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A COMPARISON OF INFLATION FORECASTS*

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Interest rate models provide slightly better monthly forecasts and substantially better eight- and fourteen-month forecasts of inflation than a univariate time series model. The Livingston surveys underestimate eight- and fourteen-month inflation rates, especially during the high inflation period of 1978–81. In contrast, eight- and fourteen-month inflation forecasts extrapolated from one-month interest rates show little bias and track *ex post* eight- and fourteen-month inflation rates better than the survey forecasts.

1. Introduction

Several methods for forecasting inflation are popular. Fama (1975) argues that an interest rate model in which expected real returns on treasury bills are constant through time provides good inflation forecasts for the 1953–71 period. Nelson and Schwert (1977) show that inflation forecasts from a univariate time series model are about as reliable as those from Fama's treasury bill rate model. Hess and Bicksler (1975) and others provide evidence that expected real returns on treasury bills wander through time. Fama and Gibbons (1982) find that when expected real returns are assumed to follow random walks, treasury bill rates provide good inflation forecasts for the entire 1953–77 period. Finally, Carlson (1977) and others suggest that forecasts of inflation from the Livingston surveys are better than those from time series and interest rate models.

Attempts to compare the forecast power of different inflation models are limited. Nelson and Schwert (1977) find that the inflation forecasts from their time series model and those from Fama's (1975) interest rate model contain information not captured by the other. However, no attempt is made to compare the forecasts of the two models outside the 1953–71 period used to estimate model parameters. Pearce (1978) finds that during the 1959–76 period inflation forecasts from a univariate time series model are less biased and have

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lower error variance than the forecasts from the Livingston surveys. However, Pearce assumes that the inflation forecasts in interest rates are rational and makes no attempt to include them in his comparisons. Finally, in the studies of the rationality of the Livingston survey forecasts, for example, Pesando (1975), Carlson (1977), Mullineaux (1978), and Hafer and Resler (1980), there are no comparisons with forecasts from competing models.

This paper compares a time series model, two interest rate models and the Livingston survey forecasts of inflation. Data for the 1953–77 period are used to fit interest rate and time series models. The competing inflation models are evaluated first on within-sample data for 1953–77 and then on out-of-sample forecasts for 1978–81. All model fitting for the 1953–77 period was completed before the data for the subsequent forecast period were collected. Since the Livingston forecasts are for eight- and fourteen-month periods, the first tests on monthly inflation rates are limited to interest rate and time series models. We then compare all models on eight- and fourteen-month data.

2. Monthly inflation

2.1. Time series model

Table 1 shows the autocorrelations of the monthly inflation rate, I_t, for the 1953–77 period. The inflation rate is the change from month $t-1$ to month t in the natural log of the U.S. Consumer Price Index. The autocorrelations of I_t are in the neighborhood of 0.5, and they decline slowly at higher-order lags. Moreover, the first-order autocorrelation of the month-to-month changes in I_t is substantial, -0.53, but all higher-order autocorrelations are less than two standard errors from zero. This behavior of the sample autocorrelations suggests a first-order moving average process as a model for the change in the inflation rate [cf. the simulation evidence of Wichern (1973)],

$$I_t - I_{t-1} = a_t - \theta a_{t-1}. \tag{1}$$

The first-order moving average process is in turn consistent with a model for the inflation rate,

$$I_t = \mathrm{E}I_{t-1} + \eta_t, \tag{2}$$

in which $\mathrm{E}I_{t-1}$, the expected inflation rate for month t assessed at the end of month $t-1$, follows a random walk, and the unexpected inflation rate η_t is serially uncorrelated white noise [see, for example, Nelson (1973, ch. 4)]. In this view,

$$I_t - I_{t-1} = \Delta \mathrm{E}I_{t-1} + \eta_t - \eta_{t-1}, \tag{3}$$

and the moving average parameter θ in (1) is close to 1.0 (0.0) when the variance of the unexpected inflation rate η_t in (3) is large (small) relative the variance of $\Delta \mathrm{E}I_{t-1}$, the step of the unexpected inflation rate [Ansley (1980)].

When the nonlinear least squares procedure of Box and Jenkins (1976, ch. 7) is used to estimate the moving average parameter θ in (1), the monthly data for the 1953–77 period yield

$$I_t - I_{t-1} = \hat{a}_t - \underset{(0.0347)}{0.8027}\,\hat{a}_{t-1}, \qquad s(\hat{a}) = 0.00220. \tag{4}$$

The autocorrelations of the residuals $\hat{a}_t$ (table 1), with the $\hat{a}_t$ estimated according to the backforecasting procedure of Box and Jenkins (1976, ch. 7), are close to zero. The univariate time series model (4) is similar to the models Nelson and Schwert (1977) and Pearce (1978) estimate on monthly data for the 1953–71 and 1959–76 periods.

The estimate of the expected inflation rate for month t from the time series model (4) is the fitted value,

$$\mathrm{E}ITS_{t-1} = I_{t-1} - 0.8027\hat{a}_{t-1}. \tag{5}$$

If we write the inflation rate I_{t-1} in terms of its expected and unexpected components, $\mathrm{E}ITS_{t-2}$ and $\hat{a}_{t-1}$, (5) becomes

$$\mathrm{E}ITS_{t-1} = \mathrm{E}ITS_{t-2} + \hat{a}_{t-1}(1 - 0.8027). \tag{6}$$

In short, the estimate, 0.8027, of the moving average parameter θ in (1) implies that the variance of the step of the expected inflation rate in (3) is small relative to the variance of the unexpected inflation rate. Eq. (6) then says that, as a consequence, only about 20 percent of the unexpected inflation rate for month $t-1$ is incorporated into the expected inflation rate for month t.

2.2. Interest rate model

Following Irving Fisher (1930), the one-month interest rate, TB_{t-1}, observed at the end of month $t-1$ can be broken into an expected real return for month t, $\mathrm{E}R_{t-1}$, and an expected inflation rate, $\mathrm{E}I_{t-1}$,

$$TB_{t-1} = \mathrm{E}R_{t-1} + \mathrm{E}I_{t-1}. \tag{7}$$

Isolating the inflation forecast $\mathrm{E}I_{t-1}$ in the interest rate requires a model for the expected real return. The evidence of Hess and Bicksler (1975), Fama (1976b), Garbade and Wachtel (1978) and Fama and Gibbons (1982) suggests a model in which the expected real return is a random walk.

Table 1

Means, standard deviations and autocorrelations of monthly variables: 1953–77.[a]

Variable (x)	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	ρ_9	ρ_{10}	ρ_{11}	ρ_{12}	$\bar{x}$	$s(x)$	N
I_t	0.55	0.58	0.52	0.52	0.52	0.52	0.48	0.49	0.51	0.48	0.44	0.47	0.00286	0.00299	299
$I_t - I_{t-1}$	−0.53	0.11	−0.06	−0.01	−0.05	0.03	−0.04	−0.04	0.06	0.02	−0.08	0.09	0.00003	0.00285	298
$\hat{a}_t$	−0.01	0.09	−0.04	−0.03	−0.01	0.01	−0.04	−0.01	0.09	0.06	−0.00	0.10	0.00010	0.00220	298
$TB_{t-1} - I_t$	0.20	0.27	0.15	0.12	0.14	0.13	0.10	0.14	0.22	0.20	0.15	0.25	0.00028	0.00224	298
$(TB_{t-1} - I_t) - (TB_{t-2} - I_{t-1})$	−0.53	0.12	−0.05	−0.03	0.02	0.01	−0.04	−0.04	0.07	0.03	−0.19	0.12	−0.00002	0.00286	298
$\hat{u}_t$	0.03	0.12	−0.05	−0.06	−0.04	−0.04	−0.07	−0.02	0.08	0.06	0.01	0.14	−0.00010	0.00214	298
$\hat{\varepsilon}_t$	0.02	0.11	−0.06	−0.08	−0.05	−0.05	−0.10	−0.05	0.03	−0.00	−0.05	0.08	0.00002	0.00211	288

[a] I_t is the inflation rate for month t. TB_{t-1} is the one-month treasury bill rate for month t observed at the end of month $t-1$. $\hat{a}_t$ is the estimated unexpected inflation rate for month t from the time series model of inflation of eq. (4). $\hat{u}_t$ is the estimated unexpected real return (the negative of the unexpected inflation rate) from the interest rate model (11) which allows the expected real return component of the interest rate to follow a random walk. ε_t is the estimated unexpected inflation rate from the naive interest rate model which estimates the expected real return as a simple average of the twelve most recent monthly real returns. $\bar{x}$ and $s(x)$ are the sample mean and standard deviation of the variable. ρ_τ is the sample autocorrelation at lag τ. Under the hypothesis that the true autocorrelations are zero, the standard errors of the estimated autocorrelations are about 0.06. N is the sample size.

If we express the *ex post* real return for month t as

$$TB_{t-1} - I_t = \mathrm{E}R_{t-1} + \xi_t, \tag{8}$$

then the difference between the real returns for t and $t-1$ is

$$(TB_{t-1} - I_t) - (TB_{t-2} - I_{t-1}) = \Delta \mathrm{E}R_{t-1} + \xi_t - \xi_{t-1}, \tag{9}$$

where $\Delta \mathrm{E}R_{t-1}$ is the change in the expected real return from month $t-1$ to month t, and ξ_t is the unexpected component of the real return for month t. If $\mathrm{E}R_{t-1}$ is a random walk, $\Delta \mathrm{E}R_{t-1}$ and ξ_t are both white noise. The difference between the real returns for months t and $t-1$ can then be represented as a first-order moving average process [Box and Jenkins (1976, app. to ch. 4)],

$$(TB_{t-1} - I_t) - (TB_{t-2} - I_{t-1}) = u_t - \theta u_{t-1}, \tag{10}$$

and the moving average parameter θ is close to 1.0 (0.0) when the variance of ξ_t is large (small) relative to the variance of $\Delta \mathrm{E}R_{t-1}$.

The autocorrelations of the monthly levels and differences of the real return $TB_{t-1} - I_t$ are shown in table 1. I_t is the *ex post* inflation rate for month t, and TB_{t-1} is the *ex ante* continuously compounded one-month treasury bill rate observed at the end of month $t-1$. The treasury bill rates are from the quote sheets of Salomon Brothers [see Fama (1976, ch. 6)]. Consistent with the random walk model for the expected real return $\mathrm{E}R_{t-1}$ in (8), the autocorrelations of the real return $TB_{t-1} - I_t$ are in the neighborhood of 0.2, and they show no tendency to decay toward zero at higher-order lags. Moreover, the first-order autocorrelation of the monthly differences of $TB_{t-1} - I_t$ is large, -0.53, but all higher-order autocorrelations are less than two standard errors from zero. This is consistent with the model's implication that the differences can be represented as a first-order moving average process.

When nonlinear least squares is used to estimate the moving average parameter θ in (10), the monthly data for 1953–77 yield

$$\begin{aligned}(TB_{t-1} - I_t) - (TB_{t-2} - I_{t-1}) &= \hat{u}_t - \underset{(0.0226)}{0.9223}\,\hat{u}_{t-1}, \\ s(\hat{u}) &= 0.00214.\end{aligned} \tag{11}$$

The autocorrelations of the $\hat{u}_t$ (table 1), with the $\hat{u}_t$ estimated according to the backforecasting procedure of Box and Jenkins (1976, ch. 7), are close to zero.

The estimate of the expected real return for month t implied by (11) is the fitted value

$$\mathrm{E}R_{t-1} = (TB_{t-2} - I_{t-1}) - 0.9223\hat{u}_{t-1}. \tag{12}$$

When the real return for month $t-1$ is expressed as

$$TB_{t-2} - I_{t-1} = \mathrm{E}R_{t-2} + \hat{u}_{t-1}, \tag{13}$$

eq. (12) becomes

$$\mathrm{E}R_{t-1} = \mathrm{E}R_{t-2} + (1 - 0.9223)\hat{u}_{t-1}. \tag{14}$$

In short, the estimate 0.9223 of the moving average parameter θ in (10) implies that the variance of the step of the random walk expected real return in (9) is small relative to the variance of the unexpected component of the real return. Eq. (14) then says that because $\hat{\theta}$ is so close to 1.0, only about 8 percent of $\hat{u}_{t-1}$, the unexpected component of the real return for month $t-1$, is incorporated into the expected real return $\mathrm{E}R_{t-1}$ for month t.

Using the expected real return estimated from (12), the expected inflation rate for month t extracted from the one-month treasury bill rate is

$$\mathrm{E}ITB_{t-1} = TB_{t-1} - \mathrm{E}R_{t-1}. \tag{15}$$

Finally, the maximum likelihood procedure discussed by Ansley (1979) has also been used to estimate the moving average parameters in (1) and (10). The estimates, 0.7999 and 0.9184 respectively, are trivially different from those in (4) and (11), 0.8027 and 0.9223, estimated by nonlinear least squares. The fact that the two procedures yield similar estimates is reassuring, given that the estimates of the moving average parameters are close to 1.0.[1]

2.3. Naive interest rate model

If the month-to-month change in the real return is a first-order moving average process with moving average parameter $\theta < 1.0$, the real return can be expressed as an exponentially weighted average of past real returns [see, for example, Box and Jenkins (1976, ch. 5)],

$$\begin{aligned} TB_{t-1} - I_t = {} & (1-\theta)(TB_{t-2} - I_{t-1}) + \theta(1-\theta)(TB_{t-3} - I_{t-2}) \\ & + \theta^2(1-\theta)(TB_{t-4} - I_{t-3}) + \cdots + u_t. \end{aligned} \tag{16}$$

[1] When the moving average parameter θ is close to 1.0, a first-order moving average process is close to non-invertible and probability statements about $\hat{\theta}$ are problematic. On the one hand, the simulations of Ansley and Newbold (1980) indicate that when θ is less than 1.0, standard asymptotic sampling results hold to a reasonable approximation for samples as large as ours (298 observations), but there is some tendency for estimates of θ to 'pile up' at the boundary value 1.0. The pileup effect implies a higher probability that the hypothesis $\theta = 1.0$ will be accepted when it is false. On the other hand, the simulations of Plosser and Schwert (1977) indicate that applying asymptotic sampling theory causes the null hypothesis $\theta = 1.0$ to be rejected more often than would be expected when it is true. Given these statistical ambiguities, it is comforting that different estimation techniques yield similar inferences about θ. These statistical problems also provide motivation for the naive interest rate model that follows.

The estimate $\theta = 0.9223$ in (11) then implies weights on past real returns (0.078, 0.072, 0.066, 0.061, ...) that decline slowly with increasing lags

One way to approximate such a model for the real return is to estimate the expected real return as an equally weighted moving average of some number of past real returns. Denoting this 'naive' estimate of the expected real return for month t as $\mathrm{E}RN_{t-1}$, the implied expected inflation rate is

$$\mathrm{E}INTB_{t-1} = TB_{t-1} - \mathrm{E}RN_{t-1}, \tag{17}$$

and the inflation rate for month t can be expressed as

$$I_t = \mathrm{E}INTB_{t-1} + \varepsilon_t. \tag{18}$$

We have estimated time series of expected real returns using equally weighted moving averages of from one to twenty-four months of past real returns. When these estimates are substituted into (17), the expected real return estimated as the average of the most recent twelve months of real returns produces a time series of unexpected inflation rates ε_t in (18) with about the smallest standard error (0.00211), and the autocorrelation (table 1) of the ε_t are close to zero. This version of the expected real return is used henceforth to obtain the 'naive' treasury bill rate forecast of inflation, $\mathrm{E}INTB_{t-1}$. However, the properties of the expected and unexpected inflation rates estimated from the naive interest rate model are much the same for estimates of the expected real return based on anywhere from six to twenty-four months of past real returns.

3. Comparisons of monthly inflation forecasts

3.1. *Within-sample forecasts*

Table 2 shows regressions of the monthly inflation rate I_t on the estimated expected inflation rates, $\mathrm{E}ITS_{t-1}$, $\mathrm{E}ITB_{t-1}$ and $\mathrm{E}INTB_{t-1}$, of the three competing inflation models. The regressions are on the data for the 1953–77 period used to estimate the parameters of the models. Thus, they provide perspective on the within-sample properties of the models.

In the single-variable regressions (1) to (3) the criteria for a good inflation model are (a) conditional unbiasedness, that is, an intercept close to zero, and a regression coefficient for the model's expected inflation rate close to 1.0, (b) serially uncorrelated residuals and (c) a low residual standard error. The two interest rate models do slightly better on these tests than the time series model. The intercepts and the coefficients of expected inflation rates for the interest rate models in regressions (1) and (2) are closer to the theoretical values 0.0 and 1.0 than the intercept and slope estimated for the time series model in regression (3). The expected inflation rates from the two interest rate models

Table 2

Within-sample (1953–77) regressions of monthly inflation rates on estimated expected inflation rates.[a]

Regression number	Estimated regression	R^2	$s(e)$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_{12}
(1)	$I_t = 0.00015 + 0.98 EITB_{t-1} + e_t$ (0.00020) (0.06)	0.50	0.00212	0.03	0.12	−0.02	−0.06	0.14
(2)	$I_t = 0.00020 + 0.94 EINTB_{t-1} + e_t$ (0.00020) (0.05)	0.50	0.00211	0.02	0.11	−0.05	−0.08	0.08
(3)	$I_t = 0.00042 + 0.89 EITS_{t-1} + e_t$ (0.00020) (0.06)	0.46	0.00219	0.00	0.10	−0.02	−0.02	0.10
(4)	$I_t = 0.00016 + 0.07 EITS_{t-1} + 0.91 EITB_{t-1} + e_t$ (0.00020) (0.19) (0.20)	0.50	0.00212	0.03	0.11	−0.03	−0.06	0.14
(5)	$I_t = 0.00020 + 0.13 EITS_{t-1} + 0.81 EINTB_{t-1} + e_t$ (0.00020) (0.19) (0.19)	0.51	0.00211	0.01	0.10	−0.06	−0.07	0.09
(6)	$I_t = 0.00014 + 0.40 EITB_{t-1} + 0.56 EINTB_{t-1} + e_t$ (0.00021) (0.42) (0.39)	0.51	0.00211	0.02	0.11	−0.05	−0.08	0.11

[a] I_t is the inflation rate for month t. $EITS_{t-1}$ is the expected inflation rate for month t estimated from the time series model. $EITB_{t-1}$ is the expected inflation rate for month t estimated from the interest rate model in which the expected real return component of the interest rate is presumed to follow a random walk. $EINTB_{t-1}$ is the expected inflation rate from the naive interest rate model in which the expected real return is estimated as the simple average of the twelve most recent realized monthly real returns. R^2 is the coefficient of determination. $s(e)$ is the residual standard error (adjusted for degrees of freedom). ρ_τ is the residual autocorrelation at lag τ. Under the hypothesis that the true autocorrelations are zero, the standard errors of the residual autocorrelations are about 0.06. The numbers in parentheses below the estimated regression coefficients are standard errors. The data for regressions (1), (3) and (4) cover the 298 observations from March 1953 to December 1977. Since the twelve months of real returns for 1953 are needed to compute the first value of $EINTB_{t-1}$, the data for regressions (2), (5) and (6) cover the 288 observations from January 1954 to December 1977. Given the evidence in table 1 that I_t may be mean non-stationary, the R^2 values reported above may not be meaningful. Since the residual autocorrelations are close to zero, however, the residual standard errors $s(e)$ are meaningful.

also produce lower residual standard errors than the expected inflation rate from the time series model. However, residual autocorrelations are small and quite similar for all three models. Moreover, the fact that the differences among the models are generally small is support for the conclusion of Nelson and Schwert (1977) that a time series model of monthly inflation captures about as much information as interest rate models.

A more interesting competition is provided by the multiple regressions (4) to (6) of table 2 in which the expected inflation rates of the three models meet each other in pairwise comparisons. Regression (4) shows that $EITS_{t-1}$, the expected inflation rate from the time series model, has no marginal explanatory power in a regression that also includes $EITB_{t-1}$, the expected inflation rate from the interest rate model that allows for a random walk expected real return. Including $EITS_{t-1}$ as an explanatory variable has little effect on the coefficient of $EITB_{t-1}$, which remains close to 1.0. Regression (5) then shows that $EINTB_{t-1}$, the expected inflation rate from the naive interest rate model, also dominates the expected inflation rate from the time series model. At least within the period used to estimate the models, the time series model does not contain information about inflation missed by the treasury bill market in setting interest rates. Thus, the data are consistent with the hypothesis that the forecasts of inflation in interest rates are efficient or rational with respect to the information in past inflation rates.

In contrast, Nelson and Schwert (1977) find that in a multiple regression of the monthly inflation rate on the one-month treasury bill rate and on the expected inflation rate from a time series model, both variables have marginal explanatory power. They conclude that the forecasts of inflation in interest rates overlook some of the information in past inflation rates, but the interest rate forecasts also include information beyond that in past inflation rates. Regressions (4) and (5) of table 2 confirm the latter conclusion but not the former. However, our results support the Nelson-Schwert conjecture that the marginal explanatory power of the time series model relative to the interest rate in their results reflects the absence of an adjustment for a wandering expected real return in the interest rate model [Fama (1975)] they use.

Regression (6) shows that when the expected inflation rates from the two interest rate models are included together in an inflation regression, the standard errors of their estimated coefficients are so large that inferences about relative importance are impossible. These results are due to the high collinearity between $EITB_{t-1}$ and $EINTB_{t-1}$. The correlation between the monthly forecast errors of the two interest rate models is 0.987. In other words, either interest rate model provides a good model for monthly inflation, and neither has marginal explanatory power relative to the other. Thus, the data confirm the inference from (16) that the naive treasury bill rate model, in which the expected real return component of the interest rate is estimated as a simple average of the twelve most recent monthly real returns, is a close approximation to the more sophisticated model in which the expected real return is allowed to follow a random walk.

We have checked the robustness of the results in table 2 in several ways. For example, similar results were obtained on data for the January 1953 to July 1971 period preceding the imposition of temporary price controls. In particular, the expected inflation rates from the two interest rate models dominate the expected inflation rate from the time series model, while neither interest rate model has marginal explanatory power relative to the other. These conclusions were also supported by regressions of the change in the inflation rate, $I_t - I_{t-1}$, on the difference between an expected inflation rate and the lagged inflation rate, that is, $EITB_{t-1} - I_{t-1}$, $EINTB_{t-1} - I_{t-1}$ or $EITS_{t-1} - I_{t-1}$. These regressions avoid problems of inference that may be caused by the apparent mean non-stationarity of the levels of I_t and the expected inflation rates.

Finally, Fama (1982) compares the explanatory power of the interest rate forecast $EITB_{t-1}$ with the conditional expected inflation rate from a model that combines money demand theory and the quantity theory of money. This money-demand–quantity-theory model explains inflation in terms of current and past growth rates of money and current, past and future growth rates of real activity. In the monthly data for the 1953–77 period, the expected and unexpected inflation rates estimated from the interest rate and money demand models are highly correlated. For example, the correlation between the unexpected inflation rates of the two models is 0.91. However, the interest rate model dominates the money-demand–quantity-theory model when the information available to the latter is restricted to current and past growth rates of money and real activity. Thus, the forecasts of inflation in interest rates seem to be efficient or rational with respect to the information about inflation in current and past growth rates of money and real activity. Because of these earlier results we see no need in this paper, which is ultimately concerned with pure forecasts of inflation, to include the money-demand–quantity-theory model in the set of competing inflation models, or to supplement any of the included models with current and past measures of the variables (money and real activity growth rates) which are among the proximate determinants of the inflation rate.

3.2. *Out-of-sample forecasts*

The properties of the pure monthly forecast errors of the three inflation models for the out-of-sample period January 1978 to June 1981 are shown in part A of table 3. For comparison, part B of the table shows the same statistics for the forecast errors of the within-sample period 1953–77. As in the within-sample data, the out-of-sample forecasts do not indicate that any one model does noticeably better than the others. The average forecast errors of the three models are substantially less than two standard errors from zero. The standard

Table 3

Comparisons of monthly inflation forecasts.[a]

Model	$\overline{FE}$	$t(\overline{FE})$	$s(FE)$	$RMSE$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_{12}	N
Part A: Out-of-sample period, January 1978 – June 1981										
$EITB_{t-1}$	−0.00046	−1.12	0.00266	0.00267	0.47	0.21	0.34	0.21	0.08	42
$EINTB_{t-1}$	−0.00050	−1.26	0.00256	0.00258	0.44	0.17	0.32	0.18	0.09	42
$EITS_{t-1}$	0.00046	1.14	0.00261	0.00262	0.45	0.15	0.09	0.10	0.14	42
Part B: Within-sample estimation period, 1953–77										
$EITB_{t-1}$	0.00010	0.82	0.00212	0.00211	0.03	0.12	−0.02	−0.06	0.14	298
$EINTB_{t-1}$	0.00002	0.17	0.00211	0.00211	0.02	0.11	−0.06	−0.08	0.08	288
$EITS_{t-1}$	0.00010	0.80	0.00220	0.00220	−0.01	0.09	−0.04	−0.03	0.10	298

[a] $\overline{FE}$ is the average monthly forecast error. $t(\overline{FE})$ is the t-statistic for the test of the null hypothesis that the expected forecast error is equal to zero. $s(FE)$ is the standard deviation of the monthly forecast errors. $RMSE$ is the root mean squared error (the square root of the average squared forecast error). N is the sample size. ρ_τ is the sample autocorrelation of the monthly forecast errors for lag τ. Under the hypothesis that the true autocorrelations are zero, the standard error of the sample autocorrelations is about 0.17 for the out-of-sample forecasts and about 0.06 for the within-sample forecasts.

deviations of the forecast errors and the root mean squared forecast errors are similar across models.

There is some decline in the power of the three inflation models in the out-of-sample forecasts. The standard deviations of the forecast errors for the post-1977 period are all about 20 percent higher than for the earlier within-sample period. Moreover, whereas the within-sample forecast errors show no evidence of autocorrelation, the first-order autocorrelations of out-of-sample forecast errors are substantial and of similar magnitude (0.44 to 0.47) for the three inflation models.

The inflation models may do relatively better on the data for the 1953–77 period because their parameters are chosen on the basis of performance on the data for this period. However, a different explanation for the deterioration of the out-of-sample forecasts is suggested by table 4 which summarizes the forecast errors of the three inflation models for subperiods of the 1953–77 period used to estimate model parameters. There is a U-shaped pattern in the standard deviations and root mean squared errors of the forecast errors, with variability declining during the earlier subperiods and then shifting to a higher level during the 1970–77 period. Moreover, the forecast errors of the last subperiod of the 1953–77 period show the same high autocorrelation as the out-of-sample forecasts for the 1978–81 period in table 3. All this suggests that the deterioration of the out-of-sample forecasts reflects changes in the inflation process that make inflation harder to predict during the later years of the sample period. The tests for longer-term forecasts that follow shed further light

Table 4

Subperiod comparisons of monthly inflation forecasts.[a]

nrModel	$\overline{FE}$	$t(FE)$	$s(FE)$	$RMSE$	ρ_1	ρ_2	ρ_3	ρ_4	$\rho_{12} N$
				Subperiod 1: 1954/1–1957/6					
$EITB_{t-1}$	0.00036	0.99	0.00236	0.00235	−0.00	0.09	−0.12	0.01	0.2042
$EINTB_{t-1}$	0.00021	0.57	0.00236	0.00234	−0.00	0.08	−0.12	0.01	0.1642
$EITS_{t-1}$	0.00037	0.98	0.00243	0.00243	−0.05	0.05	−0.15	0.04	0.1742
				Subperiod 2: 1957/7–1960/12					
$EITB_{t-1}$	−0.00028	−0.83	0.00215	0.00214	0.00	0.73	−0.11	0.02	0.1642
$EINTB_{t-1}$	−0.00016	−0.48	0.00219	0.00217	0.05	0.26	−0.10	0.02	0.1642
$EITS_{t-1}$	−0.00024	−0.72	0.00216	0.00215	−0.13	0.14	−0.19	0.04	0.1742
				Subperiod 3: 1961/1–1964/6					
$EITB_{t-1}$	−0.00027	−1.08	0.00160	0.00160	−0.09	−0.07	−0.25	−0.12	0.1342
$EINTB_{t-1}$	0.00024	−0.95	0.00161	0.00160	−0.06	−0.07	−0.26	−0.11	0.0742
$EITS_{t-1}$	−0.00003	−0.11	0.00171	0.00169	−0.13	−0.08	−0.26	−0.08	0.1442
				Subperiod 4: 1964/7–1967/12					
$EITB_{t-1}$	0.00019	0.70	0.00173	0.00171	0.03	0.18	−0.19	−0.17	−0.0442
$EINTB_{t-1}$	0.00022	0.83	0.00176	0.00175	0.07	0.22	−0.17	−0.16	−0.0842
$EITS_{t-1}$	0.00022	0.80	0.00175	0.00174	−0.05	0.13	−0.23	−0.16	−0.0342
				Subperiod 5: 1968/1–1971/6					
$EITB_{t-1}$	0.00023	0.94	0.00156	0.00156	0.04	−0.24	0.08	−0.15	0.2242
$EINTB_{t-1}$	0.00011	0.45	0.00157	0.00156	0.06	−0.23	0.06	−0.15	0.1842
$EITS_{t-1}$	0.00015	0.62	0.00159	0.00158	0.06	−0.22	0.05	−0.13	0.1842
				Subperiod 6: 1971/7–1974/6					
$EITB_{t-1}$	0.00064	1.32	0.00291	0.00294	−0.29	0.15	0.02	−0.06	0.0236
$EINTB_{t-1}$	0.00042	0.89	0.00286	0.00285	−0.33	0.13	−0.01	−0.09	−0.0136
$EITS_{t-1}$	0.00069	1.34	0.00310	0.00313	−0.28	0.16	0.0[illegible]	−0.02	−0.0336
				Subperiod 7: 1974/7–1977/12					
$EITB_{t-1}$	−0.00030	−0.85	0.00225	0.00224	0.38	0.13	−0.05	−0.10	−0.1042
$EINTB_{t-1}$	−0.00054	−1.57	0.00228	0.00229	0.40	0.15	−0.01	−0.06	−0.1242
$EITS_{t-1}$	−0.00054	−1.57	0.00225	0.00229	0.33	0.07	−0.06	−0.14	−0.1042

[a] $\overline{FE}$ is the average monthly forecast error. $t(\overline{FE})$ is the t-statistic for the test of the null hypothesis that the average forecast error is equal to zero. $s(FE)$ is the standard deviation of the monthly forecast errors. $RMSE$ is the root mean squared error (the square root of the average squared forecast error). ρ_τ is the sample autocorrelation of the monthly forecast errors for lag τ. N is the sample size. Under the hypothesis that the true autocorrelations are zero, the standard error of the sample autocorrelations ranges from 0.16 (for $\tau = 1$ and $N = 42$) to 0.21 (for $\tau = 12$ and $N = 36$).

on these issues. They also allow us to distinguish better among competing inflation models.

4. Comparisons of eight- and fourteen-month inflation forecasts

This section compares the forecasts of eight- and fourteen-month inflation rates from the Livingston surveys, as reported by Carlson (1977), with forecasts from the time series model and the two treasury bill rate models of the preceding section.[2]

4.1. The inflation models

In May of each year the columnist Joseph Livingston surveys a group of economists for forecasts of the level of the CPI for December of the same year and June of the following year. The survey is repeated in November of each year, with forecasts solicited for the following June and December. Carlson (1977) argues that since the May (November) questionnaires are typically returned early in June (December), the latest CPI information available to the forecasters is the level of the index for April (October), reported toward the end of May (November). We follow Carlson's conventions. The consensus forecasts (the averages of the forecasts of individual respondents) solicited in May of year t of the levels of the CPI for December of year t and June of year $t+1$ are linked with the level of the CPI for April for year t to get the implied eight- and fourteen-month forecasts of inflation. Likewise, the consensus forecasts of the level of the CPI for June and December of year $t+1$ obtained from the November survey of year t are linked with the level of the CPI for October of year t.

These timing conventions are also used for the eight- and fourteen-month forecasts of inflation estimated from the interest rate and time series models. Moreover, since eight- and fourteen-month interest rates are not easily available, the inflation forecasts are estimated from one-month interest rates. In the case of $EITB_{t-1}$, the estimate of the one-month random walk expected real return is subtracted from the one-month treasury bill rate observed at the end of April (October) of each year, and the resulting one-month expected inflation rate is extrapolated (multiplied by eight or fourteen) to cover the following eight- and fourteen-month periods. The procedure for $EINTB_{t-1}$ is the same, except that the expected real return component of the one-month interest rate observed at the end of April (October) is estimated as the simple average of the twelve most recent realized real returns on one month bills. Likewise, time series estimates of eight- and fourteen-month expected inflation rates are

[2]We thank Professor Carlson for providing updated Livingston forecasts for the 1976–80 period.

obtained by multiplying the one-month inflation forecasts for May (November) from the monthly time series model by eight and fourteen. Extrapolating one-month expected inflation rates to estimate longer-term expected inflation rates is consistent with the evidence of Fama (1976b), Nelson and Schwert (1977), Pearce (1978) and our time series model that the one-month expected inflation rate is close to a random walk.

The Livingston survey forecasts have some advantages in the competition with the inflation forecasts from the interest rate models. For example, there is no presumption in the interest rate models that the expected inflation rate is a random walk. If the expected inflation rate is not close to a random walk, extrapolating eight- and fourteen-month expected inflation rates from one-month interest rates will not capture the forecasts of inflation used by a rational bond market to set longer-term interest rates. Perhaps more important, although the last available reported level of the CPI is for April (October), the May (November) survey respondents return their questionnaires in early June (December). Thus, they have at least a month of information from product markets about inflation which was not available to the treasury bill market in setting one-month bill rates at the end of April (October). These advantages of the Livingston surveys strengthen the evidence below that the survey forecasts are dominated by the interest rate models.

4.2. *Within-sample tests*

Table 5 shows regressions of *ex post* eight- and fourteen-month inflation rates for the 1953–77 period on the corresponding estimated expected inflation rates from the two interest rate models, the time series model and the Livingston surveys. Note first that the residuals in all the eight-month regressions have substantial first-order autocorrelation. This is expected given that successive eight-month inflation rates, measured at six-month intervals, have two months of overlap. For example, the *ex post* error of the inflation forecast for November of year t to June of year $t+1$ includes the unexpected inflation rates for November and December of year t, which are also included in the eight-month forecast error calculated for the period covering June of year t to December of year t. Similarly, successive fourteen-month inflation rates, which are sampled at six-month intervals, have eight months of overlap. This induces first- and second-order autocorrelation in successive forecast errors which is apparent in the residuals for the fourteen-month regressions. The regression coefficients in table 5 are estimated with ordinary least squares, but the method of Hansen and Hodrick (1980) is used to correct the standard errors of the coefficients for the autocorrelation induced by the overlap of the observations.

As in the monthly tests of table 2, unbiasedness of an eight- or fourteen-month inflation forecast, conditional on the level of the expected inflation rate, implies that when the *ex post* eight- or fourteen-month inflation rate is

Table 5

Within sample regressions of eight- and fourteen-month inflation rates on estimated expected inflation rates.[a]

Regression number	Estimated regression	R^2	$s(e)$	ρ_1	ρ_2	ρ_3	ρ_4	N
	Part A: Eight-month inflation rates							
(1)	$I_t = 0.0017 + 0.98\mathrm{E}ITB_{t-1} + e_t$ (0.0024) (0.09)	0.81	0.00826	0.29	0.09	0.10	0.30	49
(2)	$I_t = 0.0030 + 0.91\mathrm{E}INTB_{t-1} + e_t$ (0.0025) (0.08)	0.78	0.00868	0.23	−0.06	0.06	0.30	47
(3)	$I_t = 0.0046 + 0.83\mathrm{E}ITS_{t-1} + e_t$ (0.0027) (0.09)	0.70	0.01026	0.20	0.05	0.02	0.30	49
(4)	$I_t = 0.0060 + 1.15\mathrm{E}ILS_{t-1} + e_t$ (0.0027) (0.14)	0.73	0.00969	0.42	0.17	0.09	0.47	49
(5)	$I_t = 0.0021 + 0.77\mathrm{E}ITB_{t-1} + 0.28\mathrm{E}ILS_{t-1} + e_t$ (0.0024) (0.20) (0.25)	0.81	0.00820	0.29	0.09	0.06	−0.35	49
(6)	$I_t = 0.0012 - 0.52\mathrm{E}ITS_{t-1} + 1.53\mathrm{E}ITB_{t-1} + e_t$ (0.0024) (0.24) (0.27)	0.82	0.00798	0.36	0.10	0.16	0.22	49
(7)	$I_t = 0.0046 + 0.34\mathrm{E}ITS_{t-1} + 0.73\mathrm{E}ILS_{t-1} + e_t$ (0.0026) (0.19) (0.26)	0.75	0.00940	0.28	0.11	0.05	0.44	49
(8)	$I_t = 0.0030 - 0.24\mathrm{E}ITS_{t-1} + 1.15\mathrm{E}INTB_{t-1} + e_t$ (0.0024) (0.27) (0.28)	0.79	0.00870	0.22	0.08	0.08	0.27	47
(9)	$I_t = 0.0018 + 0.94\mathrm{E}ITB_{t-1} + 0.03\mathrm{E}INTB_{t-1} + e_t$ (0.0026) (0.53) (0.50)	0.80	0.00845	0.31	0.09	0.10	−0.30	47
(10)	$I_t = 0.0028 + 0.63\mathrm{E}INTB_{t-1} + 0.42\mathrm{E}ILS_{t-1} + e_t$ (0.0024) (0.17) (0.24)	0.80	0.00838	0.23	−0.03	0.01	−0.41	47
	Part B: Fourteen-month inflation rates							
(11)	$I_t = 0.0063 + 0.91\mathrm{E}ITB_{t-1} + e_t$ (0.0061) (0.13)	0.73	0.0168	0.57	0.23	0.06	−0.31	48
(12)	$I_t = 0.0091 + 0.83\mathrm{E}INTB_{t-1} + e_t$ (0.0060) (0.12)	0.71	0.0170	0.57	0.14	0.10	0.30	46
(13)	$I_t = 0.0108 + 0.78\mathrm{E}ITS_{t-1} + e_t$ (0.0063) (0.13)	0.63	0.0194	0.50	0.15	−0.14	0.32	48
(14)	$I_t = 0.0106 + 1.14\mathrm{E}ILS_{t-1} + e_t$ (0.0059) (0.29)	0.72	0.0169	0.67	0.23	0.21	0.45	48
(15)	$I_t = 0.0069 + 0.49\mathrm{E}ITB_{t-1} + 0.57\mathrm{E}ILS_{t-1} + e_t$ (0.0059) (0.25) (0.31)	0.76	0.0159	0.61	0.23	0.16	−0.41	48
(16)	$I_t = 0.0055 - 0.47\mathrm{E}ITS_{t-1} + 1.40\mathrm{E}ITB_{t-1} + e_t$ (0.0060) (0.28) (0.31)	0.74	0.0165	0.56	0.27	0.04	0.24	48
(17)	$I_t = 0.0095 + 0.18\mathrm{E}ITS_{t-1} + 0.91\mathrm{E}ILS_{t-1} + e_t$ (0.0060) (0.21) (0.30)	0.73	0.0169	0.62	0.21	0.21	0.46	48
(18)	$I_t = 0.0091 + 1.06\mathrm{E}INTB_{t-1} - 0.23\mathrm{E}ITS_{t-1} + e_t$ (0.0060) (0.31) (0.30)	0.71	0.0171	0.54	0.13	0.07	0.26	46
(19)	$I_t = 0.0077 + 0.26\mathrm{E}INTB_{t-1} + 0.62\mathrm{E}ITB_{t-1} + e_t$ (0.0065) (0.60) (0.64)	0.72	0.0170	0.59	0.21	0.06	0.30	46
(20)	$I_t = 0.0073 + 0.44\mathrm{E}INTB_{t-1} + 0.63\mathrm{E}ILS_{t-1} + e_t$ (0.0059) (0.22) (0.31)	0.75	0.0158	0.62	0.16	0.21	0.46	46

[a] I_t is the inflation rate for the eight- or fourteen-month period t. $\mathrm{E}ITB_{t-1}$, $\mathrm{E}INTB_{t-1}$, $\mathrm{E}ITS_{t-1}$ and $\mathrm{E}ILS_{t-1}$ are expected inflation rates for the eight- or fourteen-month period t, estimated at the end of period $t-1$. $\mathrm{E}ILS_{t-1}$ is the estimated expected inflation rate from the Livingston survey. $\mathrm{E}ITS_{t-1}$ is from the time series model, while $\mathrm{E}ITB_{t-1}$ and $\mathrm{E}INTB_{t-1}$ are from the two interest rate models. R^2 is the coefficient of determination. $s(e)$ is the residual standard error (adjusted for degrees of freedom). ρ_τ is the residual autocorrelation at lag τ. Under the hypothesis that the true autocorrelations are zero, the standard errors of the residual autocorrelations are about 0.15. The numbers in parentheses below estimated regression coefficients are standard errors corrected for residual autocorrelation with the method suggested by Hansen and Hodrick (1980). N is the sample size. Since the first Livingston survey ($\mathrm{E}ILS_{t-1}$) of the 1953–77 period is for the eight- and fourteen-month periods beginning May 1953, the first value of $\mathrm{E}ITB_{t-1}$ is also taken at this date. The last date for both forecasts is May 1977. The first monthly value of $\mathrm{E}INTB_{t-1}$, the expected inflation rate from the naive treasury bill rate model, is for January 1954. Since the first subsequent Livingston survey is taken during May 1954, the eight- and fourteen-month versions of $\mathrm{E}INTB_{t-1}$ are started at the beginning of May 1954.

regressed on the forecast, the intercept is close to 0.0 and the slope is close to 1.0. In table 5 the slope coefficients in the regressions (4) and (14) of the eight- and fourteen-month inflation rates on the Livingston survey forecasts are close to 1.0. However, the intercept in the eight-month regression is more than two standard errors above zero, and the intercept in the fourteen-month regression is almost two standard errors above zero. Thus, like Pearce (1978), we find that the Livingston surveys provide downward biased forecasts of inflation.[3]

On the other hand, the eight-month regressions (1) and (2) for the interest rate models are consistent with the unbiasedness criteria. Regression (11) shows that the expected inflation rate $EITB_{t-1}$ from the interest rate model that allows for a random walk expected real return, also does well on the unbiasedness criteria in the fourteen-month tests. Moreover, $EITB_{t-1}$ produces lower residual standard errors in the eight-month tests than either the expected inflation rate from the naive interest rate model, $EINTB_{t-1}$, or the forecast from the Livingston survey, $EILS_{t-1}$.

While the interest rate forecast $EITB_{t-1}$ is the overall winner of the competition among the inflation models in table 5, the overall loser is the estimated expected inflation rate $EITS_{t-1}$ from the time series model. The residual standard errors from regressions (3) and (13) are larger than those for the other three models. In the multiple regressions that pair $EITS_{t-1}$ with the expected inflation rates from other models, the expected inflation rate from the time series model never has clearcut marginal explanatory power.

The fourteen-month tests suggest that combining the Livingston survey forecasts with those from one of the interest rate models can produce more powerful inflation forecasts than any of the models separately. Thus, in regressions (15) and (20), $EILS_{t-1}$ has marginal explanatory power relative to $EITB_{t-1}$ and $EINTB_{t-1}$, and the survey forecast contributes about as much to the explanatory power of these regressions as the interest rate forecasts. We follow up on these results for combined inflation models in the out-of-sample tests that follow.

4.3. *Out-of-sample forecasts*

The Livingston surveys are pure forecasts of inflation. In contrast, the parameters of the interest rate and time series models are chosen on the basis of their fit to the monthly data for the 1953–77 period. As a consequence, the comparisons of inflation forecasts for this period may be biased against the

[3]To avoid problems of inference that may be caused by possible mean non-stationarity of the levels of the inflation rates and the expected inflation rates, we subtracted the second (third) lagged value of the eight- (fourteen-) month inflation rate from both the dependent and the explanatory variables in the regressions of table 5. Second (third) lags are needed to avoid the overlap caused by sampling eight- (fourteen-) month inflation rates at six-month intervals. Regressions based on the transformed variables support all of the conclusions drawn from table 5. If anything, the performance of the Livingston survey forecasts deteriorates relative to the other models.

surveys. A cleaner test of the power of the various models is provided by their forecasts for the post-1977 period. The errors of these forecasts are summarized in part A of table 6. The beginning of the first forecast period is November 1977. The last full eight-month forecast period is November 1980 through June 1981, while the last fourteen-month forecast period is May 1980 through June 1981. There are seven eight-month forecasts for each model and six fourteen-month forecasts. Results are shown for six models: the two interest rate models, the time series model, the Livingston surveys, and models that combine the Livingston forecasts with those from one or the other of the interest rate models. In a combined model the Livingston survey forecast and the forecast from the relevant interest rate model are weighted with the coefficients estimated in regression (5), (10), (15) or (20) of table 5.

The out-of-sample inflation forecasts confirm in most respects the results from the within-sample tests. Thus, in the out-of-sample tests, the forecast errors from the interest rate model that allows for a random walk expected real return have lower standard deviations and root mean squared errors than the forecast errors from the naive interest rate model. However, the differences between the two interest rate models are small. This again confirms the inference from (16) that the moving average estimate of the expected real return in the naive interest rate model is a close approximation to the expected real return estimated for the random walk model. More interesting, the interest rate model that allows for a random walk expected real return produces forecast errors with less variability than the errors of either the Livingston surveys or the time series model.

Unlike the other inflation models the Livingston survey forecasts are downward biased. The average error of the Livingston surveys is about 1.7 percent in the eight-month forecasts for the post-1977 period and 3.7 percent in the fourteen-month forecasts. The average out-of-sample forecast errors for the interest rate models are always less than one quarter of those from the Livingston surveys.

One result not confirmed in the out-of-sample forecasts is the suggestive evidence of table 5 that combining the Livingston surveys with an interest rate model improves inflation forecasts. In the out-of-sample tests, the combined models have larger standard deviations and root mean squared forecast errors than the interest rate model that allows for a random walk expected real return. Thus, there is no confirming evidence that the Livingston surveys contain information about inflation neglected by the bond market in setting interest rates.

As in the monthly tests of table 3, comparison of parts A and B of table 6 documents deterioration in the eight- and fourteen-month inflation forecasts for the post-1977 period. The standard deviations of the forecast errors for the two interest rate models are about 35 and 40 percent larger for the out-of-sample period than for the 1953–77 within-sample period. In both the eight- and the fourteen-month forecasts, the standard deviations of the forecast errors of

Table 6

Comparisons of long-term inflation forecasts.[a]

Model	$\overline{FE}$	$t(\overline{FE})$	$s(FE)$	$RMSE$	ρ_1	ρ_2	ρ_3	N
			Part A: Post-1977 out-of-sample period					
8-month								
$EITB_{t-1}$	0.0006	0.14	0.0116	0.0107	0.43	−0.03	−0.16	7
$EINTB_{t-1}$	−0.0005	−0.10	0.0118	0.0110	0.46	−0.05	−0.12	7
$EITS_{t-1}$	0.0055	0.82	0.0177	0.0173	0.11	−0.03	−0.18	7
$EILS_{t-1}$	0.0172	3.15	0.0145	0.0218	0.34	−0.26	−0.40	7
$EITB_{t-1}$ & $EILS_{t-1}$	−0.0005	−0.10	0.0121	0.0113	0.47	−0.08	−0.21	7
$EINTB_{t-1}$ & $EILS_{t-1}$	0.0005	0.10	0.0126	0.0117	0.48	−0.13	−0.23	7
14-month								
$EITB_{t-1}$	0.0084	0.91	0.0226	0.0223	0.17	−0.01	−0.33	6
$EINTB_{t-1}$	0.0062	0.62	0.0246	0.0233	0.15	0.02	−0.33	6
$EITS_{t-1}$	0.0132	0.92	0.0351	0.0346	0.31	−0.13	−0.20	6
$EILS_{t-1}$	0.0365	3.84	0.0233	0.0422	0.23	−0.37	−0.40	6
$EITB_{t-1}$ & $EILS_{t-1}$	−0.0097	1.08	0.0220	0.0223	0.26	−0.21	−0.35	6
$EINTB_{t-1}$ & $EILS_{t-1}$	−0.0103	1.10	0.0229	0.0233	0.24	−0.20	−0.35	6
			Part B: 1953–77 within-sample period					
8-month								
$EITB_{t-1}$	0.0013	1.07	0.0082	0.0082	0.29	0.08	0.09	49
$EINTB_{t-1}$	0.0009	0.73	0.0087	0.0087	0.20	−0.10	0.03	47
$EITS_{t-1}$	0.0009	0.60	0.0106	0.0106	0.11	−0.01	−0.03	49
$EILS_{t-1}$	0.0083	5.89	0.0098	0.0128	0.49	0.23	−0.03	49
14-month								
$EITB_{t-1}$	0.0029	1.21	0.0168	0.0169	0.54	0.19	−0.11	48
$EINTB_{t-1}$	0.0026	1.01	0.0176	0.0176	0.52	0.06	−0.19	46
$EITS_{t-1}$	0.0026	0.89	0.0204	0.0204	0.42	0.07	−0.24	48
$EILS_{t-1}$	0.0141	5.75	0.0170	0.0220	0.70	0.29	−0.13	48

[a] $\overline{FE}$ is the average forecast error. $t(\overline{FE})$ is the t-statistic for testing the hypothesis that the expected forecast error is zero. $s(FE)$ is the standard deviation of the forecast errors. $RMSE$ is the root mean squared error (the square root of the average squared forecast error). ρ_τ is the sample autocorrelation of the forecast errors at lag τ. N is the sample size. Under the hypothesis that the true autocorrelations are zero, the standard errors of the sample autocorrelations range from about 0.45 ($\tau = 1$) to about 0.7 ($\tau = 3$) for the forecast errors of the post-1977 period. The standard errors of the sample autocorrelations for the within-sample period 1953–77 are about 0.15. Since the denominator of $RMSE$ is N and the denominator of $s(FE)$ is $N-1$, $s(FE)$ can be greater than $RMSE$ when the average forecast error $\overline{FE}$ is close to zero. We have also calculated t-statistics for $\overline{FE}$ adjusted for the autocorrelation of the forecast errors induced by sampling successive eight- or fourteen-month inflation rates at six-month intervals [see Box and Jenkins (1976, p. 195)]. The adjusted t-statistics support all the inferences about bias drawn from the results above.

the time series model increase about 70 percent for the post-1977 period. There is about a 50 percent increase in the standard deviation of the out-of-sample errors of the eight-month Livingston forecasts, and a 37 percent increase in the fourteen-month forecasts. Moreover, the standard deviations ignore bias, and the bias of the eight- and fourteen-month survey forecasts more than doubles in the out-of-sample period. In contrast, there is no apparent bias in the out-of-sample forecasts of the interest rate models.

The deterioration of the inflation forecasts for the post-1977 period allows interesting inferences about changes in the inflation process and the adaptability of various models to such changes. The Livingston surveys involve no model estimation. Thus, the deterioration of these forecasts for the post-1977 period suggests that there is a change in the inflation process that makes inflation more difficult to predict. Since the time series model imposes the inflation process estimated for the 1953–77 period on the subsequent out-of-sample forecasts, the relatively more substantial deterioration of the time series forecasts is not surprising. In contrast, the interest rate models impose models for expected real returns estimated for the earlier within-sample period on the post-1977 forecasts. However, the bond market can adjust the out-of-sample forecasts of inflation built into interest rates for changes in the inflation process. Since the post-1977 forecasts from the interest rate models deteriorate

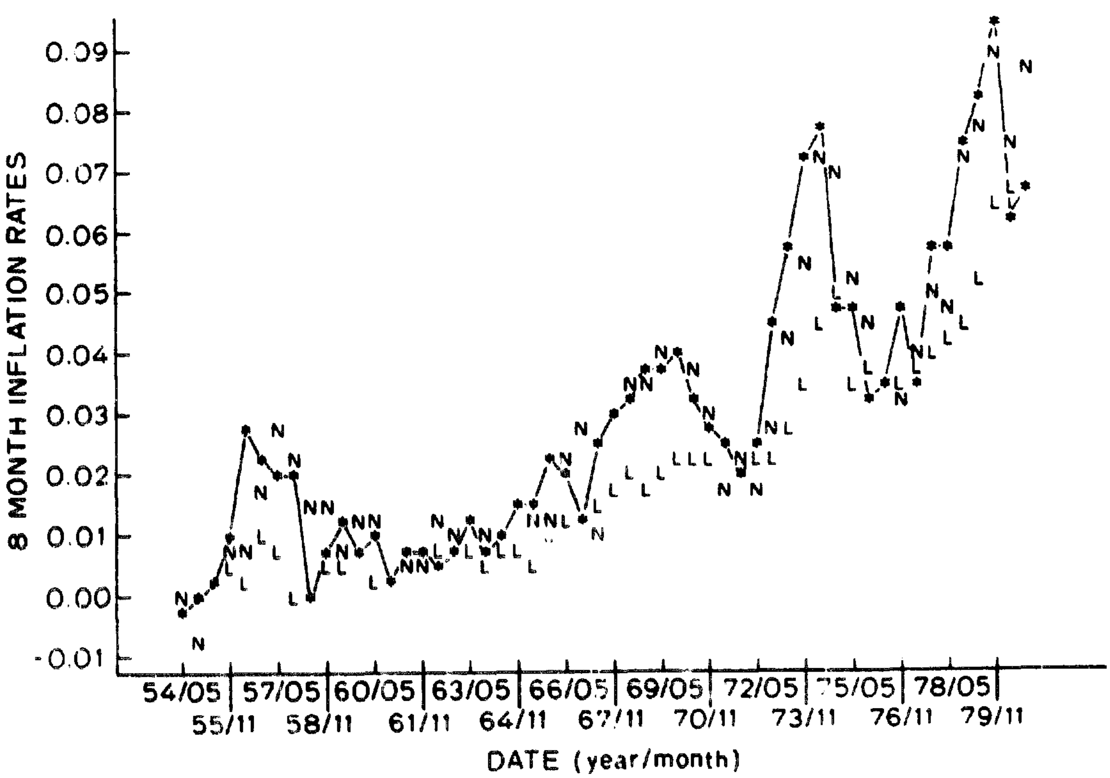

Fig. 1. Plot of actual inflation rate (•), inflation forecast from Livingston [illegible] L), and inflation forecast from naive interest rate model (N): eight-month data, 1954–1981 [illegible] ting convention: • denominates L dominates N.

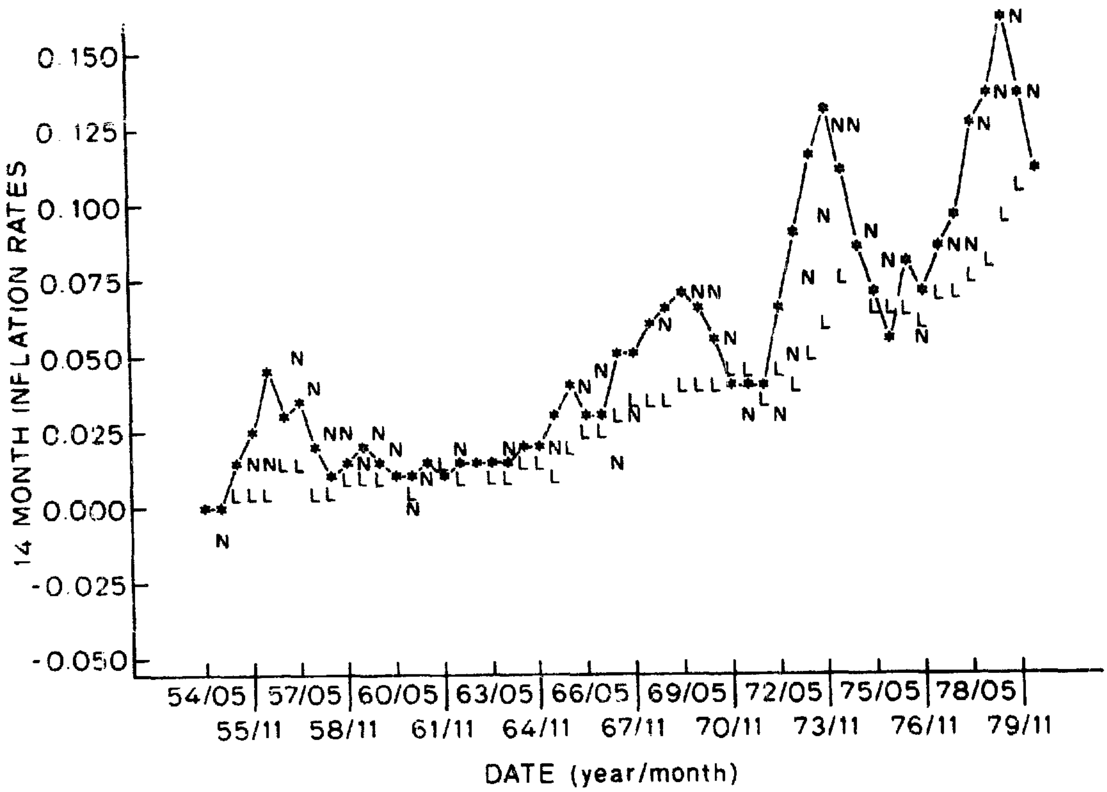

Fig. 2. Plot of actual inflation rate (*), inflation forecast from Livingston survey (L), and inflation forecast from naive interest rate model (N): fourteen-month data, 1954–1980. Plotting convention: * dominates L dominates N.

less than those from the survey forecasts, the bond market apparently adjusts better to changes in the inflation process than the economists of the Livingston surveys.

The superiority of the forecasts of inflation extracted from interest rates over the forecasts from the Livingston surveys is perhaps best illustrated in figs. 1 and 2 which show time series plots of actual and forecasted eight- and fourteen-month inflation rates for the entire sample period. The inflation forecasts are from the Livingston surveys and the naive interest rate model. The downward bias of the Livingston forecasts is apparent in the eight-month inflation data and striking in the fourteen-month forecasts, especially the forecasts for the later high inflation period. The estimates of eight- and fourteen-month expected inflation rates from the naive interest rate model show no obvious bias, and they track the *ex post* eight- and fourteen-month inflation rates better than the Livingston forecasts.

5. Conclusion

Tests on monthly data indicate that estimating the expected real return component of the interest rate on one month treasury bills as a simple average of the twelve most recent realized real returns mimics the estimates of a more sophisticated model in which the expected real return follows a random walk.

As a consequence, the two models also produce nearly identical estimates of the expected inflation component of the interest rate.

In monthly data the interest rate models seem to produce inflation forecasts with slightly lower error variance than a univariate time series model for inflation. Moreover, in multiple regressions of the *ex post* monthly inflation rate on both the expected inflation rate from the time series model and the expected inflation rate from one of the interest rate model, the time series estimate has no marginal explanatory power. Thus, the forecast of inflation in the one-month interest rate does not seem to neglect information in the time series of past inflation rates, and it includes information beyond that in the time series of past inflation rates.

For eight- and fourteen-month inflation rates, the advantage of the interest rate model over the time series model is more substantial, especially in the pure forecasts for the post-1977 period. Moreover, extrapolating inflation forecasts estimated from the one-month treasury bill rate observed at the beginning of each eight- or fourteen-month period produces forecast errors with less variation and much less bias than the forecasts from the Livingston surveys. The Livingston surveys underestimate eight- and fourteen-month inflation rates, especially during the high inflation period of 1978–81. The forecasts of eight- and fourteen-month inflation rates extracted from the one-month interest rate show little bias and track *ex post* eight- and fourteen-month inflation rates better than the survey forecasts.

Our results on the relative power of different inflation models may, of course, be specific to the 1953–81 period. However, the fact that the ordering of competing models in the out-of-sample forecasts for 1978–81 replicates the ordering for the 1953–77 period used to fit the models is evidence that the results reflect systematic differences across models.

Finally, the evidence that the forecasts of inflation from interest rates dominate those from the Livingston surveys is not a condemnation of survey forecasts. The interest rate forecast is an aggregation of the inflation forecasts (explicit or implicit) of bond market investors. This aggregation of forecasts, where the participants back their forecasts with wealth, simply performs better than the consensus forecast of the economists of the Livingston surveys.

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