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Modeling Long-Term Government Bond Yields

An Efficient Market Approach

Paul Sundell
Mark Denbaly
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Abstract

Movements in long-term Treasury bond (T-bond) rates directly influence interest rate sensitive sectors such as agriculture. More specifically, T-bond yields underpin private intermediate and long-term lending rates such as long-term agricultural mortgage and farm equipment loans. Because of this, forecasts of long-term lending rates for agriculture must begin with forecast assumptions concerning the T-bonds. This report builds upon previous empirical work that indicates term premiums on bonds are variable and partly predictable over time. The model developed here also accounts for increasing globalization of financial markets and the increased substitutability of foreign and U.S. bonds. This report constructs a model for generating forecasts of T-bond rates that can be used as an input in predicting specific agricultural long-term interest rates.

Keywords: Yield to maturity, forward rates, term premiums, real exchange rate, real foreign bond rates, unit roots, dynamic forecasts.
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Modeling Long-Term Government
Bond Yields

An Efficient Market Approach

Paul Sundell
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Introduction

The level and determination of real long-term interest rates have important implications for the
general economy in the areas of business investment, productivity, monetary policy, and the efficient
allocation of resources. Movements in the long-term Treasury bond (T-bond) rates directly influence
interest rate sensitive sectors such as agriculture. More specifically, T-bond yields underpin the rates
charged on long-term agricultural mortgage and farm equipment loans. Because of this, forecasts of
long-term lending rates for agriculture typically are based upon forecast assumptions concerning the
T-bonds.

Previous empirical work by many researchers (including Shiller, Campbell, and Schoenholtz; Fama
(1984); Fama and Bliss; Mankiw; and Mankiw and Summers) provides strong evidence that term
premiums are variable. However, there is little empirical work incorporating the effects of
globalization of bond markets across major industrialized countries. In this report, we construct a
model of the monthly change in the 10-year constant maturity T-bond rates that incorporates known as
well as unexpected information, including international information, believed to influence long-term
bond rates. The model produces forecasts for long-term bond rates that can be used as an input in
forecasting specific agricultural long-term interest rates.

A linear, efficient market term structure equation is used to model long-term T-bond interest rate
determination. The model accounts for the effects of known and unexpected economic information on
the term structure. The known and unexpected variables are discussed in the model specification
section. The known information variables are viewed as primarily affecting shortrun movements in
the term-premium component of long-term bond yields. The unexpected information variables
influence the path of the expected short-term interest rates, as well as their term premiums. In the
empirical analysis section, data construction and sources are first discussed. Next, unit root tests are
conducted to ensure that the standard statistical inference procedures are valid. Estimates of the
model are presented for the 1980.01-1989.12 period, using ordinary least squares (OLS), Cochrane-
Orcutt, and Fair's two-stage procedures. Finally, the dynamic forecasts for the 12 months of 1990
are obtained to validate the model.
Model Specification

Long-term bond rates are modeled using the liquidity premium version of the expectations hypothesis. The hypothesis is that the yield on a long-term zero-coupon bond $R_n$ is equal to the geometric average of the current short-term rate ($r_i$) and known forward rates ($f_2, \ldots, f_n$).

$$R_n = [(1+r_1)(1+f_2)\ldots(1+f_n)]^{1/n} \quad (1)$$

Forward rates are loan rates negotiated at time $t$ that begin at specified times in the future. The liquidity premium version of the expectations hypothesis decomposes the forward rate into a short-term rate that is expected to prevail at a particular time in the future and a term premium that compensates lenders for the increased price volatility of long-term securities.\(^1\) Thus, any variable or event that alters current short-term rates or expected forward rates will cause long-term T-bonds to change.

In addition to the liquidity premium hypothesis, the theoretical formulation of the model is based upon the efficient-markets propositions that prices and holding period returns of financial assets respond quickly to publicly available information and that changes in bond rates are dominated by new (unexpected) information. Pesando, and Berger and Craine show that, when markets are efficient, movements in zero-coupon, long-term bond rates follow (to a very close approximation) a random walk if liquidity premiums are nonexistent or constant over time. Based on this finding, Dwyer and Hafer, Mishkin, Robinson, and Phillips and Pippenger model the change in the long-term bond rate (or returns) as a function of unexpected information represented by changes in one or more of the following variables: short-term money market rates, unemployment rate, industrial production, inflation, and the money supply.

The random walk characterization of movements in long-term interest rates is not strictly valid for two reasons. First, relatively few bonds are zero or near-zero coupons. In the case of coupon bonds, the weights given the forward rates decline with the time to commencement of the forward rate. Therefore, the expected path, as well as the expected average level of short-term interest rates will matter in the determination of bond yields (Pesando and Shiller). Second, most empirical studies have demonstrated that term premiums vary over time.\(^2\) If changes in term premiums are partly predictable, then changes in long-term interest rates should have a partly predictable component as well. Therefore long-term bond rates evolve through time as a function of both known or expected information as well as unexpected information.

$$\Delta R_t = f(\text{known or expected and unexpected information}) \quad (2)$$

Term-Premium and Known Information Variables

Theory and empirical work on the term structure of interest rates indicate that, as the likelihood of significantly higher long-term bond rates increases, term premiums rise (Van Horne, ch. 5, and Cook and Hahn, p. 22). In addition, as expected bond market volatility increases, term premiums and yields will tend to rise. Term premiums and holding period yields have been tied empirically to information known to agents at the beginning of the investment period. Some of the variables used in these studies include measures of recent interest rate volatility, current levels of bond yields relative

\(^{1}\)Cox, Ingersol, and Ross have shown that the zero forward premium version of the expectations model is incompatible in terms of bond pricing with the zero-holding period premium version of the expectations hypothesis. Campbell argues that the differences in terms of bond yields, holding premiums, and forward rate expected spot rate spreads implied between the two theories, especially in the case of positive holding premiums, are small and may be safely ignored for most empirical applications.

\(^{2}\)For a recent survey and critique of the literature on liquidity and average-term premiums see Cook and Hahn. They conclude that such premiums are highly variable.
to their past normal ranges, and the slope of the yield curve. We use three variables to explain the term premiums: last month’s yield spread between Treasury bonds and bills, the expected change in the 1-month bill rate, and last month’s change in the long-term bond rate. These variables capture the near-term effect on long-term bond yields and their term premiums of short- and long-term interest rate expectations, as well as general interest rate uncertainty.

Expected Signs of the Known Explanatory Variables

In discussing the expected signs of the known information variables, by the rational expectation assumption, we assume the known information variables are orthogonal to the unexpected information variables. Therefore, assuming orthogonality, the expected signs of the known variables should not depend on the choice of unexpected variables. However, by including proxies for unexpected information, the estimates of the coefficients for the known information variables should be more efficient, reflecting the smaller standard error of the regression. In examining the actual data set used, we found the correlations between the known information variables and the unexpected information variables to be small.

The yield-spread variable provides information on both the expected movements of long-term interest rates and the level of term premiums. If the premiums are relatively stable over time, abnormally large yield spreads will reflect expectations of rising long-term interest rates (Shiller, and Mankiw and Summers). However, if term premiums are highly variable, abnormally large yield spreads may merely reflect large premiums in the term structure and not expectations of rising long-term interest rates. Therefore, the expected sign of the spread parameter is indeterminate.

Shiller, and Mankiw and Summers found empirically that, for various sample periods and data frequencies, abnormally large yield spreads preceded declining long-term interest rates, indicating the presence of large term premiums in the term structure. Recent empirical studies of term premiums on bonds have corroborated these findings. Fama and French, and Fama (1990) found average term premiums on Treasury and private bonds to be positively related to bond-money market yield spreads.

The expected change in the 1-month T-bill rate contains information about very-short-term expected changes in money market interest rates. If short-term interest rates are expected to increase in the near future, bond yields may be pushed up through two channels. First, term premiums may be positively related to the current level of interest rates, reflecting the better substitutability of short-term securities for money in times of rising interest rates (Kessel). Second, near-term expected interest rate increases may push up bond yields because near-term forward rates receive greater weight in coupon-bond yield determination than forward rates far in the future. Therefore, the estimated coefficient is expected to have a positive sign.

The previous month’s change in the long-term rate is used as an additional proxy for market uncertainty influencing bond yields. Investors are never certain about the exact structure generating returns. In times of rising bond rates caused by negative news, term premiums may increase to compensate investors for increased uncertainty. If bond yields begin to stabilize as no additional shocks occur, bond yields may begin to fall as term premiums decrease with reduced uncertainty. Therefore, the estimated parameter for this variable is expected to be negative.

Unexpected Information

Four variables in our model capture the effect of domestic and foreign new information on T-bond yields: 1) the change in the real foreign bond rate, 2) the change in the 3-month forward rate, 3) the change in the real exchange rate, and 4) the change in the unemployment rate. These variables
are proxies for real foreign bond shocks, inflation, and real shocks that contain important new information for the bond market.

During the 1980’s, foreign bonds became increasingly closer substitutes for domestic bonds. The greater substitutability occurred for two reasons. First, theoretical work in portfolio management theory in the 1970’s showed that higher expected returns with reduced risk were obtainable for portfolios that diversified into foreign assets. By the 1980’s, international portfolio diversification had become prevalent first at the institutional level and then at the individual level, primarily through mutual funds designed for small investors. Second, an investor may cover the currency risk of foreign bond cash-flows for intermediate-term foreign bonds by using currency and bond swaps.3

Most empirical studies of real interest rate movements across countries have been limited to the money market.4 Our study is unique in that it incorporates the effect of changing real foreign bond yields on U.S. bond yields. Our model includes the change in the real foreign bond yield for the non-U.S. G7 countries (Britain, France, Germany, Italy, Canada, and Japan). An increase in the real foreign bond rate will put an upward pressure on U.S. real bond rates by causing capital to flow out of the United States. The estimated sign is, consequently, expected to be positive.

It is important to distinguish nominal and real movements in foreign bond yields. Increases in nominal foreign bond rates caused by higher inflation or inflationary expectations, which leave real foreign bond yields unchanged, will primarily generate an adjustment in the nominal exchange rate with little effect on U.S. bond yields. In this case, higher current foreign inflation (or expectations of higher foreign inflation) will generate a contemporaneous depreciation of the foreign currency.5

Short and long-term bonds react to much of the same current information set, although long-term bonds are much more forward looking. Therefore, the change in the 3-month forward rate serves as a summary variable for much of the relevant new short-term domestic information and money market shocks that influence both short- and long-term interest rates.

The change in the money market conditions variable may convey more information than including many proxies for unexpected changes in economic time series such as real output, inflation, and money growth. The unexpected economic time series proxy procedure is likely to be inefficient for two reasons. First, the reaction of short- and long-term rates to real, nominal, and financial information is not likely to be a simple linear process of expected and unexpected information. The interpretation of one economic release depends in part upon the information in other economic releases. Therefore, efficient-market models that regress the change in long-term yield on unexpected information are likely to ignore the joint influence of individual economic news. Second, as pointed out by Belongia and Sheehan, correctly anticipated movements still reveal information about the current state of the economy and whether movements in various series are best viewed as transitory or permanent. Therefore, even correctly anticipated information contains information that may influence interest rates.

See Popper for a theoretical and empirical discussion of hedging foreign bond portfolios with currency and bond swaps. Popper indicates that bond and currency swaps are available to hedge currency risk on most major industrialized country bonds up to a maturity of 7 years.

Empirical work by Cumby and Mishkin, and Whitt showed strong co-movements in real short-term interest rates across countries. Husted and Kitchen found that German money market rates responded positively to U.S. money surprises. Increases in real foreign money market rates can be expected to raise real foreign bond rates through their effect on expected future real foreign short-term interest rates.

Some small effects on U.S. bond rates may be generated, such as changes in the perceived relative riskiness of foreign bonds as foreign inflationary expectations increase. However, these effects are likely to be small, especially for modest changes in foreign inflationary expectations.
A change in the 3-month forward T-bill rate is composed of a change in the expected nominal 3-month T-bill rate and a change in the 3-month forward premium. The effect of an unexpected rise in the T-bill forward rate on longer term forward rates will depend on how much longer term forward rates are revised. The more intermediate- and longer term forward rates are revised in response to unexpectedly higher short-term money market forward rates, the greater will be the effect of a money market shock on long-term bond rates.

Bond yields are influenced differently by rising nominal short-term interest rates caused by rising inflationary expectations than by higher real ex-ante real interest rates. The differing effects of short-term inflationary expectations and real ex-ante short-term interest rates were first noted by Modigliani and Shiller in 1973. They found that a rise in short-term nominal interest rates caused by an increase in expected inflation had a greater effect on long-term bond rates than an equal increase in short-term interest rates due to higher ex-ante real short-term interest rates.

Modigliani and Shiller attributed this greater inflationary effect on long-term interest rates to the relatively greater persistence of inflation over time. The greater persistence of inflation causes an inflationary shock to generate a greater increase in intermediate-term inflationary expectations and forward rates. Fama (1990) recently confirmed the greater persistence of inflation. He found that autocorrelations for annual inflation were larger and decayed more slowly than autocorrelations of ex-post real returns for 1-year bonds.

Rational forecasts of future forward rates must reflect the differing dynamics of inflation and real interest rates. Long-term bond rates and long-term forward rates should, consequently, be affected less by an increase in short-term interest rates caused by rising ex-ante real rate than increased short-term inflationary expectations.6

Our model extends the work of Modigliani and Shiller on the relative effects of real and inflationary money market shocks on long-term bond rates. The Modigliani and Shiller model is naive in that long-term bond rates are determined only by distributed lags of current and past values of short-term rates and inflation. By including the effects of other relevant information, such as changes in real foreign bond rates and the unemployment rate, as well as known information believed to influence forward rate premiums, our model provides a stronger test of real and inflationary money market shocks.

In the present model, real interest rate effects are accounted for by real foreign bond rates, real exchange rates, and the unemployment rate. Thus, holding real variables constant, the forward T-bill rate primarily reflects short-term inflationary expectations. Therefore, the expected sign for the coefficient on the forward rate variable is positive.

Theoretical and empirical work on exchange rate determination has shown that shortrun movements in real exchange rates are dominated by changes in relative long-term real interest rates across countries. The portfolio balance models of real exchange rate determination (Branson, and Hutchison and Pigott), as well as the dynamic monetary model (Dornbusch), predict a sharp initial overshooting of the real value of the dollar in response to a rise in U.S. real interest rates relative to the rest of the world. Empirical evidence by Hardouvelis indicates that unanticipated domestic economic news that results in higher U.S. real interest rates results in a real appreciation of the dollar.

6The tendency of long-term bond rates to rise relatively less in response to rising real short-term rates is consistent with the steeply negative sloped yield curves and high real short-term interest rates observed in the early 1980's.
Empirical studies indicate that expected real returns on U.S. assets, including Treasury securities, vary inversely with expected inflation (Fama and Gibbons, and Fama 1990). Holding real foreign interest rates and currency risk premiums constant, rising U.S. real long-term interest rates will increase the real exchange rate. Therefore, upward movements in the real exchange rate generally reflect information about declining long-term inflationary expectations and rising real interest rates. In our model, with U.S. nominal short-term interest rates and foreign real interest rates held constant, a rising real exchange rate reflects expectations of lower future nominal U.S. short-term interest rates and, thus, lower bond rates.

Finally, an increase in the U.S. real exchange rates may influence U.S. long-term interest rates by indicating probable slower economic growth in the future. A sharp rise in the exchange value of the dollar is likely to slow intermediate-term output, as higher real exchange rates slow future net exports. Therefore, the expected sign of the exchange rate variable is unambiguously negative.

We examined other variables that could have an influence on T-bonds independent of the other variables in our model. Specifically, changes in domestic inflation, the unemployment rate, and industrial output were added to our model. If these series do not depart significantly from random walks, changes in these series are reasonable approximations of unanticipated movements in these series. We also tested whether past months' changes in these series influenced bond yields.

With the exception of the contemporaneous change in the unemployment rate, the inclusion of these additional variables was neither individually nor jointly significant. The independent significance of the change in the unemployment rate is probably due to its prominent role in the setting of monetary policy targets (Sundell, McNees, and Sheehan). Given the important role of the unemployment rate in the setting of Federal funds rate targets, an unexpected change in the unemployment rate will generally alter the expected path for short-term interest rates over a prolonged period. Through its large effect on expected future short-term interest rates, the change in the unemployment rate has an independent channel of influence.

**Empirical Analysis**

**Data Description**

We estimated our equation using monthly data from 1980.01 to 1989.12. The monthly frequency was chosen to minimize the time aggregation problems. Engle and Liu, and Black have argued that time aggregation problems are especially serious in dynamic models, such as the one here, where the relevant market adjusts quickly. For example, if adjustments occur over months rather than quarters, and the true model is a distributed lag over the current and the previous months, application of the model to quarterly data results in coefficients that are both biased and inconsistent. Therefore, monthly observations were chosen because for most of the series the shortest interval for which meaningful data can be obtained was a month. Table 1 describes sources and construction of the data.

---

7Many theoretical reasons have been given for the negative relationship between expected returns and inflation. First, expectations of higher inflation raises nominal interest rates, encouraging the dishoarding of money balances which, in turn, increases the supply of loanable funds (Tobin). Second, for given money growth, higher inflation reduces real output and investment demand (Fama and Gibbons). Finally, higher inflation may also generate greater uncertainty concerning future rate of inflation as well as greater tax distortions that reduce future investment and, thus, the overall demand for loanable funds.

8ARIMA models of changes in the unemployment rate, inflation, and industrial production explained 8, 17, and 31 percent of their respective variances. Therefore, especially for the unemployment and inflation series, their respective deviations from random walks were relatively minor. The deviation of the industrial production from a random walk was more pronounced. Results of using the residuals from the ARIMA models or changes in the explanatory variables were similar. Therefore, only the regressions involving the changes in the explanatory variables are reported.
Table 1—Data description and sources of explanatory variables

Yield spread, $S_{t-1}$:
Previous month’s spread between 10-year constant-maturity T-bond and 3-month T-bill rates (Board of Governors).

Change in long-term bond yield, $\Delta R_{t-1}$:
Previous month’s change in 10-year constant-maturity T-bond rate.

Change in 3-month T-bill forward rate, $\Delta R_3$:
Constructed, on a discount basis, from 6- and 3-month T-bills. 2

Expected change in 1-month bill rate, $\Delta R_{1,T}$:
Approximated by subtracting the current 1-month T-bill rate from the expected 2-month bill rate, which is calculated from the term structure. 3 Expected change in the 2-month rate was used because data on 2-month bill rates, hence the 1-month forward rates, are not available from Federal Reserve’s interest rate reports.

Percentage change in real value of the dollar, $\Delta E_t$:
Trade-weighted measure of real exchange rate (Board of Governors)

Change in real foreign bond yields, $\Delta R_F$:
Weighted average of non-U.S. real bond yields of Canada, Japan, Italy, Germany, France, and the United Kingdom. For each country, nominal yields were converted to real terms by subtracting an intermediate-term inflationary expectations proxy. The proxy is G7’s annualized rate of inflation using price level data for the preceding 24 and the following 12 months of any period. The real yields were weighted by each country’s share of non-U.S. G7 industrial production in 1985. Data were obtained from monthly issues of Main Economic Indicators and Main Economic Indicators Historical Statistics published by the OECD.

Change in civilian unemployment rate, $\Delta UR_t$:
Civilian unemployment rate from Department of Labor (preliminary estimate).

\[ \Delta \] is the difference operator.

1 All yields are measured at the end of the month.

2 The forward 3-month T-bill rate is equal to the following:
\[ \frac{(1+tb3)/(1+tb1)}{(1+tb6)/(1+tb3)-1} \]

3 The 2-month expected T-bill is calculated from previous 3- and 1-month bill rates as follows:
\[ (1+tb3)/(1+tb1)^2-1.0055 \]. The .0055 represents the estimated average term premium on a 3-month bill (Cook and Hahn). In deriving the expected change in the 1-month T-bill rate, the expected 1-month bill rate is assumed to be equal to the expected 2-month bill rate.

All explanatory variables, with exception of the T-bond/T-bill spread, are differenced. An ARIMA examination of these processes indicated that they are all stationary. For standard inference procedures to be valid, the dependent variable must also be stationary (Plosser and Schwert, pp. 642-3). Therefore, in the next section, the level of the long-term rate is tested for stationarity.

Stationarity Test: Unit Roots

To determine whether the rate is stationary, we apply the unit-root test procedure suggested by Dickey and Fuller. To implement the test, we estimated equation 3.
\[
\Delta R_t = \alpha + (\rho - 1)R_{t-1} + \sum_{i=1}^{k} \rho_i \Delta R_{t-i} + \epsilon_t
\]  

(3)

where \( \Delta \) is the difference operator, \( R \) is the end-of-the-month yield on constant-maturity 10-year government bonds, \( \alpha \) and \( \rho \)'s are parameters to be estimated, and \( k \) is the number of lags that ensures that the error term, \( \epsilon_t \), is white noise. The null hypothesis for a unit root requires that \( \rho = 1 \), indicating that the variable \( R \) is nonstationary; that is, its variance will explode in time.\(^9\) The statistic used, \( \tau_p \), is the usual t statistic calculated under the null hypothesis. However, it is not distributed as the standard studentized t (Fuller calculates the point distribution).

To determine the lag structure of equation 3, that is, \( k \), the results of Fuller’s proof (1976, ch. 8) were applied. Fuller shows that while limit distributions of OLS estimators of \( \alpha \) and \( \rho \) are not normal, although consistent, the distribution of such estimators for \( \rho_i \)'s converge in the limit to a multivariate normal. Consequently, ordinary t-test are valid and suggest one lag (\( k=1 \)) for equation 3. At -1.38, \( \tau_p \) failed, even at the 10-percent significance level, to reject the hypothesis that a unit root exists, indicating that variable \( R \) is nonstationary in levels. To ensure that a second unit root does not exist, we estimated the first-difference version of equation 3. At -7.77, the \( \tau_p \) test indicated that the first difference is stationary, even at the 1-percent level. Therefore, the dependent variable is \( \Delta R_t \).

**Estimation Results**

To capture the increasing globalization of the financial markets during the 1980's, we fitted the model to the 1980.01-1989.12 period. The OLS estimates are presented in table 2. All coefficients have the expected signs; and with the exception of the lagged dependent variable, they are all significant at the 10-percent level. However, the h-statistic suggests the presence of some positive autocorrelation. Application of the Cochrane-Orcutt procedure to correct for the autocorrelation produced the second column of table 2.\(^{10}\)

The results are similar to those generated by the ordinary least squares procedure. All the signs are the same and the fit is slightly better. Moreover, neither Durbin’s h statistic nor ARIMA modeling of the error term suggested a more complicated error structure.

Finally, to avoid the simultaneity bias caused by joint determination of U.S. and foreign bond rates, we applied Fair’s two-stage procedure. The results, shown in the last column of table 2, were similar to those of the Cochrane-Orcutt procedure. The effect of the forward rate was reduced slightly while the influence of the other explanatory variables generally increased slightly. While larger in absolute value, the coefficient of the foreign bond rate was not statistically larger, even at the 10-percent significance level.\(^{11}\)

\(^9\)Strictly speaking, if the alternative hypothesis cannot be rejected, certain additional conditions are needed for \( R \), to be stationary. (For a simple exposition of this and details of unit-root test procedures, see Dickey and others, appendix A.)

\(^{10}\)The use of the Cochrane-Orcutt procedure in a model with a lagged dependent variable and autocorrelated disturbances is not technically correct. Betancourt and Kelejian show that applying the Cochrane-Orcutt procedure to a serially correlated model with a lagged dependent variable will not necessarily yield consistent estimates. In this case, the Cochrane-Orcutt process may not converge to a global minimum. To ensure a global minimum is reached, the authors argue that a Hildreth-Lu grid search procedure should be used. We performed a grid search procedure on our GLS and Fair regressions. The grid search procedures indicated that the reported Cochrane-Orcutt regressions in these cases converged to global minimum squared errors. Therefore, by using the Hildreth-Lu grid search procedure and assuming the postulated model is correct, the parameter estimates should be consistent.

\(^{11}\)We acknowledge that other simultaneous relationships exist in the model, especially between the long-term bond and real exchange rates. However, the development of a fully simultaneous complete domestic and international model for long-term Treasury bond yield determination is beyond the scope of this report.
Table 2—Estimation results, 1980.01-1989.12

<table>
<thead>
<tr>
<th>Variable</th>
<th>OLS</th>
<th>Cochrane-Orcutt</th>
<th>Fair's 2SLS&lt;sup&gt;1&lt;/sup&gt;</th>
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<tr>
<td>Constant</td>
<td>0.00125</td>
<td>0.00141</td>
<td>0.0012</td>
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<td>t-stat</td>
<td>(2.78)</td>
<td>(2.47)</td>
<td>(1.82)</td>
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<tr>
<td>$S_{t-1}$</td>
<td>-0.0720</td>
<td>-0.0821</td>
<td>-0.0748</td>
</tr>
<tr>
<td>t-stat</td>
<td>(-3.72)</td>
<td>(-3.24)</td>
<td>(-2.70)</td>
</tr>
<tr>
<td>$AR_{t-1}$</td>
<td>-0.0790</td>
<td>-0.1328</td>
<td>-0.1752</td>
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<tr>
<td>t-stat</td>
<td>(-1.48)</td>
<td>(-2.19)</td>
<td>(-2.57)</td>
</tr>
<tr>
<td>$AR_{3,t}$</td>
<td>-0.4620</td>
<td>0.4552</td>
<td>0.4170</td>
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<tr>
<td>t-stat</td>
<td>(12.67)</td>
<td>(12.69)</td>
<td>(8.14)</td>
</tr>
<tr>
<td>$AR_{1,t}$</td>
<td>0.04481</td>
<td>0.0434</td>
<td>0.0517</td>
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<tr>
<td>t-stat</td>
<td>(1.77)</td>
<td>(1.74)</td>
<td>(1.92)</td>
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<tr>
<td>$AE_{t}$</td>
<td>-0.0272</td>
<td>-0.0310</td>
<td>-0.0364</td>
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<td>t-stat</td>
<td>(-2.35)</td>
<td>(-2.65)</td>
<td>(-2.71)</td>
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<td>$AR_{F,t}$</td>
<td>0.3356</td>
<td>0.3768</td>
<td>0.6912</td>
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<tr>
<td>t-stat</td>
<td>(2.46)</td>
<td>(2.70)</td>
<td>(2.03)</td>
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<tr>
<td>$AR_{R,t}$</td>
<td>-0.0031</td>
<td>-0.0031</td>
<td>-0.0032</td>
</tr>
<tr>
<td>t-stat</td>
<td>(-2.46)</td>
<td>(-2.53)</td>
<td>(-2.49)</td>
</tr>
<tr>
<td>rho</td>
<td>—</td>
<td>0.2004</td>
<td>0.2170</td>
</tr>
<tr>
<td>t-stat</td>
<td>—</td>
<td>(1.68)</td>
<td>(1.86)</td>
</tr>
<tr>
<td>Adj. R&lt;sup&gt;2&lt;/sup&gt;</td>
<td>.74</td>
<td>.74</td>
<td>.73</td>
</tr>
<tr>
<td>St. error</td>
<td>.002844</td>
<td>.002818</td>
<td>.002882</td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>1.67</td>
<td>1.92</td>
<td>1.87</td>
</tr>
<tr>
<td>h-statistic</td>
<td>2.20</td>
<td>.62</td>
<td>1.04</td>
</tr>
</tbody>
</table>

<sup>1</sup>Fair's procedure consisted of regressing the endogenous right-hand side variable on the lagged dependent variable, the lagged endogenous variables, and current and 1-period lagged exogenous variables. The additional first stage variables included the contemporaneous and lagged real G7 money supply growth, the percentage change in industrial production as well as lagged changes in G7 yield spreads. The first-stage variables were chosen because of their theoretical relationship to the world bond rate, their ability to empirically explain changes in real world bond rates, and the availability of data.

The negative coefficient of the spread variable is consistent with the term-structure model where a steeply positive yield curve primarily reflects high term premiums. The finding of a negative coefficient on the yield spread is consistent with the empirical findings of Shiller, Campbell and Shiller, and Shiller, Campbell, and Schoenholtz. Therefore, the view that, in general, positively sloped yield curves predict declining Treasury bond yields is supported.

The 3-month forward rate is the most significant term. Nearly 46 percent of the changes in the forward rate is passed onto the long-term rate within a month. The second largest coefficient belongs to the real foreign bond rate. Roughly 38 percent of the movement in the real foreign bond yields is passed on to U.S. bond yields within a month.
Overall, the empirical results suggest that changes in Treasury bond rates contain both predictable and unpredictable components. The predictable component reflects predictable changes in term premiums as well as the presence of bond coupon payments. The unexpected change component reflects real and nominal money market interest rate shocks as well as real foreign bond shocks.

Model Validation: Out-of-Sample Forecasts

Poor out-of-sample forecasts often reflect omitted variables or misspecified dynamics. To test the validity of the model, yields for each month of 1990 were forecast in a dynamic simulation.

As figure 1 demonstrates, the model captured the three turning points during this period. Second, the dynamic forecast error was 15.35 basis points compared with the in-sample standard error of 28.18. Third, the mean absolute percentage error for the level of the bond rate was 0.096 percent. Finally, forecast bias was examined more formally by using a standard parametric test. The procedure required regressing the forecast errors on the actual forecasts. A significant constant term indicates a constant bias while a significant coefficient on the forecast term indicates that the bias varies with forecasts. The coefficients were neither individually nor collectively significant, indicating that such bias did not exist.

Conclusions

In this analysis, an econometric model for long-term T-bond yields was developed and estimated. The formulation allows for the effects of nominal and real shocks. The specification follows the earlier research that finds the unanticipated news to have the dominant role in determining prices of and returns to financial assets. The unexpected news was represented by current changes in the 3-month forward T-bill rate, real exchange rates and real foreign bond rates, and the unemployment rate. The earlier research on the determination of T-bond yields is extended by recognizing that term premiums vary over time. Based on recent work, slope of the yield curve and change in the 1-month T-bill rate at the beginning of the month and the lagged dependent variable were included to account for fluctuations in the term premium.

The model was applied to monthly data covering the 1980-89 period. All estimated coefficients were statistically significant and had their expected signs. Estimated coefficients were used to generate dynamic forecasts for the 12 months of 1990. The model was capable of tracing the three turning points which occurred during this period and produced rather small random forecast errors.

T-bond yields create a floor on long-term interest rates. Other long-term bond rates and loan rates will be above comparable Treasury yields, reflecting their default risk, risk premiums, and lower liquidity. Therefore, T-bonds underpin the private structure of farm credit securities as well as farm equipment and mortgage loans. Movements in real agricultural short-term interest rates and nonagricultural real short-term rates were found to be correlated in the 1980's by Mishkin. Because of this, forecasts of long-term lending rates for agriculture must begin with some forecast assumptions.
concerning T-bond yields. This report provides a useful model for generating forecasts of T-bond rates that can be used to predict specific agricultural long-term interest rates.

References


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