



**ECONOMIC RESEARCH**  
FEDERAL RESERVE BANK OF ST. LOUIS  
WORKING PAPER SERIES

## A Look at the ASA-NBER Inflation Forecasts: Tests of Rationality and Formation

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<b>Working Paper Number</b>	1985-003A
<b>Creation Date</b>	January 1985
<b>Citable Link</b>	<a href="https://doi.org/10.20955/wp.1985.003">https://doi.org/10.20955/wp.1985.003</a>
<b>Suggested Citation</b>	Hafer, R.W., 1985; A Look at the ASA-NBER Inflation Forecasts: Tests of Rationality and Formation, Federal Reserve Bank of St. Louis Working Paper 1985-003. URL <a href="https://doi.org/10.20955/wp.1985.003">https://doi.org/10.20955/wp.1985.003</a>

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A LOOK AT THE ASA-NBER INFLATION FORECASTS:  
TESTS OF RATIONALITY AND FORMATION

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\*The views expressed are the author's and may not represent those of his employer. I would like to thank Larry DiMariano for his research assistance.

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by R.W. HAFER

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The importance of expectations and the existence of several survey measures has generated a relatively large literature that investigates the economic characteristics of these different series. For example, studies have examined the Livingston price forecasts [Turnovsky (1970), Pesando (1975), Carlson (1977), Pearce (1979), Hafer and Resler (1982)], interest rate forecasts [B. Friedman (1980)] and weekly money supply forecasts [Grossman (1981), Urich (1982), and Hafer (1983a, b)].

A survey-based forecast series that has received surprisingly little attention is that conducted by the American Statistical Association and the National Bureau of Economic Research (ASA-NBER).<sup>1/</sup> This survey, which has been conducted on a quarterly basis since 1968, polls a sample of professional economic forecasters for their predictions of several economic variables, one of which is the level of the GNP deflator. Unlike the Livingston price expectations survey, which provides only 6-month and 12-month forecasts, the ASA-NBER survey asks respondents to

forecast the price level over a span of several quarters.

Our purpose in this paper is to provide some evidence on the economic properties of the ASA-NBER median inflation forecasts. To do this, we test for the forecasts' rationality by means of standard bias and efficiency tests. Also, we investigate the process by which the expectations are formed through the testing for adaptive and extrapolative characteristics. The tests use multi-period inflation forecasts derived from the survey for the sample 1970 through 1984. Because this period is characterized by a variety of inflationary experiences, we also provide evidence based on shorter sample periods.

The format of the paper is as follows. Section II briefly describes the ASA-NBER survey. Section III describes the bias and efficiency tests and presents the empirical results from their implementation. Section IV is devoted to determining the expectations formation process for the various forecast horizons. Section V closes the paper with conclusions and some suggestions for further research.

## II. THE ASA-NBER SURVEY DATA

The inflation forecasts analyzed in this paper are taken from the ASA-NBER quarterly survey. This

survey, conducted on a regular basis since IV/1968, is mailed to a list of professional forecasters in the middle month of each quarter. Provided with the previous quarter's preliminary estimate of the GNP deflator, the individuals are asked to forecast the deflator for the current quarter and several quarters hence.

In this paper, we examine the 1, 2, 3 and 4 quarter forecasts. The inflation rates are calculated by subtracting from the logarithm of the survey's median forecast for the current quarter and three quarters hence the logarithm of the actual price level in the pre-survey quarter. Thus, we generate ex ante inflation forecasts from one- to four-quarters in length. In contrast to most studies, therefore, our data set allows us to evaluate the characteristics of multi-period quarterly forecasts.<sup>2/</sup>

### III. TESTING FOR RATIONALITY

Rationality is premised on the notion that wealth maximizing agents have an incentive to learn the structure of the process generating observed economic phenomena. Because these agents presumably will not make forecasts that are continually wrong in the same direction, rational forecasts should be statistically unbiased. Also, because there exists an implicit

incentive to reduce forecast errors, rational forecasts should make use of all the relevant information to accurately forecast the variable. Although there is some question concerning the extent of the information set to gauge this aspect of rationality [see, for example, Feige and Pearce (1976)], a necessary condition for efficiency is that the information contained in at least the past of the forecasted variable be utilized. Thus, if the forecast errors could have been reduced by using information in the series itself, then forecasters have not efficiently utilized the relevant data available.

#### Bias Tests

Forecasts of inflation are unbiased predictors of the actual rate if the actual and predicted values differ by some random term. To test for this, the regression

$$\pi_t = \alpha_0 + \beta_1 \pi_t^e + \epsilon_t \quad (1)$$

is estimated where  $\pi_t$  is the actual rate of inflation and  $\pi_t^e$  is the forecasted inflation rate. To test for unbiasedness, the joint hypothesis that  $\hat{\alpha}_0 = 0$  and  $\hat{\beta}_1 = 1.0$  is tested. If we cannot reject the null hypothesis, then the forecasts are not biased. Moreover, it also should be the case that the error

term ( $\epsilon$ ) does not exhibit properties of serial correlation. If this latter condition is rejected, this suggests that the forecast error is not random, but follows some autoregressive process.

Equation (1) was used to test the biasedness of our multi-period inflation forecasts for the period 1970/I - 1984/II. Because of the variety of inflation experience over this period, results also are presented for the subperiods 1970/I - 1974/IV, 1975/I - 1979/IV and 1980/I - 1984/II. The results of estimating equation (1) along with the relevant test statistics are reported in table 1.

Turning first to the full sample results, all the estimate  $\beta_1$  coefficients are significant and close to unity. Indeed, as reported in the right side of the table, only for the 4-quarter inflation forecasts can we reject the hypothesis that  $\hat{\beta}_1 = 1$ . Even so, the test of the joint hypothesis that  $\hat{\alpha}_0 = 0$  and  $\hat{\beta}_1 = 1$  is easily rejected for all forecast horizons except the 1-quarter ahead predictions. The rejection of the joint-hypothesis generally is due to the large constant term. Also, the reported Durbin-Watson test statistics indicate that each regression is plagued by first-order serial correlation among the estimated residuals. Thus, based on the full period evidence, the inflation forecasts over different horizons do not appear to satisfy the criterion of unbiasedness.

To see if these results are sensitive to changes in the sample, equation (1) was reestimated for each of the three subperiods. The test results of the joint hypothesis for the 1970-74 period easily reject the notion of unbiasedness for each forecast horizon: the calculated F-statistics exceed any reasonable level of significance. It is interesting to note, however, that while the rejection of unbiasedness for forecast horizons 2-4 is due to the fact that  $\hat{\beta}_1 \neq 1.0$ , this hypothesis cannot be rejected for the 1-quarter ahead prediction ( $t = 0.19$ ). In that instance, rejection of unbiasedness is the result of the estimated constant being statistically different from zero ( $t = 1.85$ ).

During the 1975-79 sample, we cannot reject the joint hypothesis for any forecast horizon. Only the calculated F-statistic for the 4-quarter ahead forecasts is close to statistical significance at a reasonable level (9 percent). Although we cannot reject the joint hypothesis, the residuals of the longer-term forecasts generally exhibit significant first-order serial correlation. For the 1-quarter ahead predictions, however, we cannot reject the notion that the residuals are not autoregressive. Thus, only for the 1-quarter ahead forecasts can we not reject the hypothesis of unbiased forecasts.



The results for the 1980-84 sample again indicate that we cannot reject the joint hypothesis for the 1-quarter ahead forecast. Moreover, the reported Durbin-Watson statistics indicate an absence of first-order serial correlation. Once the forecast horizon increases, however, the unbiasedness of the forecasts is rejected easily. The calculated F-statistics are significant at extremely high levels and, for the 3- and 4-quarter ahead forecasts, there also is evidence of significant first-order serial correlation. It is interesting to note that the rejection of the null hypothesis for the 2-quarter forecast is due to a large, negative constant term, a result also found for the 3- and 4-quarter predictions.<sup>3/</sup>

To summarize, the evidence from the bias test indicates that the hypothesis of unbiased forecasts is not rejected only for the 1-quarter predictions for the sample periods 1975-79 and 1980-84. Although we could not reject the joint hypothesis that  $\hat{\alpha}_0 = 0$  and  $\hat{\beta}_1 = 1$  for each forecast in the 1975-79 sample, the 2-4-quarter horizon regressions were subject to significant first-order serial correlation. Thus, the longer-horizon forecasts generally do not meet the criterion of unbiasedness.<sup>4/</sup>

### Efficiency Tests

Efficiency requires that the forecast reflects pertinent and available information. Since one cannot know what information set is used by all forecasters, a useful approach is to determine whether the forecasts incorporate at least the information contained in past inflation rates. This allows us to test whether the survey forecasts of inflation are at least "weak-form" efficient.

To test for efficiency, it is assumed that the process generating actual inflation and the expected inflation series are the same. The simplest process to assume is an autoregressive model, where the current rate of inflation and its forecasts are generated only by the past history of the series itself. Thus, we have the two equations

$$\pi_t = \sum_{i=1}^N \beta_i \pi_{t-i} + \epsilon_{1t} \quad (2)$$

and

$$\pi_t^e = \sum_{i=1}^N \beta_i' \pi_{t-i} + \epsilon_{2t} \quad (3)$$

where  $\epsilon_{1t}$  and  $\epsilon_{2t}$  are random error terms.

The test for weak-form efficiency requires that  $\beta_i = \beta_i'$  for all  $i$ . To test this, equation 3 is subtracted from equation 2, producing the test equation

$$\pi_t - \pi_t^e = \sum_{i=1}^N b_i \pi_{t-i} + \phi_t \quad (4)$$

where  $b_i = (\beta_i - \beta_i')$  and  $\phi_t = (\epsilon_{1t} - \epsilon_{2t})$ . Thus, the test for weak-form efficiency amounts to regressing the forecast errors  $(\pi_t - \pi_t^e)$  on lagged values of actual inflation. The null hypothesis to be tested is that the estimated  $b_i$  are not statistically different from zero as a group. Moreover, the estimated error structure should not exhibit serial correlation.

Equation (4) was estimated using the errors from the different forecast horizons. To keep the estimation manageable, the lag length was arbitrarily set at four quarters. The results of estimating equation (4) for the various forecast horizons and for the different sample periods are presented in table 2.<sup>5/</sup>

The evidence for the 1970-84 sample period indicates that only the 1-quarter forecasts are weak-form efficient at the 5 percent level of significance ( $F = 2.39$ ). This is not true, however, if the significance level is lowered only slightly: the calculated F-statistic is significant at the 6 percent level. Also, for the 3- and 4-quarter forecast horizons, there is evidence of significant serial correlation among the residuals. Thus, based on the findings reported for the full sample, we generally can reject the hypothesis of weak-form efficiency at reliable levels of significance.

Rejection of the weak-form efficiency hypothesis generally carries over to the sub-sample estimates for the 2-4 quarter forecast horizons. In one instance, that of the 2-quarter horizon for 1975-79, the hypothesis is rejected only at the 13 percent level of significance. Overall, however, the evidence for the longer-term forecasts indicates that survey respondents have not made efficient use of past inflation rates in forming their predictions.

This finding does not generally hold for the 1-quarter forecasts, however. The evidence from the subperiods indicates that we cannot reject the weak-form efficiency hypothesis at any reasonable level of significance for the 1970-74 and 1975-79 sample periods. During these two periods, no lag terms were found to be significant, either individually or jointly. Also, there is no evidence of any serial correlation in the residuals. The test results for the recent 1980-84 sample, however, strongly reject the efficiency hypothesis. For that sample, we find the  $\pi_{t-3}$  and  $\pi_{t-4}$  terms to be highly significant, as well as the calculated joint F-statistic (6.78).

The evidence suggests that the survey respondents as a group did not efficiently utilize available inflation information in their forecasts during the

past 15 years. Except for the 1-quarter forecasts for the 1970-74 and 1975-79 periods, the null hypothesis of weak-form efficiency generally is rejected at high levels of significance.

#### IV. THE FORMATION OF EXPECTATIONS

The evidence presented in the preceding section indicates that, in general, the survey forecasts of inflation are biased and do not efficiently incorporate readily available information. In this section, we attempt to ascertain the underlying process that generates the forecasts. To do this, we test for whether an adaptive or extrapolative process best describes the survey forecasts. As in the previous section, our tests are conducted using the different forecast horizons and sample periods.

##### Adaptive Expectations

The notion of adaptive expectations hypothesizes that forecasters adjust their current forecast to past forecast errors by some fraction. This expectations formation process can be modelled as

$$\pi_t^e = \alpha_0 + \beta_1 \pi_{t-1}^e + \beta_2 \pi_{t-1} + \varepsilon_t \quad (5)$$

where  $\pi_{t-1}^e$  is the inflation expectations formed in period  $t-2$  for period  $t-1$ , and  $\pi_{t-1}$  is the actual inflation rate last period. If it empirically is found that  $\hat{\alpha}_0 = 0$  and  $\hat{\beta}_1 + \hat{\beta}_2 = 1.0$ , equation

(5) reduces to the more common model

$$\pi_t^e - \pi_{t-1}^e = \lambda (\pi_{t-1} - \pi_{t-1}^e) \quad (6)$$

where  $0 \leq \lambda \leq 1.0$ . Estimation of equation (5) clearly is less restrictive. Moreover, the larger is the estimated value of  $\beta_2$ , the more sensitive are the forecasters to recent errors. Finally, if expectations are formed adaptively, it should be the case that  $\hat{\beta}_1 + \hat{\beta}_2 > 0$ .

Because some lagged response of expectations to past changes in inflation can be expected, equation (5) is generalized to allow for this. Thus, in testing the adaptive model a less restrictive version of equation (5) is estimated. This version is

$$\pi_t^e = \alpha_0 + \beta_1 \pi_{t-1}^e + \sum_{i=1}^K \beta_{i+1} \pi_{t-i} + \epsilon_t \quad (7)$$

The outcome from estimating equation (7) for each forecast horizon and different samples are reported in table 3. The results for the full period show that the adaptive model explains movements in forecasts quite well. The lowest  $\bar{R}^2$  is for the 1-quarter forecast horizon, and it is about 75 percent. The hypothesis that expectations are formed adaptively cannot be rejected, since  $\hat{\beta}_1 + \hat{\beta}_2 > 0$  in every instance.

Our estimates indicate that the adjustment parameter ( $\lambda$  in equation (6)) declines as the

forecast horizon lengthens. For example, the estimate of  $\lambda$  from the 1-quarter forecasts is 0.45, suggesting that forecasters adjust their forecasts by 45 percent of their recent error. This value declines as the forecast horizon lengthens: 24 percent for the 2-quarter forecasts; 23 percent for the 3-quarter forecasts; and 22 percent for the 4-quarter forecasts. This result suggests that forecasters are less apt to revise their prediction when looking at a longer horizon than relatively short-term predictions. This may reflect the fact that longer-term inflation forecasts are based on certain fundamental economic relationships, such as the trend of money growth, and not on transitory aberrations to the path of prices.<sup>6/</sup>

The sub-period results from estimating equation (7) provide quite a different picture. The estimates for the 1970-74 period are difficult to interpret. For example, the 1-quarter forecast results show the estimated  $\beta_1$  coefficient to be zero and only the first lag on actual inflation achieves significance at acceptable levels. This result implies that  $\lambda = 1.0$  in equation (6). In other words, this period's forecast is based solely on last period's actual inflation rate: a case of static expectations.

The results for the 2- and 3-quarter forecasts also show that the estimated  $\beta_1$  coefficient is

not statistically different from zero. For the 2-quarter forecast, only the  $\pi_{t-1}$  term achieves significance. When the 3-quarter horizon is used, only  $\pi_{t-2}$  is significant. Moreover, the calculated adjustment parameters indicate that the adaptive model does not adequately explain the expectations formation process.

In contrast to the above results, the evidence for the 4-quarter forecasts supports the use of the adaptive model. The estimated  $\beta_1$  coefficient is significantly different from zero, yielding an estimated  $\lambda$  of 44 percent which is much larger than that found for the full-period estimation. Thus, the evidence for the 1970-74 supports the use of the adaptive model only when the 4-quarter forecast horizon is used.

The evidence for the adaptive model from the 1975-79 period also is mixed. There we find that, looking at the 1-quarter forecast horizon, only the lagged forecast term is statistically significant. This suggests that these expectations are highly autoregressive: indeed, it is impossible to reject the hypothesis that the estimated  $\beta_1$  coefficient equals unity ( $t = 0.71$ ). The results based on the longer-term forecast horizons are more supportive of the adaptive process. In each instance, the lagged



expectations term is significant, as are the lagged inflation terms. For example, the results for the 2-quarter forecasts suggests that forecasters' rate of adaptation is almost 50 percent. For the 3- and 4-quarter horizons, the adjustment speed is 45 percent and 58 percent, respectively. Interestingly, the significance of the lagged actual inflation rates changes across the forecast horizon. This result suggests that, as the forecast horizon is extended, recently observed behavior of inflation causes forecasters little concern in adjusting their prediction.

Finally, the results for the 1980-84 period again provide mixed support of the adaptive model. The 1-quarter forecast results are similar to those from the 1975-79 period: only the lagged expectation term is reliably significant, suggesting an autoregressive nature to the expectations formation process. In contrast, the evidence based on the 2- and 4-quarter forecast horizons generally support the model. The estimated equations have a high degree of explanatory power. Moreover, the estimated adjustment term for the 2-quarter horizon is 38 percent and, for the 4-quarter forecast, 42 percent. This results suggests that, in contrast to that found for the 1970-74 sample, forecasters adjusted their longer-term forecasts more rapidly to previous errors.

The 1980-84 results for the 3-quarter forecast horizon are not supportive of the adaptive expectations model. The lagged expectation term is not statistically different from zero, suggesting that the adjustment parameter is unity. This, however, is not found for the lagged values of actual inflation: the summed value of the lag terms (0.51) is statistically different from unity ( $t = 3.74$ ). Thus, the adaptive expectations model does not appear appropriate to explain the formation of the 3-quarter forecasts.

To summarize the empirical evidence presented thus far, the evidence on the adaptive expectations model is mixed. Although the evidence for the full period suggests that this model is an accurate description of the underlying process by which expectations are formed, the sub-period results reveal a variety of outcomes. This is especially true for the 1-quarter forecasts, whose results seemed to vary most with changes in the sample.

#### Extrapolative Expectations

Extrapolative expectations are based on the assumption that past trends in the forecasted series are expected to continue or to be reversed (regressive expectations). A general model to investigate this expectations process is given by

$$\pi_t^e = \alpha_0 + \beta_1 \pi_{t-1} + \beta_2 \Delta \pi_{t-1} + \epsilon_t \quad (8)$$

where  $\Delta\pi_{t-1} = \pi_{t-1} - \pi_{t-2}$ . If  $\alpha_0 = 0$  and  $\beta_1 = 1$ , equation (8) reduces to the more restrictive version

$$\pi_t^e - \pi_{t-1} = \delta \Delta\pi_{t-1} + \epsilon_t \quad (9)$$

To test for extrapolative expectations, we test for  $\hat{\beta}_2 > 0$ . If, however,  $\hat{\beta}_2 < 0$ , expectations are regressive. Finally, if  $\hat{\alpha}_0 = \hat{\beta}_2 = 0$  and  $\hat{\beta}_1 = 1.0$ , expectations are said to be formed statically. As in our test of adaptive expectations, we allow for some lagged response of expectations to past changes. Thus, the estimated model to test for extrapolative expectations is

$$\pi_t^e = \alpha_0 + \beta_1 \pi_{t-1} + \sum_{i=0}^J \beta_{2+i} \Delta\pi_{t-1-i} + \epsilon_t \quad (10)$$

The results from applying equation (10) to the survey forecast data are reported in table 4.<sup>7/</sup> The full period results generally are supportive of the model. Specifically, the  $\hat{\beta}_1$  coefficient is statistically significant at high levels of confidence and the estimated coefficients on the lagged changes in inflation are generally significant. The important result is the finding that for all forecast horizons, the evidence indicates that  $\sum \beta_{2+i} < 0$ , implying that past trends are expected to be reversed. Thus, the data do not reject the regressive expectations model.

The sub-period results also support the regressive expectations model. The estimated  $\beta_{2+1}$  coefficients are generally significant and, except for one coefficient, negatively signed. It is interesting to note that there are considerable differences in the magnitude of the estimated parameters across the subperiods for each forecast horizon. This result is especially evident for the 1-quarter forecast. Its  $\sum \beta_{2+1}$  coefficient takes the value -1.12, -0.36 and -1.42 for the three subperiods. This suggests that during periods of dramatic movements in inflation, such as the run-up in 1974 and the more recent decline in inflation, forecasters anticipated a return to trend. Although the inflation of 1979 was dramatic, the evidence suggests that forecasters did not anticipate the sharp reversal occurring in 1980-84, since the trend of inflation had been increasing.

The evidence presented in table 4 suggests that modelling the expectations formation process of the survey inflation forecasts is, overall, more appropriately done using a regressive expectations model. Although there is some evidence of adaptive behavior in certain time periods and for certain forecast horizons, the regressive expectations model never is rejected by the data.

## V. SUMMARY AND CONCLUSION

This study has presented evidence on the rationality of multi-period inflation forecasts generated by respondents to the ASA-NBER quarterly survey. Using data from the sample period 1970-84 and three sub-periods, our evidence suggests that forecasts of inflation beyond 1-quarter ahead generally do not satisfy the criteria of unbiasedness and weak-form efficiency. Moreover, the results for the 1-quarter forecasts are mixed: these forecasts appear unbiased for the 1975-79 and 1980-84 subperiods, but not for the 1970-74 sample. Weak-form efficiency of the 1-quarter forecasts cannot be rejected for the 1970-74 and 1975-79 periods, but is easily rejected for the 1980-84 sample.

These results complement those of Zarnowitz (1983), where the biasedness of multi-quarter inflation forecasts was tested. Based on mean forecast values, unbiasedness was rejected for each forecast horizon. In that study, however, the evidence is based solely on the 1968-79 sample period. Our bias test results, in contrast, suggest that the results are somewhat sensitive to the sample period.

Our analysis of the survey forecasts also includes an attempt to determine the most appropriate model

that captures the expectations formation process. Again using the different forecast horizon and various sample periods, the evidence suggests that the forecast formation process is best modelled as regressive. This suggests that the average survey respondent expected past inflation trends to reverse themselves in the future.<sup>8/</sup>

The results of this study further our understanding of the expectations process captured in the ASA-NBER survey. Future research should investigate, along the lines of Zarnowitz (1983), the effect of aggregation on the forecasts. Also, comparisons of survey and time-series forecasts would provide useful information on the relative accuracy of these two forecasting approaches.<sup>9/</sup> This is especially true of multi-quarter forecast comparisons.

#### FOOTNOTES

<sup>1/</sup>A notable exception is the work of Zarnowitz (1969, 1979, 1982, 1983).

<sup>2/</sup>That is, in each quarter a new four-quarter forecast is made. Thus, we have a quarterly series of four-quarter forecasts, in contrast to the Livingston series where 12-month forecasts are available only at six-month intervals.

<sup>3/</sup>This finding suggests that the forecasters significantly over predicted inflation during the past five years. This result is not surprising, given the difficulty of most economic models in forecasting inflation during this period.

<sup>4/</sup>This result is similar to that reported in Zarnowitz (1983). In that study, the percentage of unbiased forecasts declined as the forecast horizon was lengthened. Unlike our study, Zarnowitz's is based on the accuracy of a subset of survey respondents who participated in at least 12 surveys. Moreover, his results are based on the entire 1968-1979 sample.

<sup>5/</sup>Although it is not specified in the theoretical model, a constant term is estimated instead of subsuming it into the error term.

<sup>6/</sup>Evidence presented in Mullineaux (1980) suggests that inflation expectations, based on the Livingston survey, are influenced by past money growth and by past inflation.

7/ Note that in several instances, it was necessary to correct for first-order serial correlation among the residuals.

8/ Given the volatile behavior of actual inflation during the 1970-84 period, it is not too surprising that the regressive model is not rejected. This notion is based on the historical relationship between trend money growth and inflation. During periods of high inflation, such as 1974-75 and 1979-80, inflation was well-above trend money growth. Thus, the level of inflation might be expected by many to return to the lower trend money growth rate. During the 1980-84 period, in contrast, inflation fell dramatically, falling well-below trend money. Again, it may be expected that the downward trend of inflation would reverse itself, increasing back to the higher rate of trend money growth.

9/ Some preliminary evidence from such a comparison is found in Hafer and Hein (1984).



Table 1  
Bias Test Results

Forecast horizon	Estimated coefficients on: <sup>1/</sup>		Summary statistics <sup>2/</sup>		Test results <sup>3/</sup>	
	Constant	$\tau_t^e$	$\bar{R}^2/SE$	DW	$\beta_1 = 1$	$\alpha_0 = 0; \beta_1 = 1$
<u>1970/I-1984/II</u>						
1-quarter	0.592 (1.04)	0.963 (10.69)	0.665 1.392	1.44	0.41	2.13 (0.13)
2-quarter	0.932 (1.67)	0.920 (10.23)	0.645 1.312	0.70	0.88	4.01 (0.02)
3-quarter	1.499 (2.44)	0.842 (8.34)	0.546 1.407	0.30	1.57	6.23 (0.00)
4-quarter	2.028 (3.14)	0.764 (7.10)	0.464 1.475	0.20	2.19	8.59 (0.00)
<u>1970/I-1974/IV</u>						
1-quarter	1.118 (1.85)	1.022 (8.83)	0.802 1.073	2.00	0.19	13.03 (0.00)
2-quarter	0.252 (0.43)	1.284 (10.03)	0.840 0.849	2.10	2.22	33.45 (0.00)
3-quarter	-0.734 (1.12)	1.607 (10.22)	0.845 0.745	1.54	3.86	60.51 (0.00)
4-quarter	-1.256 (1.42)	1.811 (7.99)	0.768 0.805	0.81	3.58	58.14 (0.00)
<u>1975/I-1979/IV</u>						
1-quarter	-0.192 (0.11)	1.031 (4.06)	0.450 1.420	1.41	0.12	0.01 (0.99)
2-quarter	-0.197 (0.13)	1.072 (4.78)	0.535 1.203	0.98	0.32	0.58 (0.57)
3-quarter	-0.095 (0.05)	1.090 (3.78)	0.412 1.301	0.74	0.31	1.44 (0.26)
4-quarter	-0.753 (0.32)	1.228 (3.30)	0.342 1.348	0.54	0.61	2.82 (0.09)
<u>1980/I-1984/II</u>						
1-quarter	-1.671 (1.77)	1.231 (8.78)	0.817 1.244	2.56	1.65	1.56 (0.24)
2-quarter	-2.251 (2.97)	1.261 (11.79)	0.890 0.885	1.98	2.44	5.57 (0.02)
3-quarter	-3.086 (3.94)	1.361 (12.51)	0.902 0.804	0.83	3.32	9.87 (0.00)
4-quarter	-3.680 (3.57)	1.430 (10.16)	0.857 0.946	0.62	3.06	8.35 (0.00)

1/ Coefficient estimates based on equation (1) in text. Absolute value of t-statistics reported in parentheses.

2/  $\bar{R}^2$  is the coefficient of determination adjusted for degrees of freedom; SE is the regression standard error; and DW is the Durbin-Watson test statistic.

3/ The test  $\beta_1 = 1$  reports t-statistics. The joint test uses an F-statistic: marginal significance levels reported in parentheses.

Table 2  
Efficiency Test Results

Forecast horizon	Estimated coefficients on: <sup>1/</sup>					Summary statistics <sup>2/</sup>		
	Constant	$\pi_{t-1}$	$\pi_{t-2}$	$\pi_{t-3}$	$\pi_{t-4}$	$\bar{R}^2/SE$	DW	F <sup>3/</sup>
<u>1970/I-1984/II</u>								
1-quarter	0.812 (1.37)	0.099 (0.94)	-0.006 (0.06)	0.168 (1.43)	-0.327 (3.07)	0.089 1.318	1.68	2.39 (0.06)
2-quarter	0.334 (0.70)	0.441 (5.16)	-0.189 (1.99)	0.065 (0.68)	-0.292 (3.38)	0.333 1.070	1.31	8.10 (0.00)
3-quarter	-0.242 (0.50)	0.452 (5.18)	0.085 (0.88)	-0.108 (1.11)	-0.296 (3.35)	0.414 1.091	0.81	11.07 (0.00)
4-quarter	-0.700 (1.38)	0.387 (4.27)	0.164 (1.63)	0.085 (0.85)	-0.416 (4.54)	0.446 1.134	0.48	12.486 (0.00)
<u>1970/I-1974/IV</u>								
1-quarter	1.046 (0.88)	0.042 (0.21)	-0.004 (0.02)	0.077 (0.31)	-0.086 (0.36)	-0.240 1.167	2.05	0.06 (0.99)
2-quarter	0.212 (0.29)	0.421 (3.44)	-0.134 (0.95)	0.044 (0.29)	-0.120 (0.80)	0.404 0.720	2.77	4.21 (0.02)
3-quarter	-0.674 (1.34)	0.361 (4.27)	0.150 (1.54)	-0.074 (0.70)	-0.021 (0.20)	0.742 0.498	2.09	14.68 (0.00)
4-quarter	-1.178 (2.54)	0.234 (3.02)	0.235 (2.62)	0.204 (2.11)	-0.136 (1.44)	0.801 0.458	1.44	20.11 (0.00)
<u>1975/I-1979/IV</u>								
1-quarter	0.123 (0.08)	0.097 (0.50)	-0.064 (0.30)	0.059 (0.28)	-0.105 (0.58)	-0.218 1.526	1.68	0.15 (0.96)
2-quarter	-0.481 (0.47)	0.378 (2.81)	-0.168 (1.15)	-0.002 (0.01)	-0.094 (0.76)	0.191 1.056	1.59	2.12 (0.13)
3-quarter	-1.734 (2.06)	0.446 (4.04)	0.077 (0.64)	-0.064 (0.54)	-0.138 (1.34)	0.533 0.868	1.94	6.41 (0.00)
4-quarter	-2.903 (5.39)	0.393 (5.58)	0.223 (2.91)	0.080 (1.05)	-0.183 (2.79)	0.825 0.554	2.20	23.39 (0.00)
<u>1980/I-1984/II</u>								
1-quarter	-0.597 (0.95)	0.139 (1.10)	0.098 (0.80)	0.429 (3.50)	-0.571 (4.28)	0.576 0.849	2.20	6.78 (0.00)
2-quarter	-1.374 (3.81)	0.426 (5.88)	-0.201 (2.86)	0.270 (3.82)	-0.330 (4.30)	0.765 0.488	2.56	14.85 (0.00)
3-quarter	-2.015 (5.24)	0.375 (4.86)	0.109 (1.46)	-0.027 (0.36)	-0.210 (2.57)	0.737 0.520	2.11	12.93 (0.00)
4-quarter	-2.374 (8.22)	0.362 (6.24)	0.127 (2.25)	0.190 (3.37)	-0.379 (6.17)	0.886 0.390	1.60	33.98 (0.00)

<sup>1/</sup> Coefficient estimates based on equation (4) in text. Absolute value of t-statistics reported in parentheses.

<sup>2/</sup> See footnote 2, table 1.

<sup>3/</sup> The reported F-statistic tests the null hypothesis  $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ . Values in parentheses are relevant significance levels.

Table 3  
Estimation Results for Adaptive Model

Forecast horizon	Estimated coefficients on: <sup>1/</sup>					F-test <sup>2/</sup>	Summary statistics <sup>3/</sup>	
	Constant	$\pi_{t-1}^e$	$\pi_{t-1}$	$\pi_{t-2}$	$\pi_{t-3}$	$\pi_{t-1}^e + \pi_{t-1} - 1$	$\bar{R}^2/SE$	DW
<u>1970/I-1984/II</u>								
1-quarter	0.487 (1.08)	0.546 (3.81)	0.277 (2.79)	-0.063 (0.62)	0.131 (1.57)	2.46 (0.12)	0.748 1.029	2.13
2-quarter	0.082 (0.33)	0.764 (9.60)	0.292 (6.46)	-0.019 (0.33)	-0.068 (1.31)	0.58 (0.45)	0.914 0.565	2.42
3-quarter	-0.011 (0.05)	0.766 (14.21)	0.060 (1.60)	0.195 (4.56)	-0.037 (0.82)	0.23 (0.64)	0.934 0.476	2.06
4-quarter	-0.090 (0.47)	0.782 (21.26)	0.034 (1.09)	0.044 (1.22)	0.134 (3.90)	0.03 (0.86)	0.951 0.400	1.80
<u>1970/I-1974/IV</u>								
1-quarter	-1.704 (1.79)	-0.260 (0.88)	0.771 (3.77)	0.346 (1.46)	0.262 (1.25)	0.50 (0.49)	0.769 1.022	1.62
2-quarter	-0.306 (0.53)	0.214 (0.77)	0.407 (3.44)	0.181 (1.16)	0.086 (0.60)	0.80 (0.39)	0.825 0.636	2.22
3-quarter	0.282 (0.57)	0.220 (0.87)	0.163 (1.74)	0.245 (2.58)	0.118 (1.02)	3.16 (0.10)	0.808 0.476	2.08
4-quarter	0.098 (0.20)	0.565 (3.24)	0.141 (2.33)	0.027 (0.40)	0.134 (1.95)	0.89 (0.36)	0.826 0.340	1.98
<u>1975/I-1979/IV</u>								
1-quarter	1.884 (1.69)	0.774 (2.43)	-0.010 (0.06)	-0.047 (0.34)	0.001 (0.01)	2.98 (0.11)	0.478 0.928	1.58
2-quarter	1.060 (1.25)	0.527 (2.12)	0.302 (4.28)	0.016 (0.15)	-0.022 (0.26)	1.74 (0.21)	0.798 0.553	1.57
3-quarter	1.047 (1.05)	0.547 (2.51)	0.052 (0.85)	0.244 (3.71)	-0.024 (0.26)	1.26 (0.28)	0.792 0.473	1.22
4-quarter	2.153 (2.79)	0.421 (3.16)	-0.051 (1.00)	0.053 (0.96)	0.210 (3.90)	8.98 (0.01)	0.771 0.397	1.58
<u>1980/I-1984/II</u>								
1-quarter	0.270 (0.39)	0.723 (2.80)	0.205 (1.38)	-0.241 (1.62)	0.231 (2.14)	0.73 (0.41)	0.861 0.801	2.07
2-quarter	0.631 (0.93)	0.624 (2.12)	0.304 (3.59)	0.050 (0.39)	-0.071 (0.71)	1.17 (0.30)	0.934 0.516	1.89
3-quarter	1.557 (2.72)	0.282 (1.51)	0.132 (2.23)	0.218 (3.41)	0.163 (2.00)	7.96 (0.01)	0.954 0.386	1.47
4-quarter	0.821 (1.53)	0.581 (4.48)	0.099 (2.14)	0.062 (1.14)	0.150 (2.59)	2.44 (0.14)	0.956 0.342	1.97

1/ Absolute value of t-statistics reported in parentheses.

2/ Values in parentheses are significance levels.

3/  $\bar{R}^2$  is the adjusted coefficient of determination; SE is the regression standard error; DW is the Durbin-Watson test statistic for first-order autocorrelation.

Table 4  
Estimation Results for Extrapolative Model

Forecast horizon	Estimated coefficients on: <sup>1/</sup>						Summary statistics <sup>2/</sup>		
	Constant	$\pi_{t-1}$	$\Delta\pi_{t-1}$	$\Delta\pi_{t-2}$	$\Delta\pi_{t-3}$	$\Sigma\Delta\pi_{t-1}$	$\bar{R}^2$	SE	DW/ $\hat{\rho}$
<u>1970/I-1984/II</u>									
1-quarter	1.959 (1.86)	0.614 (3.97)	-0.436 (3.04)	-0.361 (3.09)	-0.178 (2.22)	-0.975	0.162	0.971	2.29 0.69
2-quarter	1.957 (2.51)	0.609 (5.51)	-0.331 (3.36)	-0.130 (1.73)	-0.062 (1.30)	-0.523	0.468	0.584	2.36 0.81
3-quarter	2.383 (2.89)	0.518 (5.20)	-0.456 (5.24)	-0.214 (3.32)	-0.046 (1.16)	-0.716	0.415	0.482	2.16 0.90
4-quarter	2.720 (2.88)	0.409 (4.67)	-0.408 (5.36)	-0.341 (6.10)	-0.156 (4.63)	-0.905	0.366	0.416	1.83 0.95
<u>1970/I-1974/IV</u>									
1-quarter	-1.910 (1.84)	1.213 (6.28)	-0.584 (2.13)	-0.356 (1.40)	-0.178 (0.84)	-1.118	0.768	1.025	2.02
2-quarter	-0.645 (1.04)	0.909 (7.84)	-0.495 (3.01)	-0.248 (1.63)	-0.166 (1.30)	-0.909	0.836	0.615	1.75
3-quarter	0.385 (0.79)	0.665 (7.30)	-0.468 (3.63)	-0.210 (1.76)	-0.052 (0.51)	-0.730	0.802	0.483	1.70
4-quarter	0.961 (2.39)	0.524 (7.00)	-0.341 (3.21)	-0.269 (2.74)	-0.159 (1.93)	-0.769	0.763	0.397	1.23
<u>1975/I-1979/IV</u>									
1-quarter	4.827 (2.58)	0.307 (1.27)	-0.189 (0.89)	-0.125 (0.74)	-0.041 (0.35)	-0.355	0.450	0.962	2.16 0.64
2-quarter	2.653 (2.76)	0.575 (4.56)	-0.277 (2.47)	-0.099 (1.07)	-0.030 (0.47)	-0.406	0.823	0.540	1.61 0.57
3-quarter	2.989 (3.93)	0.495 (4.90)	-0.467 (5.08)	-0.208 (2.65)	-0.092 (1.63)	-0.767	0.784	0.477	1.28 0.49
4-quarter	3.867 (10.13)	0.342 (6.51)	-0.386 (6.97)	-0.357 (6.86)	-0.151 (3.25)	-0.894	0.776	0.393	1.30
<u>1980/I-1984/II</u>									
1-quarter	3.114 (1.55)	0.559 (2.14)	-0.521 (2.09)	-0.579 (2.96)	-0.318 (2.36)	-1.418	0.666	0.741	1.90 0.89
2-quarter	1.919 (2.71)	0.743 (7.50)	-0.430 (3.46)	-0.157 (1.33)	-0.066 (0.69)	-0.653	0.864	0.540	1.74 0.52
3-quarter	2.434 (5.34)	0.687 (10.78)	-0.517 (6.28)	-0.245 (3.13)	0.016 (0.25)	-0.746	0.923	0.366	1.41 0.48
4-quarter	2.649 (6.62)	0.653 (11.67)	-0.618 (8.55)	-0.458 (6.64)	-0.222 (3.90)	-1.298	0.933	0.323	1.53 0.48

<sup>1/</sup> Absolute value of t-statistics appear in parentheses.

<sup>2/</sup>  $\bar{R}^2$  is the coefficient of determination adjusted for degrees of freedom; SE is the regression standard error; DW is the Durbin-Watson test statistic; and  $\hat{\rho}$  is the estimated first-order autocorrelation correction coefficient based on an iterative maximum-likelihood procedure.

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