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ON THE ACCURACY OF TIME SERIES, INTEREST RATE AND SURVEY FORECASTS OF INFLATION

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I. INTRODUCTION

There has been much work examining different methodologies in forecasting inflation. For example, Fama (1975, 1977) develops an interest rate model to predict the one-month ahead rate of inflation using the CPI. Fama and Gibbons (1982, 1984) modify the interest rate model compare it to a univariate time series forecasting model. Carlson (1977) and others analyze the consensus forecasts from the Livingston survey pertaining to multiperiod forecasts of inflation.

Of the three different forecasting approaches--interest rate model, univariate time series or survey--there is much disagreement in the literature as to which forecasts are more accurate. Carlson (1977), for example, found that the Livingston survey consensus was more accurate than the early Fama interest rate model. Fama and Gibbons (1984) conclude just the opposite: the interest rate forecast "...where the participants back their forecasts with wealth simply perform better than the consensus forecast of the economists of the Livingston surveys." (p. 347). The evidence comparing the accuracy of time series relative to other procedures is mixed.

Our purpose in this paper is to further investigate the relative forecasting ability of the three different methodologies. In contrast to previous studies that have generally used the CPI to measure inflation, our analysis uses the implicit GNP deflator. This modification is motivated largely by the fact that calculations of the CPI inflation rate often are distorted greatly by changes in relative prices [e.g., Blinder (1980) and Fischer (1981)]. This modification necessitates that the periodicity of the data be quarterly. This does not cause any difficulties for the development of the univariate time series model, nor the interest rate model since the appropriate forecast horizon is captured by the three-month Treasury bill rate. This modification also does not cause problems in obtaining a survey measure. The American Statistical Association and the National Bureau of Economic Research (ASA-NBER) have been conducting a quarterly survey of 30 to 50 individuals professionally engaged in economic forecasting since the late 1960s. Thus, the existence of this survey allows us to compare true *ex ante* forecasts from a time series model, an interest rate model and a survey for the sample 1970-84, a period with a much wider range of inflationary conditions than previous studies have examined.

The format of the paper is as follows: Section II presents a description and estimation results of the interest rate model. Section III discusses outcome of estimating the time-series model. Both the interest rate and time series models are estimated initially over the 1953-69 period. Section IV briefly discusses the ASA-NBER survey forecasts. Comparison of the three different sets of inflation forecasts is made in Section V. This comparison is made for the period 1970/I-1984/II and three subperiods. Evidence is presented in Section VI testing the biasedness of each forecast series. In Section VII, we investigate the relative informational content of each forecast series in head-to-head contests in explaining the actual behavior of prices. Section VIII closes the paper with concluding remarks.

II. INTEREST RATE MODEL

The interest rate model used to forecast inflation is based on the so-called Fisher equation

(1) $R^t_{t-1} = r^t_{t-1} + I^t_{t-1}$

where R^t_{t-1} is the nominal interest rate observed at the end of period t-1 and expected to hold in period t, r^t_{t-1} is the expectation formed in period t-1 of the real interest rate for period t, and I^t_{t-1} is the expectation in t-1 of the rate of inflation for period t. Fama (1975) presents evidence suggesting that the rates on U.S. Treasury bills are efficient predictors of short-term inflation. This finding was based on re-writing equation (1) in the form

(2) $I^t_{t-1} = -r^t_{t-1} + R^t_{t-1}$

and estimating the regression equation

(3) $I_t = \alpha_o + \beta_1 R_{t-1} + \varepsilon_t$

where α and β are coefficients to be estimated, and ε_t is unexpected inflation. Estimates of equation (3) presume that changes in the expected real rate of interest can be subsumed in the constant term α_o. Studies by Hess and Bicksler (1975), Nelson and Schwert (1977), Garbade and Wachtel (1978) and Fama and Gibbons (1982), however, show that there is significant variation in the expected real rate over time.

These latter studies present evidence suggesting that the expected real return behaves as random walk. This means that changes in the ex post real return may be captured by a moving-average model. To see this, write the ex post real return for period t as

(4) $R_{t-1} - I_t = r_t + \eta_t$.

If r_t does behave as a random walk, then changes in r_t and η_t should be white noise processes. Following Fama and Gibbons (1984), this then suggests the following time series model for period-to-period changes in the ex post real return:

(5) $(R_{t-1} - I_t) - (R_{t-2} - I_{t-1}) = a_t - \theta a_{t-1}$

where θ is the moving average parameter to e estimated. Fama and Gibbons estimate equation (5) using monthly, ex post real returns based on the CPI measure of inflation and a one-month Treasury bill rate observed at the end of month t-1. They find that for the period 1953-77 the change in the ex post real rate is adequately captured by a first-order moving average model. The size of the estimated θ parameter (0.9223) suggests that the variance of η_t in equation (4) is large relative to the change in the expected real rate.

We test the assumption that the change in the ex post quarterly real return can be approximated by a first-order MA process. In our test, the nominal interest rate is measured the 3-month Treasury bill rate observed in the last week of the preceding quarter. The inflation rate is measured as the annualized log differences between the level of the GNP deflator in quarter t and t-1. The estimation period is 1953-1969.[1/]

Table 1 presents the sample autocorrelations of the level of the ex post real return (r_t) and the change in the real return ($r_t - r_{t-1}$). The autocorrelations on the level of the real return (row 1) decline relatively slowly, hovering around 0.3 for lags 1 through 3. Differencing the real return yields autocorrelations (row 2) that are indicative a first-order moving average model: the first-order autocorrelation is large relative to its standard error (0.12), and the remaining autocorrelations remain well within two standard errors of zero. Moreover, the inverse autocorrelation (not shown) reveals a pattern suggestive of an MA(1) process; the correlations exhibit a slow decline over the first nine lags before flattening to a value of approximately 0.20.

Based on the autocorrelations of the change in the real rate in table 1, an MA(1, 1) model on the level of the real rate was estimated for the period 1953/II-1969/IV. The outcome is (absolute value of t-statistics in parentheses):

$$(6) \qquad (1-B)r_t = a_t - \underset{(10.27)}{0.7831}\, a_{t-1}$$

$$SE = 1.328 \qquad Q(11) = 4.27$$

This result does not reject the hypothesis that changes in the ex post real rate of return are captured by a first-order moving average process. The estimated value for the θ parameter is significantly different from zero at the one percent level, and the reported Q-statistic indicates that we cannot reject the hypothesis of white-noise residuals at any reasonable level. The estimated value of θ is relatively large, suggesting that most of the observed variation in the ex post real return comes from changes of the unanticipated component in the real return and not from the expected real return itself.[2/]

The estimates from equation (6) are used to generate ex ante, one-step-ahead forecasts of the level of the real return. More specifically, the best forecast of next period's real rate (r_{t-1}^{t}) is given by $r_{t-1}^{t} = (R_t - I_{t-1}) - 0.7831\ \hat{a}_{t-1}$. With these predictions of the real return for period t and the nominal interest rate observed at the end of period t-1, using equation (2) we generate ex ante forecasts of the inflation rate for the current quarter.

III. TIME SERIES MODEL

An alternative to the interest rate model's inflation forecast is one derived solely from the information contained in past rates of inflation. To construct such a time-series model, the autocorrelations of the rate of inflation measured using the log difference of the GNP deflator were examined for the sample period 1953-69. These autocorrelations are reported in row 3 of table 1. The behavior of the autocorrelations are indicative of a non-stationary series: the reported values decay slowly as the lag increases. Consequently, the inflation series was differenced and the autocorrelations checked.

The autocorrelations of the differenced inflation rate series, reported in row 4 of table 1, indicate that differencing has reduced the series to stationarity. The first-order autocorrelation statistic (-0.490) is the only value significantly greater than its standard error (0.12), suggesting an IMA(1, 1) model of the inflation rate. Such a model selection also is indicated by the partial and inverse autocorrelation functions (not shown).

Given this information, a first-order moving average model was fitted to the first-difference of the inflation rate for the sample period

1953/I-1969/IV. The estimation results are (absolute value of t-statistics in parentheses):

$$(7) \quad (1-B)I_t = a_t - \underset{(6.67)}{0.6332}\, a_{t-1}$$

$$SE = 1.449 \quad Q(11) = 7.37$$

The estimated MA parameter (0.6332) is significantly different from zero at the one-percent level.[3/] Moreover, the calculated Q-statistic (7.37) indicates that the simple model has reliably reduced the residuals to white noise. Thus, equation (7) is used to generate ex ante forecasts of the inflation rate for the post-1969 period.

IV. THE ASA-NBER SURVEY

The period 1970/I through 1984/II is chosen to compare relative forecasting ability, because it allows us to compare the interest rate and time series model forecasts to those that derived from the median survey response to the quarterly ASA-NBER questionnaire.[4/] Along with the questionnaire, participants are provided with the preliminary figure of the level of the GNP deflator for the previous quarter. Thus, when the first quarter questionnaire is received, respondents know the fourth-quarter preliminary number. At each survey, participants are asked to forecast (among other series) the level of the deflator for the current quarter and three quarters hence. By taking the previous quarter's preliminary number and the respondents' median forecast, we can calculate an ex ante one-step-ahead inflation forecast.

Before turning examining the relative accuracy of the various forecasts, some comments concerning the timing for the different forecasts are appropriate. Because the survey response is made in the middle of the quarter for which the respondents are asked to forecast inflation, this would appear to favor the survey forecasts. Afterall, the respondents have at their disposal two more months of information. Two points temper this conclusion: First, our one-step-ahead forecasts for the time series and interest rates models presume that the previous quarter's actual inflation rate is known. Due to calculation and publication lags, this information is not available until sometime into the following quarter. In this regard, all forecasts presume some information which is not available at the end of the prior calendar quarter.

The second point is that our time series and interest rate model forecasts not only presume knowledge of the prior quarter's actual inflation rate, but also the revisions in the data series which are only currently available. The information set used to generate the time series and interest rate model forecasts is more current than the information available to the survey respondents; that is, it includes revisions and benchmark changes unknown to the survey respondents. This point is especially important since the currently available, revised series is the standard by which the different forecasts are judged.

In summary, the survey respondents had more recently available information than the Treasury bill market participants did at the end of the quarter. On the other hand, the time series and interest rate models presume information about revisions in inflation that were unavailable to survey respondents. Lacking knowledge about the quantitative importance of these differences we presume they cancel each other.

V. COMPARING EX ANTE FORECASTS

In order to generate ex ante one-step-ahead forecasts for the non-survey models, the following procedure was followed. For each time-series model (real return and inflation rate), the original coefficient estimates are taken from the 1953-69 period. These estimates are used to generate the 1970/I forecast. Then, the estimation sample is updated to include the actual data for 1970/I, the model is re-estimated, and a new ex ante forecast is generated for II/1970. This updating, re-estimation and forecast procedure is continued throughout the forecast sample until 1984/II, the last available data on the actual inflation rate and the survey forecast.[5/]

The outcome of forecasting inflation for the 1970-84 period using the time series, interest rate and survey methods is summarized in table 2. The results for the full period indicate that the three alternative procedures have mean-absolute-errors (MAE) that are all less than two percentage points. The Theil forecast decomposition statistics further reveal that the forecast errors from each approach are due mainly to unequal covariation (CV) between actual and predicted inflation. In fact, the forecast error due to bias (β) is small for all forecasts and zero for the time-series model.

The ordering of the forecast accuracy indicates that the survey respondents, on average, provided more accurate predictions of the inflation rate than those derived from the time-series or interest rate models. Based on a mean-squared-error (MSE) criterion, the survey forecasts were more accurate than the interest rate model by over 50 percent and by almost 40 percent relative to the time series forecasts.

Moreover, the full-period statistics indicate that the time-series model's forecasts produce an MSE 21 percent lower than that of the interest rate model.

Because the full forecast period encompasses numerous of changes in the inflationary environment, it is useful to compare the relative forecasting properties of the alternative models for different subperiods. Table 2 also reports results from three separate subperiods. The first subperiod covers the span 1970/I-1974/IV. This period is characterized by several notable events: the breakdown of the Bretton Woods agreement and the establishment of a floating exchange rate regime; the imposition of wage and price controls beginning in August 1971 and continuing in different forms until April 1974; the OPEC oil boycott in late 1973 which lead to a quadrupling of oil prices; and the increase in the relative price of food in 1973 and 1974.

The forecast statistics in table 2 indicate that the models did fairly well in forecasting inflation during this turbulent period. The average absolute errors are again low. Interestingly, the MAE, MSE and RMSE statistics indicate that the different procedures are now much closer to one another in their relative forecasting errors. Although the survey responses continue to outperform the other models, the relative reduction in the MSE is modest: a 9 percent reduction compared with the interest rate model and a 5 percent reduction relative to the time-series forecasts. The decomposition statistics in table 2 reveal that, unlike the full period, much of the models' forecast errors for this subperiod are due to bias. This results from a tendency to underestimate inflation as illustrated in figures 1, 2 and 3. This underprediction appears in each of the forecasts after 1972 and is most obvious in the case of the survey responses.

The second subperiod covers 1975/I-1979/IV. During this sample, although the effects of the first oil price shock had dissipated, relative energy prices again began to rise sharply in 1979. Although less severe than the mid-1970s, the relative price of food increased substantially between 1977/IV and 1979/IV. The forecast summary statistics indicate that the time series and interest rate models actually did somewhat worse in this period than in the previous one. For example, the MSE of the time series model increased from 2.67 percent in the 1970-74 period to 3.78 percent for the 1975-79 sample. A similar decline in accuracy is revealed for the interest rate model. As table 2 shows, this general deterioration in forecast accuracy does not result from further bias. In fact, the general tendency to underestimate inflation in the 1970-74 period was corrected during this subperiod.

In contrast to the time series and interest rate models, the survey respondents did better in forecasting inflation over the 1975-79 sample than 1970-74 by any statistical criterion reported. Relative to the other models, the survey responses again were much more accurate: relative to the time-series forecasts, the survey forecasts yielded a lower MSE by over 50 percent; compared to the interest rate model forecasts, the reduction is over 40 percent.

The final period covers the post-1979 era, noted for the change in the operating procedures of monetary policy, the brief special credit control program enacted by the Carter administration in 1980, the largest post-war recession, falling relative prices of energy and volatile nominal rates of interest. The statistics indicate again that the survey respondents more accurately forecast inflation than either alternative model. The survey forecasts yield an MSE that is 51 percent lower than that for the time series model and 75 percent lower than the interest rate model. Moreover, the statistics show that the time series model improves upon the forecasts from the interest rate model, yielding an MSE that is almost 50 percent lower. The fact that the interest rate model fares so poorly during this period can be ascribed mainly to the large forecast errors generated during 1980--during the credit control program--through 1982, as shown in figure 2.

To summarize the results, the statistical evidence indicates that respondents to the ASA-NBER survey provided more accurate forecasts of the quarterly inflation rate from 1970-84 than alternative time series and interest rate models. Although the improvement during the 1970-74 period is slight, the reduction in the forecast error is substantial for each of the 1975-79 and 1980-84 samples. This finding is in sharp contrast to most previous studies where survey forecasts were shown to be inferior to time series forecasts or predictions derived from interest rates. Also, the evidence concerning the relative ability of a time series approach compared with an interest rate model is mixed. Although the time series model yielded a lower MSE during the 1970-74 and 1980-84 samples, the gain in the first subperiod was slight. The dramatic deterioration of the interest rate model forecasts in the 1980-84 sample period suggests that the approach may be sensitive to large changes in nominal rates which in turn impact on the time-series forecasts of the expected real return.[6]

VI. BIAS TESTS

In addition to directly comparing the different inflation forecast records, it is instructive to investigate the forecasts' rationality. To do this we test only for the necessary condition of bias.[7/] This is done by estimating the regression

$$(8) \quad I_t = \alpha_o + \beta_1 \hat{I}_t + \varepsilon_t$$

where I_t is the actual rate of inflation in t, $\hat{I}_t$ is the ex ante forecast of inflation, and ε_t is an error term with the usual classical properties. This latter condition is important because, if the forecasts are unbiased, then there should be no autocorrelation in the residuals. More importantly, rational forecasts do not permit rejection of the joint hypothesis that $\hat{\alpha}_o = 0$ and $\hat{\beta}_1 = 1.0$. If <u>any</u> of these conditions are not satisfied, then the hypothesis of unbiasedness is rejected.

The three forecast series were used to estimate equation (8) for the 1970-84 sample, as well as the three subperiods. The calculated F-statistics from testing the joint hypothesis that $\hat{\alpha}_o = 0$ and $\hat{\beta}_1 =$ 1.0 and the Durbin-Watson statistics for each model and sample period are reported in table 3. The outcome for the full period indicates that we cannot reject the joint hypothesis for both the time series forecasts and the survey responses at the 5 percent level of confidence. In contrast, the F-value using the interest rate model forecasts (13.32)is well above the 5 percent critical value. This rejection stems from both the fact that the estimated constant term is 2.4 (t = 4.30), and that the slope coefficient is statistically different from unity, taking on a value of

0.60 (t = 7.60). For each equation, however, we cannot reject the hypothesis of first-order serial correlation at the 5 percent level, suggesting that the forecasts are not unbiased across the full period.

The subperiod results reported in table 3 are useful to examine the robustness of the full period estimates. The evidence using the time series forecasts indicate that unbiasedness cannot be rejected at the 5 percent level in any of the sample periods examined. Moreover, the problem of serial correlation does not arise in any of the subperiods. The rejection of unbiasedness for the interest rate model forecasts for the full period stems in large part from the model's performance in the 1980-84 sample. During the 1970-74 and 1975-79 samples, the data do not reject the hypothesis of unbiasedness. Moreover, the evidence indicates no first-order serial correlation. During the 1980-84 period, however, the calculated F-value far exceeds the 5 percent critical value. This result, along with the documented deterioration in table 2 of the interest rate model's forecasting ability during this period, again suggests that this procedure may be very sensitive to relatively large swings in nominal and real interest rates.

Finally, the subperiod results for the ASA-NBER survey responses indicate that, contrary to the full period outcome, we can reject unbiasedness during the 1970-74 subperiod: the F-statistic is 13.03, easily significant at the 5 percent level. This result occurs because the estimated constant term is relatively large (1.12) undoubtedly stemming from the general underprediction of inflation during the late-1973 through 1974 period. During the post-1974 sample periods, however, the calculated F-statistics are well-below the critical value, and the Durbin-Watson statistics indicate no first-order serial correlation.

VII. COMBINATION RESULTS

As a final test concerning the relative forecasting accuracy of the three procedures, the marginal information content of each is investigated. In other words, once we know the information contained in one series, say, the time series forecast, can we improve upon that (statistically) by allowing for the information inherent in the survey forecasts? To assess the marginal contribution of each forecast, the following regression is estimated:

$$(9) \quad I_t = \alpha_o + \beta_1 \hat{I}_t^i + \beta_2 \hat{I}_t^j + \varepsilon_t$$

where $\hat{I}_t^i$ and $\hat{I}_t^j$ are two alternative inflation forecasts. The estimated β_i coefficients provide the marginal contribution for each forecast.[8/] Insignificance of the estimated β_2 coefficient indicates that the I^j forecast provides no marginal information in forecasting inflation not already included in the I^i forecast. If both βs are insignificant, this suggests that each contains similar information. If both are significant, then each contributes to the other's explanation of inflation.

Pairwise combinations of the forecast series are used to estimate equation (9): the outcome for the full period is presented in the upper panel of table 4. The time series and interest model pairing indicates that the information in the time series forecast is only marginally significant. The calculated t-statistic for the interest rate model's forecast is highly significant, indicating that this model already incorporates the information reflected in the time series forecasts. This finding is interesting, given the full-period forecast comparison presented in table 2. Recall that the time series model yielded more accurate forecasts than the interest rate model. The results in table 4 indicate that the time series forecasts could be improved by consideration for the information contained in the interest rate model forecasts. No significant improvement in the interest rate forecast could be obtained by also including the time series forecasts, however.

To see how robust the full period result is, the time series/interest rate model pairing was examined for each subperiod: these results also are reported in table 4. The subperiod results indicate that the marginal contribution of the time series and interest rate forecasts vary over time. During the 1970-74 sample, the time series forecast dominates those from the interest rate model, although the latter coefficient is significant at the 10 percent level. The evidence from the 1975-79 period is reversed: the interest rate model forecasts incorporate the marginal information contained in the time series forecasts. This result also holds for the 1980-84 subperiod, although the marginal impact of the time series forecast is significant at the 10 percent level. Thus, these results do not indicate a clear superiority of the interest rate forecasts over those derived from a time series model, but suggest that the informational content in each forecast series varies over time.

The equations that combine the survey forecasts with either of the time series or interest rate models indicate that there is no marginal improvement over the survey. This result, which is found for the full period and in each of the subperiods, is quite different from previous results using the Livingston survey forecasts of inflation.[9/] Indeed, as the statistics in table 4 show, the significance of the time series forecast or that derived from the interest rate model never approaches a reasonable level of significance. This strong result thus indicates that the informational content of the two model forecasts is subsumed into that of the median survey response.

VIII. CONCLUSION

Our purpose in this paper was to investigate the relative abilities of three alternative approaches to forecasting inflation. The three methods examined include a time series approach to modeling and forecasting inflation, an interest rate model developed in Fama (1975) and recently extended in Fama and Gibbons (1984), and the responses to the ASA-NBER survey of professional forecasters. The evidence presented, based on ex ante one-step-ahead forecasts of inflation measured using the GNP deflator for the period 1970/I to 1984/II. The outcome from our comparison indicates that the survey responses provide, on average, the most accurate forecasts of inflation. Although the improvement over the other methods is modest during the 1970-74 period, the median survey response was much more accurate during the remaining 1975-84 sample. Also, regression tests indicate that for no period studied does the forecast from the interest rate or time series model yield an significant, marginal improvement in forecast accuracy once the survey forecasts are known.

An important finding to emerge from our study is the fact that the interest rate model does not dominate the time series forecasts in all periods. Based on forecast accuracy, more accurate forecasts were made by the time series model in the 1970-74 and 1980-84 periods. Only during the 1975-79 sample were the interest rate model forecasts statistically superior. Moreover, only the forecasts derived from the time series model were found to satisfy the condition of unbiasedness in each of the subperiods. This evidence concerning the relative accuracy of a simple time series model further supports the findings of Nelson and Schwert (1977) suggesting that the time series and interest rate models perform on a par when used to forecast monthly inflation.

FOOTNOTES

1/ The estimation period runs through 1969/IV, allowing us to generate true ex ante one-step-ahead forecasts for the period 1970/I-1984/II. This period to forecast is chosen to coincide with the survey data used in later sections.

2/ Fama and Gibbons (1984) estimate θ to be 0.923 using monthly data for the sample period 1953-77. This indicates that about 8 percent of the unexpected component of the last period's real rate change is incorporated into this period's forecast. Our estimate of 0.7831 suggests about 22 percent of the unexpected change is reflected in this period's forecast, indicating that unforeseen shocks are more important in analyzing quarterly movements in the real rate.

3/ Our quarterly estimates relative to the monthly results of Fama and Gibbons (1982, 1984) suggest that the variance of the expected component of the inflation rate is larger relative to the variance of the unexpected part. Interestingly, their model for the monthly CPI inflation rate also is MA(1, 1).

4/ For a description of the survey, see Zarnowitz (1969, 1983) and Su and Su (1975). It generally is reported that the survey is mailed to "about fifty" professional forecasters. It is interesting to note that, although the exact number of surveys mailed is not known to us, we have evidence showing a decline in responses over time. For example, in 1970 there were 52 responses. By 1975 this had fallen to 44 and, in the first two surveys of 1984, the number of responses averaged 32. This reinforces the view that care should be taken in recognizing that these forecasts are not representatives of a "market" forecast but, rather, of a number of professionals.

5/ In generating the forecasts, the time series models for the real return and the inflation rate were estimated 59 times. Although inspection of each estimated equation revealed that we could not reject the continued adequacy of the MA model (the Q-statistics could not reject white-noise residuals), it is interesting to note that the estimated coefficients changed somewhat over time. For comparison purposes, we report the model estimates for the full period 1953-1984 (absolute values of t-statistics in parentheses):

A) $$(1-B)\, r_t = a_t - \underset{(9.18)}{0.6365}\, a_{t-1}$$

$$SE = 1.673 \quad Q(11) = 11.73$$

B) $$(1-B)\, I_t = a_t - \underset{(6.19)}{0.4840}\, a_{t-1}$$

$$SE = 1.603 \quad Q(11) = 14.02$$

Note that, relative to the 1953-69 estimates, the MA parameters have declined over time, implying an increase in the variance of the expected inflation rate relative to the variance of the unexpected inflation rate. In terms of the inflation model, the decline in the MA parameter is fairly smooth during 1970-84 period. The estimated θ coefficient for the real return, however, exhibits more variability across the period.

These findings are important, because they suggest that basing forecasts on coefficient estimates obtained soley from an earlier sample may provide misleading information. That is to say, holding the estimated coefficients constant during the forecast period when there is evidence indicating that such constancy is incorrect may bias forecast accuracy comparisons.

6/ It is interesting to note that the variability of the ex post real rate during the 1980-84 period was noticeably larger than during the previous samples. For instance, during the 1970-74 period, the standard deviation of the ex post real rate was 1.82 percent; during the 1975-79 period, it was 1.70 percent. For the 1980-84 sample, however, the standard deviation rose to 2.55 percent. It also should be noted that the mean value of the ex post real rate, about -0.22 percent for the 1970-74 and 1975-79 samples, increased sharply to 4.83 percent for the recent period.

7/ A complete test of rationality also would necessitate testing for efficiency. Studies examining the rationality of the Livingston data include, among others, Carlson (1977), Brown and Maital (1981), Figlewski and Wachtel (1981), and Hafer and Resler (1982). Comparisons of Livingston and time series forecasts are found in Pearce (1979). Investigations of the ASA-NBER survey data can be found in Zarnowitz (1983). Note, however, that Zarnowitz, following Figlewski and Wachtel, uses only the median response of a subset of the survey respondents who regularly participated (i.e., 12 or more survey responses).

8/ This type of test was suggested originally by Bates and Granger (1969) as a procedure to obtain weighted combinations of forecasts. See also Nelson (1972) and Granger and Ramanathan (1984).

9/ Fama and Gibbons (1984), for example, found the Livingston survey responses to be statistically inferior to both the time series and interest rate forecasts of inflation. See Pearce (1979) for a similar conclusion.

Table 1
Sample Autocorrelations: 1953-1969

Variable	1	2	3	4	5	6	7	8	9	10	11	12
r_t	0.268	0.273	0.324	0.154	0.133	0.200	0.121	0.154	0.123	0.167	0.005	0.101
$r_t - r_{t-1}$	-0.495	-0.036	0.143	-0.082	-0.079	0.108	-0.071	0.043	-0.049	0.122	-0.176	0.126
I_t	0.427	0.414	0.436	0.285	0.226	0.266	0.125	0.101	0.065	0.105	0.016	0.095
$I_t - I_{t-1}$	-0.490	-0.027	0.190	-0.153	-0.028	0.160	-0.134	0.008	-0.052	0.143	-0.159	0.137

NOTES: r_t is the ex post real return in period t; I_t is the inflation rate in period t, measured as the log difference in the GNP deflator.

Table 2
Summary Forecast Statistics
Full Period and Subperiods

MODEL	MAE	MSE	RMSE	B	V	CV
			70/I-84/II			
ARIMA	1.39	3.27	1.81	0.00	0.07	0.93
T-BILL	1.68	4.14	2.04	0.01	0.05	0.94
ASA-NBER	1.18	2.02	1.42	0.07	0.06	0.87
			70/I-74/IV			
ARIMA	1.42	2.67	1.63	0.15	0.44	0.41
T-BILL	1.38	2.79	1.67	0.14	0.11	0.75
ASA-NBER	1.38	2.54	1.59	0.59	0.03	0.38
			75/I-79/IV			
ARIMA	1.22	3.78	1.94	0.02	0.02	0.96
T-BILL	1.43	3.16	1.78	0.11	0.00	0.89
ASA-NBER	1.08	1.82	1.35	0.00	0.21	0.79
			80/I-84/II			
ARIMA	1.54	3.38	1.84	0.06	0.07	0.87
T-BILL	2.29	6.73	2.60	0.08	0.22	0.70
ASA-NBER	1.06	1.66	1.29	0.02	0.33	0.64

NOTES: The mnemonics for the models are: ARIMA is the time series model; T-BILL represents the interest rate model; and ASA-NBER is the survey result. MAE is the mean absolute error, MSE is the mean squared error and RMSE denotes the root mean square error. B, V and CV are, respectively, the Theil decomposition statistics measuring the degree of error due to bias, variance and covariance between the actual and predicted series.

Table 3
Bias Test Results: F-values/Durbin-Watson Statistics

Forecast Model	Period 1970-84	1970-74	1975-79	1980-84
ARIMA	0.96/1.45*	4.06/1.56	2.61/1.65	0.61/1.80
TBILL	13.32*/1.39*	1.47/1.54	3.24/1.79	10.28*/1.40
ASA-NBER	2.10/1.43*	13.03*/2.00	0.01/1.41	1.62/2.56

NOTES: Model definitions are found in the notes accompanying table 2. An asterisk (*) denotes significance at the 5 percent level of confidence. The reported F-value is based on testing the joint hypothesis $\alpha_o = 0$ and $\beta_1 = 1.0$ in the equation $I_t + \alpha_o + \beta_1 \hat{I}_t + \varepsilon_t$.

Table 4
Combination Results: 1970/I-1984/II

Equation Estimated: $I_t = \alpha_o + \beta_1 \hat{I}_t^i + \beta_2 \hat{I}_t^j + \varepsilon_t$

Combination	α_o	β_1	β_2	$\bar{R}^2$/SE	DW
		1970/I-1984/II			
ARIMA/TBILL	1.418 (1.85)	0.347 (1.88)	0.414 (3.31)	0.520 1.668	1.47
ASA/TBILL	0.598 (1.06)	0.809 (5.47)	0.139 (1.32)	0.670 1.385	1.45
ASA/ARIMA	0.627 (0.97)	0.983 (6.15)	-0.025 (0.15)	0.659 1.406	1.42
		1970/I-1974/IV			
ARIMA/TBILL	-2.130 (1.61)	1.065 (3.10)	0.446 (1.84)	0.690 1.343	2.02
ASA/TBILL	0.600 (0.79)	0.875 (5.03)	0.227 (1.13)	0.805 1.065	2.00
ASA/ARIMA	0.805 (0.59)	0.961 (3.65)	0.112 (0.26)	0.791 1.102	1.98
		1975/I-1979/IV			
ARIMA/TBILL	2.718 (1.61)	-0.219 (0.57)	0.762 (2.20)	0.268 1.638	1.71
ASA/TBILL	-0.127 (0.07)	1.059 (3.24)	-0.036 (0.14)	0.418 1.461	1.38
ASA/ARIMA	-0.194 (0.11)	1.033 (2.18)	-0.002 (0.00)	0.417 1.461	1.41
		1980/I-1984/II			
ARIMA/TBILL	0.626 (0.50)	0.492 (1.80)	0.333 (2.10)	0.658 1.705	1.63
ASA/TBILL	-1.658 (1.71)	1.399 (4.47)	-0.165 (0.59)	0.810 1.271	2.53
ASA/ARIMA	-0.515 (1.37)	1.151 (4.17)	0.050 (0.35)	0.807 1.280	2.50

NOTES: See table 2 for model definitions. $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom, SE is the regression standard error, and DW is the Durbin-Watson test statistic.

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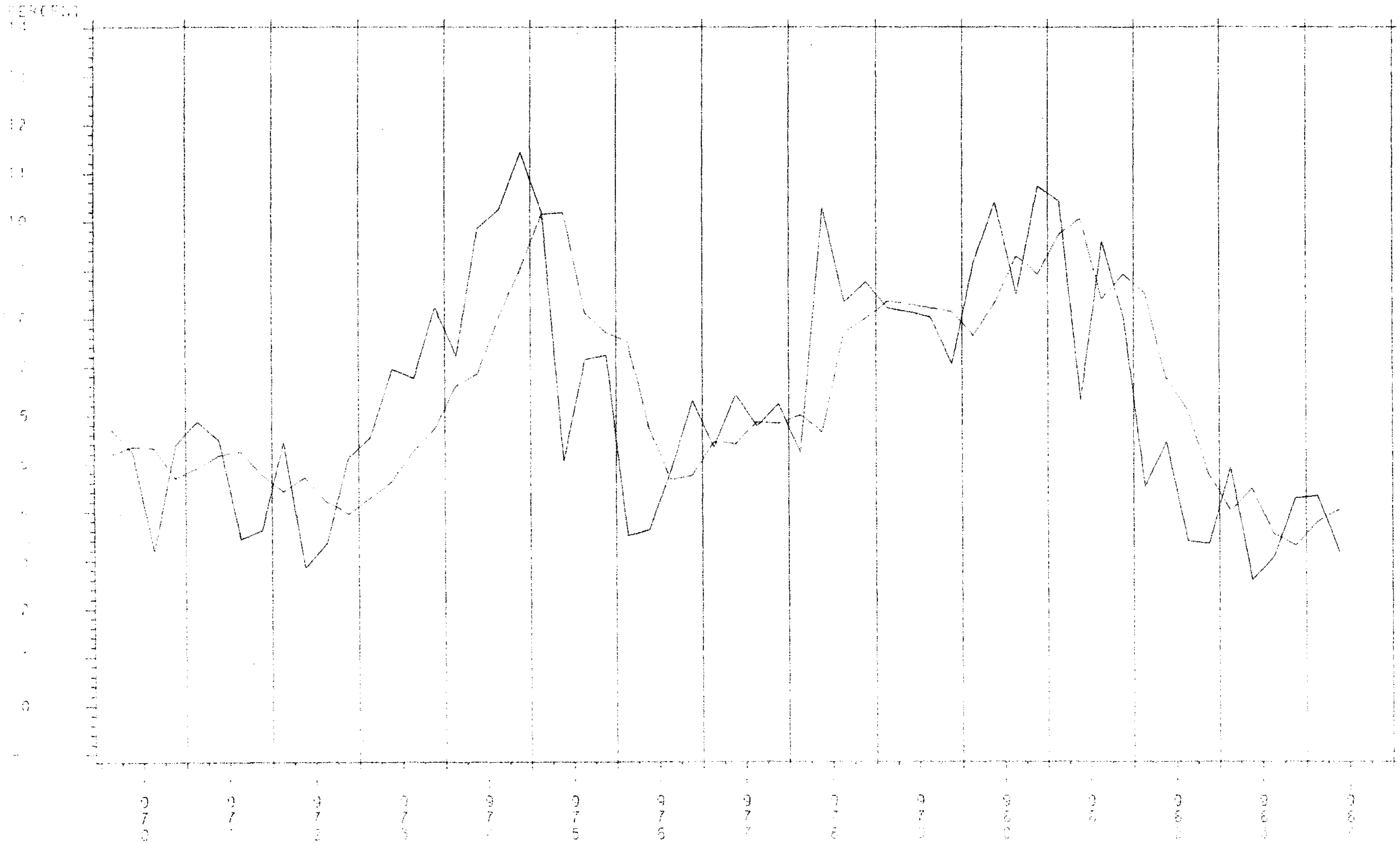
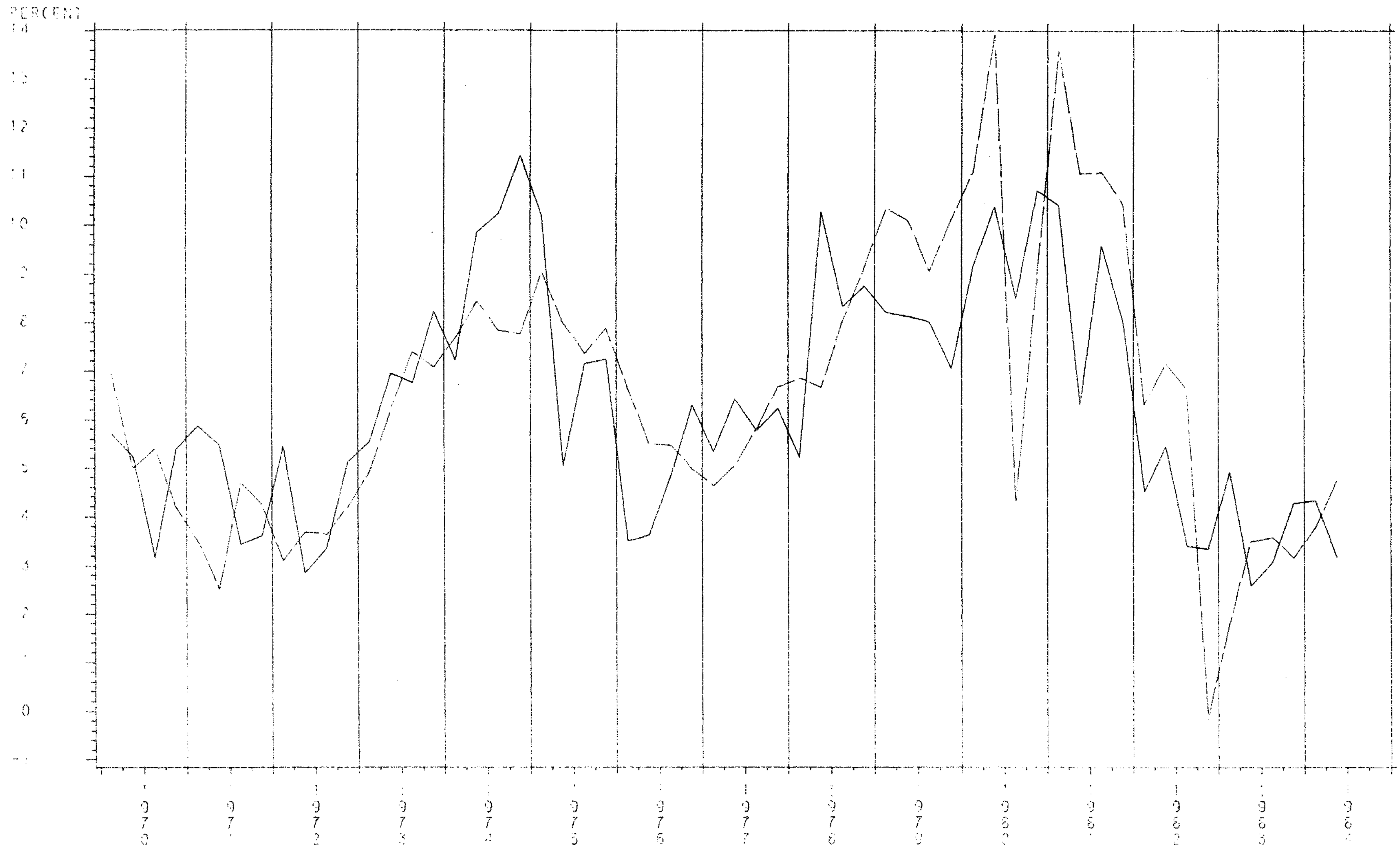
Figure 1



ACTUAL INFLATION ———

ARIMA FORECASTS — —

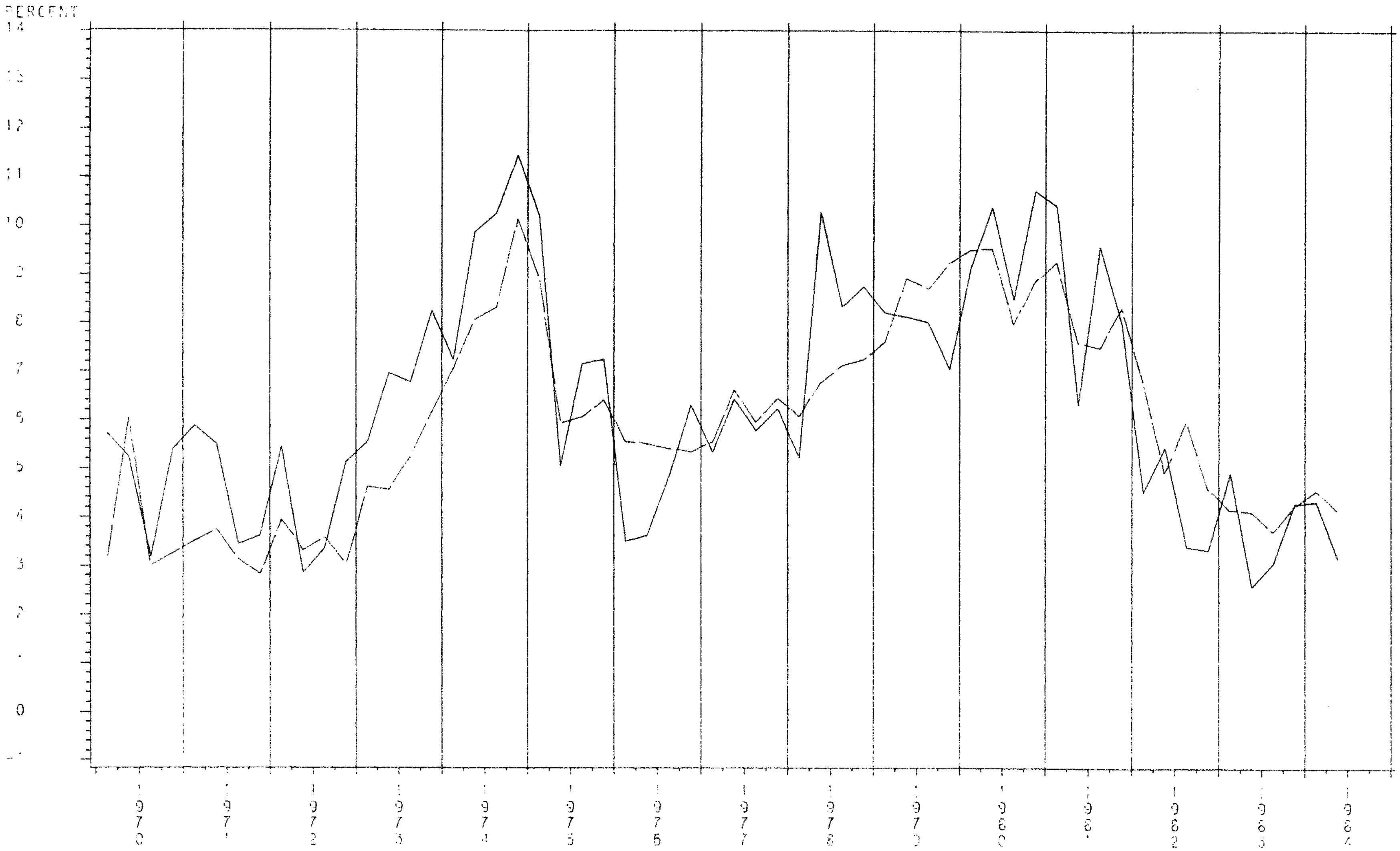
Figure 2



ACTUAL INFLATION ———

TBILL FORECASTS — —

Figure 3



ACTUAL INFLATION ———

SURVEY FORECASTS — —