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ARE MARKET FORECASTS RATIONAL?

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ABSTRACT

Recent work with survey data indicates that survey forecasts of inflation and interest rates are not rational. However, because the behavior of a market is not necessarily the same as the behavior of an average individual, this survey evidence does not demonstrate a lack of rationality in market forecasts. This paper develops and conducts tests rationality in the bond market using security price data, and these tests are similar to those conducted on survey data. The results provide no evidence that bond market forecasts of interest rates are irrational and this casts doubt on the accuracy of survey measures of interest rate forecasts as a description of bond market behavior. Results on inflation forecasts in the bond market are more mixed. This paper also makes the argument that empirical tests in Modigliani and Shiller's seminal paper are incomplete. New evidence using the test procedures developed here confirms Modigliani and Shiller's conclusion that the term structure of interest rates is "rational."

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I

INTRODUCTION

This paper conducts tests of the rationality of both inflation and short-term interest rate forecasts in the bond market. These tests are developed with the theory of efficient markets and make use of security price data to infer information on market expectations. A closer look at whether market forecasts of inflation and interest rates are rational seems necessary because of recent work (James Pesando, John Carlson, Donald Mullineaux and Benjamin Friedman) which has evaluated the inflation and interest rate forecasts from the Livingston and Goldsmith-Nagan surveys. A common empirical result in these studies is that the survey forecasts are inconsistent with the restrictions implied by the theory of rational expectations. What conclusions about the behavior of market expectations should we draw from these results?

One view which associates survey forecasts with those of market would take these empirical results as evidence that the market is not exploiting all information in generating its forecasts. The B. Friedman results are particularly disturbing in regard to the possible irrationality of the bond market because this study uses data from the Goldsmith-Nagan interest-rate survey which is made up of interest-rate forecasts from actual participants in that market.

An alternative view would hold that markets probably do display rationality of expectations. Irrationality in the Livingston and Goldsmith-Nagan survey data would then indicate that these data cannot be used in empirical work to describe market expectations.[1]

There are two reasons why the latter view receives support. Survey data are frequently believed to be inaccurate reflections of market participants' behavior and are thus considered to be unreliable. Of even greater importance is a point that is often ignored in discussing the properties of expectations. <u>Not all market participants have to be rational in order for a market to display rational expectations</u>. The behavior of a market is not neceaasrily the same as the behavior of the average individual. As long as unexploited profit opportunities are eliminated by some par-

This implication is the basis of the tests of rationality found in the studies of survey forecasts mentioned above. Consider the following equations

(2) $$X_t = b_o + \sum_{i=1}^{k} b_i X_{t-i} + u_{1t}$$

(3) $$X_t^e = c_o + \sum_{i=1}^{k} c_i X_{t-i} + u_{2t}$$

These equations can be estimated with ordinary least squares (OLS), under the assumption that $E(u_{1t}|\phi_{t-1}) = E(u_{2t}|\phi_{t-1}) = 0$ (implying that the u's are serially uncorrelated and uncorrelated with the X_{t-i}). Under the hypothesis of rational expectations, the estimated b_i coefficients should not differ from the estimate c_i coefficients except by chance.[3] This null hypothesis that

(4) $$b_i = c_i \text{ for all } i = 0, \ldots, k$$

is tested in the studies of survey forecasts with a conventional F-test.

The rationale behind this test becomes more obvious by subtracting (3) from (2) to obtain

(5) $$X_t - X_t^e = (b_o - c_o) + \sum_{i=1}^{k} (b_i - c_i) X_{t-i} + (u_{1t} - u_{2t})$$

The rationality criterion in (1) combined with $E(u_{1t}|\phi_{t-1}) = E(u_{2t}|\phi_{t-1}) = 0$ implies the null hypothesis $b_i = c_i$ for all i. Since the OLS estimates of $b_i - c_i$ in (5) is numerically equal to the OLS estimate of b_i in (2) minus the OLS estimate of c_i in (3), these seperate estimates of b_i and c_i should be equal, except for statistical variation. Note that even if other information besides the k lagged values of X is used to forecast X, it is clear from (5) and (1) that the test of these cross-equation rationality restrictions is still valid.[4] However, because $E(u_{1t}|\phi_{t-1})$ and $E(u_{2t}|\phi_{t-1})$ need not equal zero in this case, the u's could be correlated with lagged X's. Then the estimated b_i and c_i coefficients would not that all participants in the market are rational and use information efficiently.

Equation (7) above implies that $BRET_t - r_{t-1}$ should be uncorrelated with any past available information or linear combinations of this information. Thus, an equivalent characterization of the efficient markets model consistent with (7) is:

(8) $$BRET_t - r_{t-1} = \delta + (X_t - X_t^e)\alpha + \varepsilon_t$$

where an e superscript denotes expected values conditional on all past available information (i.e., $X_t^e = E_m(X_t | \phi_{t-1})$, a one period ahead optimal forecast), and

X_t = a variable (or vector of variables) relevant to the pricing of long bonds,

α = a coefficient (or vector of coefficients),

ε_t = an error process where $E(\varepsilon_t | \phi_{t-1}) = 0$ and hence ε_t is serially uncorrelated.

The efficient markets model stresses that only when new information hits the market will BRET differ from $r_{t-1} + \delta$. As equation (8) makes clear, this is equivalent to the proposition that only unanticipated changes (surprises) in variables can be correlated with $BRET_t - r_{t-1}$.[8] This distinction between the possible effects from unanticipated versus anticipated changes in variables is indeed an important feature of recent empirical work (for example, Barro (1977, 1978)).

The assumption that the coefficient on r_{t-1} equals one in equation (6) has been subjected to empirical test in work by Fama and Schwert (1977) and Mishkin (1978) and is not rejected.[9] Furthermore, as is discussed in Fama (1976), as long as $E_m(BRET | \phi_{t-1})$ has small variation relative to other sources of variation in the actual returns - - and this appears to be the case for the long-term bonds discussed here[10] - - assumptions describing the equilibrium return are not critical to empirical tests of the efficient markets model.[11]

Substituting expectations of X from equation (3) into (8) we have an efficient markets model of the following form:

(9) $$BRET_t - r_{t-1} = \delta + \alpha(X_t - (c_o + \sum_{i=1}^{k} c_i X_{t-i})) + \varepsilon_t'$$

where

$$\varepsilon_t' = \varepsilon_t - \alpha u_{2t}$$

III

EMPIRICAL RESULTS

The first set of tests to be conducted here will scrutinize B. Friedman's result that the survey measures of interest rate forecasts are inconsistent with rationality. Friedman's results were obtained using 30 quarterly observations extending from September 1969 to December 1976, and this sample period is used to estimate the equation (9) and (2) system using bond return and treasury bill rate data described in the Data Appendix. His choice of six lagged quarters in his autoregressive specification will also be used in these tests. An additional test will be conducted over the longer 1954-76 sample period to provide more information on the rationality of the bond market's forecasts.

Tests of the rationality of inflation forecasts will also be conducted in a similar manner using the nonlinear efficient markets procedure. The 1959-69 sample period used by Pesando, Carlson and Mullineaux, where so many rejections of rationality have been found, will be used in these tests, as well as the longer 1954-76 sample period. Here, the Consumer Price Index (CPI) will be used to calculate the inflation rate and this data is also discussed in the appendix.

RESULTS ON THE RATIONALITY OF INTEREST RATE FORECASTS

Table 1 provides the tests for the rationality of forecasts in the bond market using both Friedman's 1969-76 sample period and the longer 1954-76 sample period; while Table 2 provides the parameter estimates of the constrained efficient markets model using both sample periods. The p-values in Table 1 are the probability of obtaining that that value of χ^2 or higher, under the null hypothesis that the rationality constraints are valid. A p-value less than .05 would indicate a rejection at the 5 percent level of the null hypothesis and, therefore, a rejection of forecast rationality in the bond market.

As the likelihood ratio statistics in Table 1 indicate, there is very little evidence in the bond market data supporting irrationality of interest-rate forecasts.

Table 2 Nonlinear Estimates of the Efficient-Markets Model:

$$BRET_t - r_{t-1} = \delta + \alpha (r_t - b_0 - \sum_{i=1}^{6} b_i r_{t-i}) + \varepsilon'_t$$

$$r_t = b_0 + \sum_{i=1}^{6} b_i r_{t-i} + u_t$$

	Sample period	
	1969:3 to 1976:4	1954:1 to 1976:4
δ	.0055 (.0091)	-.0018 (.0032)
α	-13.4452 (4.6568)	-12.3800 (1.8264)
b_0	.0060 (.0023)	.0006 (.0003)
b_1	.6158 (.1750)	1.0706 (.0869)
b_2	.0639 (.1913)	- .3123 (.1287)
b_3	.3159 (.1869)	.2189 (.1331)
b_4	-.1434 (.1872)	.0296 (.1348)
b_5	-.3195 (.1911)	-.1473 (.1324)
b_6	.0463 (.1790)	.0906 (.0909)

$BRET_t$ = quarterly bond return at quarterly rate.

r_t = treasury bill rate at a quarterly rate

Asymptotic standard errors in parentheses.

Table 3 Test of Forecast Rationality: Inflation

	Sample period	
	1959:1 to 1969:4	1954:1 to 1976:4
Likelihood Ratio Statistic	23.77	8.70
p-value	.001	.191

Likelihood Ratio Statistic is distributed asymptotically as $\chi^2(6)$.

However, the likelihood ratio test rejects the rationality restrictions for the 1959-69 sample period at the 1 percent significance level,[20] and this is the sample period where other studies (Pesando, Carlson and Mullineaux) have also found the Livingston price expectations data to be irrational.[21]

A look at the unconstrained estimates of the autoregressive model of inflation and the efficient-markets model provides a clue as to why this rejection of rationality occurs. The sum of the coefficients on the lagged inflation rates in the autoregressive model of inflation is positive and greater than one, indicating that a rise in inflation would persist. On the other hand, the sum of these autoregressive parameters derived from the unconstrained efficient-markets model is negative, indicating that the bond market expected that a rise in inflation would be reversed.[22] This discrepancy is what leads to the rejection of the rationality of the bond market's forecasts of inflation, and it should not be all that surprising considering the sample period chosen. This sample period started with a low inflation rate which then rose to unusally high levels by the end of this period. The fact that this was an unusual period might then be the cause of the rejection of the rationality restrictions found in Table 3, even though the bond market would normally have rational inflation forecasts. A similar problem has been found for the rationality of inflation forecasts (represented by forecasts of exchange rate changes) in the German hyperinflation (Jacob Frenkel), again an unusual inflationary episode. The likelihood ratio test on the rationality of the inflation forecasts in the longer 1954-76 period does provide some evidence supporting this conjecture. In this period there is no rejection of the rationality restrictions at the 5 percent significance level. Thus it appears that the bond market may have had rational inflation forecasts when a longer time horizon is taken into account.[23]

What do these results tell us about the accuracy of the Livingston price expectations data? We must be somewhat careful in our interpretation of these results because the Livingston survey does not specifically sample those who are participants in the bond market, yet the following conclusion does seem to be indicated. Because the implies that if the short rate is a random walk, i.e.,

(11) $$r^e_{t+1} = r_t$$

then the long rate will be a random walk as well. Holbrook Working has shown that a variable that has a random walk characterization will, if it is averaged, have an ARIMA (0, 1, 1) time-series process with the correlation coefficient at lag one eqaul to .25. Hence, if the short rate is a random walk as is the long rate, then averages of both these variables should have the same ARIMA (0, 1, 1) characterization with the .25 coefficient at lag one. Using (10) with the averaged short rate time-series process being the ARIMA (0, 1, 1) described above, the implied time-series process of the averaged long rate data is not the same as that of the averaged short rate data, as is appropriate. Rather, it will display a time-series process that is closer to that of a random walk. For example, taking the plausible value $\gamma = .95$, the implied time-series process derived from (10) of the averaged long rate series is ARIMA (0, 1, 1) with the autocorrelation at lag one equal to .01 rather than the appropriate .25.[25]

The above example thus indicates that if the data is averaged, equation (10) cannot be used with the lag weights in an autoregressive short rate equation to derive the lag weights of short rates in a long rate equation. Modigliani and Shiller's evidence on the rationality of the term structure involves doing exactly this derivation with averaged data, and then comparing these lag weights with those actually estimated from a long rate equation. Yet as the example here indicates, this is not a valid procedure.

The efficient-markets model discussed in this paper leads to a formal statistical test of the Modigliani-Shiller results discussed above. Including both short-term interest rate and inflation movements as relevant information to the pricing of long-term bonds as is done by Modigliani and Shiller, we can write the efficient-markets model as:

(12) $$BRET_t - r_{t-1} = \delta + \alpha_r\,(r_t - r^e_t) + \alpha_\pi(\pi - \pi^e_t) + \varepsilon_t$$

TABLE 5. Modigliani - Shiller Tests of Forecast Rationality

	Sample Period	
	1954:4 to 1966:4	1954:1 to 1976:4
Likelihood Ratio Statistics	13.87	12.90
p-value	.179	.230

Likelihood ratio statistic is distributed asymptotically as $\chi^2(10)$.

TABLE 6 Continued

Sample Period 1954:1 to 1976:4

	δ = −.0013 (.0032)		α_r = −12.1804 (1.9664)	α_π = −1.3112 (.8497)			
r = .0007 (.0005)				k_π = −.0016 (.0013)			
d_1 = .8013 (.0841)	d_{10} = .0326 (.0178)	e_1 = .1427 (.1545)	e_{10} = −.0409 (.0340)	f_1 = .1277 (.0563)	f_{10} = −.0184 (.0113)	g_1 = −.0298 (.1075)	g_{10} = −.0195 (.0219)
d_2 = −.0520 (.0544)	d_{11} = .0389 (.0183)	e_2 = .0605 (.1158)	e_{11} = −.0406 (.0266)	f_2 = .0435 (.0362)	f_{11} = −.0040 (.0115)	g_2 = .2530 (.0776)	g_{11} = −.0233 (.0186)
d_3 = −.0410 (.0328)	d_{12} = .0431 (.0192)	e_3 = .0334 (.0693)	e_{12} = −.0388 (.0220)	f_3 = .0051 (.0215)	f_{12} = .0106 (.0121)	g_3 = .1889 (.0457)	g_{12} = −.0228 (.0180)
d_4 = −.0296 (.0208)	d_{13} = .0449 (.0197)	e_4 = .0114 (.0437)	e_{13} = −.0362 (.0219)	f_4 = −.0217 (.0132)	f_{13} = .0239 (.0125)	g_4 = .1348 (.0281)	g_{13} = −.0185 (.0195)
d_5 = −.0179 (.0179)	d_{14} = .0440 (.0189)	e_5 = −.0061 (.0398)	e_{14} = −.0331 (.0241)	f_5 = −.0383 (.0113)	f_{14} = .0345 (.0121)	g_5 = .0900 (.0255)	g_{14} = −.0113 (.0210)
d_6 = −.0063 (.0190)	d_{15} = .0401 (.0173)	e_6 = −.0195 (.0448)	e_{15} = −.0300 (.0254)	f_6 = −.0461 (.0122)	f_{15} = .0409 (.0111)	g_6 = .0537 (.0288)	g_{15} = −.0019 (.0211)
d_7 = .0049 (.0197)	d_{16} = .0328 (.0191)	e_7 = −.0292 (.0479)	e_{16} = −.0273 (.0254)	f_7 = −.0466 (.0128)	f_{16} = .0418 (.0124)	g_7 = .0253 (.0306)	g_{16} = .0092 (.0207)
d_8 = .0153 (.0192)	d_{17} = .0218 (.0301)	e_8 = −.0357 (.0466)	e_{17} = −.0256 (.0292)	f_8 = −.0412 (.0124)	f_{17} = .0355 (.0198)	g_8 = .0042 (.0295)	g_{17} = .0211 (.0252)
d_9 = .0247 (.0183)	d_{18} = .0069 (.0509)	e_9 = −.0394 (.0415)	e_{18} = −.0252 (.0460)	f_9 = −.0313 (.0117)	f_{18} = .0208 (.0337)	g_9 = −.0105 (.0261)	g_{18} = .0332 (.0408)

The $d_2 - d_{18}$, $e_2 - e_{18}$, $f_2 - f_{18}$, and $g_2 - g_{18}$ have each been estimated with a third order polynomial with no fore- or endpoint constraints.

Asymptotic standard errors in parentheses.

DATA APPENDIX

The data sources and definitions of the variables used in this paper are as follows:

$BRET_t$ = quarterly return from holding a long term- U.S. government bond from the beginning to the end of the quarter. The data was obtained from the Center for Research in Security Prices (CRSP) at the University of Chicago, and are described in Lawrence Fisher and James Lorie and Mishkin (1978).

r_t = the end of quarter 90 day Treasury bill rate at a quarterly rate. The bill rate data were obtained from the Board of Governors of the Federal Reserve Board.

π_t = the CPI inflation rate (quarterly rate) calculated from the change in the log of the CPI (seasonally adjusted) from the last month of the previous quarter to the last month of the current quarter. The CPI was collected from the U.S. Department of Commerce's *Business Statistics* and *Survey of Current Business*.

would expect to be the case for the interest rate and inflation data analyzed here.

8 It is easy to show that this efficient markets model is consistent with the expectations hypothesis of the term structure where predictions of future short-term interest rates are optimal forecasts. To be more concrete, if the long-term bond is a discount security where the liquidity premium is a constant δ, the expectations hypothesis of the term structure is approximated by: $RL_t = \frac{1}{n} E_t(r_t + r_{t+1} + \dots + r_{t+n-1}) + \delta$. When expectations of future short rates in this equation are optimally formed, or equivalently are "rational" in the sense of Muth, then the expectations hypothesis described by the equation above leads to the same implications as equation (8) in the text. Note also that the efficient-markets model does not imply causation from $X_t - X_t^e$ to $BRET_t - r_{t-1}$. It is equally plausible that causation runs in the other direction or that a third factor affects both of these variables simultaneously.

9 This assumption was also tested using the 1954-1976 sample period. A quarterly bond returns series was regressed on the beginning of period, 90 day treasury bill rate (also at quarterly rates) using weighted least squares to correct for heteroscedasticity. (Mishkin (1978) describes this procedure). The coefficient on the bill rate was not significantly different from one at the five percent level ($t = .51$). In a recent paper, Robert Shiller has found evidence which can be interpreted as implying that the liquidity premium is correlated with the spread between long rates and short rates. To test this proposition for the 1954-76 sample period, $BRET_t - r_{t-1}$ was regressed on this spread, again using weighted least squares to correct for heteroscedasticity. The evidence supporting Shiller's proposition is even weaker in this sample period than was true in the regression results reported in Mishkin (1978): the coefficient on the spread variable was not significantly different from zero at even the ten percent significance level ($t = 1.01$).

14 Clearly, if this maintained hypothesis, which arises from efficient markets theory were invalid, this test could lead to rejection of these restrictions even if rationality were valid. This issue is analyzed empirically in footnote 21.

15 See Steven Goldfeld and Richard Quandt (1972). Note that the same weights used for the heteroscedesticity corrections in the constrained system (see footnote 12) are used in the unconstrained system.

16 The test is valid in the sense described in footnote 4. For example if $u_{2t} \neq 0$ so that there would be errors in variables bias in the estimated α coefficient, the test is still valid. Correlation of $X_t - X_t^e$ with ε_t also leads to inconsistent estimates of α yet it again does not invalidate the likelihood ratio test for rationality.

17 Yet, as we shall see, the tests conducted here do yield more information than the more common test.

18 Note that Mishkin (1978) used treasury bill data which is at an annual rate. Thus the coefficient on the unanticipated bill rate in that case must be multiplied by four when compared to the α coefficients in Table 1.

19 See Fama's (1970) Survey and the more recent work of Mishkin (1978 , 1980) and Sargent (1979).

20 Because this rejection of rationality was so striking and therefore should be checked out, I performed a standard test of bond market efficiency, similar to those in Mishkin (1978) where I regressed $BRET_t - r_{t-1}$ on six lagged values of the inflation rate. The results for the 1959-69 sample period were similar to those of Table 3. The restrictions imposed by market efficiency (rationality) were rejected at the 1% significance level: $F(6,37) = 5.26$ while the critical F at 1% is 3.78.

one: -.27, .25, 1.04, -.30, -.94, and -1.60.

23 The efficient markets model does not specify whether seasonally adjusted versus unadjusted data should be used in these tests. Seasonally adjusted data were used in these tests reported in the text because they are more comparable to the rationality tests of the Livingston data found in the literature. However, seasonal adjustment of the CPI with the X-11 program tends to "smudge" the data and thus the tests described in the text were repeated with seasonally unadjusted data. The results are similar to those reported in Tables 3 and 4. The likelihood ratio statistic for the 1959:1 to 1969:4 sample period was 23.25 (p-value = .001) and for the 1954:1 to 1976:4 sample period 12.32 (p-value = .055).

24 The argument here is exactly the same if the more common approximation for a n-period discount bond is used, i.e.,

$$R_t^n = k + \frac{1}{n} \sum_{i=0}^{n-1} r_{t+1}^e$$

where R_t^n = the yield to maturity on the n-period bond.

25 The result is calculated as follows: the ARIMA(0,1,1) model for the short rate average (r^a) with an autocorrelation at lag one of .25, is

$$\Delta r_t^a = (1 + .268L)\ u_t \quad .$$

Then an innovation of $\tilde{u}$ would lead to a higher value of r^a by $\tilde{u}$ in the initial period and 1.268 $\tilde{u}$ thereafter. With γ = .95, (10) implies that the averaged long rate (RL^a) would be higher by 1.255 $\tilde{u}$ initially and 1.268 $\tilde{u}$ thereafter. The ARIMA model for the averaged long rate would thus be

$$\Delta RL_t^a = (1 + .011\ L)\ u_t$$

which is an ARIMA (0,1,1) with the autocorrelation at lag one equal to .01.

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