PREDICTION OF RECESSION

by

Young Sub Lee
Bachelor of Business Administration

and

Qian (Sanna) Zhu
Master of Arts

**PROJECT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF**

MASTER OF BUSINESS ADMINISTRATION

**In the
Global Asset and Wealth Management**

SIMON FRASER UNIVERSITY

Spring 2009

APPROVAL

Name:	**Young- Sub Lee & Qian (Sanna) Zhu**
Degree:	**MBA – Global Asset and Wealth Management**
Title of Thesis:	**Prediction of Recession**

Examining Committee:

_____

Dr. Peter Klein
Senior Supervisor
Professor of Finance

_____

Dr. Evan Gatev

Second Reader
Assistant Professor of Finance

Date Defended/Approved: _____

Contents

Abstract

The purpose of our research is to examine the predictive power of inverted yield curve for the recession in the near future. The data used in this research are between Jan 1, 1959 to Nov, 2008. There are 8 recessions during this period, including current one. We conducted two sets of tests. The first set consists of spread between 10-year Treasury bond and 3-month Treasury bill and spread between 10-year Treasury bond and 3-month LIBOR; and we find the predictive power of spread between 10-year Treasury bond and 3-month Treasury bill is much stronger than the other one. The second set consists of spread between 10-year SWAP rate and 3-month LIBOR, spread between 10-year Treasury bond and 3-month Treasury bill, as well as the spread between 10-year Treasury bond and 3 month LIBOR. For the second test, we find that although there is a couple of recession involved and data is relatively limited, predictive power of spread between 10-year T-bond and 3 month still stands out and we also find the spread between 3-month LIBOR and 10-year SWAP could be a better indicator in the future by using more data. We conclude that term spread of Treasury rate is still the most powerful tool for forecasting the recession.

Keywords: T-bill，LIBOR, SWAP, Recession, Predicative Power

Executive Summary

We choose this topic because the world currently is facing probably the worst recession in the history. December 16, 2008, in a historic statement, the Federal Reserve said it would target a record low interest rate in a range of between zero and 0.25 per cent. It also vowed to use "all available tools to promote the resumption of sustainable growth and to preserve price stability". On January 9th 2009, The Bank of England cut interest rates by half a percentage point to its lowest since the bank was founded in 1694. On Jan. 20th 2009, Bank of Canada cut its borrowing rate to the lowest since the institution was founded in 1934. The number of unemployment escalated and nobody can estimate when the recession will be over. During 2007 and 2008, there was huge debate on whether U.S. economy would face recession or not. Many economists and analysts forecasted that U.S. economy and at least world economy won't be under recession and that is why the oil price raised to US$ 150 per barrel in 2008 and all the raw materials had been appreciated although finance sector in U.S. was extremely volatile.

We notice that many investors lost money due to finance market turmoil and we believe that people could avoid loss by forecasting recession more accurately and by using defensive strategy on their portfolio. Since the debate on the forecast of economy exists, we want to find out the current recession possibility by using the methodology of Estrella and Mishkin (1998) and current data set. We calculate that the possibility of recession is 33% for the current recession by using Estrella and Mishkin's methodology. In addition, we also apply the same methodology of Estrella

and Mishkin (1998) by using market rates (3-month LIBOR and 10-year SWAP) since we notice that there was huge gap recently between 3-month LIBOR and Treasury Bill and we believe that the spread of 3-month LIBOR and 10-year SWAP could explain more regarding the current recession than spread of 3-month Treasury bill and 10-year Treasury bond.

Acknowledgement

We would like to thank Dr. Peter Klein for both inspiring and guiding us to research a timely and interesting topic. We are also grateful to Dr. Evan Gatev for his insightful advice.

Introduction

In December 2008, The National Bureau of Economic Research (NBER), the organization that officially dates recessions in U.S., announced that US economy was under recession since December 2007. Back to mid of 2006, Nouriel Roubini, an economics professor at New York University, says the effects of the ongoing housing bust on real residential investment, wealth and consumption, and employment will be more severe than the tech bust that triggered the 2001 recession.

"And on top of the housing bust, U.S. consumers are facing oil above US$70, the delayed effects of rising fed-fund and long-term rates, falling wages, negative savings, high debt ratios and higher and higher debt-servicing ratios," Mr. Roubini wrote on his website (www.rgemonitor.com).

In the second quarter of 2006, GDP has faded to an annual rate of 2.5% in the second quarter from 5.6% in the first[1]. And job creation has slowed down as well. Job creation has not been above 125,000 in the second quarters.[2] A report on service businesses released in February 2007 started to set off the alarm bell of recession. The service sector is the majority of US economy and even bigger than manufacturing. The report of the Institute of Supply Management indicated that activity in the service sector declined for the first time in nearly five years. This report also indicated that employers are cutting staff. At the same time, the government's report on losing of 17,000 jobs

[1] US Department of Commerce

[2] US Department of Labor

in January showed the first monthly net loss in jobs in more than four years. [3]To certain extend these two reports are signalling a recession coming near. Fearing that banks tightening their lending standards, Fed announced two large rate cuts in just the course of eight days in late January, reducing the key federal funds rate from 4.25% to 3%.

In Feb 2008, the sluggish U.S. job market deteriorated further, adding to troubling signs for an economy that barely grew in the final quarter of 2007, according to government reports. Labour Department data showed first-time claims for jobless benefits increased by 19,000 to a seasonally adjusted 373,000, a level considered to be near-recessionary. GDP rose in the fourth quarter of 2007 at a glacial annual rate of 0.6 percent, slowing almost to a halt from the rapid 4.9.[4] In December 2008, The United States has fallen deeper into recession, data showed that the number of people filing unemployment claims reaching a 26-year high and consumers cutting spending for the fifth successive during November and their incomes shrank, according to a Commerce Department report that pointed to deepening recessionary pressures. Spending contracted by 0.6 per cent and incomes contracted by 0.2 per cent after a slight 0.1 per cent gain in October. New U.S. orders for long-lasting manufactured goods fell 1 per cent in November. Across the United States almost 2 million workers have lost jobs this year, driving the unemployment rate to 6.7 per cent.

[3] US Department of Labor

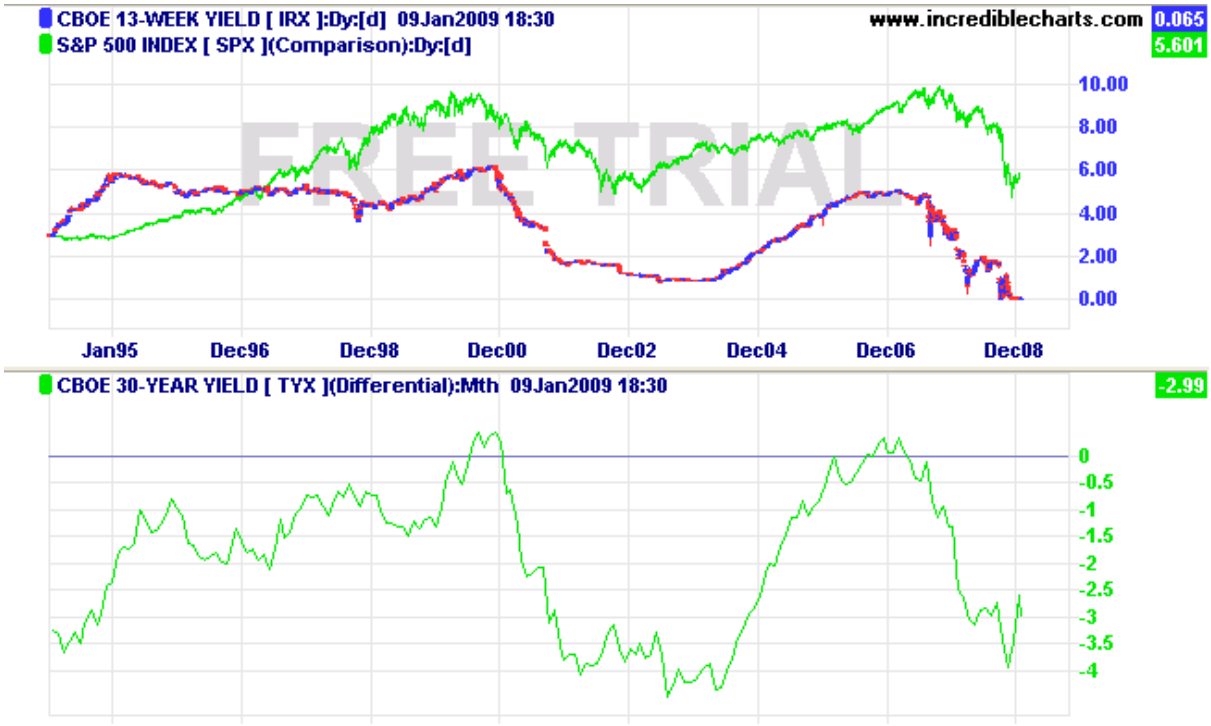
[4] US Department of Commerce

Importance of forecasting recession

The year 2008 would be the most memorable year for the 21st century. There were dramatic collapse and rescue events among major financial institutions in U.S. In early March, Bear Stern was in serious trouble as rumours about it financial health caused investors to rush to withdraw funds and eventually merged by JPMorgan Chase with Federal Reserve Funded. Fannie Mae and Freddie Mac followed the same destiny in September. Eventually, Merrill Lynch sold itself to Bank of America and 158-year-old Wall Street Institution, Leman Brothers filed for bankruptcy on September 15th, transferring U.S. financial crisis to global equity markets and leading world economy recession.

The year 2008 was very challenging year to investors. The market volatility index hit the record and the global stock indexes drop around 30% to 70% compared to previous peak level. If we take a look at the historical relation (15 years) between yield curve and stock market performance illustrated by the following chart which compared S&P 500 against the yield on 3-month T-bill, and the spread between 30 year T- bonds and three month T-bill, we can see that the inverted yield curve is followed by a sharp decline in S&P 500. [5] The reason is simple: the inverted yield curve serves as a leading indicator of the recession in the near future and as a result of recession, the stock market is hit hard.

[5] www.incrediblecharts.com



Here is our issue that money mangers can be free from the loss or from clients' complain. Is it a proper way to measure the performance of money manager based on benchmark? Are clients willing to give money managers who focus on beating the benchmarks? Do money managers need to spend more time to forecast economy cycles to minimize the market risk (systemic risk) rather than focusing on firm-specific risk (unsystematic risk)? In this paper, we want to prove that yield curve spread are still the best factor to predict economy recession and we suggest that money managers should consider yield curve spread in managing portfolio regarding assets class range. Additionally, it is a good tool to forecast economic cycle by using yield curve and change "beta" of portfolio according to this speculation.

Has the yield curve signalled the recent recession?

The above chart[6] indicates that between Oct 2006 and March 2007, investors witnessed the inverted yield curve. Did the investors realize that the inverted yield curve was flashing the signal of danger of recession? Not really. The inverted yield curve was explained: the higher short- term rate is result of the tightening of monetary policy, and the lowering of long term rates was a sign that Asian central banks and OPEC oil barons still have no good alternative to U.S. bonds. It is not an economic warning sign at all. The inverted curve signified the global liquidity is chasing yields. Even the Fed publicly opposed the usefulness of the yield curve as an economic indicator and confirmed the idea that a heavy flow of overseas capital into the U.S.

[6] www.incrediblecharts.com

has driven the yield on 10-year notes to low levels -- distorting the yield curve's predictive abilities. [7]

The Predictive Power of Inverted Yield Curve

The expectations hypothesis indicated that long-term interest rates are determined by expected future short-term rates. Because short-term rates are governed by monetary policy, investors should expect declines as a phase of monetary tightening transitions to monetary easing. As expected future short-term rates fall below current short-term rates, the yield curve inverts. Estrella and Adrian (2008) show that the yield-curve inversion that comes at the end of a tightening cycle has historically been followed by a decline in real activity, which provides a compelling link between yield-curve inversion and an imminent recession.

The reasons to choose LIBOR to forecast recession

It become a fact that the yield curve spread has strong forecast power for economy recession and it has been proven by many economists; however we like to improve our predictability by using Libor rates.

The short-term institutional lending market can be roughly divided along two dimensions: government versus private sector issued, and secured versus unsecured. Treasury bills are government issued short term debt instruments secured by U.S government. Treasury are considered risk free and offer the lowest yields. Libor has

[7] Ben S. Bernanke, "Reflections on the Yield Curve and Monetary Policy", March 20, 2006

been recognized as the benchmark yield for unsecured private loans. In time of financial crisis, the potential losses forced banks and other financial institutions to reduce their inter-bank lending in order to make sure they can meet the capital reserve requirements and also to build enough liquidity. Libor yields increase as a result.

As viewed by many economists that the 3 month T-bill rate is a proxy for the federal funds rate, [8] which means the rate is closely related to the Fed fund rate and monetary policy, the treasury yield spread can be biased and could lose the predictability of recession based on the decision of the policy makers. Thus, we want to use a market rate which is similar to treasury rates.

The London Interbank Offered Rate (LIBOR) is a daily reference rate based on the interest rates at which banks borrow unsecured funds from banks in the London wholesale money market or interbank market. It is roughly comparable to the U.S. Federal funds rate and their gap and movement have been very close to each other. Thus, we decide to use LIBOR for market rate replace treasury rates (policy rate). However, LIBOR became a key barometer of market stress since the credit crisis began in 2007, rising to record levels above Treasury bills in a sign of risk aversion on the part of banks and money market funds. LIBOR remains far above the Fed's 1 per cent target overnight rate. Before the onset of the credit squeeze in August 2007, three-month Libor averaged 12 basis points higher. Thus, it is pretty worth while

---

[8] Edward N. Gamber and David R. Hakes," Is monetary policy important for forecasting real growth and inflation?" Journal of Policy Modeling, Volume 27, Issue 2, March 2005, Pages 177-187)

checking the difference between 3-month LIBOR rate and 3-month Treasury bill and seeing the difference of predictability of recession.

We also replace 10 year Treasury bond for 10-year Interest rate swaps since swap rate is calculated based on short LIBOR rates currently trade on the interbank market.

Literature review

Since the credit crunch broke out in the summer of year 2007, a series of US economic data indicated that US economic growth has slowed down and some economists suggested that US economy might have entered into recession, which was not confirmed by NBER until October 2008. In the meantime, the predictive power of yield curve is facing with another empirical test.

There are two divergent views in the recession predictionn literature. One group of economists believes that recession can not be forecasted. Zarnowitz and Braun (1993) indicated that economic forecasters made their largest prediction errors during recessions, and Diebold and Rudebusch (1989) showed that ability of the well-known index of leading indicators to forecast the future recessions is not significant.

However, some of the economists come to a very different conclusion about the predictability of recessions. The term spread is useful in forecasting recessions. Kessel (1965) maybe the first to point out that spreads between long- and short-term rates tend to be low at the start of recessions and high as expansions starts. Butler (1978) argued that the slope of the yield curve can be used as a predictor of short-term interest rates and he also pointed out what the declining short-term rates implied for the economic activity. His idea had great influence on the later thoughts. Stock and Watson (1989) constructed an index of leading economic indicators. Three term spreads were selected as the leading economic indicators. They pointed out that an inverted Treasury bond yield curve was found to be important indicator of declines in economic activity.

Harvey (1989) developed a model to predict the future economic growth and argued that the term structure of interest rates could be used to forecast economic growth. His evidence was impressive: 50% of the variance in real GNP growth could be explained. Several years later, Harvey (1995) perform a post-mortem on the out-of-sample performance with the recent recession, which show that the term structure model provided accurate and timely forecasts of the most recent business cycle. He also indicated that if recession is expected, the term structure or yield curve will become flat or inverted. The shape of yield curve provides a forecast of future economic growth.

Mishkin (1990) empirically showed that yield spreads are positively correlated with future changes in short-term interest rates, particularly at long horizons. However, yield spreads are negatively correlated with next period's change in long-term interest rates. The yield curve has almost no ability to forecast future inflation changes for short horizons: the yield curve contains a great deal of information about the future path of inflation for the longer horizons.

Furlong (1989) noticed some predictive power for recessions, but expressed skepticism about the yield curve's reliability as a leading indicator. Estrella and Hardouvelis (1989, 1990, 1991) showed empirically that the yield curve may be used to predict the probability of recessions. They chose to use spread alone, because they believed the spread already contains information for future economic growth, which does not show in the current real economic data; thus, the slope could have provided useful information.

Hu (1993) shown that yield spread serves as a good predictor of future economic growth. The out-of-sample forecasting performance of the yield spread compares

favorably with that of the alternative stock price-based model and ARMA model.

Plosser and Rouwenhorst (1994) investigated the predictive power of spread between various maturities of long-term bonds and the three-month bill rates. They find that the term spread has significant in-sample predictability for industrial production's future changes of up to five years. They also found that information in the longer end of the term structure is useful in predicting future economic activity by examining how the term spread affects the forward rates.

Estrella and Mishkin (1996b) examines the performance of various financial variables as predictors of U.S. recessions. Interest rates and spreads, stock prices, currencies, and monetary aggregates are evaluated individually and in comparison with other financial indicators. They found the slope of the yield curve emerges as the clear individual choice and typically performs better by itself out of sample than in conjunction with other variables.

Estrella and Mishkin (1998) use data between period 1959 to 1995 and show that the spread between the yield on the ten-year and three-month Treasury securities is the best out-of-sample predictor of the probability of a recession occurring in the next four quarters. They found that a spread greater than 1.2 percentage points translates into a recession probability of less than 5 percent. As the spread narrows, however, the recession probability increases—reaching roughly 25 percent when the two interest rates become equal. Once the yield curve inverts and the spread falls to a negative 0.8 percentage points, the probability of recession jumps to 50 percent. With a negative 2.4 percentage point spread, the likelihood of a recession rises to 90 percent. The probability of recession rises moderately as the yield curve flattens and increases dramatically as it inverts.

Haubrich and Dombrosky (1996) found that between the periods of 1961 to 1995, the yield spread is a important predictor of four-quarter economic growth but that its predictive power has changed over time. The yield spread may not be a very good predictor of economic activity over the period 1985 to 1995.

Dueker (1997) observed that the yield-curve slope remains the single best recession predictor in the examined set of variables, even under two extensions of the basic time-series Probit model. He also pointed out two factors that make the term spread a favorable recession indicator: its theoretical foundation of expectation theory. He suggested considering dynamic serial correlation in the Probit recession model.

Estrella and Mishkin (1998) examines the relationship of the term structure of interest rates to monetary policy instruments and to subsequent real activity and inflation in both Europe and the United States. The results show that monetary policy is an important determinant of the term structure spread, but it unlikely to be the only determinant. In addition, there is significant predictive power for both real activity and inflation. The yield curve is thus a simple and accurate measure that should be viewed as one piece of useful information which, along with other information, can be used to help guide European monetary policy.

Estrella, Rodrigues and Schich (2003) found that slope of yield curve predicts recessions is stable over their full sample period in both Germany and the United States. This idea was further strengthened by Estrella (2005a) that there is a persistent predictive relationship between term spreads and future real output, though the precise parameters may change over time. Yield curve inversions and economic recessions correspond to extreme values of those variables, a connection between inversions and recessions may be observable even if parameters change over time.

Stock and Watson (2003) examine a large number of competing indicators of output growth and find that the term spread works best, but it exhibits some instability. This instability indicated the combining the term spread with some other indicators may improve performance in their equations.

Atta-Mensah and Tkaez (1998) from Bank of Canada examined the ability of the term structure of Canada interest rates. Their results show that compared to other financial variables, the spread between Canadian long bonds and the 90-day commercial paper rate is the best at predicting recessions in Canada.

Bidirectional relationship between yield curve and monetary policy

Most of the literature in this field deals with the yield curve as a predictor of future activity, but there could be influences in the opposite direction. The term spread contains expectations of future activity, and it is affected by current monetary policy, which is influenced in turn by current economic activities.

Eijffinger, Schaling and Verhagen (2000) examine the implications of the expectations theory of the term structure for the implementation of inflation targeting. They concluded that short term interest rates in the central bank's forward looking monetary policy rule need to respond more strongly to the output gap and deviations of inflation from its target. Thus, in general the term structure implies a higher degree of policy activism. The paper also show the sensitivity of the term spread to economic fundamentals, and the extent to which the spread predicts future output, are increasing in the duration of the long bond and the degree of structural output persistence. If the central bank becomes relatively less concerned about inflation

stabilization the term spread becomes less sensitive to fundamentals, and the spread will be less successful in predicting real economic activity.

Evans and Marshall (2001) find consistent evidence that monetary policy shocks affect the nominal yield curve. They study the effect of different types of macroeconomic impulses on the nominal yield curve. They find that monetary policy shocks are the only macroeconomic shocks with a consistent and significant impact on the slope of the yield curve.

Diebold, Rudebusch and Aruoba (2004) find that the influence in the direction from activity to the term structure is even stronger than the predictive relationships. They find strong evidence of the effects of macro variables on future movements in the yield curve and evidence for a reverse influence as well. Evidence is supportive of a bidirectional relationship.

Bordo and Joseph (2004) showed empirically the spread between corporate bonds and commercial paper reliably predicts future growth over the period 1875-1997. The predictability varies over time, and is related to monetary policy credibility. Regimes with low credibility (high persistence of inflation) tend to have better predictability.

Why should a negative term spread predict a recession?

The expectations hypothesis indicated that long-term interest rates are determined by expected future short-term rates. Because short-term rates are governed by monetary policy, investors should expect declines as a phase of monetary tightening transitions to monetary easing. As expected future short-term rates fall below current short-term rates, the yield curve inverts. Estrella and Adrian (2008) show that the yield-curve inversion that comes at the end of a tightening cycle has historically been followed by

a decline in real activity, which provides a compelling link between yield-curve inversion and an imminent recession.

Current Issues

Chen, Iqbal and Lai (2008) pointed out that Probit-Recession forecasting model can include only up to several predictors in a model specification and useful information embedded in large number of available but excluded variables can be missed. Therefore, they used principal component analysis based on recent dynamic factor modeling theory and they illustrated on March 2008 that there is very high recession probability (73%) for the next 6 month which is proven in current situation.

Methodology[9]

Formulations of Discrete Choice Models

We define models which are able to connect qualitative dependant variable (recession) and quantity variable (yield spread) and explain the dependable/qualitative variable based on independent/quantity variable. Dependant variable being described is inherently discrete as qualitative response (QR) models and the response may be the outcome of a decision or the data in a survey – recession or not. We found three models - Linear Probability, Logit, Probit - which can explain qualitative variable by using quantity variable. Linear Probability model is the simplest model but a lot of bias are involved since it assumes that the marginal or incremental effect of dependable remains constant throughout. The non-linear relationship between independent variable and dependent variable is more realistic. The popular cases are the simple Probit model in which the dependent variable is usually binary (1 or 0, Recession or not) and the Logit model in which the process being modeled is usually one of the discrete choice among a small set of alternatives.

In order to quantifying economic recession, the definition of independent dummy variable for recession is defined as follows.

R_t= 1 (If the economy is in the recession in t period)

R_t= 0 (Otherwise)

[9] "Econometric Models and Economic Forecasts", Pindyck and Rubinfeld, (McGraw-Hill , 1998) and http://polsci.colorado.edu/

The Linear Probability Model

Linear probability model is the OLS model applied to a dichotomous dependent variable. The alpha and beta can be calculated very easily by using simple OLS model below between recession dummy dependent variable (R_t) and the yield spread (S_{t-k})

OLS model: $R_t=\alpha +\beta S_{t-k}+\varepsilon_t$ (K: forecast horizon)

The probability is easily obtained because expected return of OLS model formula is the probability of recession. Linear probability model use dichotomous dummy variable as a linear function of explanatory model. The conditional probability of an event that economy is in recession is simply conditional expectation of R_t given S_{t-k}. The expected value of R_t given $R_t = 1$ is:

$E(R_t = 1 \mid S_{t-k}) = E(\alpha +\beta S_{t-k}+\varepsilon_t)$ = P* 1 + (1-P)*0 = Probability

Probability: $P(R_t) = E(\alpha +\beta S_{t-k}+\varepsilon_t) = \alpha +\beta S_{t-k}$

The Probability of R_t and Expected value of R_t are the same since R_t is dichotomous dummy variable which has only binary value between 0 and 1 and there is no additional value when recession does not happen (R_t=0, no expected value). Thus, the probability can be calculated and the Interpretation of the coefficients is straightforward. A one unit increases in independent variable (S_{t-k}), which is associated with a β, increases in the probability of an event occurring and the

relationship is linear so the impact of S_{t-k} on R_t is constant.

However, this linear probability model presents a number of problems. First, since $\alpha + \beta S_{t-k}$ must equal zero or one, the variance of the errors depends on β, leading to heteroscedasticity. Second, it is impossible to assure that the range of predictions from this model will look like probabilities since $\alpha + \beta S_{t-k}$ is not constrained to be within the zero-one interval.

Logit and Probit Model

We use Probit and Logit model instead because there are some problems with Linear probability model. The inadequacies of the linear probability model suggest that a nonlinear specification is more appropriate. A natural candidate is an S-shaped curved bounded in the interval zero-one. One such curve is the cumulative normal distribution function corresponding to the Probit model and another is curve corresponding to the Logit model. This Logit model is derived as follows. Let R_t^* represent an unobservable variable given by

$$R_t^* = \alpha + \beta S_{t-k} + \varepsilon_t$$

Where $\varepsilon_t \sim N(0,1)$ and ε_t are independent. The observable binary variable R_t is related to R_t^* in the following way:

$R_t = 1$ if $R_t^* > 0$

$R_t = 0$ if $R_t^* < 0$

Then, same as Linear Probability Model

$$E(R_t) = p = P(R_t = 1)$$

$$= P(R_t^* > 0) = F(\alpha + \beta S_{t-k} + \varepsilon_t)$$

Where the function F(t) represents the standard normal distribution. Thus, the probability can be calculated by following cumulative distribution function (CDF)

$$\text{Probability } (R_t = 1) = \int_{-\infty}^{\alpha + \beta S_{t-k} + \varepsilon_t} \Phi(t)dt$$

Where F(*t*) represents the density function of $t \sim N(0,1)$. Since $P = F(\alpha + \beta S_{t-k} + \varepsilon_t)$, we can write

$$F^{-1}(p) = \alpha + \beta S_{t-k} + \varepsilon_t$$

Where $F^{-1}(p)$ is the inverse of the standard normal cumulative distribution functions. The parameters β can be estimated by the maximum likelihood method using the log-likelihood function[10].

An alternative S-shaped curve is the logistic curve corresponding to the Logit model. This model is very popular because of its mathematical convenience and is given by:

[10] http://www3.wabash.edu/econometrics (Excel Add-in Program)

Logit Model Probability: $P(R_t) = \frac{1}{1+e^{-(\alpha+\beta S_{t-k}+\varepsilon_t)}}$

The logistic function is used because it represents a close approximation to the cumulative normal and is easier to work with. In dichotomous situations, however, both functions are very close although the logistic function has slightly heavier tails than the cumulative normal. Among three ways to quantifying the yield spread [11] as a predictor of economic recession, Estrella and Mishkin (1998) chose to use Probit model. So did we.

Testing

There are many measures to test good-fit, analogous to the coefficient of determination R^2 in linear regression models. As a measure of fit for probit models, Estrella (1998) proposed a pseudo-R^2 in which the log-likelihood of a model. The log-likelihood functions for a Probit and Logit model above are:

Probit Model: $L = \sum R_t \ln P\left(R_t = 1 \mid S_{t-k}\right) + (1 - R_t) \ln P\left(R_t = 0 \mid S_{t-k}\right)$

Logit Model: $L = \left(\frac{1}{1+e^{-(\alpha+\beta S_{t-k}+\varepsilon_t)}}\right)^{P(R_t)} \left(1 - \frac{1}{1+e^{-(\alpha+\beta S_{t-k}+\varepsilon_t)}}\right)^{1-P(R_t)}$

And pseudo-R^2 is defined as:

[11] 3 month and 10 year treasury yield spread

$$\text{Pseudo-}R^2 = 1 - \left(\frac{\log L_u}{\log L_c}\right)^{\frac{2}{n}\log L_u}$$

L_u is the value of the likelihood of the estimated model and L_c is the value of a model implying the constant recession probability in every month and n is number of observation. The range of pseudo-R^2 is 0 and 1 since L_u is always greater than L_c and the greater value has more explanatory power. The strength of the pseudo-R^2 is that it corresponds more closely to the linear R^2 when its values are away from the range between 0 and 1.

Data

It is important how to define the recession in our analysis, which is binary dependent variable[12]. The standard dating of U.S. recessions derives from the cyclical peaks and troughs identified by the National Bureau of Economic Research (NBER). To convert the NBER monthly dates into a monthly recession indicator, we classify as a recession every month between the peak and the subsequent trough, as well as the trough itself. We simply use NBER definition and use the data from NBER.

We use the spread between monthly average 10 year T- bond and 3 month T- bill rate data from Federal Reserve Bank of New York[13] to calculate the probability of the recession in the United States. The 3 month LIBOR[14] and 10 year SWAP rate[15] are also used in order to analyze the recession by using market rate rather than policy rates.

Comparison between LIBOR and 3-month Treasury Bill

We measure the difference by replacing 3-month LIBOR for 3-month Treasury bill since we expect that it is also worth while comparing policy rate and market rate by replacing only short term rate with 3-month LIBOR. We calculate the spread between 3-month LIBOR and 10-year Treasury bond, as well as the spread between

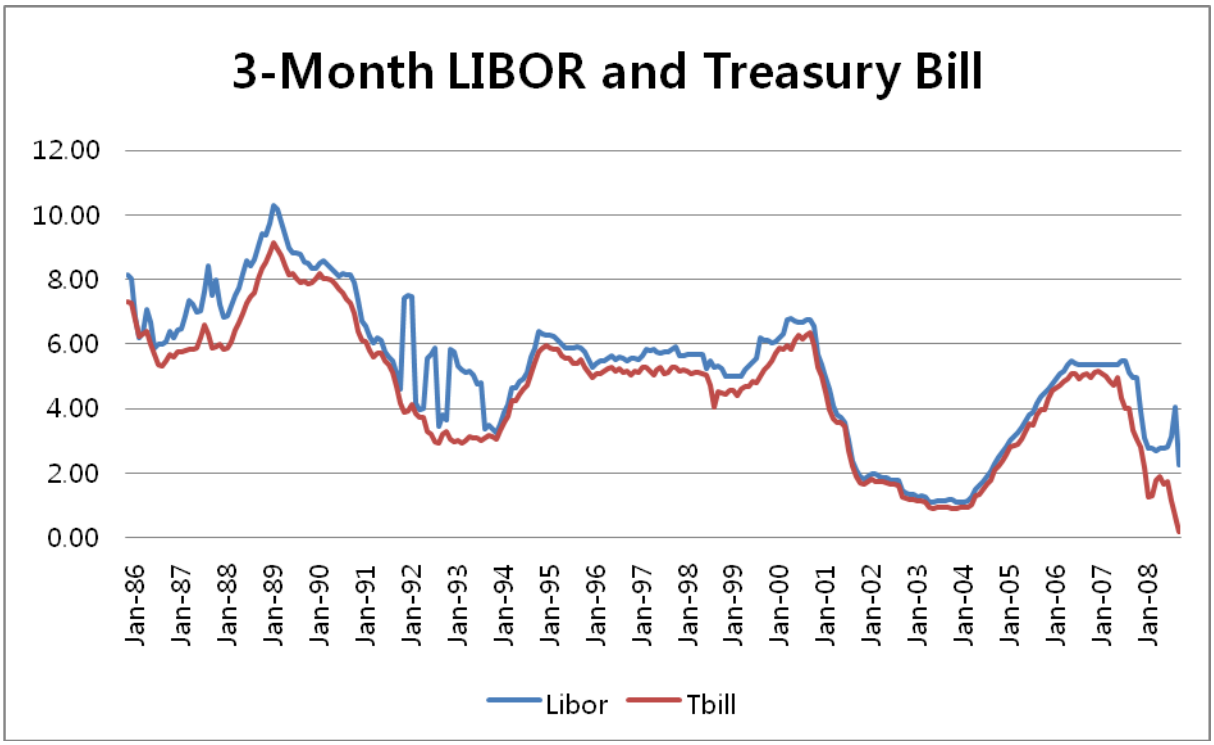
[12] Recession: 1, otherwise: 0

[13] www.newyorkfed.org/research/capital_markets/ycfaq.html

[14] British Bankers' Association: http://www.bba.org.uk/public/libor/

[15] Federal Reserve: www.federalreserve.gov/releases/h15/data.htm

3-month Treasury bond and 10-year Treasury bond and check the difference of predictability of recession. In order to have 'apple to apple comparison', we only use data in both calculations from 1986 to 2008 due to limitation of LIBOR data.



The chart above shows that the relation between 3-month LIBOR and 3-month Treasury bill seem similar to each other; however some big difference is observed in 1991 ~ 1993 and 2008. Additionally, the spread between two rates is not consistent since 1986. There was only one negative spread in April 1986 and the spread was much smaller in 2001 ~ 2005 than the whole period (average spread in 2001~2005: 0.24, total average spread: 0.67)

Especially, during 1992 ~ 1993, the correlation between LIBOR and Treasury bill was only 0.55 compared to 0.96 during total period. Since we can notice that there is different movement between two rates, we decide to compare two rates to test the predictability for economy recession and check which rate is better to forecast recessions.

Empirical result

Application of Methodology

Since we follow the same method (Probit Model) of Arturo Estrella, Estrella and Mary R. Trubin[16] (2006) published their parameters of Probit model on the website of Federal Reserve Bank of New York. It is meaningful to compare our result to Estrella and Trubin's by using the same data set and test our methodology. The following charts used data from January 1959 to December 2005, the same as Estrella and Trubin's.

	Alpha	Beta
Estrella and Trubin	-0.6045	-0.7374
Our methodology	-0.6159	-0.7443

We obtained the very similar result so that we can conclude that our mythology is applicable to verify the predictability of recession.

The predictability of Treasury Spread

Models Result

The probability of a recession occurring with 12 month forecast horizon (k=12) is used from the viewpoint of information available in month t. The regression results show that the slopes are negative in both models as we expect intuitively and the t-value shows that both parameters are significant at a 99% level of confidence.

[16] The Yield Curve as a Leading Indicator, Arturo Estrella and Mary R. Trubin, August 2006

Probit Model Probability: $P(R_t) = \Phi(-0.657 + -0.7076\ S_{t-k} + \varepsilon_t)$

T-values: (-8.0782) (-9.1976)

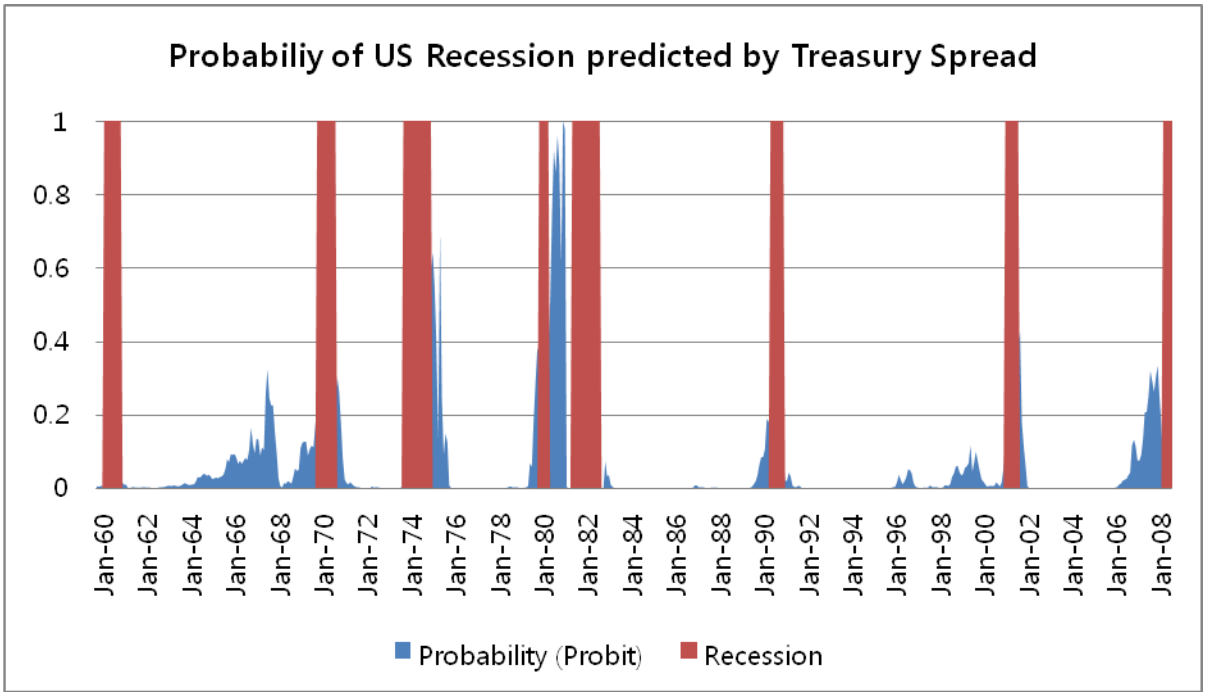
Logit Model Probability: $P(R_t) = \frac{1}{1+e^{-1.091+(-1.2965)S_{t-k}+\varepsilon_t}}$

T-values: (-7.4982) (-8.5179)

Arturo Estrella and Mary R. Trubin estimated the values of α= -0.6045 and β= -0.7374 by using data from January 1959 to December 2005. We also obtain the very similar results in our Probit Model, which means the predictability of treasury spread are still very powerful for the current U.S. recession even under the current extra-ordinary credit crisis.

Forecast Power

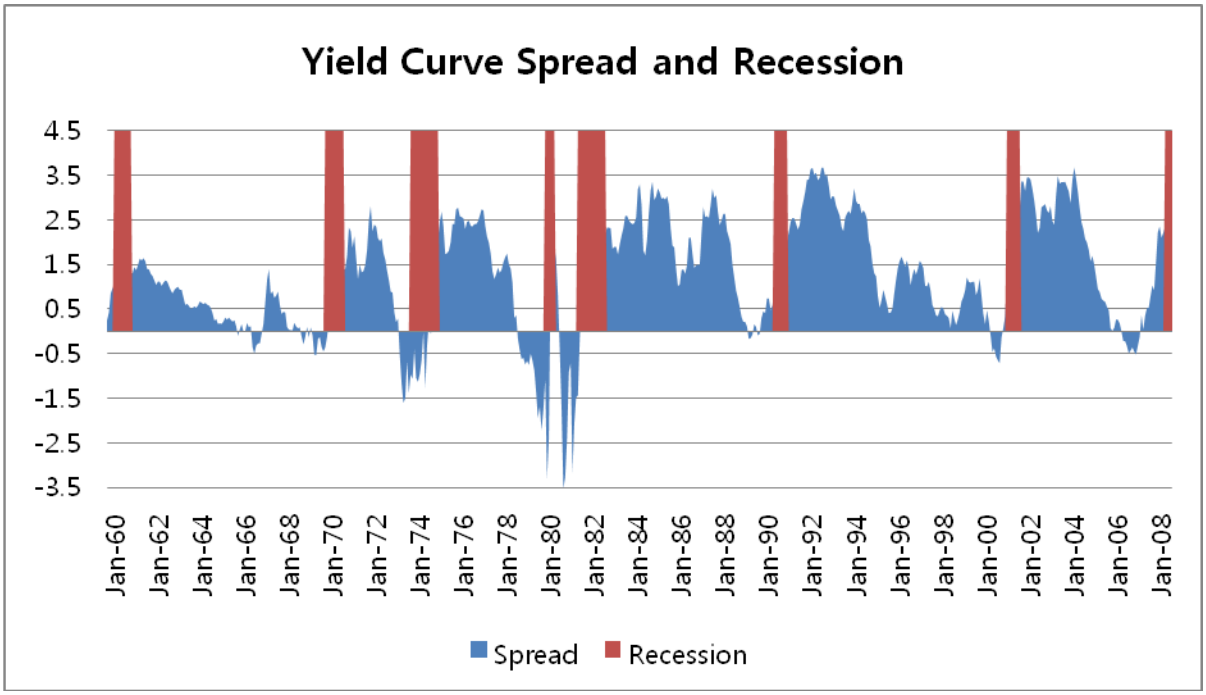
Although there was negative spread before recession during 2008 ~ 2009, the probability of recession was relatively low (probability: 39%, spread: -51bp) compared to recession during 1981 ~ 1982 (probability: 99%, spread -351bp) which forecasted recession with the highest possibility.



This chart clearly shows that 10-year to 3-month Treasury spread is very useful in predicting recessions. We also try to analyze our results to get a clue of how long the current recession will last. Although inversion has been major recession signal in recent decades, the precise level and duration of the negative spread has varied with each recession. The following table shows the highest monthly level of the spread between 10-year and 3-month Treasury rates was -3.51 and the recession lasts only for six months in 1980 while the recession lasts for 16 months in lowest level (-0.08) of the spread in 1981 – 1982. In addition, we also found that there is no significant relationship between duration of recession and the number of months with negative monthly spread. However, Estrella and Hardouvelis (1991) proved that there is evidence that more pronounced inversions have generally been associated with deeper subsequent recessions.

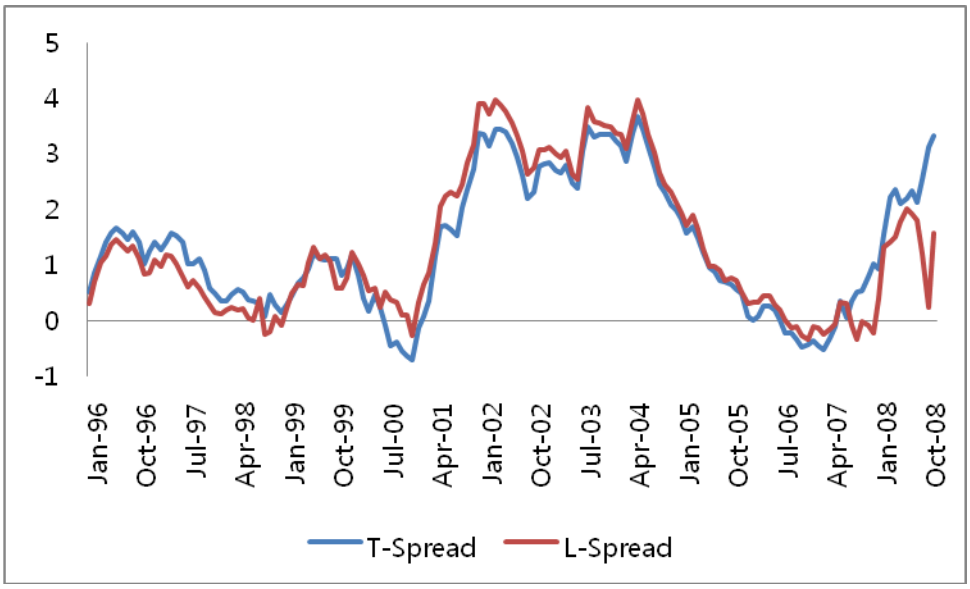
NBER Recession	Recession Duration	Number of Months With Negative Monthly Spread	Minimum Level of Spread
May 1960 - February 1961	10	10	-0.51
January 1970 – November 1970	11	6	-1.59
December 1973 – March 1975	16	12	-2.2
February 1980 – July 1980	6	10	-3.51
August 1981 – November 1982	16	3	-0.08
August 1990 – March 1991	8	7	-0.7
April 2001 – November 2001	8	9	-0.7
September 2008 – Present	N.A.	10	-0.51

Therefore, we conclude that it is appropriate to look at this spread as a recession indicator and the level and duration of negative spread does not have forecasting power regarding how long the recession will last.



The predictability of LIBOR and SWAP Spread

The both spreads were highly correlated and they had moved almost to the same direction; however the results are not the same as the result of Treasury spread.



Model Result

The probability of a recession occurring with 7 month forecast horizon (k=7) is used from the viewpoint of information available in month t. The regression results show that the slopes are positive in both models opposite to Treasury spread model and the t-value shows that both parameters are significant at a 90% level of confidence.

Probit Model Probability: $P(R_t) = \Phi(-1.9756 + 0.2243\ S_{t-k} + \varepsilon_t)$

T-values: (-6.43265) (1.643239)

Logit Model Probability: $P(R_t) = \frac{1}{1+e^{-3.55164+(0.415402)S_{t-k}+\varepsilon_t}}$

T-values: (-5.48238) (1.551049)

Especially β has been changed radically from -0.7076 to 0.2243 in Probit Model and the T-value is not sufficient enough. It means that negative spread does not indicate

the higher probability of recession in LIBOR and SWAP spread. We infer the reason that the estimate periods (Treasury: 1959 – 2008, Libor: 1996 – 2008) are different as well as market rate (LIBOR and SWAP) does not have deep negative spread compared to Treasury spread. We also got the very similar result in our Logit Model, which means the predictability of LIBOR and SWAP spread are less powerful to forecast U.S. recession.

Forecast Power

We estimate the Pseudo-R^2 statics by using different time horizon since we expect that market rate will have more predictability with shorter time lag compared to treasury spread (K=12). The table below shows that 7 month time horizon has the best Pseudo-R^2 value among different 12 months horizon.

Prediction of US recession at various horizons (based on pseudo - R Square)

Model/Horizon	Pseudo R Square		Beta		T-value (Beta)	
(k)	Logit	Probit	Logit	Probit	Logit	Probit
0	0.03460	0.03860	0.39120	0.21504	1.66520	1.74643
1	0.01738	0.01955	0.27787	0.15360	1.18751	1.25128
2	0.02945	0.03374	0.36300	0.20220	1.48487	1.57690
3	0.03634	0.04163	0.40562	0.22282	1.57937	1.67632
4	0.03779	0.04306	0.41653	0.22397	1.53944	1.62975
5	0.03803	0.04336	0.41615	0.22409	1.54330	1.63424
6	0.03837	0.04376	0.41624	0.22449	1.54910	1.64074
7	**0.03853**	**0.04396**	**0.41540**	**0.22434**	**1.55105**	**1.64324**
8	0.03849	0.04393	0.41362	0.22363	1.54863	1.64113
9	0.03840	0.04383	0.41158	0.22276	1.54494	1.63768
10	0.03824	0.04365	0.40929	0.22175	1.53992	1.63281
11	0.03759	0.04291	0.40549	0.21983	1.52488	1.61714
12	0.03668	0.04187	0.40127	0.21771	1.50529	1.59662

Even with 7 months horizon in LIBOR and SWAP rate, the probability of recession are still pretty low. The probability range is from 2% to 14%, which means that the Spread between LIBOR and SWAP is not a strong recession forecast indicator.

Comparison between 3-month LIBOR and Treasury Bill

In this part, we only focus on the comparison of predictability between 3-month LIBOR and 3-month Treasury bill in order to check whether 3-month LIBOR is a good alternative rate for 3-month Treasury bill in predicting recession. Thus, we measure the predictability of recession by using the spread between 3-month LIBOR and 10-year Treasury bond and original model spread between 3-month LIBOR and 10-year Treasury bond.

Models Result

The probability of a recession is measured considering different quarterly horizons and quarterly time horizon (K=0, 3, 6, 9, 12, 15) is used. The regression results show that the slope, intercept and Pseudo R square are different depending on different forecast time horizon. As it is proven by Estrella and Trubin, 4 quarters time lag on Treasury Spread shows the best result in our model, as well. T-value shows that both parameters are significant at a 99% level of confidence with 4 quarter forecast time horizon.

Comparing to the result from January 1960 to December 2008, we can observe that the absolute values of beta increase in Treasury yield curve model. But the t-values are a little bit lower than the previous results. By using shorter period data set (’86 ~’08), we also obtain slightly different results in other values, which means the

predictability of treasury spread is changed based on what period is used. There is not much difference to forecast recession between Probit and Logit models. Even though the Beta in Logit model is higher than Probit model, the predictability is the almost same statistically.

Probit Model

Model/	Pseudo R Square		Beta		T-value (Beta)	
Horizon (k)	Tbill	LIBOR	Tbill	LIBOR	Tbill	LIBOR
0	0.002	0.008	0.050	0.110	0.492	1.053
3	0.011	0.019	-0.128	-0.172	-1.191	-1.588
6	0.073	0.085	-0.363	-0.379	-2.849	-3.129
9	0.335	0.256	-1.219	-0.894	-5.277	-4.217
12	**0.459**	**0.317**	**-1.797**	**-1.176**	**-5.552**	**-4.264**
15	0.332	0.277	-1.230	-0.983	-4.622	-4.179

Logit Model

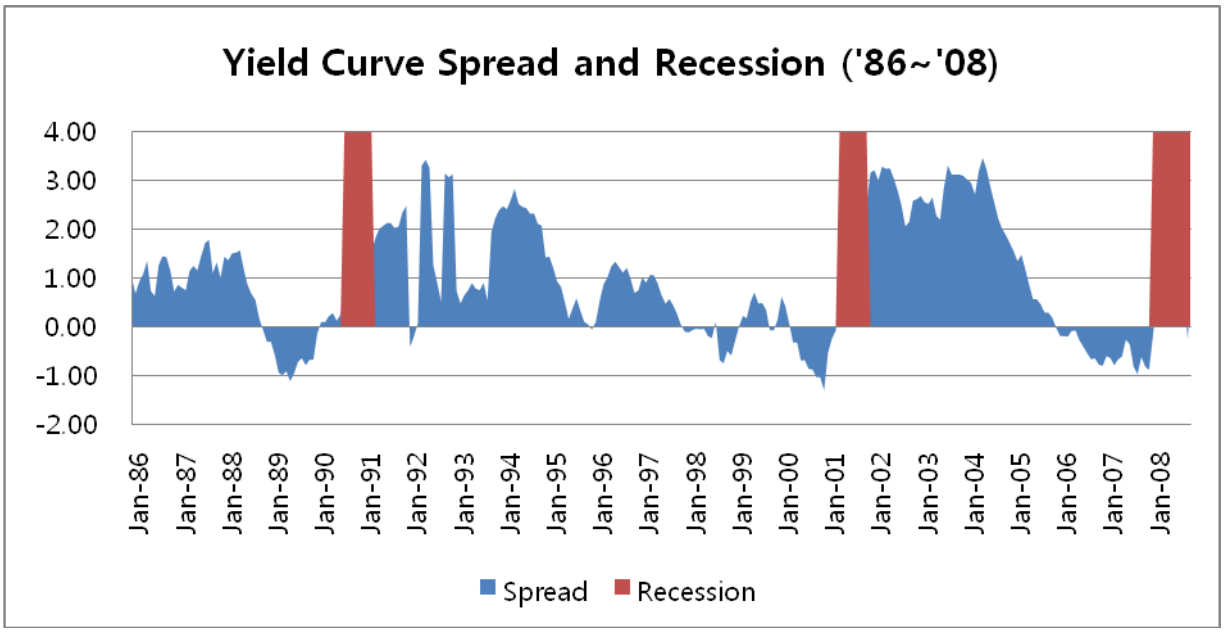
Model/	Pseudo R Square		Beta		T-value (Beta)	
Horizon (k)	Tbill	LIBOR	Tbill	LIBOR	Tbill	LIBOR
0	0.002	0.007	0.091	0.205	0.466	0.998
3	0.010	0.017	-0.236	-0.322	-1.123	-1.509
6	0.069	0.084	-0.708	-0.774	-2.767	-3.054
9	0.331	0.256	-2.234	-1.785	-5.224	-4.297
12	**0.452**	**0.307**	**-3.206**	**-2.127**	**-5.389**	**-4.432**
15	0.329	0.266	-2.372	-1.806	-4.564	-4.309

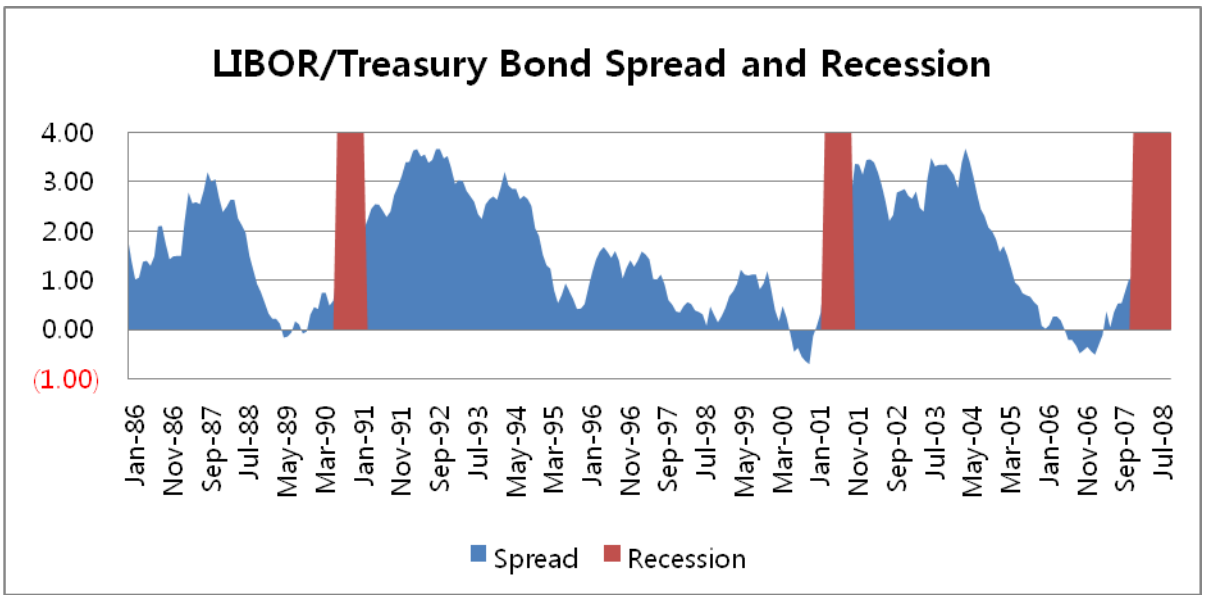
Forecast Power

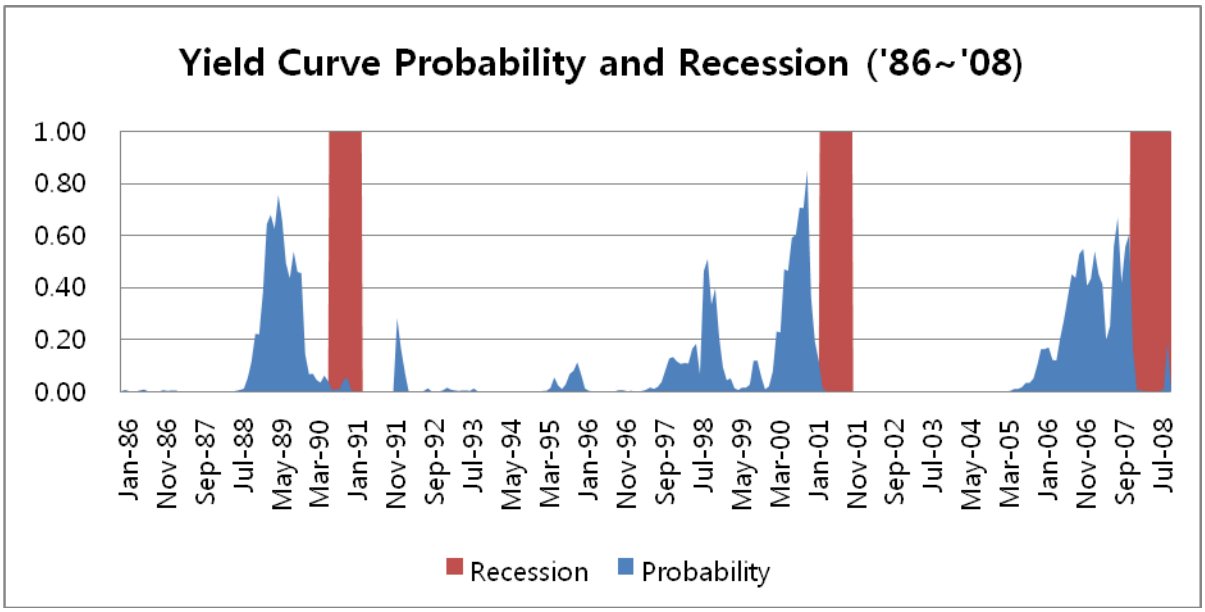
The probability of recession becomes higher when using the data during 1986 ~ 2008 compared to data during 1960 ~ 2008. For instance, the probability of current recession is 67% in data set (1986 ~ 2008) while it is 39% during 1960 ~ 2008.

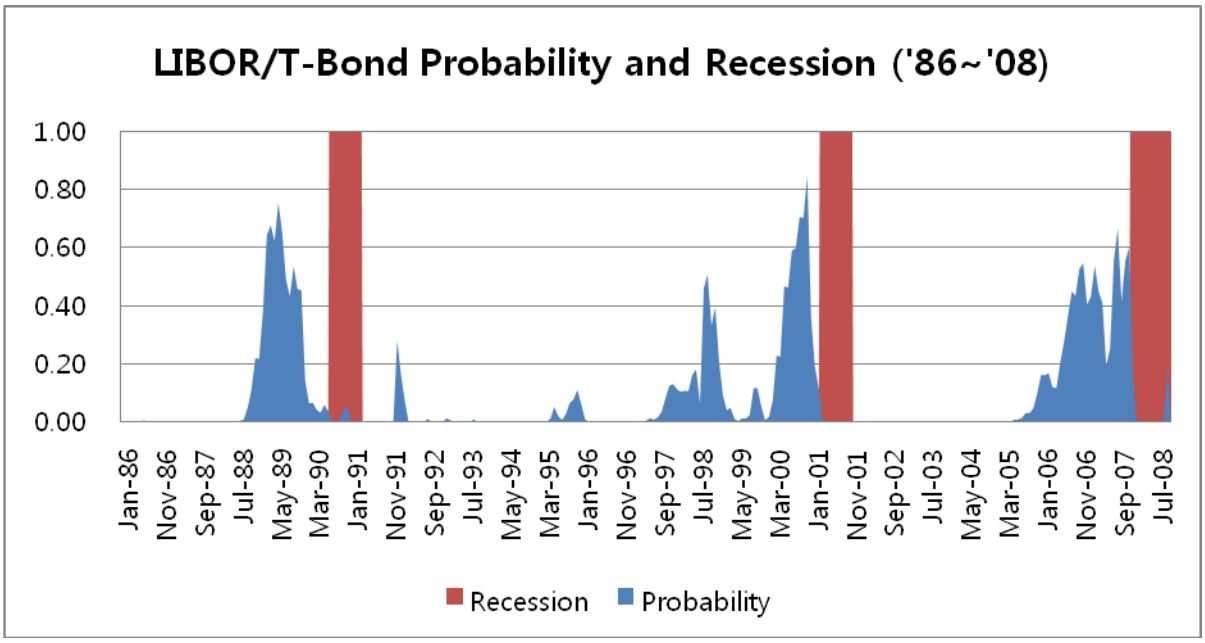
LIBOR and Treasury bill show almost the same results; however LIBOR rate clearly show that there is always recession right after negative spread without any exception while in case of Treasury bill, there is sometime no recession after negative spread.

Even though it can't be proved statistically due to the lack of enough data set, it is clear that the negative spread between 3-month LIBOR and 10-year bond could be a good sign that recession will incur soon. The probability itself is generally higher value in Treasury bill than LIBOR but it is worthwhile watching out whether the some phenomena will continue in the future and we can see the potential that 3-month LIBOR and 10-year Treasury bond spread could be a better indicator to forecast recession.


Yield Curve Spread and Recession ('86~'08)
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Spread
Recession


LIBOR/Treasury Bond Spread and Recession
4.00
3.00
2.00
1.00
0.00
(1.00)
Jan-86
Nov-86
Sep-87
Jul-88
May-89
Mar-90
Jan-91
Nov-91
Sep-92
Jul-93
May-94
Mar-95
Jan-96
Nov-96
Sep-97
Jul-98
May-99
Mar-00
Jan-01
Nov-01
Sep-02
Jul-03
May-04
Mar-05
Jan-06
Nov-06
Sep-07
Jul-08
Spread
Recession


Yield Curve Probability and Recession ('86~'08)
1.00
0.80
0.60
0.40
0.20
0.00
Jan-86
Nov-86
Sep-87
Jul-88
May-89
Mar-90
Jan-91
Nov-91
Sep-92
Jul-93
May-94
Mar-95
Jan-96
Nov-96
Sep-97
Jul-98
May-99
Mar-00
Jan-01
Nov-01
Sep-02
Jul-03
May-04
Mar-05
Jan-06
Nov-06
Sep-07
Jul-08
Recession
Probability


LIBOR/T-Bond Probability and Recession ('86~'08)
1.00
0.80
0.60
0.40
0.20
0.00
Jan-86
Nov-86
Sep-87
Jul-88
May-89
Mar-90
Jan-91
Nov-91
Sep-92
Jul-93
May-94
Mar-95
Jan-96
Nov-96
Sep-97
Jul-98
May-99
Mar-00
Jan-01
Nov-01
Sep-02
Jul-03
May-04
Mar-05
Jan-06
Nov-06
Sep-07
Jul-08
Recession
Probability

Current Predictability of Different Interest Rates Spread

We calculated the predictability of recession by using different combination of spread among 3-month Treasury / LIBOR as short-term rate, and 10-year Treasury bond / SWAP as long-term rate and try to see which rate and which spread shows the best predictability of recession by using current data set. Thus, we build four spreads through the combination of four different interest rates from July 2000 ~ Nov 2008. The results are as follows;

Different Spreads Comparison ('00~'08)					
	Alpha	T-value	Beta	T-value	Pseudo R
3-month Treasury and 10-year Treasury	0.215	-1.033	1.069	-3.320	0.387
3-month Treasury and 10-year SWAP	0.345	1.107	0.899	-3.478	0.320
3-month LIBOR and 10-year Treasury	N.A.	N.A.	N.A.	N.A.	N.A.
3-month LIBOR and 10-year SWAP	0.108	0.449	1.685	-2.868	0.458

As you can see the chart above, the spread of 3-month LIBOR and 10-year SWAP is the best spread to explain the predictability of recession in term of Pseudo-R square. It is even better than the spread of 3-month Treasury bill and 10-year Treasury bond; however, the T-values are not big enough compared to the previous result. We consider that this result is not reliable to conclude that one spread is better than the other since the more data is required to obtain the better assessment and the spared of 3-month LIBOR and 10-year Treasury bond can not run the Probit model due to short of data; however we expect that the spread of LIBOR and SWAP could be better measurement in the future.

Conclusion

Why the term structure predicts recessions? We believe that there could be two explanations for this relationship. The first explanation is when people believe that the economy is heading toward recession in near future. The desire by investors to hedge against recession would lead to purchase the long-term bonds that will deliver pay-offs in recession. The rush to purchase the longer term bonds will cause the price of bond to rise and the corresponding yield will fall. In order to finance investing the longer term bonds, investor will sell off their shorter-term bonds. Thus, the price of shorter term bonds will fall while the yield will rise. This explanation indicates that if a recession is predicted, people should be able to see long rates fall and short rate rise. Based on this explanation and our result, yield curve will become inverted or at least flat prior to a recession.

The second explanation for yield spread change is that the spread is a better measure of the liquidity effect of monetary policy than 3-month Treasury bill rate itself. If Government tightens monetary policy by raising short-term rates, the rise in current short-term rate will lead banks to expect future short term rates to rise by less than the current change in short-term rate. Based on the expectation of the term structure, the long-term rates will rise by less than the current short rate and it will lead to the inversed yield curve. Since there is time lagged for monetary policy to affects real economic activity, the tightening of the monetary policy will cause a reduction of future economic activity more than current economy and an increase in the probability of a recession.

We examine the predictability by using interest rate spread between 3-month Treasury Bill and 10-year Treasury Bond. The results shows that the spread between 3-month Treasury bill and 10-year Treasury bond has still strong predictive power for the current U.S. Recession. We update the result of Estrella and Mishkin (1998) and our results support the findings of Estrella and Mishkin (1998) who find the interest rate spread to be a good predictor for U.S. Recession. We also found that there is no significant relationship between the recessions and the level and duration of negative Treasury spread. Additionally, it becomes clear that market rate spread has shorter time-horizon for the predictability of recession since market rates are more directly affected by real economic situation.

In addition, we also apply the Estrella and Mishkin's methodology to measure probability by using 3-month LIBOR and 10-year bond. As using the same data period (1986 ~ 2008) in both spread (LIBOR/Treasury Bond, Treasury Bill/Bond), we also found that the predictability of Treasury spread still is better than the predictability of the method using LIBOR and noticed the potential for recession prediction of LIBOR. Even considering the discrepancy between 3-month LIBOR and Treasury bill, the spread between 3-month LIBOR and 10-year Treasury bond also have the power to predict the recession and we proved that the spread with 1 year time lag is best to predict the possibility of recession.

Our drawback of model is we find that market rate spread (LIBOR and SWAP) could be better indicator of current economic recession; however it is not statistically sufficient enough to prove that market rate spread is better than policy rate spread (Treasury Spread). Especially since the correlation between Treasury bill and LIBOR

has been radically changed recently, we expect that the result could be significantly enough if we have more data set for LIBOR and SWAP. When the more data is available in the future, the result will be much better to analyze the difference between market rata and policy rate to forecast recession.

In addition, it becomes a fact that inverted yield curve causes recession. But there is no finding or methodology how long it takes time that recession is over. It could be very helpful to investors to find out how long it takes time that recession is over by use the positive spread after inverted yield curve and how it leads economy to become expansion.

Bibliography

Bordo, Michael D. and Joseph G. Haubrich (2004) “The yield curve, recessions and the credibility of the monetary regime: Long run evidence 1875 -1997.” NBER Working Paper 10431.

Butler, Larry (1978) “Recession? – A Market View.” Federal Reserve Bank of San Francisco Weekly Letter, December 15.

Diebold, Francis X., Glenn D. Rudebusch and S. Boragan Aruoba (2004) “The macroeconomy and the yield curve: A dynamic latent factor approach.” Journal of Econometrics, Forthcoming

Dueker, Michael J. (1997) “Strengthening the case for the yield curve as a predictor of U.S. recessions.” Federal Reserve Bank of St. Louis Review 79: 41-51.

Eijffinger, Sylvester, Eric Schaling and Willem Verhagen (2000) “The term structure of interest rates and inflation forecast targeting.” CEPR Discussion Paper No. 2375

Estrella, Arturo and Frederic S. Mishkin (1996b) “The yield curve as a predictor of U.S. recessions.” Federal Reserve Bank of New York Current Issues in Economics and Finance.

Estrella, Arturo and Frederic S. Mishkin (1998) “Predicting U.S. recessions: Financial variables as leading indicators.” Review of Economics and Statistics, 80: 45-61

Evans, Charles L. and David Marshall (2001) “Economic determinants of the nominal Treasury yield curve.” Unpublished paper, Federal Reserve Bank of Chicago

Furlong, Frederick T. (1989) “The yield curve and recessions.” Federal Reserve Bank of San Francisco Weekly Letter, March 10.

Harvey, Campbell R. (1989) “Forecasts of economic growth from the bond and stock markets.” Financial Analysts Journal, September/October: 38-45.

Haubrich, Joseph G. and Ann M. Dombrosky (1996) “Predicting real growth using the yield curve.” Federal Reserve Bank of Cleveland Economic Review 32: 26-35.

Hu, Zuliu (1993) “The yield curve and real activity.” IMF Staff Papers 40: 781-806.

Kessel, Reuben A. (1965) “The cyclical behavior of the term structure of interest rates.” National Bureau of Economic Research Occasional Paper No. 91.

Mishkin, Frederic S. (1990a) “What does the term structure tell us about future inflation?” Journal of Monetary Economics 25: 77-95.

Plosser, Charles I. and K. Geert Rouwenhorst (1994) “International term structures and real economic growth.” Journal of Monetary Economics 33: 133-155.

Stock, James and Mark Watson (1989) “New indexes of coincident and leading

indicators." In Blanchard, Olivier and Stanley Fischer, eds. NBER Macroeconomic Annual 4 (November): 351-394.

Stock, James and Mark Watson (2003a) "Forecasting output and inflation: The role of asset prices." Journal of Economic Literature 41: 788-829.

Atta-Mensah and Greg Tkaez (1998) "Predicting Canadian Recessions Using Financial Variables: A Probit Approch" 1-11

Chen, Iqbal and Lai (2008) "Forecasting US Recession: Probit and Dynamic Factor Medeling Approach" 4-6