The Macroeconomy and Long-Term Interest Rates: An Examination of Recent Treasury Yields

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Abstract
From 2001 to 2006, U.S. long-term interest rates have remained steady while the federal funds rate has both declined and increased, as Figure 1 shows. Historically, long term interest rates tend to respond to changes in short term rates, but recently this does not appear to be the case. Former chairman of the Federal Reserve, Alan Greenspan, recently dubbed this occurrence a “conundrum,” because no one can provide a distinct explanation concerning this phenomenon. There are several noteworthy incentives for why long-term yields should have increased from 2004 to 2006, but they have remained constant during this time period. According to current economic theory, the U.S. budget deficit, the Federal Open Market Committee’s (FOMC) recent increases in short term rates, the latest recovery from recession, and the hefty current account deficit should all be contributing to higher long-term rates. Despite these macroeconomic influences, rates have not responded. Therefore, a supplementary force(s) must be creating a substantial impact. For example, this trend may be explained by a decrease in interest rate volatility, the Federal Reserve’s ability to maintain low inflation expectations, or an increase in foreign demand for U.S Treasuries. Is the ten-year Treasury yield truly a conundrum, or have macroeconomic influences caused long-term interest rates to maintain at an appropriate level? [excerpt]

Keywords
interest rate, deficit, Federal Open Market Committee, macroeconomics
The Macroeconomy and Long-Term Interest Rates: An Examination of Recent Treasury Yields

Hans W. Hardisty

INTRODUCTION

From 2001 to 2006, U.S. long-term interest rates have remained steady while the federal funds rate has both declined and increased, as Figure 1 shows. Historically, long term interest rates tend to respond to changes in short term rates, but recently this does not appear to be the case. Former chairman of the Federal Reserve, Alan Greenspan, recently dubbed this occurrence a “conundrum,” because no one can provide a distinct explanation concerning this phenomenon. There are several noteworthy incentives for why long-term yields should have increased from 2004 to 2006, but they have remained constant during this time period. According to current economic theory, the U.S. budget deficit, the Federal Open Market Committee’s (FOMC) recent increases in short term rates, the latest recovery from recession, and the hefty current account deficit should all be contributing to higher long-term rates. Despite these macroeconomic influences, rates have not responded. Therefore, a supplementary force(s) must be creating a substantial impact. For example, this trend may be explained by a decrease in interest rate volatility, the Federal Reserve’s ability to maintain low inflation expectations, or an increase in foreign demand for U.S Treasuries. Is the ten-year Treasury yield truly a conundrum, or have macroeconomic influences caused long-term interest rates to maintain at an appropriate level?

Over the years, much has been written about interest rates and their interaction with macroeconomic variables. Both Ang and Piazzesi (2003), and Wu (2002) establish that macro changes affect the slope of the yield curve. Ang and Piazzesi confirm this argument with vector autoregression (VAR) analysis. They use inflation, latent variables, macro growth, and real activity regressors in their model. Their variables are able to explain up to 85% of the changes in bond yields. The authors ascertain that economic adjustments lead to greater alterations in short term securities, but they recognize that these variables influence long-term bonds as well. Wu (2002) also uses VAR analysis and finds that
monetary policy can explain a significant portion of the movements in interest rates. Wu’s paper establishes that the slope of the term structure is affected by monetary policy shocks after 1982 by using a six-variable VAR model. The variables used in the paper include the federal funds rate, industrial production, payroll employment, the PCE deflator, monetary aggregate, and a smoothed change in the index of sensitive material prices.

Diebold, Rudebush and Aruoba (2004) recognize that economists have produced a number of models that attempt to explain interest rates, and they mention that these models often vary in “form and fit.” In their paper, they follow the work of Ang and Piazzesi (2003), Hördahl, Tristani, and Vestin (2002) and Wu (2002), to build a model that incorporates macroeconomic changes, and evaluate the connection between these alterations and the yield curve. They also use VAR analysis to confirm that the slope of the yield curve is affected by real activity, inflation, and monetary policy. In their investigation, they find strong confirmation that macroeconomic adjustments affect future interest rates and less evidence in favor of the yield curve affecting future macroeconomic changes.

Warnock and Warnock (2005) explain recent low long-term interest rates by investigating foreign flows into the U.S. Treasury market. They build a model that is similar to the one presented in Sack (2004). Their paper estimates an ordinary least squares (OLS) model that explains the ten-year Treasury yield using macroeconomic factors that are, according to current economic theory, likely to influence this yield. The six explanatory variables include: inflation and growth expectations, the budget deficit, the federal funds rate and a risk premium.

In this paper, I build on the previous work regarding interest rates and macroeconomic changes. I generate a six-variable OLS model that is similar to the one created by Warnock and Warnock (2005), and I focus on the ten-year Treasury yield. Unlike the Warnock paper I use ten-year-ahead inflation expectations as an explanatory variable. They proxy for inflation expectations by subtracting one year expectations from ten-year expectations. In addition, the survey data in my model derives from alternative sources.

With this model, I also use out-of-sample forecasting to confirm that recent long-term interest rates have been unusually low. I extend my assessment and use VAR analysis using the same macro variables. In general, the VAR estimations tend to agree with economic theory, and impulse response charts
show that the estimators respond in the anticipated direction immediately after a macro shock or several quarters after a shock. In addition, these graphs confirm that the variables react similarly to the OLS results. Finally, I use this VAR to do an additional out-of-sample forecast and reestablish that long-term interest rates are slightly lower than the model would have anticipated, but the model does a good job of predicting long-term interest rate levels.

Theories of the Term Structure

The term structure, also known as the yield curve, shows the relationship between the annual rate of return on an investment and maturity dates for a set of similar bonds, usually Treasuries, at a given point in time. The U.S. Treasury yield curve is used as an interest rate benchmark, because it is the most frequently used and analyzed. Many risks associated with other fixed income securities essentially do not exist with U.S. Treasuries. These bonds are issued by the U.S. government, and the United States has never defaulted on a Treasury payment. Consequently, there is negligible default and liquidity risk associated with the Treasury Market, which makes these securities the safest, and one of the most popular, investments in the world (Campbell 1995).

There are three theories that explain why the yield curve is shaped the way that it is: the unbiased expectations theory, the liquidity premium theory, and the market segmentation theory. Sanders (2004) explains that according to the unbiased expectations theory, long-term interest rates can be considered an average of current and expected future short term rates. The logic behind this argument is that investors can choose to invest their money in one of two different ways. If an individual wants to invest for 30 years, he can either opt to buy one 30 year bond and wait for it to mature, or each year he can buy 30 consecutive one year bonds. If investors expect short term interest rates to increase during the 30 years, then the yield on the 30 year bond should be higher than the short term bonds. If investors expect average short term rates to decline during the next thirty years then long term interest rates will fall. The general rules of supply and demand should make the returns between these two investment strategies identical. Saunders (2004) provided the equation below: where \( i_N \) is the actual rate today, \( N \) is the term to maturity, \( i_1 \) is the actual current one year rate, and \( E_N(R_1) \) are the expected future one year rates.
The liquidity premium theory is the same as the unbiased expectations theory, but accounts for a liquidity risk, which increases with the maturity of the bond. It states that investors would rather hold short term securities over long-term securities. Typically, the yield curve is upward sloping because a higher yield is required to entice investors to take on various risks associated with longer maturities and to persuade them to tie up their money for longer periods of time. The liquidity premium theory helps explain why long term interest rates tend to have higher yields. For example, the longer a person invests in a fixed income security the greater the chance that a period of high inflation will occur during the life of the bond. Since inflation reduces the value of an investment, higher yields are typically associated with long-term bonds. These premiums encourage investors to take on extra risk associated with uncertainty. The longer the term to maturity, the greater the likelihood that the security will see periods of higher short term yields. The uncertainty of future interest rates and inflation levels must be compensated for. In summary, investors consider short term securities less risky because of long-term interest rate uncertainty; therefore, investors require a yield higher than the average expected short term interest rates to entice them to buy long-term securities (Saunders 2004).

The market segmentation theory, which is also called the preferred habitat hypothesis by Haubrich and Dombrosky (1995), states that different maturity segments of the yield curve are imperfect substitutes, and according to this theory investors and financial institutions have specific demands when it comes to maturities. For example, banks may wish to hold short term securities, but insurance companies may wish to hold long-term bonds (Saunders 2004). As the supply of short term bonds decreases, or the demand for these securities increases, the yield curve becomes steeper. Similarly, if the supply increases or the demand decreases for long-term bonds the yield curve will become steeper. The market segmentation theory also argues that investors are naturally unwilling to change their maturity preferences unless they are offered a significant premium. Therefore, the typical upward slope of the yield curve is simply caused by a greater demand for short term investments. Assuming that the yield curve is segmented, a cumulative mathematical equation for these three theories can be seen below, where \( L_i \) represents the risk premium described in the liquidity.
premium theory and the incentive premium discussed in the market segmentation theory. These risk premiums will vary based on the term to maturity.

\[
(1 + i_N)^Y = (1 + i_1)(1 + E(i_2) + L_2)...(1 + E(i_N) + L_N)
\]

**Rates Should be Increasing**

We can now use this economic theory to examine the present yield curve. There are currently several economic forces that should be putting upward pressure on long-term yields. The first example is associated with the current budget deficit. The United States is currently facing a steadily increasing budget deficit caused by increases in government spending and a reduction in tax revenue. Figure 2 shows that the U.S. government had deficits in the most recent time periods. Governments will often borrow in the loanable funds market to finance government spending that exceeds tax revenue. To fund government projects and pay for current expenditures governments frequently borrow by issuing their own debt. According to the loanable funds theory, the current increase in the supply of government debt should place pressure on interest rates to rise. Higher returns lure more money towards these securities and investors avoid investment and consumption expenditures. This crowding out occurrence can lead to lower levels of future economic growth and reduce consumption spending through a wealth effect.

Engen and Hubbard (2004) point out that the empirical results concerning government debts and interest rates fluctuate extensively. Many have established a correlation between these two variables, but others find contrasting results. Regardless, they establish that a one percent increase in government debt can lead to an approximately 3 basis point change in the ten year bond rate.

Another economic activity that should have caused long-term rates to increase is related to the FOMC’s recent increases in short term rates. In the past, gradual increases in short term interest rates have caused long-term rates to respond similarly. This response is consistent with economic theory and agrees with Model B. However, until very recently the yield curve has been acting uncharacteristically. Figure 3 illustrates that the FOMC has increased the federal funds rate for the past ten sessions. This increase in short term rates has not caused all interest rates to respond upwardly. Long-term rates have fallen and the yield curve has continued to flatten.
According to Haubrich and Dombrosky (1995) the slope of the yield curve shares a relationship with the business cycle. Historically, higher long-term interest rates correspond with high growth expectations. Currently, the U.S. economy is recovering from a recession and economic growth indicators look promising. Under the present circumstances the spread between short and long-term rates should be widening, but this is not the case. Figure 4 is a scatterplot graph of the ten-year three month interest rate spread and expected GDP in one year. According to this graph, Haubrich and Dombrosky’s argument appears to be true. There is a positive relationship between these two variables, yet long-term interest rates are falling while the economic recovery is promising.

In addition, the current account deficit in the United States has grown, and almost every economist would agree that there will be some correction in the future. The U.S. current account as a percent of GDP can be seen in Figure 5. This graph illustrates the extensive decline in the current account balance over the past two and a half decades. The Federal Reserve Bank of St. Louis stated that the current account balance stood at negative $225 billion in October of 2005. For an adjustment to occur, domestic goods must look more appealing to foreign consumers. The primary way in which this can take place is if the dollar depreciates and U.S. goods become comparably less expensive. According to the interest rate parity theory the difference in interest rates between two countries is equal to the differential between forward exchange rates and the spot exchange rate. Therefore, if a foreign investor was to convert his or her money into U.S. dollars and invest in Treasuries, he would have to take into consideration that his American currency will likely be worth less in the future. This loss in value can be compensated with higher interest rates, but investors seem to be settling for lower yields despite the likelihood of depreciation.

Each of these economic conditions should be placing upward pressure on long-term interest rates, but recently they have continued to fall. Alan Greenspan, the former chairman of the Federal Reserve dubbed this current situation a “conundrum” during his semiannual Monetary Policy Report to the Congress in February 2006. There are several possibilities that could be counteracting the downward pressures, but no one is exactly sure which prospect is the cause for lower long-term bond yields.
Possible Reasons for Lower Yields

Figure 1 shows that long-term interest rates have remained steady, short-term interest rates have risen, and consequently the yield curve has recently flattened. According to the loanable funds theory, the liquidity premium theory and the market segmentation theory, the supply, demand or liquidity risk for these fixed income securities must have been altered. This behavior may be related to several macroeconomic influences that have been putting downward pressure on long-term yields.

One possible explanation, proposed by Mr. Bernanke, is that foreign central banks have created a savings glut, by saving large quantities in government bonds (Bernanke 2006). Some foreign countries have established fixed exchange rates with the US dollar and depend on buying U.S. fixed income securities to maintain their desired exchange rate. Others are simply attracted to U.S. Treasuries because they are considered a safe haven, considering the economic and political stability that the United States has demonstrated in the past, and the reality that United States has never defaulted on its Treasury debts. Such credibility makes this market very appealing to foreign countries looking to invest in both short and long-term securities. According to Bernanke national savings is high in foreign countries, and their central banks have been increasing the demand for government bonds. This increases the demand for Treasuries, prices rise and yields fall (there is an inverse relationship between price and yields). It is clear according to Figure 6 that there has been a substantial increase in foreign demand for treasuries since 2001. Furthermore, according to the Federal Reserve of San Francisco, in 2004 foreign countries purchased $235 billion dollars worth of U.S. Treasuries. Therefore, one possibility is that foreign central banks have created a savings glut, causing an extensive increase in demand for U.S. securities.

Another possible cause for lower long-term rates may be a reduction in investors’ inflation expectations. Inflation erodes the purchasing power of money. Therefore, a lender typically expects to be compensated for this loss in purchasing power by receiving higher interest on loans. This concept holds true with the bond market. If investors believe inflation will remain low throughout the life of their investment, then they will be willing to invest in the lower yields, because their real return will remain relatively high. Since the late 1980s, the Federal Reserve has kept inflation under control and has been able to maintain stable low inflation rates. Figure 7 is a visual representation of ten-year-out infla-
tionary expectations that was survey data taken from the Survey of Professional Forecasters on the Philadelphia Fed website. According to this graph, expected inflation has been declining since the early 1980s, and is at its lowest level in recent history. However, from 2000 to 2006 inflation expectations have remained low and stable. Therefore, we can continue to look for alternative explanations for the conundrum.

Greenspan believes that the risk associated with long-term investments has subsided, because the Federal Reserve has successfully controlled inflation in recent years. This explanation implies a reduction in the risk premium, and investors are settling for lower yields because of the reduced risk. Regardless, nobody is exactly sure why interest rates are behaving the way that they are.

Interest rate risk is the primary threat associated with U.S. Treasuries. As interest rates fluctuate, bonds held by investors become worth more or less. The longer the term to maturity, the greater the possibility that interest rate volatility will affect the value of the security. This risk is also incorporated in the liquidity premium. Therefore, one possible cause for lower long-term interest rates may be directly related to a reduction in this interest rate risk premium. As I have mentioned, long-term interest rates are dependent on two variables: expected futures short term rates, and an additional risk premium. A reduction in interest rate risk may be responsible for a reduction concerning interest rate premiums. In this model we calculate a risk premium by using a 36 month rolling standard deviation in the ten-year yield. Figure 8 visually shows how the volatility in the ten-year yield has declined since the mid 1980s.

Ben Bernanke has referenced the possibility of lower risk premiums. Before the 1980s, economic trends were much more volatile. Since the 1980s the United States government has learned how to limit its GDP growth and inflation volatility. Economists call this phenomenon the “Great Moderation.” This trend can be seen in Figure 8. U.S. interest rate volatility has been on a downward trend since the early 1980s and is at its lowest level in decades. This change has created a more predictable economy and increased investors’ confidence. It is possible that this change is directly responsible for lower long-term yields, because if investors expect this trend to continue they should be willing to accept lower liquidity (risk) premiums.
Data and Results

Model of Ten-Year Treasury Yield

The model in this paper builds on the basic methods presented in the Warnock and Warnock paper “International Capital Flows and U.S. Interest Rates.” This paper concentrates on the ten-year Treasury yield as the dependent variable, and several independent macroeconomic variables that theory suggests affect this interest rate. These variables were chosen because they provide an explanation for long-term interest rates, based on macroeconomic conditions, policy, and future expectations. Some of the variables proxy for expectations and derive from survey data, since bond yields are greatly influenced by future expectations. However, robustness checks reconfirm my initial results when the survey data is removed from the model. Like the Warnock paper, I found that my model is very good at explaining the ten-year yield level, and in the most recent years long-term rates are only slightly lower than would be expected.

Theory suggests that the ten-year-ahead inflation expectation variable has a positive relationship to the ten-year interest rate. When investors believe inflation will be high they require a higher yield to compensate for the loss in the purchasing power of money. In other words, nominal interest rates must increase to ensure desired real interest rates. In addition, an expected GDP variable is also added to the model, because this feature is likely to affect government, and monetary policy, given that expected GDP is typically a signal for future inflation (Warnock 2005). Inflation tends to appear when there are high levels of economic growth. To combat high levels of inflation the Federal Reserve will increase the federal funds rate. Higher interest rates encourage more investing, slow economic growth, and lower inflation by siphoning money out of the economy. Therefore, an expected GDP variable is used to proxy for these policy decisions. Additionally, using net foreign purchases of U.S. treasuries as a percent of GDP, I account for foreign countries influence on the U.S. Treasury market. The model shows that an increase in foreign investment in the Treasury market does lead to an increase in the demand for bonds, causing prices to rise, and interest rates to fall. The current account data could not be used in this regression, because the data are not exogenous.

Monetary policy and fiscal policy are also a determinant of long-term interest rates. As expected, the model shows that the federal funds rate also

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1 Additional information concerning the data used in this paper is located in the data appendix
positively affects these yields. According to the liquidity premium equation, expressed in Model B, long-term interest rates are dependent on expected short term rates. Therefore, when the Federal Reserve increases short-term interest rates, long-term rates will be affected according to investors’ future short term rate expectations. Moreover, the U.S. deficit as a percent of GDP was chosen, because as federal debt increases more Treasuries are issued to pay for the debt. Therefore, the deficit causes the supply of bonds to increase, prices to fall and yields to rise.

Furthermore, the risk premium variable is anticipated to have a direct positive relationship to long-term interest rates. If investors consider long-term investments to be less risky, they will require a lower premium. Warnock and Warnock mention that U.S. government bonds are considered to have no default risk, because the government has never defaulted on a Treasury payment. However, investors are subject to interest rate risk. To proxy for this, a variable was generated by calculated a 36 month rolling standard deviation of the ten-year interest rate.

With these variables I use an ordinary least squares (OLS) regression, and out-of-sample forecasting to evaluate recent long-term interest rate trends. This regression holds the ten-year interest rate as the dependent variable. The regressors used include: ten-year-ahead inflation expectations ($g_{t+1}$); the federal funds rate ($ft$); an interest rate risk premium ($rft$); expected GDP growth over the next year ($gt_{t+1}$); the budget deficit; and foreign purchases of U.S. bonds.\(^2\)

$$i_{t,10} = c + a(p_{t,10}) + b(ft) + c(rp) + d(gt_{t+1}) + e(deficit_{t+1}) + f(foreign) + e_t$$

**Econometric Issues**

There are three econometric issues that must be addressed. The first deals with the simultaneity of the variables. I will presuppose that the variables on the right-hand side of the expression do not respond to the ten-year level. This is a sensible assumption, because the work of Diebold, Rudebush and Aruoba (2004) establishes that interest rates have little influence on macro conditions, while macroeconomic changes do affect yields. In addition, Warnock and Warnock mention that this tactic is reasonable, and it is a generally accepted practice. Some variables are more credible than others. For example, it is possible that the federal funds rate and the survey data are likely influenced by the interest rate levels, but this assumption is still held.

\(^2\) Additional information concerning these variables can be located in the data appendix.
The remaining issues that need to be addressed deal with autocorrelation and heteroskedasticity. The potential problem with autocorrelation comes from the cyclical nature of several of the macroeconomic regressors. For example, it is likely that expected GDP will trend up for a time period, and then tend back down for a phase, and this pattern will continue. According to Schmidt (2005), these macroeconomic shocks suggest that the error terms will not be independent of each other. This is an econometric problem, because this violates the Gauss-Markov theorem that variations are not correlated with other disturbances. I account for this problem by using a correlation variable [AR(1)] that considers the residual from the past observation in the regression model for the current observation.\(^3\) The software package that I use is capable of transforming the regression results by adjusting the sample to account for the lagged data used in the estimation, and reports the adjusted sample along with the remainder of the estimation output. For example, in Table 1 the AR(1) variable has a coefficient of 0.79. This means that when there is a positive error, and one of the explanatory variables is one percent higher than we would expect, the following quarter it will still be 0.79 percent higher than we would have expected. In the next quarter, the effect is (0.79) squared or 0.62. When this coefficient is incorporated the Durbin-Watson statistic is 1.74. This value falls inside of the upper and lower critical levels of 1.518 and 1.801, for a regression with 88 observations and seven independent variables. Therefore, I do not reject the null hypothesis of no autocorrelation, and I use the OLS estimates of the parameters.

The final issue concerns heteroskedasticity, or the possibility that regressors have different variances throughout the sample period. According to Schmidt (2005), alteration in the error terms may cause the parameters to be more or less accurate, because the Gauss-Markov theorem also states that each error term must continually have the same variance, or standard deviation. To test for this, I performed a White heteroskedasticity test which can be seen in Table 1. This test reported an R-squared statistic of 30.52 and a probability of 0.29. Therefore, according to these results the model does not suffer from a heteroskedasticity problem.

After running the regression, the results show that all of these variables are statistically significant, with inflation expectations and the federal funds

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\(^3\) The program used was EViews 4.1. More information on the AR(1) variable can be located in the Student help section under serial correlation theory.
rate significant at the one percent level. Furthermore, the risk premium and expected GDP fall into the five percent range, while the budget deficit and foreign purchases are significant at the ten percent level. *Table 1* illustrates that a one percent increase in ten-year-ahead inflation expectations leads to a 69 basis point (0.69%) increase in the ten-year yield. If the Federal Reserve increases the federal funds rate by one percent, it causes a 17 basis point increase in the ten-year interest rate. The same logic is held for the remaining variables, where all coefficients are intuitively correct, and each abides by the macroeconomic theory discussed earlier in this paper. For example, if the risk premium increases by one percentage point, the interest rate will jump 20 basis points. In addition, when one-year-ahead GDP expectations increases by one point, long-term interest rates will fall by 30 basis points. The ten-year Treasury yield is also expected to decline by 18 basis points when the deficit increases by one percent. Finally, when foreign purchases of U.S. Treasuries increases by one percent, long-term interest rates will decline by 57 basis points.

**Forecast**

*Figure 9* illustrates the actual long-term Treasury yield compared to a fitted model produced by dynamic out-of-sample forecasting. The dotted line is the actual ten-year bond rate, and the solid line is the expected interest rates from the first quarter of 2002 to the first quarter in 2006. The graph shows that during recent years actual long-term interest rates have been lower than the model would have anticipated. At the beginning of 2003, the spread between the ten-year rate and the forecasted level was greater than one hundred basis points. This is partially due to a period of declining foreign purchases and a reduction in the budget deficit from 2002:2 to 2003:1. This spread narrows in 2004:1 because of large increases in foreign flows and the budget deficit. In the third quarter of 2005, long-term interest rates and the model's predicted level nearly converged. However, a significant drop in net foreign purchase of long-term U.S. treasuries from 2005:4 to 2006:1, and the Federal Reserve's increase in the federal funds rate caused the forecasted level to spike. At the same time, the ten-year interest rate dropped slightly, causing a 70 basis point spread at the start of 2006. Therefore, according to this forecast long-term interest rates should have been slightly higher in recent years and at the start of 2006.

Using this single equation model, I also find the relative importance of each variable during my forecast period. I did this by calculating each variable's
sample average from 1990:1 to 2002:1, and each average from 2002:2 to 2006:1. According to this model, the difference between these two numbers, multiplied by the corresponding coefficients of each variable provided by the OLS regression results, is the average effect that each variable has on the level of long term interest rates during the 2002:1 to 2006:1 time period in relation to the 1990:1 to 2002:1 sample.

Table 3 provides the results from this exercise. This table shows that the average level of long term interest rates is 216 basis points lower in 2002:1 to 2006:1 than they were during the 1990:1 to 2002:1 sample. Furthermore, this model suggests that inflation expectations has the greatest influence and should have caused interest rates to be 59 basis points lower during the more recent time period. In addition, the federal funds rate should have caused long-term rates to go down by 55 basis points. The model also suggests that the risk premium, expected GDP, and foreign flows variables have the same downward pressure with 37, 30, and 26 basis points respectively. The budget data variable was the only exception causing interest rates to rise by 29 basis points. Finally, this table also shows that only 38 basis points are not explained by the model.

Vector Autoregression (VAR)

There is a noteworthy weakness concerning the OLS regression that the Warnock and Warnock paper does not fully address. In this model there are possible dynamic interactions between the variables. According to Schmidt (2005), vector autoregressions (VAR) are commonly used to forecast macroeconomic data when the performance of the variables over time is important. A VAR is especially useful when an individual desires to create a model that accounts for the progress of interrelated variables over time. VARs consider the likelihood that a change in one variable at time $t$ will likely affect each of the other variables at time $t + 1$. Furthermore, the change at time $t$, and the adjustment at time $t + 1$ causes an additional change at time $t + 2$.

I estimated a VAR including the budget deficit, an interest rate risk premium ($\Delta ff_t$), ten-year-ahead inflation expectations ($\Delta g_{t+1}^e$); the federal funds rate ($\Delta ff_t$), expected GDP growth over the next year ($\Delta g_{t+1}^e$), foreign purchases of U.S. bonds, and the ten-year interest rate ($\Delta i_{t,10}$). Four lags for each variable were used and the sample period ranged from 1981:1 to 2002:2. The impulse response functions shown in Figure 10 illustrate how the ten-year bond rate responds to a one standard deviation shock in each of the other variables. The
Cholesky decomposition was used to orthogonalize the residuals under the assumption that the ten-year bond rate responds contemporaneously to all of the other variables. The ordering of the variables used to create this response is the same as the order as they were mentioned, and the same order as they appear in Figure 10.

Figure 10 illustrates the ten-year Treasury yield’s response to a one standard deviation shock in each of the explanatory variables. For example, the first graph on the left-hand side of Figure 10 shows that a one standard deviation shock in the Treasury yield will lead to an immediate, positive, statistically significant increase. This shock will have its greatest effect initially, approximately 45 basis points, and will eventually correct itself over time. The graph directly below shows the effect of a one standard deviation shock to inflation expectations (1.29%) on long-term interest rates. As the chart shows, an increase in inflation expectations today will have the greatest affect approximately eight periods (2 years) later, where it peaks at approximately 28 basis points. This response is also intuitively correct, according to economic theory higher inflationary expectations lead to higher long-term yields.

The chart at the bottom of Figure 10 also coincides with economic theory. This graph visually shows the negative response in the ten-year treasury yield when there is a one standard deviation increase in the foreign purchases of U.S. Treasuries (0.24% of GDP). The ten-year bond rate initially decreases by roughly 10 basis points and continues to fall throughout all five years. This response agrees with economic theory that an increase in the demand for these securities causes prices to rise and yields to fall. At the same time, the chart at the top and middle of Figure 10 shows how a one standard deviation increase in the budget surplus (reduction in the deficit) affects the interest rate. This graph is relatively inconsequential with a small initial decrease in the interest rate, followed by a short spike one year later, and a steady move towards is original level. It is not statistically significant, but the initial reaction agrees with economic theory. If the government has a smaller deficit then there is less need to issue Treasuries, causing prices to rise and yields to fall.

The chart in the middle of the second row illustrates that a one standard deviation increase in the federal funds rate (3.37%) causes the interest rate to rise by approximately 17 basis points in the first quarter. The rate bumps its way back to its original level by the start of the sixth quarter. This coincides with
economic theory, because long-term rates, according to Model B, are dependent on short term rates.

The graph at the top right-hand side of Figure 10 shows how the ten-year interest rate responds to a one standard deviation increase in the risk premium (2.24%). Initially, there is little response, but starting in the second quarter the rate begins to rise, until it reaches its greatest effect, roughly 33 basis points, in quarter six. It continues to correct towards its original value, but remains positive throughout the five-year span. Again, macroeconomic theory supports this outcome. Model B shows that interest rates include a term premium which is total risk associated with the securities. Therefore, as a bond becomes more risky, yields on that bond rise.

Finally, the chart at the lower right-hand side of Figure 10 demonstrates how the ten-year bond responds to a one standard deviation increase in one year out expected GDP (0.67%). This increase originally causes the interest rate to fall slightly. However, the bond rate then continues to rise and reaches its peak of 15 basis points in quarter three. The rate reaches its original level by quarter four and continues its downward trend until it arrives at its lowest level of negative ten basis points in quarter seven. Following quarter seven, the ten-year bond rate moves back to its original level, and reaches this level around quarter ten. The initial increase in yields agrees with macroeconomic theory. Often, as GDP increases, inflation coincides with this increase. Therefore, if investors see higher GDP growth as an indication of inflation they will demand higher yields.

VAR Forecast

Figure 11 illustrates a dynamic out-of-sample forecast using this VAR model, and it compares the forecast to actual historical ten-year yields. This graph shows that the model is quite good at shadowing the ten-year yield. However, it is also clear that from 2002:2 to 2006:1, the forecasted model would have expected long-term interest rates to be higher than they have been. Figure 11 shows, according to this VAR model, that the ten-year Treasury yield should have been approximately 20 to 60 basis points higher from 2002:2 to 2006:1. In 2006:1 the ten-year interest rate was approximately 30 basis points lower than the model would have predicted.
Robustness Checks

I believe that my original model explains long-term interest rates very well, but in this section I will examine some variations of the model. First, I eliminated the survey data of expected one-year GDP growth and ten-year inflation expectations, and replaced it with the previous quarter’s percent change in GDP and the percent change in the consumer price index (CPI) respectively. All other aspects concerning this model are held constant. The elimination of the survey data makes this model more like standard forecasting exercises. The results from the OLS regression can be seen in Table 2. This table shows that the change in CPI and the federal funds rate variables are both significant at the one percent level. In addition, the percent change in GDP variable, which is significant at the five percent level, is the only other variable that remains statistically significant. The results from this regression also show that when one of these statistically significant variables increase by one percent, the CPI variable will cause the ten-year to rise 28 basis points, the change in GDP variable will cause the ten-year to fall 12 basis points, and the federal funds rate will lead to a 13 basis point increase. Each of these results correspond with the economic theory discussed earlier in the paper.

Figure 12 shows the new the out-of-sample forecast for 2002:1 to 2006:1. Once again, it is clear that long-term interest rates are lower than the model would have suggested for this sample period. In fact, this version of the model is more dramatic than the original. It shows that in 2006:1 the model would have placed ten-year interest rates over 200 basis points higher.

I also used dummy variables to see if there was a shift in the ten-year interest rate during my sample period. The dummy variables showed that there was not a shift in the curve in 2001:1, 2002:1, or 2003:1. The dummy variable was statistically insignificant in each of these checks, and the other regressors remained significant at the ten percent, five percent or one percent levels.

I do additional robustness checks by altering both the order of the variables and the number of lags in the VAR estimates. First, I used the same ordering as the original VAR estimate, but I changed the number of lags from four, to six and eight. The impulse response to these VARs can be seen in figures 13 and 14 respectively. These charts illustrate that the robustness checks tend to correspond with the original model. Furthermore, each of the charts has a tendency to agree with the economic theory previously discussed. In addition, impulse response charts can be seen for a VAR with the original variables, but
arranged in the reverse Cholesky order. The only exception is that the ten year variable remains last in the ordering. These graphs illustrate that the order of the variables is relatively insignificant, because each variable responds similarly despite the change.

Conclusion

According to Model B, there are two possible reasons for lower interest-rates. Yields will fall if the demand for these securities increases, or the risk associated with the bonds declines. Mr. Greenspan and Mr. Bernanke have each provided different solutions. Mr. Greenspan tends to believe that there has been a reduction in the risk premium. According to him, the Fed's ability to control inflation and the “Great Moderation” have led to lower volatility and reduced risk associated with longer maturities. This implies investors are accepting uncharacteristically low historical yields, because there is less risk. Table 3 supports this concept. The table shows that the risk premium variable used in the OLS regression should have caused the ten-year rate to decline by 37 basis points. On the other hand, Mr. Bernanke, and the Warnock paper, tends to believe that there has been a significant increase in foreign demand for U.S. Treasuries. According to Bernanke, this increase in demand has caused prices to rise and yields to fall substantially. Once again, this is another possible reason for recent low long-term interest rates. According to the results in Table 3, foreign demand for U.S. Treasuries has caused interest rates to decline by 26 basis points.

I generate a model similar to the one produced by Warnock and Warnock, and this regression is used to evaluate the recent phenomena concerning long-term interest rates. Economic theories provide support for the selection of the variables used in the model, and these theories explain each of the variables’ effects on the ten-year Treasury rate. The results from the OLS regression confirm previous findings, with all of the variables being statistically significant, and all influencing interest rates in accordance with economic theory. Out-of-sample forecasting shows that from 2002:2 to 2006:1 long-term interest rates have been slightly lower than the model would have predicted them to be. However, the OLS model accounts for approximately 80 percent of the downward pressure on long-term interest rates.

This paper builds on earlier work, and I use a VAR analysis to reconfirm that long-term interest rates respond to macroeconomic shocks, and the responses are consistent with economic theory. Figure 11 shows that from 2002:1
to 2006:1 the ten-year Treasury yield has been consistently lower than the model would have anticipated, and in 2006:1 interest rates remain roughly 30 basis points lower than the forecasted level. Using the results from the VAR and the OLS regressions presented in this paper we can conclude that long-term interest rates are in fact low, but not unexpectedly low. My model is able to account for approximately eighty percent of the downward pressure on long-term interest rates during the 2002 to 2006 sample period. Therefore, according to this model the U.S. Treasury market conundrum only consists of 30 to 38 basis points.
Table 1: OLS Regression results.

Dependent Variable: Ten Year

Method: Least Squares
Sample(adjusted): 1980:2 2002:1
Included observations: 88 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (t-Statistic)</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>3.25 (3.62)</td>
<td>0.90</td>
</tr>
<tr>
<td>Expected Inflation (t+10)</td>
<td>0.69 (2.84)</td>
<td>0.24</td>
</tr>
<tr>
<td>Federal Funds Rate</td>
<td>0.17 (3.24)</td>
<td>0.05</td>
</tr>
<tr>
<td>Risk Premium</td>
<td>0.20 (2.34)</td>
<td>0.09</td>
</tr>
<tr>
<td>Expected GDP (t+1)</td>
<td>-0.30 (-1.79)</td>
<td>0.17</td>
</tr>
<tr>
<td>Budget Deficit (Fiscal)</td>
<td>-0.18 (-1.82)</td>
<td>0.10</td>
</tr>
<tr>
<td>Net Foreign Purchases</td>
<td>-0.57 (-1.73)</td>
<td>0.33</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.79 (10.26)</td>
<td>0.08</td>
</tr>
<tr>
<td>R-squared</td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td></td>
<td>0.94</td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td></td>
<td>1.74</td>
</tr>
</tbody>
</table>

White Heteroskedasticity Test:

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>Probability</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.18</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>30.52</td>
<td>0.29</td>
<td></td>
</tr>
</tbody>
</table>

OLS Regression

\[ i_{t,10} = c + a(\pi^e_{t,10}) + b(ff^t) + c(rp^t) + d(\gamma_{t+1}) + e(deficit^t_{t-1}) + f(foreign^t) + \varepsilon \]

Ten-year-ahead inflation expectations ($\pi^e_{t,10}$); the federal funds rate ($ff^t$); an interest rate risk premium ($rp^t$); expected GDP growth over the next year ($\gamma_{t+1}$); the budget deficit; and foreign purchases of U.S. bonds

EViews automatically adjusts the sample to account for the lagged data used in estimation, estimates the model, and reports the adjusted sample along with the remainder of the estimation output when [AR(1)] is added to the regression. Further explanation can be seen in the "Data and Results" section of this paper.

---

*Significant at the 99% level
**Significant at the 95% level
*Significant at the 90% level
Table 2: OLS regression results for robustness check.

Dependent Variable: TEN YEAR  
Method: Least Squares  
Sample: 1980:1 2002:1  
Included observations: 89

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (t-Statistic)</th>
<th>Std. Error</th>
<th>t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>15.01 (2.98)</td>
<td>5.04</td>
<td>2.98</td>
</tr>
<tr>
<td><strong>Change in CPI</strong></td>
<td>0.28 (2.69)</td>
<td>10.57</td>
<td>2.69</td>
</tr>
<tr>
<td><strong>Change in GDP(-1)</strong></td>
<td>-0.12 (-1.91)</td>
<td>605.13</td>
<td>-1.91</td>
</tr>
<tr>
<td><strong>Federal Funds Rate</strong></td>
<td>0.13 (2.91)</td>
<td>0.046</td>
<td>2.91</td>
</tr>
<tr>
<td>Risk Premium</td>
<td>0.06 (0.72)</td>
<td>0.087</td>
<td>0.72</td>
</tr>
<tr>
<td>Budget Deficit</td>
<td>-0.05 (-0.48)</td>
<td>0.11</td>
<td>-0.48</td>
</tr>
<tr>
<td>Foreign Purchases</td>
<td>-0.37 (-1.23)</td>
<td>0.30</td>
<td>-1.23</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.94 (23.66)</td>
<td>0.04</td>
<td>23.66</td>
</tr>
</tbody>
</table>

R-squared: 0.95
Adjusted R-squared: 0.95
Durbin-Watson stat: 1.71

Percent change in CPI; the federal funds rate (ƒt); an interest rate risk premium (rp_t); 
Percent change in GDP growth over previous quarter; the budget deficit; and foreign 
purchases of U.S. bonds

EViews automatically adjusts the sample to account for the lagged data used in 
estimation, estimates the model, and reports the adjusted sample along with the remainder 
of the estimation output when [AR(1)] is added to the regression. Further explanation can 
be seen in the "Data and Results" section of this paper.

---

5***Significant at the 99% level  
**Significant at the 95% level  
*Significant at the 90% level
Table 3: The differences between the average level of each variable (multiplied by its corresponding coefficient in the OLS regression results) for 1990:1 to 2002:1 and 2002:1 to 2006:1. The difference in the ten-year yield, is the difference in the average ten-year rate from 1990:1 to 2002:1 and 2002:2 to 2006:1

<table>
<thead>
<tr>
<th>Difference in Ten-Year Yield Due to:</th>
<th>-2.1598</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Inflation (t +10)</td>
<td>-0.5936</td>
</tr>
<tr>
<td>Federal Funds Rate</td>
<td>-0.5455</td>
</tr>
<tr>
<td>Risk Premium</td>
<td>-0.3736</td>
</tr>
<tr>
<td>Expected GDP</td>
<td>-0.2992</td>
</tr>
<tr>
<td>Budget</td>
<td>0.2888</td>
</tr>
<tr>
<td>Foreign Purchases</td>
<td>-0.2552</td>
</tr>
<tr>
<td>Total</td>
<td>-1.77829</td>
</tr>
<tr>
<td>Total Unexplained</td>
<td>-0.38150</td>
</tr>
</tbody>
</table>

Graphs

Figure 1: Ten year Treasury and federal funds rate 2001:1 to 2006:1.

*For all figures refer to the data appendix for further information and the source of the data.*
Figure 2: U.S. Federal Budget Deficit/Surplus as a percent of GDP.

Figure 3: Effective federal funds rate as a percent.
**Figure 4:** Scatterplot graph with expected GDP and the ten-year to three month interest rate spread.

![Scatterplot graph with expected GDP and the ten-year to three month interest rate spread.](image)

**Figure 5:** Graph of the U.S. current account as a percent of GDP.

![Graph of the U.S. current account as a percent of GDP.](image)
Figure 6: Net Foreign Purchases of U.S. Treasuries as a Percent of GDP.

Figure 7: Survey data for ten-year-out inflation expectations.
Figure 8: Risk premium was calculated by creating a 36 month rolling standard deviation for the ten-year yield.

Figure 9: Actual ten-year Treasury yield compared to the fitted model produced by dynamic forecasting for 2002:1 to 2006:1.
Figure 10: The ten-year interest rate response, over time, to a one percent increase in one of the alternative variables with four lags.
**Figure 11:** VAR forecast compared to actual ten-year yields from 2002:1 to 2006:1.

**Figure 12:** Robust out-of-sample forecast.
Figure 13: The ten-year interest rate response, over time, to a one percent increase in one of the alternative variables with six lags.
Figure 14. The ten-year interest rate response, over time, to a one percent increase in one of the alternative variables with eight lags.
Figure 15: The ten-year interest rate response, over time, to a one percent increase in one of the alternative variables, with four lags, the reverse Cholesky order but ten year is still last in the order.
REFERENCES


DATA APPENDIX

Budget Deficit, United States, 1960:1-2004:4 (United States deficit as a percent of GDP), Federal Reserve Bank of St. Louis, calculated as a percent of GDP, observations 2005:1 to 2006:1 were not available so the last five observations are the same as 2004:4

Expected GDP One-Year-Out, 1968:1-2005:2 with 5 missing variables, last three observations are the same as 2005:2 (the log of expected United States GDP divided by base year), Federal Reserve Bank of St. Louis


Federal Funds Rate, 1960:1-2005:2 last three observations are the same as 2005:2, (United States), Federal Reserve Bank of St. Louis


Percent change in the consumer price index, Consumer Price Index for All Urban Consumers, 1960:1 to 2006:1, Federal Reserve Bank of St. Louis

Percent change in GDP, Seasonally adjusted real GDP; 1960:2006:1, (United States), Federal Reserve Bank of St. Louis

Risk premium was calculated by creating a 36 month rolling standard deviation for the ten-year bond rates, 1960:1-2006:1

Ten-Year Interest Rate, Constant Maturity Rate as a percent, 1960:1-2006:1 first month in each quarter, (United States), Federal Reserve Bank of St. Louis