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Smant, David / D.J.C.

Erasmus University Rotterdam

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Real time data, regime shifts, and a simple but effective estimated Fed policy rule, 1969-2009

David J.C. Smant
Erasmus School of Economics
Erasmus University Rotterdam
P.O. Box 1738
3000 DR Rotterdam
The Netherlands

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Abstract

Estimates of Taylor rule equations for Federal Reserve policy over periods before the Greenspan period are misleading. Until 1979 Fed policy changed the real funds rate in response to the output gap, with no response to an inflation target. During the Volcker period the policy rule kept the real funds rate at a high but constant level, with no response to the output gap. Taking into account the regime shifts, a simple but effective funds rate equation can be estimated using only inflation and output gap.

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Email: smant@ese.eur.nl

Phone: +31 10 4081408

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1. INTRODUCTION

There is and has been a long-time interest in central bank's reaction functions, or, in modern parlance, estimated policy rules. Modelling monetary policy reaction functions is important for a variety of reasons. For example, financial market practitioners need to understand policymaking in order to make sound forecasts of future monetary policy and to evaluate the likely direction of future financial market prices. Macroeconomists require a reaction function to endogenize policy in macroeconomic models. Many empirical analyses of economic theories depend on expected values of future variables that are linked to monetary policy, for example, the expectations theory of the term structure of interest rates.

Unfortunately, estimating central bank reaction functions has turned out to be complicated. The literature provides many studies, for many countries, containing mixed or contradictory results with respect to the significance of variables and the sign and size of coefficients.¹ There are several reasons for the empirical difficulties with estimated policy rules. First, in practice, policy decision makers tend to look at 'everything' and the range of possible explanatory variables is very large, both in scope and in their precise measurement. For a long time, economists were also strongly divided on how to actually measure the stance of monetary policy, arguing for or against alternative definitions of money and some policy interest rate.² Furthermore, policy decisions are probably asymmetric and non-linear, giving different weights to variables under different economic circumstances.³ Also, policy regimes are subject to structural breaks, leading to multiple periods with consistent but different policy making.

Since the seminal work of Taylor (1993) monetary economists have converged on the so-called Taylor rule as a fundamental framework for most monetary policy descriptions. The Taylor rule simplifies the policy reaction function and focuses on two key economic variables that determine central bank policy interest rates: inflation relative to an inflation target (inflation gap) and the real economy relative to its long-run equilibrium (output gap or unemployment gap). These two variables are closely linked to the main goals of macroeconomic policy. Furthermore, focusing on these two indicator variables has been shown to provide a robust and reasonably efficient monetary policy in a wide variety of alternative economic models. More importantly from a practical viewpoint, the Taylor rule has shown to be a reasonably accurate description of monetary policy in several countries, at least for more recent time periods starting somewhere in the 1980s.⁴ Today, the Taylor rule has become a standard component of macroeconomic analyses, exemplified by the frequently used 3-equation small macroeconomic model (for example, Rudebusch and Svensson, 1999)

¹ For the U.S., Khoury (1990) found that there appeared to be little consistency in the results for the various explanatory variables. Smant (2002) provides a survey of studies of Deutsche Bundesbank reaction functions with similar results.

² Although consensus has settled on the interest rate as the measure of monetary policy, technically this is an assumption that depends on the structure of the market of bank reserves and the operating procedures selected by the central bank. See Bernanke and Mihov (1998). Incorrect identification of policy actions can result in seriously misleading empirical results, although the problem is most severe for high frequency (daily, weekly) data.

³ For example, Bernanke and Mishkin (1992) stress the behaviour of central banks, switching between their inflation and real economy objectives.

⁴ A cautionary note is that several monetary policy strategies can be shown to result in Taylor-type equations linking interest rate with inflation and the output gap. Therefore, although the Taylor rule may work as a description of monetary policies, we cannot conclude that policy makers actually have implemented the Taylor rule strategy.

and the structural interpretation of the short-term interest rate in VAR models (for example, McCallum, 1983).

Despite its appeal of simplicity, using the Taylor rule as a unified description of monetary policy over long time periods without taking into account structural breaks can have serious consequences. One example is that in tests of the expectations theory of interest rates, VAR models are frequently used to generate interest rate forecasts and to test theoretical restrictions on the model.⁵ Fuhrer (1996) reports that the performance of this type of model is seriously affected by the presence of structural breaks in the short-term interest rate equation. Taking into account monetary policy regime changes dramatically improves the relationship between the actually observed long-term interest rate and its theoretical value derived from forecasted monetary policy rates. Empirical failures of the expectations theory reported in many empirical studies may be related more to failing interest rate forecasting models than to a failure of the tested theory itself.

The purpose of this paper is to re-evaluate the use of the estimated Taylor rule as a simple standard long-run monetary policy reaction function in macroeconomic analyses. I will largely follow Judd and Rudebusch (1998) and estimate Taylor rule functions for periods linked to various Chairmen of the Federal Reserve. The period estimates do indeed exhibit important regime shifts. The various regimes have simple but economically plausible interpretations. Finally, three different policy regimes are unified in a simple but effective Taylor-type reaction function that covers the full period under review and provides an accurate description of Federal Reserve policy over the period 1969-2009.

The remainder of this paper is structured as follows. Section 2 provides a brief discussion of important issues in the estimation of policy rules. Section 3 discusses the empirical estimates. Section 4 concludes.

2. ISSUES IN ESTIMATING TAYLOR RULES

The basic Taylor (1993) equation is

$$i_t = r^* + \pi_t + \beta_\pi (\pi_t - \pi^*) + \beta_y y_t$$

where i , r^* , π , π^* , and y denote the federal funds rate (policy rate), the equilibrium real federal funds rate, inflation rate, target inflation rate and the output gap. Coefficients β_π and β_y are the policy response coefficients to the inflation gap and the output gap. Taylor (1993) assumed for β_π and β_y values of 0.5 and also assumed for r^* and π^* values of 2 percent, which seemed appropriate for Federal Reserve policy during the period 1987-1992.

When estimating the Taylor rule coefficients as a description of monetary policy, the literature over time has identified several issues that need to be addressed.

Real time data

⁵ These tests follow Campbell and Shiller (1987).

At least since the work of Orphanides (2001) the estimated policy rule literature has seen an increased emphasis on using real-time datasets.⁶ Not only do we need to consider the fact that official economic statistics become available after the reporting period, but, more importantly, some statistics are subject to major revisions, for example when at future moments in time additional source material becomes available and when definitions and statistical procedures are changed. An important part of this paper has been to collect a real time database to estimate the Fed's historical policy rule. Specifically, the real time data I use in this study are 'first release' data. By using the first released values for a given reporting period, I ignore publication lags which have varied somewhat over time and assume that Federal Reserve staff is able to predict contemporaneous values of variables using a variety of leading indicators.

Inflation

Inflation in the Taylor rule is most commonly measured by the annual change in the aggregate price index, Q/Q-4 or M/M-12. Somewhat more contentious is the precise measure of the aggregate price level that should be used. Reviews of Fed policy suggest that the Fed's preferred inflation measure has changed over time. Historically the Fed used the GNP and later GDP deflator. In the February 2000 Monetary Policy Report to Congress the Fed's emphasis changed to the PCE chain-type index. And in July 2004 the emphasis changed to the core-PCE index (i.e, excl. food and energy). The headline CPI appears not to have been in favour with Fed policy makers.

I use the current (revised) data for the GNP (GDP) deflator in the estimations that aim to represent usual practice. In the second part of the analysis, using real time data, the definition of inflation is period specific. Real time inflation data are for the GNP/GDP deflator until 1999Q4, PCE chain-type index from 2000Q1, and core-PCE from 2004Q2.

Output gap

The output gap has a long history in U.S. economic policy and was first introduced in the early 1960s as part of policy analysis by the Council of Economic Advisors (CEA).⁷ Official estimates were subsequently published by the Bureau of Economic Analysis (BEA) and the Congressional Budget Office (CBO). The Federal Reserve also produced its own estimates in preparation for the regular FOMC policy discussions, but data contained in the Greenbook are only available with a substantial lag. One important problem with the output gap variable is that potential or trend output is unobserved and must be estimated. Various methods of potential output estimation have been used in the literature, such as linear trends, quadratic trends, segmented trends, moving average or filter methods and structural or production function methods. Most importantly, available evidence shows that the (quasi-) official estimates of potential output have changed drastically over time. I use a reproduction of real-time potential output and output gap values based on the analyses by the CEA, BEA and CBO. Information available at the start of every year is used to construct an expected quarterly time series for expected potential output during that year. These estimates of expected potential output are then matched with the first release data on actual real GNP and GDP to create a real time series of the estimated output gap.

⁶ Other important contributions to the real-time data literature are Runkle (1998), Keane and Runkle (1990), Diebold and Rudebusch (1991) and Croushore and Stark (1999).

⁷ For a brief discussion see Orphanides (2003). It has been argued that historically the Fed has not actually used the output gap but tended to focus more on the unemployment gap. However, Orphanides found that the output gap did feature in the FOMC policy discussions and that official estimates and Federal Reserve staff estimates of the output gap were close.

Equilibrium r^ and π^**

The Taylor rule includes an important role for the equilibrium real interest rate and the inflation target, both of which are in the case of the U.S. Fed not directly observed. For some other countries, such as Germany, central banks have long published inflation targets which could be used in the estimated policy rule. More commonly, r^* and π^* are estimated indirectly as part of the intercept of an estimated Taylor equation. Of course, this approach is only valid if we can assume that both r^* and π^* are on average constant over the sample period. The literature on both real interest rates and monetary policy's historical struggle with periods of inflation and deflation suggests that constancy is a heroic assumption and a likely cause of structural breaks in the estimated policy rule. In the absence of further independent information on equilibrium real interest rates and U.S. policy inflation targets the best way to approach the problem appears to be to examine subperiods.

Further specification issues

Besides the question of possible additional information variables, some economists have suggested that real world monetary policy is (or should be) more forward looking than the basic Taylor rule.⁸ Specifically, policy makers may respond to expected inflation and/or the expected output gap. However, limited data availability usually prevents an appropriate examination of this issue.

Another specification issue that has appeared in the literature is the possibility of smoothing and momentum effects in the policy target rate and the presence of partial adjustment dynamics in the policy rate.⁹ Although it is, for example, common to include lagged policy rates in the policy rule, interpretation of the empirical results is confounded by the possibility of autocorrelated shocks and autocorrelated missing indicator variables.

The previous comments suggest that there is much room for debate on the appropriate details of any estimated policy rule. Without wanting to belittle any of the issues, the empirical analysis in the next section will take a simple approach. The objective is to obtain a general characterization of the main policy features, using only inflation and the output gap as the major explanatory variables. The objective is not to obtain a complete description of policy actions on a high data frequency.

3. EMPIRICAL RESULTS

In this paper I follow Judd and Rudebusch (1998) and proceed under the assumption that the Fed's policy rule is affected by changes in the Fed Chairman. Table 1 presents the various tenures of Fed Chairmen, starting in the early 1950.

Table 1 Federal Reserve Chairmen

Chairman	Tenure
William M. Martin, Jr.	Apr 1951 – Jan 1970
Arthur F. Burns	Feb 1970 – Jan 1978
G. William Miller	Mar 1978 – Aug 1979

⁸ See McNees (1986) for an early investigation of policy responses to economic forecasts. The forward-looking nature of an optimal Taylor rule was stressed by many, see for example Svensson (1997).

⁹ The debate on interest rate smoothing, or its extreme version of interest rate targeting, has a long history and a large literature. Common in the Taylor rule literature is the partial adjustment model $\Delta i_t = \rho (i_t^* - i_{t-1})$, where i^* and i are the Taylor rule target rate and the actually observed rate. Very similar in effect is the error correction model $\Delta i_t = \rho (i_{t-1}^* - i_{t-1})$. For a critical perspective on the issues and debate see for example Rudebusch (2002).

Paul A. Volcker Alan Greenspan Ben S. Bernanke	Aug 1979 – Aug 1987 Aug 1987 – Jan 2006 Feb 2006 -
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Judd and Rudebusch find that their sample of quarterly data from 1970Q1 to 1997Q4 can be divided into three structurally different regimes, with the subperiods identified by the terms of Chairmen Burns (1970Q1-1978Q1), Volcker (1979Q3-1987Q2) and Greenspan (1987Q3-1997Q4). The Miller term (1978Q2-1979Q2) is excluded from their analysis because of the relatively short time span. More formal statistical breakpoint tests could be used, and will probably result in slightly different break points but the empirical results suggest that the breakpoints are close to the change in Chairman. For example, Fuhrer (1996) identified breakpoints in 1974Q1, 1980Q1 and 1986Q1.

Contrary to Judd and Rudebusch, who employ an expanded and dynamic estimation equation, I estimate the following basic Taylor rule equation.

$$i_t = \alpha + \beta \pi_t + \gamma y_t$$

Here, in terms of the original Taylor rule parameters, the estimated coefficients are defined as $\alpha = (r^* - \beta_\pi \pi^*)$, $\beta = (1 + \beta_\pi)$ and $\gamma = \beta_y$. It can be seen that the coefficient estimates from the Taylor rule are not able to pin down both the equilibrium real interest rate (r^*) and the inflation target rate (π^*). Following established practice, I will calculate r^* as the average of the real federal funds rate observed over the relevant sample period. Because the maturity of the fed funds rate is very short the current, backward looking inflation rate is used rather than inflation expectations. In practice, any divergence between actual or ex post and expected inflation rates is more important for long maturity interest rates. Following the estimate of r^* , π^* is calculated as $(r^* - \alpha) / (\beta - 1)$.

Estimating the Taylor rule model without further dynamics or any other short-term influences, introduces some econometric issues. First, there are questions with respect to the stationarity of the variables. We assume that we can effectively view the model as a cointegration equation. In view of the relatively short sample periods the use of special cointegration estimation methods, relying on asymptotic properties, does not appear to provide much benefit. Second, the absence of equation dynamics introduces residual serial correlation as well as questions about possible missing variables bias. Assuming that the missing variables bias is small, I proceed with the estimation using basic ordinary least Squares and Newey-West HAC standard errors.

Table 2 Taylor rule estimates for Federal Reserve Chairman periods using real time data

	α	β	γ	adjR ²	SEE	DW
Burns	4.271 (0.700) _a	0.827 (0.144) _a	0.440 (0.116) _a	0.689	1.224	0.836
	$r^* = 0.49$ $\pi^* = 21.88$					
Volcker	4.366 (0.986) _a	1.128 (0.166) _a	-0.005 (0.099)	0.658	2.131	1.806
	$r^* = 5.11$ $\pi^* = 5.79$					
Greenspan	0.758 (0.496)	1.714 (0.138) _a	0.501 (0.065) _a	0.786	1.046	0.343
	$r^* = 2.49$					

	$\pi^* = 2.43$					
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Estimated Taylor rule equation: $i_t = \alpha + \beta \pi_t + \gamma y_t$ where $\alpha = (r^* - \beta_\pi \pi^*)$, $\beta = (1 + \beta_\pi)$ and $\gamma = \beta_y$.

The estimation periods are Burns (1970Q1-1978Q1), Volcker (1979Q3-1987Q2) and Greenspan (1987Q3-2006Q1). Full period is 1970Q-2006Q1. Real time data on inflation and output gap discussed in the main text. Newey-West HAC standard errors. a, b, c denote significance at 1, 5, 10 percent levels.

Table 2 presents the estimation results using real time data on (policy relevant, i.e. mixed measure of) inflation and the output gap. Details of the data were already discussed earlier. For comparison, alternative results based on a commonly used dataset of current inflation and output gap data is provided in the appendix Table A1. Comparing current and real time data estimations, the results for each of the subperiods turn out to be very similar. A closer examination of the current and real time data (provided as appendix Figure A1) suggests that the major difference lies in the average level of the output gap in the subperiods, therefore affecting primarily the constant term of the estimated Taylor rules. Perhaps worth specific mention is the substantial increase in explanatory power of the real time data for the Greenspan period.

The most important differences in empirical estimates are found in the comparison of subperiods. A remarkable result is the extremely high implied inflation target found for the Burns policy regime, estimated at 22 percent. However, this result is unlikely to reflect a true policy target value. Examination of the inflation and output gap coefficients shows that the policy regimes have to be interpreted very carefully. First, both the Burns and Volcker regimes suggest that the inflation coefficient is not significantly different from 1. Therefore, policy makers did not adhere to the so-called Taylor principle, i.e. raising the real interest rate when inflation is above target. Second, in the Volcker regime there is no significant (positive) response of the policy rate to the output gap.

Whereas the estimated policy rule for the Greenspan period is clearly very close to the Taylor rule (with policy rule coefficients suggested of 1.5 and 0.5), the Burns and Volcker periods suggest a different interpretation is more likely. In the Burns regime, the policy rule appears to have been to respond with changes in the real funds rate ($\beta=1$) to the observed output gap ($\gamma>0$). The Volcker period policy rule appears to have been to keep the real funds rate ($\beta=1$) constant and at a relatively high level, but not respond to the economy ($\gamma=0$). Further interpretation based on the value of the constant terms suggests that the Burns regime does not appear to have had an inflation target at all, whereas the high target real funds rate in the Volcker period could be interpreted as depending on the stated objective of achieving disinflation.

To summarize, one likely interpretation of the three policy regimes could be as follows:

Burns: real rate = f(output gap), no inflation target

Volcker: real rate = f(disinflation target), no output gap effect,

Greenspan: Taylor rule model

It is possible to combine the policy regimes in one comprehensive interest rate equation, using dummy variables for the Burns-Miller, Volcker and Greenspan periods (DBM, DV, DG).

$$i_t - \pi_t = c_{00} + c_{01}DV + c_{02}DG + c_1 DG * \pi_t + c_{21}DBM * y_t + c_{22}DG * y_t$$

Here, c_{00} is interpreted to represents the long-run equilibrium real rate and

One further addition is made to the interest rate equation in order to capture the short run policy reversal in 1980, with respect to interest rate policy and credit controls. Two dummy variables are used for the second and third quarter in 1980 (D80Q2, D80Q3).

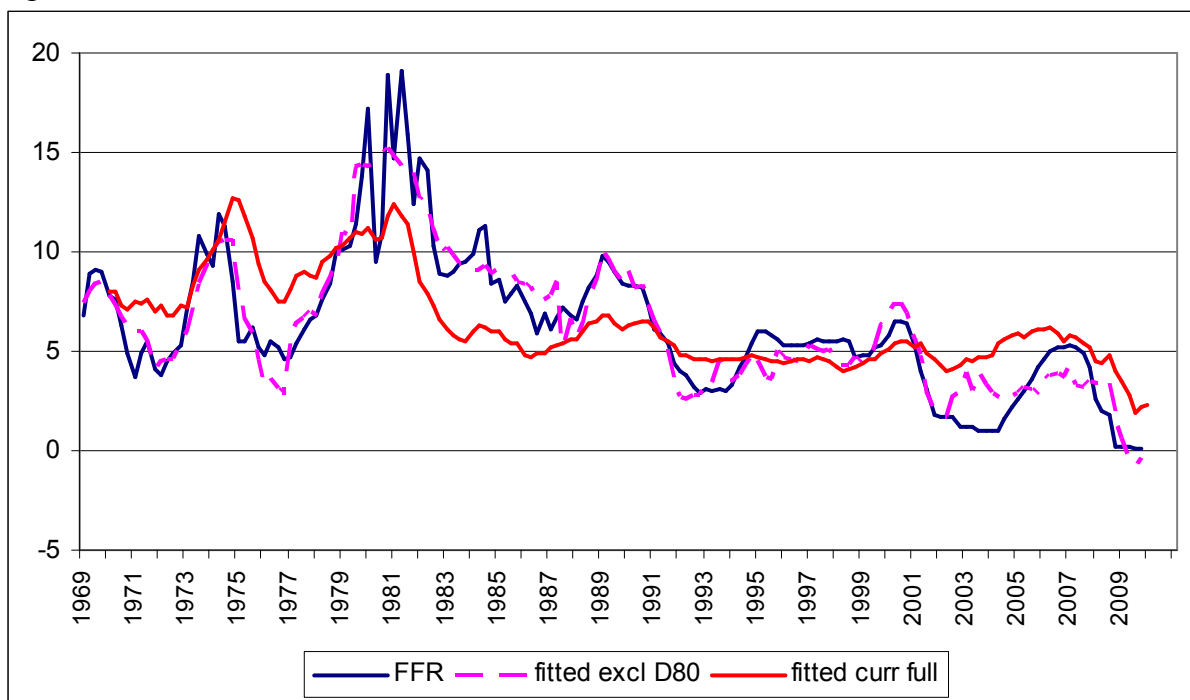
Table 3 Federal Reserve policy rule estimate using real time data

	c_{00}	c_{01}	c_{02}	c_1	c_{21}	c_{22}
Full period	3.440 (0.582)a	1.947 (0.726)a	-2.683 (0.794)a	0.714 (0.149)a	0.480 (0.107)a	0.501 (0.068)a
	adjR ² =	0.729				
	SEE =	1.285				
	DW =	0.991				
	Greenspan period π^* =	3.75				

Estimated equation $i_t - \pi_t = c_{00} + c_{01}DV + c_{02}DG + c_1 DG * \pi_t + c_{21}DBM * y_t + c_{22}DG * y_t$
 Additional included coefficients D80Q2, Q3 not shown. Estimation period is 1970Q1-2006Q1. Greenspan period inflation target is calculated as $-c_{02}/c_1$.

Table 3 shows the estimates of the Federal Reserve policy rule spanning the period 1970Q1-2006Q1. In addition to the interpretation of the various policy regimes as discussed before, we find a plausible estimate for the long run real interest rate of 3.44 percent. For the Greenspan policy regime the average inflation target is estimated at 3.75 percent, which is substantially higher than the previous subperiod-only estimate of 2.43 percent (reported in Table 2). For the Greenspan period we again confirm the Taylor rule hypothesis with respect to inflation gap and output gap coefficients ($\beta = 1.5$ and $\gamma = 0.5$).

Figure 1 Observed and fitted federal funds rate, 1969Q1-2009Q4



Fitted excl.D80: fitted value for the policy rule from Table 3, using real time data, but D80Q2-Q3=0.

Fitted curr full: fitted value for the policy rule from Table 2, estimated and fitted using current data and no regime shifts. Out-of-sample fitted values for 1969Q1-1969Q4 and 2006Q2-2009Q4 are also shown, assuming that the Burns-Miller and Greenspan regimes can be extended backward and forward respectively.

Figure 1 is a graphical representation of the explanatory performance of the estimated policy rules. The first policy rule is the preferred estimate using real time data and regime shifts. The other policy rule is the full period estimate of the Taylor equation using current data. The difference in performance and the long run bias in the results can be clearly seen.

The small out-of-sample expansions of the policy rule into 1969Q1-1969Q4 and 2006Q2-2009Q4 are difficult to evaluate, but at first glance there is little indication of any regime changes. As a result we may assume that the estimated equation of Table 3, using real time data and taking into account the Burns-Miller, Volcker and Greenspan regime changes presents a simple but effective representation of Federal Reserve policy for the period 1969-2009.

4. CONCLUSION

Many empirical studies include monetary policy functions at some point in the analysis and their results depend on the accuracy of the policy description. Unfortunately, many empirical studies ignore the problem of regime shifts in policy equations, estimating only one uniform equation across the entire sample period. As a consequence, the results and conclusions of the empirical analyses must be treated with caution. One example particularly mentioned are some tests of the expectations theory of the term structure of interest rates (see Fuhrer, 1996).

In this paper I have shown the different results for a basic Taylor rule equation estimated for different Federal Reserve monetary policy regimes. The empirical results suggest a fundamental change in policy between the tenure periods of Fed Chairman Arthur Burns (1970Q1-1978Q1), Paul Volcker (1979Q3-1987Q2) and Alan Greenspan (1987Q3-1997Q4). The Burns regime focused on changing the real funds rate in response to the output gap, without a clear consideration of any inflation target. The Volcker regime consisted of keeping the real funds rate at a high constant level, without consideration of the output gap. The Greenspan regime closely follows the now familiar Taylor rule principles: increase the real funds rate in response to both the inflation gap and output gap.

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APPENDIX Table A1 Taylor rule estimates for various periods using current data

	α	β	γ	adjR ²	SEE	DW
Burns	0.952 (1.211)	0.952 (0.195)a	0.796 (0.134)a	0.641	1.315	0.932
	$r^* = 0.11$ $\pi^* = 17.70$					
Volcker	4.778 (0.710)a	1.098 (0.125)a	0.023 (0.117)	0.702	1.989	1.928
	$r^* = 5.26$ $\pi^* = 4.89$					
Greenspan	1.277 (1.065)	1.467 (0.438)a	0.649 (0.140)a	0.407	1.739	0.068
	$r^* = 2.35$ $\pi^* = 2.31$					
Full period	2.820 (0.864)a	0.939 (0.215)a	0.151 (0.205)	0.418	2.662	0.290

	$r^* = 2.46$					
	$\pi^* = 5.82$					

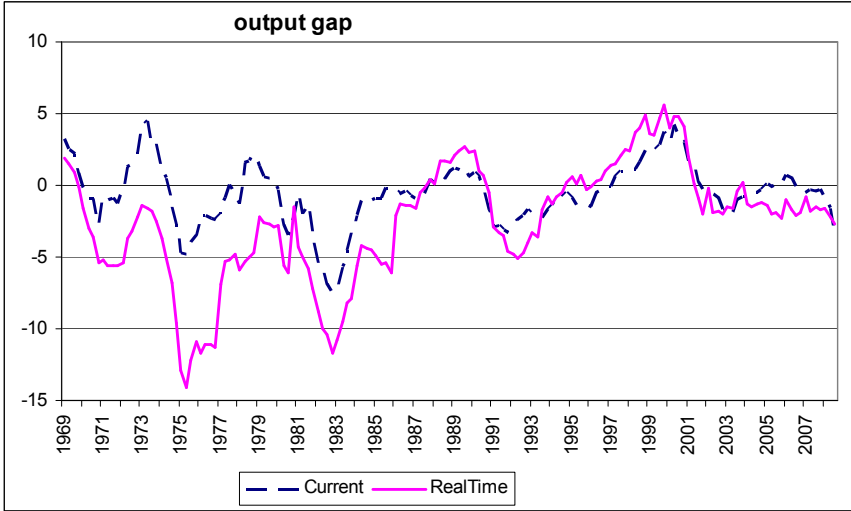
Estimated Taylor rule equation: $i_t = \alpha + \beta \pi_t + \gamma y_t$ where $\alpha = (r^* - \beta_\pi \pi^*)$, $\beta = (1 + \beta_\pi)$ and $\gamma = \beta_y$.

The estimation periods are Burns (1970Q1-1978Q1), Volcker (1979Q3-1987Q2) and Greenspan (1987Q3-2006Q1). Full period is 1970Q-2006Q1. Current data for inflation and output gap are based on GNP/GDP deflator and CBO potential output (vintage August 2010).

Newey-West HAC standard errors. a, b, c denote significance at 1, 5, 10 percent levels.

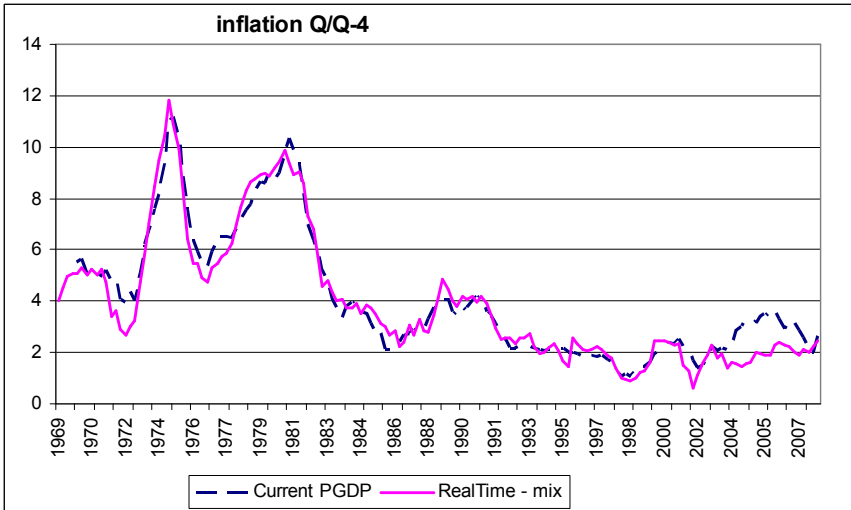
APPENDIX Figure A1. Comparison of current and real-time data on output gap and inflation

a) output gap



Current output gap data are based on the CBO potential output estimate. Real-time output gap data are based on first-release GNP/GDP data and potential output estimates of the CEA, BEA and CBO.

b) inflation



Current PGDP Q/Q-4 inflation is based on the current GDP chain-type price index. Real-time inflation data are first release data and reflect changes in Fed emphasis on GNP/GDP, PCE and PCE-core.