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Federal Reserve Bank of Dallas

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ABSTRACT

This paper demonstrates that the time series properties of inflation have changed dramatically since 1983. Specifically, the inflation rate can now best be described as a stationary white-noise process with strong mean-reverting tendencies. These findings contrast sharply with the nonstationary and highly persistent characteristics of inflation for the rest of the post-Accord period. The most recent behavior of inflation has important implications for the perceived anti-inflation credibility of the Federal Reserve, for empirical models of inflation, and for the formation of inflation expectations.

The analysis also shows that, in contrast to the rest of the post-Accord period, inflation is now neutral **vis-a-vis** its effects on real interest rates. This independence between real interest rates and inflation, during the 1983-89 period, is consistent with the Fisher equation.

Introduction

Barsky (1987) and Klein (1977) document the dramatic differences between the behavior of the inflation rate under the gold standard period of 1880-1910 and under the post-Accord period since 1953. Under the gold standard period, the inflation rate was mean-reverting and followed a white noise process. In the post-Accord period, the inflation rate has been nonstationary and highly persistent with no mean-reverting tendencies. It is argued that these two characterizations of inflation are consistent with the principles underlying their respective monetary regimes. Under a gold standard, convertibility serves as a nominal anchor for the price level and ensures long-term price stability as long as the demand for and supply of gold are stable. Therefore, with convertibility, inflation would be expected to be mean-reverting and stationary. Under a fiat standard, there are usually no automatic rules governing the behavior of the monetary authorities. Nothing guarantees long-term monetary stability; therefore, nothing assures long-term price stability.

The purpose of this paper is twofold. The first goal is to show that since 1983 the behavior of inflation resembles what one would expect under a convertibility standard rather than under the current fiat standard. Specifically, since 1983 inflation can be modelled as white noise around a constant mean, so that inflation exhibits very little persistence. This result is surprising given that no rules have been imposed on the Federal Reserve to help ensure long-term price level stability. This finding, however, is consistent with the hypothesis that the central bank has become increasingly concerned with long-term price level stability and is attempting to build its credibility as an anti-inflation institution.

The second purpose of this paper is to show that, coincidental to the most recent change in the behavior of inflation, inflation no longer appears to be nonneutral **vis-a-vis** its effects on real interest rates. Mishkin (1981) showed that, during the post-Accord period, high lagged inflation systematically predicted lower **ex post** real interest rates. Under rational expectations, this finding also implies that **ex ante** real rates correlated negatively with lagged inflation. Barsky (1987) extended Mishkin's analysis to show that such a relationship between past inflation and **ex ante** real interest rates is evidence against the Fisher equation. Barsky's main point is that, according to the Fisher equation, forecastable inflation should not systematically influence real rates of interest. Since forecastable inflation systematically lowers real interest rates during the post-Accord period, he views this as evidence against the Fisher equation. Barsky also shows that there was no relationship between real interest rates and inflation during the gold standard regime of 1880-1910. Barsky's findings contradict the conventional wisdom that the high correlation between nominal interest rates and inflation during the post-Accord period provides support for the Fisher equation while the lack of such a correlation, during the gold standard period, is viewed as evidence against the Fisher equation. The results of this paper indicate that since 1983, there is no evidence of nonneutrality of inflation **vis-a-vis** real interest rates. Thus, as during the gold standard period of 1880-1910, the evidence is consistent with the Fisher equation during the 1983-89 period.

The findings of this paper have several implications. First begging an explanation, is that over the past six to seven years inflation has behaved in a manner similar to that which would be expected under a convertibility standard. Clearly lacking the automatic discipline provided by a system of convertibility, the most recent behavior of the price level lends support to the hypothesis that the Federal Reserve is interested in building credibility as an anti-inflation institution. Second, since 1983 lagged values of inflation have very little predictive power for future inflation. This development has important implications for models of inflation. Specifically, the evidence in this paper suggests that inflation models which fit the data well before 1983 may exhibit parameter instability and have less explanatory power thereafter.[1] Last, the change in the behavior of inflation coincides with a change in the relationship between real interest rates and inflation that is consistent with the Fisher equation. Unlike in the rest of the post-Accord period, creditors have recently not systematically underestimated the impact of inflation on their real rates of return. This may be a contributing factor to the relatively high real interest rates during the 1980s as compared with the rest of the post-Accord period.

The first part of the paper examines the autocorrelation functions of inflation for the post-Accord period and for the period since 1983. Box-Jenkins time series models of inflation are then fit for the two periods. Both exercises confirm that the behavior of inflation has changed dramatically since 1983. In the second part of the paper, methodology outlined by Mishkin (1981) is used to examine the relationship between inflation and ex ante real interest rates during the two periods.

1. Time Series Properties of Inflation

This section addresses the behavior of inflation during the periods 1953-79 and 1983-89 by examining their autocorrelation functions and by fitting Box-Jenkins identifications. The 1979Q3-82Q4 period is excluded from the analysis because many studies have concluded that this period constituted a separate monetary regime.[2] The starting date is 1953 because the collection of price data improved substantially at this time (Huizinga and Mishkin 1984, p. 238). The data are seasonally unadjusted quarterly and monthly observations on the Consumer Price Index for the period 1953Q1 through 1989Q7. Using monthly data, in addition to quarterly data, allows more degrees of freedom and is particularly useful in the smaller 1983-89 sample.

Table 1 shows the autocorrelations for the two periods. All of the autocorrelations are positive, and the Ljung-Box Q-statistics reject the null hypothesis of white noise at the various lag lengths. Additionally, augmented Dickey-Fuller tests, with and without time trends, could not reject the null hypothesis of a unit root in the inflation rate. The autocorrelations for the period 1953-79 thus confirm Barsky's and Klein's characterization of inflation process during this period.

The autocorrelations for the 1983-89 period are in sharp contrast to the earlier period. When tested using the quarterly data, the null hypothesis cannot be rejected for any lag length. Additionally, seven of the first sixteen autocorrelations are negative. Using monthly data, ten of the first twenty-four autocorrelations are negative; and at the end of twenty-four lags the Ljung-Box Q-test marginally indicates white noise.[3] Figures 1 through 4 highlight the differences in the characterization of inflation between the two periods. The behavior of inflation in the latter period is very similar to the behavior of inflation during the gold standard period of 1880-1910.

Table 2 shows univariate models of inflation for the two periods derived using Box-Jenkins methods. For the 1953-1979 period, integrated moving average processes best describe the data. Integrated moving average models characterize series which are nonstationary and whose levels are updated each period based upon a permanent and transitory component of the disturbance. For the quarterly data, the moving average component is of order one, while for the monthly data the moving average component is of order three. For 1983-89, using quarterly data, the inflation series is best described as white noise. Using monthly data the Box-Jenkins model fit is an AR(1) process. The autoregressive component is estimated to be approximately 0.4. These Box-Jenkins identifications are consistent with the autocorrelation functions and generally characterize the inflation rate as highly persistent and nonstationary during the period 1953-79 while mean-reverting and stationary during the 1983-89 period.

A consequence of these characterizations of inflation is that past inflation rates should have had substantial predictive power for future inflation rates in the earlier sample, while having had very little predictive power in the later period. Table 3 displays the adjusted R^2's obtained from regressing current inflation on various lags of past inflation for the two periods.[4] As shown in the table, lagged values of inflation are able to explain from one-half to nearly three-fourths of the actual variation in inflation during the period 1953-79. For the period 1983-89, however, the adjusted R^2's are negative for the quarterly data (and never get above 0.2 for the monthly data) implying current inflation holds little predictive content for determining future rates of inflation. Nonetheless, if the inflation rate continues to exhibit stationarity and is close to white noise, long-term forecasts will be relatively accurate. Klein (1977) drew similar conclusions concerning short-term and long-term price level uncertainty under convertibility and fiat monetary standards. As long as convertibility is maintained, short-term uncertainty is high relative to long-term uncertainty. Under a fiat standard, the opposite is true.

The analysis in this paper, however, shows that the behavior of the price level during the fiat regime of 1983-89 has been very similar to the behavior of the price level during the gold standard period of 1880-1910. Under the current fiat standard, then, the evidence is consistent with the hypothesis that the automatic discipline provided by a convertible standard has been replaced by the self-imposed monetary discipline of the Federal Reserve.

2. The Impact of Inflation Behavior on Real Interest Rates

This section demonstrates that the recent change in the behavior of inflation coincides with a change in the relationship between inflation and real interest rates. Mishkin (1981) outlines a method for using real ex post rates of return to draw inferences concerning correlations between ex ante rates of return and predetermined variables. He finds that, for the 1970s, the real rate of interest correlates negatively with inflation, suggesting that Fama's (1975) finding of real rate constancy was sample specific. Subsequently, Barsky (1987) interprets these findings as evidence inconsistent with the Fisher equation. To illustrate Barsky's point, note that the real rate of interest using Fisher's definition may be written as:

$$i_t = rr_t + \pi_t^e \quad (1)$$

where i_t = the nominal interest rate earned on a one-period bond maturing at time t.

π_t^e = the rate of inflation from t-1 to t expected by the bond market at time t-1.

rr_t = the one-period real rate of interest expected by the bond market at time t-1 for the bond maturing at time t.

Beacause rr_t is an expected yield, it is often referred to as the ex ante real rate of return. The actual, or **ex post**, real rate of return can be defined as the nominal interest rate minus the actual rate of inflation.

$$eprr_t = i_t - \pi_t = rr_t - (\pi_t - \pi_t^e) \quad (2)$$

Mishkin then invokes the assumption of rational inflation expectations in the bond market, which implies:

$$E(\pi_t - \pi_t^e | \phi_{t-1}) = 0 \quad (3)$$

where ϕ_{t-1}= information available at time t-1.[5]

If the **ex ante** real rate determined at t-1, rr_t, is correlated with variables, X_{t-1}, then we can write

$$rr_t = X_{t-1}\beta + u_t \quad (4)$$

Substituting (4) into (2) yields

$$\mathrm{eprr}_t = X_{t-1}\beta + u_t - \epsilon_t \qquad (5)$$

where ϵ_t equals the inflation forecast error, $\pi_t - \pi_t^e$.

Since data on the ex post real rates of return are observable, (5) can be estimated. Mishkin (1981) demonstrates several propositions regarding the relationships between the estimates of β in (5) and the estimates of β in (4), assuming that (4) is estimable. He shows that the coefficient estimates from (4) and (5) are equal in expectation. This is true regardless of the assumptions regarding u_t. In other words, the estimates are equal in expectation even if β_{rr} is a biased estimate of the true β. Mishkin also demonstrates that the variance-covariance matrix of (5) will be larger than the variance-covariance matrix of (4). This result occurs because (5) contains the error term, ϵ_t, which increases the variance-covariance matrix of (4) by the variance of the inflation forecast's errors. Therefore, the statistical tests of these regressions will have lower power than those of (4).

Mishkin uses (5) to show that there is a negative correlation between the ex post real rate of return and lagged inflation, using quarterly data, for the sample period 1953-79. He attributes Fama's (1975) finding of no relationship between inflation and the ex post real rate to be caused by a lack of variation in the real rate for his sample, 1953-71. Barsky (1987) points out that the essence of the Fisher equation is that nominal interest rates should be set such that forecastable inflation does not systematically lower real interest rates. He therefore interprets Mishkin's results as evidence against the Fisher hypothesis. For various numbers of lags, Barsky finds that lagged inflation systematically lowers ex post real interest rates for 1930-79. He also shows that this systematic relationship does not hold during the gold standard period.

This section employs the methodology outlined by Mishkin to extend the empirical results on the Fisher equation to include the 1980s. Since there appears to be a break in the underlying inflation process at 1983, it would be worthwhile to investigate any changes in the relationship between inflation and real interest rates for this period.

Note first that, in this section, the analysis uses only quarterly data. This is because, as pointed out by Mishkin (1981), the appropriate dating of the Consumer Price Index in a particular month is ambiguous given that price quotations have been collected over the entire month. Therefore, there is no accurate way to match the timing of the one-month rates with the dating of the CPI in the construction of **ex post** real interest rates. This problem is less severe for quarterly data.[6]

Table 4 presents the regressions of **ex post** three-month T-bill rates regressed on lags of inflation. The results confirm Mishkin's finding of a negative relationship between lagged inflation and real interest rates for 1953-79. That is, lagged inflation helps predict **ex post** real rates. This finding suggests that inflation was nonneutral in its effects on real rates over the 1953-79 period. F-statistics for the regressions are all highly significant and the adjusted R^2's are approximately .25. However, for 1983-89, the F-statistics are all insignificant. Additionally, the sums of the coefficients are all positive and insignificant, except for the regression with eight lags of inflation. Two of the three adjusted R^2's are, in fact, negative. This suggests that forecastable inflation did not help predict real rates over this period.

In framing the Fisher equation this way, it appears that during periods when inflation is highly forecastable and persistent, nominal interest rates fail to fully compensate for the effects of inflation. During periods such as the gold standard years and 1983-89, when inflation is not forecastable, there is no evidence of nonneutrality of inflation on real interest rates.

Conclusions

The analysis here demonstrates that the time series properties of inflation have changed dramatically since 1983. Specifically, the inflation rate can now best be described as a stationary white-noise process with strong mean-reverting tendencies. These findings contrast sharply with the nonstationary and highly persistent characteristics of inflation for the rest of the post-Accord period. The recent behavior of inflation is consistent with the hypothesis that the Federal Reserve is interested in building credibility as an anti-inflation institution. It is also suggests that empirical models of inflation may have recently exhibited parameter instability.

The analysis here also shows that, in contrast to the rest of the post-Accord period, inflation is now neutral **vis-a-vis** its effects on real interest rates. The change in the relationship between real interest rates and inflation is consistent with the view that, since 1983, creditors have not systematically underestimated the impact of inflation on their real rates of return. Thus, the evidence is consistent with the Fisher equation for the 1983-89 period.

Table 1
Autocorrelations of Inflation
(Rate of Change of Seasonally Unadjusted CPI)

Sample Period	Lags								
1953Q1-1979Q3	1-8	.75	.67	.63	.60	.52	.41	.38	.32
	9-16	.34	.29	.32	.31	.31	.33	.39	.42
Q(16)= 391.29									
1953M1-1979M9	1-8	.49	.59	.49	.49	.45	.44	.43	.44
	9-16	.47	.42	.41	.47	.40	.35	.38	.32
	17-24	.28	.27	.23	.28	.28	.22	.28	.24
Q(24)= 1230.6									
1983Q1-1989Q2	1-8	-.02	.003	.10	.04	.07	-.29	.15	.03
	9-16	-.14	-.26	-.20	.08	-.14	-.09	.03	.13
Q(16)= 13.62	$Q(16)_{.05}$=26.3								
1983M1-1989M7	1-8	.43	.001	-.07	-.03	.02	-.02	.17	.19
	9-16	.05	-.14	-.13	.06	-.03	-.004	.10	.07
	17-24	-.08	-.22	-.09	.08	.14	.07	.06	.05
Q(24)= 38.01	$Q(24)_{.05}$=36.4	$Q(24)_{.10}$=39.4							

Figure 1
Autocorrelation Function of Inflation
Monthly Data, 1953-1979

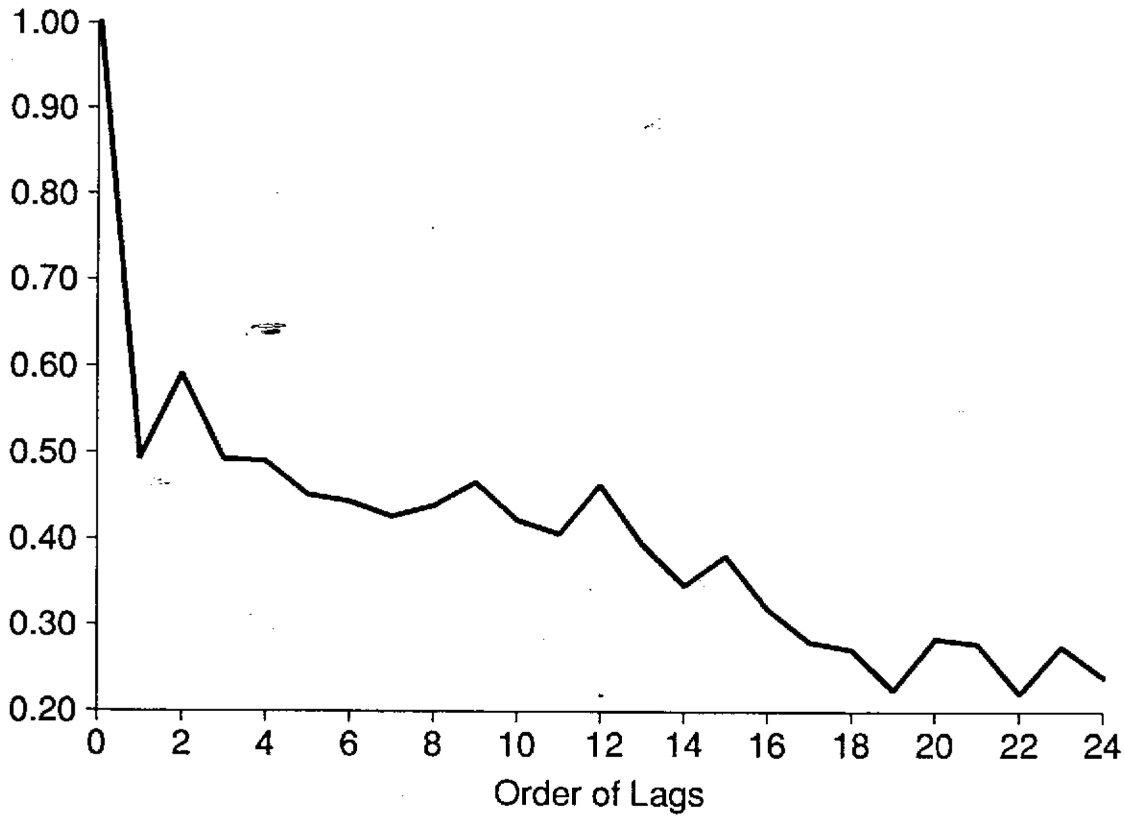

Figure 2
Autocorrelation Function of Inflation
Monthly Data, 1983-1989

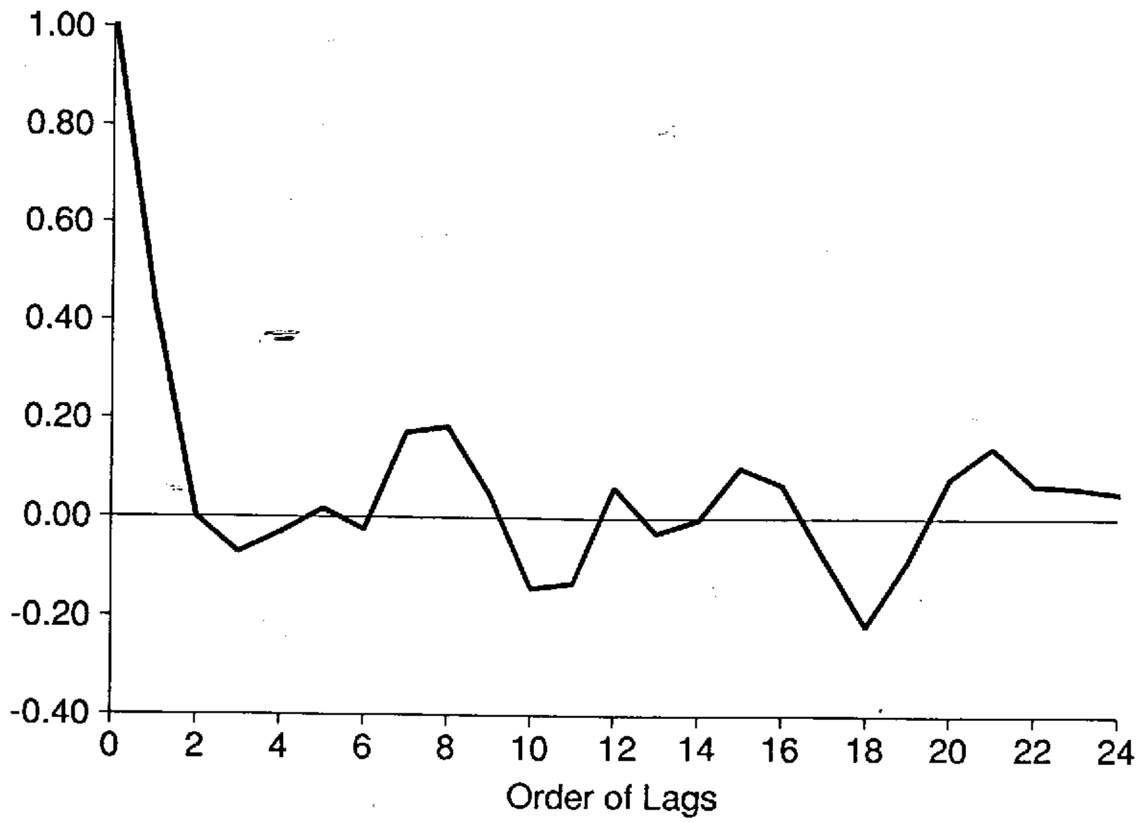

Figure 3
Autocorrelation Function of Inflation
Quarterly Data, 1953-1979

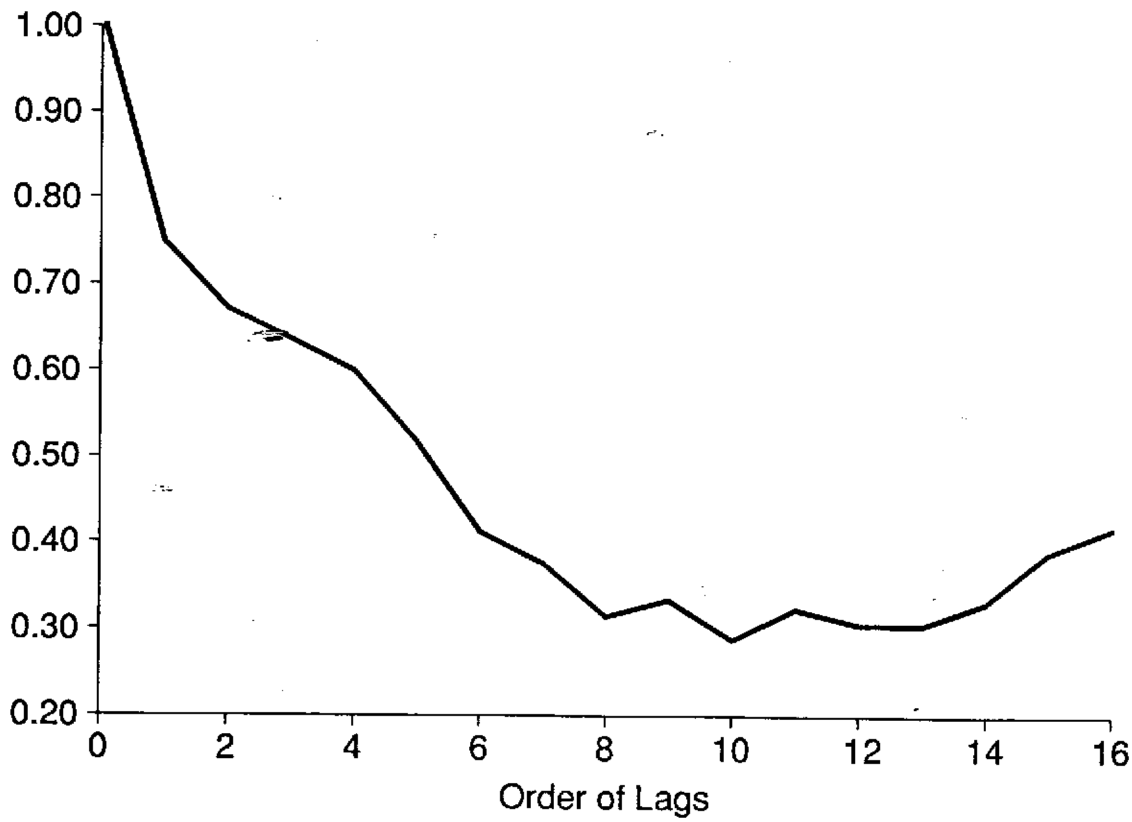

Figure 4
Autocorrelation Function of Inflation
Quarterly Data, 1983-1989

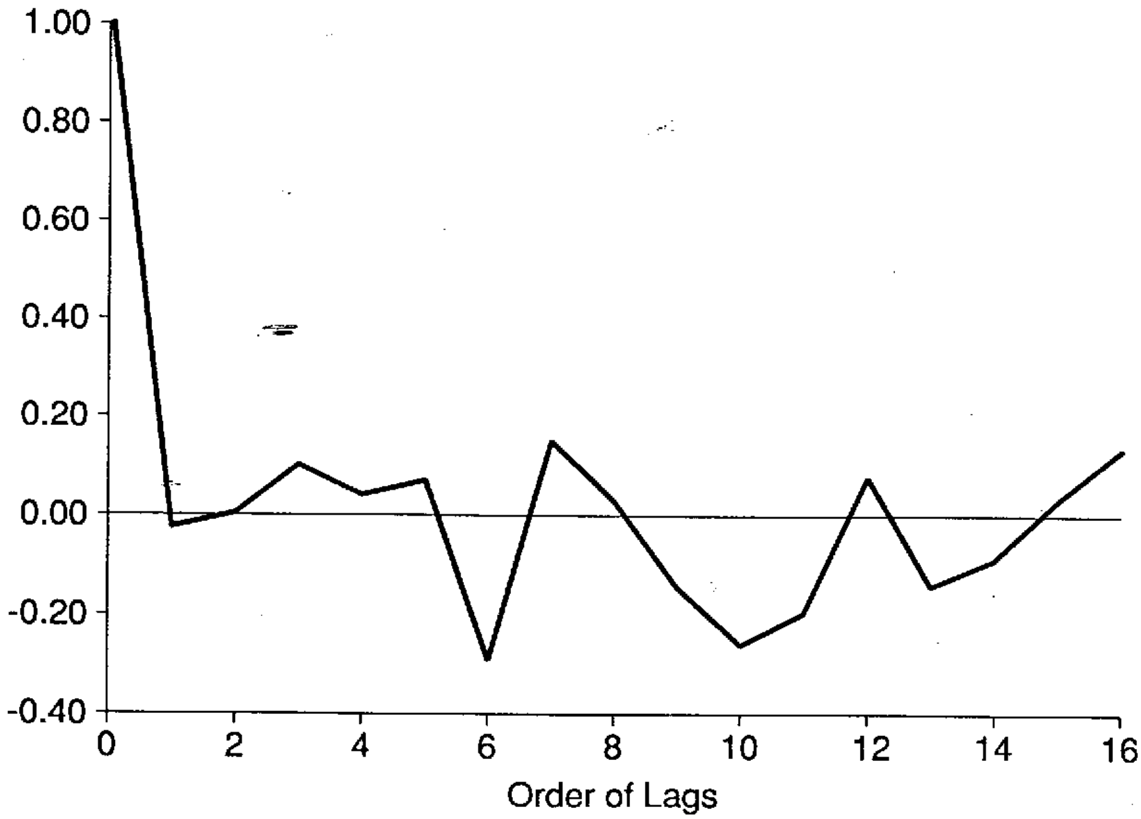

Table 2
ARIMA Models of Inflation

Sample 1953-1979

1953Q1-1979Q2	IMA(1,1)	$x_t = x_{t-1} + \underset{(.03)}{.85}e_{t-1} + e_t$
1953M1-1979M9	IMA(1,3)	$x_t = x_{t-1} + \underset{(.06)}{.93}e_{t-1} - \underset{(.08)}{.22}e_{t-2} + \underset{(.06)}{.14}e_{t-3}$

Sample 1983-1989

1983Q1-1989Q2	White Noise	
1983M1-1989M7	AR(1)	$x_t = \underset{(.0004)}{.003} + \underset{(.103)}{.43}x_{t-1} + et$

Table 3

Adjusted R^2's From Inflation on Its Lagged Values

Sample	Adjusted R^2's		
	4 lags	8 lags	12 lags
1953Q1-1979Q3	.68	.68	.71
1953M1-1979M9	.45	.47	.49
1983Q1-1989Q2	-.09	-.06	-.32
1983M1-1989M7	.19	.19	.19

Table 4

Regressions of **ex poste** Real Rate on Lagged Information

Sample Period:	# of lags of inflation	Sum of lag coefficients	$\bar{R}^2$	F-test of signific. of reg.
1953-1979	1	-.309 (.051)	.25	36.09
	4	-.385 (.024)	.27	11.00
	8	-.337 (.039)	.27	5.90
1983-1989	1	.098 (.219)	-.03	0.20
	4	.583 (.800)	-.06	0.68
	8	1.195 (.318)	.01	1.04

Literature Cited

Barsky, Robert B. "The Fisher Hypothesis and the Forecastability of Inflation." Journal of Monetary Economics 19 (January 1987), 3-24.

Box, George E., and Gwylim M. Jenkins. Time Series Analysis: Forecasting and Control, 2nd ed. San Francisco: Holden-Day, 1976.

Fama, Eugene F. "Short-Term Interest Rates as Predictors of Inflation." American Economic Review 65 (June 1975), 269-82.

Huizinga, John and Mishkin, Frederic. "Monetary Policy Regime Shifts and the Unusual Behavior of Real Interest Rates." Carnegie-Rochester Conference on Public Policy, 24 (Spring 1986), 231-74.

Klein, Benjamin. "Our New Monetary Standard: Measurement and Effects of Price Uncertainty, 1880-1913." Economic Inquiry 13 (December 1975), 461-84.

Mishkin, Frederic S. "The Real Rate: An Empirical Investigation." Carnegie-Rochester Conference Series on Public Policy 12 (Autumn 1981), 519-41.

FOOTNOTES

I wish to thank Mike Cox, Axel Leijonhufvud, Seonghwan Oh, and Cara Lown for helpful comments and suggestions. The author retains all responsibility for any remaining errors.

1. Clearly, models that assume an unchanging univariate reduced form representation of inflation <u>will</u> begin to err after 1983.

2. The Federal Reserve followed a policy of directly targeting nonborrowed reserves and, unlike before and after this period, paid little attention to interest rates. Nevertheless, the characteristics of inflation during 1979-82 are very similar to those during the 1953-79. Additionally, the use of seasonally adjusted, rather than unadjusted data, does not affect the results.

3. $Q(24)=38.01$ $Q(24)_{.05}=36.4$ $Q(24)_{.025}=39.4$

Augmented Dickey-Fuller tests could not reject the null hypothesis of a unit root in inflation for the 1983-89 period at the 5 percent level. This is not surprising given the size of the sample and the large standard errors of the estimated coefficients in the Dickey-Fuller regression.

4. As the sample size increases the adjusted R^2's converge in probability to the ratio of the forecastable variance to the total variance.

5. Mishkin notes that a large body of evidence supports this assumption.

6. The potential timing error from using the CPI in the last month of the quarter as a match for a three-month bill maturing at the end of the quarter is less than if a one-month bill is matched up with the CPI in that month.

Illustrations

1. Figure 1 Autocorrelation Function of Inflation
Monthly Data, 1953-1979

2. Figure 2 Autocorrelation Function of Inflation
Monthly Data, 1983-1989

3. Figure 3 Autocorrelation Function of Inflation
Quarterly Data, 1953-1979

4. Figure 4 Autocorrelation Function of Inflation
Quarterly Data, 1983-1989