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DO LONG-TERM INTEREST RATES OVERREACT TO SHORT-TERM INTEREST RATES?

N. Gregory Mankiw

Lawrence H. Summers

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ABSTRACT

This paper examines the hypothesis that financial markets are myopic by studying the term structure of interest rates. While rejecting decisively the traditional expectations hypothesis regarding the term structure, our statistical results also lead us to conclude that long term interest rates do not overreact to either the level or the change in short term rates. This finding suggests that participants in bond markets are not myopic or overly sensitive to recent events. Our statistical results also suggest that most variations in the yield curve reflect changes in liquidity premia rather than expected changes in interest rates.

N. Gregory Mankiw
Department of Economics
M.I.T.
Cambridge, MA 02139

Lawrence H. Summers
Department of Economics
Littauer Center 229
Harvard University
Cambridge, MA 02138

The term structure of interest rates has been extensively studied by economists. It is of interest to financial economists because of its close connection with the pricing of bonds of different maturities. More important, understanding the term structure of interest rates is also critical to the evaluation of the effects of alternative macroeconomic policies. For example, it is widely believed that the monetary authority can most directly control short-term interest rates, but that aggregate demand depends primarily on long-term interest rates.[1] If this conviction is correct, the monetary transmission mechanism relies on the behavior of the term structure of interest rates.

During the first few months of 1984, the yield curve has been very steep by historicial standards. The yield on twenty-year bonds has been about 300 basis points above the yield on three-month Treasury bills. Only rarely have such large spreads been observed in the past.[2] The yield curve is widely interpreted as reflecting market participants' conviction that interest rates will rise over the next several years under the pressure of large Federal deficits. It is sometimes even suggested that because of such expectational effects, prospective Federal deficits are exerting a dampening effect on the current level of economic activity. These arguments presume that long rates reflect

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[1]For example, in the simple IS-LM model of Richard H. Clarida and Benjamin M. Friedman, "Why Have Short-Term Interest Rates Been So High?," BPEA 2:1983, pp. 553-578, the short rate enters the LM curve but the long rate enters the IS curve.

[2]The average spread between twenty-year bond yields and three-month bill yields over the past two decades is 96 basis points; the standard deviation is 136 basis points. The average since October 1979 is 110; the standard deviation is 206.

market expectations of future short rates. In this paper, we examine this view of the yield curve.

Most work on the term structure is based on some variant of the expectations hypothesis. This hypothesis holds that the long-term interest rate is a weighted average of present and expected future short-term interest rates. An approximately equivalent form of the hypothesis holds that the expected one period holding returns on riskless bonds of all maturities are the same or differ by constant risk premia.[3] Unfortunately, many investigators using various techniques and data sets reject the joint hypothesis of rational expectations and the expectations theory of the term structure.[4]

The failure of interest rates to move as the theory predicts is not a new phenomenon. In 1938 Frederick Macaulay wrote the following:[5]

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[3]The approximate nature of the equivalence is discussed extensively by John Cox, John Ingersoll and Stephen Ross, "A Re-examination of Traditional Hypotheses about the Term Structure of Interest Rates," Journal of Finance, September 1981. As demonstrated by Robert J. Shiller, John Y. Campbell and Kermit J. Schoenholtz, "Forward Rates and Future Policy: Interpreting the Term Structure of Interest Rates," BPEA, 1:1983, the equivalence is exact after linearization.

[4]There are many recent examples. David S. Jones and V. Vance Roley, "Rational Expectations and the Expectations Model of the Term Structure: A Test Using Weekly Data," Journal of Monetary Economics 12, September 1983, perform regression tests on the holding returns on T-Bills of different maturities. Robert Shiller, "The Volatility of Long-Term Interest Rates and Expectations Models of the Term Structure," Journal of Political Economy, December 1979, performs volatility tests using six different data sets on American and British interest rates. Shiller, Campbell and Schoenholtz, "Forward Rates," find that long-term interest rates have almost no predictive power for future short-term interest rates.

[5]Frederick R. Macaulay, Some Theoretical Problems Suggested by Movements of Interest Rates, Bond Yields and Stock Prices in the United States Since 1856, New York: NBER, 1938, p. 33.

> To preserve the thoeretical relationship between long term and future short term interest rates, the 'yields' of bonds of the highest grades should fall during a period in which short term rates are higher than the yields on bonds and rise during a period in which short term rates are lower. Now experience is more nearly the opposite.

As we show below, the test of the expectations theory derived under the assumption of rational expectations is exactly the test Macauley suggested almost fifty years ago. Moreover, the behavior of long rates in the recent period we examine is also "nearly the opposite" from that implied by the theory.

While statistical rejections of the expectations theory are ubiquitous, previous research has not made clear the substantive significance of the failure of the theory. One problem with interpreting previous test results is the absence of an economically meaningful alternative hypothesis. In this paper, we embed the expectations theory of the term structure within two wider classes of hypotheses. We can thus form judgments as to whether the empirical deviation from the expectations hypothesis is substantively important.

The first class of hypotheses includes a quantitative expression of the notion that the long rate responds "too much" to the contemporaneous short rate. This alternative hypothesis is suggested by work on the volatility of long-term interest rates. Since the long rate is, under the expectations hypothesis, a weighted average of expected future short rates, the long rate should be a much smoother series than the short rate. Robert Shiller examines this smoothing property of the expectations hypothesis and finds that long rates are too volatile to be consistent with the theory.[6] The excess sensitivity hypothesis we examine here is one possible explanation for this excess volatility.

The excess sensitivity hypothesis is also suggested by evidence that the response of interest rates to money supply announcements is similar at all maturities, even though standard theories suggest that the response of long rates should be much more attentuated. Moreover, this view appears to be widely held among participants in the bond market, where it is conventional wisdom that "long rates follow short rates." This hypothesis is also implicit in the popular claim that financial markets "overreact" to news or are in some sense "myopic".

Whether long rates are excessively sensitive to short rates has important implications for macro-economic policy. Excess sensitivity, for example, would increase the potency of monetary policy. A reduction in short rates would have a greater impact on long rates than under the expectations hypothesis. Such an expansionary action by the Federal Reserve would therefore have a greater impact on aggregate demand.

To our surprise, the results of our tests decisively reject the notion that long rates are overly sensitive to short rates. The results taken literally imply that current interest rates have a much lower (sometimes negative) weight than theory would suggest and that expected future short rates exert a disproportionate influence on long-

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[6] Shiller, "Volatility," 1979.

term rates. This literal interpretation of the results, however, does not seem satisfactory. Alternatively, the results may reflect the failure of the assumption that market forecasts of future interest rates represent rational expectations. These conclusions appear robust, with similar results obtained from analyses of yields on short-term and long-term bonds, and three-month and six-month Treasury bills.

Using data on three-month and six-month bills, we are also able to examine the possibility that expectations are formed irrationally, with excessive weight placed on the current short rate in forecasting future short rates. We show that the observed behavior of the term structure is also inconsistent with this view. Our estimates taken literally imply that market participants place too little weight on the current short rate in forecasting future yields.

Having found that the excess sensitivity hypothesis cannot explain the term structure, we turn to a second alternative hypothesis. This second hypothesis assumes that the expectations theory holds except for a random unexplained liquidity premium. The results suggest that, at least at the short end of the term structure, the expectations theory is not very useful in explaining the spread between long-term and short-term interest rates. In particular, only one quarter of the variation in the spread between six-month and three-month Treasury bill yields is attributable to expected movements in short rates. The remainder is attributable to movements in what are tautologically labelled liquidity premia. Large and highly variable liquidity premia, especially within the very short end of the maturity spectrum, are not easy to understand.

EXCESS SENSITIVITY

In this section, we consider the hypothesis that long rates overreact to short rates. We first examine the behavior of twenty-year bonds and three-month bills. We then turn to examining the behavior of three-month and six-month bills.

Long Rates and Short Rates

Let r_t be the one-period yield and R_t be the yield on a consol, i.e., an infinitely-lived bond paying a fixed coupon each period. We consider the following class of hypotheses of which the standard expectations hypothesis is one special case:

$$(1) \qquad R_t = \theta + (1-\gamma) \sum_{k=0}^{\infty} \gamma^k E_t r_{t+k}$$

where $0 < \gamma < 1$. E_t denotes the rational expectation conditional on information available at time t. The term θ is the risk premium. For this section, we assume θ is constant; in the next section, however, we consider the possibility that the risk premium changes through time.

The expectations theory of the term structure implies that $\gamma = 1/(1+R^*)$, where R^* is an average interest rate around which the linearization is made. For lower values of γ, greater weight is given to the contemporaneous short rate. The alternative hypothesis of excess sensitivity is thus represented in equation (1) by a low value of γ. Informally, excess sensitivity arises either if agents place too little weight on rationally expected future short rates or if agents irrationally place too much weight on the current short rate in forecasting future short rates.

Equation (1) is easily transformed into a simple regression test of the model. Note that (1) implies (2):

$$(2) \qquad \gamma R_{t+1} = \gamma\theta + (1-\gamma)\sum_{k=1}^{\infty} \gamma^{k+1} E_{t+1} r_{t+k}$$

Subtract (2) from (1) to obtain equation (3):

$$(3) \qquad R_t - \gamma R_{t+1} = (1-\gamma)\theta + (1-\gamma) r_t - \varepsilon_{t+1}$$

where $\varepsilon_{t+1} = (1-\gamma)\sum_{k=1}^{\infty} \gamma^k (E_{t+1} r_{t+k} - E_t r_{t+k})$

The term ε_{t+1} reflects new information about future short rates that becomes available between time t and time t+1. Algebraic manipulation of (3) yields (4):

$$(4) \qquad (R_{t+1} - R_t) = \frac{-(1-\gamma)\theta}{\gamma} + \frac{(1-\gamma)}{\gamma}(R_t - r_t) + \varepsilon_{t+1}/\gamma$$

Equation (4) provides a simple test of the model (1).

How should we estimate equation (4)? Ordinary least squares produces consistent estimates only if the error term in the regression is uncorrelated with the variables on the right hand side. The assumption of rational expectations implies that this condition is satisfied here. The error term ε_{t+1} measures the "news" that arrived between time t and time t+1. The right hand side variable, $(R_t - r_t)$, is known at time t. If expectations are rationally formed, "news" should not be predictable from known information. In this case, rational expectations implies $(R_t - r_t)$ and ε_{t+1} are uncorrelated. We can thus estimate equation (4) using ordinary least squares.

Equation (4) embodies both the standard expectations theory of the term structure and the possibility of excess sensitivity of long rates to current short rates. Under the expectations hypothesis, the coefficient on $(R_t - r_t)$ is R^*, i.e., roughly 0.02.[7] If excess sensitivity of long rates to short rates explains the failure of the expectations hypothesis, the estimated coefficient should exceed R^*, implying an estimate of γ below $1/(1+R^*)$.

The logic of equation (4) is fairly intuitive. Ignoring the risk premium, equation (1) states that the long rate is a weighted average of short rates, with more recent short rates given greater weight than more distant ones. If R_t is greater than r_t, then the short rate must be rising. Next period's long rate R_{t+1} must be higher than this period's, as it gives greater weight to the higher future short rates. Thus, according to both the expectations theory and the excess sensitivity hypothesis, when the current long rate exceeds the current short rate, the long rate will (on average) rise.

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[7]With quarterly data, the appropriate R^* is the mean quarterly interest rate, which with our sample is 0.019.

We can give equation (4) another intuitive interpretation. The holding period return on long bonds is approximately

$$R_t - (R_{t+1} - R_t)/R^*.$$

The first term in this expression is the coupon yield, while the second term is the capital gain or loss attributable to changes in the long rate. If we regress this holding return less the short rate on available information, we learn whether there are exploitable profit opportunities. Rejecting the null hypothesis that the coefficient in (4) is R^* is equivalent to finding statistically significant profit opportunities.

If markets were myopic, then when the short rate is high relative to the long rate, the long rate would nonetheless be "too" high and the price of a long bond "too" low. Holding long-term bonds would be a profitable strategy. This would imply that, when regressing the excess holding return on the spread, we would obtain a negative coefficient. Finding a negative coefficient in this regression is precisely equivalent to estimating a coefficient in (4) greater than R^*.

Equation (4), and thus the original equation (1), is a consequence of a variety of models of asset returns. For example, it follows from the now popular "consumption beta" model of asset returns. If all the relevant variables in this model are jointly log-normal and homoskedastic, then the model implies that excess return are not forecastable.[8] In other words, except for a constant term that depends on variances and

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[8]See Lars Peter Hansen and Kenneth J. Singleton, "Stochastic Consumption, Risk Aversion and the Temporal Behavior of Stock Market Returns," Journal of Political Economy, 1983. This is strictly true only after linearization; that is, we are approximating log(1+r) as r.

covariances, there are no expected profit opportunities in this model. Any empirical failure of this implication implies either that the "consumption beta" theory is wrong or that the relevant variances and covariances change through time.[9]

We estimate equation (4) using U.S. quarterly data from 1963:1 to 1983:4. R_t is the yield at the first week of the quarter on Treasury securities of a constant maturity of twenty years. r_t is the yield on three-month Treasury bills. Table 1 presents the results.

The coefficient on the spread $(R_t - r_t)$ has the wrong sign. Regression (1.1) is the OLS estimate using the entire sample. The null hypothesis that the slope coefficient is 0.02 is rejected at the five percent level using a one-tailed test. Since the coefficient is negative, the hypothesis that it is larger than 0.02 is also rejected. Thus, we reject the standard expectations theory of the term stucture, but we also must reject the excess sensitivity of long rates to current short rates.

In October of 1979, the Federal Reserve changed its operating procedure and began relying more on targetting monetary aggregates and less on targetting interest rates. One might suspect that this change in the policy rule altered the relationship between interest rates of different maturities. In fact, an examination of the residuals from regression (1.1) indicates substantial heteroskedaticity coinciding with this change in monetary regime. After the change in October 1979, the resi-

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[9]For a discussion of this point, see Robert J. Shiller, "Consumption, Asset Markets, and Macroeconomic Fluctuations," Journal of Monetary Economics Supplement, Carnegie-Rochester Conference, Volume 17, 1982.

dual variance is much greater.

In regressions (1.2) and (1.3), we split the sample to examine whether the change in policy rule affected the relation between long rates and short rates. The estimates suggest there has been no shift in this relation. In both subsamples, the coefficient has the incorrect sign. The hypothesis that it is 0.02 is rejected for the earlier period. It is not rejected for the latter period, since there are many fewer observations and much greater residual variance. The residuals from the split samples appear Gaussian. In particular, an examination of the third and fourth moments indicates no skewness nor unusual kurtosis that might lead one to distrust the reported standard errors. The rejection of the theory for the first subsample appears statistically sound. Moreover, the point estimate for the second subsample indicates that the theory has worked no better since 1979.[10]

Regression (1.4) uses the entire sample, but weights the two subsamples to correct for the heteroskadasticity. The weight is the reciprocal of the root mean squared residual from equation (1). Again, the coefficient is negative, and the null hypothesis that it is 0.02 or larger is rejected at the five percent level. The data support neither the expectations hypothesis nor the excess sensitivity hypothesis.

These empirical results cannot be interpreted within the context of equation (1). Equation (1) is valid only if γ is between zero and

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[10] The change in the Fed operating procedures in 1979 roughly coincides with the introduction of future markets in Treasury bills. While one might have expected that the availability of future markets would, by facilitating "yield curve arbitrage," improve the performance of the expectations hypothesis, the point estimates suggest otherwise.

Table 1: Long Rates (R) and Short Rates (r)

Dependent Variable: $(R_{t+1} - R_t)$

	(1.1)	(1.2)	(1.3)	(1.4)*
Period	63:1-83:4	63:1-79:2	79:3-83:4	63:1-83:4
Constant	0.18	0.11	0.29	0.13
	(.09)	(.05)	(.34)	(.06)
$(R_t - r_t)$	-0.086	-0.041	-0.136	-0.055
	(.055)	(.034)	(.166)	(.040)
D.W.	2.49	2.31	2.59	2.41
s.e.	0.64	0.30	1.32	0.40

Standard errors are in parentheses.

Asterisk (*) denotes weighted least squares.

one. The coefficient estimates taken literally, however, imply that γ is greater than one. Nonetheless, we are left with the conclusion that myopia does not explain the excess volatility of long-term interest rates and the other rejections of the expectations theory.

While our results imply that an investor could, on average, make money by taking advantage of the failure of the expectations theory, the risks involved are very large. For example, at the present time, the profitable strategy suggested by regression (1.4) is to go short in three-month Treasury bills and to use the proceeds to buy twenty-year bonds. The estimates indicate that a $1000 investment of this sort would yield an expected profit of $28 in three months less any transactions costs. Such an investment, however, is very risky. At the level of uncertainty observed since 1979, the standard deviation of this $28 profit is $165. The probability that this strategy would actually produce a loss exceeds forty percent. Thus, the failure of the expectations theory does not imply the presence of relatively riskless profit opportunities.

Potential problems with sample selection and data mining always make the evaluation of statistical results difficult. For example, one might argue that our results are attibutable to an unusual sequence of inflation surprises over our sample period. A standard practice is to check the validity of the conclusion on an independent data set. One can view our regressions as just such a validity check. As we point out in the introduction, Macaulay was aware that long rates do not move as the theory predicts. Moreover, he made his observation many years prior to the beginning of our data set. Furthermore, Shiller reports estimates of a regression equation parallel to (4) for six different data sets covering a variety of different sample periods and interest rates.[11] In five of the six cases, the estimates slope coefficient is negative, and in the sixth it is close to zero. In all cases, his results are consisent with our finding that the failure of the expectations theory cannot be related to excess sensitivity of the long rate. The results in Table 1 are not just an artifact of recent experience, but appear to be an empirical regularity.

Short Rates and Shorter Rates

There are a number of potential objections to the test in the preceding subsection using long-term and short-term yields. The linearization on which the derivation depends may be an unsatisfactory approximation for such long-term yields. It is also possible that there is significant segmentation between the short-term and long-term bonds markets, as investors may have differing "preferred habitats." We can address both of these objections by examining yields only at the short end of the term structure. Moreover, the use of short-term instruments obviates the need to model expectations over a long horizon, making possible the examination of a broader range of issues. This section therefore develops tests of the term structure hypotheses similar

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[11] Shiller, "Volatility," 1979. The data sets Shiller uses extend back to 1919 for the United States and to 1824 for the United Kingdom. All his data sets end before 1978. As we point out above, recent data appears to confirm the historical pattern.

to those in the preceding section for three-month and six-month Treasury bills.

Let r_t be the one-period yield and R_t be the two-period yield. We consider this class of hypotheses:

$$(5) \qquad R_t = \theta + \lambda r_t + (1-\lambda) E_t r_{t+1}.$$

For pure discount bonds, the expectations hypothesis posits that $\lambda = 1/2$. In this case, the yield from holding a two-period bond equals the expected yield from holding two one-period bonds in sequence plus a constant risk premium. Under the alternative hypothesis that the long rate R is excessively sensitive to the short rate r, the current short rate receives greater weight than under the expectations theory. That is, the excess sensitiviety hypothesis implies $\lambda > 1/2$.

We can explicitly derive the excess sensitivity model for one and two-period bills under the assumption that expectations are partly myopic. Let us suppose that the expectations theory of the term structure holds but with expectations that are not necessarily rational. That is,

$$(6) \qquad R_t = \theta + 1/2 \; r_t + 1/2 \; r^e_{t+1}$$

where r^e_{t+1} is the market expectation of r_{t+1}. Let us also suppose that the market expectation is partly rational and partly myopic:

(7) $$r^e_{t+1} = \omega\, r_t + (1-\omega)\, E_t r_{t+1}.$$

If $\omega = 0$, expectations are purely rational. If $\omega = 1$, expectations are purely myopic. Combining (6) and (7), we obtain

(8) $$R_t = \theta + \left(\frac{1+\omega}{2}\right) r_t + \left(\frac{1-\omega}{2}\right) E_t r_{t+1}.$$

Equation (8) is identical to equation (5), where $\lambda = (1+\omega)/2$. If expectations are partly myopic ($\omega > 0$), then λ exceeds one half and the two-period yield is excessively sensitive to the one-period yield.

We now wish to manipulate (5) to derive a test of the model. As in the last subsection, the properties of rational expectations permit such a test. We first write the realized value r_{t+1} as the sum of the expected value $E_t r_{t+1}$ and "news" ϵ_{t+1}.

(9) $$r_{t+1} = E_t r_{t+1} + \epsilon_{t+1}$$

We now combine (5) and (9). Simple algebraic rearrangement yields:

(10) $$(r_{t+1} - R_t) = -\frac{\theta}{1-\lambda} + \frac{\lambda}{1-\lambda}(R_t - r_t) + \epsilon_{t+1}.$$

As discussed above in connection with equation (4), the error term ϵ_{t+1} is uncorrelated with the right hand side variable, since $(R_t - r_t)$ is known at time t. Hence, we can estimate (10) using ordinary least squares.

Equation (10) provides another simple test of the standard expectations theory and the excess sensitivity model. Under the expectations theory, the coefficient on $(R_t - r_t)$ is one, since $\lambda = 1/2$. If there is excess sensitivity, this estimated coefficient should exceed one, implying $\lambda > 1/2$. Thus, as in the previous subsection, a simple OLS regression is capable of measuring the excess sensitivity of the longer-term rate to the current short rate.

Equation (10) is also intuitive. Ignoring the risk premium, (5) implies that the two-period rate is a weighted average of the two consecutive one-period rates. Therefore, when the current long rate is above the current short rate, the current long rate should be below next period's short rate. A regression of $(r_{t+1} - R_t)$ on $(R_t - r_t)$ should yield a positive coefficient.

We can write equation (10) in two other equivalent ways. First, by adding $(R_t - r_t)$ to both sides of the equation, we obtain a regression of $(r_{t+1} - r_t)$ on $(R_t - r_t)$. This new equation relates the spread to the change in short rates. Second, by subtracting $(R_t - r_t)$ from both sides of (10), we obtain a regression of $(r_t - (2R_t - r_{t+1}))$ on $(R_t - r_t)$. Under the null hypothesis that $\lambda = 1/2$, the coefficient in this regression is zero. This second equivalent form has a natural interpretation. Since $(2R_t - r_{t+1})$ is the one-period holding return on a two-period bond, the left hand side variable is the difference in holding return between short and long bonds. Under the expectations theory, this excess return is not forecastable. The failure to find a zero coefficient in this regression, or (equivalently) a coefficient of one in equation (10) , indicates the existence of expected profit opportunities.

If markets were myopic, then when the short rate is high relative to the long rate, the long rate would nonetheless be "too" high and the price of a long bond would be "too" low. Long bonds would thus be profitable when the short rate is relatively high. A regression of the excess return $(r_t - (2R_t - r_{t+1}))$ on the spread $(R_t - r_t)$ would yield a positive coefficient. Finding a positive coefficient in this regression is exactly equivalent to estimating $\lambda > 1/2$ in equation (10).

We estimate equation (10) with U.S. quarterly data from 1963:1 to 1983:4. R_t is the yield at the first week of the quarter on six-month Treasury bills, while r_t is the yield on three-month bills. Table 2 presents the results.

The coefficient on the spread has the wrong sign. Regression (2.1) is the OLS estimate for the entire sample. The null hypothesis that the coefficient is one is rejected at the one percent level. The parameter estimates, taken literally, imply insufficient rather than excessive sensitivity of longer-term interest rates to short yields.

The residuals in regression (2.1), like those of regressions (1.1), indicate substantial heteroskadasticity associated with the change in Federal Reserve operating procedure in 1979. Regressions (2.2) and (2.3) split the sample. In both subsamples, the sign of the coefficient is incorrect. As for equation (4), the recent subsample has too few observations to reject the expectations hypothesis. Yet the

Table 2: Short Rates (R) and Shorter Rates (r)

Dependent Variable: $(r_{t+1} - R_t)$

	(2.1)	(2.2)	(2.3)	(2.4)*
Period	63:1-83:4	63:1-79:2	79:3-83:4	63:1-83:4
Constant	0.02	-0.04	-0.01	-0.02
	(.19)	(.13)	(.68)	(.15)
$(R_t - r_t)$	-0.719	-0.407	-0.996	-0.470
	(.556)	(.428)	(1.536)	(.421)
D.W.	2.45	1.82	2.61	2.05
s.e.	1.39	0.69	2.82	0.80

Standard errors in parentheses.

Asterisk (*) denotes weighted least squares.

theory is rejected for the earlier subsample, and the point estimates do not indicate any structural change caused by the change in monetary policy regime. An examination of the residuals from regression (2.2) indicates no skewness nor unusual kurtosis, suggesting they are at least roughly Gaussian. As in the previous section, the rejection of the expectations theory and the excess sensitivity hypothesis appears statistically sound.[12]

Regression (2.4) again uses the entire sample, but weights the two subsamples by the reciprocal of the root mean squared residual from regression (2.1) to correct for heteroskedasticity. Again, the null hypothesis that the coefficeitn is one or larger is rejected at the one percent level. Again the estimate implies $\lambda < 0$, which taken literally implies that the current short rate has a negative weight in forming longer-term yields. This finding is clearly implausible, and we do not suggest acceptance of this literal conclusion. This finding does indicate, however, that the data are consistent with neither the expectations hypothesis nor the excess sensitivity hypothesis.[13]

As we note above, the excess sensitivity model for one and two-period bills is equivalent to a model in which expectations are partly myopic. The estimate in regression (2.4) implies λ is -0.89 and $\tilde{\omega}$ is

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[12]These results raise the question of whether the results in the preceding subsection are due only to the failure of the expectations hypothesis at the very short end of the term structure. This possibility was tested by replicating the previous tests with one-year and 20-year bonds. Very similar results were obtained.

[13]David Wilcox has recently performed regression (2.4) using weekly data, correcting for the implied moving average error. He obtains a slope coefficient of -0.040, with a standard error of 0.385. He also examines the quarterly samples beginning at different weeks in the quarter. For each subsample, the slope estimate is well below one,

-2.8. Thus, in the myopic expectations interpretation of the model, the market expectation gives a negative weight to the current short rate and an excessively large weight to the rational expectation. This interpretation of the results is again implausible. It does indicate, however, that the failure of the expectations theory cannot be easily explained by an appeal to naive expectation formation.

Observers of financial markets often comment that these markets are myopic. The empirical results in both subsections decisively reject a simple quantitative expression of this view. The implausibility of the results suggest that equations (1) and (8) are not satisfactory models of the term structure. Taken on face value, the results imply that the market is hyperopic. They indicate that the market gives too little weight to contemporaneous fundamentals and too much weight to future fundamentals.

A parallel phenomenon has been observed in the stock market. Shiller finds that when current dividends are high relative to the current price, the holding return on the stock market is high.[14] Using an argument similar to that used with regard to equation (1), this suggests that the market gives too little weight to contemporaneous dividends. Similarly, Sanjoy Basu shows with cross-sectional data that when a company's current earnings are high relative to its price, the

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although for some subsamples, a coefficient of one could not be rejected. David Wilcox, "Linear and Nonlinear Tests of the Expectations Hypothesis in the Treasury Bill Market," MIT.

[14]Robert J. Shiller, "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?," American Economic Review 71, 1981, pp. 421-436.

company's stock will on average outperform the market.[15] Again, the market price appears to give too little weight to contemporaneous earnings. Thus, none of these violations of the efficient markets hypothesis is consistent with the alternative hypothesis of myopia.

An Alternative Model of Overreaction

As we explain above, the excess sensitivity model we examine is equivalent to a model in which investors irrationally place too large a weight on the current short rate in forecasting future short rates. Although this formulation appears a natural model of "irrational" expectations, it is not the only possible one. In this subsection, we consider another plausible model of overreaction. Instead of placing too large a weight on the current level of the short rate, investors here place too large a weight on the news contained in the current short rate.

Let us again suppose that the expectation theory holds:

$$(11) \qquad R_t = \theta + 1/2\, r_t + 1/2\, r^e_{t+1}$$

where r^e_{t+1} is the market expectation of r_{t+1}. Let ν_t be the innovation in the short rate. In other words, ν_t is the "news" about the path of short rates that arrived in period t. Let us consider the possibility

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[15] Sanjoy Basu, "Investment Performance of Common Stocks in Relation to Their Price-Earnings Ratio: A Test of the Efficient Markets Hypothesis," Journal of Finance, June 1977, pp. 663-682, and Sanjoy Basu, "The Relationship Between Earnings' Yields, Market Value and Return for NYSE Common Stocks: Further Evidence," Journal of Financial

that investors overreact to this news in forming their expectations. That is, the following rule describes their expectations:

$$(12) \quad r^e_{t+1} = E_t r_{t+1} + \phi \nu_t$$

If $\phi = 0$, then the market expectation is rational. If $\phi > 0$, then the market overreacts to the current news about short rates.

Algebraic manipulation of (11) and (12) produces an equation similar to the one we estimate above:

$$(13) \quad r_{t+1} - R_t = -2\theta + (R_t - r_t) - \phi \nu_t + \varepsilon_{t+1}$$

Thus, we obtain equation (10) with an additional term: the innovation in the short rate.[16] This alternative model of overreaction suggests a slightly different regression test.[17]

To investigate this alternative model, we must obtain a measure of the innovation in short rates. To do this, we model the short rate as a third order autoregressive process, although other specifications appear to produce similar results. Estimation of this process yields:[18]

Economics 12, June 1983, pp. 129-156.

[16]Note that under the null hypothesis, the news term equals the following period's residual (i.e., $\nu_t = \varepsilon_t$). Our estimation strategy, however, does not exploit this fact.

[17]This test is analogous to the test of the permanent income hypothesis suggested by Marjorie A. Flavin, "The Adjustment of Consumption to Changing Expectations of Permanent Income," Journal of Political Economy 89, 1981.

[18]Since we require three lagged short rates, the estimation in this subsection is for the period 1963:4 to 1983:4.

$$r_t = 0.60 + 0.64\, r_{t-1} - 0.02\, r_{t-2} + 0.30\, r_{t-3} + \nu_t$$
$$\quad (0.37) \quad (0.11) \qquad (0.13) \qquad (0.11)$$

D.W. = 1.86 s.e. = 1.30 Adjusted $R^2 = 0.81$

We use the residuals from this regression as measures of the innovation in the short rate.

Estimation of equation (13), with the heteroskadasticity correction, produces the following result:

$$r_{t+1} - R_t = -0.05 - 0.40\,(R_t - r_t) + 0.03\,\nu_t$$
$$(0.13) \quad (0.44) \qquad\qquad (0.11)$$

D.W. = 2.04 s.e. = 0.79

Thus, contrary to the implications of this alternative model of overreaction, the innovation has a positive and insignificant coefficient. Moreover, the coefficient on the spread remains negative and significantly different from one.

If we impose the restriction that the coefficient on the spread is one, as implied by equation (13), the results are no more supportive of the model. We find:

$$r_{t+1} - R_t = -0.36 + 1.0\,(R_t - r_t) + 0.12\,\nu_t$$
$$(0.09) \qquad\qquad\qquad (0.11)$$

D.W. = 1.96 s.e. = 0.83

Again, the coefficient on the innovation has the wrong sign. The data do not appear consistent with the view that investors place too much weight in recent "news" in forecasting future short rates.[19]

VARIABLE LIQUIDITY PREMIA

The previous section demonstrates the failure of the expectations theory of the term structure. The alternative hypothesis that long rates respond too much to short rates cannot explain the rejection. The purpose of this section is to show in another way that the failure is substantively significant.

Consider the following slight modification of the expectations theory for one and two-period bills:

$$(14) \quad R_t = \theta_t + 1/2\, r_t + 1/2\, E_t r_{t+1}$$

In this formulation, the long rate R_t differs from an average of the current and future short rates by the term θ_t. Our test above assumes θ_t is constant. In this section we make the less restrictive assumption that θ_t is uncorrelated with short rates.

The term θ_t can be interpreted in two alternative ways. First, we can view θ_t as a time-varying liquidity premium, i.e., the extra compensation required to induce a lender to hold the longer-term bond. Edward Kane finds, based upon surveys of the expectations of market participants, that liquidity premiums are positive and time varying.[20] Note

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[19] An analogous test can be derived for the case of short-term bills and long-term bonds. The results were again not supportive of this alternative model of overreaction.

[20] Edward J. Kane, "Nested Tests of Alternative Term Structure Theories," Review of Economics and Statistics, February 1983.

that once it is extended to include a time-varying liquidity premium, the expectations theory becomes almost vacuous. The liquidity premium is a *deus ex machina*. Without an explicit theory of why there is such a premium and why it varies, it has no function but tautologically to rescue the theory. If fluctuations in the liquidity premium are needed to account for a large fraction of the variance in the slope of the yield curve, then the expectations theory fails to provide a useful guide for understanding these fluctuations. Estimating the extent of variations in the liquidity premium thus provides a way of evaluating the power of the expectations theory as a vehicle for understanding the term structure of interest rates.

A second interpretation of the term θ_t is a measure of the extent to which the market fails to produce the "right" long rate given current and expected future short rates. In other words, θ_t is the deviation of the market rate from the long rate based upon fundamentals.[21] If the variance of θ_t is relatively small, we can conclude that the expectations theory is approximately correct.[22] On the other hand, if fluctuations in θ_t dominate fluctuations in expectations, then we can conclude that the expectations theory fails to capture the primary feature of fluctuations in long rates.

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[21]The analysis here is parallel to that in Lawrence H. Summers, "Do We Really Know That Financial Markets are Efficient?", NBER Working Paper.

[22]Explaining a mean value significantly different from zero would also pose problems.

The previous section derives a simple test of the expectations theory. With the term θ_t, equation (10) becomes equation (15).

$$(15) \quad (r_{t+1} - R_t) = \alpha\theta_t + \beta(R_t - r_t) - \varepsilon_{t+1}$$

According to the theory, $\alpha = -2$ and $\beta = 1$. Of course, θ_t is not observable. The regressions in Table 2 thus omit this variable. Since θ_t is correlated with R_t, this omission leads to a biased estimate of β. In particular, the estimate of β is the following.

$$(16) \quad \hat{\beta} = \beta + \alpha \text{ Cov}(R_t - r_t, \theta_t)/\text{Var}(R_t - r_t)$$

Under the null hypothesis that the model is correct ($\alpha = -2$, $\beta = 1$, and θ_t is uncorrelated with r_t), the estimate of β becomes:

$$(17) \quad \hat{\beta} = 1 - 2 \text{ Var}(\theta_t)/\text{Var}(R_t - r_t)$$

Thus, so long as θ_t is not constant, the estimate of β is biased downward.

Using (17), we can produce estimates of $\text{Var}(\theta_t)/\text{Var}(R_t - r_t)$ from our estimates in Table 2. See Table 3. From regression (2.4), which uses the entire sample and corrects for heteroskedasticity, we find that $\text{Var}(\theta_t)/\text{Var}(R_t - r_t)$ is 0.74 with a standard error of 0.21. This ratio has a very natural interpretation. Maintaining our assumption that θ_t is uncorrelated with short rates, equation (8) implies the following:

$$(18) \quad \text{Var}(R_t - r_t) = \text{Var}(\theta_t) + 1/4 \text{ Var}(E_t r_{t+1} - r_t)$$

Table 3: Estimates of $Var(\theta_t)/Var(R_t - r_t)$

Regression:	(2.1)	(2.2)	(2.3)	(2.4)
Period:	63:1-83:4	63:1-79:2	79:3-83:4	63:1-83:4
$Var(\theta_t)/Var(R_t - r_t)$	0.86	0.70	1.00	0.74
	(.28)	(.21)	(.77)	(.21)

Standard errors are in parentheses.

The variance of the spread between long and short rates is thus decomposed into variance in expected changes in short rates and $Var(\theta_t)$. This decomposition implies that expected changes in the short rate account for only 26 percent of the variance in the spread between the six-month and three-month Treasury bills. We can reject the null hypothesis that $Var(\theta_t) = 0$, while we cannot reject the null hypothesis that expected changes in the short rate account for none of the variance in the spread between three-month and six-month bills.

It is important to note that, although this unexplained liquidity premium θ_t appears central to the spread between long and short rates, it is relatively unimportant to the level of long rates. In particular, we can decompose the variance in the long rates as follows:

$$(19) \quad Var(R_t) = Var(\theta_t) + Var(r_t) + 1/4 Var(E_t r_{t+1} - r_t) + Cov(r_t, E_t r_{t+1} - r_t)$$

Simple calculation demonstrates that $Var(R_t)$ is much larger than $Var(\theta_t)$. In particular, $Var(r_t)/Var(R_t)$ is 1.05, while $Var(\theta_t)/Var(R_t)$ is only 0.01. Thus, although θ_t is critical to $(R_t - r_t)$, its importance to understanding R_t is much less.[23]

CONCLUSIONS

The data decisively reject the expectations hypothesis regarding the term structure of interest rates both statistically and substantively.

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[23]The reason for this is that both short and long rates are highly autocorrelated, and thus the variance of R_t is much greater than the variance of $(R_t - r_t)$. For example, suppose that r_t followed an AR(1) process with parameter 0.8 and that the expectations hypothesis held exactly. Then we can show that $Var(R_t - r_t)$ would be one percent of

The alternative hypothesis that long rates are overly sensitive to short rates is also decisively rejected. The expectations theory can be modified to include an unexplained random liquidity premium, but then expected interest rate movements account for only a small part of the variance in the spread between interest rates of different maturities reflect these changing liquidity premia or expectations that do not satisfy the standard postulates of rationality.

These results suggest the importance of developing models capable of explaining fluctuating liquidity premia.[24] Presumably this would involve in some way recognizing the heterogeneous liquidity positions of different economic agents. They also raise important questions about the monetary transmission mechanism. If, as usually thought, spending decisions and capital assets valuations depend primarily on long-term rates, monetary policy may operate by changing liquidity premia as well as by affecting short rates. Although the efficacy of open market operations directed at shifting the yield curve, such as "Operation Twist," is widely questioned, the issue is difficult to evaluate without a fuller understanding of the deteminants of liquidity premia. The failure of the expectations hypothesis does make more plausible the view that the supplies of assets of different maturities influences yields.[25]

$Var(R_t)$. Introducing a random liquidity premium increases both variances equally and thus increases $Var(R_t - r_t)$ proportionally more.

[24]For work along these lines, see Zvi Bodie, Alex Kane, and Robert McDonald, "Why are Real Interest Rates So High?", NBER Working Paper No. 1141.

[25]For a discussion of this type of effect, see Benjamin M. Friedman, "Financial Flow Variables and the Short-Run Determination of Long-Term Interest Rates," Journal of Political Economy 85, August 1977, pp. 661-690.

It is, however, difficult to understand why these effects would be important in the market for three-month and six-month bills.

Our negative results provide an additional reason for uncertainty in predicting the effects of alternative monetary and fiscal policies on financial markets. They suggest that estimating the impact of policies on future short-term rates is not likely to be a good guide to predicting their impact on long-term rates or asset valuations. These effects may depend more on liquidity premia than on expectations. Without a satisfactory theory of liquidity premia, predicting the effect of policies on the shape of the yield curve is almost impossible.