THE PREDICTIVE POWER OF YIELD CURVE IN FORECASTING U.S. RECESSIONS

by

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ABSTRACT

Since the last recession in 2001, the U.S. economy has continued to grow; yet speculation of a recession has surfaced on the basis of the yield curve flattening. Yield curve inversion has been strongly associated with U.S. recessions over the last forty-six years. This paper examines the predictive power of the yield curve, the index of leading indicators, monetary growth and stock returns in forecasting U.S. recessions. A probit model is used to generate recession probability forecasts three, six, nine and twelve months forward. Empirical results show that the yield curve embodies the highest degree of explanatory power beyond a three-month forecast horizon. Results for the last two recessions are analyzed as well as forecasts going forward into 2006. As a final observation, an asset allocation trading strategy is tested out-of-sample.

EXECUTIVE SUMMARY

Rumours of yield curve inversion approaching and incongruity surrounding its association with recessions enticed me to examine the subject matter in further detail. Stable long-term interest rates along with thirteen consecutive increases in short-term interest rates (Fed Funds Rate) stirred up economic debate on whether this was signalling that a recession was imminent. Federal Reserve chairman Alan Greenspan challenged the notion that an inverted yield curve would lead the U.S. economy into a recession. This paper attempts to provide answers to the believers and sceptics of the yield curve's predictive power. The yield curve is measured as the spread between 10-year Treasury bonds and 3-month Treasury bills.

I start with a more casual observation by examining the yield curve's track record. The yield curve has inverted prior to six out of the last seven recessions, dating back to 1959. The exception was the 1960-61 recession, where the yield curve flattened to a mere 9 basis points yet escaped inversion. In spite of the yield curve's track record, many claim that it sends just as many false signals as correct signals and therefore lacks credibility. In reality, the yield curve as measured by inversion has only sent one false signal (1966) in forty-six years.

For my empirical analysis, I use the time series probit model to examine the predictive power of four variables: the yield curve, the index of leading indicators, monetary growth, and stock market returns. The methodological approach is parallel to that of Dueker (1997) who also uses the probit model, and primarily focuses on the yield curve variable. My research extends the data set from Dueker (1997) by ten years, employs a unique test excluding a time frame, and tests an asset allocation trading strategy. Probit regressions are run with the use of dummy variables, distinguishing between recessionary periods and non-recessionary periods as designated by the

National Bureau of Economic Research. Unlike, many models that forecast economic growth, this model provides a signal directly in relation to a recession. Moreover, the model generates recession probabilities based on forecast horizons of three, six, nine and twelve months. I test the predictive power of the four-variable probit model, but more importantly I test the yield curve in isolation as the sole explanatory variable in the probit model and then provide comparative analysis between the two models. Four main periods are studied. The first two represent the most recent recessions, 1990-91 and 2001. Next, recession forecasts for the future are presented to address current speculation in the market. Finally, the probit model is examined with the exclusion of four years of historical data.

My results strongly support the predictive power of the yield curve particularly at forecast horizons beyond three months. The coefficient estimates are significant and the fit of the model is quite strong based on pseudo-R^2. In addition, the predictive power of the yield curve improves as the forecast horizon increases from three to nine months. There is no significant difference between the predictability of the yield curve model and the four -variable model. As for forecasting the 1990-91 and 2001 recessions, the yield curve probit model signals a heightened probability of a recession prior to both. The probability surges from near zero to about 30 percent in each case. Going forward the recession probabilities are not significantly different from the constant probability generated by the probit model and therefore no recession is forecasted out to mid 2006. An interesting observation arises when excluding four years of data (1979 to 1982), a period in history where interest rates were unusually volatile. The sensitivity of recession probabilities as they relate to yield spreads strengthens. The range of spreads for recession probabilities between 5 and 90 percent is reduced from roughly 360 to just 90 bps.

Several researchers have suggested that the predictive power of the yield curve has deteriorated over the last few decades. My response is that this should be expected, given that most forecasters including the Federal Reserve monitor the yield curve. Basically, if everyone

incorporates the yield curve into their indices and research, the explanatory power of the yield curve should soften as its volatility becomes more controlled. The most plausible explanation for the change in the yield curve's predictive power in my opinion is the evolution of monetary policy from reactionary to proactive (Stock and Watson, 2003). The Federal Reserve's monetary policy has become much more transparent as of late (less surprises), reducing volatility and uncertainty in the marketplace. Moreover, the Federal Reserve has been able to better control the degree of swings in business cycles. Consequently, I believe the extreme volatility of interest rates during the late 1970s and early 1980s is misrepresentative of the economic environment the past two decades. Thus, it may be appropriate for this data subset to be excluded when employing the model. Doing so results in the yield curve probit model generating extremely strong recession signals prior to the 1990-91 and 2001 recessions. The probability forecasts nine months ahead are 58 percent and over 90 percent respectively.

Finally, I examine an asset allocation trading strategy of switching to bonds from equity when a recession is signalled. The results are underwhelming, as the trading strategy adds value in just three out of six periods observed. On the other hand, the strategy does not underperform an equity buy and hold strategy based on absolute risk and return in any period.

Despite some weaknesses, the yield curve embodies many strengths such as the data being readily available at high frequency, and easy to interpret (Dueker, 1997). In addition, the empirical support the yield curve has received over the last two decades has been phenomenal. Likewise, my results indicate that the predictive power of the yield curve still exists, and is extremely strong when some subjectivity is applied such as considering the current economic environment (i.e., excluding the 1979 to 1981 data set). In my opinion, the most powerful factors in support of the yield curve as a predictor of U.S. recessions is its theoretical foundation and track record.

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I would like to thank all the great people in my life that have helped me accomplish this goal. My senior supervisor Dr. Andrey Pavlov and assistant supervisor Dr. Peter Klein, for their knowledge, expertise and guidance all through graduate school. My friends, classmates, relatives, and wife's family for their encouragement. My family for their endless support. My parents, Ranjit and Gurcharanjit for providing me with a solid foundation of morals and values such as work ethic that have been invaluable during my pursuit of higher education. My brothers Rimpal and Narvinder, for encouraging me to set my goals high in both academics and athletics, for having faith in my abilities, and for the financial and emotional support during my time at the University of Alberta. My wonderful wife Jane, for understanding the time commitment and dedication that was required to achieve this goal. You have been my inspiration. Thanks for enduring this journey with me. I could not have done it without you.

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1 INTRODUCTION

A highly controversial topic concerning the yield curve exists not on the basis of whether or not it has inverted prior to recessions of the past but moreover, whether this fact is coincidence or theoretically based. As shown in Chart 1 below (the shaded bars represent recessionary periods), there is no doubt that the yield curve has inverted prior to six out the last seven recessions. The exception was the recession of 1960-61 where the yield curve compressed to a mere nine basis points (.09 percent) yet escaped inversion.

Chart 1   Slope of the Yield Curve
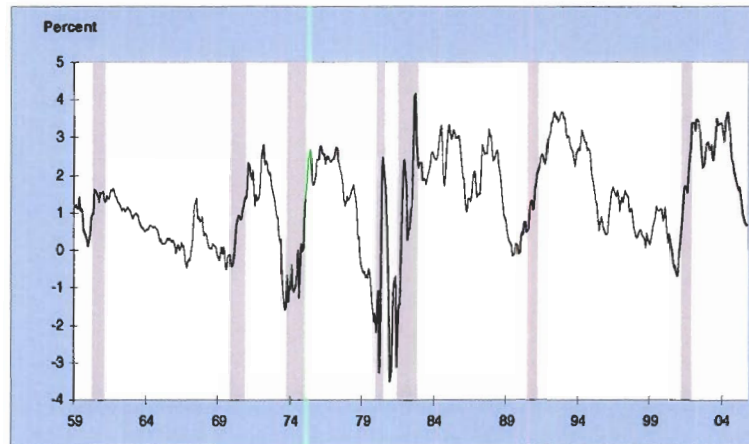
Over the last four years we have witnessed flattening of the yield curve that has some speculating that a recession is on the horizon. Short-term rates have been rising as the Federal Reserve has increased the overnight rate thirteen consecutive times with eight increases in 2005 alone. Despite this, long-term interest rates have trended downwards, refusing to adhere to pressure on yields from the Federal Reserve's monetary actions. This phenomenon of long-term rates falling when short-term rates are rising is what Alan Greenspan, the Chair of the Federal Reserve, refers to as a "conundrum". In the summer of 2005, Greenspan rejected the notion that

an inverted yield curve is a legitimate leading indicator of a recession. This announcement created a buzz on Wall Street and Bay Street as observers debated the hot topic. Greenspan did not criticize the yield curve's historical track record, but suggested that the predictability is no longer bona fide because times have changed. This paper will make an effort to respond to Greenspan's statement, and will hopefully provide some insight on the evolution of the relationship between the yield curve and recessions.

Before delving into further analysis of recessions it is important to understand the meaning of a recession. The technical definition of a recession is commonly identified as two consecutive quarters of negative economic growth as measure by GDP. Another definition comes from the National Bureau of Economic Research (NBER), which officially dates the start and end of recessions based on a broad decline in aggregate economic activity (Filardo, 1999). The NBER believes that the technical definition is too narrow a measure of economic activity; nevertheless declines in GDP are closely correlated to NBER recession periods (Filardo, 1999).

1.1 Why Study the Predictability of Recessions?

The state of the economy affects everyone either directly or indirectly. The impact of a recession can be severe if you are an employee or business owner in a cyclical industry, or conversely minor if you are involved in a non-cyclical sector such as a healthcare. The scope of the impact can be very broad. Therefore, I focus on why the ability or inability to predict recessions for organizations involved in investment management and economic policy is so critical. Since the U.S. economy is of primary interest in this paper it is natural to first consider one of the most influential economic organizations in the world, the Federal Reserve also known as the central bank for the United States. The Federal Reserve is responsible for managing the country's monetary policy. It is committed to providing an environment in the U.S. that promotes employment, price stability and moderate long-term interest rates. Controlling inflation is one of

the key preconditions for maximizing sustainable output growth. One of the criterions to control inflation and output growth is to avoid recessions. This is not a trivial task, but the Federal Reserve can use monetary policy to influence the economy through changes in interest rates. For instance the Federal Reserve may decide to stimulate the economy through lowering interest rates in an attempt to elude a recession or at least reduce its impact on the country. The ability to forecast a recession can also work to help the Federal Reserve grasp an appropriate time to increase rates to reduce inflation without triggering a recession. For example, if a forecasting model indicates a near zero probability of a recession, then the Federal Reserve may find this reassuring and proceed to tighten its monetary policy. For investment managers, forecasting economic activity is fundamental for several reasons. First, financial market participants are forward looking, and as a result security prices embody expectations of future economic activity (Dotsey 1998). Economic forecasts influence growth and earnings prospects for firms impacting security valuation. For example, if a recession is forecasted, equity analysts may reduce earnings growth and adjust their return requirement (discount rate) to reflect expected market conditions. Cyclical stocks would be affected to a greater extent than non-cyclical stocks from a change in the expected direction of the economic cycle. For this reason, a recession forecast can be extremely valuable. Economic conditions also impact government and corporate debt financing requirements and correspondingly, terms available on the market for issuance and investment. Therefore, a bond fund manager would certainly want to know if a recession is imminent. Even some hedge fund managers should be interested, as a recession could result in reduced volatility and/or volume in capital markets. Third, recessions are a major source of non-diversifiable risk (Dueker 2002) creating a need for market participants to take notice of its potential. Policy makers and market participants can benefit from recession forecasts therefore interest in the subject will persist. As such, the forecasting power of financial indicators will continue to be tested as the U.S. economy progresses towards and through recessions.

1.2 Why does the Yield Curve Tilt Prior to a Recession?

The yield curve represents the relationship between interest rates and maturity dates. There are three main shapes of yield curves. An upward sloping yield curve indicates that the longer the maturity the higher the yield. This type of yield curve is considered to be normal because it is the most common shape for the Treasury yield curve. The current U.S. Treasury yield curve is upward sloping as depicted in Chart 2, although it is relatively flat by historical standards. A flat yield curve occurs when shorter and longer-term yields are essentially the same. Finally, an inverted yield curve occurs when shorter-term yields are higher than longer-term yields.

Chart 2   Treasury Yield Curve January 1, 2006
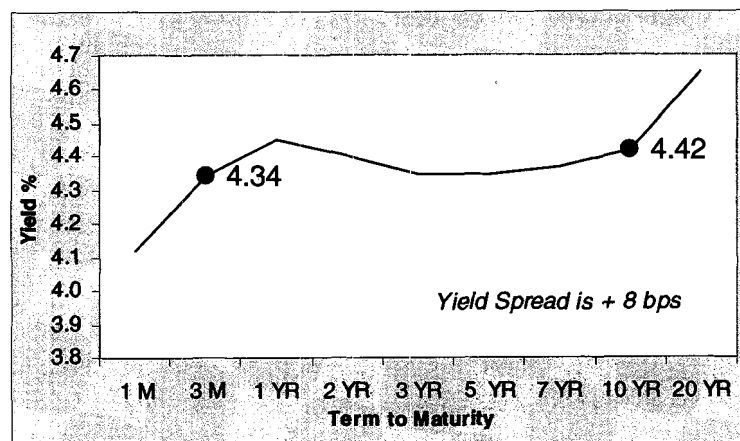
Several term structure of interest rate theories attempt to explain the rationale for the shape of the yield curve. The Expectations Hypothesis consists of three theories: the Pure Expectations Theory, the Liquidity Preference Theory, and the Preferred Habitat Theory. All three believe that future interest rates are a product of expected short-term rates, however, they differ in terms of if and why other factors influence the term structure. The Pure Expectations Theory believes that forward rates are simply a product of expected future spot rates. Therefore, the theory suggests that investors expect the return for any investment horizon to be the same.

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Implying that an investor would be indifferent between investing in a 10-year or 30-year bond over a seven-year investment horizon since the investor expects both bonds to generate the same return over the seven-year period. A key shortcoming of this theory is that it assumes that investors are unconcerned with interest rate risk and other risk factors associated with purchasing bonds with different maturities. Next, the Liquidity Preference Theory states that investors need to be compensated by a higher yield to undertake higher interest rate risk associated with investing in longer-term maturities. This theory suggests that forward rates should reflect both interest rate expectations and a liquidity risk premium that increases with term to maturity. Finally, the Preferred Habitat Theory adopts the view that term structure reflects future interest rates along with risk premium. However, in contrast to the Liquidity Preference Theory, it does not support the theory that the risk premium rises uniformly with maturity. Investors do not have perfect foresight in determining future spot rates (Dueker, 1997), is a statement that implies the shape of the yield curve can very well be different than that supported by the Expectations Hypothesis. Despite this statement, the Expectations Hypothesis theories of term structure of interest rates are well founded and can provide rationalization for the shape of the yield curve.

Historical evidence indicates that when a recession nears short-term interest rates tend to fall as depicted in Chart 3 (next page). Short-term interest rates are driven by monetary policy established by the Federal Reserve through controlling the overnight federal funds rate. The pattern of interest rate changes prior to and during recessions should not be surprising given the Federal Reserve is most likely employing a counter-cyclical monetary policy. Low interest rates are used to stimulate the economy in order to avoid a recession, or at least mitigate the repercussions thereof. An alternate explanation given by Dueker (1997) claims that during recessions low interest rates may simply reflect low real rates of return.

Chart 3   Changes in the 3 Month Treasury Bill: 1 Year
Moving Average
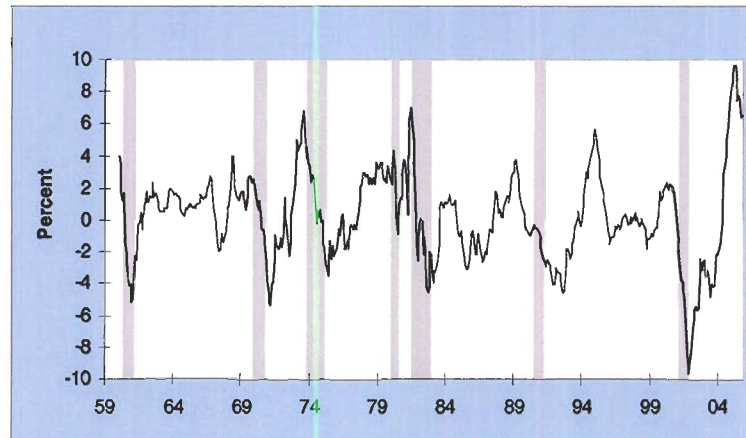
As mentioned earlier, the Expectations Hypothesis suggests that forward rates are based on market participant expectations of short-term rates in the future. On this basis, if a recession were anticipated, future short-term rates would be expected to fall, which in turn should drive down current long rates. If a recession is expected in the near future, there is incentive to sacrifice today to purchase a bond that pays off in bad times (Harvey, 1989). In this case demand for the bond will bid up its price and lower its yield (Harvey, 1989). Ultimately the magnitude and duration of the anticipated recession should determine the extent of the relative change in short and long rates. This relationship is referred to as the slope of the yield curve, the difference between long and short-term interest rates. The typical definition for this relationship is the spread between the 10-year Treasury bond rate and the 3-month Treasury bill rate.   Therefore, an inverted yield curve in this paper occurs when the 3-month Treasury bill rate exceeds the 10-year Treasury bond rate. Often yield curve inversion is associated with recessions, however, inversion is not necessary to signal that a recession is imminent; it may simply flatten relative to normal (Dueker, 1997). Researches have found that the slope of the yield curve (also referred to as the yield spread) is a valuable indicator of recessions. Furthermore, the degree in which the yield curve tilts away from its normal shape is identified as a valuable indicator of predicting recessions (Dueker, 1997). The observations above should not be surprising given that the slope

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of the yield curve has fallen prior to all seven recessions dating back to 1959 (refer to Chart 1). Also, as mentioned earlier, the yield curve inverted prior to each of these recessions with the exception of the 1960-61 occurrence. An extremely important factor in determining the meaningfulness of the yield curve is to not only consider its correct signals but also critique the false signals. If yield curve inversion is designated as the signal (spread less than zero), then the yield curve has only produced one false signal (1966) since 1959. The theoretical and empirical foundations in support of the yield curve as a predictor of recessions is the reason why this indicator will be the focal point of the analysis in this paper.

2 REVIEW OF LITERATURE

The review given here is brief and focuses on articles that are significantly related to the tests carried out later in this paper. In the late 1980s and early 1990s the term structure of interest rates received a lot of attention from researchers. A study by Stock and Watson (1989) examines combinations of fifty-five various macroeconomic variables and select the combination that best predicts future economic activity (Dotsey, 1998). Out of the massive sample of variables they limit their selection to seven variables in order to create an index used to predict future economic activity. Of the seven variables they find that the yield spread measured by the difference between the 10-year and 1-year Treasury bond was a valuable component of their index. Their search for a leading indicator series was fairly exhaustive, for that reason, the fact that they chose to include the yield spread in their index was enough for researches to examine its predictive credibility in isolation (Dotsey, 1998).

An article that tested the yield spread in isolation was that of Harvey (1989). Examining economic growth over the 1953 to 1989 period, he compares forecasts of economic growth as measured by GNP (Gross National Product) from the bond and stock markets. His results overwhelmingly indicate that the bond market contains information that more accurately predicts economic growth. The bond market variable tested is the yield spread. A simple linear regression model is used with real GNP as the dependent variable and the yield spread as the independent variable. The yield spread is tested in two forms. One, as the spread between the 5-year and 3-month Treasury yields. Two, as the spread between the 10-year and 3-month Treasury yields (same form as the one tested in this paper). The results indicated that the yield curve variable (coefficient) is significant in terms of its ability to explain the variability of economic

growth. During the entire sample period its R-squared measure is greater than 30 percent, indicating that the yield curve is able to explain more than 30 percent of the variation in economic growth. In contrast, the stock market was tested using the return on the S&P 500 as the independent variable, and the results during the entire sample period were bleak, as the stock market variable indicated less than 5 percent explanatory power on economic growth. The results were even more compelling in the sub-periods tested. Furthermore, explanatory power for the yield curve holds in the out-of-sample results as well. An interesting observation is that the yield spread based forecasts for the third quarter of 1989 through the third quarter of 1990 suggested slowing of economic growth. Needless to say, the start of the third quarter in 1990 was designated as the start of the 1990 recession. The recession was considered to be mild, a possible explanation for the forecasting model predicting slowing versus negative economic growth.

The yield curve as a predictor of economic activity is once again tested in an article by Estrella and Hardouvelis (1991). Examining data from 1955 to 1988 they find that the slope of the yield curve has extra predictive power over and above the predictive power of lagged output growth, lagged inflation, the index of leading indicators and the level of real short-term interest rates. Further, they find that the yield curve is a useful predictor of cumulative economic growth up to four years into the future and marginal changes up to eighteen months. The yield curve is also found to predict the private sector components of real GNP: consumption, consumer durables and investment. The usefulness of the slope of the yield curve is tested in and out-of-sample. The results from this article strongly support the slope of the yield curve as a valuable indicator of future economic activity, however, states that the useful could be diluted if the Federal Reserve were to adopt the slope as an information variable in its decision criteria.

The next flood of articles emerged when the 1990 recession provided another opportunity for researchers to test the usefulness of financial indicators in predicting recessions. The predictive power of the yield curve was tested out-of-sample by Hu (1993) through examining

real GDP growth rates in the G7 industrialized countries. He finds that the yield spread is a good predictor of future economic growth. The empirical results suggest that the slope of the yield curve has more forecasting power than variables such as lagged GDP growth, stock price changes and inflation. He advocates that policy makers and private investors can obtain useful information about the business cycle by simply observing the yield curve.

Plosser and Rouwenhorst (1994) examine whether the ability of term structure to predict economic activity stems from information in the short-end or long-end of the yield curve. This is important because monetary policy primarily has control over rates on the short-end, therefore, if the predictability is coming from the short-end then a connection may exist between monetary policy and future economic growth. They use data from 1973:08 to 1988:12 and match the maturity of the yield spread with the forecast horizon. The most significant finding in this paper is that the slope of the yield curve has information about economic growth beyond movements in short-term interest rates. Elements of the term structure beyond two years appear to be very useful for predicting economic growth. The results indicate that the yield curve has forecasting power out to five years, although, this is mainly the result of its significant predictive power out to two years.

Haubrich & Dombrosky (1996) use out-sample testing to examine the yield curve's ability to predict future economic activity. The sample period runs from 1961 to 1995. They consider how well the yield curve predicts the severity of recessions, not just their probability. The yield curve is defined identically to that of which will be tested in this paper, the spread between the 10-year Treasury bond and the 3-month Treasury bill. The forecast results indicate that a narrowing yield curve often signals a decrease in real GDP growth. An inverted yield curve (negative spread) on the other hand usually precedes recessions, but not always. They identify that the yield spread turned negative in the third and forth quarters of 1966, yet no recession occurred for the next three years. They also state that the yield curve leading up to the

1990-91 recession was more flat than inverted. Their findings suggest that the yield spread has significant predictive power on real economic growth with a caveat. The study examines several other financial indicators such as lagged GDP growth, index of leading indicators, Blue Chip Economic Indicators forecast and the DRI/McGraw-Hill forecast. The empirical tests indicate that the yield spread provides the best forecast of real growth four quarters into the future over the past 30 years. However, the caveat arises in examining the sub-period of 1985-95, which completely reverses the results. During this sub-period, the yield curve actually produces the worst results and the leading indicators index the best results. One of the explanations given for this phenomenon is the changing relationship between the yield curve and the economy over the last 30 years. Advances in technology, new production processes and the markets reaction to new information may have altered the relationship between the yield curve and economic activity. Despite this the yield curve is still suggested to be a useful indicator of economic activity primarily because the data is readily available, although they question the accuracy of its predictive power.

The next article by Estrella and Mishkin (1996) is where the empirical testing technique employed in my paper originated. The methodology presented by Estrella and Mishkin (1996) is very unique and extremely important to new research and the analysis presented later in my paper. Unlike previous studies that tested the ability of financial variables to forecast economic activity, Estrella and Mishkin (1996) simply focus on their ability to forecast recessions. They examine out-of-sample results for truer tests of forecasting ability. The sample period for the data runs from the first quarter of 1960 to the first quarter of 1995. The yield spread is the difference between the 10-year and 3-month Treasury yield. The predictive power of each variable is measured using a probit model, which relates the probability of being in a recession to a financial variable. The following variables are tested: yield spread, New York Stock Exchange (NYSE) price index, the Commerce Department's index of leading indicators, and the Stock-Watson

index. The forecast horizons observed are one, two, four, and six quarters into the future. The probability of a recession ranges from zero to one (0 percent to 100 percent). The empirical results indicate that all variables have some forecasting ability one quarter ahead. The leading economic indicator index and the Stock-Watson index produce the best forecasts over this horizon. When the predicting horizon is two or more quarters the results are completely different. The yield curve is by far the best forecast variable and its predictive power increases with the forecast horizon unlike the other variables. The Commerce Department's index of leading indicators produces several incorrect recession signals during the 1982-90 period. The Stock-Watson index completely misses the 1990-91 recession. In contrast to past observations by researchers, they suggest that the yield curve gives a relatively strong signal in forecasting the 1990-91 recession. Despite the recession signal being weaker they provide two explanations for why they believe the signal was still significantly strong. One, they suggest that monetary policy played a smaller role in the 1990-91 recession than in the past. Two, the amount of variation in the yield curve has changed over time and was much less during the 1990s. The recession probability although more significant for the yield curve than the other variables tested, was only 25 percent for the 1990-91 recession. However, Estrella and Mishkin (1996) state that although the probability range is 0 percent to 100 percent, a probability less than 100 percent can be a strong signal of an upcoming recession. The reasoning for this observation is that the probability of a recession in any given quarter is quite low thus a probability of 50 percent is going to be quite unusual. On this basis, they claim the 25 percent probability forecast for the 1990-91 recession may have been a strong signal that a recession was ahead. A table is provided that matches the probability of a recession with a corresponding value of yield spread. For example, if the yield spread is negative the probability of a recession is slightly greater than 25 percent (refer to page 34 Table 5 for complete results). Estrella and Mishkin (1996) strongly endorse the yield curve as a useful forecasting tool because it is simple and easily observed, and it

outperforms other financial and economic indicators in predicting recessions two to six quarters ahead.

My research is most influenced by an article written by Michael Dueker (1997), a senior economist at the Federal Reserve Bank of St. Louis. He revisits the yield curve as a predictor of U.S. recessions using the simple probit model from Estrella and Mishkin (1996) and extends the analysis further with two econometric models. This study provides a detailed analysis of the research that originated from Estrella and Mishkin (1996) with a few enhancements. Dueker (1997) uses a simple probit model but also examines recession probabilities from the probit model using a lagged dependent variable and Markov-Switching. He tests five explanatory variables: the change in the Commerce Department's index of leading indicators, real M1 growth, credit spread, change in the Standard and Poor's 500 index of stock prices, and the yield curve. The sample period runs from January 1959 to May 1995. Results from the regression analysis are provided for the five variables at various forecast horizons. The results are based on forecast horizons of one, two, three and four quarters ahead. The performance of the variables is measured by pseudo-R^2 proposed by Estrella and Mishkin (1996). Similar to results from previous studies such as Plosser and Rouwenhorst (1994), Haubrich & Dombrosky (1996) and, Estrella and Mishkin (1996), he finds that slope of the yield curve becomes the best predictor of recessions with longer forecast horizons. More specifically, he finds that the yield curve is dominant beyond a one-quarter forecast horizon. Further, the empirical results indicate that the yield curve slope lagged nine months is the greatest recession predictor. Although the yield curve is found to be the best predictor out of the variables tested, he states that it does not absolutely predict the onset or duration of recessions. Nevertheless, he provides two factors that support the usefulness of the yield curve in predicting recessions. First, it is observable at high frequencies and gives a signal that is easy to interpret. Second, it has a sound theoretical foundation in support of its predictive power.

Once again, Estrella and Mishkin (1997) examine the usefulness of various financial variables in predicting recessions one to eight quarters into the future. They focus on recession predictability and use out-of-sample data in their analysis that uses quarterly data from 1959 to 1995. Many variables are tested such as interest rates, interest rate spreads, stock price indexes, monetary aggregates, Commerce Department's index of leading indicators and lagged growth in real GDP. The paper supports the use of quarterly data by stating that monthly data is too noisy and produces weaker results. The in-sample and out-of-sample results find that the yield curve dominates all other variables starting with predictions beyond one quarter. In addition to these findings, the out-of-sample results are even stronger than in-sample results for two and three quarters ahead. The out-of-sample predictive power of the yield curve is found to be non-existent at seven and eight quarters ahead. Also noteworthy, is that only stock price indexes improve the predictive power of the yield curve beyond one quarter. The predictability of the 1990-91 recession is examined and the results indicate that the yield spread and NYSE were much more useful in predicting the recession than leading indicator variables. They state that the yield curve itself was quite informative in forecasting the 1990-91 recession four quarters ahead. They also suggest that the weakness of the recession signal should be interpreted by analysing the term structure of interest rates in the 1980-81 recessions. The yield curve was extremely steep and it was also very negative which produced an unusually broad range of spreads. In this context even though the signal was weaker than in the past it was still significant.

In contrast to Estrella and Mishkin (1997), Dotsey (1998) claims that the yield curve spread failed to predict the 1990-91 recession. He examines the relationship between the yield curve and real GDP growth from 1955 to 1997. Before providing detailed statistical analysis he presents some casual observations. For example, he discusses yield spread behaviour during recessions and also analyses false signals of recessions. He shows that prior to most recessions the yield curve inverts and the spread usually remains negative for a good part of recessions.

Next, he examines true and false recession signals from the yield curve. When a recession signal was based on a negative spread, twenty signals were produced with eighteen true signals, two false signals and eight true signals within a recession. Based on these results an inverted curve indicates an 83.3 percent probability of an upcoming recession. When the threshold spread is moved to 25 basis points the results indicate thirteen false signals and the probability of a recession is only 55 percent. The detailed statistical analysis is based on in-sample and out-of-sample research. In addition to providing results for the entire sample period, sub-periods are also examined. This is worth mentioning because he claims that the spreads predictive power diminished vastly during the 1985-97 period. This is supported by empirical results that show the yield spread variable is found to be insignificant at a 5 percent level in forecasting cumulative output growth (GDP) two years forward. The out-of-sample tests show that the spread helps improve the predictive accuracy of the model that includes lagged values of GDP growth and short-term interest rates. However the improvement is not significant. Additionally, in the most recent sub-period (1985 to 1997), they find that the model performs worse with the spread than without. Next, recession predictability is analyzed using the probit model from Estrella and Mishkin (1997). A variable for monetary policy is tested based on the concept that the yield curve generally inverts during times of contractionary monetary policy, or tight monetary policy. The results suggest that adding a term that incorporates tight monetary policy does not help forecast recessions. The probit results indicate significant predictive power of the yield spread based on pseudo-R^2 consistent with previous findings. Furthermore, he tests four different probit models with combinations of the spread, lagged GDP, and lagged short-term interest rates. A unique feature of the test is that false recession forecasts are penalized. He finds that the spread actually reduces the possibility of falsely predicting the onset of a recession. This paper reinforces the yield curves ability to forecast GDP growth and recessions. Perhaps the most notable finding is the insignificance of the yield curve in predicting GDP growth during the sub-period of 1985 to 1997.

Following the mild 1990-91 recession U.S. economic growth accelerated leading

economists to question how long this expansion could last at average growth rates exceeding 4

percent for the three years leading up to 1999 (Filardo, 1999). Filardo (1999) suggesting that no

signs of slowing were in sight decided to test five recession prediction models to see if they could

help resolve uncertainty regarding the possibility of an upcoming recession. The five recession

models tested were: simple rules of thumb using the Conference Board's composite index of

leading indicators (CLI), Nefti's probability model of imminent recessing using the CLI, probit

model, GDP forecasting model, and a Stock-Watson recession model. The strengths and

weaknesses of the five models are identified followed by an evaluation of their historical

forecasting performance. Finally, the message the recession models are sending now is

evaluated. The usefulness of the models is attributed to the premise that the behaviour of the

economy during periods of transition between expansion and recession is much different than

when a recession is not imminent (Hymans, 1973). Several strengths of the probit model are

identified. First, the model has the ability to predict at a specified forecast horizon. Second, the

model can easily be amended to include or exclude variables. Third, the model uses variables

that are easily observable and do not require revisions. Two main weaknesses are identified.

First, the model may miss recessions that exhibit unusual lead times. Second, if specific variables

are used based on data mining, the model may be over-fitting on the basis that the new variables

in truth have no predictive content for recessions. At short forecast horizons, the probit model is

criticized for sending false signals in 1966, 1983 and 1988. For midrange forecast horizons the

model is said to have only produced one false signal, and failed to spot two recessions, 1960-61

and 1990-91. The only variable that is significant beyond nine months is the yield spread, which

is consistent with findings of Estrella and Mishkin (1997) and Dueker (1997). In testing the five

models, Filardo finds that all models are sending the same clear signal that a recession is not

imminent. In his closing remarks he proposes that recession signals are clearest when all models

are in agreement. In addition he states that past successes of the models, does not guarantee future predictability.

Dueker (2002), like so many others finds that in general, recession forecasting models failed to predict the 1990-91 recession. He then goes on to test the most recent recession in 2001 in order to question whether or not the 1990-91 recession was uniquely difficult to forecast. Out-of-sample testing is observed because recessions are infrequent which could lead to over-fitting in-sample. Three recession forecasting models are examined, one of which is the simple probit model used in this paper. The other two are regime-switching models. The two regime-switching models are observed in order to address criticism that recession probability models make too much out of recession probabilities. Meaning that ex-post they can claim to have predicted a recession even if the probability signal was only 35 percent. Therefore the two innovative models provide a yes/no recession signal based on a critical value. The results indicate that all three models failed to predict the 1990-91 recession. However, the two regime-switching models were fairly accurate in predicting the 2001 recession whereas the simple probit model largely missed the 2001 recession. The conclusion is that the 1990-91 recession was an anomaly.

Stock and Watson (2003) suggest that the 2001 recession was different than past recessions dating back to the 1980s in its cause, severity and scope. As a result, they examine the forecasting performance of leading indicators for the 2001 recession. They claim that unlike past recessions that were caused by factors such as the Federal Reserve battling inflation or consumer spending, the 2001 recession was spurred by corporate America cutting expenditures particularly investment in information technology that led to declines in manufacturing output and the stock market. Recall that Dueker (2002) tested the hypothesis that the inability to forecast the 1990-91 recession was an anomaly using new information from the 2001 recession. Stock and Watson (2003) on the other hand are suggesting that the 2001 recession was an anomaly and therefore

tests its significance in forecasting recessions. They examine how a wide range of leading economic indicators performed in signalling a recession. The results from testing twelve leading indicators suggested that the yield spread provided a clear signal that the economy was slowing down. The decline in the stock market and a sharp rise in unemployment insurance claims also suggested a slowing economy. In contrast, consumer confidence, consumer spending, growth of money supply, the junk bond spread and housing starts provided no signal of a recession. In the conclusion, they state that while the yield curve predicted an economic slowdown in 2001, it did not give an early indication of a slowdown prior to the 1990-91 recession; consistent with the results from Dueker (2002). Further, they suggest failure of individual indicators in forecasting recessions consistently should not be surprising given that the U.S. economy has undergone significant changes during the past three decades. These changes include: expansion of international trade, the development of financial markets, the relaxing of liquidity constraints facing consumers, and the rise of information technology. In addition to these changes, they provide an interesting depiction of the change, the evolution of monetary policy from reactionary to proactive.

Filardo (2004) once again evaluates the performance of recession prediction models, however this time he is only concerned with the 2001 recession. The four recession models tested are: simple rules of thumb using the Conference Board's composite index of leading indicators (CLI), Nefti's probability model of imminent recessing using the CLI, probit model, and a Stock-Watson recession model. All models with the exception of the Stock-Watson model signalled a recession in advance. The message from the probit model was relatively clear based on several different forecast horizons. The probability was above or in the case of the three-month horizon close to 50 percent. Although the forecasts varied in terms of the precise start date, they sent a relatively consistent signal in late 2000 that a recession was looming. Some concern was raised regarding the probit models sensitivity to real-time data. Ultimately, the CLI

model is claimed to have resurrected based on its superior performance in predicting the 2001 recession.

A recent study completed by Chauvet and Potter (2005) examines the predictive content of the yield curve for U.S. recessions using several extensions of the Estrella and Mishkin (1996) probit model. Using data from January 1955 to December 2000, they compare recession forecasts using four different probit models: a time invariant conditionally independent version, a business cycle specific conditionally independent model, a time invariant probit with autocorrelated errors, and a business cycle specific probit with autocorrelated errors. They argue that the yield curve's predictive power is not stable over time. Further they state that most models that used the spread were not able to predict the 1990 recession. The empirical results indicate that the more complex models provided less strong and precise signals. The standard probit model appears to be the best, lending support to the explanatory power of the yield curve. Although, the authors advise that this is the wrong conclusion to draw because they claim that the information of the model formed with information up to March 2001 did not allow for updating of information. For example, they claim that the terrorist attacks of September 11, 2001 contributed to the probability of a recession, and yet the yield curve data up to March 2001 could not have possibly predicted this event. Their main point is that the standard probit model tends to over predict recession events. In addition, the standard probit model predicts economic slowdowns as well as recessions and not all economic slowdowns result in a recession. Essentially, the findings suggest that a simple model outperforms complex models; however, the results should not be relied on heavily because other factors also play a significant role in the occurrence of a recession. A final criticism of models that simply use the yield curve as a predictor of U.S. recessions is based on the argument that these models assume that no additional information other than the NBER business cycle dates is relevant to predict recessions.

3 METHODOLOGY

The main focus of this paper is to replicate the analytical approach of Dueker (1997)

while incorporating ten years of new data. The objective is to examine recession probabilities

from the simple probit model as tested by Estrella and Mishkin (1996). The probability probit

model is used to predict a recession dummy variable, R_t where

$R_t = 1$ if the economy is in a recession at period t

$R_t = 0$ otherwise

The dummy variables enable the isolation of recession forecasts. Dueker (1997) uses a simple

probit model, a standard econometric model to forecast the probability of a recession. The

equation is located below with the dependent variable defined as the probability of a recession at

time t. The model is based on the cumulative standard normal density function Φ. The forecast

horizon is k periods (months), and the X is a set of explanatory variables used to forecast

recessions. The parameter estimates c_0 and c_1 are derived from the regression analysis.

$$(1) \qquad \text{Prob } (R_t = 1) = \Phi \, (c_0 + c_1 \, X_{t-k})$$

The log-likelihood function for the probit model above is

$$(2) \qquad L = \Sigma \, R_t \, \ln\text{Prob } (R_t = 1 \mid X_{t-k}) + (1 - R_t)\ln\text{Prob}(R_t = 0 \mid X_{t-k})$$

The measure of fit for the probit model is based on pseudo-R^2 developed by Estrella in the

working paper version of Estrella and Mishkin (1997). The log-likelihood of the model tested L_u,

is compared to the log-likelihood L_c from a model that only contains a constant (no explanatory

variable) implying a constant probability of a recession each month Dueker (1997). The number of observations n, is the only other variable in the formula.

$$(3) \qquad \text{pseudo-} R^2 = 1\text{-}(L_u / L_c)^{-(2/n)Lc}$$

The pseudo-R^2 generates a value between 0 and 1 because L_c will always be greater than L_u. The closer the value of pseudo-R^2 is to 1, the greater the explanatory power of the model.

Two forms of the probit model will be tested in this paper. First, the yield curve as the sole explanatory variable:

$$(4) \qquad \text{Prob } (R_t = 1) = \Phi (c_0 + c_1 \text{ Yield Curve }_{t\text{-}k})$$

Next, a four-variable probit model:

$$(5) \qquad \text{Prob } (R_t = 1) = \Phi (c_0 + c_1 \text{Yield Curve }_{t\text{-}k} + c_2 \text{Lead }_{t\text{-}k} + c_3 \text{Money}_{t\text{-}k} + c_4 \text{Stock }_{t\text{-}k})$$

Each variable is defined in the next section.

The value of studying the predictability of recessions is based on inputting available data into the model to forecast a recession in the future. Therefore, out-of-sample tests will be carried out in this paper. The research in this paper differs from most literature on recession predictability primarily because the focus is solely on the yield curve variable. The standard probit model will be tested under four different time horizons. The first two will correspond to the latest recessions, 1990-91 and 2001. The third will represent recession forecasts for the future incorporating the latest data. Finally, the probit model will be tested with four years of data excluded in the regression analysis. Forecast horizons examined in this paper will be three, six, nine and twelve months. Charts and estimates will be provided for the nine-month forecast horizon, data for the other forecast horizons will be provided in the appendices.

4 DATA

I examine probit results for four explanatory variables: the percentage difference between the yield on a 10-year Treasury bond and a 3-month Treasury bill (**Yield Curve**); percentage change in the Conference Board's index of leading indicators (**Lead**); monetary growth (**Money**); and the percentage change in the Standard and Poor's 500 index of stock prices (**Stock**). The credit spread variable examined by Dueker (1997) is not tested in this paper as the data series for the 6-month commercial paper rate has been discontinued by the Federal Reserve of St. Louis. I use monthly time series data ranging from January 1959 to October 2005. The recession binary variables of 0 or 1 are retrieved from the National Bureau of Economic Research. The source and precise composition of the variables is provided in Appendix A. The data set for specific testing periods will be identified accordingly. Note that the yield curve variable (i.e., the spread between the 10-year and 3-month Treasury yield) is the most widely used metric internationally for measuring the slope of the yield curve.

5 EMPIRICAL RESULTS

5.1 Predictability of the 1990-91 Recession

According to the National Bureau of Economic Research, the 1990-91 recession officially started July 1990 and lasted eight months until March 1991. Although not severe by historical standards the impact of the recession on employment was significant. Researchers seem to agree that this recession was unique for various reasons and studies have argued that recession predictors of the past failed this time around. Dotsey (1998), Dueker (2002), and Stock and Watson (2003) denounced the yield curve's ability to forecast the 1990-91 recession. I analyze the degree of validity in their claim by examining the results using the simple probit model methodology. In order to present out-of-sample recession probability results, the data used for the probit regression ranged from January 1959 to April 1990 for the model with a three-month forecast horizon (k periods prior to the recession). For the following example, since the forecast horizon is nine months, data ranged from January 1959 to nine months prior to the start of the recession. The probit regression generated the following coefficient estimates where the forecast horizon (k) is nine months (the corresponding t-stats are provided below the coefficient estimates correspondingly):

$$(4) \qquad \text{Prob } (R_t = 1) = \Phi \, (\text{-}0.5297 + \text{-}1.8212 \text{ Yield Curve}_{t\text{-}9})$$
$$\phantom{(4) \qquad \text{Prob } (R_t = 1) = \Phi \, (} (\text{-}5.5290) \quad (\text{-}8.5650)$$

The t-stats indicate that both coefficient estimates are significant at a 99 percent level of confidence. The negative value for the yield curve coefficient should make sense intuitively, as a negative yield curve spread would increase the probability of a recession (the result of a double negative). The nine-month forecast horizon recession probabilities are shown in Chart 4.

Remember that the recession probabilities in this case are based solely on the yield curve as an explanatory variable and the last three months are out-of-sample forecasts.

A result that is consistent across all forecast horizons tested is the sharp increase in the recession probability prior to the 1990-91 recession. The strength of the signal may be scrutinized but it is quite clear the model is identifying a change as the probability surges from a near zero percent range prior to 1989 to 30 percent in the second half of 1989 and early 1990.

Chart 4 Recession Probabilities from the Simple Probit Model: 9-Month Forecast Horizon

$$Prob(Rt=1) = \Phi(c_o + c_1(Yield\ Curve_{t-k})$$
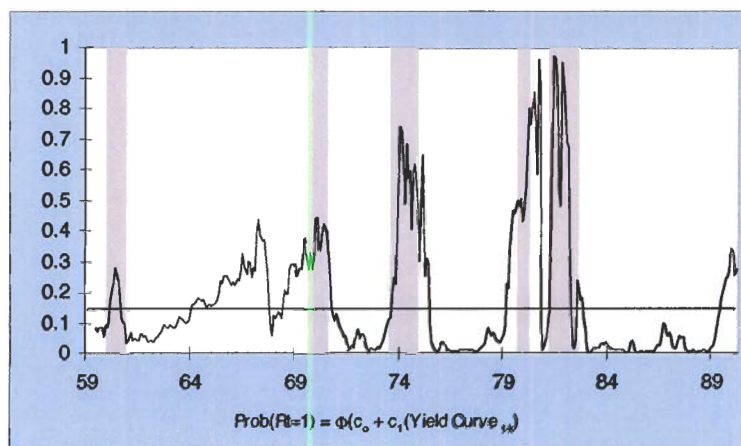
The interpretation of the results obviously cannot be completely objective; however, the trend is definitely clear even if a recession probability of 30 percent is not. A salient point here is that the probit model decision criteria is based on a threshold of 50 percent. Meaning that if the probit model generates a probability greater than 50 percent, then a recession is signalled otherwise it is not signalled. However, remember that the standard probit model is based on five variables (Dueker, 1997). In Chart 4, we are only considering the significance of one explanatory variable, the yield curve. Therefore, it is trivial that the recession probabilities will be somewhat less. This may and likely should justify a lower threshold value. Recall that Estrella and Mishkin (1996) suggested that a 25 percent probability of a recession could be interpreted as a strong signal on the basis that the signal is normally quite low. This concept will be addressed in section 5.4.

The analysis would not be complete without examining the results from the four-variable probit model (Equation 5):
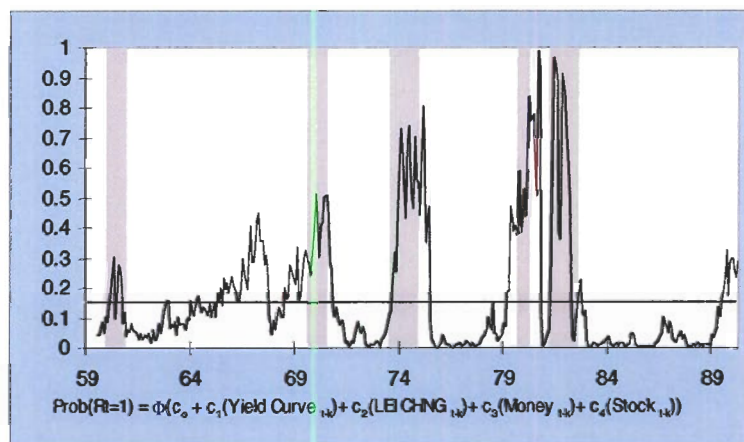
$$\text{Prob}(R_t = 1) = \Phi(-.5930 + -1.5664 \text{ Yield Curve}_{t-k} + -.2671 \text{ Lead}_{t-k} + .0947 \text{ Money}_{t-k} + -.0402 \text{ Stock}_{t-k})$$
$$(-5.6404) \quad (-6.0925) \qquad\qquad (-1.8535) \qquad (.2242) \qquad\qquad (-.5933)$$

Only the intercept and the yield curve are significant at a 99 percent confidence level. Monetary growth and stock returns are insignificant, and the index of leading indicators is only significant at a 90 percent confidence level. Monetary growth is the only coefficient estimate that is positive meaning that it moves in the same direction as the recession probability. In other words, if monetary growth is positive the probability of a recession increases.

Although the model does not have all five variables (missing the credit spread variable) as in the model that was dismissed by Filardo (1999) it does provide insight on what the probit model signalled. Moreover, it provides an opportunity to compare its forecasts to the probit model that simply uses the yield curve variable.

Chart 5   Recession Probabilities from the Four-Variable Probit Model: 9-Month Forecast Horizon

$$\text{Prob}(Rt=1) = \Phi(c_o + c_1(\text{Yield Curve}_{t-k}) + c_2(\text{LEI CHNG}_{t-k}) + c_3(\text{Money}_{t-k}) + c_4(\text{Stock}_{t-k}))$$

The results of the recession forecasts generated by the four-variable probit model are shown in Chart 5. The results of the two models are quite similar, implying that the yield curve is the main driver of the four-variable model. Once again visually the probability significantly

increased prior to the recession, although both models only peak at a probability of approximately 30 percent.

Next, if we examine the pseudo-R^2 results in Table 1 (on the following page), we can see that the yield curve becomes the dominant predictor beyond a three-month forecast horizon, and the explanatory power of the yield curve is much greater than the other variables, particularly at longer horizons. The results are consistent with those obtained by Dueker (1997).

Table 1   Pseudo R^2 Measures of Fit for Recession Predictors

	REGRESSION RESULTS FOR 1959:1 TO 1990:4			
Predictor	Forecast Horizon			
	k=3	k=6	k=9	k=12
Yield Curve	0.143	0.255	0.296	0.243
	(145.1)	(124.9)	(117.8)	(127.6)
LEI CHNG	0.242	0.185	0.167	0.079
	(127.1)	(137.6)	(141.1)	(157.3)
Money	0.099	0.073	0.092	0.053
	(153.3)	(158.1)	(154.7)	(161.9)
Stock	0.067	0.063	0.040	0.020
	(159.1)	(160.0)	(164.3)	(168.0)
Log-like.Lc	(171.5)	(171.5)	(171.5)	(171.5)

Log-likelihood values are in parentheses

Notice that the explanatory significance of all variables with the exception of the yield curve declines as the forecast horizon increases. At the shorter end, the leading economic indicator index embodies the greatest predictive power; however, it loses considerable strength as the forecast horizon increases. The yield curve on the other hand performs the best at forecast horizons of six, nine and twelve months. This finding is important particularly for policymakers as implementing policy changes can take several months to take effect. Foresight is also invaluable for investment managers. The results from this period indicate that the yield curve did

provide a signal of a recession prior to the 1990-91 recession, albeit not a strong signal. Nevertheless, the yield curve is still by a large margin the best predictor of recessions among the four variables observed. As mentioned by Estrella and Mishkin (1997), the broad range of spreads experienced in the early 1980s may be one of the reasons why the probit model generates such modest results for this recession. Another explanation given is that monetary policy has evolved (Stock and Watson, 2003), reducing the volatility of spread.

5.2 Predictability of the 2001 Recession

The 2001 recession officially started in March and lasted nine months, shorter than the historical average of twelve months since 1959. The recession was preceded by numerous economic shocks on the US economy. These shocks included bursting of the tech bubble, and massive corporate scandals. Besides these shocks it had been nearly a decade since the last recession so some suggest it was overdue. For economists it was another opportunity to test recession forecasting models. Dueker (2002) found that the probit model which includes a yield curve variable largely failed to predict the 2001 recession. On the other hand, Stock and Watson (2003) test numerous financial indicators and find that the yield curve clearly indicated that the economy was going to be slowing down. In order to present out-of-sample recession probability results, the data used for the probit regression ranged from January 1959 to December 2000. The probit regression generated the following coefficient estimates where the forecast horizon (k) is nine months (the t-stats for the coefficient estimates are provided correspondingly):

(4) $\text{Prob} (R_t = 1) = \Phi (-0.5470 + -1.9400 \text{ Yield Curve}_{t-9})$
              (-6.1341) (-9.2917)

Once again both coefficients are significant at a 99 percent level of confidence. The yield curve coefficient is more negative during this period relative to 1990-91, indicative of increased sensitivity to changes in the slope of the yield curve. The recession probabilities are shown in Chart 6. The recession probability increased to about 25 percent based on a forecast horizon of

nine months prior to its onset. At a six-month forecast horizon, it peaks at nearly 40 percent.

Bear in mind that only the slope variable was used in this forecast.

Chart 6   Recession Probabilities from the Simple Probit
Model: 9-Month Forecast Horizon

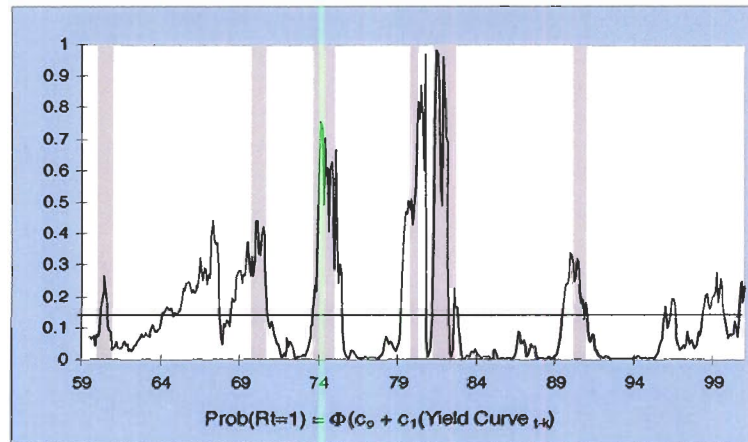$$Prob(R_t = 1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t+t}))$$

Chart 6 illustrates that recession probability gradually increased. In contrast, with a six-month forecast horizon the recession probability surges prior to the onset of the recession (see Appendix C). Although, both forecast horizons generate an increase in recession probability, the six-month forecast horizon provides a much stronger signal. Unlike the 1990-91 observations, the yield curve probit model generated two significant upward surges well in advance of the recession (1996 and 1998). As a result, the change in the recession probability is less pronounced during this period. Longer forecast horizons generated stronger recession signals prior to the 1990-91 recession, whereas shorter forecast horizons generated stronger recession signals prior to the 2001 recession. Therefore, although the 1990-91 recession was identified earlier (25 percent probability twelve months ahead), the signal was stronger in absolute terms prior to the 2001 recession (40 percent probability six months ahead). In addition, if the cumulative probability is considered the gradual increase in recession probability could be construed as a stronger signal.
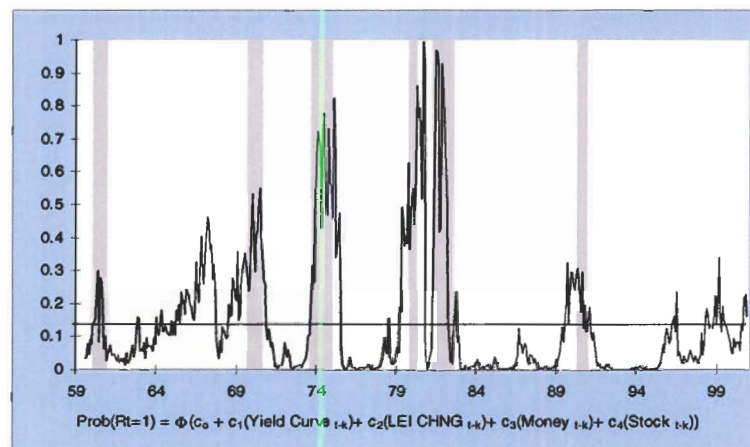
Next, we examine the results from the four-variable probit model (Equation 5):

$$\text{Prob } (R_t = 1) = \Phi \, (-.5865 + -1.7335 \text{ Yield Curve }_{t-k} + -.2785 \text{ Lead }_{t-k} + .3147 \text{ Money }_{t-k+} -.0530 \text{ Stock }_{t-k})$$
$$\quad\quad\quad\quad\quad (-5.9630) \quad (-7.1071) \quad\quad\quad\quad\quad (-2.0239) \quad\quad\quad (.8338) \quad\quad\quad (-.8518)$$

The yield curve is even more significant with the additional ten years of data. The leading

indicator is significant at a 95 percent level of confidence, unlike the results from the previous

period. Once again, monetary growth and stock returns are insignificant. Chart 7 shows the

recession probabilities generated by the probit model. We can see that the recession probability

was moderately weaker for the four-variable probit model than the yield curve model. Only at

with a forecast horizon of three months does this model generate better results than the yield

curve model (54 percent recession probability versus 36 percent). These results lend support to

the predictive power of the yield curve. As shown, the recession probability surged prematurely

in 1996 and 1998. This was also the case for the yield curve model however, not as pronounced.

The constant recession probability during this period was 14.5 percent thus the recession signal

from each model was well above this threshold.

Chart 7   Recession Probabilities from the Four-Variable
Probit Model: 9-Month Forecast Horizon

$$\text{Prob}(Rt=1) = \Phi \, (c_0 + c_1(\text{Yield Curve }_{t-k}) + c_2(\text{LEI CHNG }_{t-k}) + c_3(\text{Money }_{t-k}) + c_4(\text{Stock }_{t-k}))$$

Next, the pseudo-R^2 results are displayed in Table 2. Consistent with outcomes from

previous studies, the yield curve is the most significant explanatory variable beyond a three-

month forecast horizon. The leading indicator index is the best predictor at a three-month

forecast horizon. Similar to the results from Dueker (1997), the yield curve lagged nine months is the best overall predictor of recessions. Notice that only the yield curve variable demonstrates significant predictive power out to twelve months.

Table 2 Pseudo R^2 Measures of Fit for Recession Predictors

| Predictor	Forecast Horizon			
	k=3	k=6	k=9	k=12
Yield Curve	0.130	0.229	0.277	0.241
	(176.5)	(152.9)	(141.8)	(150.7)
LEI CHNG	0.225	0.169	0.142	0.067
	(153.7)	(167.2)	(173.8)	(192.2)
Money	0.065	0.053	0.059	0.034
	(192.4)	(195.5)	(194.1)	(200.2)
Stock	0.059	0.060	0.033	0.016
	(193.9)	(193.6)	(200.3)	(204.5)
Log-like.Lc	(208.5)	(208.5)	(208.5)	(208.5)

REGRESSION RESULTS FOR 1959:1 TO 2000:12

Log-likelihood values are in parentheses

Although the collapse of the U.S. stock market preceded the 2001 recession, historically, the stock market variable (S&P 500) appears to have the least amount of explanatory power in predicting recessions based on results from Table 2. This is consistent with results from Harvey (1989) who finds that the stock market variable (S&P 500) only explains about 5 percent of the variation in economic growth. A popular joke that illustrates the weakness of the stock market variable in forecasting recessions is that the stock market correctly forecasted the last nine out of four recessions (Harvey, 1989). This leads us to consider an extremely important factor in determining the usefulness of forecast variables. At forecast horizons beyond three months, the yield curve unlike the stock market variable has only generated one false signal in the last forty-six years, during which time the U.S. endured seven recessions.

5.3   Is a 2006 Recession on the Horizon?

Since the 1960-61 recession, on average it has taken 5.8 years for another recession to surface. Today, four years have past since the last U.S. recession enticing many economists and individuals alike to consider the probability of an upcoming recession. The state of the economy over the last four years can be described in one word 'resilient'. Economic growth has continued despite major set backs such as the terrorist attacks on September 11, 2001, the war against Iraq which started on March 23, 2003, high commodity prices particularly oil prices reaching levels not seen in twenty years, and finally hurricane Katrina the costliest tropical cyclone of all time which struck the state of Louisiana on August 23, 2005. Strength in consumer spending, the housing market, employment and controlled inflation, along with monetary stimulus through a low interest rate environment has helped the U.S. economy persevere. The yield curve has continued to flatten over the last four years   Short-term rates have risen steadily despite stable long rates creating speculation of an inverted yield curve (Chart 8).

Chart 8   Interest Rate Environment Since the 2001 Recession
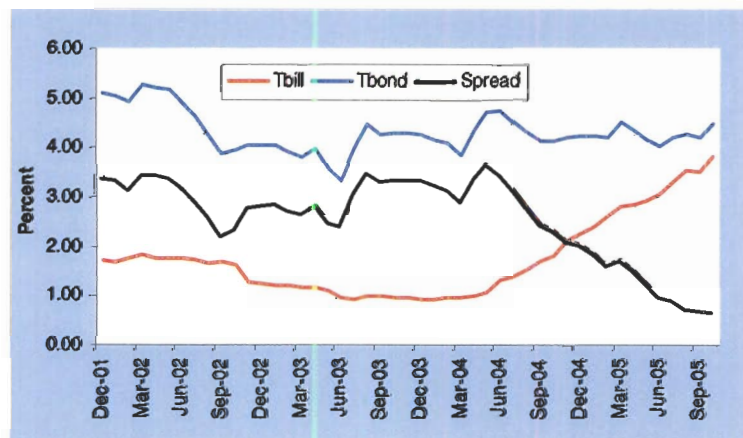
The Federal Reserve has continued to raise short-term interest rates despite facing rising commodity prices on the premise of strong output growth and employment. If output growth and/or employment weaken in conjunction with this commodity bull market, the Federal Reserve

will face an extremely difficult decision in terms of balancing monetary policy to counter

weakness without losing grip on inflation. As for now, it appears the yield curve is headed for

inversion.

The latest monthly data is used in the probit model, January 1959 to October 2005. The

probit regression generated the following coefficient estimates where the forecast horizon (k) is

nine months (the t-stats for the coefficient estimates are provided correspondingly):

$$(4) \quad \text{Prob } (R_t = 1) = \Phi \ (-0.4829 + -2.0549 \text{ Yield Curve }_{t-9})$$
$$(-5.5869) \ (-9.9433)$$

Once again, as should be expected from the data set, both coefficient estimates are significant.

The additional data leads to new observations in support of the yield curve: reduced significance

of the intercept and increased significance of the yield curve. Examining the recession

probabilities based on the yield curve model shows an increase in the probability of a recession,

however, the signal is relatively weak (Chart 9). The recession signal is consistent across all

forecast horizons: three, six, nine, and twelve months. The out-of-sample forecast estimates fall

well into 2006. The furthest forecast ends in October 2006 with a recession probability of 14.5

percent, not significantly different from the constant probability of 14.6 percent, yet, if the spread

continues to narrow the probability will increase.

**Chart 9   Recession Probabilities from the Simple Probit
Model: 9-Month Forecast Horizon**

$$\text{Prob}(Rt=1) = \Phi(c_o + c_1(\text{Yield Curve }_{t-k})$$
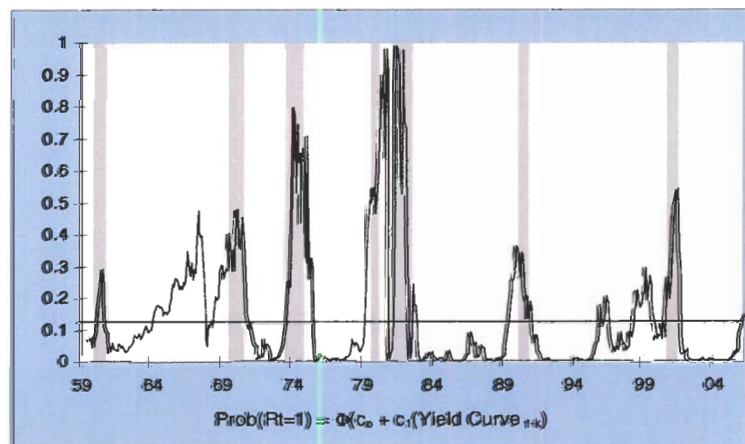
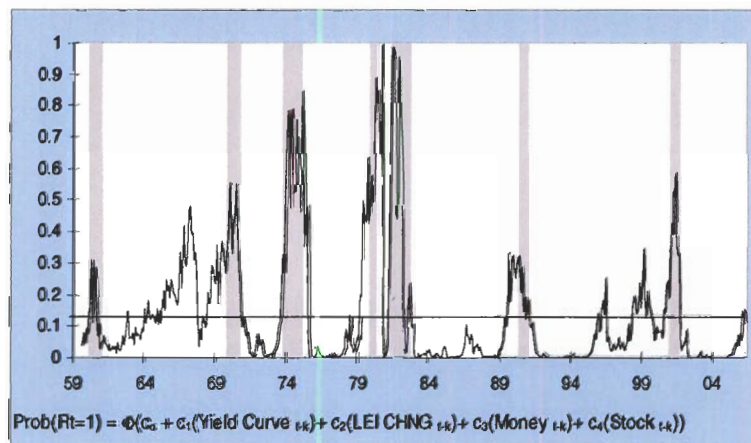Next, we examine the results from the four-variable probit model (Equation 5):

$$\text{Prob}(R_t = 1) = \Phi(-.5273 + -1.8469 \text{ Yield Curve}_{t-k} + -.2506 \text{ Lead}_{t-k} + .1798 \text{ Money}_{t-k} + -.0449 \text{ Stock}_{t-k})$$
$$(-5.5621)\quad(-7.7013)\qquad\qquad(-1.8402)\qquad(.5227)\qquad(-.7556)$$

Again, only the intercept and the yield curve coefficient estimates are significant at a 99 percent level of confidence. Furthermore, the yield curve estimate is even greater in this model than the 1990-91 and 2001 coefficient estimates.

The recession probability forecasts are almost identical to those of the yield curve model. As illustrated in Chart 10, the recession probability is on the rise, yet well below a definitive recession signal. The recession probability peaks at about 15 percent, not significantly different than the constant recession probability of 14.6 percent. Still with the rate at which the yield curve has been flattening a substantial increase would not be surprising. Also recognize that the recession probability until just recently was close to zero for several years. As such, the yield curve and four-variable probit model are both signalling a change in the economic environment. Whether or not this will ultimately be designated as the start of a true recession forecast signal remains to be seen.

**Chart 10 Recession Probabilities from the Four-Variable
Probit Model: 9-Month Forecast Horizon**

$$\text{Prob}(Rt=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k}) + c_2(\text{LEI CHNG}_{t-k}) + c_3(\text{Money}_{t-k}) + c_4(\text{Stock}_{t-k}))$$

The pseudo-R² results are shown in Table 3. Once again the yield curve is by far the best recession predictor beyond a three-month forecast horizon. Consistent with previous results the yield curve is best with a forecast horizon of nine months. Note that these results are similar to Dueker's (1997) even with the inclusion of ten years of extended data. Similar to previous outcomes the index of leading indicators is the best predictor three months forward. Monetary growth and stock returns fail to exhibit any significant explanatory power.

Table 3   Pseudo R^2 Measures of Fit for Recession Predictors

REGRESSION RESULTS FOR 1959:1 TO 2005:10

Predictor	Forecast Horizon			
	k=3	k=6	k=9	k=12
Yield Curve	0.133	0.244	0.306	0.261
	(196.7)	(167.3)	(151.5)	(163.5)
LEI CHNG	0.213	0.171	0.147	0.068
	(175.4)	(187.0)	(193.6)	(214.9)
Money	0.040	0.046	0.060	0.039
	(222.5)	(220.8)	(217.1)	(222.8)
Stock	0.053	0.054	0.029	0.013
	(218.8)	(218.6)	(225.6)	(230.0)
Log-like.Lc	(233.5)	(233.5)	(233.5)	(233.5)

Log-likelihood values are in parentheses

Until now, I simply compared the four-variable model to the yield curve model, and therefore thought it would be interesting to examine how combining the yield curve with other variables would impact its pseudo-R^2 measure. The results are shown in Table 4.

Table 4   Pseudo R² Measures of Fit for Recession Predictors

REGRESSION RESULTS FOR 1959:1 TO 2005:10

Predictor	Forecast Horizon			
	k=3	k=6	k=9	k=12
Yield Curve & LEI CHNG	0.241	0.289	0.319	0.265
& MONEY & STOCK	(168.1)	(155.6)	(148.3)	(162.7)
Yield Curve & LEI CHNG	0.235	0.277	0.318	0.263
	(169.6)	(158.9)	(148.7)	(163.1)
Yield Curve & Money	0.137	0.245	0.307	0.264
	(195.9)	(167.2)	(151.4)	(162.9)
Yield Curve & Stock	0.170	0.273	0.313	0.262
	(186.9)	(159.8)	(150.0)	(163.4)
Yield Curve ONLY	0.133	0.244	0.306	0.261
	(196.7)	(167.3)	(151.5)	(163.5)
Log-like.Lc	(233.5)	(233.5)	(233.5)	(233.5)

Log-likelihood values are in parentheses

Notice that the yield curve holds up extremely well on its own at forecast horizons of nine and twelve months. As such, the predictive power of the probit model with all four variables is only marginally better than simply using the yield curve at nine and twelve-month forecast horizons. The only real significant difference is at the three-month forecast horizon. The best single variable to add to the yield curve is the leading economic indicator, at shorter forecast horizons for the most part. This should be expected given the index of leading economic indicators embodies the greatest explanatory power at three-month forecast horizons.

5.4   Collating the Empirical Results

The empirical results thus far have provided some valuable insight on understanding the yield curve's role in predicting U.S. recessions. Moreover, the yield curve probit regression model can be used to create a scale of reference for determining the probability of a recession. This scale can be used to retrieve a recession probability associated with a specific yield spread.

For example, the probit model for the period of 1959 to 2005, indicates that a spread of zero basis points (i.e., a flat yield curve) is associated with a 30 percent probability of a recession. These findings are very similar to those of Estrella and Mishkin (1996). However, as some researches have identified (Estrella and Mishkin 1997), the volatility of interest rates during the late 1970s and early 1980s was exceptionally high, and therefore distort the results generated by the probit model. This argument is used to defend the yield curve's track record in failing to accurately predict the last two recessions. It also refutes the hypothesis that the yield curve is losing its predictive power. Maybe the instability of monetary policy, and inflation during this period in history is unrepresentative of current and future economic conditions. Therefore, I have decided to test the yield curve model excluding a four-year time frame (January 1979 to December 1982). This four-year period, although only four out of the forty-six years observed, represents a period of extreme interest rate volatility and two recessions. This is important, because even though we are reducing our data set by less than 10 percent, we are eliminating two out of only seven recession periods. Basically, in the context of eliminating data points, it may not be significant; however, in the context of eliminating economic cycles it is definitely significant. January 1979 was used as a starting point on the premise that it was one year prior to the start of the 1980 recession, thus recession forecasts would not be impacted by the recession dummy variables directly, given the longest forecast horizon tested is twelve months.

The pseudo-R^2 results from this period are essentially a mirror image of those generated by the entire sample (not excluding the four-year period). The only exception was a slightly higher pseudo-R^2 at a nine-month forecast horizon (.321 versus .306). This indicates that there is no fundamental difference in the fit of the yield curve probit model when the four-year period is excluded. Next, I provide a significant yet anticipated outcome. The recession probabilities as they relate to the yield curve change considerably. The relationship between yield spread and recession probability is shown for three scenarios. The first column of spreads is based on results

obtained by Estrella and Mishkin (1996). The second column is the full data set examined in this paper and the third is based on the full data set excluding the 1979 to 1982 time frame.

Table 5   Recession Probabilities Using the Yield Spread

Recession Probablity Rp	Estrella and Mishkin Spread	1959:1 to 2005:10 Spread	1959:1 to 2005:10 Ex 1979 to 1982 Spread
5%	121	136	40
10%	76	93	28
15%	46	64	21
20%	22	43	15
25%	2	22	10
30%	-17	6	5
40%	-50	-26	-2
50%	-82	-58	-10
60%	-113	-86	-18
70%	-146	-125	-26
80%	-185	-167	-36
90%	-240	-238	-50

Estrella and Mishkin (1996) – Data set 1960:Q1 to 1995:Q1
Note: Spread is defined as the difference between the yields on the 10-year Treasury bond and the 3-month Treasury bill.

First comparing the three scenarios, by and large you can see that the sensitivity of recession probabilities to the slope of the yield curve change as you move from left to right (scenario one to three). The recession probability with a flat yield curve (i.e. spread equal to zero) is approximately 25, 30 and 40 percent respectively. The most important observation here is the range of spreads for the recession probabilities. The range of spreads is quantified by taking the difference between the spread at 5 percent and 90 percent recession probabilities. The ranges are 361, 374, and 90 basis points respectively, with the latter being the period where four years of volatile interest rates are excluded. This disparity amongst the scenarios particularly between scenarios one and two relative to three, is best illustrated with an example. If the spread of the yield curve is –50 bps, the recession forecasts will be 40, 48 and 90 percent respectively. The difference is huge, and the implications of these results on forecasts going forward are major. For example, the yield curve inverted in mid January of 2006 implying recession probabilities of

25, 30, and 40 percent respectively. However, the month began with a spread of 18 basis points implying recession probabilities of 22, 27, and 14 percent respectively. Notice that the scenario with the four years of volatile data excluded is extremely sensitive to the spread in both directions, positive and negative because the range of spreads is extremely narrow. For illustration purposes, if this range were used to forecast the 1990-91 and 2001 recessions as tested earlier, the signal would have proven to be much stronger. The 1990-91 recession for which the yield curve inverted 16 basis points nine months prior to the recession would have generated a recession probability of 58 percent, a clear signal of a recession based on the 50 percent criterion. As for the 2001, the signal would have been greater than 90 percent, also nine months prior to its onset. Clearly, the decision of whether or not to exclude the four-year period greatly influences recession forecasts generated by the probit model consequently the decision to include or exclude this time period is a critical one.

6 IS IT POSSIBLE TO BENEFIT FROM RECESSION FORECASTS GENERATED BY THE YIELD CURVE?

Investment management firms carefully track the state of the economy in order to capitalize on investment opportunities. Fixed income portfolio managers are unquestionably interested in the state of the economy and therefore a signal of a recession looming is considered valuable foresight. Principally, because interest rates tend to fall during recessionary periods due to expectations of lower future spot rates combined with loosening of monetary policy in order to stimulate economic growth, employment and/or control inflation. This is bullish for bonds, as their price moves inversely to interest rates. In other words, bond prices go up when interest rates go down. The portfolio manager can implement the appropriate bond strategy based on information regarding the direction of interest rates (i.e., long or short duration bet). For equity managers the information is also critical, however, the impact on stocks is somewhat less transparent. Earnings expectations, future cash flows, and dividends all may be negatively effected by a recession, particularly for cyclical stocks. However, low interest rates will lower the discount rate used in equity valuation and therefore the magnitude of the two forces is most relevant, nevertheless it is difficult to foresee the net effect. Comparing the two asset classes it is not clear whether or not bonds outperform stocks prior to or during recessions. Nor is the distinction evident in examining the returns relative to recession forecasts generated by the yield curve probit model. Furthermore, the comparison must not only consider returns, because the level of risk is also relevant. In order to test empirically whether or not the information of an upcoming recession can be useful in practice, I examine a trading strategy.

6.1 The Trading Strategy

The strategy entails allocating between two asset classes, stocks and bonds. The decision is based on allocating 100 percent to an asset class based on the forecast from the probit model.

$$(4) \qquad \text{Prob } (R_t = 1) = \Phi (c_0 + c_1 \text{ Yield Curve }_{t-9})$$

The forecast horizon observed is nine months because it generates the best pseudo-R^2 results for predicting recessions. The decision criterion is based on allocating to bonds when a recession is signalled (recession probability greater than the designated threshold) otherwise allocating to stocks. The allocation criterion is not based on historical performance of the assets classes, but rather is a strategy that becomes defensive or more conservative if you will, when a recession is signalled. Standard deviation, the most widely accepted measure of risk, measures the volatility of returns from the asset classes. Over the last thirty years, (ending October 2005), the standard deviation for bonds was 5.5 percent versus 14.9 percent for stocks illustrating the lower risk level associated with investing in bonds. The defensive strategy is used in an attempt to stay clear of major losses. The default allocation towards equity tailors the usefulness of this study primarily to fund managers required to make strategic asset allocation decisions.

6.2 Data

The data used in this test is based on monthly time series. The probit model is initially estimated using data from January 1959 to October 1975. The coefficient estimates generated by the model are then used to forecast recession probabilities based on the yield spread for the following five years. It is during this five-year period (i.e. 1975:11 to 1980:10) that the allocation decision is made. The model is re-estimated every five years to ensure new data is incorporated into the model. As for the asset class returns, thirty years of monthly returns are used. The Lehman Brothers Government Bond Index represents bond returns. The Standard and Poor's 500 Index represents stock returns.

6.3 Empirical Results

Six sub-periods are tested out-of-sample, each five years in length. Three levels of recession thresholds (R_t) are observed. The **Return** and **Risk** figures for the tables in this section correspond to the results generated by the trading strategy. The return for an all equity portfolio is represented by R_s and σ_s is the risk measure. The return and risk results for an all bond portfolio are R_b and σ_b. The results from Table 6 show that the trading strategy generated superior performance (risk and return) relative to the all equity portfolio in three of the sub-periods at various thresholds. The three thresholds examined provided mixed results, each with superior performance in specific periods. It is important to understand that anytime bonds are added to a portfolio during the investment period, the standard deviation is expected to decline because of their lower volatility. For that reason, the outperformance of the trading strategy is only considered relevant when the return is higher and the risk level is lower relative to the 100% stock portfolio. If we examine the results closer we can break down the reasoning for the outperformance of the strategy. First looking at sub-period 1980:11 to 1985:10, the risk and return outperformance of the trading strategy can be attributed to exceptionally high bond returns, and low standard deviation. Allocation to bonds resulted in higher returns and lower risk than stocks, so the success of the trading strategy should not be surprising. Despite this, the timing of the allocations must have been gainful for the trading strategy to have generated higher return and lower risk than an all equity portfolio and a higher return than a bond portfolio. A similar explanation can be offered for the results during the 2000:11 to 2005:10 period. In this sub-period bonds once again outperformed stocks with a higher return and lower risk level. The unique feature to this period is the trading strategy return was lower than the return on bonds. Whereas in the 1980:11 to 1985:10 sub-period, the trading strategy outperformed an all bond portfolio. Another similarity between the two sub-periods is that the trading strategy outperforms an all equity portfolio for all three recession thresholds observed. The only other period that was

decisively successful for the trading model was 1995:11 to 2000:10, using the 30 percent recession probability threshold. Allocation to bonds when the probit model signalled a 30 percent or greater recession probability added value to the portfolio by increasing the return and lowering the risk. The return was 40 basis points higher (annually) and the risk level was lower by 70 basis points. Note that one basis point equals .01 percent.

Table 6   Trading Model Results: Risk and Return Analysis
for a Stock versus Bond Asset Allocation Strategy

Investment Period	R_t	Return	Risk	R_s	σ_s	R_b	σ_b
1	10%	2.9%	13.8%	-1.7%	15.3%	5.9%	5.0%
(2000:11-2005:10)	30%	0.1%	14.8%	-1.7%	15.3%	5.9%	5.0%
	50%	-1.4%	15.3%	-1.7%	15.3%	5.9%	5.0%
2	10%	12.1%	8.7%	21.7%	15.6%	6.3%	3.7%
(1995:11-2000:10)	30%	22.1%	14.9%	21.7%	15.6%	6.3%	3.7%
	50%	21.7%	15.6%	21.7%	15.6%	6.3%	3.7%
3	10%	16.0%	10.1%	17.2%	10.3%	9.5%	4.4%
(1990:11-1995:10)	30%	17.2%	10.3%	17.2%	10.3%	9.5%	4.4%
	50%	17.2%	10.3%	17.2%	10.3%	9.5%	4.4%
4	10%	12.2%	16.6%	13.6%	18.9%	9.7%	5.7%
(1985:11-1990:10)	30%	11.4%	18.6%	13.6%	18.9%	9.7%	5.7%
	50%	13.6%	18.9%	13.6%	18.9%	9.7%	5.7%
5	10%	16.8%	12.3%	13.6%	14.4%	15.1%	6.8%
(1980:11-1985:10)	30%	15.2%	12.8%	13.6%	14.4%	15.1%	6.8%
	50%	13.9%	13.1%	13.6%	14.4%	15.1%	6.8%
6	10%	10.5%	11.8%	12.8%	13.8%	5.3%	6.6%
(1975:11-1980:10)	30%	9.3%	12.6%	12.8%	13.8%	5.3%	6.6%
	50%	9.7%	12.6%	12.8%	13.8%	5.3%	6.6%

Table 7 shows the results for the entire thirty-year period. Comparing the risk and returns during the period is not enough to give us an idea of whether the trading strategy was actually able to add value to portfolio management. Therefore, I have included the Sharpe ratio for both strategies (Trading model versus 100 percent equity). The risk-free rate used in calculating the Sharpe ratio was based on the average 3-month T-bill rate over the entire sample period. Notice that the Sharpe ratio for the trading strategy is slightly higher than the all equity portfolio at thresholds of 10 and 30 percent (.65 vs. .62 and .63 vs. .62).

Table 7   Overall Trading Model Performance

Investment Period	R_f	Return	Risk	Sharpe	R_s	σ_s	Sharpe
	10%	14.10%	12.30%	0.65	15.30%	14.70%	0.62
(1975:11-2005:10)	30%	15.00%	14.00%	0.63	15.30%	14.70%	0.62
	50%	14.80%	14.30%	0.60	15.30%	14.70%	0.62

The results from the trading model are mixed and certainly not strong enough to draw any major conclusions from. The only periods in which the strategy truly appears to have added value is 1980:11 to 1985:10 and 1995:11 to 2000:10. Nevertheless, the trading strategy did not underperform an all equity portfolio, in terms of risk and return, in any of the sub-periods.

In order to comprehend the outcome of the trading strategy I consider two important aspects of the strategy: 1) The correlation between stock and bond returns with recession probabilities and 2) stock and bond return behaviour prior to and during recessions. The period in consideration here is January 1973 to October 2005. During this time period five recessions were encountered. First examining the correlation between stock and bond returns with recession probabilities generated by the yield curve probit model from section 5.3, I find that there is no distinct correlation. In other words, it is not clear whether stocks or bonds perform better when a recession is signalled by the probit model (refer to Charts 11 and 12 below).

**Chart 11   Distribution of Bond Returns**
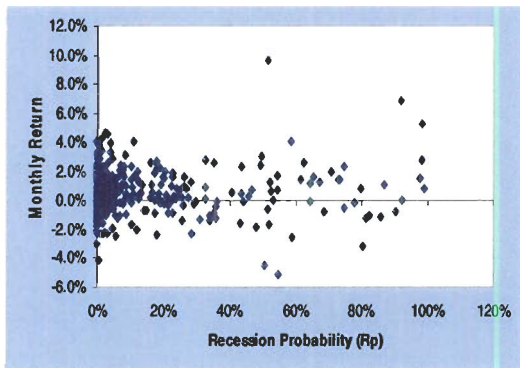
Chart 12   Distribution of Stock Returns
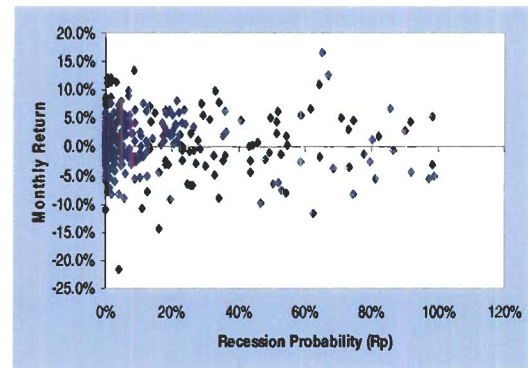
On the second point, I break the observation down to three time frames: returns prior to the recession, returns in the first half of the recession, and returns in the last half of the recession. Out of the five recessions observed, bonds outperform stocks prior to the recession in three of the cases. During the first half of the recessions, bonds outperform stocks in four out of five cases. The only exception is the 2001 recession where stocks performed extremely well during the first half of the recession as shown in Chart 13.

Chart 13 Return Comparison for the 2001 Recession
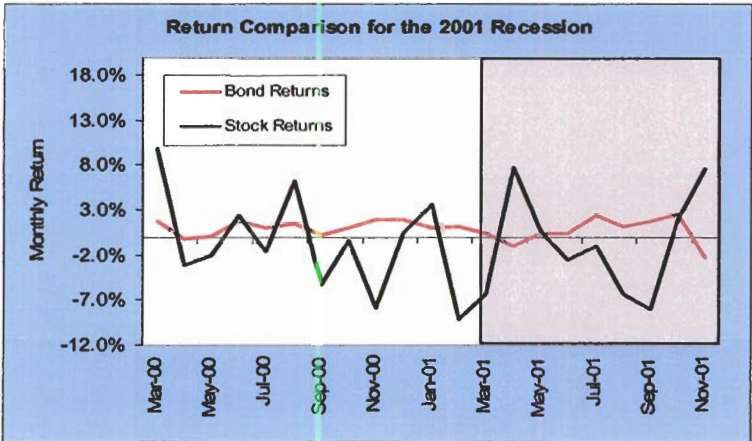
A common trend that holds true for all five recessions is that stocks outperform bonds significantly towards the end of recessions. In four out of five recessions observed, stocks clearly outperform bonds in the last half of the recession. The only exception once again is the 2001 recession shown in Chart 13. Examining the return patterns leading up to and during recessions helps identify possible reasons behind the lacklustre performance of the asset allocation trading strategy. The significant outperformance of stocks towards the end of recessions is likely a major factor in the trading strategy not generating stronger results principally because recession probabilities generally remain high during recessions (refer to Appendix D). Ultimately, whether or not bonds outperform stocks during recessions is ambiguous. One explanation may be that the market already prices in the impact of the business cycle. In other words, market participants are forward looking and this may explain the high stock returns towards the tail end of recessions.

Another plausible explanation may be that when long-term interest rates decline, stocks increase more than bonds because stocks are a riskier investment. Strategies other than allocation between stocks and bonds can certainly be explored. For example a strategy I considered was the allocation between cash and bonds during recessions on the premise that if the yield curve is inverted, short-term yields will be higher than long-term yields. Unfortunately, the strategy only added value during the late 1970s and early 1980s, a time in history when the yield spread was extremely negative. Another plausible strategy to explore is a sector allocation strategy, differentiating between cyclical and non-cyclical sectors.

7 DISCUSSION AND CONCLUSIONS

As in Dueker (1997), I use a time series probit model to analyze the yield curve's ability to forecast recessions. Some key extensions include incorporating ten years of new data, testing out-of-sample, observing a period with four years of data excluded, and examining the practical implications using a trading strategy. The yield curve is found to be the best recession predictor out of the four variables observed beyond a three-month forecast horizon. In addition its predictive power is most significant at a nine-month forecast horizon. Unique to the yield curve variable is its predictive power actually improves as the forecast horizon increases from three to nine months. In spite of mass criticism for failing to predict the 1990-91 and 2001 recessions, my results indicate otherwise. The recession forecasts generated by the yield curve model prior to the 1990-91 and 2001 recessions may have been mild on a historical basis, yet indeed signalled a significant increase in the probability of a recession. I also find that the yield curve model was just as effective as the four-variable model in its forecasting ability. As well, the yield curve inverted prior to each of the last two recessions.

Using the recession probabilities generated by the yield curve to create a strategic asset allocation strategy did not produce results as strong as I had anticipated. Conceptually, I thought this strategy would have outperformed an all equity portfolio on the basis of employing a defensive investment approach upon signal of an economic downturn. Two reasons are provided for the outcome of the trading strategy. First, the correlation between stock and bond returns with recession probabilities appears to be ambiguous. Second, stocks perform extremely well towards the latter part of recessions even though recession probabilities generally remain high.

Many criticisms and weaknesses of the probit model and the yield curve are recognized in this paper. For instance, the subjectivity involved in deciding whether or not a recession was signalled. This is true because although the probit model (five-variable) has a threshold criterion of 50 percent for determining whether or not a recession is signalled, many suggest that even a 25 percent probability could be a valid signal of a recession given that under normal conditions the probability is extremely low. Some subjectivity seems necessary given the extreme interest rate environment during the late 1970s and early 1980s which skew the probit model regression results as demonstrated in this paper. At shorter forecast horizons, the model is said to have sent three false recession signals (Filardo, 1999). This is also a fact, although at horizons beyond three months the yield curve model sent only one false signal over a forty-six year period, an impressive statistic.

Next, the predictive power of the yield curve is suggested to be deteriorating, primarily in last few decades. This should be expected, given that most forecasters including the Federal Reserve monitor the yield curve. Basically, if everyone incorporates the yield curve variable into their indices and research, the explanatory power of the yield curve should soften and thus the volatility should become more controlled. Several other explanations for the deterioration have been offered such as expansion of international trade, the development of financial markets, the relaxing of liquidity constraints facing consumers, and the rise of information technology (Stock and Watson 2003). The most intriguing and plausible explanation in my opinion is the evolution of monetary policy from reactionary to proactive (Stock and Watson, 2003). My rationale for this perspective is that the Federal Reserve's monetary policy has become much more transparent as of late (less surprises), reducing volatility and uncertainty in the marketplace. Moreover, the Federal Reserve has been able to control the degree of swings in business cycles more effectively. Consequently, I believe the extreme volatility of interest rates during the late 1970s and early 1980s is misrepresentative of the economic environment over the past two decades. Thus, it may

be appropriate for this data subset to be excluded when employing the probit model. Doing so results in the yield curve probit model generating extremely strong recession signals prior to the 1990-91 and 2001 recessions. The probability forecasts nine months ahead are 58 percent and over 90 percent respectively.

The inability of the yield curve to accurately predict the onset and duration of recessions is cited by Dueker (1997). This is definitely a valid point, but my perception based on historical yield curve inversion is that the greater the inversion, the greater the expected duration of the recession. As for precisely predicting the onset, the probit model provides a time horizon, whether it will be accurate to the month seems less important than the correct forecast for the direction of the economy. Finally, the yield curve probit model is criticized on the basis that it assumes no additional information other than the NBER business cycle dates is relevant to predict recessions (Chauvet and Potter, 2005). The NBER business cycle dates are based on a broad decline in economic activity and are closely correlated to declines in GDP, thus, although not inclusive of all economic data, it is an easy and effective way to measure recession probability versus simply forecasting economic growth.

My results reveal that the yield curve is still a valuable predictor of recessions. The yield curve coefficient estimates are unquestionably significant, and the fit of the model is strong. Furthermore, the yield curve model displays predict power equivalent to that of the four-variable probit model at longer forecast horizons. Its track record of inverting prior to six out of seven recessions is irrefutable. At longer forecast horizons it has only sent one false signal in forty-six years. One of the best features of the yield curve is that the data is readily available at high frequencies and is easy to interpret (Dueker, 1997). Also, as mentioned by Dueker (1997) the expectations hypothesis provides a theoretical foundation for the predictive power of the yield curve. Thus, although the yield curve displays some weaknesses, my empirical results and the theoretical foundation of the yield curve reinforce its value as a predictor of U.S. recessions.

APPENDICES

Appendix A - Defining the Explanatory Variables

EXPLANATORY VARIABLES IN THE PROBIT MODEL DEFINED

Total Data Set: January 1959 to October 2005 (562 Observations)
Data Frequency: Monthly

Yield Curve: The percentage difference between the yield on a 10-year Treasury bond and a 3-month Treasury bill.

Lead: Percentage change in the Conference Board's index of leading indicators.

Money: Monetary growth measured using M1 Money Stock.

Stock: Percentage change in the Standard and Poor's 500 index of stock prices.

QUANTIFYING THE VARIABLES

Yield Curve	$100*(\ln(1+ (TB10/100)) - \ln(1+TB3/100))$
Lead	$LI_t - Li_{t-1}$
Money	$100*(\ln(M1_t/CPI_t) - \ln(M1_{t-1}/CPI_{t-1}))$
Stock	$100*(\ln(S\&P\ 500_t /S\&P\ 500_{t-1}))$

THE COMPONENTS ARE DEFINED AS FOLLOWS

TB10 = 10 Year Treasury Bond Constant Maturity Rate (Percent)
Source: research.stlouisfed.org

TB3 = 3 Month Treasury Bill Secondary Market Rate (Percent)
Source: research.stlouisfed.org

LI = Conference Board's Index of Leading Economic Indicators
Source: Bloomberg, symbol LEI CHNG

M1 = M1 Money Stock (seasonally adjusted)
Source: research.stlouisfed.org

CPI = Consumer Price Index for All Urban Consumers: All Items (seasonally adjusted)
Source: research.stlouisfed.org

S&P 500 = Standard and Poor's 500 U.S. Equity Index
Source: FactSet

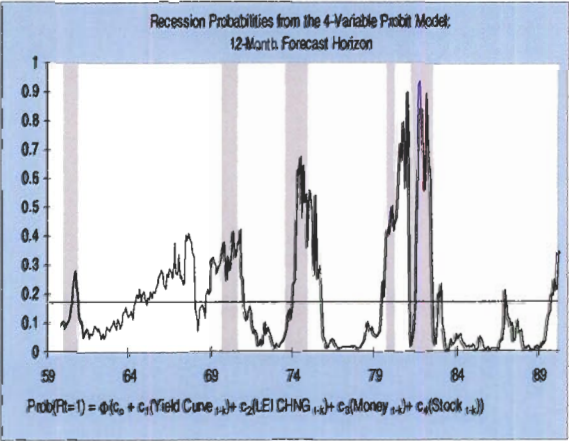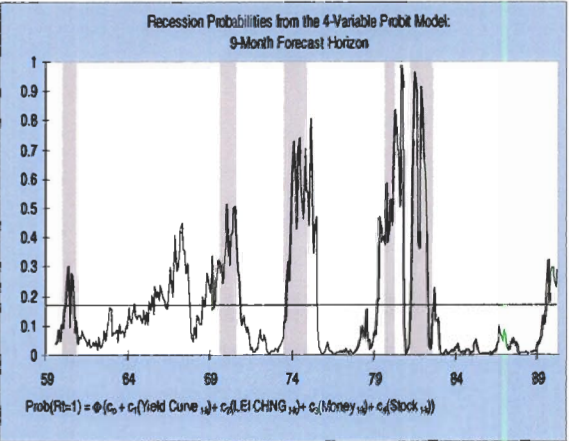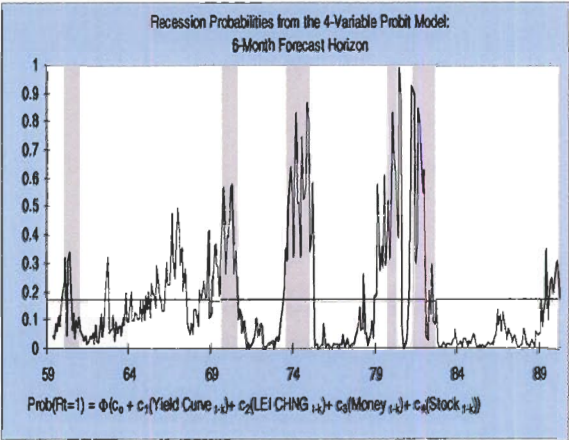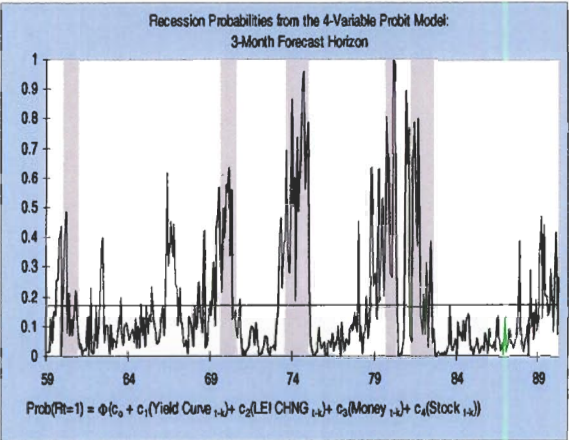# Appendix B -
Recession Probability Charts

Recession Probability Charts for the Yield Curve Probit Model

Predictability of the 1990-91 Recession

Recession Probabilities from the Simple Probit Model: 3-Month Forecast Horizon
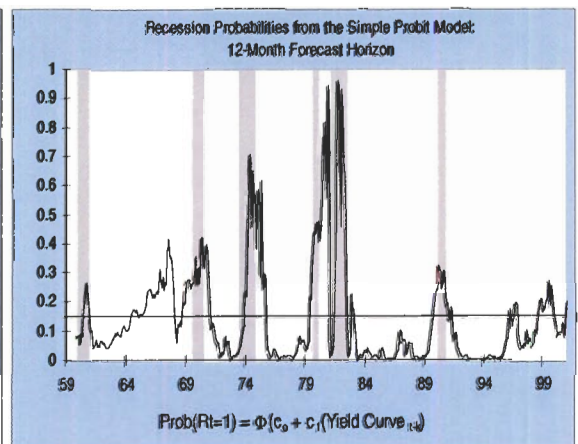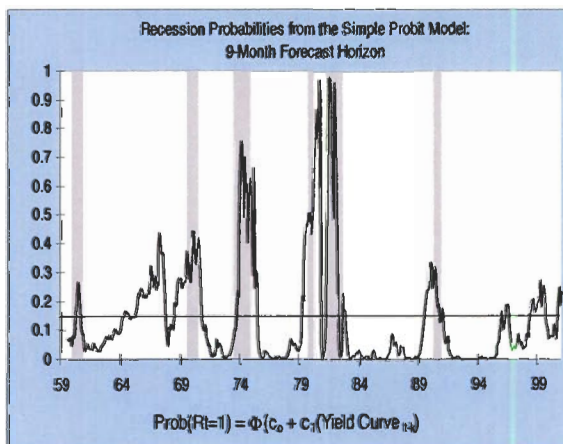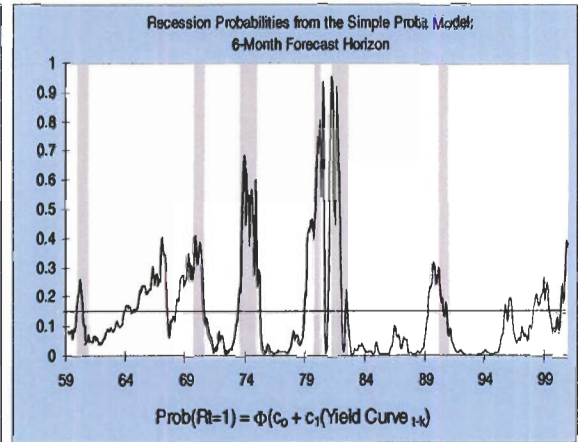$$Prob(R_t=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k})$$

Recession Probabilities from the Simple Probit Model: 6-Month Forecast Horizon
$$Prob(R_t=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k})$$

Recession Probabilities from the Simple Probit Model: 9-Month Forecast Horizon
$$Prob(R_t=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k})$$

Recession Probabilities from the Simple Probit Model: 12-Month Forecast Horizon
$$Prob(R_t=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k})$$
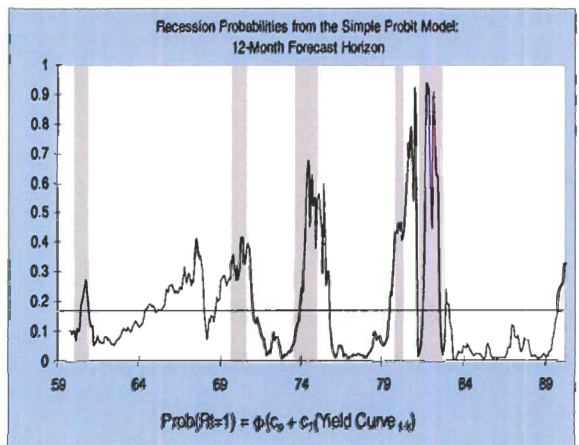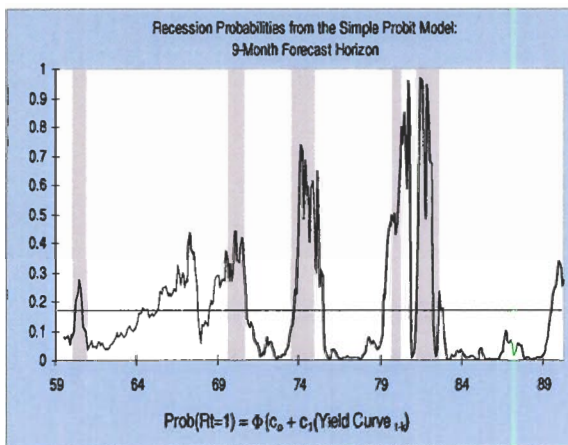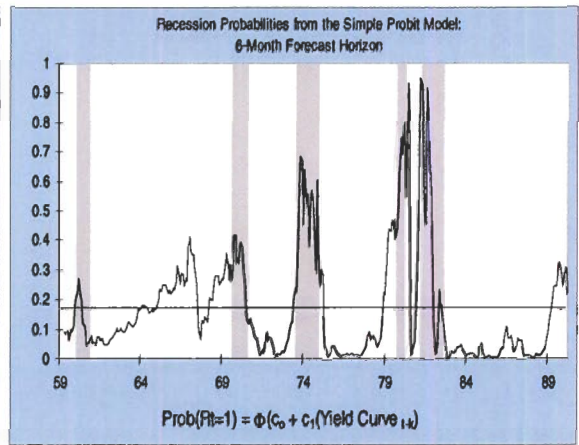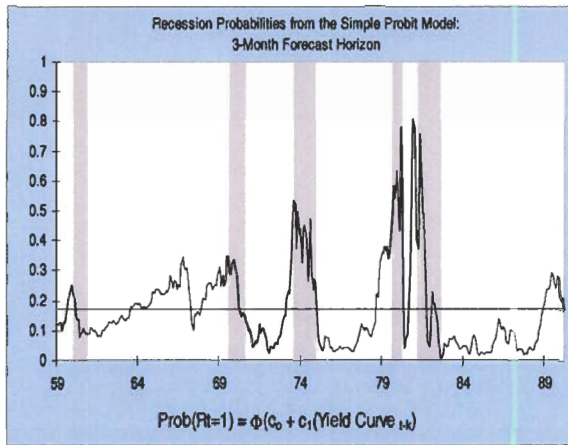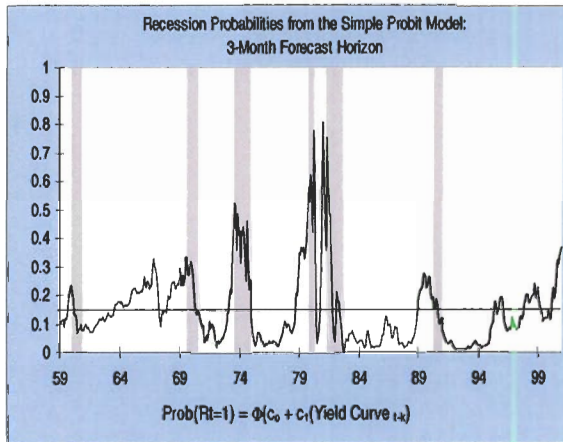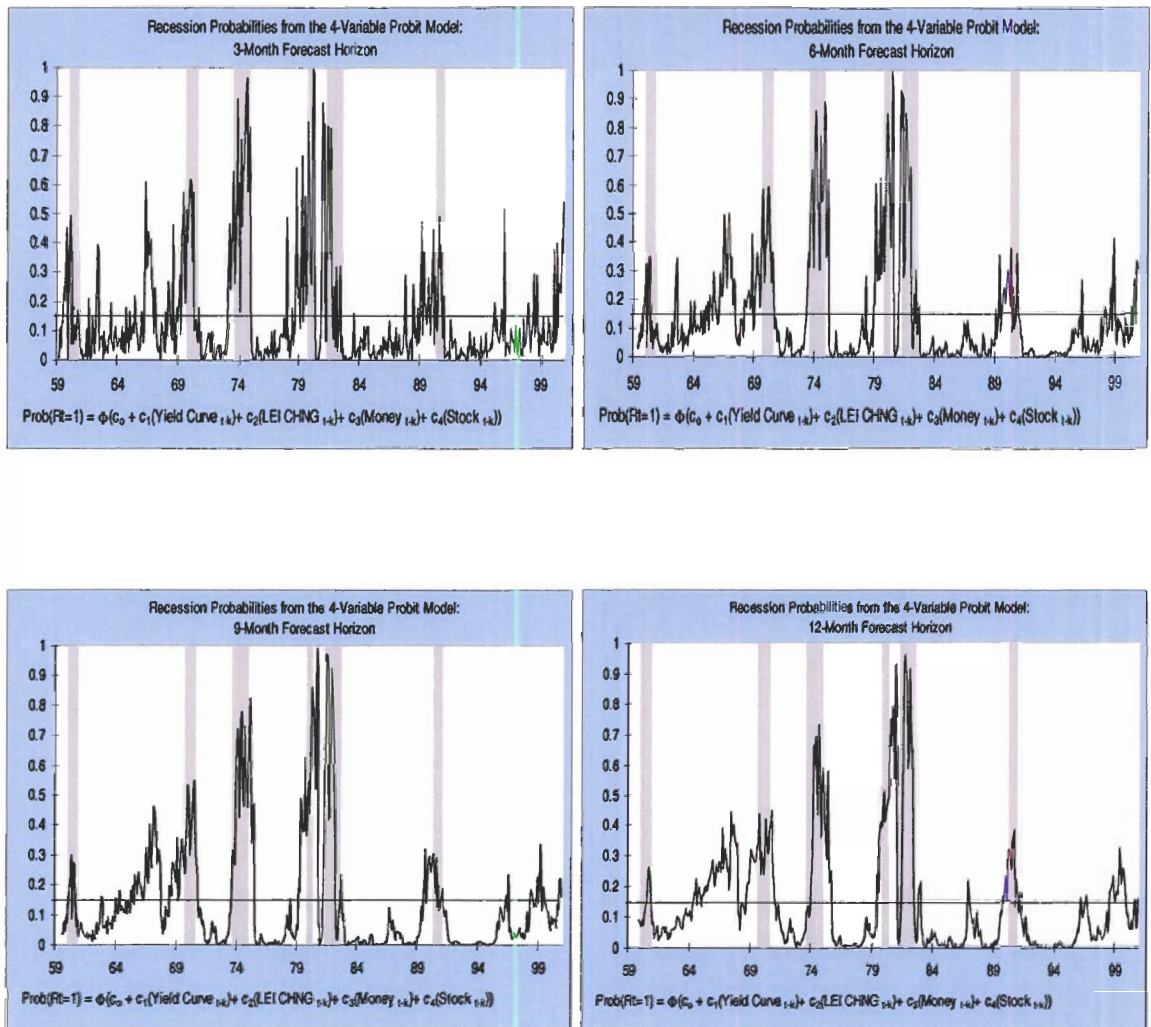
Recession Probability Charts for the Four-Variable Probit Model

Predictability of the 1990-91 Recession

Appendix C -
Recession Probability Charts

Recession Probability Charts for the Yield Curve Probit Model

Predictability of the 2001 Recession

Recession Probabilities from the Simple Probit Model: 3-Month Forecast Horizon
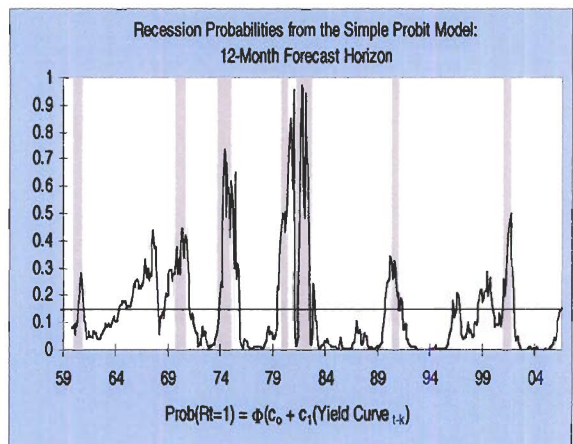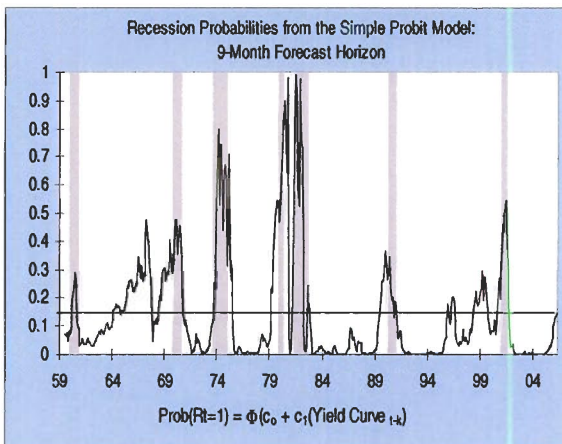
$Prob(Rt=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k})$

Recession Probabilities from the Simple Probit Model: 6-Month Forecast Horizon

$Prob(Rt=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k})$

Recession Probabilities from the Simple Probit Model: 9-Month Forecast Horizon

$Prob(Rt=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k})$

Recession Probabilities from the Simple Probit Model: 12-Month Forecast Horizon

$Prob(Rt=1) = \Phi(c_0 + c_1(\text{Yield Curve}_{t-k})$

Recession Probability Charts for the Four-Variable Probit Model
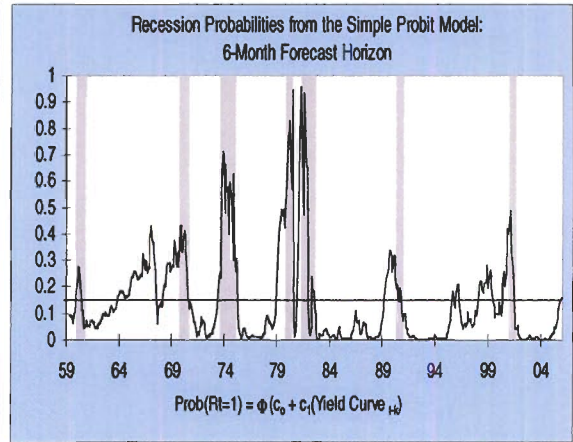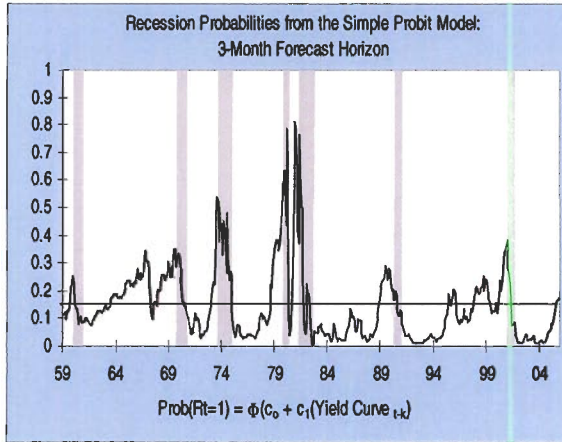
Predictability of the 2001 Recession
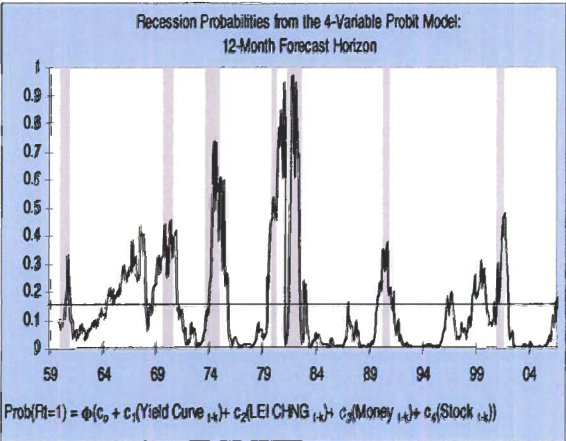
Appendix D -
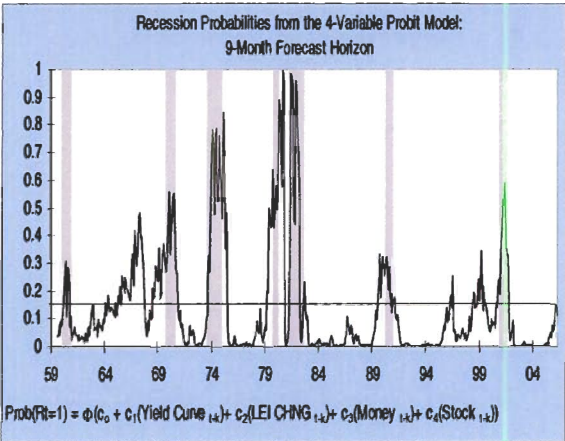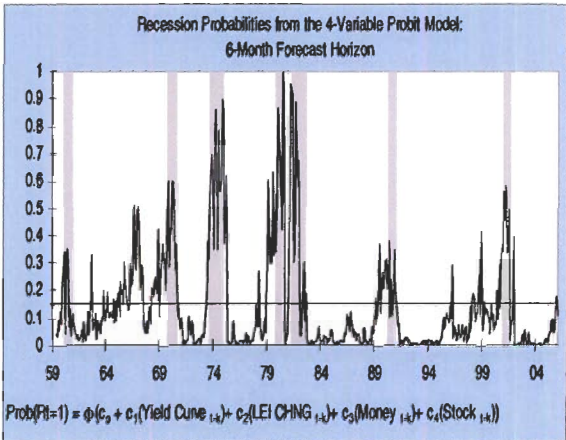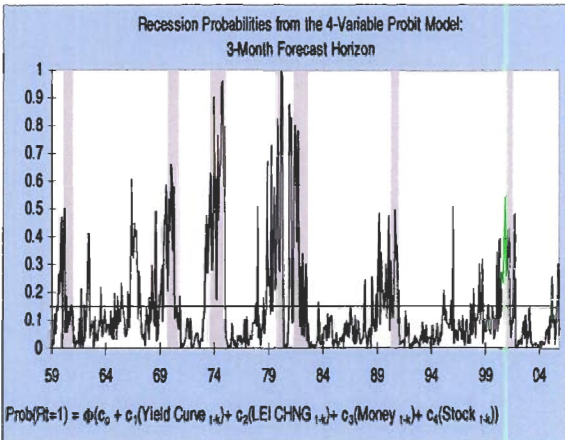# Recession Probability Charts

Recession Probability Charts for the Yield Curve Probit Model
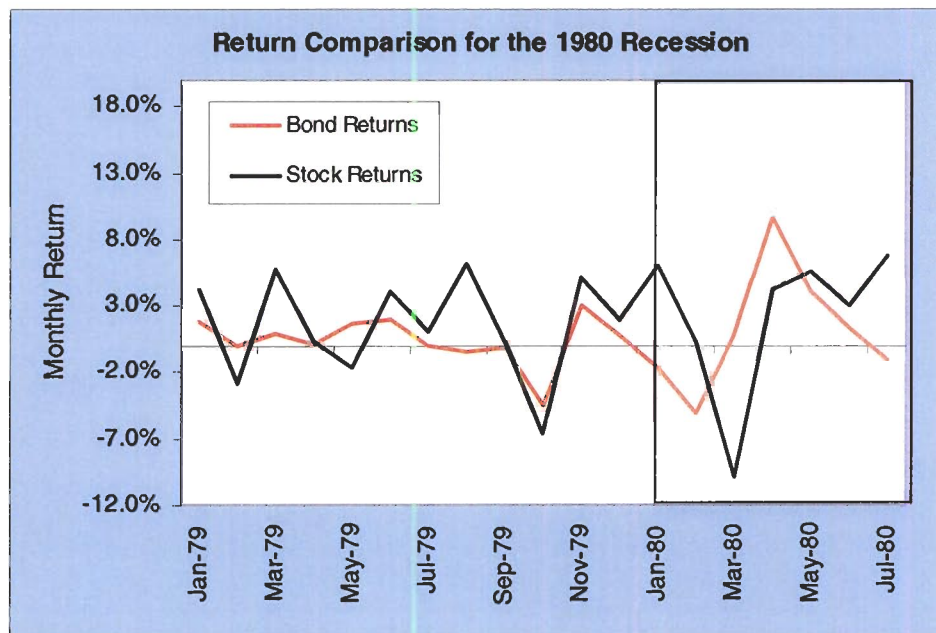
Predictability for 2006

Recession Probability Charts for the Four-Variable Probit Model
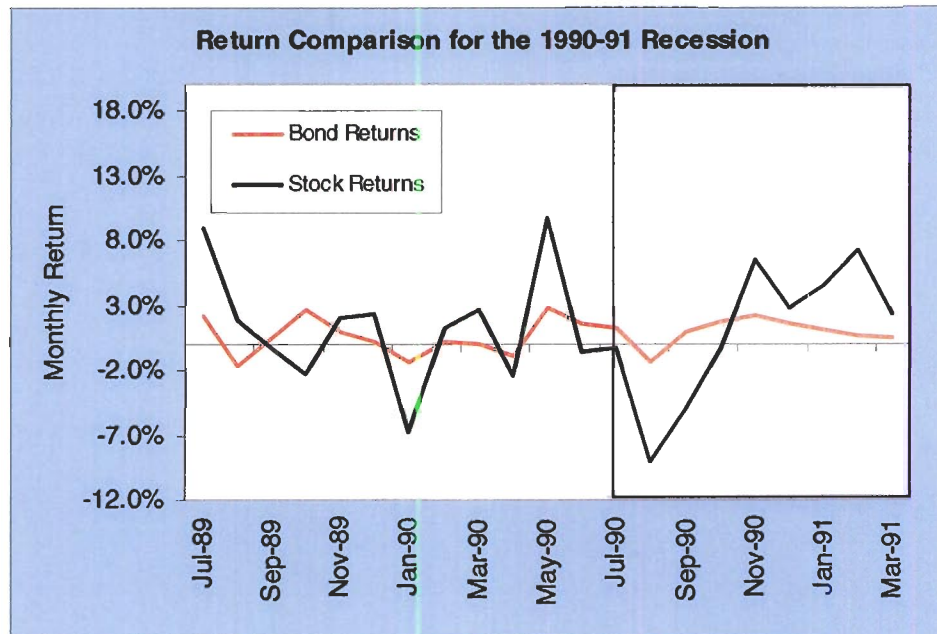
Predictability for 2006

Recession Probabilities from the 4-Variable Probit Model: 3-Month Forecast Horizon

$Prob(Rt=1) = \Phi(c_0 + c_1(Yield\ Curve_{t-k}) + c_2(LEI\ CHNG_{t-k}) + c_3(Money_{t-k}) + c_4(Stock_{t-k}))$

Recession Probabilities from the 4-Variable Probit Model: 6-Month Forecast Horizon

$Prob(Rt=1) = \Phi(c_0 + c_1(Yield\ Curve_{t-k}) + c_2(LEI\ CHNG_{t-k}) + c_3(Money_{t-k}) + c_4(Stock_{t-k}))$

Recession Probabilities from the 4-Variable Probit Model: 9-Month Forecast Horizon

$Prob(Rt=1) = \Phi(c_0 + c_1(Yield\ Curve_{t-k}) + c_2(LEI\ CHNG_{t-k}) + c_3(Money_{t-k}) + c_4(Stock_{t-k}))$

Recession Probabilities from the 4-Variable Probit Model: 12-Month Forecast Horizon

$Prob(Rt=1) = \Phi(c_0 + c_1(Yield\ Curve_{t-k}) + c_2(LEI\ CHNG_{t-k}) + c_3(Money_{t-k}) + c_4(Stock_{t-k}))$

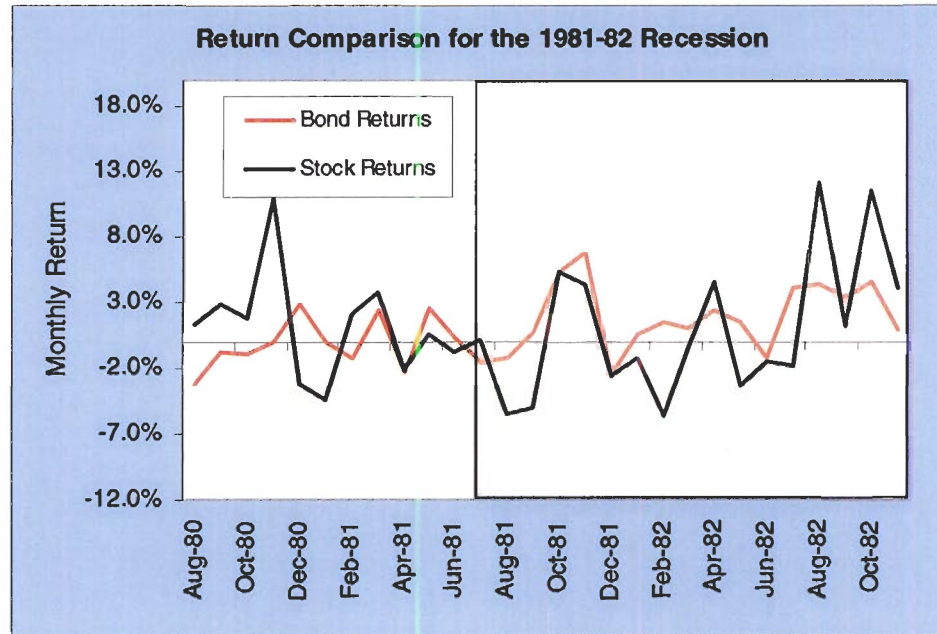# Appendix E -
Stock and Bond Return Behaviour

Stock and Bond Return Behaviour Prior to and During Recessions Since 1973
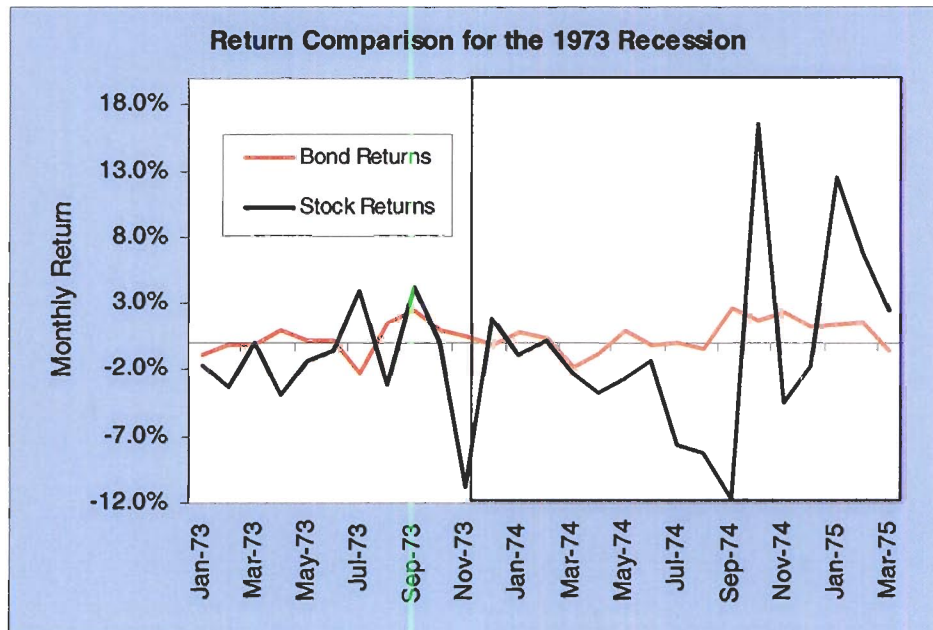
Return Comparison for the 1973 Recession

Return Comparison for the 1980 Recession

Stock and Bond Return Behaviour Prior to and During Recessions

Return Comparison for the 1981-82 Recession

Return Comparison for the 1990-91 Recession

Stock and Bond Return Behaviour Prior to and During Recessions
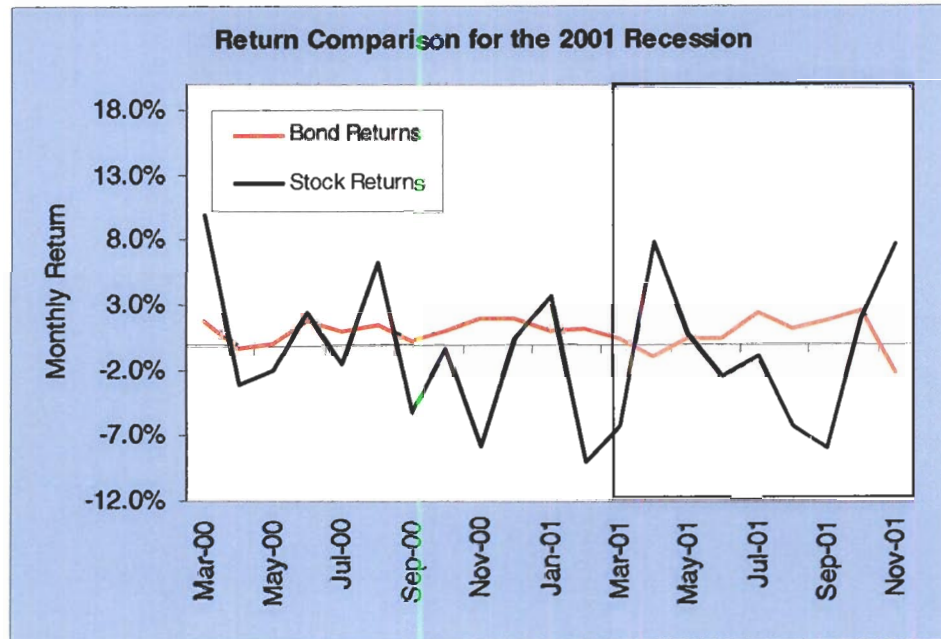
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Stock J., & Watson M. "New Indexes of Coincident and Leading Economic Indicators", NBER Macroeconomics Annual. Cambridge: The MIT Press (1989).