THE YIELD SPREAD BETWEEN THE 10-YEAR TREASURY BOND AND THE 3-MONTH TREASURY BILL AS A PREDICTOR OF REAL, QUARTERLY GDP GROWTH RATES

A THESIS

Presented to

The Faculty of the Department of Economics and Business

The Colorado College

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Arts

By

Spencer Collins

February 2015

THE YIELD SPREAD BETWEEN THE 10-YEAR TREASURY BOND AND THE 3-MONTH TREASURY BILL AS A PREDICTOR OF REAL, QUARTERLY GDP GROWTH RATES

Spencer Collins

February 2015

Economics

Abstract

This thesis proves that the yield spread, between the 10-year Treasury Bond and the 3-month Treasury Bill ("my spread") is able to explain roughly 5% of the variation in real, quarterly GDP growth rates, four-quarters in the future. It also demonstrates that a yield spread of this maturity-combination is marginally more predictive than the other, commonly used spread, between the 10-year Treasury Bond and the 1-year Treasury Bond.

KEYWORDS: (Yield Spread, Interest Rates, GDP Growth Rates, Federal Reserve, Monetary Policy)

JEL CODES: (G100, E43, E52)

ON MY HONOR, I HAVE NEITHER GIVEN NOR RECEIVED UNAUTHORIZED AID ON THIS THESIS

Signature

TABLE OF CONTENTS

ABSTRACT ii

1 INTRODUCTION 1

3 PREVIOUS RESEARCH AND MODELING 4

4 THEORETICAL EXPLANATION 11

5 MODEL PROCEDURE 16

6 DATA DISCUSSION 17

7 MODELING RESULTS 18

8 SIGNIFICANCE OF RESULTS AND CONSLUSIONS 23

LIST OF TABLES

1 PROBIT Regression Results 9

2 Summary Statistics of Predicted Probabilities of Recessions 15

3 Descriptive Statistics of Predicted Quarterly GDP Growth Rates 16

4 Summary Statistics of Predicted Probabilities of Recessions (2) 16

5 Marginal Effects of a 1% Increase in the Spread on Predicted Probabilities of Recession 16

6 OLS Regression Results 17

7 Variables' Descriptive Statistics 18

8 Marginal Effects of a 1% Increase in the Spread on Predicted Probabilities of Recession (2) 18

9 OLS Regression Results (2) 20

10 Descriptive Statistics of Predicted Quarterly, Real GDP Growth Rates 20

LIST OF FIGURES

1 Phillips Curve 6

2 Predicted vs. Actual Quarterly GDP Growth Rates 22

Introduction

Business cycles have long been accepted as fundamental conditions of developed economies. No developed economy has ever sustained itself on consistent, uninterrupted real GDP growth since inception; there are always periods of negative growth. The commencement of such contractionary periods is of particular importance because they often produce financial hardship for both individuals and organizations.

The ability to forecast variations in GDP growth is quite valuable; it may allow families and businesses to preemptively reduce current spending to account for suppressed future revenues. Accurate growth forecasts could also potentially allow central bank authorities to take proactive steps in avoiding recessions altogether. Essentially, if forecasting models are accurate, individuals and businesses can make more informed decisions.

However, though it is well known that the market experiences both expansionary and recessionary periods, individuals and businesses have often been unable to adequately prepare for such market turbulence. It seems as though, during every recessionary period, individuals are left with debt that they cannot service. Businesses are not immune either; they repeatedly fail to reduce their exposure to cyclically affected revenue streams and rarely reserve enough capital to sustain current operation levels *through* depressed periods. This forces organizations to reduce their workforce and increases unemployment rates. If models could accurately predict variations in GDP growth, then families and businesses alike would presumably be able to plan accordingly and avoid the most damaging consequences of recessions. Therefore, I used the yield spread between the 3-month Treasury bill and the real rate on 10-year Treasury bonds to predict quarterly GDP growth rates, four-quarters in advance.

Several leading academics have constructed predictive models of GDP growth that include between four and twenty explanatory variables. These models have achieved marginal success in accurately predicting historical GDP fluctuations. Specifically, the Leading and Coincident Economic Indexes (LEI and CEI) that James Stock and Mark Watson tested achieved R^2 = 0.116 when predicting GDP growth rates one quarter in advance, and when predicting two-quarters ahead the R-squared value deteriorated to 0.028. The R-squared values of both of their models are less than the R-squared value of my model ($R^2 = 0.1556$), which makes my model a better predictor of real GDP quarterly growth rates (1989, p. 382). Unfortunately, their indexes tend to perform better in-sample but fail to make accurate out-of-sample predictions, which is the best measure of a model's forecasting abilities. This issue is what led me to develop my model with only one explanatory variable: the "spread" (difference) between the ten-year Treasury bond and three-month Treasury bill interest rates.

The Fed is the U.S.'s financial regulatory agency and is chartered by the U.S. government to monitor the state of the economy and promote financial stability vis-à-vis monetary policy actions. The Fed wields the power to manipulate interest rates and monetary supply by adjusting the Federal Funds rate, mainly through buying and selling Treasury bonds. This is implemented on the basis of current macroeconomic conditions and the array of forecasts that the Fed makes (Woodford, 2007). These forecasts are the best available, better than commercial and private forecasts, so the monetary policy decisions that are based on the Fed's forecasts are indicators of the economy's current condition and the path it is likely to assume over the forecasts' span (Romer & Romer, 2000). Therefore, because the Fed takes a great deal of information into account when making monetary policy decisions, I believe that the yield spread is an inclusive and simplistic explanatory variable. The 3-month Treasury bill serves as an instrumental variable for the Fed's monetary policy (as implemented by the Federal Fund's rate). The inclusion of the 10-year Treasury bond instruments for long-term inflation expectations (influenced by short-term monetary policy), and significantly affects the housing industry – a sizeable piece of the investment category in GDP. However, for the sake of fair comparison, the 10-year bond rate that I use has the current quarter's rate of inflation removed from the nominal rate. This is necessary because the model is predicting real GDP, so the spread between short and long-term assets must be adjusted for inflation.

Included in the literature on economic and market forecasts is the recurring conclusion that the yield spread, between different maturities of Treasury debt products, seems to converge at zero**,** and eventually become negative, four quarters prior to periods of negative GDP growth (Stock & Watson, 1989). Stock and Watson found that such yield curve inversions preceded the recessions of 1960, 1973, 1978 and 1981, by one year, with only one false-positive in 1966 (1989, p. 383). For this reason, and those that make this variable concise yet powerful, I utilize it as the sole independent variable in my modeling.

Previous Research and Modeling

Market participants and analysts have long strived to predict future outcomes, given what has already occurred. Though such efforts have been made for centuries, the financial landscape has never stagnated. Therefore, models must be continuously amended; what has worked in the past may not in the future. For this reason, all of the literature I reference is from the post World War II era (post 1946).

James Stock and Mark Watson, the two most prominent authors in the field of economic forecasting research, made progress in developing models and indices that predict a portion of economic cycles. In the oldest piece that I reference, *New Indexes of Coincident and Leading Economic Indicators*, Stock and Watson develop an index comprised of four macroeconomic variables (Industrial Production, Average Personal Income Level, Index of Manufacturing Sales, and Number of Employees on Non-Agricultural payrolls) to predict future cycles (Stock & Watson, 1989). They incorporated these variables because they believe these metrics most quickly and accurately react to any market, policy or political shocks. In the same article, Stock and Watson also found that the yield spread between the ten-year and one-year Treasury bonds converges, and becomes negative, four quarters before the economy officially entered a recession (Stock & Watson, 1989, p. 383).

In their more recent work, Stock and Watson (1992) focus on the *paths* and *patterns* of the economy, preceding economic recessions. This research led them to consider yield spreads more carefully, and examine the effects of different maturity combinations.

Ultimately, they concluded that such yield spreads continue to precede "cyclical peaks," meaning that sometime after such spread conversions the market peaks and begins to decline (Stock & Watson, 1992).

Arturo Estrella and Mary Trubin (2006) provide important perspective in their discussion of the "practical issues" of using interest rate spreads as predictors of future economic activity. Principally, they note that "the lack of a single accepted explanation for the relationship between the yield curve and recessions has led some observers to question whether the yield curve can function practically as a leading indicator" (Estrella & Trubin, 2006, p. 1). Ultimately, without a clear explanation as to why a yield curve inversion *causes* future recessions all that can be proven is mere correlation. Therefore, I present the theories that most clearly explain this relationship.

One of the most widely referenced explanations that postulate causation is that tight monetary policy causes these inversions and subsequent recessions. This is a curious explanation because while it makes sense that tight monetary policy leads to "a rise in short-term rates, typically intended to lead a reduction in inflationary pressure," it also infers that the Fed deems inflation to be a greater threat to the long-term economy than a recession (Estrella & Trubin, 2006, p. 2). One can make this conclusion because if the Fed felt otherwise it would not risk a recession to combat inflation. While it may seem counter-productive that the Fed would be willing to put the economy on a path towards recession, it has good reason to do so. As the Phillips curve illustrates (see next page), when the economy is growing quickly (Aggregate Demand "AD" shifts outward) unemployment rates

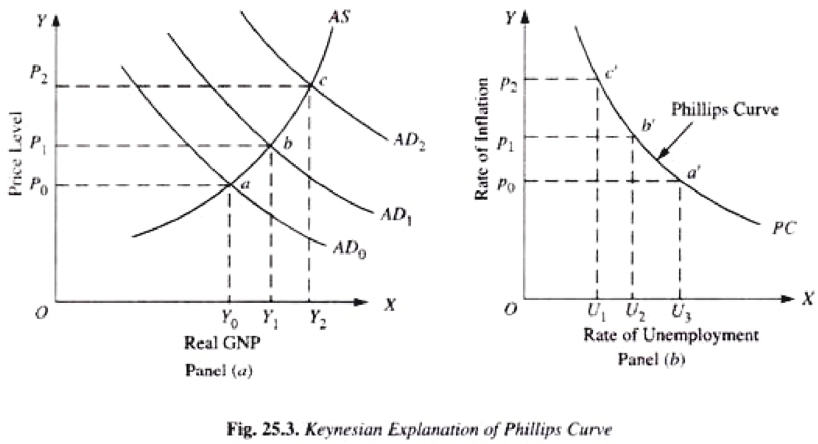

Figure 1 Phillips Curve (Retrieved from YourArticleLibrary.com)

decrease, and the rate of inflation increases. This reduces the purchasing power of workers' wages since wages are "sticky," and pushes the economy towards an unsustainable environment, beyond full employment. Consequently, in these scenarios the Fed takes steps to slow the economy enough to avoid this state. This is most commonly accomplished by enacting tight monetary policies. Therefore, it makes intuitive sense that if the economy is growing too rapidly the Fed will curb the economy by raising short-term interest rates, to reduce near-term spending and investment, even though doing so increases the probability that the economy will become recessionary. However, as history has shown, these measures can be too extreme and cause negative growth. Essentially, this is an attempt to suffer a little now in order to avoid suffering more severely in the future. While other theories reference investor expectations, and clientele preferences as the basis for yield curve inversions and subsequent recessions, I believe the Fed possesses more market-power than the summation of individual expectations and preferences (Estrella & Trubin, 2006).

The Fed also enacts tight-monetary policies in times of high-inflation. The Federal Reserve Reform Act of 1977 made "price stability" a main objective of the Fed's monetary policies (Zhu, 2013). Prior to this Act the Fed's policies were principally tasked with maximizing the economy's growth, but made no mention of controlling inflation. Of relevant consideration is the economic landscape that Paul Volcker, the 12th chairman of the Federal Reserve, faced when President Carter appointed him in 1979 (Boundless, 2014). When Volcker assumed his chairmanship stagflation plagued the economy, with annualized inflation of 10.5%; in 1981 the inflation rate was 13.5% and unemployment rates remained high (~8%). In June 1981, Volcker raised the Federal Funds target rate to 20%, an 8.8% increase from its 1979 levels (Boundless, 2014). These interest rates suppressed the building of new homes and caused GDP growth to become recessionary. However, by 1983, inflation had dropped to 3.2% and unemployment rates had fallen from their 10% highs as well. Therefore, while Volcker understood that tight monetary policies can make the economy recessionary, he also knew that if he did not do so the alternative consequences would be more severe and enduring.

Ben Bernanke, another former Chairman of the Fed (2006 - 2014), writes extensively on the use of yield spreads as leading predictors of economic performance. In a 1990 paper, long before he served the Fed, he concluded that the "Treasury bill spread predicts the economy because it measures the stance of monetary policy, which is an important determinant of future economic activity" (Bernanke, 1990, p. 3). Considering that this conclusion was made by the future Chairman of the Fed, at the time this article was published, one must understand that the Fed is well versed in the potential consequences of monetary policy decisions. Furthermore, Bernanke explains that this spread is a robust indicator of future economic performance, “Because it combines information about monetary and non-monetary factors affecting the economy” (Bernanke, 1990, p. 3).

Comparing models using this method is quite easy; one must only determine which model predicts more *appropriate* probabilities, given each quarter’s actual GDP growth. However, such predicted probabilities cannot be relied upon because preliminary OLS results yield low R-squared values (~0.05). This means that my model explains roughly 5% of the variation in quarterly GDP growth rates, four-quarters in the future. As a result, the most useful data from the PROBIT regressions are the marginal effects coefficients. These coefficients explain what a 1% increase in the yield spread has on the probability that a recession will occur (theorized to be negative).

My model benefits from its simplicity because, as Estrella and Mishkin find, when incorporating explanatory variables “in the out-of-sample context, more is not necessarily better” (1998, p. 2) . In their research they find that, “Liberal inclusion of explanatory variables in the regression will not necessarily help, and frequently hurts, when extrapolating beyond the sample’s end” (1998, p. 2). Therefore, because real-world application would use my model to make predictions about future GDP growth, out-of-sample use is elemental to my model’s usefulness.

Estrella and Mischkin also conclude that the most successful model they test is that which only uses “the spread between the 10-year Treasury note and the 3-month Treasury bill as an explanatory variable” (Estrella & Mishkin, 1998, p. 55). In their PROBIT modeling their R-squared value (0.296) is larger than my model’s (0.1556), and their t-score

Table 1 PROBIT Regression Results

PROBIT Regression Results				
	Est. Coeff.	Std. Dev.	Z-Score	Pseudo R-Sq.
Spread	-0.4785	0.1073	-4.46	0.1556
Alternative Spread	-0.444	0.112	-3.96	0.1177

was higher as well (their -4.99, versus my 4.46) (1998, p. 54). However, their modeling only included data from 1972 to 1995, which likely explains why my model did not perform as well (my data spans from 1961 to Q2 of 2014). As more data points are included in the regression, there is more variation in the following: (1) real, quarterly GDP growth rates, (2) levels of the spread, and (3) the relationship between spread levels and real, quarterly GDP growth rates. This heightened variation over my model's sample period makes it harder for my model to have an R^2 value as high as Estrella and Mishkin's.

James Hamilton and Heon Dong Kim research alternative, predictive models that use explanatory variables such as net oil price increases and decreases (2000). They too test different yield spreads for predictive power, finding that rate spreads, when paired with net changes in oil price, "predict real GDP up to 16 quarters ahead," albeit they explain only a small amount of GDP growth variation. The yield spread on its own produced R^2 = 0.183, with no statistical significance (with data from 1959 – 1983), and the inclusion of these price changes marginally increased the model's R^2 value to 0.19 (Hamilton & Kim, 2000, p.35). As a result, I tested whether or not the incorporation of the net change in oil prices would increase my model's R-Squared value (R^2 value was roughly doubled to .106, but all statistical significance was lost since the t-score = -1.14).

Nathan Powell raises another important consideration regarding causation in his finding that "narrowing or flattening, of the spread has tended to foretell both slower economic growth and increased pressure on bank earnings" (2006, p. 2). This details an oftentimes-overlooked consequence of tight monetary policy that may catalyze future economic recessions. Powell adds that, "the largest banks have seen their margins squeezed substantially," which diminishes supply of capital and curbs potential investment (Powell, 2006, p. 2). Furthermore, Powell explains that an increase in the short-term treasury rate can push long-term rates downward. Specifically, since the rate of inflation must be priced into the "term premium…investors require an inflation premium in the form of higher long-term rates," tight monetary policy reduces inflation and minimizes expectations. Thus, this reduces the "term premium" on long-term investments, which subsequently lowers the interest rate (Powell, 2006, p. 2). Therefore, because tight monetary policy raises short-term interest rates to combat inflation, long-term rates cannot rise as quickly as short-term rates are manipulated, and thus the spread narrows or becomes negative.

The effect of such predictions is the final aspect of forecasting worthy of discussion. Most importantly, if a forecast predicts a market meltdown how should one publish these predictions? If the Fed reports a prediction of a major market meltdown in the 12-month horizon, the economy will more than likely meltdown the very second that the report is published. Victor Zarnowitz refers to this reaction as the "feedback effect," and considers the best ways to publish such forecasts (1972, p. 234). Countries such as Holland, Sweden and France have banks that produce "highly authoritative and influential forecasts," but alongside such forecasts they carefully outline a clear set of steps that, if followed by the public and private sectors, will allow their economy to avoid the predicted outcomes (Zarnowitz, 1972, p. 236). Finally, if central banks such as the ones mentioned here can forecast such events, it is imperative to posit the question whether or not they have the power to avoid such crashes. Furthermore, even if avoiding such recessions is possible, is it best to do so? To answer this one must decide whether submission to rising inflation rates, in the long-run, is more damning than a temporary recession, which is what the Fed concluded. I believe unchecked inflation rates are worse then temporary recessions, and this is why the Federal Reserve willingly risks recessions when reducing these rates, just as Volcker did.

Theoretical Explanation

With the birth of complex global markets, the pursuit of creating financial models to predict future market performance began. Countless econometricians look at different economic variables and composite indices of leading indicators for predictive power. Initial research on leading economic variables and indices suggests that there is no consensus on which models most accurately and precisely forecast future market performance. Therefore, to provide some clarity in the yield spread arena, I compare the predictive abilities of the 3-month Treasury Bill and 10-year Treasury Bond (Spread) and the 1 and 10-year spread (AltSpread).

$$(GDP_t = Spread_{t-4} + \varepsilon)$$

$$(GDP_t = AltSpread_{t-4} + \varepsilon)$$

The theory behind using the 3-month Treasury bill as the short-term interest component in my model is that it reflects Fed policy decisions as well as market sentiments and momentums. While the Federal Fund's Rate is the primary instrument of Federal Reserve monetary policy decisions, using this as a variable ignores market participants' perceptions and reactions to such decisions. The Federal Fund's rate is an extremely short-term interest rate because it is the overnight rate at which the Fed will loan capital to banks such that they meet reserve requirements. Therefore, because the 3-month Treasury bill is the shortest-term debt issuance, closest in maturity to the Federal Fund's rate, its interest rate most closely reflects the Federal Fund's rate. Furthermore, while the Fed sets the Federal Fund's rate, the 3-month Treasury bill also reflects market forces of supply and demand (Stanton, 2000). Consequently, the 3-month Treasury bill is a better short-term instrument of Fed policy than the 1-year Bond rate because: (1) it is quicker to reflect movements of the Federal Fund's rate, (2) is only concerned with nearer-term economic movements, and (3) is more susceptible to supply and demand forces, since it competes in the money markets against other short-term debt instruments.

Most yield spreads use the 10-year bond rate for several reasons. In predicting GDP performance, the 10-year bond rate influences investment levels. One of the largest investments that an individual or family makes is the building or purchase of a home (capital equipment in the context of businesses). To finance this transaction nearly all individuals and families take out mortgages. The rates on such mortgages, which are usually of 30-year maturities, influence both the quantity and value of mortgages demanded.

Mortgage rates are highly correlated with the 10-year Treasury bond rate because mortgages are packaged as debt instruments that must compete with the Fed's debt vehicles. It may seem counterintuitive that a 30-year mortgage rate competes with that of the 10-year Treasury bond; the reason is that, on average, 30-year mortgages mature or close after seven years (Plaehn, N.D.). Therefore, because mortgages must compete with the Fed's debt instruments, and mortgages are usually close before their 10-year anniversary, mortgage rates closely mirror the rates of the 10-year Treasury bond.

Aside from home-purchasers and builders, mortgage rates also affect the investment and consumption decisions of current homeowners. High mortgage rates discourage potential homebuyers, causes homebuilders to take out smaller mortgages, and the housing industry slows (Amadeo, N.D.). As a result, home prices fall; homeowners have less equity in their homes and feel poorer, causing individuals to reduce their consumption and delay potential investments. The 10-year Treasury bond rate is almost always used as the long-term rate in spreads because of its affect on mortgage rates and the ripple effects that the housing industry has on individuals' consumption and investment levels. Furthermore, this explains why a narrowing or inverted spread is predominantly attributed to rising short-term rates, not falling long-term rates. If rates on the 10-year bond fell dramatically the housing industry would improve, people would consume more because they would *feel* richer and GDP growth levels would be lifted, making a recession less likely to occur. However, when long-term rates increase and short-term rates do so more rapidly, and actually exceed long-term rates, this suppresses the housing industry (long-term *investment* decreases) and short-term *consumption* falls, pushing GDP growth rates downwards. The over-arching theory behind why spreads – the difference between interest rates on long and short-term assets – predict future GDP performance is that they instrument for short-term policies as well as long-term expectations.

It is important to consider what I am asking my model to predict, and how the right side of the equation, the spreads, produces these predictions. In attempting to determine real GDP by differencing the short-term Treasury bill rate and the long-term Treasury bond rate one must control for inflation on both sides. Essentially, because real GDP accounts for inflation, it does not make economic sense to predict real GDP with the nominal 10-year rate because inflationary expectations are incorporated. Therefore, to control for inflation and to produce the fairest comparison possible, we subtract the inflation rate for the current quarter from the 10-year rate to produce the real 10-year rate ($Real10YRRate_t$ = $NominalRate_t - InflationRate_t$). The 3-month Treasury bill, however, is too short-term to incorporate inflation expectations, so the 3-month rate is already a real rate. Inflation is realized on an annual basis, so the 1-year rate does incorporate inflationary expectations. However, because both the 1-year and 10-year rates are subject to such expectations, subtracting the rate of inflation from each would not affect this spread's levels. Therefore, this nominal spread's values still reflect the *difference* between real returns on 1-year and 10-year debt instruments.

Valid comparison of the coefficients and R-Squared values of each model is made possible by the spreads being regressed over the same sample period. The model with the highest R-Squared value is the better spread, which is why I conclude that my spread (marginally) outperforms the alternative spread (Spread: R^2 = 0.0507, AltSpread: R^2 = 0.0281). Further comparison of PROBIT results and marginal effects data prove my spread to be slightly more predictive than the alternative spread.

Both models' regressions spanned from Quarter 4 of 1961 through Quarter 2 of 2014. This time period provides ample data on the relationship between the yield spreads and

Table 2 Summary Statistics of Predicted Probabilities of Recession

Summary Statistics of Predicted Probabilities of Recession				
	Mean	**Std. Dev.**	**Min.**	**Max.**
Spread	0.121	0.1126	0.0072	0.5235
Alternative Spread	0.1208	0.0962	0.0089	0.4942

GDP growth rates; during this period there were 25 recessionary quarters, out of the sample's 211 quarters (11.85%). However, this means that these models' predicted probabilities for quarters of negative growth are greatly biased downwards; since 88.15% (186 quarters) of the observations reported positive growth rates during this time, the probability that any quarter posts negative growth is extremely low (Maximum probabilities of negative growth: Spread = 52.35%, AltSpread = 49.42% -- see Table 2). Again, note that the mean predicted probabilities (~ 12.1%) are very close to the period's actual prevalence of recessionary quarters (11.85%). This is also observed in Table 3; while each spread predicts the correct *average* growth over the entire sample period, it fails to capture *any* quarters with negative growth because the minimum predicted growth rates from both spreads is positive.

Table 3 Descriptive Statistics of Predicted Quarterly GDP Growth Rates

Descriptive Statistics of Predicted Quarterly GDP Growth Rates				
	Mean	Std. Dev.	Min.	Max.
Spread	0.756	0.189	0.303	1.1
Alternative Spread	0.756	0.14	0.397	1.048
Historic GDP Growth	0.762	0.835	-2.11	3.887

Model Procedure

Each model regresses over the sample period against the "recession" dummy-variable (recession = 1, no recession = 0). However, in doing so it is important to note that, "Because in any given quarter the probability of recession is quite low, a forecasted probability of, say, 50 percent is going to be quite unusual" (Estrella & Mischkin, 1996, p.4). Therefore, while it is important to note the marginal effects that a one percent change in the yield spread has on the probability of a recession occurring (see Table 5 on next page), the PROBIT coefficients are difficult to understand because a 10% marginal increase/decrease cannot be interpreted on a normal probability, 0-100%, distribution scale.

Table 4 Summary Statistics of Predicted Probabilities of Recession

Summary Statistics of Predicted Probabilities of Recession				
	Mean	Std. Dev.	Min.	Max.
Spread	0.121	0.1126	0.0072	0.5235
Alternative Spread	0.1208	0.0962	0.0089	0.4942

Table 5 Marginal Effect that a 1% Increase in the Spread has on Probability of Recession

Marginal Effects: "PROBIT Recession (Variable)" - All Available Data						
Variable (Lag)	Coefficient	Std. Error	T-Stat	P-Value	95% Confidence Int.	
Spread (4Q)	-0.0749243**	0.01593	-4.7	0.00	-.10615	-0.043699
Alt. Spread (4Q)	-0.0746195**	0.01779	-4.2	0.00	-0.109481	-0.039758

The coefficients in Table 5 cannot be interpreted on a normal distribution scale but Table 4's distributions give valuable context. Given the distributions described in Table 4, one can conclude that because a 1% increase in the spread reduces the probability of a recessionary quarter by roughly 7.5%, and predicted probabilities of recessions ranged between 0.7% and 52.35%, that a 7.5% marginal effect is significant.

Each model also regresses against actual GDP growth levels to produce coefficient estimates and levels of significance. This data explains how a one-percent increase in each spread affects predicted quarterly GDP growth rates, as Table 6 shows.

Table 6 OLS Regression Results

OLS: "Regress GDP Growth Rate (Variable), Robust" - All Available Data							
Variable (Lag)	Coefficient	Rbst. Std. Error	T-Stat	P-Value	95% Confidence Int.		R-Squared
Spread (4Q)	-0.1522088**	0.0522383	2.91	0.00	0.0492156	0.255202	0.0507
Alt. Spread (4Q)	-0.1227713*	0.0546243	2.25	0.02	0.0150739	0.8186679	0.0281

**Significance at 99%, *Significance at 95%

While the coefficients are statistically significant, because the R-squared values are low (.05 and .028) these models cannot be solely relied upon to predict future GDP growth rates. These low R-Squared values mean that predicted GDP growth rates are densely clustered around the mean, because the models can only explain a small portion of the variation in these values.

Data Discussion

The origins of my data provide exceptional validity and reliability. All of my treasury data sources from the St. Louis Federal Reserve's online database. This database's credibility eliminates any concerns of accuracy, validity or reporting consistency. The U.S. Energy Information Administration, a similarly credible source, provides the oil price data that is used to calculate the net percentage price change per barrel. Therefore, the data used in this modeling is dependable and available for replication.

Table 7 provides the descriptive statistics for all the variables referenced in my modeling. Most importantly, observe the statistics for real, quarterly GDP growth rates; given that the standard deviation is larger than the mean, it is apparent that quarterly GDP growth rate fluctuations are dramatic when compared to the sample's average rates.

Table 7 Variables' Descriptive Statistics (Retrieved from St. Louis Federal Reserve Database)

Total Sample Period: Q1 of 1961 through Q2 of 2014					
Variable	**Observations**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
GDP Growth, as a Percentage	211	0.7626	0.8356	-2.1126	3.8879
3-Month Treasury Bill Interest Rate	211	6.2471	2.9758	0.92	15.05
1-Year Treasury Bond Interest Rate	211	5.4853	3.304	0.1	16.31
10-Year Treasury Bond Interst Rate	211	6.5034	2.753	1.64	14.84
Spread (10-Year - 3-Month)	211	1.5347	1.2399	-1.4677	3.7726
Alternative Spread (10-Year - 1-Year)	211	1.0181	1.1549	-1.94	3.36

Results and Modeling

In running PROBIT regressions between the recession dummy-variable (recession = 1, no recession = 0) and the two yield spreads, the marginal effects of a 1% increase in each yield spread on the probability of a recession occurring are significant (see Table 8).

Table 8 Marginal Effects of 1% Increase in Spread on Predicted Probability of Recession

Marginal Effects: "PROBIT Recession (Variable)" - All Available Data						
Variable (Lag)	**Coefficient**	**Std. Error**	**T-Stat**	**P-Value**	**95% Confidence Int.**	
Spread (4Q)	-0.0749243**	0.01593	-4.7	0.00	-.10615	-0.043699
Alt. Spread (4Q)	-0.0746195**	0.01779	-4.2	0.00	-0.109481	-0.039758

**Significance at 99%

In the instance of the 10-year, 3-month spread a 1% increase reduced the probability of a recession by 7.49% at the 99% confidence level (z-score = -4.7). Additionally, the 10-year, 1-year spread reduced the probability of a recession by 7.46% at the 99% confidence level (z-score=-4.2). In the context of my model, narrowing spreads in 1% increments, the opposite is true in that the probability of a recession increases by the same amount when each spread decreases by 1%. These coefficients and z-scores qualify my spread to be better than the alternative spread. My spread's coefficient is larger, albeit marginally, and its z-scores are stronger, so it produces greater marginal variations in its predicted probabilities and with greater confidence too.

However, again it is important to realize that such percentages cannot be interpreted as they would on a normally distributed, 0-100% scale. The predicted probabilities do not assume a normal distribution. The mean predicted probability, over the entire sample, is 12.1% with a standard deviation of 11.2%, so less than 1% of the predicted probabilities exceed 45% (three standard deviations above the mean), and because one cannot have a negative probability, the minimum probability is asymptotically bounded to 0% (see Table 4). Given this model's obscure distribution scale, if interpreted on a 0-100%, normal distribution scale the marginal effects coefficients would be more than doubled, because 99% of the predicted probabilities are below 45%, as opposed to 45% of the predicted probabilities being below the 45% level. Nevertheless, these results prove that as either yield spread narrows, the probability of a recession, four quarters in the future, increases.

The standard OLS regression yielded similarly significant results for each yield spread and its affect on GDP growth levels (see Table 4). A 1% increase in the 10-year, 3-month spread produced a .1522% increase in GDP growth at the 99% significance level.

Table 9 OLS Regression Results of Quarterly GDP Growth Rates and Yield Spreads

OLS: "Regress GDP Growth Rate (Variable), Robust" - All Available Data							
Variable (Lag)	Coefficient	Rbst. Std. Error	T-Stat	P-Value	95% Confidence Int.		R-Squared
Spread (4Q)	-0.1522088**	0.0522383	2.91	0.00	0.0492156	0.255202	0.0507
Alt. Spread (4Q)	-0.1227713*	0.0546243	2.25	0.02	0.0150739	0.8186679	0.0281

**Significance at 99%, *Significance at 95%

While this may appear to be a negligible affect, one must note that GDP is an incredibly enormous variable that is affected by countless inputs in very complex manners, making a .1522% increase in GDP growth that is attributable to this yield spread noteworthy. Furthermore, because GDP growth per quarter averages .762% over the entire sample (see Table 10), the estimated coefficient suggests that a 1% increase in this spread produces, on average, a 20% increase in quarterly GDP growth rates. However, it is also important to note that the R-Squared value for this regression is an abysmal 0.05, suggesting that while this spread has a statistically significant affect on GDP growth rates, it can only account for 5% of the variation in growth rates. As I explain in my conclusion, this presents serious issues when attempting to predict actual GDP growth rates. The 10-year, 1-year spread produces a slightly smaller coefficient estimate, at a slightly lower level of confidence (95%). A 1% increase in this spread caused, on average, a .1227% increase in GDP growth levels. Again, while this may seem like a small difference it is actually over a 16% change

Table 10 Descriptive Statistics of Predicted Quarterly Real GDP Growth Rates

Descriptive Statistics of Predicted Quarterly GDP Growth Rates				
	Mean	Std. Dev.	Min.	Max.
Spread	0.756	0.189	0.303	1.1
Alternative Spread	0.756	0.14	0.397	1.048
Historic GDP Growth	0.762	0.835	-2.11	3.887

in the average GDP growth rate. But, again one must note the extremely low R-Squared value of 2.8% here.

When using these models to predict GDP growth rates the consequences of the models' low R-Squared values became evident. After regressing the two-spreads against GDP growth rates, separately, and having each predict GDP growth levels throughout the sample, it became apparent that such predictions are accurate across the entire sample, but not on a quarter-by-quarter basis (see Table 10, above). This means that while the average of the predicted values (made by the 10-year, 3-month spread) for the whole sample (.756%) is extremely close to the overall average quarterly GDP growth rates for the period (.762%), these predicted values densely cluster around the period's mean. The standard deviations for the predicted values and actual values are 0.189 and 0.835, respectively. The disparity in each dataset's variability is to be expected because my model's predictions minimize the sum of squared errors, and while it is correct *on average*, it is not accurate on a quarter-by-quarter basis (illustrated on the following page by actual GDP growth rate's variability far exceeding the variability of predicted GDP growth rates, in Figure 2).

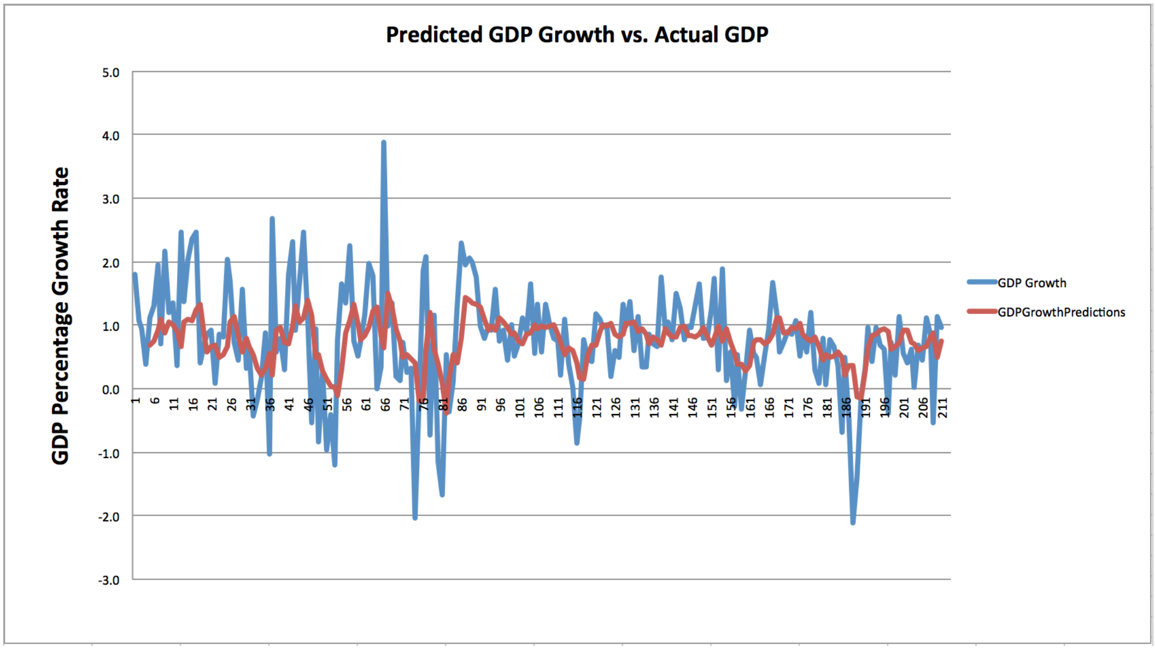

Figure 2 Predicted vs. Actual Quarterly GDP Growth Rates

Therefore, while the yield spread may have a statistically significant affect on GDP growth rates overall, it explains so little of the variation in these growth rates that using it alone produces predicted values that do not accurately represent quarter-by-quarter rates. This is the unfortunate limitation of using models that have so little predictive power to predict quarterly GDP growth rates.

In pursuit of producing a model that could potentially improve the yield spread's predictive power (R-Squared value) I posit that the yield spread controls for monetary policy, which affects the money supply and any shocks to such. Therefore, the other half of the puzzle, that could potentially improve predictive power, should instrument for fiscal policy, or more specifically, real shocks to the economy that are not orchestrated by the Fed. As a result, because net price changes in barrels of oil, on a percentage basis, have been offered as a leading indicator of GDP performance and instruments for real shocks to the economy, I included a dummy-variable called *OilShock*. In any instance where the price of oil per barrel increased by more than 20% from the previous quarter a 1 is coded. When we add this dummy-variable to the model's equation ($GDP_t = \beta_1 SPREAD_{t-4} + \beta_2 OilShock_t + \varepsilon$) the predictive power of the model roughly doubles, producing an R-Squared value of .106. However, the Oil Shock's coefficient (-0.264) is insignificant (t-score = -1.14), so this increase in predictive power may simply be the product of overfitting from adding another explanatory variable. Therefore, while the addition of Oil Shocks as an instrument for fiscal policy shocks improves the predictive power of the model, the model cannot be relied upon given its lack of statistical insignificance.

Significance of Results and Conclusions

While the yield spread, specifically the maturity that I champion (10-year, 3-month with inflation subtracted from the 10-year rate), did not prove its ablity to predict future GDP growth rates, it still provided a statistically significant explanation for *part* of GDP performance. Therefore, while it is ill advised to rely solely upon the predictions provided by my yield spread, it still provides useful information about which variables should be considered for inclusion in predictive models.

GDP is a complex statistic that is affected by any number of factors in sophisticated manners, so to be able to accurately predict GDP growth rates one must instrument for as many different parts of GDP as possible. While my interest rate spread reflects the real difference (unaffected by expected inflation rates) between short and long-term returns on capital, which presents valid information about the housing industry, capital investment and monetary policy, these only describe the investment portion of GDP. Therefore, this spread fails to instrument for the consumption, government spending, and net exports portion of GDP. As a result, because consumption alone accounts for roughly two-thirds of GDP, this model can only predict a small portion of the variation in GDP growth rates.

In constructing a model that accounts for a reliable amount of variation in growth rates, one must include variables that instrument for consumption, government spending and net exports. However, that is not to claim that either yield spread fully accounts for the investment portion of GDP. Of course, selecting the proper combination of variables, with the proper lags and manipulations (logged, squared, etc.) is incredibly difficult. Furthermore, even if the proper combination and manipulation were discovered, the structure of the economy is constantly changing, making every model subject to the challenge of appropriately evolving *with* the economy to accommodate such developments. This explains why, despite the countless efforts and model permutations econometricians have made, a robustly predictive model has yet to be discovered.

The application of my results is that the yield spread is, at the very least, a piece of the puzzle – a variable that explains *some* of the variation in GDP growth rates. This conclusion can assist others as they decide which variables contain predictive power and instrument for portions of GDP. Ultimately, while my yield spread's simplicity did not advantage its predictive power, as I had hoped, its statistically significant (at the 99% confidence level) 5% explanation of variation in GDP growth rates benefits the GDP forecasting arena. While it cannot be assumed that my spread's coefficient, statistical significance or explanatory power would remain unchanged, when used in conjunction with other variables, it proved itself worthy of consideration in constructing predictive models.

Additionally, the yield spread can still produce marginal probabilities that a recession will occur. This means that while the yield spread cannot accurately predict the probability of a recession occurring, one can conclude that the probability of recession is reduced/increased when the spread is widening/narrowing. This allows business managers and individuals to conclude that if the yield spread increases relative to the previous quarter, then the economic outlook four-quarters in the future is favorable because the reduced probability of a recession.

Bibliographic Citations

Amadeo, K. (n.d.). What Is the Relationship Between Treasury Notes and Mortgage Rates? Retrieved December 5, 2014.

Arestis, P., & Karakitsos, E. (2014). How Might the U.S. "Quantitative Easing" Develop? *Challenge, 57*(1), 5-19.

Ang, A., Piazzesi, M., & Wei, M. (2006). What Does the Yield Curve Tell us about GDP Growth? *National Bureau of Economic Research,* 359-403. Retrieved October 17, 2014, from http://www.nber.org/papers/w10672

Auerbach, A. (1982). The Index of Leading Indicators: "Measurement without Theory," Twenty-Five Years Later. *National Bureau of Economic Research, 64*(4), 589-595. Retrieved October 17, 2014, from http://www.nber.org/papers/w0761

Boundless. "Volcker Disinflation." Boundless Economics. Boundless, 03 Jul. 2014. Retrieved 18 Dec. 2014 from https://www.boundless.com/economics/textbooks/boundless-economics-textbook/monetary-policy-28/historic-federal-reserve-policy-120/volcker-disinflation-475-12571/

Bernanke, B. (1990). On the Predictive Power of Interest Rates and Interest Rate Spreads. *National Bureau of Economic Research,* 51-68. Retrieved October 17, 2014, from http://www.nber.org/papers/w3486

Chen, J., Hong, H., & Stein, J. (2000). Forecasting Crashes: Trading Volume, Past Returns and Conditional Skewness in Stock Prices. *National Bureau of Economic Research,* 1-49. Retrieved October 1, 2014, from http://www.nber.org/papers/w7687

Estrella, A., & Trubin, M. (2006). The Yield Curve as a Leading Indicator: Some Practical Issues. *Federal Reserve Bank of New York, 12*(5), 1-7.

Estrella, A., & Mishkin, F. (1998). Predicting U.S. Recessions: Financial Variables as Leading Indicators. *Review of Economics and Statistics,80*(1), 45-61. Retrieved October 17, 2014, from http://www.nber.org/papers/w5379

Fair, R. (2001). Actual Federal Reserve Policy Behavior and Interest Rate Rules. *FRBNY Economic Policy Review,* 61-72. Retrieved October 1, 2014, from http://www.nber.org/chapters/c1829

Fair, R. (2000). Fed Policy and the Effects of a Stock Market Crash on the Economy. *Yale Business Economics,* 7-14.

Friedman, B., & Kuttner, K. (1993). Why Does the Paper-Bill Spread Predict Real Economic Activity? *National Bureau of Economic Research,* 213-254. Retrieved October 17, 2014, from http://www.nber.org/chapters/c7193

Gertlet, M., & Lown, C. (2000). The Information in the High Yield Bond Spread for the Business Cycle: Evidence and Some Implications.*National Bureau of Economic Research,* 132-150. Retrieved October 17, 2014, from http://www.nber.org/papers/w7549

Hamilton, J., & Kim, D. (2000). A Re-Examination of the Predictability of Economic Activity Using the Yield Spread. *National Bureau of Economic Research,* 1-36.

Leamer, E. (2001). The Life cycles of US Economic Expansions.*National Bureau of Economic Research,* 1-45. Retrieved October 17, 2014, from http://www.nber.org/papers/w8192

Mincer, J., & Zarnowitz, V. (1969). Economic Forecasts and Expectations: Analysis of Forecasting Behavior and Performance. *National Bureau of Economic Research,* 1-46. Retrieved October 1, 2014, from http://www.nber.org/chapters/c1214

Muller, U., & Stock, J. (2011). Forecasts in a Slightly Misspecified Finite Order. *National Bureau of Economic Research,* 1-52. Retrieved October 1, 2014, from http://www.nber.org/papers/16714

Plaehn, T. (n.d.). Why Are Mortgage Rates Correlated with the Yield on Long-Term Treasury Bonds? Retrieved December 5, 2014.

Powell, N. (2006, February 22). What the Yield Curve Does (and Doesn't) Tell Us. Retrieved October 17, 2014.

Romer, C., & Romer, D. (2000). Federal Reserve Information and the Behavior of Interest Rates. *The American Economic Review,* 429-457.

Rudebusch, G., & Williams, J. (2008). Forecasting Recessions: The Puzzle of the Enduring Power of the Yield Curve. *Federal Reserve Bank of San Francisco Working Paper Series,* (2007-16), 1-21.

Stanton, E. (2000, November 3). How Does the Fed Funds Rate Affect Treasury Bills? Retrieved December 5, 2014.

Stock, J., & Onatski, A. (2000). Robust Monetary Policy Under Model Uncertainty In a Small Model of the U.S. Economy. *National Bureau of Economic Research,* 1-44. Retrieved October 1, 2014, from http://www.nber.org/papers/w7490

Stock, J., & Watson, M. (1992). A Procedure for Predicting Recessions with Leading Indicators: Econometric Issues and Recent Experience. *National Bureau of Economic Research,* 1-81.

Stock, J., & Watson, M. (1998). Business Cycle Fluctuations in U.S. Macroeconomic Time Series. *National Bureau of Economic Research,* 1-83. Retrieved October 1, 2014, from http://www.nber.org/papers/w6528

Stock, J., & Watson, M. (1993). Business Cycles, Indicators and Forecasting. *National Bureau of Economic Research,* 1-10. Retrieved October 1, 2014, from http://www.nber.org/books/stoc93-1

Stock, J., & Watson, M. (2012). Disentangling the Channels of the 2007-2009 Recession. *National Bureau of Economic Research,* 1-55. Retrieved October 1, 2014, from http://www.nber.org/papers/w18094

Stock, J., & Watson, M. (1989). New Indexes of Coincident and Leading Economic Indicators. *National Bureau of Economic Research,* 351-409. Retrieved October 1, 2014, from http://www.nber.org/chapters/c10968

Tutor2u. "The Phillips Curve." Tutor2u Economics. Tutor2u, 03 Jul. 2014. Retrieved 03 Feb. 2015 from http://tutor2u.net/economics/revision-notes/a2-macro-phillips-curve.html

US Business Cycle Expansions and Contractions. (2010). *National Bureau of Economic Research*. Retrieved October 17, 2014, from http://www.nber.org/cycles.html

Woodford, M. (2007). Forecast Targeting as a Monetary Policy Strategy: Policy Rules in Practice. *National Bureau of Economic Research,* 1-52. Retrieved October 1, 2014, from http://www.nber.org/papers/w13716

Zarnowitz, V. (1972). Forecasting Economic Conditions: The Record And The Prospect. *Economic Research: Retrospect and Prospect: The Business Cycle Today, 1*, 183-240. Retrieved October 1, 2014, from http://www.nber.org/chapters/c4397

Zhu, J. (2013). Federal Reserve Reform Act of 1977. *Federal Reserve History,* 1-2.