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Actual Federal Reserve Policy Behavior and Interest Rate Rules

- Several studies have attempted to model how the Federal Reserve makes policy choices affecting interest rates. These studies have yielded "rules" relating the interest rate that the Fed is assumed to control to a set of variables thought to affect Fed policy behavior.

- Many of these studies conclude that interest rate rules do not have stable coefficient estimates over time—a finding that suggests structural change in the Fed's policy behavior.

- A specification of an interest rate rule, estimated over the 1954:1–1979:3 and the 1982:4–1999:3 periods, does pass a stability test.

- Nevertheless, the results show a large economic difference in the coefficient on inflation between the first and second periods, and the relatively restrained behavior of inflation in recent years makes it hard to determine whether there has been a structural break.

Economists attempting to approximate the policy behavior of the Federal Reserve often have done so by estimating interest rate rules for the United States. In these rules, the variable on the left-hand side is the interest rate that the Federal Reserve is assumed to control, while the variables on the right-hand side are those that are assumed to affect Federal Reserve behavior.

There have been numerous examples of estimated interest rate rules over the past forty years. The first appeared in Dewald and Johnson (1963), who regressed the Treasury bill rate on a constant, the Treasury bill rate lagged once, real GNP, the unemployment rate, the balance-of-payments deficit, and the consumer price index. The next example can be found in Christian (1968), followed by many others. In 1978, I added an estimated interest rate rule to my U.S. macroeconometric model (Fair 1978). Later, McNees (1986, 1992) estimated rules in which some of the explanatory variables were the Federal Reserve's internal forecasts of different variables, and Khoury (1990) provided an extensive list of estimated rules through 1986. More recently, Judd and Rudebusch (1998) estimated rules for various subsets of the 1970-97 period and Clarida, Galí, and Gertler (2000) estimated them for different Federal Reserve chairmen.

An interesting question that arises from these studies is whether the policy behavior of the Federal Reserve has changed over time. If one interprets such behavior as being approximated by a particular rule, this question can then be viewed as whether the coefficients in the rule have changed

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over time. There seems to be a general view in the recent literature that estimated interest rate rules do not have stable coefficient estimates over time. For example, Judd and Rudebusch (1998, p. 3) observe that, "Overall, it appears that there have not been any great successes in modeling Federal Reserve behavior with a single, stable reaction function."

It seems clear that the Federal Reserve's policy behavior over the 1979:4-1982:3 period (which I refer to as the "early Volcker" period) differed from that of other periods.[1] The stated policy of the Federal Reserve during this period was to focus more on monetary aggregates than it had done before. Any interesting stability question must therefore exclude this period, since any hypothesis of stability that includes it is quite likely to be rejected. One obvious hypothesis to test is whether a rule's coefficients were the same before 1979:4 as they were after 1982:3. In a recent paper (Fair 2000), I tested this hypothesis using the 1978 specified rule mentioned above, and it was not rejected. Further test results are presented in the next section of this article.

If one finds a rule that seems to be a good approximation of the Federal Reserve's policy behavior, how should the residuals from the equation be interpreted? It is important to realize that estimated interest rate rules in general are not optimal. If the Federal Reserve behaves by minimizing the expected value of a loss function subject to a model of the economy, its optimal rule depends on all the predetermined variables in the model. The coefficients in the optimal rule are a combination of the coefficients in the loss function and the coefficients in the model. In this case, any estimated rule is just an approximation of the optimal rule, where the approximation may or may not be any good. If we assume that the Federal Reserve optimizes, then the actual values of the interest rate are the optimal values, so a residual for an estimated rule is the difference between the predicted value from the rule and the optimal (actual) value. The residuals are "mistakes" made by the econometrician, not by the Federal Reserve. This line of reasoning is pursued later on.

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Estimated Interest Rate Rules

The rule that I added to my U.S. macroeconometric model in 1978 has been changed slightly over time. The main modification has been the addition of a dummy variable term to account for the change in Federal Reserve operating procedure during the early Volcker period. As noted above, the Federal Reserve's stated policy during this period was to focus more on monetary aggregates than it had done in the past. The estimated interest rate rule already had the lagged growth of the money supply as an explanatory variable, and the change in policy was modeled by adding the lagged growth of the money supply multiplied by a dummy variable as another explanatory variable. The dummy variable is 1 for the 1979:4-1982:3 period and 0 otherwise.

The specification of the rule used in this article is

$$(1)\quad r = \alpha_1 + \alpha_2 \dot{p} + \alpha_3 u + \alpha_4 \Delta u + \alpha_5 \dot{m}_{-1} + \alpha_6 D1 \times \dot{m}_{-1} + \alpha_7 r_{-1} + \alpha_8 \Delta r_{-1} + \alpha_9 \Delta r_{-2} + \varepsilon,$$

where r is the three-month Treasury bill rate, $\dot{p}$ is the quarterly rate of inflation at an annual rate, u is the unemployment rate, $\dot{m}$ is the quarterly rate of growth of the money supply at an annual rate, and $D1$ equals 1 for 1979:4-1982:3 and 0 otherwise. The estimates of equation 1 for three different sample periods are presented in Table 1.[2]

The endogenous variables on the right-hand side of equation 1 are inflation and the unemployment rate, and the two-stage least squares technique is used to estimate the equation. In the first-stage regression, inflation and the unemployment rate are regressed on a set of predetermined variables (the main variables in the U.S. model, which can be found at <http://fairmodel.econ.yale.edu>). The predicted values from these regressions are then used in the second stage. One can look at these regressions as those used by the Federal Reserve to predict inflation and the unemployment rate, so one need not assume that the Federal Reserve has perfect foresight.

If the Federal Reserve's expectations of *future* values of inflation and the unemployment rate affect its current decision, these expectations should be added to equation 1. A way to test this possibility is to add future values of inflation and the unemployment rate to equation 1 and then estimate it using Hansen's (1982) method-of-moments estimator, where the instruments used are the main predetermined variables in the U.S. model. Hansen's method in this context is simply two-stage least squares adjusted to account for the serial correlation properties of the error term. The test is to see if the future values are statistically significant. I have performed this test on various versions of my estimated interest rate rules using different lead lengths, and the lead values do not turn out to be significant.[3] Thus, there is no evidence that future values are needed in equation 1, and they have not been used. Clarida, Galí, and Gertler (2000) use future values in many of their specifications, but they point out (p. 164) that their conclusions are not changed if they do not use these values.

Equation 1 is a "leaning-against-the-wind equation." The variable *r* is estimated to depend positively on the inflation rate and the lagged growth of the money supply and negatively on the unemployment rate and the change in the unemployment rate. Adjustment and smoothing effects are captured by the lagged values of *r*. The coefficient on the lagged money supply growth is more than ten times larger for the early Volcker period than it is for the period before or after—a finding that is consistent with the Federal Reserve's stated policy of focusing more on monetary aggregates during this period. This method of accounting for the Federal Reserve's policy shift does not, of course, capture the richness of the change in behavior, but at least it seems to capture some of the change.

The Wald value in Table 1 is used to test the hypothesis that the coefficients in the 1954:1-1979:3 period are the same as those in the 1982:4-1999:3 period. (The early Volcker period is excluded from this test, so the *D*1 term is excluded.) The Wald statistic is presented in Andrews and Fair (1988, equation 3.6). It has the advantage of working under very general assumptions about the properties of the error terms and can be used when the estimator is two-stage least squares, which it is here. The Wald statistic is distributed as x^2, with (in the present case) eight degrees of freedom. The estimates of the equation for the two subperiods are presented in Table 1. The value of the Wald statistic is 11.13, which has a *p*-value of .194. The hypothesis of equality thus is not rejected even at the 10 percent level.

Equation 1, estimated for the entire 1954:1-1999 period, underwent a number of other tests.[4] First, the lagged values of all the variables in the equation $(r_{-4}, \dot{p}_{-1}, u_{-2}, \dot{m}_{-2}, D1 \times \dot{m}_{-2})$ were added and the joint significance of these variables was tested. The x^2 value was 5.69, with five degrees of freedom, which has a *p*-value of .338. Adding these variables encompasses a number of alternative hypotheses about the dynamics, and these hypotheses are rejected because the added variables are not significant.[5] Second, the equation was estimated assuming first-order serial correlation of the error term. The x^2 value was 1.30, with one degree of freedom, which has a *p*-value of .255. Third, the percentage change in

Table 1

Estimated U.S. Interest Rate Rule

	1954:1-1999:3		1954:1-1979:3		1982:4-1999:3		1954:1-1999:3	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Constant	.855	5.42	.762	3.36	.409	1.93	.663	3.98
$\dot{p}$	.071	4.17	.077	3.05	.145	3.30	.080	4.35
u	-.131	-4.18	-.114	-3.00	-.085	-2.29	-.111	-3.55
Δu	-.748	-6.05	-.380	-3.04	-.901	-4.53	-.567	-4.43
$\dot{m}-1$	.014	2.26	.027	3.65	.001	0.16	.010	1.73
$D1 \times \dot{m}-1$	.219	9.71	-		-		.349	8.72
$r-1$	.916	47.32	.887	21.60	.939	36.17	.922	38.71
$\Delta r-1$	.210	3.75	.251	2.89	.280	2.88	.338	5.36
$\Delta r-2$	-.345	-6.71	-.225	-2.54	-.195	-2.26	-.357	-7.23
$D1 \times \dot{p}$							-.148	-3.40
$D2 \times \dot{p}$							.060	1.67
SE	.471		.411		.317		.450	
R^2	.971		.960		.970		.974	
DW	1.85		1.82		2.09		2.17	
Wald (*p*-value)	11.13 (.194)							
Number of observations	183		103		68		183	

Source: Author's calculations.

Notes: The dependent variable is *r*. The estimation period is 1954:1-1999:3. The estimation technique is two-stage least squares. *r* is the three-month Treasury bill rate, $\dot{p}$ is the inflation rate, *u* is the unemployment rate, and $\dot{m}$ is the growth rate of the money supply. *D*1 equals 1 for 1979:4-1982:3, 0 otherwise; *D*2 equals 1 for 1982:4-1999:3, 0 otherwise.

real GDP was added (without excluding the change in the unemployment rate). The x^2 value was 0.51, with one degree of freedom, which has a p-value of .476. Finally, an output gap variable and the change in the variable were added (without excluding the unemployment rate and the change in the unemployment rate).[6] The x^2 value was 2.43, with two degrees of freedom, which has a p-value of .297. Overall, the equation performs well in these tests. The added variables, including the output gap and the change in the output gap, do not have additional explanatory power.

When the unemployment rate and the change in the unemployment rate are added to the equation with the output gap and the change in the output gap already included, the x^2 value is 9.53, with two degrees of freedom, which has a p-value of .009. The unemployment rate and the change in the unemployment rate thus have additional explanatory power.

One likely reason why the stability hypothesis generally has been rejected is that most tests have included the [1979:4–1982:3] period, which is clearly different from the periods before and after.

Since the output gap and the change in the output gap do not have such power, in this sense the unemployment rate dominates the output gap. Many interest rate rules in the literature use some measure of the output gap as an explanatory variable, and the current results suggest that the unemployment rate may be a better variable.

Returning to the stability test, again note that the passing of this test is contrary to the overall view in the literature. One likely reason why the stability hypothesis generally has been rejected is that most tests have included the early Volcker period, which is clearly different from the periods before and after. The tests in Judd and Rudebusch (1998), for example, include the early Volcker period.

Clarida, Galí, and Gertler (2000) do not perform any stability tests; they simply note that the coefficient estimates for the different periods look quite different, especially the inflation coefficient. The equations for the two subperiods in Table 1 also show a large difference in the inflation coefficient. For the first subperiod, the long-run coefficient is 0.68 [=.077/(1.0 - .887)], and for the second subperiod it is 2.38 [=.145/(1.0 - .939)]. The Clarida, Galí, and Gertler coefficients (p. 150) are .83 for their pre-Volcker period (1960:1-1979:2) and 2.15 for their Volcker-Greenspan period (1979:3-1996:4).

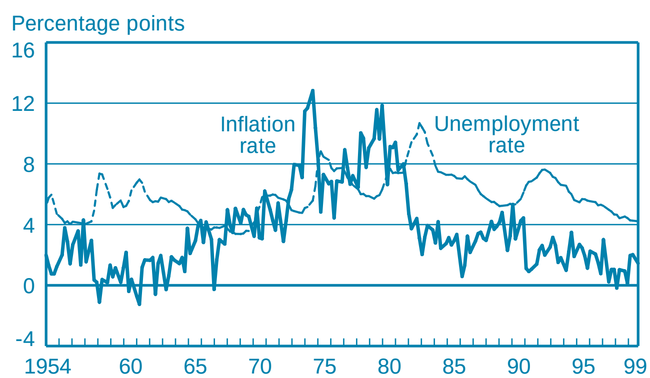
Although the inflation coefficients seem quite different in Table 1, the Wald test does not reject the hypothesis of stability. It could be, however, that the test had low power, so another test was performed. This test is represented in the last two columns of Table 1. It is based on the assumption that all the coefficients are constant across time, except for the inflation coefficient, which is postulated to be different in each of the three subperiods: 1954:1-1979:3, 1979:4-1982:3, and 1982:4-1999:3, which I refer to as the "first," the "early Volcker," and the "second" periods, respectively. The coefficient estimate for $D1 \times \dot{p}$ is the estimated difference between the early Volcker period and the first period. This difference is not of much interest, however, since the added variable is just meant to dummy out the early Volcker period. The estimated difference is negative and significant (with a t-statistic of -3.40). The total coefficient for this period is -0.068 [= .080 - .148]. This negative value is not sensible, reflecting the fact that the early Volcker period is unusual and hard to model. (This is why the period was completely ignored in the Wald test.)

The coefficient estimate for $D2 \times \dot{p}$ is the estimated difference between the second and first periods. This estimated difference is .060, with a t-statistic of 1.67, which is not significant at the 5 percent level for a two-tailed test. Again, the long-run inflation coefficient for the second period of 1.79 [= .080 + .060)/(1 - .922)] is noticeably larger than that for the first period of 1.03 [= .080/(1 - .922)].

The results thus show a large economic, but not statistically significant, difference for the inflation coefficient between the first and second periods. One important fact to keep in mind is that the variance of inflation is much smaller in the second period than it is in the first. This can be seen from Chart 1, where inflation and the unemployment rate are plotted for the

Chart 1

Unemployment and Inflation: 1954:1-1999:3



Source: U.S. Department of Labor, Bureau of Labor Statistics.

1954:1-1999:3 period. The largest value of inflation in the second period is 5.33 percent, in 1990:1, and no other value is above 5 percent. However, the largest value for the first period is 12.83 percent, in 1974:3, and twenty-nine other values are above 5 percent.

If inflation were to rise substantially in the future, it would make for an interesting test of whether there has been a structural change in Federal Reserve policy behavior. The third equation in Table 1 implies a much larger Federal Reserve response than the first equation does; the test is which equation predicts the actual Federal Reserve response better. If the third equation is the better predictor, we will have strong evidence in favor of a shift in behavior from the earlier period. If the first equation excels, it will suggest that focusing only on the post-1982 period, when inflation has been low, has resulted in misleading estimates (in effect, a small-sample problem). In short, although the statistical tests in this article suggest that there has not been a shift in behavior, more observations are needed—particularly high-inflation ones—before much confidence can be placed in any conclusion.

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Deviations from the Rule

Equation 1, estimated for the 1954:1-1999:3 period, was solved dynamically for this period using the actual values of inflation, the unemployment rate, and the growth of the money supply. Chart 2 plots the predicted values from this simulation along with the actual values, and the appendix table presents the values. The actual values of inflation, the unemployment rate, and the growth of the money supply are also presented in the appendix table. For this exercise, the Federal Reserve is assumed to know the current values of inflation and the unemployment rate, since the actual values of these two variables are used.

Nine subperiods appear in Chart 2. They represent periods in which the actual values differ from the predicted values by noticeable amounts for a number of consecutive quarters. There are six quarters in the early 1960s in which the interest rate was noticeably higher than predicted: 1959:4, 1960:1, and 1961:1-1961:4, and there are three subperiods from the mid-1980s for which this was true: 1984:1-1985:2, 1988:4-1991:4, and 1994:4-1998:1. Conversely, the interest rate was noticeably lower than predicted in the mid-1950s, in the late 1960s, and in two periods in the 1970s: 1955:2-1957:3, 1966:1-1969:2, 1971:1-1973:2, and 1976:4-1978:2. Chart 2 presents the average deviation for each of these subperiods in parentheses. The largest average deviation in absolute value is -1.87 percentage points, for the 1971:1-1973:2 period.

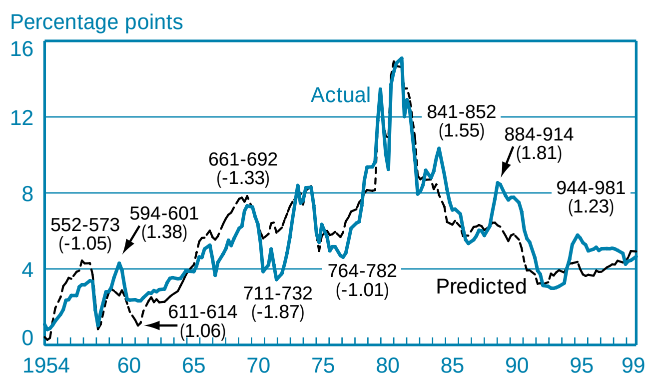
If the Federal Reserve is behaving optimally, then the deviations [from the interest rate rule] are actually errors made by the econometrician.

Taylor (1999) presents charts similar to Chart 2 using calibrated interest rate rules, and he interprets the deviations as policy mistakes. According to this interpretation, Chart 2 shows that the Federal Reserve's policy was too tight in the early 1960s, too loose in the late 1960s and in about half of the 1970s, and too tight in the mid-1980s, the late 1980s to early 1990s, and part of the second half of the 1990s.

However, if the Federal Reserve is behaving optimally, then the deviations are actually errors made by the econometrician. At each Federal Open Market Committee meeting, the Federal Reserve clearly knows more than is reflected in the rule, even if

Chart 2

Actual and Predicted Values of *r*: 1954:1-1999:3



Sources: Board of Governors of the Federal Reserve System; author's calculations.

Notes: Equation 1 in the text was estimated for the 1954:1-1999:3 period. The average deviations are in parentheses.

it is not formally solving an optimal control problem. According to this interpretation, deviations from the rule can be viewed as the use of more information by the Federal Reserve.

The Stabilization Effectiveness of Rules

There is a large literature examining the stabilization effectiveness of different interest rate rules. The general approach in this literature is to choose a rule and then use a model of the economy to examine how the economy would have behaved under the rule.[7] Using a calibrated model of the economy, Clarida, Galí, and Gertler (2000) show that interest rate rules with inflation coefficients less than 1 can be destabilizing. They then criticize the Federal Reserve's pre-1979 policy for being too timid, but praise it after 1979. This evaluation of policy is based on the assumption that there was a change in behavior after 1979: the Federal Reserve used a coefficient less than 1 before that year and a coefficient greater than 1 after it.

The judging of interest rate rules . . . can be sensitive to the economic model used.

A different conclusion about interest rate rules is reached in Fair (2000) using the U.S. model mentioned above. Stochastic simulation was used to compute variances of the endogenous variables for different rules.[8] The simulation period was 1993:1-1998:4.

The estimated rule in this article—estimated for the 1954:1-1999:2 period—was first tried. The variances using this rule for real output, the price level, and the Treasury bill rate are presented in the first row of Table 2. Two calibrated rules were then tried. The first was the Taylor rule, which has a coefficient of 0.5 on the output gap and 1.5 on inflation. The second was a rule with a coefficient of 0.5 on the output gap but only 0.25 on inflation; this will be called the ".25 rule." The variances using these two rules are presented in the second and third rows of Table 2, respectively.

Compared with the estimated and .25 rules, the Taylor rule achieved a lower price level variance (0.61, versus 0.69 and 0.71) at the cost of a considerably higher interest rate variance (2.86, versus 1.14 and 1.19). Some insight into this result can be gleaned from a property of the price equation in the U.S. model, which is that the price level responds only modestly to demand (a common feature of most estimated price equations). Since the interest rate affects the price level primarily through its effects on demand, the price level responds only modestly to interest rate changes. The Taylor rule has a large coefficient on inflation, so a large price shock leads to a large change in the interest rate, but this in turn has only a modest impact on offsetting the effects of the price shock. For a rule like the estimated or the .25 rule, the interest rate responds much less to a price shock, so the interest rate variance is smaller. The cost of a smaller interest rate response in terms of offsetting the effects of the price shock is modest because of the modest effect of the interest rate on the price level.

Why are the estimated and .25 rules not destabilizing, as they would be in the Clarida, Galí, and Gertler model? The answer is that the response of output to a price shock is much different in that model than it is in the U.S. model. Consider a positive price shock with no change in the nominal interest rate. In the Clarida, Galí, and Gertler model, this shock is expansionary because the real interest rate, which has a negative effect on output, is lower. In the U.S. model, however, a positive price shock with no change in the nominal interest rate is contractionary. In the short run, the aggregate price level rises more than wage rates rise, so a fall in real income occurs. Real wealth also falls. These effects are contractionary on demand. In addition, the empirical results suggest that households respond to nominal interest rates and not real interest rates, so there is no positive household response to lower real interest rates. The net effect of a positive price shock with no change in the nominal interest rate is contractionary in the U.S. model. If this is true, then the Federal Reserve, in response to a positive price shock, does not have to increase the nominal interest rate more than the increase in inflation to

Table 2
Variability Estimates

	Y	P	r
Estimated rule	4.12	0.69	1.14
Calibrated rule (1.50, Taylor)	4.04	0.61	2.86
Calibrated rule (.25)	3.57	0.71	1.19

Source: Author's calculations.
Notes: The simulation period is 1993:1-1998:4. Y is real GDP, P is the GDP deflator, and r is the three-month Treasury bill rate. The variability measures are the squares of percentage points. The rules are described in the text.

achieve a contraction. There will be a contraction even if there is no increase in the nominal interest rate at all!

The judging of interest rate rules therefore can be sensitive to the economic model used. Using an economic model in which positive price shocks are expansionary—as Clarida, Galí, and Gertler do—leads to a much different conclusion than using a macroeconometric model like the U.S. model, in which positive price shocks are contractionary. Using small, calibrated models to make policy conclusions is risky if the models are at odds with more empirically based ones. It may be that the specification and calibration have not captured reality well.

Appendix: Variable Values, 1954:1-1999:3

Quarter	r	$\hat{r}$	$r-\hat{r}$	$\dot{p}$	u	$\dot{m}$	Quarter	r	$\hat{r}$	$r-\hat{r}$	$\dot{p}$	u	$\dot{m}$
1954:1	1.08	0.41	0.67	1.99	5.23	0.85	1967:1	4.53	5.67	-1.14	-0.27	3.81	6.10
1954:2	0.81	0.27	0.55	1.29	5.78	3.69	1967:2	3.66	5.54	-1.88	1.68	3.81	-0.54
1954:3	0.87	0.36	0.51	0.75	5.97	10.01	1967:3	4.34	5.72	-1.37	3.01	3.78	18.80
1954:4	1.04	1.23	-0.19	0.75	5.36	-1.09	1967:4	4.79	6.37	-1.59	2.72	3.92	6.92
1955:1	1.26	1.94	-0.68	1.23	4.71	6.45	1968:1	5.06	6.65	-1.59	4.98	3.73	3.60
1955:2	1.61	2.52	-0.91	2.00	4.38	0.17	1968:2	5.51	6.86	-1.35	3.97	3.54	0.89
1955:3	1.86	3.10	-1.24	3.79	4.11	5.58	1968:3	5.23	6.96	-1.73	3.48	3.51	15.26
1955:4	2.35	3.27	-0.93	2.89	4.21	-3.17	1968:4	5.58	7.23	-1.65	5.07	3.39	13.59
1956:1	2.38	3.53	-1.15	1.42	4.03	2.33	1969:1	6.14	7.69	-1.55	4.09	3.38	-1.31
1956:2	2.60	3.48	-0.89	2.67	4.19	0.92	1969:2	6.24	7.75	-1.51	4.99	3.42	1.15
1956:3	2.60	3.85	-1.25	3.58	4.13	1.76	1969:3	7.05	7.53	-0.49	4.64	3.59	6.25
1956:4	3.06	3.91	-0.85	1.34	4.10	0.27	1969:4	7.32	7.83	-0.52	4.54	3.58	7.88
1957:1	3.17	4.44	-1.27	4.30	3.95	1.29	1970:1	7.26	7.17	0.09	3.23	4.16	9.29
1957:2	3.16	4.29	-1.14	1.55	4.06	-0.04	1970:2	6.75	6.74	0.01	5.08	4.75	5.13
1957:3	3.38	4.30	-0.91	2.96	4.21	1.14	1970:3	6.37	6.24	0.13	3.13	5.17	21.44
1957:4	3.34	3.70	-0.36	0.35	4.92	-4.16	1970:4	5.36	5.94	-0.59	3.07	5.80	-14.35
1958:1	1.84	2.28	-0.45	0.20	6.28	3.48	1971:1	3.86	5.60	-1.74	6.21	5.91	16.99
1958:2	1.02	0.83	0.18	-1.11	7.36	0.06	1971:2	4.21	5.84	-1.63	4.99	5.91	10.58
1958:3	1.71	1.07	0.64	0.38	7.31	10.24	1971:3	5.05	6.40	-1.35	4.27	5.98	12.58
1958:4	2.79	2.30	0.49	0.18	6.35	2.60	1971:4	4.23	6.44	-2.21	3.63	5.95	-12.19
1959:1	2.80	2.73	0.07	1.33	5.80	4.84	1972:1	3.44	5.90	-2.46	5.42	5.77	18.84
1959:2	3.02	2.94	0.08	0.56	5.10	0.75	1972:2	3.75	6.17	-2.42	2.89	5.66	6.14
1959:3	3.53	2.85	0.68	1.15	5.29	3.41	1972:3	4.24	6.56	-2.32	4.25	5.58	10.20
1959:4	4.30	2.60	1.70	0.20	5.59	-4.99	1972:4	4.85	6.91	-2.06	5.71	5.30	5.01
1960:1	3.94	2.88	1.06	1.15	5.16	0.58	1973:1	5.64	7.28	-1.64	6.29	4.95	5.95
1960:2	3.09	2.58	0.51	2.17	5.23	-0.27	1973:2	6.61	7.53	-0.92	7.96	4.89	12.45
1960:3	2.39	2.16	0.23	-0.40	5.55	5.29	1973:3	8.39	7.86	0.53	7.90	4.79	-0.09
1960:4	2.36	1.73	0.63	0.40	6.25	-2.63	1973:4	7.46	7.99	-0.52	7.10	4.77	8.46
1961:1	2.38	1.31	1.06	-0.72	6.77	7.69	1974:1	7.60	7.39	0.21	11.47	5.09	3.25
1961:2	2.32	1.02	1.30	-1.25	6.97	1.10	1974:2	8.27	8.11	0.16	11.67	5.16	8.56
1961:3	2.32	1.15	1.17	1.18	6.75	6.72	1974:3	8.29	8.36	-0.07	12.83	5.58	-0.63
1961:4	2.48	1.76	0.71	1.67	6.17	0.74	1974:4	7.34	7.42	-0.09	10.37	6.56	4.82
1962:1	2.74	2.31	0.43	1.65	5.61	1.94	1975:1	5.87	5.78	0.09	8.26	8.22	3.38
1962:2	2.72	2.51	0.21	1.83	5.48	0.66	1975:2	5.40	4.94	0.46	4.83	8.83	20.43
1962:3	2.86	2.25	0.61	-0.59	5.54	3.09	1975:3	6.34	5.74	0.59	7.30	8.47	-1.66
1962:4	2.80	2.40	0.40	1.44	5.51	4.82	1975:4	5.68	6.00	-0.32	6.69	8.26	1.03
1963:1	2.91	2.24	0.67	1.96	5.78	1.22	1976:1	4.95	5.78	-0.82	6.84	7.72	10.21
1963:2	2.94	2.27	0.67	-0.28	5.68	2.46	1976:2	5.17	5.83	-0.66	4.44	7.53	7.94
1963:3	3.28	2.40	0.88	0.63	5.49	6.50	1976:3	5.17	5.95	-0.78	6.87	7.70	0.20
1963:4	3.50	2.54	0.95	1.88	5.57	3.77	1976:4	4.70	5.68	-0.98	6.81	7.73	9.49
1964:1	3.54	2.65	0.88	1.67	5.46	1.58	1977:1	4.62	5.92	-1.29	8.93	7.49	12.65
1964:2	3.48	2.83	0.65	1.43	5.22	2.70	1977:2	4.83	6.50	-1.67	7.76	7.10	6.01
1964:3	3.50	3.11	0.39	1.83	4.99	15.32	1977:3	5.47	6.71	-1.24	6.66	6.86	9.01
1964:4	3.69	3.38	0.31	0.91	4.95	1.87	1977:4	6.14	7.02	-0.89	7.22	6.61	6.38
1965:1	3.90	3.69	0.21	3.76	4.87	0.21	1978:1	6.41	7.14	-0.73	6.46	6.33	7.82
1965:2	3.88	3.92	-0.04	2.10	4.66	-1.29	1978:2	6.48	7.50	-1.02	10.04	6.00	9.66
1965:3	3.86	4.22	-0.36	2.94	4.35	14.91	1978:3	7.32	7.66	-0.34	9.69	6.02	7.52
1965:4	4.16	4.85	-0.69	3.94	4.10	6.35	1978:4	8.68	8.00	0.68	7.77	5.88	6.20
1966:1	4.63	5.44	-0.81	4.27	3.85	4.27	1979:1	9.36	8.15	1.21	9.05	5.88	4.53
1966:2	4.60	5.63	-1.03	2.82	3.81	-3.27	1979:2	9.37	8.11	1.26	9.66	5.71	11.85
1966:3	5.05	5.64	-0.60	4.17	3.75	7.59	1979:3	9.63	8.15	1.48	11.57	5.87	14.40
1966:4	5.25	6.02	-0.77	3.03	3.68	2.31	1979:4	11.80	11.57	0.24	9.64	5.94	5.69

Source: Author's calculations.

Appendix: Variable Values, 1954:1-1999:3 (Continued)

Quarter	r	$\hat{r}$	$r-\hat{r}$	$\dot{p}$	u	$\dot{m}$	Quarter	r	$\hat{r}$	$r-\hat{r}$	$\dot{p}$	u	$\dot{m}$
1980:1	13.46	12.89	0.57	11.85	6.30	-0.09	1990:1	7.76	5.76	2.00	5.33	5.30	7.95
1980:2	10.05	10.98	-0.93	6.63	7.32	8.29	1990:2	7.77	5.83	1.94	3.06	5.34	7.30
1980:3	9.24	10.93	-1.69	9.14	7.68	10.40	1990:3	7.49	5.54	1.95	4.25	5.69	1.88
1980:4	13.71	14.17	-0.46	9.07	7.40	0.82	1990:4	7.02	5.09	1.93	4.44	6.11	-0.32
1981:1	14.37	14.92	-0.55	9.42	7.43	8.48	1991:1	6.05	4.38	1.67	1.12	6.57	8.13
1981:2	14.83	14.68	0.15	7.59	7.40	3.71	1991:2	5.59	3.92	1.67	0.91	6.82	6.62
1981:3	15.09	14.62	0.47	8.00	7.42	2.47	1991:3	5.41	3.93	1.48	1.06	6.85	10.89
1981:4	12.02	13.49	-1.47	6.70	8.24	9.85	1991:4	4.58	3.71	0.88	1.40	7.10	6.76
1982:1	12.90	13.50	-0.60	4.72	8.84	-0.25	1992:1	3.91	3.22	0.69	2.34	7.38	20.21
1982:2	12.36	12.99	-0.63	3.73	9.43	-0.39	1992:2	3.72	3.25	0.48	2.62	7.60	4.67
1982:3	9.71	10.88	-1.17	4.40	9.94	13.74	1992:3	3.13	3.20	-0.07	1.99	7.63	14.48
1982:4	7.94	8.90	-0.97	3.10	10.68	13.26	1992:4	3.08	3.30	-0.22	2.52	7.41	15.11
1983:1	8.08	8.72	-0.64	2.03	10.40	15.76	1993:1	2.99	3.75	-0.76	3.16	7.15	3.32
1983:2	8.42	8.82	-0.40	3.17	10.10	9.50	1993:2	2.98	3.65	-0.67	2.64	7.07	12.98
1983:3	9.19	8.69	0.49	3.93	9.36	7.39	1993:3	3.02	3.82	-0.80	1.51	6.80	12.56
1983:4	8.79	8.71	0.08	3.65	8.54	3.38	1993:4	3.08	3.93	-0.85	1.82	6.62	7.32
1984:1	9.13	8.20	0.93	2.79	7.87	19.73	1994:1	3.25	3.81	-0.56	0.99	6.56	7.10
1984:2	9.84	8.45	1.39	4.19	7.48	3.06	1994:2	4.04	4.10	-0.06	2.21	6.17	-1.27
1984:3	10.34	7.89	2.45	2.44	7.45	-2.33	1994:3	4.51	4.28	0.23	3.49	6.00	0.93
1984:4	8.97	7.28	1.70	2.75	7.28	10.01	1994:4	5.28	4.30	0.98	1.90	5.62	-0.86
1985:1	8.18	6.47	1.72	3.14	7.28	6.49	1995:1	5.78	4.37	1.41	2.69	5.47	0.39
1985:2	7.52	6.40	1.12	2.66	7.29	11.81	1995:2	5.62	3.98	1.65	2.46	5.68	1.17
1985:3	7.10	6.33	0.77	2.94	7.21	22.83	1995:3	5.38	3.71	1.67	1.93	5.67	-3.19
1985:4	7.15	6.53	0.61	3.35	7.05	5.61	1995:4	5.27	3.63	1.64	1.13	5.58	-0.56
1986:1	6.89	6.22	0.67	0.58	7.02	16.02	1996:1	4.95	3.69	1.26	2.25	5.54	-2.56
1986:2	6.13	5.73	0.40	1.33	7.18	19.97	1996:2	5.04	3.64	1.40	2.06	5.48	1.35
1986:3	5.53	5.76	-0.23	3.24	6.99	7.98	1996:3	5.14	3.91	1.22	1.50	5.27	6.17
1986:4	5.34	5.75	-0.41	2.17	6.84	31.13	1996:4	4.97	3.84	1.13	0.77	5.31	-3.21
1987:1	5.53	6.21	-0.67	2.91	6.62	-6.63	1997:1	5.06	3.85	1.21	3.01	5.23	5.72
1987:2	5.73	6.23	-0.50	3.41	6.28	8.51	1997:2	5.07	4.08	0.99	0.23	4.98	4.45
1987:3	6.03	6.31	-0.28	3.50	6.01	4.41	1997:3	5.06	4.15	0.91	1.04	4.86	-1.30
1987:4	6.00	6.25	-0.25	3.09	5.87	0.36	1997:4	5.09	4.24	0.85	1.05	4.67	6.14
1988:1	5.76	6.04	-0.28	2.96	5.73	9.72	1998:1	5.05	4.23	0.82	-0.18	4.65	4.30
1988:2	6.23	6.24	-0.01	4.21	5.49	10.22	1998:2	4.98	4.43	0.55	1.03	4.42	3.12
1988:3	6.99	6.43	0.56	3.69	5.49	0.46	1998:3	4.82	4.34	0.48	0.94	4.53	4.01
1988:4	7.70	6.43	1.27	3.88	5.35	-3.86	1998:4	4.25	4.39	-0.14	0.13	4.43	8.42
1989:1	8.53	6.29	2.24	4.14	5.22	2.99	1999:1	4.41	4.61	-0.20	1.96	4.28	2.44
1989:2	8.44	6.22	2.22	4.80	5.24	3.42	1999:2	4.45	4.94	-0.48	2.02	4.26	0.66
1989:3	7.85	5.74	2.11	2.30	5.28	-0.61	1999:3	4.65	4.92	-0.27	1.45	4.22	-2.80
1989:4	7.63	5.46	2.17	3.25	5.37	0.03							

Endnotes

1. Paul Volcker was chairman of the Federal Reserve between 1979:3 and 1987:2, but the period in question is only 1979:4 to 1982:3.

2. The data used for all estimates and tests in this article, including the data on the first-stage regressors, are available at <http://fairmodel.econ.yale.edu>. The results can be duplicated by downloading the data and some software from the site. The price variable used to construct the inflation variable is the price deflator for domestic sales. This variable was used in Fair (1978), and has been used ever since in equation 1. The three-month Treasury bill rate is used for the interest rate. Although in practice the Federal Reserve controls the federal funds rate, the quarterly average of the federal funds rate and the quarterly average of the three-month Treasury bill rate are so highly correlated that it makes little difference which rate is used in estimated interest rate rules using quarterly data. The money supply data are from the Flow of Funds Accounts of the Board of Governors of the Federal Reserve System.

3. See Fair (1994, Chapter 5) for the use of this test. The latest tests are available at <http://fairmodel.econ.yale.edu>.

4. See Fair (1994, Chapter 4) for a general discussion of these types of tests.

5. See Hendry, Pagan, and Sargan (1984).

6. The output gap measure used is $(YS - Y)/YS$, where Y is actual output and YS is a measure of potential output. These variables are in the U.S. model, which can be found at <http://fairmodel.econ.yale.edu>. YS is computed as potential productivity $\times$ potential employment, where both potential series are computed from peak-to-peak interpolations.

7. See, for example, Feldstein and Stock (1993), Hall and Mankiw (1993), Judd and Motley (1993), Clark (1994), Croushore and Stark (1994), Thornton (1995), Fair and Howrey (1996), Rudebusch (1999), Fair (2000), and Clarida, Galí, and Gertler (2000). Taylor (1985, p. 61, fn. 1) cites much of the literature prior to 1985.

8. In the following discussion, "variance" is used to refer to a particular measure of variability, not an actual variance. Variances of endogenous variables differ over time, and the variability measure is roughly an average of the quarterly variances across time.

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