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Yield Curve Theories and Their Applications Over Time

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Abstract

Introduction

Chapter I: Introduction to Yield Curve Theories and Terminology

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Abstract:

This thesis will analyze three theories that can explain the term structure of interest rates: The Unbiased Expectations Theory, the Duration Premium Theory, and Market Segmentation Theory. The paper will analyze what factors and expectations drive these theories, and how the Federal Reserve has shaped monetary policy within the context of these theories, from Paul A. Volcker to Jerome H. Powell. The paper will also analyze what narratives set out by the Federal Reserve, and their explanations of the yield curve/interest rate behavior through speeches delivered by the Fed Chairman and other Federal Reserve Governors.

Introduction:

This paper will cover three term structure of interest rate theories and how we can apply them over time to explain the behavior of interest rates. The Unbiased Expectations Theory, Duration Premium Theory, and Market Segmentation Theory, will be the three theories analyzed. The ways in which these theories explain the term structure of interest rates will be discussed as well as how monetary policy can influence the yield curve. Monetary policy and the Federal Reserve play a key role in this thesis as the narratives of the Federal Reserve will be analyzed over the timeline of Fed Chairman overtime (Paul A. Volcker - Jerome H. Powell).

Chapter I will focus on explaining the yield curve, its shape, and why it is important. In addition, Chapter I will cover the role of the Federal Reserve and why it plays an important role in determining the term structure of interest rates; the tools that the Federal Reserve has in order to carry out effective monetary policy are paramount to the story of how investors anticipate and analyze the yield curve, as the Fed is the main figure when it comes to interest rates.

Next, the basics of how fixed income securities are priced will be discussed, as it is important for how investors value these debt instruments. Lastly, Chapter I will end with the Unbiased Expectations Theory (UET), the Duration Premium Theory (DPT), and Market Segmentation Theory (MST). These theories will all be explained in Chapter I, but will be analyzed and put into context in Chapter II, where we will be able to see how to use these theories under different Fed Chairman to interpret the term structure of interest rates under different scenarios for investor expectations.

Moving into Chapter II, focus will shift from the fundamentals of the term structure of interest rates to a historical analysis of the yield curve under a variety of Federal Reserve Chairman, ranging from Paul A. Volcker (1979-1987) to Jerome H. Powell (2018-current). The historical analysis will cover the challenges that have been presented to each Federal Reserve regime.

1.1 Term Structure of Interest Rates

When we think about interest rates, we must consider them from the perspective of the lender and the borrower and their expectations, without ignoring the feedback between the market and the role played by the Federal Reserve policy makers in attempting to control those expectations. From the perspective of the lender, interest rates provide a measure of return on the principle being extended to the borrower. If we know this, then we can say that the interest rate is a method of quantifying a borrower's riskiness by lenders. On the other side of a trade, we assume the opposite to be true for the borrower, as they will seek the lowest interest rate in order to achieve the lowest cost of capital available. Economists use diagrams displaying interest rates across different terms to

maturity for a single issuer in an instant of time; this is called a yield curve. Typically the standard yield curve reports on the rates of United States Treasury bills and bonds. Banks as well as other lending institutions use the Treasury yield curve as their point of reference for pricing their own lending rates, such as mortgage rates, business loans, certificates of deposit, etc.

In terms of the different shapes that yield curve may exhibit at any time, they are closely tied to the market's (lenders' and borrowers') expectations for future short term rates. Given this baseline, the "normal yield curve" is a situation in which Treasuries with longer terms to maturity such as a 10 or 30 year securities have a higher yield than securities with shorter terms to maturity such as the 3 month or two year. This is considered a normal yield curve and could be explained by investors demanding a higher yield on bonds with longer maturities than shorter maturities due to the risk associated with a longer investment horizon (later on we shall describe this as the duration premium). In the case of an inverted yield curve, bonds with shorter terms are linked with higher yields than that of longer term bonds. This occurs despite the positive duration premium, and could be due to the expectation for the short term rate to fall in the future. Lastly we can consider a flat yield curve in which the yields of all bonds, both long term and short term, are similar to each other or almost equal. Interestingly, we shall see that a flat yield curve infers that the market expects short term interest rates to fall. Beneath is a more in depth perspective on these shapes of the yield curve - normal, flat, and inverted.

1.2 Yield Curve Slope

In looking at the figures below (1.1a-1.1c), we can note maturity or more specifically the length to maturity for each of the different investment products that are being portrayed on the horizontal axis. On the vertical axis we observe constant maturity rates, and on the horizontal axis each bonds length of maturity. In a normal situation where we would be observing an upward sloping yield curve as in the case of figure (1.1.a), we can see that as we move along left to right we will be recognizing a positive relationship between maturity and yield. This relationship is an upward sloping yield curve or in other words a positive correlation between yield and maturity of debt. In the case of a flat yield curve as seen in figure (1.1.b),

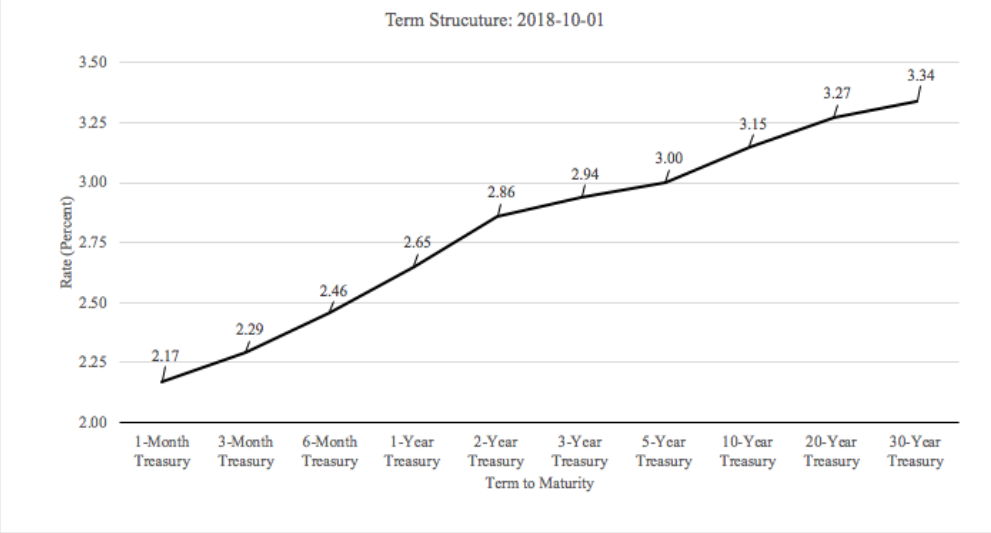

Figure 1.1.a - (Data from Figures 1.1.a-1.1.c provided by https://fred.stlouisfed.org)

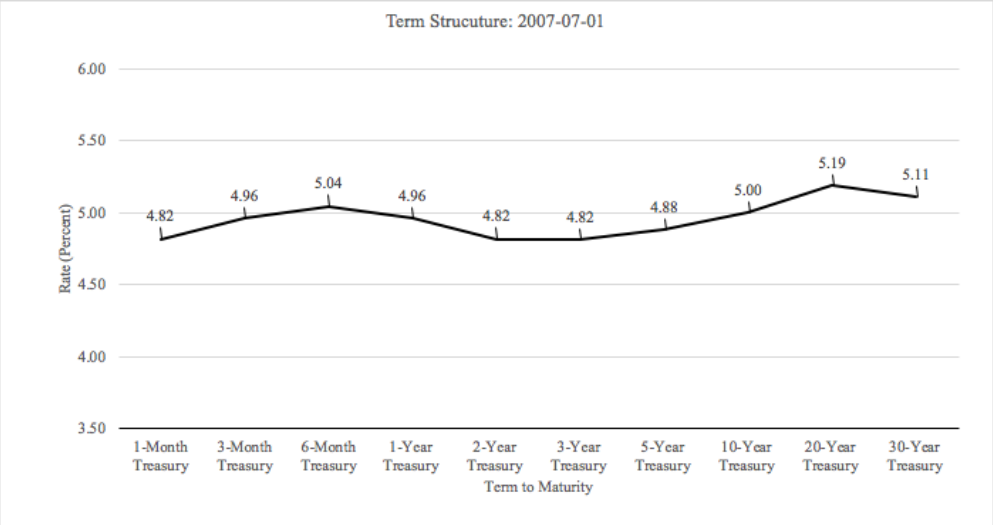

Figure 1.1.b

Figure 1.1.c

we can see that regardless of the length of maturity investors will be looking at the similar yields. Last is the event of an inverted yield curve or a downward sloping yield curve represented by figure (1.1.c). In the case of downward sloping yield curves, we are observing a situation in which products with longer lengths to maturity are offering lower yields.

The shape of the yield curve has long been associated with conversations regarding economic health, impending recessions, among other topics. There are many theories regarding the power of the yield curve to act as an indicator for future economic conditions. This paper will focus more on an historical account of the Federal Reserve's approach to monetary policy under different chairmen from Paul Volker to Jerome Powell, so that we can evaluate the ways in which investors have used the Unbiased Expectations Theory, Duration Premium Theory, and the Market Segmentation Theory in response to different forms of monetary policies in a variety of economic and financial environments.

1.3 Role of the Federal Reserve

The Federal Reserve is the Central Bank of the United States and its board serves the United States federal government while its regional Federal Reserve Banks are private corporations serving regional banks. The Federal Reserve (the Fed) is best thought of as an independent institution (although overseen by congress). The Fed has national responsibilities including but not limited to executing monetary policy, keeping the financial system stable and efficient, and providing liquidity to markets when necessary. The latter of the responsibilities of the Fed, providing liquidity to banks, is why the Fed is traditionally known as the lender of last resort to banks. This traditional role was expanded following the Great Financial Crisis of 2008-09 as the Federal Reserve became the lender of last resort to various markets e.g. the commercial paper market. In an emergency situation the Fed is able to provide significant liquidity to banks or other market participants. The Fed is able to do this by buying U.S. Treasuries from investors when bond market liquidity dries up. (Marc Labonte, Congressional Research Service, 2020,

pg.1) When considering the Fed's responsibility of monetary policy, there are certain goals which the Fed attempts to achieve when instituting monetary policy; some of these goals include "maximum employment, stable prices, and moderate long-term interest rates." (Congress Reform Act, Public Law 95-188 95th Congress, 91 STAT. 1387, November 16, 1977). The Fed targets unemployment and we will see in Chapter II how the Central Bank and FOMC use monetary policy in order to meet their employment goals, which are subject to change and informed by current economic conditions. The Federal Reserve also targets price stability as seen in the case of Alan Greenspan. Currently, the Fed's goal for price stability as of 2019-2020, is achieving and maintaining an inflation rate of roughly 2%; "In 1996, Fed policymakers privately agreed that their target for inflation was 2 percent, but, at Greenspan's insistence, they didn't tell anyone. In 2012, at the urging of then-Chair Ben Bernanke, the Fed formally and publicly announced that they were targeting a 2 percent inflation rate" (Summers and Wessel, 2018, pg. 10).

1.4 Monetary Policy Tools of the Fed

When the Federal Reserve is deciding on moving forward with either expansionary or contractionary monetary policy, the story can be told from the perspective of the Fed's balance sheet. Let us first imagine a situation in which the Federal Reserve's policy aim is to extend liquidity to the economy and financial markets. The Fed will then consider employing either Open Market Operations or a change in the Federal funds rate. Open market operations describes the Fed's ability to either buy or sell U.S. Treasuries in the secondary bond markets. The Fed will typically buy or sell U.S. Treasuries or other assets

on its balance sheet through repurchase agreements, which will be discussed later in Chapter I. Repurchase agreements or REPO's allow the Fed to control the supply of reserves in the market as well as allow them to achieve Fed Funds rates targets. In addition to REPOs, the Fed can lend to banking institutions through the discount window

1.4.2 Federal Funds Rate

The Federal funds rate is the FOMC's main policy mechanism. The Federal Reserve is able to set a target rate for the federal funds markets in which banking institutions are able to lend to one another. The Federal funds rate is referred to as the overnight lending rate, because this is that rate in which banks charge other banks for lending them reserve balances, overnight. There has been a long standing regulation that requires banking institutions to maintain a certain reserve requirement in an account at the Fed Reserve deposits held at the Fed by US deposit taking institutions (banks), which traditionally had a zero rate of return and were treated by banks as having an opportunity cost. The Fed then started paying interest on required reserves to stabilize the effective Fed funds rate and stop it from going below a lower bound target floor. Although prior to this date banking institutions would often operate with an excess of reserves on their balance sheet; however, banks now earn interest on excess reserves and "the interest rate on excess reserves (IOER rate) is also determined by the Board and gives the Federal Reserve an additional tool for the conduct of monetary policy" (Board of Governors of the Federal Reserve System, Policy Tools).

For example, if the minimum reserve requirement for banks were 10% of depositsand Bank of America (BofA) were to have $500B in deposits on its balance sheet, with only $45B in reserves; BofA would need to borrow at least $5B in the fed funds market in order to meet their reserve to deposit ratio requirement of 10%. In the fed funds market, JP Morgan could be running on an excess of $75B in reserves and decide to extend $5B in reserves to BofA at the current overnight lending rate. Exchanges such as this example happen on a daily basis and are large in volume. According to the Chicago Federal Reserve “changes in the Federal funds rate trigger changes in other short- and medium-term interest rates, the foreign exchange value of the U.S. dollar and other asset prices that influence households' and businesses' spending and investment decisions” (See Federal Reserve Bank of Chicago, www.chicagofed.org). This is what makes the Fed Funds rate the most important rate in the United States and arguably in the world, as it is the benchmark rate to which credit cards, mortgages, corporate debt, among many more important rates are pegged to. The Federal Reserve plays an enormous role in the fluctuations of the yield curve through their usage of monetary policy and the Federal funds rate. Additionally, the Federal funds rate is thought of as a target rate, which the Central Bank reserves the right to change eight times over the course of the year depending on macroeconomic conditions, and can often be informed through forward guidance. The Federal Reserve has also been known to let the Federal funds rate target become a tolerance range as in the case of Chairman Paul Volcker.

1.4.3 Repurchase Agreements (REPOs)

REPOs or repurchase agreements are contracts in which one party, typically a dealer in U.S. Treasuries will sell investors U.S. Treasuries and then buy them back the next day. The difference between the price of the sale of the treasuries and the repurchase of the treasuries from the Fed by the dealer, is the REPO rate (See Federal Reserve Bank of New York, March 2020). The Federal Reserve uses REPOs as a tool for monetary policy to regulate and can help meet monetary aggregate target rates. In addition, if the Fed needs to reduce the supply of reserves, it can engage in a reverse REPO agreement where the opposite happens with the same agents. In this case the Fed sells bonds to an institution in exchange for reserves; this temporarily decreases the supply of reserves available for a brief period of time, until the Fed must repurchase the treasuries the next day (See Federal Reserve Bank of New York, March 2020). Another noteworthy aspect of REPOs is that the security that is sold, otherwise thought of as collateral, does not have to be in the form of U.S. Treasury securities. According to the Federal Reserve Bank of New York "Securities eligible as collateral for both overnight and term operations include Treasury, agency debt, and agency mortgage-backed securities" (See Federal Reserve Bank of New York, March 2020). This makes REPOs a valuable tool for the Fed to adjust and control the money supply of reserves, in addition to being a critical tool for keeping the Federal funds rate at target level. Prior to 2008, REPO operations were the most common tool of the Fed when employing monetary policy.

1.5 Basic Pricing Mechanisms for Debt Securities

To begin to understand how debt securities of any kind are valued, it is important to understand what they are made of and how they are priced. For most purposes we can think of bonds as contracts that entail a series of payments all due at specific dates. The two entities involved: the lender and the borrower, engage in an IOU where the contract or legal document lays out the parameters for which the borrower owes the lender and when, additionally the contract will lay out details as to what should happen to the borrower if the borrower fails to meet their obligations (Cecchettim and Schoenholtz, 2008, pg. 87). In fixed income markets, we can observe hundreds if not thousands of different types of bonds available to investors; moreover there are many different borrowers available offering all different types of debt products. Out of the many different varieties of bonds, the most common type is the coupon bond. These can be structured in different ways, especially depending on the length of maturity, however they are mostly laid out in a series of payments from the borrower to the lender and typically pay back principle at the end of the contract along with a final coupon payment. The amount of the payments are simply called coupon payments, and these payments may occur as frequently as daily, weekly, monthly, or annually. Coupon payments are often described as coupon rates which refer to the total annual payments as a percentage of the face value of the bond .

In order to add color to the valuation methods of debt securities, we can consider the following equations. As an example we can think about a bond, where we are

attempting to calculate the value of the principal payment. We would do this by using the equation given by Cecchetti and Schoenholtz:

$$PV = \frac{FV}{(1+i)^{nt}} \qquad (1.1)$$

where *PV* is the present value of bond, *FV* is face value, *n* is the time to maturity, *t* is the period of coupon payment per annum, and *i* is the interest rate per period

This is also the basic equation for pricing securities, under the assumption that the instrument returns a single payment at the end of maturity, otherwise known as a zero-coupon bond. Although this can be helpful in the case of valuing a specific one payment zero-coupon bond, we know that this is not always the case. In practice most securities return multiple payments at multiple future dates. In order to put a value on these types of financial instruments we must know the amounts and dates of these payments. Once we have this information we can understand the value of the security by a summation of all future payments discounted back to the present (Mishkin, Frederic S. The Economics of Money, Banking, and Financial Markets pg 66).

$$PV = \left[\frac{CF}{(1+i)} + \frac{CF}{(1+i)^2} + \frac{CF}{(1+i)^3} + \ldots \frac{CF}{(1+i)^n} + \frac{FV}{(1+i)^n} \right] \qquad (1.2)$$

(1.2) Mishkin, Frederic S. The Economics of Money, Banking, and Financial Markets pg 66

PV=Present Value, CF=Cash Flow, i=Interest Rate, n=Years to Maturity Date.

Where the present value (*PV*) of these future cash flows (*CF)*, or future payments is what we use in order to derive the total value of the asset. In addition to this valuation of the complete life of a debt security, investors find this equation useful when trying to put a

valuation on the remaining life of a security. From a financial engineering perspective, investors can also find value in segmenting existing debt products by payment periods, therefore creating an entirely new group of products. For example, the holder of a 1 year bond that provides payments every month, could divide the preexisting bond into 12 different cash flows; the monthly payments on the previous 1 year bond would now become the ending payment for the new holder of one of the 12 products. To further the example, if the investor were to segment said 1 year bond and sell the 10th month payment to a trader at UBS Securities at the beginning of the life of the 1 year bond, the investor would sell this product at the present value of the 10th month payment, and on the 10th month or the maturity of this new product, the trader at UBS Securities would receive that payment. This kind of trade is especially helpful for those who are only looking to hold securities with a certain investment horizon, and can always be done as long as there is ample liquidity in bond markets, which is typically always true.

1.6 Unbiased Expectations Theory

Unbiased Expectations Theory (UET) attempts to predict what short term interest rates will be in the future based on current long term rates. UET suggests that a long term bond rate would equal the geometric average of current and future short term rates covering the same investment period. For example, UET suggests that the yield on a three year U.S. Treasury bond is equal to the combined yield of owning three consecutive 1 year U.S Treasuries. Additionally, UET infers that the yield curve slope depends on the expected future path of short term rates (Mishkin, 2004, pg. 129-130). The theory is

grounded in the arbitrage-free notion that an investor should realize identical gains on purchasing, for example, two consecutive one year treasury bonds or a two year treasury bond today, and therefore should be able to calculate the future one year rate, one year from now. “The expectations hypothesis implies that yields on short-term bonds will be more volatile than yields on long-term bonds. Because long-term interest rates are averages of a sequence of expected future short-term rates, if the current 3-month interest rate moves, it will have only a small impact on the 10-year interest rate” (Stephen, Cecchettim, 2016, pg. 177). The unbiased expectation theory is therefore useful for explaining the shape of the yield curve.

For example, when we are considering a positively sloping or normal yield curve, then we would assume that investors expect higher short term rates in the future. This would also suggest that investors are expecting a strong economy in the future. Conversely, if we were to consider a downward or inverted yield curve, this would convey the message that investors are predicting lower short term rates in the future. This would also indicate that investors are pessimistic about the economy in the future. The reason for the relationship between the short and long end of the yield curve being indicative of future economic conditions has to do with investors expectations about how the Fed will change rates. To go further into this, we must understand that the Fed lowering rates is a signal to investors that the economy might not be at full steam and could stand to gain from lower rates. On the other hand, if the Fed were to decide that a rate increase is suitable, this would signal to investors that the Fed views the economy as strong and could stand to benefit from a health standpoint, from a bit of deceleration in growth due to higher rates.

Going back to the yield curve, the long end of the curve (i.e. maturities of 10+ years) will be dependent on the outlook of economic health per the view of investors. In the case of an inverted or downward sloping yield curve we can see how pessimistic investor behavior is able to pull yields down on the long end of the curve, as a response to the Fed lowering Fed Funds Rates. It is this relationship between the Fed and their ability to change overnight rates with investors who are taking Fed action as signals for economic health, which makes controlling the shape of the yield curve so difficult for the Fed; a major question is whether or not the Fed is able to effectively control the term structure of interest rates.

According to this theory, the shape of the yield curve is not only a gauge of future economic conditions but also an indication to investors of future short term rates. In the case that we see a normal yield curve, UET suggests that because the curve is upward sloping, future short term rates are expected to rise. When considering a flat yield curve, future short term rates are expected to remain similar or the same. Lastly when there is an inverted or downward sloping yield curve, the expectation according to UET is that future short term rates are going to decline. In financial markets, this theory is often used as an 'arbitrage theory' in which investors are able to lock in forward rates for short term debt instruments in futures markets based on their analysis of what future short term rates may look like based on the slope of the yield curve. One of the most notable investment strategies stemming from the UET is the rollover strategy, involving analyzing futures rates in order to predict or lock in rates. "The expectations hypothesis tells us that long-term bond yields are all averages of expected future short-term yields—the same set

of short-term interest rates— so interest rates of different maturities will move together" (Stephen, Cecchettim, 2016, pg. 176).

$$(1 + {}_0r_n)^n = [(1 + {}_0r_1)(1 + {}_1f_1)(1 + {}_2f_1) \ldots (1 + {}_{t+(n-1)}f_1)] \qquad (1.3)$$

(1.3) Describes a rollover strategy equation in which we should be able to, under the UET, calculate for future short-term interest rates given the long-term rates. Where *n=Years to Maturity, r=Interest Rate, and t=Years Forward From Today, and f=Forward/Future Rate.*

Ideally, there should be no arbitrage opportunity given the assumption of the efficient markets hypothesis, so in the case of fixed income securities of different maturities an investor should be able to equate for example a two-year loan contracted today payable in two year with a one-year loan contracted today and payable this year and a one-year loan contracted next year, payable in two years. In the case of efficient markets, we should observe no opportunity for investors to make any profits from choosing between the two investment strategies. However, in the real world forward rates and expected future spot rates are often utilized in order to produce a profit for investors.

1.7 Duration Premium Theory

In its most natural form, the duration premium can be thought of as a premium on an asset that investors demand in cases where the given asset is considered to have poor liquidity. The higher the duration premium is for a given asset, the more risky the asset is deemed to be. Stephen and Cecchettim state that "long-term interest rates are typically higher than short-term interest rates because long-term bonds are riskier than short-term

bonds. Bondholders face both inflation and interest rate risk. The longer the term of the bond, the greater both types of risk. (Stephen, Cecchettim, 2016, pg. 177). Additional risk is taken on in the form of liquidity; if investors are locked into a bond with a longer term to maturity, then they would be foregoing liquidity, this is an additional reason why investors demand a premium for duration. Volatility in interest rates in terms of debt securities is a higher risk for longer term maturities. This is called duration or price elasticity to a change in interest rates. To compensate investors for investing longer term there is a higher interest premium. In addition to both liquidity and interest rate volatility risk, investments with longer time horizons are also subject to inflation risk. When we think of the liquidity premium in terms of the yield curve, and were to be observing an upward sloping yield curve, we would be able to recognize a liquidity premium between 3-month Treasury bonds and 30-years. Liquidity premium would suggest that the higher yield of the 30-year as compared to the 3-month bond would be due to the longer investment horizon of the 30-year bond, as long term investments demand a higher rate of return compared to short term investments. The Duration Premium Theory can also be thought of as similar to the expectation theory, however the assumption that all bonds can be considered perfect substitutes is not carried over to the Duration Premium Theory. When considering the increase of a premium on securities due to an increase in their maturity or investment horizon, we can make sense out of why this would contribute to an upward sloping yield curve.

1.8 Market Segmentation Theory

Market segmentation theory poses the notion that both investors and lenders have preferences for maturity that they maintain in fixed income markets. MST also differs greatly from the UET, in that bonds of different maturities cannot act as perfect substitutes for each other. Mishkin says that "the key assumption in the SMT is that bonds of different maturities are not substitutes at all, so the expected return from holding a bond of one matrity has no effect on the demand for a bond of another maturity" (Mishkin, 2004, pg. 132). The result of different preferences in fixed income markets, therefore create a variety of smaller markets which all have their own supply and demand forces, which dictate unique equilibriums for each submarket. In understanding this, market segmentation theory is suggesting that we should not be analyzing the yield curve as a whole. In contrast to analyzing the entire yield curve, we should be looking at the yield curve in segments: short term, mid-term, and long-term bonds. For example, in the corporate bond market, we could more vividly see how the demand and supply of debt securities would have its own independent forces dependent on term maturity. On the short end of the corporate bond yield curve, the supply of commercial paper would be dependent on a variety of balance sheet factors such as inventories or accounts payable. Demand for short term bonds would be dependent on the demand of investors and their appetite for short term investments for their excess cash. This market equilibrium for short term bonds between investors and corporations is what will determine short term interest rates on short-term bonds. This is how market segmentation theory would suggest that mid-term and long-term bonds operate

as well; as the supply for mid-term and long-term bonds may be determined by corporations need for mid-term or long-term financing options (property, plant, and equipment, acquisitions), and the demand for such mid-term or long-term bonds coming from the demand of investors who may need to add longer-term income to their portfolios for a variety of reasons. It's clear that the defining factor of market segmentation theory is that within the yield curve, markets function independently. Under this assumption, there is little to no correlation between the rates given in the short-term through the long-term, and neither rates are affected by each other. The assumption of independent markets is based on the notion that investors and lenders are engaging in a specific maturity based on their need to meet and match their own assets and liabilities; Johnson, Zuber and Gandar, state that "MST is the idea of unique or independent markets. According to MST, the short-term bond market is unaffected by rates determined in the intermediate or long-term markets, and vice versa. This independence assumption is based on the premise that investors and borrowers have a strong need to match the maturities of their assets and liabilities". (Johnson, Zuber, Gandar, 2010, pg. 6-7).

2.1. The Decades Preceding the Paul Volcker Era:

The story of Paul A. Volcker, the chairmen of the Federal Reserve from 1979 to 1987, is hallmarked by his successes in overcoming the challenges of a decade of high and volatile inflation in the 1980's. Volcker previously served as a Senior U.S. Treasury official throughout the 1960's up until his role as Fed Chairman in 1979. During his time with the U.S. Treasury, Volcker was involved and familiar with the inflationary challenges

in the United States. The 1960's and 1970's were a time defined by multiple economic expansions and contractions, with a variety of exogenous and endogenous economic shocks, that would help prepare Volcker for the challenges that he would eventually face as Chairman of the Federal Reserve (see Federal Reserve History, Paul Volcker).

2.1.2 The 1960's

The mid 1960's marked the beginning of the United States battle with high inflation; a byproduct of high oil prices, fiscal policies, war, and unemployment, among other causes, especially apparent in the 1970's. The years 1965 to roughly 1984 were characterized as The Great Inflation, which was not only an economic event but also a politically driven issue (Meltzer 2005, pg.145). Over this course of time, there were a multitude of global events and pressures from different administrations that proposed a series of challenges to the Federal Reserve from a monetary policy standpoint. As will be seen, the Federal Reserve during this period, would mainly fail in its ability to act as an independent entity of the White House Administrations, would not be able to curb inflation in a precautionary manner, and would continue to allow high inflation to remain as a component in the economy. In November of 1956, the change in the Consumer Price Index (CPI) was roughly 3% (data from fred.stlouisfed.org), a relatively high and concerning number as viewed by the Fed.

Following a recession in 1957-1958, Federal Reserve Chairman McChesney Martin would struggle with monetary growth. Admitting that he did not understand the money supply, Martin dismissed monetary growth, however other Governors urged for a control

over monetary growth unless it would negatively affect unemployment. For example "Governor Sherman Maisel, at the Board from 1965 to 1972 . . . urged a policy of controlling money growth. He was not, however, willing to control inflation if it required more than a modest increase in the unemployment rate" (Meltzer, 2005 pg.150). The disinterest from the Fed in finding a better balance between inflation and unemployment stemmed from a post-WWII era in which Kenyesian policies were deployed to prevent another 1930's level of unemployment (Michael Bryan, 2013).

The Phillips Curve was a theoretical model of the relationship between unemployment and inflation, a relationship which the Federal Reserve believed that they could actively manage and control in order to achieve desirable levels of unemployment. Milton Friedman found that it would be the case in which market participants would predict inflation based on the Phillips Curve, causing a cycle in which this anticipation would shift the curve upwards, leading to continued inflation in order to sustain optimal levels of unemployment. Friedman's critique would differentiate the Phillips Curve between the long run, and the short run as he would write "there is always a temporary trade-off between inflation and unemployment; there is no permanent trade-off. The temporary trade-off comes not from inflation per se, but from unanticipated inflation, which generally means, from a rising rate of inflation" (Milton Friedman, Friedman: Monetary Policy, pg 11.). Friedman points out the flaws in the Phillips Curve's original assumption that the curve maintained a constant trade-off between unemployment and inflation, where he argues that the curve exhibits a temporary trade-off.

Milton Friedman's work on the phillips curve and the relationship between inflation and unemployment is especially important in understanding why this period was ravaged by constantly growing inflation. In order to achieve the targeted low levels of unemployment, especially levels falling below the natural rate, the economy would be subject not only to high inflation, but to a constantly rising level of inflation; "Milton Friedman, first argued in the late 1960s that any tradeoff between inflation and unemployment would exist only in the short run; once the public expected higher inflation in the future, the effect would disappear. Thus, expansionary monetary policy leads to more inflation rather than a decline in the unemployment rate" (Federal Reserve Bank of Cleveland, 2011).

By this time the U.S. economy was operating at an inflation rate around 3.4% during 1966, and 3.7% at its highest in October of that year. In order to combat the concern of inflation and the speed at which the economy was expanding, the Fed had made the decision to tighten credit for a short time (6 months); this would lead the economy to experience deceleration in growth, but allow inflation to fall to 2.78% by the end of 1967, and help to avoid a recession. Following the second quarter of 1967, economic growth had begun to re-accelerate; this, coupled with the economic consequences of the United State's conflict in Vietnam, quickly spiked inflation to 4.7% by 1968 and 6.2% by 1969. (Mussa 2005,)

2.1.3 The 1970's

The story of global conflicts would continue through 1973 as inflation would hit 8.7%, and then to 12.3% in 1974; this was largely attributed to a rise in oil prices following the Arab Israeli conflict in 1973. The Fed's actions in response to the dramatic spike in inflation was to revert to monetary policy in the form of increasing the Federal funds rate. By increasing the Federal funds rate, in addition to rising energy prices, contributed to a peak in economic expansion, which led to a sharp decrease in economic conditions and more specifically a decreased U.S. inflation rate. The mid 1950's through the mid to late 1970's was a time period of drastic economic and inflationary volatility; the Federal Reserve was struggling to provide consistency in inflation to the economy, as the central bank juggled with battling inflation and challenged Fed officials to provide effective monetary policy, without inducing multiple recessions. Such a challenge is alien to the modern day economy, as the current central bank regime has been, as of 2019-2020, struggling to push inflation up to its target rate of 4% (more of this will be discussed later in Chapter II).

Mid-1974 to 1975 would mark a "deep recession" (Mussa, 2005) in history, but the central bank would have achieved partial success in lowering inflation. The Federal funds rate at its highest point was at 13% in mid-1974 and had declined to 5% in mid-1975. The decrease of the Federal funds rate was the central bank's reaction to an economy that was in a contractionary stage; further, the decrease in the Federal funds rate was a reaction to the decrease in other short-term rates.

Through 1978, economic expansion began to move in an aggressive fashion as the White House under the Carter Administration was encouraging economic growth to fight unemployment in 1977. The administration's goal of economic expansion had been met; by the end of 1978, real GNP had increased 6.3% and inflation was up from 6.7% at the end of 1977 to 9% by the end of 1978. Naturally, the reaction of the FOMC was to begin to hike Fed funds rates and they did that; in 1978 the Fed funds rate was increased 3 times, landing at 10% by the end of the year. During this time, the FOMC formally declared the objective of controlling inflation a higher concern than maintaining the current economic growth rate in April of 1978.

In 1979, the U.S. economy again faced more inflation related challenges as global pressures, specifically in energies, as oil prices began to rise once again due to conflicts in Iran. “The energy component of the CPI showed a 37.4 percent increase during 1979, compared with an 8.0 percent increase during 1978, and this helped raise the overall inflation rate from 9.0 to 13.3 percent” (Mussa, 2005, pg. 91). Again, the FOMC would continue to consider controlling inflationary pressures as its number one priority moving forward through the year. In combination with a nervous outlook on the acceleration of inflation, the FOMC midway through the year would come to expect economic declines, as second quarter data exhibited a decline in economic growth, and would suggest economic contractions to continue throughout that year. When looking at the performance of the Federal Reserve in attempting to keep inflation at bay, it is apparent that during the 1970’s, the Fed mishandled the use of the Federal funds rate in order to combat the issue. The Fed was not efficient in their abilities to prevent inflation, but were only committed to

responding to inflation; Mussa writes that “increases in the Federal funds rate often lagged behind increases in the inflation rate, indicating fairly clearly that the Federal Reserve was "falling behind the curve" in its actions to combat rising inflation” (Mussa, 2005, pg. 95).

2.2. The Paul Volcker Regime:

During August of 1979, Paul Volcker was appointed Chairman of the Fed. Volcker was familiar with the challenges and tasks of the central bank as he had been serving as president of the Fed for four years and had been acclimated with the Nixon Administration. Under the control of Volcker, the central bank would quickly begin to rethink its strategy and the ways in which it could employ its tool in order to curb volatile inflation.

The Open Market Desk would change the way in which it would operate; instead of taking directives from the FOMC in order to dictate a Federal Funds target range, it’s main objective would be to achieve target rates of monetary growth by controlling the supply of reserves. The FOMC would recommend a volume of reserves to banks that would allow the economy to achieve short term monetary growth targets, and the Open Market Desk would conduct the supply. This change marked an important point in how the central bank would behave. By changing to a monetarist conduct of policy, the central bank signaled to markets that it would be allowing the Fed funds rate to fluctuate in a wider range; this gave the central bank much greater flexibility to respond to macroeconomic developments with the Fed funds rate. For example, rather than allowing a tolerance range of the Fed funds rate of 1% or .5%, the Fed funds rate in 1979 would range from 11.5% to 15.5%.

The effects of the Fed were immediately evident in market data, as short term rates grew, long term bond prices began to drop, and the Fed Funds market immediately began to test its upper limits. By the end of 1979, the Fed had raised its range to 15.5%-20%. Inflation wasn't turning around either as the fourth quarter of 1979 as the annualized inflation rate in December was 13.4%. Moving into 1980, the economy was pushed into a recession as a result of the Feds tight monetary policy and the Carter Administration's interference with consumer credit. By May, the Fed funds rate had dropped down to 13%, and in response the FOMC lowered its lower bound tolerance rate to 10.5%. The rate cuts continued as the low range of the target rate would fall to 8.5% by June, marking a 10% decrease in the bottom range of the tolerance rate from March-June 1980. The cuts and declines of the Fed funds rate were expected, and were a direct result from the Fed's actions of targeting monetary growth; since Open Market Desk was supplying more reserves to the market, the rate in the Fed Funds market naturally declined. Due to such extreme tightening of policy, the recession was dramatic as GNP declined by roughly 9% (1980, Q1-Q2). Though the decline in the economy was steep, it was relatively brief for a recession; recovery in the economy was beginning to surface in the summer and by the end of the year the economy was showing modest gains in GNP at around 5%.

Inflation through 1980 was inconsistent, but by the end of the year it could be said that the Federal Reserve was partially successful in curbing inflation by the end of the year; annual inflation was down to 12.5% in December from 13.9% in January. Though inflation was down by the end of 1980, the central bank knew that it had come at a cost. The Federal Reserve was partial in their success to curb inflation due to political reasons as

well. The summer of 1980 preceded the election of Ronald Reagan, the Federal Reserve moved to a much more dovish tone. In choosing to delay aggressive policy, the Federal Reserve was allowing itself to become distant to the outcome of the election. Once Reagan was elected, the Fed would be free again to engage in its intended tightening of policy; the Federal Reserve did so through 1982. Following the election the Fed funds rate had reached 19% by December of 1980, in addition monetary aggregates were now beginning to fall back into the mid to higher segments of their target ranges.

Moving through 1981, tight monetary policy would continue and a recession would take place in the fourth quarter of the year; the Federal funds rate remained high throughout 1981, ranging from 15%-20%. Despite the costs to the economy, inflation was coming down. Much of the same costs that were paid in 1980, were similar to those experienced in 1981, as a recession similar to the scale of 1980's recession was looming as late 1981 economic data was signaling economic downturn. From the Q3 to the Q4 of 1981, GNP had dropped 10.1%; from Q4 1981-Q1 1982, GNP had dropped another 4%. In Q1 of 1982, the Central Bank was heavily focused on controlling the growth of monetary aggregates and this seemed to be working; December of 1981 inflation was 8.92% and by the end of March 1982 inflation was at 6.78%. In the summer, the Federal Reserve and FOMC had begun to ease their tight policy, raising monetary aggregate targets.

Although monetary aggregates did not immediately grow, the Fed funds rate had dropped from 14.5% in late June, to 9% by late August. By this time monetary aggregates were beginning to grow, and would continue to grow through 1983. Despite subjecting the economy to multiple recession, inflation was ultimately handled as average inflation in

1983 was 3.22%, in comparison to an average rate of 13.58% in 1980; inflation would remain low throughout Volckers tenure as Chairman of the Fed, not exceeding inflation of 4.5% through 1987 (Mussa, 2005, pg. 96-98).

2.2.1 Analysis of Volcker Regime:

In this portion of the chapter, we will examine the performance of monetary policy under Paul Volcker. It is clear that Volcker inherited the reigns of the Federal Reserve in an economic environment being torn apart by inflation and unemployment. Volckers greatest achievement was being able to put an end to an era of volatile and high inflation, regardless of the economic costs; Volcker succeeded. By changing the behavior of the FOMC in targeting monetary aggregates in a more direct form helped Volcker achieve such a feat, but the ways in which interest rates were manipulated is what will be more closely analyzed in this portion of the chapter. By taking a monetarist approach, Volcker subjected interest rates to extreme volatility in the first half of his tenure as Fed Chairman. Much literature discusses movements in the short end of the yield curve during this era, however for the purposes of analyzing interest rates through the interest rate theories in Chapter I, we must analyze rates beyond the short end of the curve.

2.2.2 Unbiased Expectations Theory Though the Volcker Era:

1980-1981 was a unique period for the yield curve, as it not only inverted, but interest rates were at historical highs; in the Fed's tightening of monetary policy, short-term rates rose to nearly 20%. If we were to analyze the actions of Volcker through

the lense of the Unbiased Expectations Theory, know that the UET is not only a theory of expected short term rates based on the long end of the yield curve, but further that the theory is based on expected inflation; according to UET, future inflation will impact long term rates thus providing the markets with an indication of future short term rates. In the case of 1979, Volcker had immediately begun to aggressively fight inflation as soon as he was announced Chairman. By switching to a monetarist approach, the Federal Reserve was handling the Fed funds rate by not targeting it, setting a wide tolerance range. According to UET, the market reaction to falling long term rates is a real indication that investors had strong confidence in Volckers ability to handle inflation at this point, as UET suggests that the market was anticipating a drop in the Fed funds rate in the future due to low inflation. At the end of 1979 the spread between the 10-year and 2-year U.S. Treasury was -0.9% and by March of 1980, the spread was -2.34%.

As the yield curve began to invert at a more extreme level, the Fed funds tolerance rate was and the actual Fed funds rate were at historic levels beginning in 1980; the tolerance range in late 1979 was set at 15.5%-20%. During the spring of 1980, the Fed was forced by way of nonpartisanship to the ongoing election to loosen its monetary policy for the time being, so it did. However, it was clear to markets under this theory that investors had confidence that Volcker would be able to handle inflation and that it would decrease in the future. Inflation under the UET is important because it is the first indicator to investors because it signals future action by the Federal Reserve to encourage higher short term interest rates. The significance of the UET during this time period was that the market was indicating that Volcker would be successful, putting faith in new FOMC operations. This

was historic in that the Federal Reserve would be targeting the monetary aggregates relative to other concerns, and that the Fed would be comfortable in letting short time rates skyrocket; this is why the time period of 1979-1982 is a prime example for displaying the UET.

In order to better understand how investors were analyzing the bond markets of this time period, we can use the UET with Federal Reserve Economic Data to run the theory. By the end of December 1980, the 2-Year Treasury Rate was 14.08%, and the 1-Year Treasury Rate was 14.88%; from this data we should be able to solve for the expected rate of the 1-Year Treasury Bond in December of 1981. We can get an expected rate of the 1-Year Treasury Bond, in 1981 (1 year forward from December of 1980) by recalling the expectations theory the equation as follows:

$$(1 + {}_0r_n)^n = [(1 + {}_0r_1)(1 + {}_1f_1)(1 + {}_2f_1) \ldots (1 + {}_{t+(n-1)}f_1)] \quad (2.1)$$

This equation (2.1) denotes an expected rate(s) by rolling over a series of 1-year bonds, n-years. The left side of the equation will be:

$$(1 + {}_0r_2)^2 = 1.301352045 \quad (2.2)$$

Since we know the value of the current (December 1980) 1-Year Treasury rate we can input it such that the right side of the equation now becomes:

$$1.301352045 = [(1.1488)(1 + {}_1f_1)] \quad (2.3)$$

$$1.132783554 = [(1 + {}_1f_1)] \quad (2.4)$$

$${}_1f_1 \approx 13.27\% \quad (2.5)$$

Solving for our new equation we find that ${}_1f_1$ (2.5), or our expected 1-year rate of 1981 is roughly 13%, and the actual 1-year Treasury rate in December, 1981 ranged from 11.47% to 14%, averaging roughly 12.7%.

I then tested the UET for the years 1978- 1983 (end of year) as these were the most economically unstable years under Volcker. The methodology is simple; the process of (2.1) - (2-5) is expanded for years 1978 -1983 (end of year). The ${}_1f_1$ is found for each year for a total of 72 observations (72 months - 6 years). We then subtract the ${}_1f_1$ from the actual 1-Year rate, 1 year in the future; this will give us a differential between the expected rate result from the UET equation and the actual 1-Year rate (1 year in the future). The differentials are then organized for frequency, by "Bins" which are ranges of 1%, so that we are able to see how accurate the UET is in providing expected 1-Year U.S. Treasury rates, 1 year in the future, and also so that we can observe if the UET was overestimating or under-estimating future 1-Year U.S. Treasury rates.

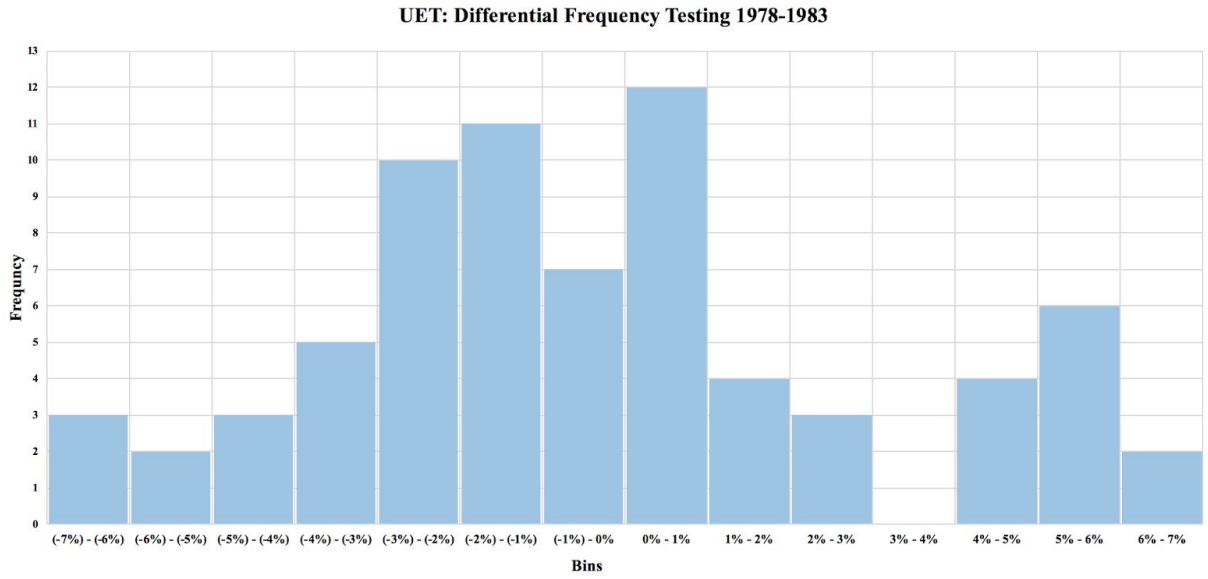

*Figure 2.2.2 - Data Source: https://fred.stlouisfed.org *displays the differentials between the expected 1-Year U.S. Treasury rate, 1-Year in the future as given by equation (2.1), and the actual 1-Year U.S. Treasury rate, 1-Year in the future*

Bin	Frequency
(-7%) - (-6%)	3
(-6%) - (-5%)	2
(-5%) - (-4%)	3
(-4%) - (-3%)	5
(-3%) - (-2%)	10
(-2%) - (-1%)	11
(-1%) - 0%	7
0% - 1%	12
1% - 2%	4
2% - 3%	3
3% - 4%	0
4% - 5%	4
5% - 6%	6
6% - 7%	2

In terms of the results of this test, 56.94% of the time equation (2.1) overestimated the 1-Year U.S. Treasury rate, 1 year in the future, and 43.06% of the time it under-estimated. In Table 2.2.2 (a), we can see the distribution and frequency of the differentials. Of the 72 observations, 65.28% of the expected 1-Year U.S. Treasury rates, 1 year in the future, from the UET equation (2.1) were accurate within a range of -3% underestimation, to 3% overestimation of the actual 1-Year U.S. Treasury rate, 1 year in the future.

*Table 2.2.2 - Data Source: https://fred.stlouisfed.org *displays the differentials between the expected 1-Year U.S. Treasury rate, 1-Year in the future as given by equation (2.1), and the actual 1-Year U.S. Treasury rate, 1-Year in the future, and the frequencies of the differentials sorted by bins with ranges of 1%*

So, if investors were using UET during this time period, they would be able to predict the future 1-Year U.S. Treasury rate, 1 year in the future, within a 6% range (-3% to 3%), 65.28% of the time, and within a 4% range (-3% to 1%), 55.56% of the time.

2.3 The Alan Greenspan Regime & Greenspan's Conundrum

Alan Greenspan followed Paul Volcker and served as both Federal Reserve Chairman and the FOMC Chairman from 1987-2006, serving five terms under four different presidents. Greenspan's tenure as Chairman can be best summarized as, like Volcker, anti-inflationary and with a strong focus on controlling prices. Greenspan is also known for what is "Greenspan's Conundrum" or also known as the "Bond Yield Conundrum" (Daniel L. Thornton, 2012, pg. 2)..

Greenspan's Conundrum was a situation in which the long-term rates of the yield curve were not responding to changes to target rates of the Federal funds rate in the ways that the Federal Reserve/FOMC were anticipating as a drop in long-term rates in response to the tightening of monetary policy is unusual.

In February 2005, Greenspan and the FOMC had previously raised the Federal funds rate target by 1.5%, however had observed that long-term rates had fallen. From June 2004 to February 2005, the 10-Year Treasury Rate had fallen from 4.37% to 4.17% in response to a 1.5% increase in the Fed funds rate during the same period of time. In February of 2005, in the Federal Reserve Board's semiannual Monetary Policy Report to Congress, Greenspan had said that:

> "In this environment, long-term interest rates have trended lower in recent months even as the Federal Reserve has raised the level of the target Federal funds rate by 150 basis points. This development contrasts with most experience, which suggests that, other things being equal, increasing short-term interest rates are

normally accompanied by a rise in longer-term yields. The simple mathematics of the yield curve governs the relationship between short- and long-term interest rates. Ten-year yields, for example, can be thought of as an average of ten consecutive one-year forward rates. A rise in the first-year forward rate, which correlates closely with the Federal funds rate, would increase the yield on ten-year U.S. Treasury notes even if the more-distant forward rates remain unchanged. Historically, though, even these distant forward rates have tended to rise in association with monetary policy tightening."
(Greenspan February 16, 2005)

(Testimony of Chairman Alan Greenspan Federal Reserve Board's semiannual Monetary Policy Report to the Congress Before the Committee on Banking, Housing, and Urban Affairs, U.S. Senate February 16, 2005).

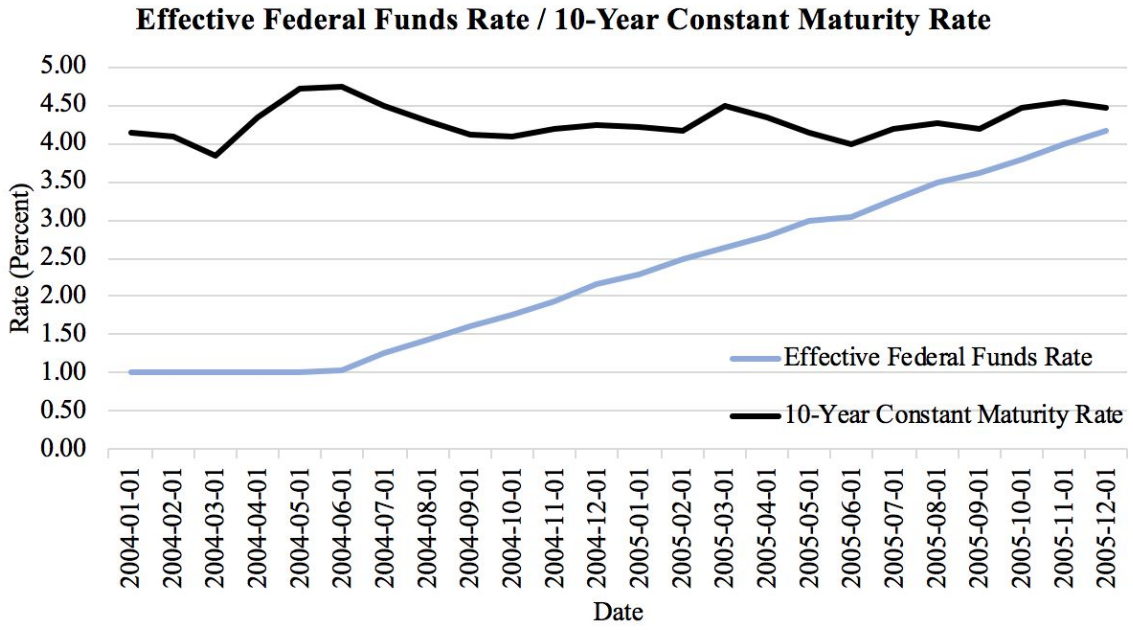

Figure 2.5 - Effective Federal funds rate & 10-Year Constant Maturity Rate - Data Source: fred.stlouis.org

In Figure 2.5, we can see how the 10-Year Treasury rate was directly responding to changes in the Federal funds rate, displaying what Greenspan was observing. Don H. Kim and Jonathan H. Wright (2005) had produced an "Arbitrage-Free Three-Factor Term Structure Model", which would help evaluate the term-premium for long term yields such as the 10-Year Treasury rate. Kim and Wright found that "estimates imply that if the term premium had not changed, ten-year yields would have risen modestly over this time period, as one would expect in an environment of monetary policy tightening" (Kim and

Wright 2005, pg.11). Kim and Wright do not however, explicitly explain what exactly is causing a decline in the term premium, however Daniel Thorton (2012) expresses that in an internal memo to the Board of Governors of the Federal Reserve, Joshua Rosenberg (Chief Risk Officer for the Federal Reserve), noted that "the decline in the term premium from Kim and Wright's (2005) model into (a) changes in risk, (b) risk aversion, and (c) foreign demand" (Daniel L. Thornton, 2012, pg. 3).

In 2007, David Backus and Jonathan Wright published a report and analysis regarding the 2004-2006 "conundrum" in which they attempt to explain the fall in the term premium. Backus and Wright (2007) analyze the cyclical behavior of interest rates, looking at how the relationship between the past three periods of tightening monetary policy (1986, 1994, 1999), and 10-Year Treasury rates. The relationship during these three periods was clear and expected as the rate on 10-Year Treasuries had increased along with higher Federal Funds target rates.

We should remember the relationship between the Unbiased Expectations Theory and the Duration Premium Theory. The Duration Premium Theory is a modification to the Unbiased Expectations Theory; it adds a premium which in theory increases as the term to maturity increases due to liquidity risks, inflationary risks, price volatility risks, among others risks which explain a higher duration premium for longer maturities. In the case of Greenspan's Conundrum the market was not reacting in a way in which the UET could explain as long term rates were decreasing in response to an 150bps increase in the Federal funds rate, however given the modification of the Duration Premium Theory, we can see how a diminishing premium to long term Treasuries could explain the drop in forward

rates as well as drops in long term rates. Kim and Wright note that "Over this time period [June 29, 2004 to July 29, 2005], the ten-year zero-coupon yield fell 50 basis points, but the associated term premium is estimated to have declined by about 80 basis points. Accordingly, the model [The Arbitrage-Free Three-Factor Term Structure Model and the Recent Behavior of Long-Term Yields and Distant-Horizon Forward Rates] estimates imply that if the term premium had not changed, ten-year yields would have risen modestly over this time period, as one would expect in an environment of monetary policy tightening" (Kim and Wright 2005, pg 11). Kim and Wright's findings that the 10-Year rate would have risen due to an increase in the Federal funds rate with an unchanged term premium, speak directly to the assumption of the Duration Premium Theory that bonds of different maturities are not perfect substitutes due to different values of risk associated with duration; in this case there is a diminishing premium for duration.

2.4 Ben Bernanke on the Decrease in the Term Premium

Moving into 2006, Ben Bernanke was appointed Chairman of the Fed and would serve two terms, ending his tenure in 2014. Bernanke was a member of the Board of Governors at the Federal Reserve as of 2004 and was able to reflect on Greenspan's Conundrum as he began his role as Chairman of the Fed. In a speech to the Economic Club of New York in March 2006, Bernanke made comments consistent with the DPT findings in 2.3. Bernanke commented on the behavior of long term yields stating

"The ten-year Treasury yield, for example, can be viewed as a weighted average of the current one-year rate and nine one-year forward rates, with the weights depending on the coupon yield of the security. As I will discuss, each of these forward rates can be split

further into (1) a portion equal to the one-year spot rate that market participants currently expect to prevail at the corresponding date in the future, and (2) a portion that reflects additional compensation to the bondholder for the risk of holding longer-dated instruments. . . As I have noted, each of the forward interest rates implicit in the term structure can be usefully decomposed into two parts: (1) the spot interest rate that market participants currently expect to prevail at the corresponding date in the future and (2) the additional compensation that investors require for the risk of holding longer-term instruments, known as the term premium. With the economic outlook held constant, changes in the net demand for long-term securities have their largest effect on the term premium."

(Reflections on the Yield Curve and Monetary Policy, Chairman Ben S. Bernanke Before the Economic Club of New York, New York, New York, March 20, 2006)

Bernanke here is describing the relationship between (1), the UET, and (2), the DPT. Additionally, Bernanke is speaking to the MST "changes in the net demand for long-term securities have their largest effect on the term premium" (Bernanke, 2006). Bernanke in the same speech then goes on to list four possible reasons that may explain the decline in the term premium. First, "longer-maturity obligations may be more attractive because of more stable inflation, better-anchored inflation expectations, and a reduction in economic volatility more generally" (Bernanke 2006). Second, "the increased intervention in currency markets by a number of governments, particularly in Asia" (Bernanke 2006). Third, that "changes in the management of and accounting for pension funds are a source of a declining term premium" (Bernanke 2006). Fourth, "as investors' demands for long-duration securities may have increased over the past few years, the supply of such securities seems not to have kept pace" (Bernanke 2006). In Bernanke's first reason for the decline in the term premium can be mostly characterized by the "Great Moderation" (Bernanke 2004), which can be defined as a period of economic stability; stability is thought of in terms of reduced inflation and GDP volatility due to "structural changes in

the economy such as deregulation, improved inventory control methods, and better risk-sharing in financial markets" (Bernanke 2006), such that the market would not be demanding such a high premium for risk, resulting in a decreased term premium.

In the second explanation for the decline in the term premium, increased intervention in currency markets by foreign agents, Greenspan notes that foreign agents, specifically central banks, were deploying "a bulk" (Bernanke 2006) of their U.S. Dollar holdings into U.S. Treasuries. This would then increase demand for long-term U.S. Treasuries, therefore depressing yields. Bernanke also notes that in 2004, long-term yields dropped during the same period as increased purchases of U.S. Dollars by other central banks.

Bernanke suggests in his third reason, that changes in pension funds may be responsible for the decline in the term premium. Due to developing reforms in the U.S. and Europe, pension funds needed to better match the duration of their assets and liabilities. Bernanke admits that there is "little direct evidence to date of sizable pension-fund portfolio shifts toward long-duration bonds" (Bernanke 2006).

Lastly, the fourth explanation for the decrease in the term premium according to Bernanke is more a general macro shift in investors preferences for maturity; Bernanke suggests that there has been a rising demand for longer maturity bonds, however the market has failed to provide adequate supply in order to sustain demands, depressing yields for long-term bonds.

2.5 The Fed's Narrative vs. Other Theories

The narrative of the Federal Reserve on why they are not able to control long term yields with tight monetary policy is simple: The economy is moderating and the decreasing term premium is the result of investors signaling to markets that they no longer demand a high duration premium for risk associated with long term securities in fixed income markets. The Fed would be able to claim that their loss over the control of the yield curve was due to economic moderation; an ode to the Feds successes. However, in the years leading up to the Financial Crisis of 2008 it is clear looking back at financial and economic trends that investors had reason to be worried about the health of the financial sector, U.S. credit, and the economy. The rise of leverage on balance sheets, deregulation of the financial sector, and the high volume of securitized loans, are the typical suspects, but were only few of the many indicators of an imminent financial collapse. We know that investors during the years preceding the financial crisis of 2008 had anticipated the crisis, and UET would suggest that bearish investors could be responsible for Greeenspan's Conundrum. Although this is what UET on its own would suggest, the explanation from the Fed and its DPT approach still remains valid as well. What we are suggesting is that these two theories can be, in conjunction with each other, responsible for the Greenspan's loss of control over the long end of the yield curve. In fact, the bearish investors that remained bearish would be push down the long end of the yield curve due to negative expectations about the health of the economy and were anticipating a rise in short-term rates; where as the bulls of the market were, under DPT, anticipating a prolonged period of financial market stability and as a result were not longer demanding a duration risk premium for long-term debt anymore due to the perceived diminishing risk associated with holding long-term bonds..

For example, if we were to rely on the DPT and the suggestions that the value of the duration premium is diminishing, then we should reasonably expect that the long end of the yield curve is coming down; however DPT would still suggest a higher rate on long term maturity securities in comparison to that of the short end of the yield curve since we are not arguing that the term premium is only decreasing and not transforming into a negative duration premium; that long-term bonds still have a higher risk profile than that of a short-term bond, but that spread in risk is diminishing. This was not always the case with the yield curve under Greenspan. For example, the diminishing value of the duration premium under the DPT cannot solely support an in which the rates on a 3-Month bond are higher than that of a 30-Year bond, or an extremely inverted yield curve.

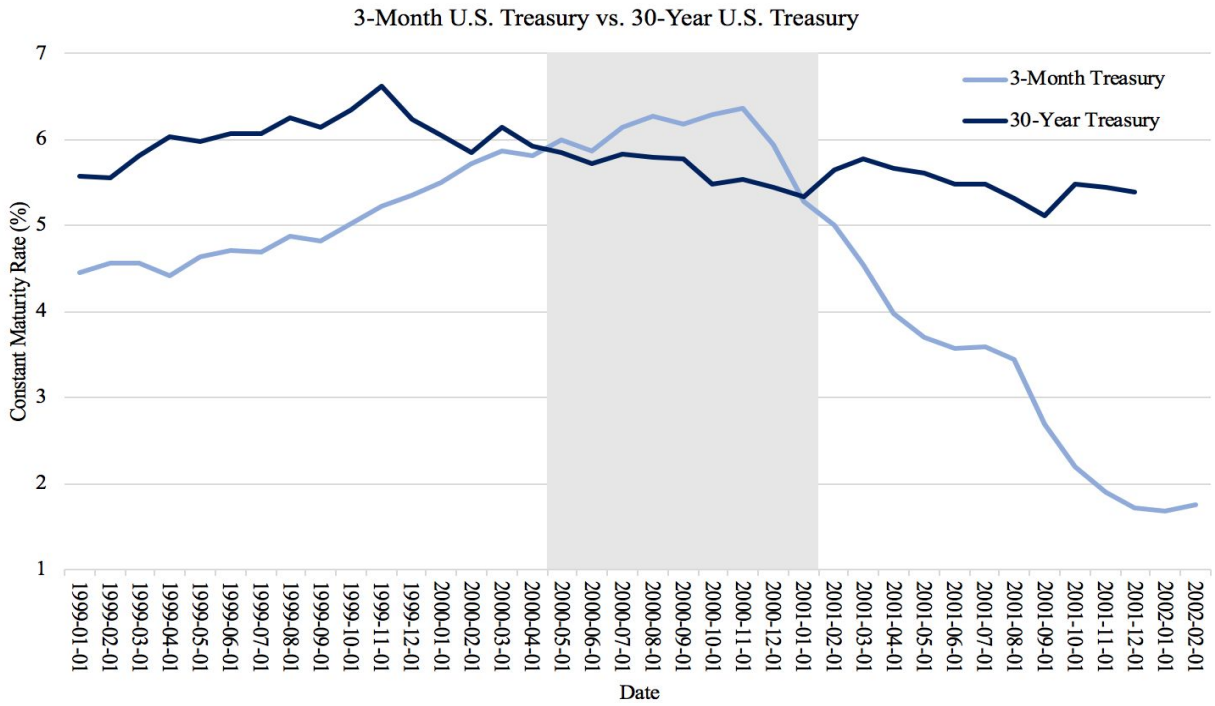

Figure 2.6 - Source of Data: https://fred.stlouisfed.org

For this case, recall DPT's assertion regarding the duration premium, that there is a positive relationship between risk and term to maturity; that is, the maturity of a bond determines the inherent levels of risk associated with the bond to the holder, including inflationary risks, liquidity risks, and interest rate volatility risks. In the highlighted portion of figure 2.6, we can see that the rates on 3-Month U.S. Treasuries are greater than that of the rates on 30-Year U.S. Treasuries. DPT in this case, does not provide a full explanation as to why this may be happening; the Federal Reserve argues that the decline in the duration risk premium is responsible, however it can only be possible that the decline in the duration premium is contributing to the conundrum and not explaining it. If the decline in the duration premium was solely responsible for the shape of the yield curve, then decrease in the duration premium would render the risk for 30-Year U.S. Treasuries to be negative; this would mean that an investor purchasing a 30-Year Treasury, which according to DPT should have more risk associated with it than a 3-Month Treasury, would be willing to accept less yield. This is certainly an unlikely event. However, it is more than reasonable to suggest that a declining duration premium is not completely, but partially, responsible for the relationship between the 3-Month and 30-Year Treasury rates during this period. So, it is possible that the relationship between the 3-Month and the 30-Year Treasuries during this time period can be supported by the UET and DPT only in conjunction with each other.

Both theories support the shape of the yield curve through Greenspan's Conundrum and there is no reason to suggest that only one theory should be responsible. However, it additionally seems possible that there are reasons as to why the Fed would prefer to push

for a narrative coinciding with DPT rather than UET. If the Fed were to admit UET being a contributing theory to the conundrum, they would be validating negative market expectations, and a future recessionary episode; this would be a problematic admittance by the Fed.

However, we are not only suggesting that two theories are responsible for Greenspan's conundrum, but that there are three theories at work. Recall Bernanke's third and fourth explanations for the decline in the term premium and we can understand that this explanation also supports the role of Market Segmentation Theory. Bernanke suggests that there was a macro-trend of the fixed-income market of rising demand for long-term securities and further that pension funds and foreign Central Banks were buying high volumes of long-term U.S. Treasury bonds (Bernanke, 2009). MST suggests that in the fixed income market there exists different supply and demand preferences which differ by term to maturity, therefore resulting in sub-markets governed by term maturity each with their own market forces. In addition to expectations under the UET which suggests a variety to reasons leading to investor expectations of lower future short-term rates, and a declining duration premium due to a new stability in the economy, the segmentation of the long end of the yield curve and the short end of the yield curve provides additional support for the decline in long term rates.

During the time period of Greenspan's Conundrum, demand for long-term U.S. debt was rising. Abroad, Asian countries specifically were contributing to much of the increase in demand for long-term U.S. debt. From 2000-2007, Chinese total foreign exchange holdings jumped from $168B to over $1.5T. China was doing this in order to

maintain the exchange rate of the Yuan to the U.S. Dollar since China was still pegging its currency to the U.S. Dollar. Then, China decided to begin to purchase long-term U.S. Treasuries since they would be able to receive interest on their holdings.

From 2000-2007 Japan and China alone account for an increase in holdings of long-term U.S. Treasuries, an increase worth over $696B. In this short span of time, this accounts for a significant amount of long-term U.S. Treasuries, this increase is a clear representation of an increase in demand for long-term U.S. Treasuries, and would additionally affect the available supply of long-term U.S. Treasuries. These results of China's and Japan's increase in allocation of long-term U.S. Treasuries are consistent with Market Segmentation Theory. MST suggests that in this case, market forces of long-term U.S. Treasuries would be impacted by foreign central banks' increase in long-term U.S. Treasuries holdings, coupled with a restricted available supply due to the increase in U.S.

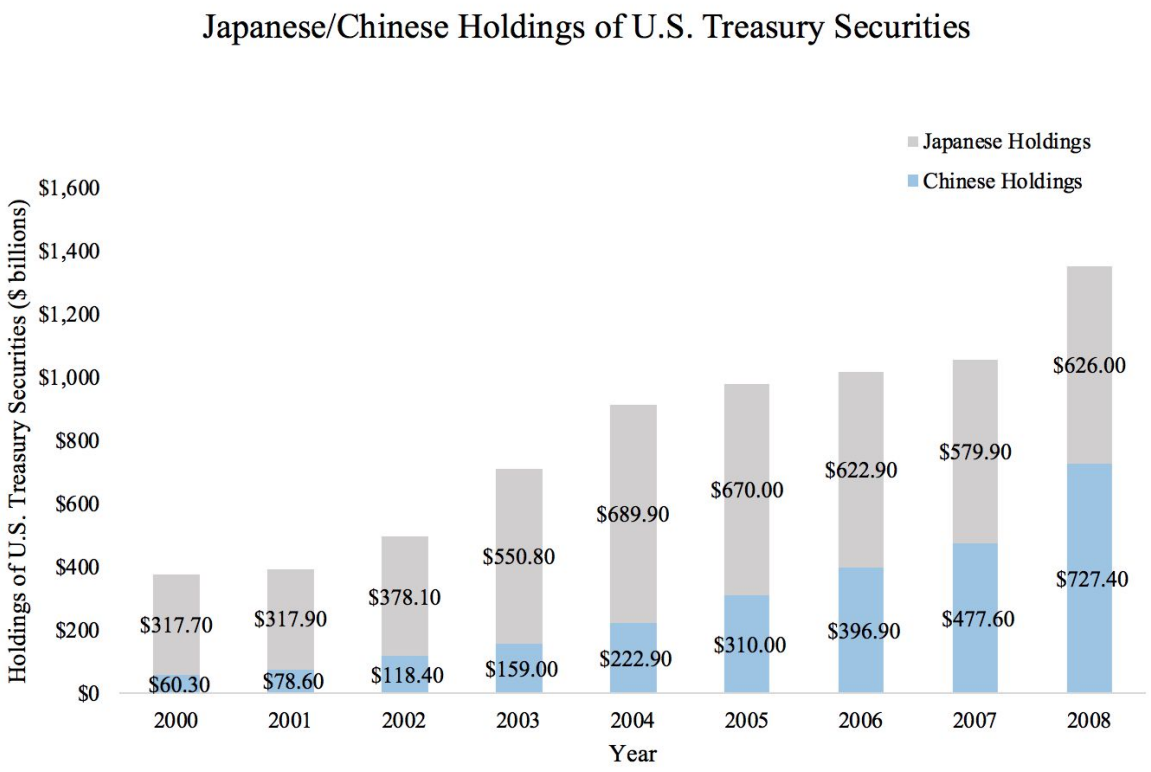

*Figure 2.7 - Source of Data: https://ticdata.treasury.gov/Publish/mfhhis01.txt - * year end data. Majority of U.S. Treasuries owned by China have maturities exceeding 10 years; although specific data is not available, it is known that the overwhelming majority of U.S. debt held by foreign central banks was in the form of bonds (+10-year maturities)*

Treasury holdings would contribute to a decrease in the yields for long-term U.S. debt. In 2004, Ben Bernanke,Vincent R. Reinhart, and Brian P. Sack wrote that "we find evidence supporting the view that asset purchases in large volume by a central bank would be able to affect the price or yield of the targeted asset" (Bernanke,Reinhart, Sack, 2004). They are not explicitly speaking to the increase in Chinese and Japanese balance sheet holdings of long-term U.S. Treasuries, however the actions of China and Japan and the findings of Bernanke, Reinhart, and Sack, are consistent. Although, as said before, and despite the evidence in support for MST, we do not attribute MST to being a total, but only a partial explanation for Greenspan's Conundrum. If we are to attribute the loss of control over long

term rates to a combination of DPT, UET, and MST, we are able to build a more complete explanation for Greenspan's Conundrum.

2.6 Ben Bernanke, The Financial Crisis (2008), and Credit/Quantitative Easing

The monetary policy actions following the financial crisis of 2008 were extreme. In September 2007, the target rate was lowered by 50bps, then lowered by another 300bps by the spring of 2008, and then by an additional 100bps in October 2008 (Bernanke 2009). By December, the federal funds target rate was reduced to 0 - 0.25 percent (Kohn 2009). Bernanke had reached the lower bound of the Federal funds rate so the next action by the Fed was to use monetary policy in order to provide short-term liquidity to markets to support credit as “liquidity provision by the central bank reduces systemic risk by assuring market participants that, should short-term investors begin to lose confidence, financial institutions will be able to meet the resulting demands for cash without resorting to potentially destabilizing fire sales of assets" (Bernanke 2009).

In November of 2008, the FOMC had announced that the Federal Reserve would be engaging in a program labeled Large Scale Asset Purchases (LSAP), in which the Fed would purchase mortgage backed securities and agency debt to provide short term liquidity to markets and would eventually begin to purchase long-term U.S. Treasuries (D’Amico, English, López-Salido, Nelson, 2012). The first round of LSAPs lasted until March 2010, which resulted in the Federal Reserve adding $175B worth of agency debt, $1.25T in MBS products, and $300B in long-term U.S. Treasuries; the Fed would also reinvest principal

payments from agency debt and MBS products into long-term U.S. Treasuries (see Federal Reserve Bank of New York, Large-Scale Asset Purchases, programs archive). The second round of LSAPs would continue to add to the Fed's balance sheet, adding $600B in long-term U.S. Treasuries from November 2010 to June 2011 (see Federal Reserve Bank of New York, Large-Scale Asset Purchases, programs archive).

In September 2011, the FOMC announced that they would be selling $400B in short-term U.S. Treasuries (maturities equal to or less than 3 years) in order to continue purchases of long-term U.S. Treasuries (maturaties equal to or greater than 6 years) (Mace 2013). The program would continue through 2012, and would be labeled "the Maturity Extension Program, commonly known as Operation Twist, included purchases of $667 billion in Treasury securities with remaining maturities of 6 years to 30 years, offset by sales of $634 billion in Treasury securities with remaining maturities of 3 years or less" (see Federal Reserve Bank of New York, Large-Scale Asset Purchases, programs archive).

These events are deeply reminiscent of Bernanke's remarks in 2004 (Bernanke, Reinhart, Sack, 2004) regarding the effects of asset purchases of central banks, when conducted in high volumes. Bernanke, Reinhart, and Sack, conclude that there is evidence to support the statement that central banking activity such as the Large-Scale Asset Purchase program, possess the ability to change the yield, rate, and price, of the asset that is being targeted; or, in other words, that the Fed's efforts to provide liquidity to financial markets will have an effect on prices. In this case, this can be seen as true. When the Fed decided to begin to add roughly $300B, then later an additional $600B worth of long-term U.S. securities to its balance sheet, yields on the targeted maturities fell in response. MST

would suggest that the decrease in supply of treasuries with longer maturities due to LSAP's, should suppress yields. Edison Yu from the Federal Reserve Bank of Philadelphia writes that "yields on Treasury bonds of the same maturity as those purchased through QE fell the most around QE events. For example, QE1's purchases focused on two- to 10-year Treasury bonds, whose yields dropped more around the time of the QE1 announcement than yields for other maturities did. This difference indicates market segmentation and that QE worked by lowering the supply of bonds of particular maturities" (Yu, 2016, pg. 9-10). So we know that MST can be supported by LSAP efforts, but what about expected movements in the short end of the curve? We can combine the findings from MST during this time period, with UET in order to explain the changes in future short-term rates through changes in current long-term rates. The effects of UET can be more closely linked with forward guidance measures. Following the announcement of the LSAP in November of 2008, expected Fed funds rate fell, due to an expectation of declines in future long-term yields. Yu finds that "the estimated signaling effect [the announcement of LSAP's] from lowering investors' expectations accounted for a significant portion of the decrease in 10-year bond rates — about 20 basis points for QE1, which was about 20 percent of the total change in yields over the same time (the 10-year Treasury yield dropped 107 basis points two days after the announcement of QE1)" (Yu, 2013, pg. 9). These outcomes of both the expectations, and actual effects of LSAP's, provide a clear picture of the relationship between MST and UET during this period. MST would indicate to investors that the yields on long-term U.S. Treasuries would fall due to a $300B purchase in open market operations, which would then under UET lead investors to believe that the

short-term rates would then fall as a result, which can be reflected in the fall of the expected Fed funds rate. The DPT also continues to be a part of the story as the duration premium would continue to fall, but for other reasons than what have been previously associated with the decline in the duration premium (i.e. great moderation, market stability). The explanation as to why the duration premium is declining in this period is more related to that of the supply and demand story of MST, although from more of a supply side perspective. In 2013 Bernanke delivered a speech and explained that "as the securities purchased by the Fed become scarcer, they should become more valuable. Consequently, their yields should fall as investors demand a smaller term premium for holding them" (Bernanke 2013). Transitioning to the end of the credit/quantitative easing period, we can see that all three theories can work together to explain the yield curve, and that one theory is not sufficient to support the entire story.

2.7 Janet Yellen's Exit of Credit/Quantitative Easing and Effective Lower Bound

Janet Yellen's tenure was notably short, being nominated as Chair of the Federal Reserve from 2014-2018. Yellen became responsible for guiding the Fed funds rates out of lower bound territory, as well as reducing the size of the Fed's balance sheet and unloading assets from the LSAP's. Control over inflation and monitoring unemployment were two important objectives for the Yellen regime, specifically maintaining a target inflation rate of 2%. From 2011, to 2015, the annual inflation rate had dropped from 3% to 0.7%. Inflation expectations in 2015 were held low as temporary but substantial decreases in oil

prices and oil futures markets depressed inflation and expected inflation (Fischer, 2015). In December of 2015, the Fed for the first time in seven years had raised the target range of the Fed funds rate, this time by 0.25%. Also, the Fed was monitoring inflation compensation through a variety of metrics but most notably they were monitoring Treasury Inflation Protected Securities (TIPS) against actual U.S.Treasuries. But in terms of the term structure, the yield curve was representing a normal and upward sloping curve.

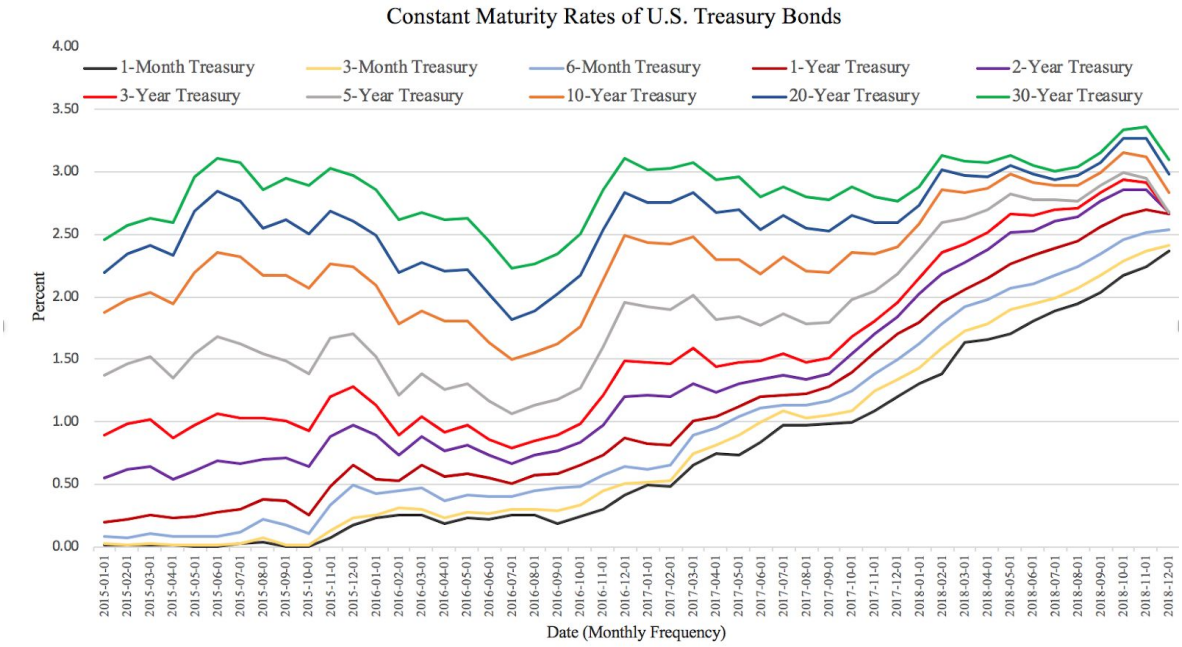

Figure 2.8 - Source of Data: https://fred.stlouisfed.org

Through 2016, not much had changed in terms of the Fed's attitude towards interest rates, with only one 25bp increase in the Fed funds rate in December. 2017 brought three rate hikes in March, June, and December, a total of 75bps bringing the target rate to 1.25%-1.75%. Despite these increases, we can see in Figure 2.8, the term premium decreased 2017 and the rates for long term yields were decreasing. In 2017 the 30-Year Treasury rate dropped from 3.02% in January, to 2.77% by December. Jerome Powell who

at the time was a governor at the Fed, continued the decreasing term premium narrative in order to explain the low long-term rates. In 2017 Powell comments that

> "The downward trend in nominal term premiums likely reflects both lower inflation risk and the fact that, with inflation expectations anchored, nominal bonds have become an increasingly good hedge against market risk. That has made bonds a more attractive investment and reduced the term premium . . . Regulations now require many financial institutions to hold more safe, high-quality liquid assets, which likely has pushed down term premiums further. Global factors may have put downward pressure on term premiums because of anxiety about the foreign outlook, which may have increased demand for U.S. assets, or because low rates abroad have depressed U.S. term premiums through a global portfolio balance channel."
>
> (Jerome H. Powell, (January 07, 2017), "Low Interest Rates and the Financial System", *At the 77th Annual Meeting of the American Finance Association, Chicago, Illinois)*

The relative attractiveness of long-term U.S. Treasuries in comparison to other asset classes that Powell is describing is also known as a flight to quality; an event in which investors tolerance for risk has diminished, and as a result reposition their portfolios with assets that are may not being providing as much yield as their previous investments, but will provide investors with positions that carry less risk. Powell mentions that expected inflation is stable, which provides investors with a favorable environment to engage in a flight to quality situation. It is also noteworthy that an investor will exercise a flight to quality with assets that match in maturity. So in this particular situation, Powell is suggesting that investors unloaded their positions in other fixed income products, for instance long maturity high-yield bonds, in exchange for U.S. Treasuries with similar maturities.

The term premium was affected in a similar fashion that it had been in the case of increased Chinese and Japanese high volume allocations of U.S. Treasuries in the early 2000's. The only difference is that in the example of China and Japan, allocations of nearly

$700B in a 7 year span, resulted in a market shift that was only able to affect the term premium in a modest amount; yet the flight to quality episode that Powell describes, which is notably smaller in volume in terms of allocations of U.S. debt by investors, is an unlikely and incomplete explanation that can account for the decrease in the term premium that Powell and the Fed had been observing. If institutional traders in combination with retail investors were engaging in a flight to quality, it would need to be a dramatically large allocation of U.S. Treasuries, similar in size to the Chinese and Japanese central bank's allocations, in order to result in a sizable impact on the term premium; comparing the increase in volume of retail and institutional investment in U.S. Treasuries due to a flight to quality to the activities of two of the largest central banks over the span of 7 years engaging in an aggressive allocation event of U.S. Treasuries seems unlikely.

Although the impact of a flight to quality event by investors could, under the MST, contribute to depressed rates for long-term treasuries, it cannot support a full explanation for decreases in the rates of long-term Treasuries. Inflation during this time period had been underwhelming initially (0.12% 2014 & 1.26% 2015), but by 2016 had risen to 2.13%, exceeding the Fed's target by 0.13%. Inflation expectations were also exhibiting their confidence in economic health from an inflation perspective as 5-Year expected inflation over the next five-year period was hovering right around 2%, with a range of 1.82% - 2.22% from January 2017 to December of 2018.

The DPT is consistent with expected inflation and the decline in the term premium during this time period. The ability of Janet Yellen to control and keep inflation around 2% was being expressed by expectations of inflation, and could also be reflected by the

decreases in the term premium. The decreases in the term premium could be, in addition to the MST contributions, due to a decrease in the duration premium demanded by investors. The demanded duration premium could have decreased during this time due to the diminishing risks associated with the duration premium, inflation specifically. Stable expected inflation would reflect a decrease in future duration risk associated with long-term securities.

The UET could contribute to the decline in the term premium in addition to DPT and MST, but would take a different approach to future expectations than the LPT. UET suggests that expectations of future short-term rates will fall as a result of low future inflation and is reflected by low long-term rates, whereas LPT had suggested that the declining term premium was a reflection of less duration and inflation risk. The 30-Year Treasury rate had fallen from 3.13% in 2018 to 3.03% by the end of the year. Under UET, the term premium was falling due to investor expectations about future short-term rates, and this was being reflected by a decline in long-term rates in 2018. Either way, both DPT and LPT were supporting the same results, although use different explanations to support the results.

However, during Yellen's tenure, UET would not support the term structure until 2019, as short-term rates through 2018 (end of Yellen's tenure) did not decline, instead they increased modestly. In chapter 2.8, we will see that it wasn't until Q2-Q3 2019, that we would see short-term rates begin to fall with Fed funds target rate cuts three times in 2019 (25bp cuts August, September, October) to a final target rate of 1.5% - 1.75%.

2.8 The Jerome Powell Regime

Jerome Powell had taken over as Chairman of the Fed in February 2018, and the Fed became comfortable with the consistency of inflation and had consequently raised their Fed funds targets on four occasions in 2018 (25bp increases in March, June, September, December), resulting in a target range of 2.25% - 2.5% by the end of 2018. (see Board of Governors of the Federal Reserve System, Open Market Operations). As a result, short-term yields were increasing, however long-term yields were relatively flat through September. From a DPT standpoint, the duration premium for long-term bonds was diminishing as was the term premium. A decrease in the term premium could still be explained by DPT through consistency in inflation expectations, and investor confidence in the Fed's ability to control over inflation. If investors were confident that inflation will be stable or decreasing and other risks to markets were decreasing, then that would be reflected in a decreased demand for risk compensation. UET during this time period supports the decline of the term premium during this time period as long-term yields which were being held flat relative to short-term yields, due to expectations that future short-term rates would fall. Following the rate cuts of August and September, the term premium had begun to increase, as spreads between 2-Year and 10-Year Treasuries rose from 0% on August 30, to 0.34% by the end of December.

DPT would explain the decline in the term premium through 2018 by maintaining the position that the financial and economic climate suggested less risk for long maturity bonds, and as such would be reflected by a decreased duration premium demanded by investors. The 5-Year, 5-Year Forward Inflation Rate would decline in a small amount

from 2.15% in January to 2.03% in December, which would support the notion that there was less inflation risk, and therefore a decrease in the demanded duration premium. 2019 showed similar behavior in the 5-Year, 5-Year Forward Inflation Rate, and would record a small decline of 0.15% (January - December 2019).

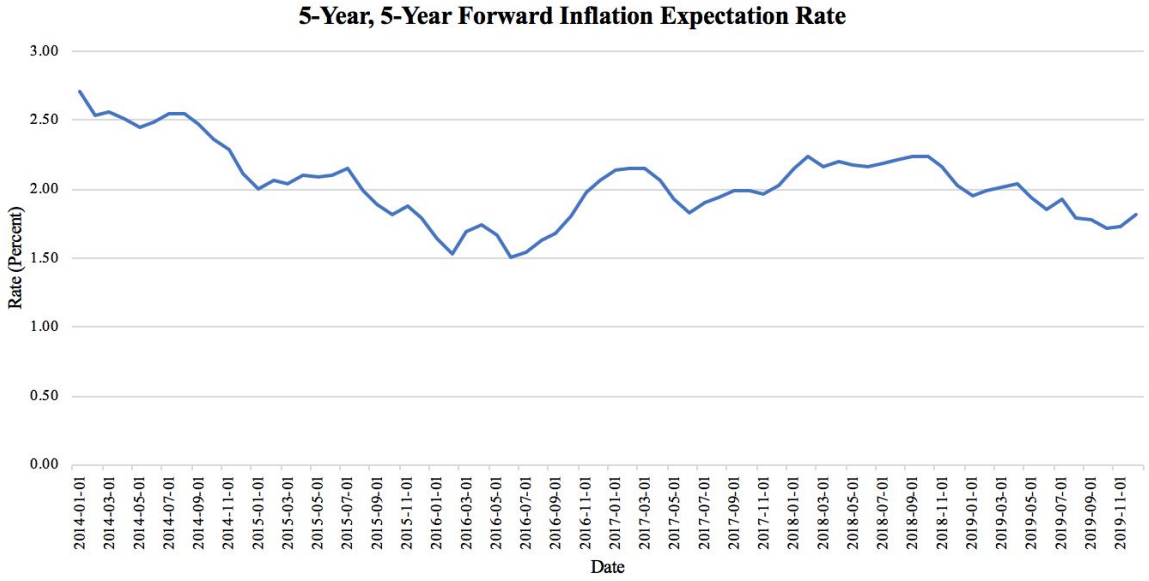

Figure 2.9 - Source of Data: https://fred.stlouisfed.org/series/T5YIFR#0

It most certainly is possible that this could be the case, and this explanation would be favorable for the Fed, however UET would suggest that the decline in the term premium could be reflective of decreases in future short-term rates, due to low expected inflation. UET during this time period supports the decline of the term premium during this time period as long-term yields which were being held flat relative to short-term yields, due to expectations that future short-term rates would fall. Following the rate cuts of August and September, the term premium had begun to increase, as spreads between 2-Year and 10-Year Treasuries rose from 0% on August 30, to 0.34% by the end of December. The yield curve in the end of 2018 through 2019 began to better support the UET as long-term yields had held relatively steady as the term premium was still declining. Around

April-May, the yield curve began to invert, which began to signal that future short-term rates would decline. Additionally, inflation had dropped from 2% in April to 1.6% by June. July marked the beginning of import tariffs that would be imposed on China, which further drove down expectations about future inflation and enhanced the possibility of future rate cuts. In August, the Fed had cut the Fed funds target rate by 25bps. Two more rate cuts followed in October, and December resulting in a new target rate of 1.5% - 1.75%. Bond markets had reacted accordingly as the rate on 3-Month Treasury bonds had dropped from 2% in August, to roughly 1.5% in December.

Conclusion

This paper has shown how the Unbiased Expectations Hypothesis, the Duration Premium Theory, and Market Segmentations Theory, provide investors with explanations of the term structure of interest rates. It has also been shown how all of the theories can be utilized in order to provide a more complete explanation of the yield curve. Further, the narrative of the Federal Reserve and their explanation for the term structure of interest rates has been analyzed and we have added to the Fed's explanations by introducing all of the theories in each of these analyzed periods. Although the explanations of the Fed have been validated, the other theories (mainly UET) have been validated in explaining the term structure of interest rates. Challenges that have been presented to each Federal Reserve Regime have been covered, and we have analyzed how monetary policies have shaped investor activities, and expectations. To conclude, it is favorable to investors to consider all

three theories when analyzing the yield curve, in contrast to only one, to build a more complete framework of the term structure of interest rates.

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