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NESTED TESTS OF ALTERNATIVE TERM-STRUCTURE THEORIES

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ABSTRACT

Controversies in term-structure theory center around the existence and variability of term premia in securities yields. In this paper, the term premium on a default-free n-period bond is defined as the difference between its observable yield to maturity and the average expected per-annum rate of return on an n-period strip of rollover investments in one-period bonds. To test alternative term-structure theories without introducing *ex post* proxies for expectational variables, this paper uses a set of cross-section interest-rate forecasts collected jointly with Burton Malkiel of Princeton University from a population of large institutional lenders at four different phases of a single interest-rate cycle. Statistical tests strongly confirm the existence of nonzero term premia at each survey date, thereby rejecting the pure-expectations theory of the term structure. Additional tests are unable to reject restrictions implied by the liquidity-premium hypothesis that term premia should be positive and increase with maturity. Finally, contrary to the martingale hypothesis, *ex ante* term-premium data vary significantly over time and show a positive association with the level of interest rates.

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NESTED TESTS OF ALTERNATIVE TERM-STRUCTURE THEORIES*

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Traditional theories of the term structure of interest rates may be interpreted as arbitrage theories of equilibrium bond prices (Malkiel, 1962). Of course, unless explicit forward, futures, and spot markets for bonds are complete in themselves, the arbitrage pressure takes place in the subjective space of participant expectations rather than in the objective space of observed bond prices. Arbitrage theories are necessarily efficient-markets theories, inasmuch as wasted information would in itself raise opportunities for arbitrage (Ross, 1977). Alternative term-structure theories differ in their views of: (1) the specific contractual elements of a long-term bond contract that the market must price, and (2) the forecastability of short-run movements in long-term interest rates.

Translated to the conventional interest-rate metric, controversies in term-structure theory revolve about the existence and variability of term premia in market yields. A term premium, T_n, may be defined for every finite term-to-maturity, n, where n=1,2,3,... . Each T_n is the difference between the observable yield on n-period bonds and the average expected per-annum rate of return on an n-period strip of rollover investments in one-period bonds. From the perspective of modern finance, term premia are best conceived as "market-completion premia" (Kane, 1980). They are algebraic transforms of the net price of whatever package of services (e.g., of providing guarantees or accepting specific portfolio risks) is deemed necessary to "complete" bond markets. In suggesting that term premia be interpreted as equilibrating allowances necessary to compensate marginal lenders or borrowers for the extra service of holding or issuing debt whose terms-to-maturity are longer or shorter than their preferred maturity "habitats," Modigliani and Sutch (1966) offer an almost equally broad interpretation.

Requirements for market completeness provide an intuitive justification for expecting positive term premia to exist. This paper presents a series of empirical tests that confirm the existence and variability of positive term premia in the market for U.S. Treasury securities. These tests compare market yields on long-term securities with cross-section forecasts of future interest rates collected at four different survey dates.

I. Alternative Term-Structure Hypotheses

With respect to the existence of term premia, the most restrictive theory is the pure-expectations theory, PET (Lutz, 1940). According to the PET, investors' expectations of future short rates completely explain the differential between short and long rates. Because additional market-completion services are not needed, term premia are identically zero. The alternative hypothesis to PET is that unspecified market-completion services are required, so that nonzero term premia exist. As portrayed in Figure One's Venn diagram, this alternative hypothesis — which we dub term-premium theory (TPT) — is itself an aggregation of several narrower hypotheses, each of which assigns the task of completing bond markets to a disparate set of borrower or lender services. Different versions of TPT may be developed intuitively from PET by relaxing differentially various of its restrictive assumptions. The least-restrictive versions of TPT may be called unconstrained-premium theories (UPT), since in the absence of extraneous information they place no restrictions on the signs or relative magnitudes of the term premia observable in different maturity sectors. UPT interprets term premia either as risk premia (e.g., Cox, Ingersoll, and Ross, 1978) or as habitat-displacement allowances (Modigliani and Sutch, 1966). Within TPT, alternative hypotheses to UPT may be divided into the Hicksian liquidity-premium theory (LPT) and other constrained-premium theories (OCPT). LPT requires term premia to be positive and to increase with maturity in a monotonically nondecreasing manner. OCPT covers the possibility that only one of the two LPT restrictions holds. From the point of view of statistical testing, OCPT is merely a logical alternative to LPT and UPT, not a fully interpreted prior hypothesis.

Term-premium theories also concern themselves with explaining the behavior of term premia over time. The hypothesis of time-invariant term premia plays a pivotal role in martingale theorists' attempts to denigrate traditional theories of the term structure. Several studies exploring restrictions that forecast rationality and market efficiency place on the joint processses of expectations formation and term-structure arbitrage have attempted to repudiate the expectations-based approach. These authors (e.g., Phillips and Piggenger, 1979) take the position that short-run movements in long-term interest rates are so nearly random as to be intrinsically unforecastable. The evidence reported here shows that term premia vary over time in systematic ways. Systematic variation shifts the burden of Occam's Razor argumentation back onto critics of the traditional approach, since it suggests that the approximation (Sargent, 1976) involved in the martingale approach is conceptually deficient (Fama, 1976; Pesando, 1979).

II. Derivations and Underlying Concepts

Notation

Traditional term-structure theory focuses on single-payment securities, uncomplicated by default risk or special features of any kind. The unit price, P_{nt}, of a security that matures in n periods is the discounted present value of a dollar at the maturity date. We find this value by discounting this future dollar n times at R_{nt}, the yield to maturity for an n-period bond:

$$P_{nt} \equiv 1/(1 + R_{nt})^n, \text{ for } n = 1,2,3,\ldots \quad (1)$$

In this discrete-time conception, the term to maturity of any bond bounds a set of n unit maturities. We presume that the "unit maturity" is a minimum period for economical investment in open-market securities. Our empirical work treats this interval as the calendar quarter and takes R_{1t} as exogenous.

PET Bond-Pricing Framework

Alternative expectations-based theories of the term structure disagree as to what basis elements span the space of bond prices. According to PET, logarithms of current and expected bond prices lie in a linear vector space. The equilibrium price of every long-term security is the product of the prices of any combination of spot and forward transactions in shorter bonds that spans the same term-to-maturity. The most convenient basis elements for the space of log-prices are the current and expected intervening future log-prices of one-period bonds (or "bills"). The familiar PET equilibrium condition expresses precisely this linear dependence.

To derive testable implications from the PET condition, it is convenient to introduce the auxiliary concept of an investment strategy of maturity n. An investment strategy is an n-tuple, $(\underline{\mathbf{M}}_n)$, that lists, for each of the n component periods, the maturity in which the present discounted value of each dollar of a planner's matured portfolio is to be held. Two focal strategies may be identified: (1) the "unit" or "rollover" strategy, whose entries are all ones, and (2) the "hold-to-maturity" or "factorial" strategy, whose entries are the successive factors of n-factorial. In vector notation:

The unit strategy: $(\underline{\mathbf{1}}_n) = (1, 1, 1, ..., 1)$;

The factorial strategy: $(\underline{\mathbf{n!}}) = (n, n-1, n-2,...,1)$.

PET makes an expected future dollar just as valuable as a certain one and requires, for each and every investment period n, that all feasible investment strategies (including the factorial strategy) have the same equilibrium price as the unit strategy, $P_t(\underline{\mathbf{1}}_n)$. Clearly, $P_t(\underline{\mathbf{n!}})$ equals the price of n-period bonds, P_{nt}. We can factor the price of an n-period unit strategy into the product of the price and quantity of bills an investor must buy at t to roll over into an expected dollar at t+n. We let $E_t(...)$ represent the expectations operator and leave implicit the conditioning information that investors use at time t in formulating their expectations of future prices.

It is convenient to proceed recursively. To buy a claim to an expected t+2 dollar via the unity strategy, one must first buy $E_t(P_{1,t+1})$ bills at the price P_{1t}. Putting $P_{1t}E_t(P_{1,t+1})$ in bills at t promises to produce $E_t(P_{1,t+1})$ dollars at t+1. On an expected-value basis, the proceeds may be rolled over into just-enough t+1 bills to produce an expected dollar at t+2. Since all 2-period investment strategies must sell at the same price, $P_t(\underline{\mathbf{1}}_2)$, which equals $P_{1t}E_t(P_{1,t+1})$, must also equal the price of two-period bonds.

Similarly, the price of the three-period unit strategy may be expressed in terms of the price of two-period bonds and the number of them one must purchase today to be able to acquire $E_t(P_{1,t+2})$ worth of bills at t+2. Summarizing, we have established that:

$$P_{2t} = P_t(\underline{\mathbf{1}}_2) = P_{1t}E_t(P_{1,t+1}); \tag{2a}$$

$$P_{3t} = P_t(\underline{\mathbf{1}}_3) = P_{2t}E_t(P_{1,t+2}) \; . \tag{2b}$$

Substituting from (2a) into (2b), we obtain (2c):

$$P_{3t} = P_e(\underline{\mathbf{1}}_3) = P_{2t}E_t(P_{1,t+2}) = P_{1t} \prod_{k=2}^{3} E_t(P_{1,t+k-1}) \; . \tag{2c}$$

For arbitrary n, this equation easily generalizes into:

$$P_{nt} = P_t(\underline{\mathbf{1}}_n) = P_{n-1,t} \; E_t(P_{1,t+n-1}) = P_{1t} \prod_{k=2}^{n} E_t(P_{1,t+k-1}), \; n=2,3,... \tag{2d}$$

<u>Term Premia</u>

Term premia are defined in the interest-rate metric. T_n is the difference between the yield to maturity on an n-period bond and the expected per-annum yield on the unit strategy:

$$T_n = [P_{nt}]^{-1/n} - [P_t(\underline{\mathbf{1}}_n)]^{-1/n}, \; n=2,3,... \tag{3}$$

T_1 is zero by construction, while equation (2d) assures us that all term premia equal zero under PET.

<u>Term-Premium Theory (TPT)</u>

According to TPT, transactions costs and maturity preferences prevent factorial and unit strategies from being equivalent portfolios, either for borrowers or for lenders. However, a number of conceptually distinct microeconomic explanations exist as to what accounts for this nonequivalence: Hicks (1946); Green (1967); Hirshleifer (1972); Kane (1980); Modigliani and Sutch (1966);

McCulloch (1973); Roberts (1980); Roll (1971); Stiglitz (1970); Tuttle, Lee, and Maness (1978). All versions agree in postulating that for each possible investment period the anticipated price of an investment strategy must vary not only with the length of the holding period n, but potentially with the maturity of every component in the strategy chosen.

Liquidity-Premium Theory (LPT)

Under the liquidity-premium theory (LPT), for any holding period n, the maximum price is paid for the unit strategy. By investing in a succession of one-period securities, an investor momentarily liquidates his investments at the beginning of every component period. When transactions costs are nonzero, this gives him the option of responding cheaply to new information (e.g., to unfolding rates of unanticipated inflation). To give up this flexibility in favor of holding in any component period a k-period security (where $k > 1$),an investor must receive a positive premium in yield, L_k. Moreover, because a bond's liquidity may be presumed to decrease with its maturity, L_k must increase (or at least not decrease) with k.

Under LPT, the *ex ante* yield on any n-period strategy, $R(\underline{\mathbf{M}}_n)$, increases monotonically with a *ceteris paribus* increase in any element of the investment-strategy vector $\underline{\mathbf{M}}_n$. $R(\underline{\mathbf{M}}_n)$ includes a specific liquidity premium to compensate investors for each and every component-period departure from the unit strategy. Letting arithmetic averaging of component-period yields approximate the complicated geometric averaging envisaged in equations (2a) to (2d), we can establish that:

$$T_2 = L_2/2 \tag{4a}$$

$$T_3 = (L_3 + L_2)/3 \tag{4b}$$

$$T_n = \frac{L_n + L_{n-1} + L_{n-2} + \ldots + L_2}{n} = \frac{L_n + (n-1)T_{n-1}}{n} . \quad (4c)$$

Properties of the average-marginal relationship assure us that LPT restrictions on the L_k carry through to the T_n. If every L_k is positive, so must every T_n be. Even in the limiting LPT case where all L_k would have exactly the same value, the T_n would still increase with maturity.

Variability of T_k over Time

Panel A of Table 1 summarizes the implications of alternative term-structure theories for term premia. Panel B indicates that disagreement also exists concerning the sign of the effect that interest rates might have on term premia.

Briefly, Kessel and Cagan portray the T_k as payments made to compensate for the imperfect moneyness of bonds. Bonds are imperfect substitutes for money and bills. Since the opportunity cost of increased moneyness is forgone yield, they hypothesize that lack-of-moneyness allowances should increase with market interest rates. Van Horne and Nelson depict the T_k instead as payments made to offset expected capital losses. Making expected changes in any bond price proportional to the difference between its current interest rate and its expected long-run average (or "normal") level, they derive a negative relation between current rates and the expected capital losses their T_k are supposed to offset. Subsequent research by Pesando (1975) and Friedman (1979) have affirmed the Kessel-Cagan hypothesis. With R_{nt} directly entering the calculation (3) of T_n , additional tests are desirable because measurement error in distributed-lag proxies for $R(1_n)$ could easily bias the results toward positive association.

It is also important to investigate the logically prior hypothesis that term premia do not vary over time at all. As the following stylized theorems indicate, the assumption that term premia are time-invariant plays a pivotal role in martingale representations of the term structure:

1. In the absence of time-varying term premia, market efficiency requires that long-term interest rates follow a random walk or martingale sequence if short-term rates do (Sargent, 1976).

2. Even if short-term rates do not follow a random-walk (and the predictability of Federal Reserve reactions to business and electoral cycles provides strong reason to believe that U.S. short rates do not), as long as term premia are time-invariant, long-term interest rates may still be well approximated by a martingale (Sargent, 1976).

3. On the other hand, if term premia can be shown to vary over time in systematic ways, the approximation involved in the martingale approach must be viewed as conceptually deficient (Pesando, 1980).

III. The Kane-Malkiel Survey Data

To explain the data set, it is necessary to emphasize the difficulty of confronting term-structure theories with time-series data. The focal issue is not whether "soft" survey data sets are as good as "hard" time-series evidence. The issue is how well ex post measurements can approximate ex ante forecasts. Term-structure theories contemplate an unobservable experiment. Proper experimentation would develop information on expectational variables that are not recorded in market transactions. Substituting ex post proxy variables whose relevance depends on the validity of untested auxiliary hypotheses about expectations formation loosens scientific rules of evidence. Even worse, because term premia are estimated as residuals and interest rates are serially correlated, commonly used distributed-lag proxies for expectations make it doubly hard to test for the effect of interest rates on term premia. Instead of experimental observations collected systematically, researchers apply untested assumptions to accounting data to generate numbers that are interpreted as "observations" on $R(\mathbf{1}_n)$, the expected holding-period return on the n-period unit strategy.

The Kane-Malkiel surveys were conceived as a way to test term-structure theory on its own terms. We collected from the population of institutional lenders *ex ante* data on the expectational variables the theory manipulates. Although the individuals that fill out our questionnaires are not observed in the experimental act of buying or selling securities, we directed our questionnaires to firms likely to be *active* in securities markets and to individuals within these firms whose job-titles suggest that they would *conceive* or *execute* securities transactions. Although the artificiality of the reporting context is an inescapable source of measurement error, at the very least, our data provide an opportunity to covalidate time-series results.

Data are presented for each of our last four survey dates: January 1969, July 1969, October 1970, and January 1972. These dates were chosen in part to sample different phases of the interest-rate cycle to let us investigate hypotheses about the effect of interest rates on term premia. Two earlier surveys (April 1965 and January 1966) are ignored here because we had not yet honed our survey instrument to develop $R(1_n)$ for long holding periods.

We distributed by mail an average of 170 questionnaires at each date.[1] An abbreviated version of the questionnaire is presented as an appendix. Our tests make use of the data reported in the last column of question 1 and of the first half of question 3. Holding-period yields are calculated as geometric averages of the value of the 91-day bill rate on the survey date and relevant forecasts of this rate at intervening future dates. Answers to questions 4 and 10 were used to develop subsamples by which to assess the representativeness of the aggregate sample.

Representativeness of Respondent Opinion

Representativeness is a central issue in survey research. Our designated population is the opinion of market participants, weighted by their market activity. In recognition of this, our surveys focus on large institutional investors: banks, nonfinancial corporations (NFCs) insurance companies (ICOs: including both life and casualty companies), and a smattering of securities dealers.[2] Treasury surveys of ownership indicate that firms in these industries owned over 40 percent of the public marketable Treasury debt outstanding at each survey date.

According to Bierwag and Grove (1967), we would want ideally to weight each response by the size of the respondent's portfolio, by the confidence it has in its estimates, and by its aggressiveness or willingness to commit funds in support of its forecasts. Question 4 attempts to sidestep this weighting problem by letting us identify a group of investors who consider themselves in equilibrium at current yields. We treat their expectations as a norm against which to measure the representativeness of aggregate-sample results.

Questions 9 and 10 (which we did not develop until the 1972 survey) let us investigate the extent to which sample subjects are representative of portfolio decisionmakers ("bosses") at respondent firms. A few interesting differences emerge between this "boss" group and the rest of the sample.[3]

Finally, although our response rate averaged well over 65 percent, non-response bias must be considered. This bias is best assessed by obtaining information from nonrespondents. We are fortunate in this respect since (to obtain information on the summary distributions of respondent forecasts promised as an incentive to respondents) many nonrespondents wrote us to explain their reasons for not completing our form. Two principal reasons were cited. First, especially in the insurance industry, some firms have a strict policy against letting their employees "waste" time completing external questionnaires. Second, nonrespondent NFCs in particular often excused themselves as lacking in current knowledgeability due to recent nonparticipation in government-securities markets. Far from being a problem, this second type of nonresponse is better for our purposes than an ignorant response.

Measuring Yields on U.S. Treasury Securities

To determine a respondent's perceived term premium, T_k, it is necessary to subtract his forecasted $R(1_k)$, from the market yield, R_k. Our calculations use data on R_k calculated by Salomon Brothers. Salomon Brothers' yield curves are widely regarded on Wall Street, but for our purposes they have three weaknesses.

First, since they are reported on a semiannual true-yield basis, they are not immediately comparable to the 3-month Treasury-bill rate forecasts impounded in our estimates of $R(1_k)$. Treasury bills are typically quoted on a bank-discount basis. Because an unknown number of respondents may have either reported true-yield figures or based their bank-discount calculations on a 360-day rather than 365-day year, it is not possible to align market yields exactly. For four different maturities at each survey date, Table 2 presents three alternative sets of market yields. Since bank-discount rates are lower than true yields, using them to calculate term premia is a conservative procedure, biased against finding large premia. We focused on 365-day yields on the grounds that at least some respondents were reporting bill rates on a true-yield basis and that 365-day yield quotations have become more common than 360-day figures. We present the 360-day yields for anyone who wants to test the sensitivity of our results to this assumption. 360-day T_k run about four basis points (a basis point is 1/100 of a percentage point) less than our 365-day estimates.[4]

Two other sources of measurement error are discussed in Section V. The effects of variation in the dates on which individual questionnaires were filled out and of distortions in market yields caused by differential taxability are handled in a post-mortem sensitivity analysis of our principal findings.

IV. Cross-Section T_k and Tests of Alternative Theories

Our cross-section focus lets us address meaningful hypotheses with elementary statistical tests. In this study, inference is based upon: (1) t-tests of significant difference of respondents' mean T_k from zero; (2) Mann-Whitney tests of differences between the means of two samples (t-tests being rendered less reliable by frequent significant differences in sample variances); (3) binomial tests focused on the percentage of observed premia that are positive; and (4) rank-correlation and concordance tests of the influence of interest rates on the level of term premia.

Evidence for Rejecting PET for TPT

Table 3 summarizes the data used in our first and most important test. For both the aggregate sample and the maturity-indifferent subsample, the table presents mean values, measured in basis points, for four premia at each survey date. For 1972, mean T_k are also calculated separately for the "Boss" subsample of each group. Four maturities are covered: half-year, one year, two years, and ten years. Only one of the 32 sample means is not significantly greater than zero. In the single case (January, 1969 $T_{1/2}$) where the mean premium is not significantly greater than zero, even using 360-day yields, one must also reject the hypothesis that the premium is significantly less than zero. A near-zero premium is least damaging to TPT when it attaches to the shortest maturity distinguishable in the data.[5]

In 1972, we can focus specifically on a subsample of respondents who make portfolio decisions for their firms. For this boss group, PET is rejected even more emphatically. Bosses' mean term premia prove generally higher than those for other respondents.[6] These differences are statistically significant in the aggregate sample, but not in the smaller maturity-indifferent subsample.

Table 4 investigates whether the average premia reported in Table 3 owe their significance to a few large outliers. We investigate this possibility by asking whether the proportion of respondents reporting a positive term premium significantly exceeds fifty percent. In these tests, the January 1969 $T_{1/2}$ continues to be troublesome, but only one other observation (aggregate-sample T_2 in 1972) fails to produce a ratio significantly larger than fifty percent.

Evidence Affirming LPT and OCPT over PHT

Tables 3 and 4 establish that term premia are generally positive, refuting the pure-expectations theory. In Table 5, we inquire whether term premia increase significantly with maturity as LPT predicts. Using Occam's Razor, we should be prepared to neglect institutional information such as the distribution of borrowers' and lenders' maturity habitats featured in the preferred-habitat theory if both LPT restrictions are upheld.

By LPT, a longer-maturity term premium always exceeds a shorter one. At each date, our data set generates six pairs of premia. In most cases, the longer premium does significantly exceed the shorter one. In the aggregate sample, only five of the 24 pairs fail to show a significant difference and a sixth case (T_2 *versus* T_{10} in July 1969) shows countersignificance. (Post-mortem analysis undertaken in Section V suggests that this anomaly traces to tax bias.) In the focal maturity-indifferent group, only eight of the twenty-four pairs fail to show a significant difference and no countersignificant evidence is observed. Within the parallel boss groups in 1972, the evidence in favor of LPT is much the same.

Behavior of Term Premia over Time

Except for one anomalous observation, Table 5 upholds the monotonically nondecreasing restriction of LPT, though the gap between two and ten years maturity leaves open the issue of an intermediate peak. Table 6 tests the straightforward null hypothesis that at each maturity the term premium is the same at each survey date. The alternative hypothesis does not specify any particular pattern of expected differences across dates. Because two-thirds to three-fourths of the paired premia differ significantly across survey dates, we reject the null hypothesis (critical to the interpretation of martingale research) that the premium structure is time-invariant.

This finding sets up our next task: to see if we can explain the changes in T_k that we observe. Neglecting other potential determinants, we investigate the relation between term premia and market interest rates. Both for the aggregate sample and the maturity-indifferent subsample, rank correlations between the T_k and the k-year yields recorded in Table 2 are strongly positive. Because each such correlation shows only three degrees of freedom, it is convenient to focus our significance tests on coefficients of concordance, W (see Siegel, 1956). Concordance calculations let us pool ranks across maturities and survey dates. For both sample groupings, W is 0.83 (after correcting for a tie in the case of maturity-indifferent respondents). This value is significant even at the one-percent level.

V. Post-Mortem Analysis

Comparing Cross-Section and Time-Series Premium Estimates

Table 7 collects parallel time-series measurements of term premia. The upper panel compares McCulloch's (1975a) mean estimates of $T_{1/2}$, T_1, T_2, and T_{10} during 1951-1966 with the mean values achieved in our surveys. Our cross-section premia are much higher, but rise proportionately as steeply as McCulloch's values. Because the generally higher values of the cross-section estimates are drawn from the higher interest-rate era of 1969-1972, they may be said to reinforce the rank-correlation evidence in favor of the hypothesis that interest rates impact positively on term premia.

Table 7's second panel develops time-series estimates for only two premia, $T_{1/2}$ and T_1, for dates one month in advance of our first three survey dates. These are rough figures calculated from worksheets that Pesando (1975) graciously made available. The dates are closely enough aligned to support comparison. Pesando's and our results show similar values for $T_{1/2}$ at each date and the lowest values for both premia occur at the first date. The major differences concern much-lower time-series estimates of T_1, especially on the first two survey dates when they are below $T_{1/2}$ and on one occasion even negative. Lacking standard errors for these premia, we cannot formally test the significance of these discrepancies, but it is clear that these data could not reject PHT or OCPT as alternative hypotheses to LPT.

Allowing for Measurement Error in Yields

Precisely because our approach to measuring term premia is so straightforward, it is important to identify potential sources of measurement error and to discuss whether and how these might affect the qualitative pattern of results observed.

We have dealt throughout with the danger that respondent forecasts might not be representative of market opinion. But two other sources of bias remain:

1. Since questionnaires were completed at different dates, various respondents' forecasts made use of different information sets.
2. The capital-gains tax preference and 4.25-percent interest ceiling on coupon bonds combined to bias long-term Treasury yields downward.[7]

1. Response-Timing Bias. In principle, we want to measure each respondent's anticipations of yield on alternative unit strategies on the survey date itself. In practice, it is unreasonable to expect busy executives to complete questionnaires the moment they receive them. Our mail brought a batch of questionnaires each

day for about two and a half weeks after our mailings, with dribs and drabs arriving even later.

If we adopt the convenient hypothesis that compounded forecast revisions would be positively related to movements in market rates between the survey date and the date shown in respondent postmarks,[8] Table 8 allows us to make some rough corrections for differences in the timing of responses. In January 1969, yields showed little net movement during the months after the survey date. Since the ten-year yield moved up relatively steadily, $R(1_{10})$ may have been overstated slightly. Correcting for this would tend to raise T_{10} above its Table 3 value.

After July, 1969 the ten-year yield was unchanged, but the other yields rose between 17 and 32 basis points. These movements would tend to raise near-term yield forecasts, resulting in underestimates of $T_{1/2}$, T_1, and T_2. Correcting for this would tend to flatten the slope of the term-premium curve and to accentuate the LPT-refuting decline from T_2 and T_{10}.

After October 1, 1970, short yields fell more sharply than ten-year ones. This would tend to lower near-term forecasts more than distant ones, making our calculations underestimate October 1 forecasts. Correcting for this would lower term-premium estimates generally but especially in the short end. This would steepen the term-premium structure and might drive $T_{1/2}$ close to zero.

After January 1, 1972, half-year and one-year rates fell, while longer rates rose. This suggests that $R(1_{1/2})$ and $R(1_1)$ may have been understated and $R(1_2)$ and $R(1_{10})$ overstated. Correcting for this would lower $T_{1/2}$ and T_1 (possibly to near-zero levels) while raising T_2 and T_{10}. This correction would steepen the term-premium structure and might very well remove the LPT-refuting decline between T_1 and T_2.

In summary, correcting for the timing of responses would steepen the structure of term premia on three of the four survey dates. It would also lower the mean value ot $T_{1/2}$ across surveys, perhaps substantially. From the point of view of LPT, the only disconfirming effect is to heighten the July 1969 decline observed between T_2 and T_{10}. However, the next section indicates that much (if not all) of this decline reflects tax bias.

2. Tax Bias. Although the Tax Reform Act of 1969 denies this privilege to financial institutions, price appreciation on U.S. Treasury bonds is generally treated as a capital gain. Because capital gains are taxed more lightly than coupon yields, at equal yields a discount security would promise a higher after-tax return.[9] If we suppose that the law of one price applies to after-tax holding-period yields, equilibrium yields to maturity on discount securities are systematically understated (Pye). Because long-term Treasurys sold at substantial discounts at every survey date (thanks to the 4.25 percent ceiling then allowed on bond coupons), this understatement of yields biases downward our estimates of T_{10}.

For ten-year yields, Table 9 provides rough estimates of the size of this bias at each survey date. The bias should be negligible for the shorter maturities, since high-coupons securities—and below one-year even Treasury bills—were available. Using the assumptions stated in the note to the table, tax bias is calculated by equalizing after-tax running yields on a 4.25-percent coupon issue and a hypothetical new issue selling at par. Adding only half of this bias to the T_{10} estimates reported in Table 3 is enough to wipe out the bothersome decline between T_2 and T_{10} observed in July 1969.

VI. Summary and Implications

Our cross-section estimates strongly confirm TPT over PET and are unable to reject the restrictions on term premia implied by LPT. In general, whatever one's holding period, one can expect to earn more by investing in a long-term instrument than in a shorter one. This higher expected yield may be interpreted as compensation for the risk and inconvenience to lenders of accepting a long-term commitment.

Statistical tests reject the martingale-theory hypothesis that term premia are time-invariant and indicate that observed variation is positively associated with the level of interest rates.

FOOTNOTES

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[1] The number distributed varied primarily because of respondent requests for deletion and because of a follow-up focus adopted in the July 1969 and January 1972 surveys (to test theories of expectations revision) that reduced the size of these mailings.

[2] Our sampling frame relied heavily on Fortune's "largest" lists. Kane and Malkiel (1967) explains our procedures in more detail and reports term premia observed in our first (April, 1965) survey.

[3] We also tested the homogeneity of estimated term premia across different classes of institutions at each survey date. About five percent of institution pairs showed differences that proved significant at five percent. No differences were significant at one percent.

[4] We might point out that converting the market yields to a bank-discount basis requires only sixteen calculations. Converting respondent estimates of $R(1_n)$ to a true-yield basis would require almost two-thousand calculations.

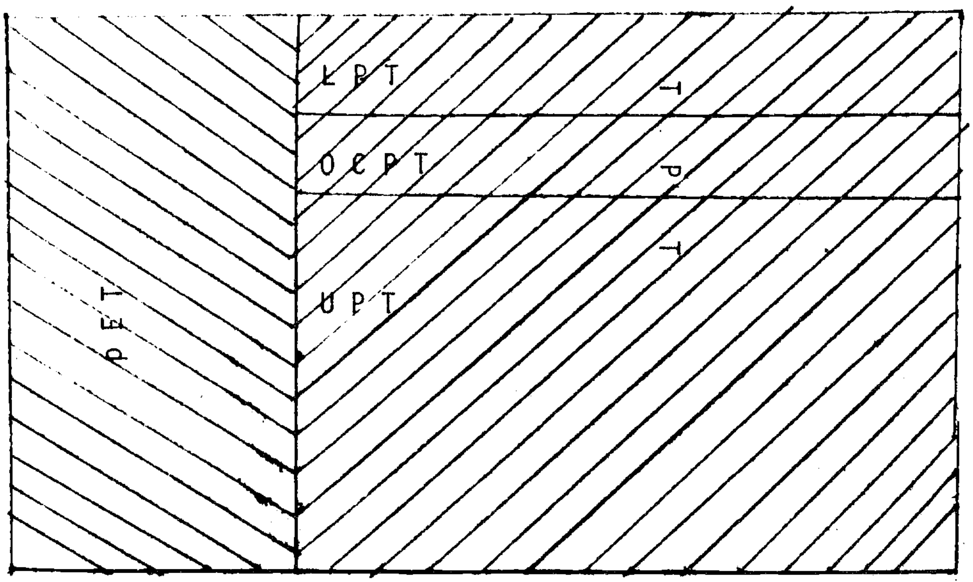
[5] Appendix Table 1 illustrates how term premia are calculated and shows that term premia average even higher and exhibit much the same qualitative pattern when the mean bill-rate forecasts are converted to bond yields and subtracted from continuously compounded yields on hypothetical single-payment bonds.

[6] Means for nonbosses differ in the opposite direction from the aggregate-sample means. The latter figures are best interpreted as a weighted average of the means for the boss and nonboss subsamples.

[7] Additional downward bias due to the preponderance of "flower bonds" (those acceptable at par in payment of federal estate taxes) among long-term Treasury securities is presumably corrected away in Salomon Brothers' calculations.

[8] This is the error-learning hypothesis. For evidence, see Meiselman (1962), Malkiel and Kane (1969), Diller (1969), and Kane (1970).

[9] See Pye (1965), Robichek and Niebuhr (1970), and McCulloch (1975b).



Schematic Partition of Expectations-Based
Term-Structure Theories

Figure One

Table I

Testable Implications of Alternative Term-Structure Theories

A. Implications for Term Premia

Theory	Implications for $T_k = [P_{kt}]^{-1/k} - [P_t(1_k)]^{-1/k}$
PET	$T_k = 0$ for all $k = 2, 3, \ldots, \infty$
LPT	$T_k > 0$ for all $k = 2,3,\ldots, \infty$ (Positive) $T_k \geq T_{k-1}$ for all $k - 2,3,\ldots, \infty$ (Nondecreasing)
OCPT	Only one of the LPT restrictions holds.
UPT	T_k are unconstrained in size or maturity pattern, but "smoothness" is presumed.

B. Relation Between T_k and R_k Over Time

Theorists	Hypothesized sign of $\frac{\partial T_k}{\partial R_k}$
Kessel; Cagan	Positive
Van Horne; Nelson	Negative
Martingale Theorists	Zero: Term premia should not vary over time.

Table 2

Market Yields at Survey Dates

Semiannual Bond Yields Reported by Salomon Brothers*

	6-month	1-year	2-year	10-year
January 1, 1969	6.36	6.32	6.29	5.95
July 1, 1969	7.20	7.28	7.22	6.45
October 1, 1970	6.40	6.60	6.79	7.11
January 1, 1972	4.03	4.35	4.72	5.96

Salomon Yields Converted to Three-Month Discount Rates (365-Day Basis)

January 1, 1969	6.21	6.17	6.15	5.82
July 1, 1969	7.01	7.09	7.03	6.30
October 1, 1970	6.25	6.44	6.62	6.93
January 1, 1972	3.97	4.28	4.64	5.83

Salomon Yields Converted to Three-Month Discount Rates (360-Day Basis)**

January 1, 1969	6.17	6.13	6.11	5.78
July 1, 1969	6.97	7.05	6.99	6.26
October 1, 1970	6.21	6.40	6.59	6.89
January 1, 1972	3.94	4.24	4.60	5.79

*Salomon Brothers, (1974), pp. 17-18.

**Taken from bond tables in Treasury Bills (1966) and Supplement (1969), Boston: Financial Publishing Company.

TABLE 3

Estimated Term Premia, T_k, for Four Different Maturities at Four Survey Dates*
(in basis points)

Maturity, k \ Survey Date	Jan., 1969 T_k	Jan., 1969 (N)	July, 1969 T_k	July, 1969 (N)	Oct., 1970 T_k	Oct., 1970 (N)	Jan., 1972 T_k	Jan., 1972 (N)	Jan., 1972 "Boss" Subsample T_k	Jan., 1972 "Boss" Subsample (N)
	A. Aggregate Sample of Survey Respondents									
1/2 year	7	(131)	52	(100)	44	(119)	21	(91)	24	(62)
1 year	29	(128)	73	(100)	69	(116)	23	(89)	28	(61)
2 years	46	(117)	94	(96)	84	(113)	15	(82)	22	(59)
10 years	45+	(119)	59	(98)	101	(118)	66	(85)	67	(58)
	B. Subset of Survey Respondents That Did Not Perceive A Particular Maturity Range as Attractive for Investment									
1/2 year	2#	(37)	53	(32)	42	(56)	21	(50)	24	(35)
1 year	23	(37)	70	(32)	66	(54)	26	(49)	31	(35)
2 years	44	(35)	84	(31)	81	(52)	20	(44)	26	(33)
10 years	62+	(32)	56	(32)	95	(56)	70	(48)	66	(33)

Notes:

* For each survey date, T_k is calculated as the difference between (1) the yield on U.S. Treasury securities of maturity k reported in Salomon Brothers (1974) adjusted to a 365-day discount basis and (2) the mean of the annual rates of return forecasted for the k-period unit investment strategy ($\mathbf{1_k}$).

\+ Difference from parallel rate in other panel is significantly different at 5 percent, using the Mann-Whitney test statistic.

\# This is the only T_k in the table that is not significantly different from zero at 5 percent.

Table 4

Number and Proportion of Respondents at Each Survey Date for Whom Estimated Term Premia Were Strictly Positive

Survey Date / Maturity, k	Jan., 1969 No.	Jan., 1969 Proportion	July, 1969 No.	July, 1969 Proportion	Oct., 1970 No.	Oct., 1970 Proportion	Jan., 1972 No.	Jan., 1972 Proportion	Jan., 1972 "BOSS" Subsample No.	Jan., 1972 "BOSS" Subsample Proportion
A. Aggregate Sample of Survey Respondents										
1/2 year	81	.62	98	.98	116	.97	83	.91	58	.94
1 year	107	.84	98	.98	113	.97	63	.71	46	.75
2 years	108	.92	94	.98	107	.95	48	.59+	38	.64
10 years	91	.76	81	.83	96	.81	74	.87	50	.86
B. Subset of Survey Respondents Who Did Not Perceive a Particular Maturity Range as Attractive for Investment										
1/2 year	20	.54+	31	.97	55	.98	45	.90	32	.91
1 year	30	.81	31	.97	52	.96	37	.76	28	.80
2 years	32	.91	30	.97	48	.92	28	.64	23	.70
10 years	27	.84	24	.75	45	.80	44	.92	29	.88

Note: + Not greater than 0.5 at 5% significance.

TABLE 5

OUTCOME OF MANN-WHITNEY TESTS FOCUSED ON DIFFERENCES IN TERM PREMIA ACROSS MATURITIES AT EACH SURVEY DATE

Survey Date	$(T_{1/2}, T_1)$	$(T_{1/2} T_2)$	$(T_{1/2}, T_{10})$	$(T_1 T_2)$	$(T_1 T_{10})$	$(T_2 T_{10})$
			Specific Pair of Term Premia Being Compared			
A. Aggregate Sample of Survey Respondents						
January 1, 1969	+	+	+	+	+	0
July 1, 1969	+	+	0	+	0	-
October 1, 1970	+	+	+	+	+	+
January 1, 1972	0	+	+	0	+	+
January 1, 1972 "Boss" subsample	0	0	+	0	+	+
B. Subset of Respondents Who Did Not Perceive a Particular Maturity Range as Attractive for Investment						
January 1, 1969	+	+	+	+	+	+
July 1, 1969	+	+	0	0	0	0
October 1, 1970	+	+	+	+	+	0
January 1, 1972	0	0	+	0	+	+
January 1, 1972 "Boss" subsample	0	0	+	0	+	+

CODE: + : Term premium is significantly larger (at 5 %) for the longer-maturity premium.

0 : Difference in term premia is not significant (at 5 %).

- : Term premium is significantly smaller (at 5 %) for the longer-maturity premium.

TABLE 6

OUTCOME OF MANN-WHITNEY TESTS FOCUSED ON WHETHER VALUES OF THE TERM PREMIA VARY ACROSS SAMPLE DATES

Maturity, k	Pair of Survey Dates Being Compared					
	(1-69,7-69)	(1-69,10-70)	(1-69,1-72)	(7-69,10-70)	(7-69,1-72)	(10-70,1-72)
	A. Aggregate Sample of Survey Respondents					
1/2 Year	+	+	+	+	+	+
1 year	+	+	0	0	+	+
2 years	+	+	+	0	+	+
10 years	0	+	+	+	0	+
	B. Subset of Respondents Who Did Not Perceive A Particular Maturity Range as Attractive for Investment					
1/2 year	+	+	+	+	+	+
1 year	+	+	0	0	+	+
2 years	+	+	+	0	+	+
10 years	0	0	0	0	0	+

CODE: + : Observed difference in T_k is statistically significant (at 5 %) across the pair of survey dates.

0 : Observed difference is not statistically significant (at 5 %).

Table 7

PARALLEL TIME-SERIES MEASUREMENTS
OF TERM PREMIA
(in basis points)

A. Calculated by McCulloch from (1975a, Table 6) Estimates of "Mean Liquidity Premia," March 4, 1951 to March 31, 1966

Maturity k	McCulloch Free-Form Estimate	McCulloch Outside Limits for Exponential-Form Estimate		Mean Value in Four Kane-Malkiel Surveys
		Lower Limit	Upper Limit	
1/2 year	9	3	15	31
1 year	15	7	22	49
2 years	19	11	27	60
10 years	22	12	31	68
Summary Description of Qualitative Pattern	Increasing	Increasing		Increasing

B. Values of Term Premia Near Three Survey Dates, Estimated from Unpublished Worksheets as Cumulative Arithmetic Averages of Liquidity Premia Estimated by Pesando (1975).

Maturity k	December 1, 1968	June 1, 1969	September 1, 1970	Mean
1/2 year	14	47	51	37
1 year	-10	36	58	28

TABLE 8

Changes in U.S. Treasury Yields During the Two Months
Following Each Survey Date

(in basis points)

	Maturity			
Post-Survey Months	1/2 year	1 year	2 years	10 years
January 1969	-4	-2	-6	+5
February 1969	+5	+7	+12	+15
July 1969	+32	+24	+17	0
August 1969	-15	+8	+1	+12
October 1970	-16	-25	-19	+8
November 1970	-103	-115	-124	-78
January 1970	-28	-15	+13	+23
February 1972	+5	+9	-6	-2

Source: Salomon Brothers (1974), pp. 16-18.

TABLE 9

Postmortem Calculation of Capital-Gains Bias
(in percent per annum)

Survey Date	10-Year Yield Reported by Salomon Brothers (assumes a 4.25% coupon)	Coupon Rate that Would Offer the Same After-tax Yield to a Corporate Investor*	Estimated Bias
January 1, 1969	5.95	6.80	.85
July 1, 1969	6.45	7.55	.90
October 1, 1970	7.11	8.25	1.14
January 1, 1972	5.96	6.64	.68

*This calculation employs a 50 percent tax rate on coupon income and a capital-gains rate of 25 percent in 1969 and 30 percent in 1970 and 1972. No allowance is made for the deferral of capital-gains taxes.

Cook and Hendershott's (1978) monthly average "new-issue equivalent U.S. bond yields" for the survey months show the following values (in percent): 6.85, 6.88, 7.81, 6.71.

APPENDIX

QUESTIONNAIRE ON INTEREST-RATE FORECASTS
(Abbreviated Version)

(1) For each of the following future dates, what are your best estimates of
(a) the range between which yields on 90 day Treasury bills will lie and
(b) the single most likely value for the yield which will prevail?

	Range	Most Likely Value
April 1, 1972:	Between ______ % and ______ %	______ %
July 1, 1972:	Between ______ % and ______ %	______ %
Oct. 1, 1972:	Between ______ % and ______ %	______ %
Jan. 1, 1973:	Between ______ % and ______ %	______ %
April 1, 1973:	Between ______ % and ______ %	______ %
July 1, 1973:	Between ______ % and ______ %	______ %
Oct. 1, 1973:	Between ______ % and ______ %	______ %
Jan. 1, 1974:	Between ______ % and ______ %	______ %

(2) For each of the following dates, please provide the same information for 10-year U. S. government bonds.

	Range	Most Likely Value
Jan. 1, 1972:	Between ______ % and ______ %	______ %
Jan. 1, 1973:	Between ______ % and ______ %	______ %
Jan. 1, 1974:	Between ______ % and ______ %	______ %

(3) For both the 90-day Treasury bill rate and the 10-year U. S. government bond rate mentioned in question 2, please indicate your estimate of the average rate over the next 10 years.

	Range	Most Likely Value
I expect the average rate on 90-day Treasury bills over the next 10 years to be	Between ______ % and ______ %	______ %
I expect the average rate on 10-year U. S. government bonds over the next 10 years to be	Between ______ % and ______ %	______ %

(4) Do you feel that, at the present time, there is a maturity range of Treasury securities which is particularly attractive?

(a)______ Yes, the maturity range from ______ years ______ months to ______ years ______ months is especially attractive for investment.

(b)______ No, prices in all maturity ranges are pretty much in line.

(c)______ Other, please elaborate: ______________________________

(9) Does your firm have an Investment Committee that meets to make portfolio decisions? ______________

(10) Are you a member of this Committee, or otherwise responsible for portfolio decisions? ______________

Appendix Table 1

Input for Alternative Calculations of Term Premia

1. Calculated Mean Ex Ante Bill Rates for Aggregate Sample of Survey Respondents

	6-month	1-year	2-year	10-year
January 1, 1969	6.14	5.88	5.69	5.37
July 1, 1969	6.49	6.36	6.10	5.71
October 1, 1970	5.81	5.74	5.78	5.92
January 1, 1972	3.76	4.05	4.49	5.17

2. Conversion of Quarterly Mean Ex Ante Bill Rates from Three-Month Bank-Discount Rates to Continuously Compounded Yields*

January 1, 1969	6.27	6.01	5.81	5.48
July 1, 1969	6.63	6.50	6.23	5.83
October 1, 1970	5.93	5.86	5.90	6.05
January 1, 1972	3.83	4.13	4.58	5.28

3. Continuously Compounded Market Yields on Hypothetical Single-Payment Bonds (Calculated in Percent Per Annum by J.H. McCulloch**)

January 1, 1969	6.56	6.62	6.59	6.42
July 1, 1969	7.20	7.67	7.49	6.59
October 1, 1970	6.54	6.60	6.68	7.30
January 1, 1972	4.03	4.29	4.83	5.97

4. Estimates of Aggregate-Sample Term Premia, Derived by Subtracting Figures in Panel 2 from Corresponding Entries in Panel 3 (in Basis Points)

	Jan.1,1969	July 1,1969	Oct.1,1970	Jan.1,1972
6 months	29	57	61	20
1 year	61	117	74	16
2 years	78	126	78	25
10 years	94	76	125	69

*These yields are converted from three-month bank-discount rates, d, to continuously compounded yields by the formula

$$R = \frac{-36500}{90}\ln(1-\frac{90}{36000}\ d).$$

**Calculated from preceding-day closing quotations via McCulloch's computer program (based on 1975b), which is available through the NBER.

REFERENCES

Bierwag, Gerald O., and Myron A. Grove. "Model of the Term Structure of Interest Rates," Review of Economics and Statistics, 49 (Jan. 1967), 50-62.

Cagan, Phillip, "A Study of Liquidity Premiums on Federal and Municipal Government Securities," in J. Guttentag and P. Cagan (ed.), Essays on Interest Rates, Vol. I, New York: National Bureau of Economic Research, 1969, pp. 107-142.

Cook, Timothy Q., and Hendershott, Patric H., "The Impact of Taxes, Risk and Relative Security Supplies on Interest Rate Differentials," Journal of Finance, 33 (Sept. 1978), pp. 1173-1186.

Cox, John C., Ingersoll, Jonathan E., Jr. and Ross, Stephen A., "A Theory of the Term Structure of Interest Rates," Stanford University Graduate School of Business (mimeographed, August 1978).

Diller, Stanley, "Expectations and Term Structure of Interest Rates," in J. Mincer (ed.), Economic Forecasts and Expectations, New York: Columbia Univ. Press for the NBER, 1969.

Fama, Eugene F., "Forward Rates as Predictors of Future Spot Rates," Journal of Financial Economics, 3 (Dec. 1976), pp. 361-377.

Friedman, Benjamin M., "Interest Rate Expectations Versus Forward Rates: Evidence From an Expectations Survey," Journal of Finance, 34 (Sept. 1979), 965-973.

Green, H. A. J., "Uncertainty and the 'Expectations Hypothesis'," Review of Economic Studies, 34 (Oct., 1967), pp. 387-398.

Hicks, John R., Value and Capital (2nd ed.), London: Clarendon Press, 1946.

Hirshleifer, Jack, "Liquidity, Uncertainty and the Accumulation of Information," in C. F. Carter and J. L. Ford (ed.), Uncertainty and Expectation in Economics: Essays in Honor of G. L. S. Shackle, Kelley, 1972.

Kane, Edward J., and Malkiel, Burton G., "The Term Structure of Interest Rates: An Analysis of a Survey of Interest-Rate Expectations," The Review of Economics and Statistics, 46 (August, 1967), 343-355.

Kane, Edward J., "The Term Structure of Interest Rates: An Attempt to Reconcile Teaching with Practice," Journal of Finance, 25 (May, 1970), 361-374.

Kane, Edward J., Market Incompleteness and Divergences Between Forward and Futures Interest Rates," Journal of Finance, 35 (May, 1980), pp. 221-234.

Kessel, Reuben A., The Cyclical Behavior of the Term Structure of Interest Rates, New York: National Bureau of Economic Research, 1965.

Lutz, F. A., "The Structure of Interest Rates," Quarterly Journal of Economics, 55 (Nov., 1940), 36-63.

Malkiel, Burton G., "Expectations, Bond Prices, and the Term Structure of Interest Rates," Quarterly Journal of Economics, 76 (May 1962), pp. 197-218.

Malkiel, Burton G., and Kane, Edward J., "Expectations and Interest Rates: A Cross-Sectional Test of the Error-Learning Hypothesis," Journal of Political Economy, 77 (July/August, 1969), 453-470.

McCulloch, J. Huston, An Estimate of the Liquidity Premium, Unpublished Doctoral Dissertation, The University of Chicago, 1973.

McCulloch, J. Huston, "An Estimate of the Liquidity Premium," Journal of Political Economy, 83 (Jan./Feb., 1975), pp. 95-119. (a)

McCulloch, J. Huston, "A Tax-Adjusted Yield Curve," Journal of Finance, 30 (June, 1975), pp. 811-830. (b)

Meiselman, David, The Term Structure of Interest Rates, Englewood Cliffs, N.J.: Prentice-Hall, 1962.

Modigliani, Franco, and Sutch, Richard, "Innovations in Interest Rate Policy," American Economic Review (Papers and Proccedings), 56 (May, 1966), 178-97.

Nelson, Charles R., "Testing a Model of the Term Structure of Interest Rates by Simulation of Market Forecasts," Journal of the American Statistical Association, 65 (September, 1970), pp. 1163-1179.

Nelson, Charles R., "Estimation of Term Premiums From Average Yield Differentials in the Term Structure of Interest Rates," Econometrica, 40 (March, 1972), pp. 277-287.

Pesando, James E., "Determinants of Term Premiums in the Market for United States Treasury Bills," Journal of Finance, 30 (December 1975), pp. 1317-1327.

Pesando, James E., "On the Random-Walk Characteristics of Short- and Long-Term Interest Rates in an Efficient Market," Journal of Money, Credit and Banking, 11 (November 1979), pp. 457-466.

Phillips, Llad, and Pippenger, John, "The Term Structure of Interest Rates in the MIT-Penn-SSRC Model: Reality or Illusion?," Journal of Money, Credit and Banking, 11 (May 1979), pp. 151-164.

Pye, Gordon, "On the Tax Structure of Interest Rates," Quarterly Journal of Economics, 83 (November, 1969), 562-579.

Roberts, Gordon S., "Term Premiums in the Term Structure of Interest Rates," Journal of Money, Credit and Banking, 12 (May 1980), pp. 184-197.

Robichek, Alexander, and Niebuhr, W. David, "Tax-Induced Bias in Reported Treasury Yields," Journal of Finance, 25 (December, 1970), pp. 1081-1090.

Roll, Richard, "Investment Diversification and Bond Maturity," Journal of Finance, 26 (Mar. 1971), 51-66.

Ross, Stephen A., "Return, Risk, and Arbitrage," in I. Friend and J. L. Bicksler (ed.), Risk and Return in Finance, Volume I, Cambridge, MA: Ballinger, 1977, pp. 189-218.

Salomon Brothers, An Analytical Record of Yields and Yield Spreads, New York: 1974.

Sargent, Thomas J., "A Classical Macroeconometric Model for the United States," Journal of Political Economy, 84, No. 2 (April 1976), 207-237.

Sargent, Thomas J., "A Note on Maximum Likelihood Estimation of the Rational Expectations Model of the Term Structure," Journal of Monetary Economics 5 (March 1979), pp. 133-143.

Siegel, Stanley, Nonparametric Statistics for the Behavioral Sciences, New York: 1956.

Stiglitz, J.E., "A Consumption-Oriented Theory of the Demand for Financial Assets and the Term Structure of Interest Rates," Review of Economic Studies 37 (Jul. 1970), 321-350.

Tuttle, Donald L., Lee, Wayne L. and Terry S. Maness, "Stochastic Cash Flow Constraints and the Term Structure of Interest Rates," Journal of Banking and Finance 2 (August 1978), 143-162.

Van Horne, James C., "Interest Rate Risk and the Term Structure of Interest Rates," Journal of Political Economy 73 (Aug. 1965), 344-351.