Delta\Delta lnP_{t-1}$	0.11 (0.78)	0.06 (1.29)
$\Delta\Delta lnP_{t-2}$	0.16 (1.21)	0.69 (1.44)
ΔTB_{t-1}	0.20 (2.12) *	0.46 (6.34) *
ΔTB_{t-2}	-0.08 (0.80)	0.11 (1.46)
ΔUt-1	-0.46 (2.84) *****	-0.25 (3.03) *
ΔU_{t-2}	-0.24 (1.44)	0.08 (0.97)
C	-0.23 (2.05) *****	-0.04 (1.69)
R^2	0.29	0.41

NOTE: For the 1985 – 2007 sub-sample, ΔlnNBR, ΔlnRPCE and ΔlnLoans and replaced by their second differences to be compatible with the stationarity tests reported in Table 1.

Table 6. Results of the Tests for Non-linearity in the Residuals from the VAR Estimation

<u>1961.01 – 1979.12 Estimation Period</u>

Fed Funds Rate – Nonborrowed Reserves

Frame 1 (1961.03 – 1963.02):	xxy: p-value = 0.000
Frame 8 (1975.03 – 1977.02)	xxy: p-value = 0.100
	yyx: p-value = 0.000

Fed Funds Rate – Loans

Frame 8 (1975.03 – 1977.02):	xxy: p-value = 0.004

Fed Funds Rate – Inflation

Frame 2 (1963.03 – 1965.02):	yyy: p-value = 0.026

Non-borrowed Reserves – Loans

Frame 8 (1975.03 – 1977.02):	xxy: p-value = 0.000

Non-borrowed Reservers – Inflation

Frame 8 (1975.03 – 1977.02):	xxy: p-value = 0.000

Non-borrrowed Reserves – T-bill Rate

Frame 8 (1975.03 – 1977.02):	xxy: p-value = 0.000

NOTES: xxy is the Hinich test statistic for the 3^{rd} order nonlinear bicovariance of the covariance of x with the level of y in that frame. yyx is the Hinich test statistic for the 3^{rd} order nonlinear bicovariance of the covariance of y with the level of x in that frame. yyy is the Hinich test statistic for the 3^{rd} order nonlinear covariance of y in that frame.

Table 7. Results of the Tests for Non-linearity in the Residuals from the VAR Estimation

<u>1985.01 – 2007.12 Estimation Period</u>

Fed Funds Rate – Nonborrowed Reserves		
	Frame 1 (1985.01 – 1986.12):	yyx: p-value = 0.000
		yyy: p-value = 0.006
Fed Funds Rate – T-bill Rate		
	Frame 7 (1997.01 – 1998.12):	yyx: p-value = 0.007
		yyy: p-value = 0.069
Nonborrowed Reserves – Loans		
	Frame 1 (1985.01 – 1986.12):	xxx: p-value = 0.006
Nonborrowed Reserves – Inflation		
	Frame 1 (1985.01 – 1986.12)	xxy: p-value = 0.000
		xxx: p-value = 0.006
Nonborrowed Reserves – T-bill Rate		
	Frame 1 (1985.01 – 1986.12)	xxy: p-value = 0.000
		xxx: p-value = 0.006
		yyy: p-value = 0.069

NOTES: xxy is the Hinich test statistic for the 3^{rd} order nonlinear bicovariance of the covariance of x with the level of y in that frame. yyx is the Hinich test statistic for the 3^{rd} order nonlinear bicovariance of the covariance of y with the level of x in that frame. yyy is the Hinich test statistic for the 3^{rd} order nonlinear covariance of y in that frame. xxx is the Hinich test statistic for the 3^{rd} order nonlinear covariance of x in that frame.

Figure 1. Alternative Interpretations of Movements in the Federal Funds Rate

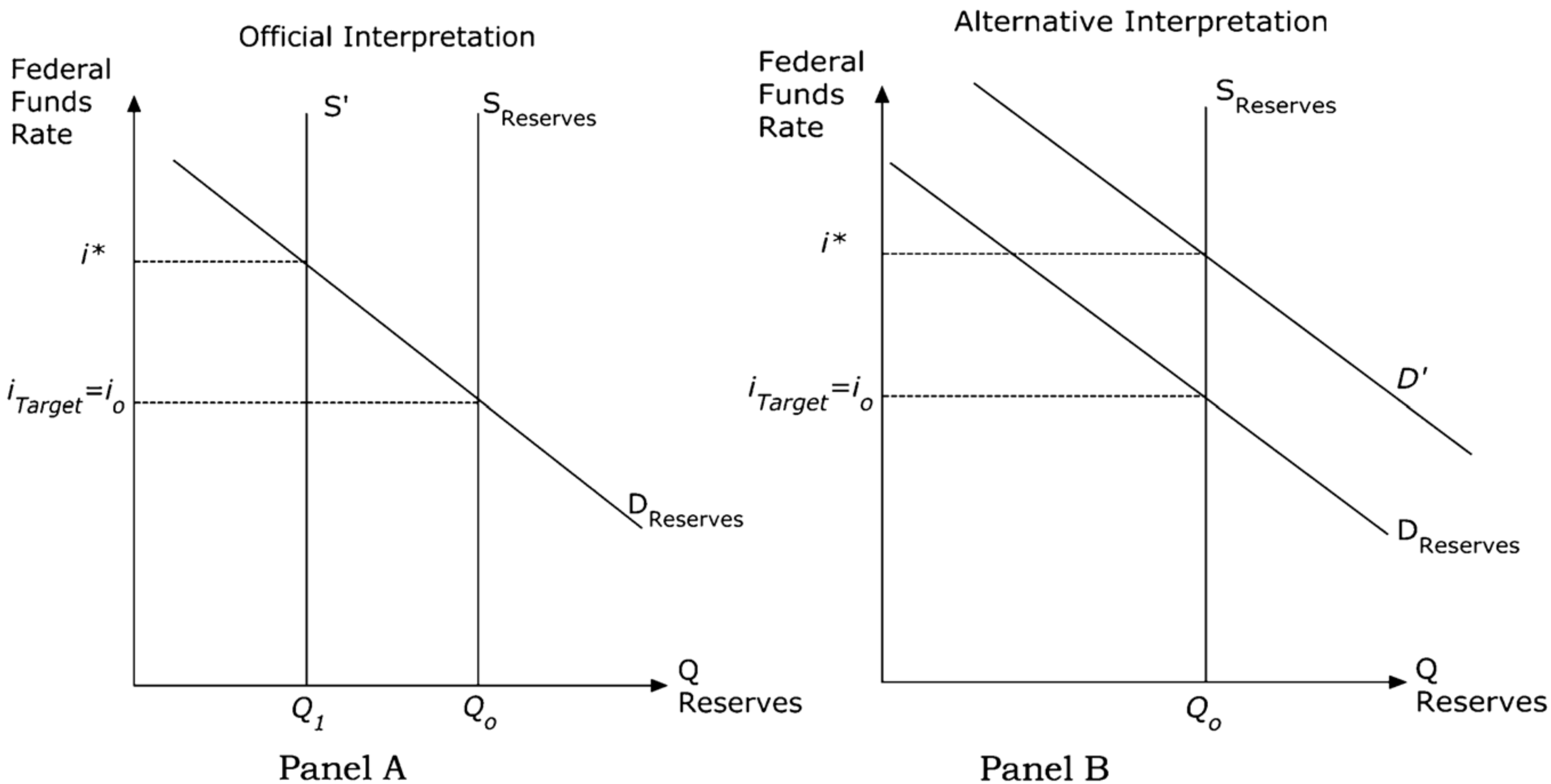


Figure 2. Innovations in the Federal Funds Rate, 1985 - 2007

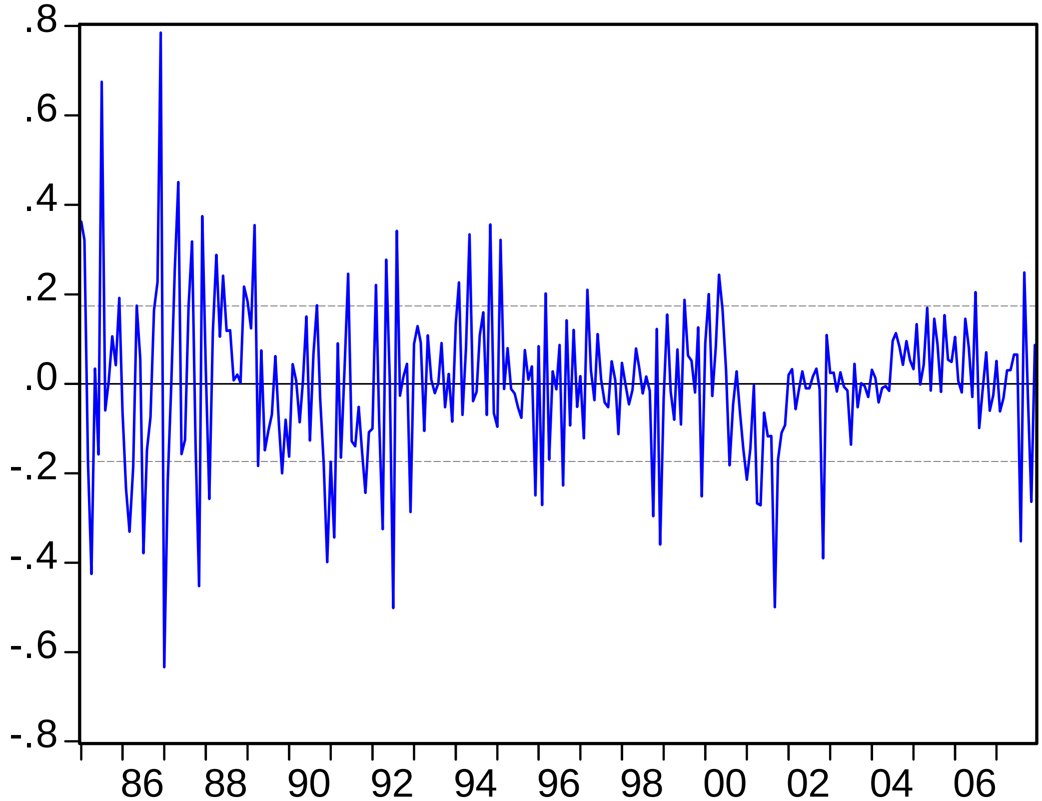
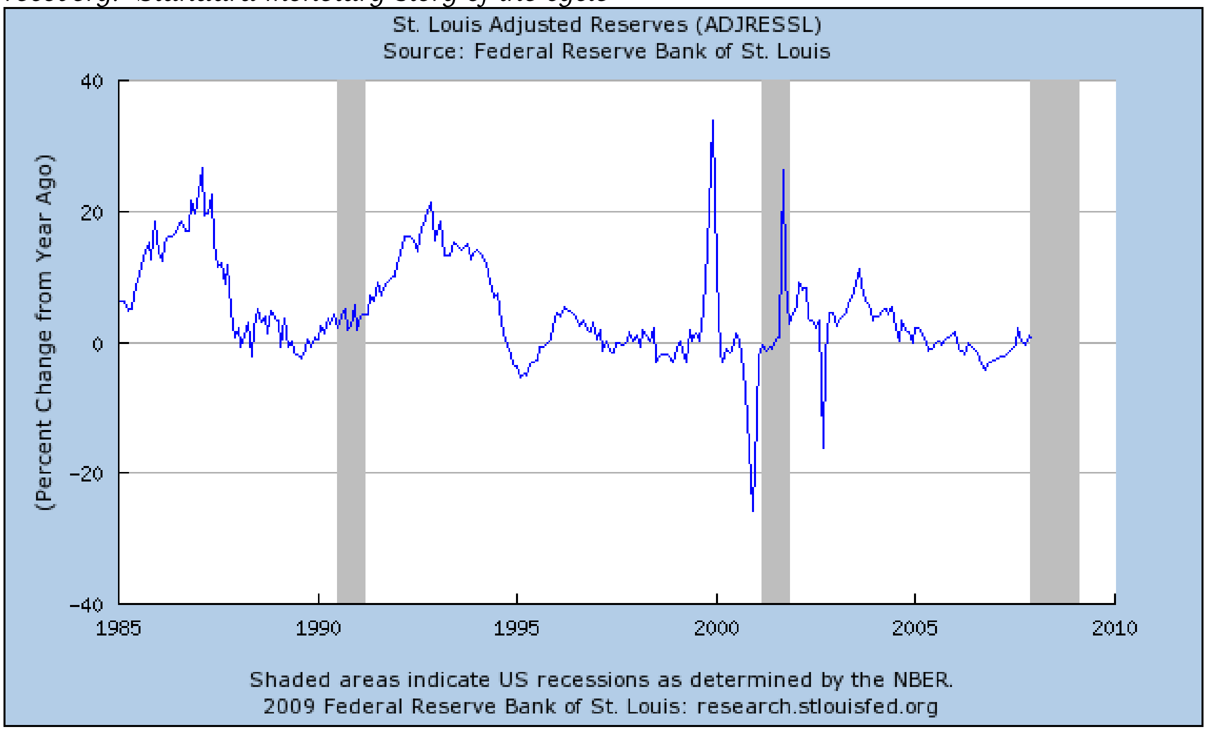
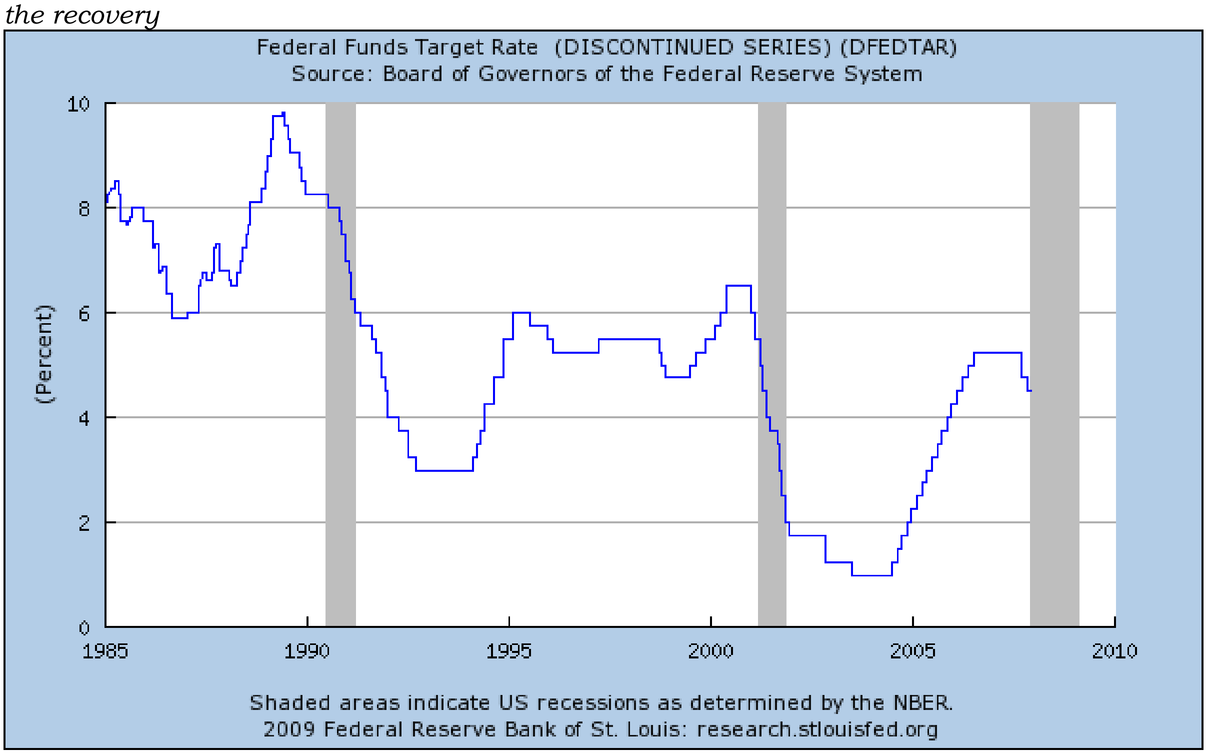


Figure 3. Two Interpretations of the 2001 Recession

Reserve growth slows substantially before the downturn and increases rapidly prior to the recovery: Standard monetary story of the cycle



Conventional wisdom: The funds rate target increases before the downturn and falls before the recovery



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ENDNOTES

[1] See, for example, Tobin (1969)

[2] Although the funds rate appears on the left-hand side of a Taylor-rule equation, this is a different kind of "endogeneity" than one in which a price, such as the funds rate, is determined by the interaction of the supply and demand of reserves.

[3] See Cochrane (2007a, b)

[4] Briefly, if the two errors are large and offsetting, the more complicated policy strategy, (b), may produce a smaller overall error than the simpler policy strategy described in (a). See the Andersen and Karnosky (1977) for more detail on this topic.

[5] For more discussion of how a misinterpretation of this figure and how a misinterpretation of the source of changes in the funds rate can lead to monetary policy mistakes, see Belongia (2007). Mistakes of this sort would lead to the pattern of procyclical money growth long-described by monetarists and also would serve as the source of post-World War II business cycle fluctuations; see, for example, Meltzer (1991).

[6] The negative findings for relationships between the Fed's official simple sum monetary aggregates and measures of economic activity are to be contrasted with the positive results reported not only for the United States, but other countries as well, when money was measured as a superlative – Fisher Ideal or Divisia – index. A collection of these results can be found in Belongia and Binner (2000). The specific question of sensitivity of inference to measurement is addressed in Belongia (1996).

[7] This was published as Hinich and Patterson (2005).

[8] In the literature in particular those on long-term dependence, pre-filtering by means of an AR-GARCH procedure is commonly adopted to remove short-term autocorrelation and time-varying volatility. However, this procedure is unnecessary since the bi-correlation and tri-correlation tests rely on the property that the bi-correlation and tri-correlation coefficients equal zero for a pure noise process, and the null hypothesis is only rejected

when there exists some non-zero bi-correlations or tri-correlations suggesting nonlinear serial dependence in the conditional mean (additive nonlinearity), but not the presence of conditional variance dependence (conditional heteroskedasticity).

[9] In principle, this window length needs to be sufficiently long enough to apply the bi-correlation and tri-correlation tests with some power and yet short enough for the data generating process to have remained roughly constant (see Monte Carlo results in Hinich, 1996; Hinich and Patterson, 1995, 2005).