Liquidity ‘life cycle’ in US Treasury bonds

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Abstract

This paper examines the predictable behavior of the liquidity premia involved in the prices of the U.S. government bonds. We use a measure of the expected future liquidity premium, in addition to the current liquidity premium. Liquidity of these fixed income securities goes over different stages throughout their life. A bond is actively traded after issued. It is the on-the-run for its time to maturity. After other new issues burst into the market, it becomes an off-the-run, and its trading activity loses intensity. A high portion of the issue is kept in investors’ inactive portfolios and its trading fades out. Through the liquidity ‘life cycle’ function, we are able to estimate the current liquidity and expected future liquidity. Using the GovPx dataset, we analyze the influence of both variables in the observed yield spreads of U.S. Treasury bonds. We find that expected future liquidity affects bond prices more than current liquidity.

Keywords: liquidity, fixed income, pricing, life cycle, government bonds

EFMA classification codes: 340, 550, 370, 360, 310

1 Introduction

Liquidity is a key factor in the pricing of fixed income securities. A number of papers emphasize their role. Since the Amihud and Medelson (1991)'s seminal work, there have been many studies showing that security's liquidity is priced in Treasury markets[1]. The observed differences in prices imply that markets price liquidity. Investors are willing to pay a higher price for the most liquid assets. Otherwise, the most liquid securities are traded with a liquidity premium that implies higher price and therefore lower yield to maturity.

The traditional static liquidity analysis examines differences in liquidity between assets, i.e. they are due to different bond characteristics as well as bond's fundamentals, such as bond age, time of maturity, amount outstanding, and coupon rate. Recent papers propose liquidity measures focus on the bid-ask spread behavior, such as different adaptations of the Roll measure (1984) to the fixed income market, or on the price impact of a trade per unit traded, i.e. Amihud (2002) illiquidity measure. The recent availability of transaction prices in the secondary U.S. corporate bond markets, i.e. the TRACE data set, has allowed the development of this new literature. This literature often tries to translate stock market liquidity measures to the new potentially analyzable data set. As bonds are by far much less liquid assets, some modifications are needed. These measures do not consider the life cycle of the bonds.

We emphasize that market participants take into account that a bond has a finite life and its liquidity goes through differences stages. The trading activity of two government bonds, all characteristics equal except time to maturity, can be equally intense during a day, but liquidity premia involved in their prices should probably be different. The reason is that market participants consider the potential liquidity of each bond. The buyer of the oldest bond is wishing to pay a lower price that he would pay for the youngest bond since its expected future liquidity is lower. In this sense, Goldreich, Hanke and Nath (2005) observe the relevance of the future liquidity, and Díaz, Merrick and Navarro (2006) analyze its impact on prices of Spanish government bonds.

[1] Kamara (1994), Fleming (2003), Chen, Lesmond, and Wei (2007), Pasquariello and Vega (2009), Favero, Pagano, and Bon Thadden (2010), Jankowitsch, Nashikkar and Subrahmanyam (2010), Goyenko, Subrahmanyam and Ukhov (2011), Lin, Wang, and Wu (2011), Bao, Pan, and Wang (2011), Dick-Nielsen, Feldhütter, and Lando (2011) study different aspects about liquidity in debt markets.

The main objective of this paper is to examine the yield spreads impact of the whole liquidity life cycle in the U.S. Treasury bond market. To that purpose we first select the individual market share or turnover of each bond as measure of current liquidity. In previous literature there are several proxies used to measure liquidity bond, since there is no direct measure to quantify liquidity.[2]

Then, we modelize the link between bond liquidity and bond age. Sarig and Warga (1989) observe that bond liquidity depends inversely on age. The on-the-run bond, i.e. the just-issued or the most recently issued bond for certain maturity, is by far the more liquid bond. It focuses the trading activity of the market. All institutional investors are wishing to include this bond in their portfolios. The higher the liquidity, the higher the liquidity premium included in the price to pay for the bond. But in the next future, the bonds will become an off-the-run bond when a new on-the-run bond is issued. This means that our measurement of liquidity, the individual bond market share, changes predictably over time. Because of this pattern, we can see that liquidity covaries with bond's age in a regular and predictable way over the time. If bonds go through a 'life cycle' we can say that also bonds liquidity goes through a similar 'life cycle' [3].

Therefore, the next objective of this work is to model this pattern that will let to measure current liquidity and hence let us to estimate expected future liquidity. With these two measures of liquidity, we can quantify the effect of the whole liquidity life cycle in the yield spreads of U.S. Treasury bonds, not only the influence of current liquidity, as has been done by the most of previous literature[4]. We test empirically which of these two measures further influences the observed yield spreads.

Our paper contributes to the existing literature in different ways. We use a liquidity 'life cycle' function to quantity the observed yield spreads in U.S. Treasury

2 Many studies have focused on identifying the most appropriate for measuring public debt securities liquidity (Fleming (2003)), and corporate debt securities (Amihud (2002), and Jankowitsch, Nashikkar and Subrahmanyam (2010)), and turn on how these measures are key factors in the assets prices.

3 Expression used in the work of Diaz, Merrick and Navarro (2006) to reflect the pattern of Spanish fixed income securities liquidity as a function of bond age.

4 The previous empirical literature has assumed that a bond's current liquidity remains at the same level over the time, with a few exceptions include Goldreich, Hanke and Nath (2005) who show that yield spreads in U.S. Treasury notes depends primarily on future liquidity, and Diaz, Merrick and Navarro (2006) who study the importance of expected future liquidity in Spanixh bond liquidity premiums.

fixed income securities. Also, we link bond liquidity with bond age, and distinguish bonds by term to maturity, so we examine both Treasury notes and Treasury bonds. We are able to investigate which liquidity measure drives the observed yield spreads on each term to maturity.

This paper is related to Goldreich, Hanke and Nath (2005), who show that expected future liquidity is the main component of the liquidity premium observed between on-the-run and off-the-run bonds. Their results are only for U.S. two-year notes, while ours are extensive to the rest of notes and bonds. Also we measure expected future liquidity using a liquidity ‘life cycle’ function. Our work is also related to Diaz, Merrick and Navarro (2006) who analyze the market liquidity of Spanish Treasuries and the impacts of the changes before the entry into the European Economic and Monetary through the role of a bond liquidity ‘life cycle' function. We extend our analysis to U.S. debt market.

Our paper is organized as follows. Section 2 defines the concept of liquidity and illiquidity, and its importance in debt markets. Section 3 refers to the factors explaining liquidity and liquidity measures used in the literature. Section 4 analyzes the specific characteristics of U.S. debt market. In section 5 we show the empirical analysis. And section 6 includes the conclusions.

2 Liquidity in debt markets

Liquidity is a key aspect in determining the price and the return offered by fixed income assets. A basic definition is that which defines liquidity as the ability of an asset to be turned into money. We say that an asset is liquid if it can be traded on the market in a short period of time without causing significant losses in value. Fleming (2003) includes a definition of liquidity from O'Hara (1995) and Engle and Lange (1997): a liquid market is defined as one in which transactions can be done without cost.

In practice, a market with low transaction costs is known as a liquid market, while one in which there are high transaction costs is called illiquid one. Measuring these costs is not simple, since they depend on numerous factors like the size of the negotiation, time, place of negotiation, and partners.

In particular, high liquidity would indicate that the asset can be negotiated quickly and without significant loss of value. In this case investors would expect higher asset prices, and lower return. In contrast, lower liquidity means that the cost to trade an asset will be high, so investors would expect lower prices, and in contrast a higher profit. Moreover, any newer issue of Treasury securities attracts the interest of investors, so that attracts the most of the market liquidity and trading volume. Therefore we could expect an inverse relationship between bond age and liquidity, because the newer ones, referred to as being 'on-the-run', are more liquid and the older ones, referred to 'off-the-run', are much less liquid. The higher the age is, the lower the liquidity is.

Liquidity is important for investors trading in securities markets and in public debt markets. The measurement and monitoring of liquidity are relevant for making investment decisions. In times of financial turmoil, there is the phenomenon known as 'flight to quality'[5], where some market participants abruptly decrease their portfolio exposure to securities bearing credit risk. They prefer safer securities, free of default risk and credit risk. Another phenomenon observed in financial markets is known as 'flight to liquidity'. It means that investors put their interest in highly-liquid securities such as government fixed income securities. They prefer higher liquid securities rather than less-liquid securities.

Therefore, it is necessary to quantify the securities liquidity in debt markets. There are previous works in a clear objective: to determine the most appropriate measures of liquidity[6]. It depends on several factors that influence the liquidity of fixed income assets, such as, among others, the outstanding balance, age, residual maturity, the economic cycle, the interest rates volatility, expected future liquidity or the trading market.

5 As examples Bernanke and Gertler (1995), Longstaff (2002), Vayanos (2004) and Beber, Brandt and Kavajecz (2008).

6 Fleming (2003) analyzes among several measures the most suitable for measuring liquidity in U.S. fixed income securities.

3 Liquidity measures for Treasury securities market in previous literature.

Measures in previous literature to quantify the liquidity of government bonds are very different. Recently, the availability of high-frequency data has allowed for detailed analysis of Treasury market liquidity. Measures such as trading volume, trading frequency, bid-ask spreads, quote sizes, trade sizes, price impact coefficients, and on-the-run/off-the-run yield spreads can be used to measure liquidity in a more effective way.

Fleming (2003) examines some measures used in the literature to quantify the liquidity in order to determine which one assess and track liquidity better. His analysis reveals that the bid-ask spread, one of the most widely used in the literature as a proxy for liquidity, is a useful tool for assessing and tracking Treasury market liquidity.

Diaz and Navarro (2002) use measures such as trading frequency and turnover to measure liquidity in the Spanish debt market. Goldreich, Hanke and Nath (2005) use the average spread quoted bid-ask, the average effective spread bid-ask, the average size quoted, the number of quotes per day, the number of trades per day, or the daily volume among others to measure liquidity in the U.S Treasury market. They find evidence that the quoted spread and measures of market trading activity adds the greatest explanatory power and the other measures, depth measures, add little explanatory power to explain the yield difference between off-the-run and on-the-run notes. Diaz, Merrick and Navarro (2006) use the individual market share of each type of issue and the status of the issue in the Spanish debt market. Another measure used by Goyenko, Subrahmanyam and Ukhov (2008), is the spread quoted bid-ask spread, which relates the price range the average effective spread. Ejsing and Sihvonen (2009) use trading volume, quoted depth and the bid-ask spread quoted, besides the "liquidity ratio" proposed by Bollen and Whaley (1998).

Also, there are some measures of illiquidity used in the previous literature, Amihud (2002) proposes a measure of illiquidity in the case of equities, which may be applicable to fixed income. Johnson (2008) uses the bid-ask spread and price impact illiquidity measure in government bonds. Bao, Pan and Wang (2011) propose a measure of illiquidity but for the case of corporate bonds, as is the covariance between changes in prices.

We will use the individual market share to measure bond liquidity. Our database gives information about trading volume. It is an indirect but widely measure of market liquidity. The individual market share is the ratio between a bond trading volume and the total market trading volume, for all outstanding issues. When we estimate the individual market share, we do this distinguishing by issues, and so we will able to compare the bond-level liquidity among different issues by term to maturity. Furthermore, we link bond-level liquidity and bond age, and thus it allows us to examine the evolution of liquidity over time, through its liquidity 'life cycle'.

4 U.S. debt market: Description and Data

4.1 U.S. debt market

U.S. Treasury securities are default risk-free debt instruments issued by the U.S. government. These securities play an important, even unique, role in international financial markets because of their safety, liquidity and low transaction costs.

It is the largest debt market in the world, both by trading volume and by number of investors and trades. In April 2001, the amount outstanding of U.S. government debt was more than $5 billion, and of this quantity more than $3.2 billion was on public holds, and $2.8 billion was traded on financial markets. In August 2007, it was more than $9 billion. In December 2011, the amount outstanding of U.S. government debt has been more than $15 billion. This increase suppose near 150%. The U.S. Treasury sells securities through auctions on a regular schedule to finance the national debt. Government bonds offer the security and safety of the U.S. federal government. These bonds, as they provide greater security, offer less interest than other bonds with similar characteristics in term and / or maturity.

There are three types of government securities in the U.S. Treasury market[7]:

[7] Mizrach and Neely (2008) analyze the microestructure el the U.S. Treasury Market, and describe the types of debt instruments: Treasury Bills, Treasury Notes, Treasury Bonds and STRIPS.

1) *Treasury Bills*: These securities have the shortest maturity, a year or less. The Federal Reserve Bank of U.S. sells these bills at discount in denominations of $10.000 to $1 million. 21% of the debt traded in the market in April 2001 is composed by bills with a maturity of one year or less, and in August 2007, 22.6% of the marketable U.S. debt is in bills.

2) *Treasury Notes*: These securities have intermediate maturities: 2-, 3-, 5-, 7- and 10-year notes. Notes pay coupons every six months. Bonds with an original maturity of 2- and 5-year are auctioned monthly the last day of each month. So that at any time there are 24 issues outstanding. The sale is also done through auctions, and is subsequently traded in secondary markets. Notes with an original maturity of 3- and 10-year are auctioned quarterly (February, May, August and November), on 15th February, May, August and November. 7-year notes are auctioned quarterly, and its maturity date is on 15th January, April, July and October. In April 2001, 52% of the debt traded on financial markets is for bonds with intermediate maturities, and made up 54.7% of the debt in August 2007.

3) *Treasury Bonds*: These bonds have the longest maturity term, 20 and 30 years and pay interest every six months. The sell is also done through auctions conducted by the Federal Reserve Bank, and the negotiation of these bonds in the secondary market is quick and easy. The bonds maturing in 20 years, issued quarterly, bonds with a maturity of 30 years are also issued quarterly and are due the 15th of February, May, August and November. 21% of negotiated debt in April 2001 on markets corresponds to longer-term bonds.

Thus, issuance cycles are different across securities. The following table shows schematically the calendar with the issue and maturity dates of each type of U.S. Treasury securities:

Table I. Release Schedule

	2 years bond	3 years bond	5 years bond	7 years bond	10 years bond	20 years bond	30 years bond
January	Issue (l.d.) Maturity (l.d.)		Issue (l.d.) Maturity (l.d.)	Issue (15) Maturity (15)		Issue (f.d.)	
February	Issue (l.d.) Maturity (l.d.)	Issue (15) Maturity (15)	Issue (l.d.) Maturity (l.d.)		Issue (15) Maturity (15)	Maturity (15)	Issue (15) Maturity (15)
March	Issue (l.d.) Maturity (l.d.)		Issue (l.d.) Maturity (l.d.)				
April	Issue (l.d.) Maturity (l.d.)		Issue (l.d.) Maturity (l.d.)	Issue (15) Maturity (15)		Issue (f.d.)	
May	Issue (l.d.) Maturity (l.d.)	Issue (15) Maturity (15)	Issue (l.d.) Maturity (l.d.)		Issue (15) Maturity (15)	Maturity (15)	Issue (15) Maturity (15)
June	Issue (l.d.) Maturity (l.d.)		Issue (l.d.) Maturity (l.d.)				
July	Issue (l.d.) Maturity (l.d.)		Issue (l.d.) Maturity (l.d.)	Issue (15) Maturity (15)		Issue (f.d.)	
August	Issue (l.d.) Maturity (l.d.)	Issue (15) Maturity (15)	Issue (l.d.) Maturity (l.d.)		Issue (15) Maturity (15)	Maturity (15)	Issue (15) Maturity (15)
Septembre	Issue (l.d.) Maturity (l.d.)		Issue (l.d.) Maturity (l.d.)				
October	Issue (l.d.) Maturity (l.d.)		Issue (l.d.) Maturity (l.d.)	Issue (15) Maturity (15)		Issue (f.d.)	
November	Issue (l.d.) Maturity (l.d.)	Issue (15) Maturity (15)	Issue (l.d.) Maturity (l.d.)		Issue (15) Maturity (15)	Maturity (15)	Issue (15) Maturity (15)
December	Issue (l.d.) Maturity (l.d.)		Issue (l.d.) Maturity (l.d.)				

In parentheses the issue and / or maturity day. f.d. refers to the first working day of the month, and l.d. refers to the last working day.

The different types of U.S. Treasury issues, depends on funding needs and monetary policy objectives. From 1993 U.S. Treasury didn't issue notes with 7-year maturities. In 1998 U.S. Treasury suspended the 3-year notes issuance, and resumes its issuance again in 2003. Also on 2006 continue the 30-year bonds issuance that had been suspended in 2001. The same goes for the 20-year bond, that didn't had issuance in 1986 and U.S. Treasury resumes its issuance again in 2004[8].

Most U.S. debt securities consist of medium-term and long-term maturity, being about 50% of the total debt issued. The following figure shows how emissions are distributed and the holders thereof:

[8] Most of the studies on U.S. Treasury securities are focused on bonds with maturities of 2, 5 and 10 years, as are the emissions that have never been interrupted, with regular broadcast dates, and are available greater number of observations and information. Goldreich, Hanke and Nath (2005) use data from 2-year bonds, Pasquariello and Vega (2009) use data from bonds to 2, 5 and 10 years, as Fleming 2003), Strebulaev (2002) uses data from bonds 2, 3, 5 and 10 years, which are those with more regular releases.

MONTHLY STATEMENT OF THE PUBLIC DEBT OF THE UNITED STATES

APRIL 30, 2001

(Details may not add to totals)

TABLE I -- SUMMARY OF TREASURY SECURITIES OUTSTANDING, APRIL 30, 2001

(Millions of dollars)

Title	Amount Outstanding: Debt Held By the Public	Amount Outstanding: Intragovernmental Holdings	Totals
Marketable:			
Bills	619,072	40	619,112
Notes	1,492,282	1	1,492,283
Bonds	622,498	459	622,957
Inflation-Indexed Notes	89,165	0	89,165
Inflation-Indexed Bonds	39,355	0	39,355
Federal Financing Bank [1]	0	15,000	15,000
Total Marketable [a]	**2,862,371**	[2] **15,500**	**2,877,872**
Nonmarketable:			
Domestic Series	29,995	0	29,995
Foreign Series	24,536	0	24,536
R.E.A. Series	1	0	1
State and Local Government Series	154,746	0	154,746
United States Savings Securities	185,198	0	185,198
Government Account Series	37,759	2,347,868	2,385,627
Other	3,372	0	3,372
Total Nonmarketable [b]	**435,608**	**2,347,868**	**2,783,476**
Total Public Debt Outstanding	**3,297,980**	**2,363,368**	**5,661,348**

Figure 1. Summary of Treasury Securities Outstanding, April 30, 2001 in $ million.
Source: The Bureau of the Public Debt. (http://www.publicdebt.treas.gov/opd/opdm042001.pdf)

MONTHLY STATEMENT OF THE PUBLIC DEBT OF THE UNITED STATES

DECEMBER 31, 2011

TABLE I -- SUMMARY OF TREASURY SECURITIES OUTSTANDING, DECEMBER 31, 2011

(Millions of dollars)

Title	Amount Outstanding: Debt Held By the Public	Amount Outstanding: Intragovernmental Holdings	Totals
Marketable:			
Bills	1,519,462	1,056	1,520,517
Notes	6,598,894	6,162	6,605,056
Bonds	1,060,111	4,001	1,064,112
Treasury Inflation-Protected Securities	738,532	223	738,755
Federal Financing Bank [1]	0	8,441	8,441
Total Marketable [a]	**9,916,999**	**19,884** [2]	**9,936,882**
Nonmarketable:			
Domestic Series	29,995	0	29,995
Foreign Series	2,986	0	2,986
State and Local Government Series	152,058	0	152,058
United States Savings Securities	185,278	0	185,278
Government Account Series	159,019	4,754,900	4,913,919
Hope Bonds [19]	0	493	493
Other	1,328	0	1,328
Total Nonmarketable [b]	**530,664**	**4,755,394**	**5,286,058**
Total Public Debt Outstanding	**10,447,663**	**4,775,277**	**15,222,940**

Figure 2. Summary of Treasury Securities Outstanding, December 31, 2011 in $ million.
Source: The Bureau of the Public Debt. (http://www.publicdebt.treas.gov/opd/opdm122011.pdf)

In terms of trading activity, the U.S. Treasury debt is one of the largest sectors of the bond market. The total volume of debt and size of any individual issue is higher compared to the other bond market sectors [9].

Since April 2001 to December 2011, the amount outstanding held by the public has changed: from 21.6% for bills, 52.7% for notes and 21.7% for bonds on 2001, to 15.3% for bills, 66.5% for notes and 10.7% for bonds on 2011.

4.2 Stages of the U.S. Treasury Market

Treasury securities go through different phases: *when issued, primary, on-the-run* and *off-the-run*. Each of these stages presents different market structures.

The primary market is where the debt is sold through auctions to investors. The Treasury publishes a calendar with upcoming tentative auction dates on the first Wednesday of February, May, August and November and bids must be submitted 30 days in advance before of the auction. In practice, however, the Treasury only announces firm auction information several days before, and most bids are submitted at that time. The short-term bills are auctioned weekly, 2- and 5-year notes are auctioned monthly, and 3-, 7-, and 10-year notes and 30-year bonds are auctioned four times a year. So, at any time there should be 24 issues outstanding for 2- and 5-year notes, and there should be 12 issues outstanding for 3-year note; 28 issues outstanding for 7-year notes; 40 issues outstanding for 10-year notes; and 120 issues outstanding for 30-year bonds. But the quantity of issues outstanding is not like this because some instruments have not been issued on regular way over the time. The most recently issued security of a given maturity is referred to as 'on-the-run' and older securities are referred to as 'off-the-run'.

The secondary market is an over-the-counter market where takes place trading between dealers, brokers, institutional and private investors, including foreign ones. It is composed of the *when-issued*, and on-the-run and off-the-run issues. In the *when-issued* market, takes place the trade of the securities several days before the auction and continues until settlement of auction purchases. And the secondary market on itself that

[9] The major emissions from the U.S. Treasury market imply that the secondary market is very liquid, with large trading volumes and bid-ask spreads narrow, as shown by Fleming and Sarkar (1998).

is madeup by the *on-the-run* and *off -the-run* securities activity trading. The *on-the-run* issues are the newly issued among that those who have the same term to maturity[10]. The remaining amount outstanding for the same maturity is the *off-the-run* issues.

Several studies find evidence of the phenomenon called the '*on-the-run liquidity phenomenon'* in U.S. Treasury securities[11]. The most recently issued (*on-the-run*) government securities of a certain term to maturity have generally higher prices and higher bond-level liquidity than previously issues (*off-the-run*) maturing on similar dates.

4.3 Data and Sample Period

The dataset used in the analysis of the U.S. Treasury liquidity has been obtained from the database GovPx (Government (securities) Pricing Information System). This database collects trade information from the large majority brokers trading in the interdealer market, and focusing most of trading activity. Its creation in 1991 was in order to demands to provide greater transparency of U.S. Treasury market. Brokers report quote and trade information from their trading activity to GovPx system that take place through participating interdealer brokers. The dataset includes only the trades and quotes registered between them, and so all the activity of dealers between them, and between dealers and their customers, is beyond the computation of the data. The posted data includes the best bid and ask quotes, the quote sizes, and the price and size of each trade.

Our sample includes every trade between January 1996 and December 2006. We analyze 2-, 3-, 5-, and 10-year Treasury notes and 30-year Treasury bonds. Although U.S. Treasury suspended the 3- and 30-year issuances on a few times, we include this securities in the analysis. 7-year Treasury notes and 20-year Treasury bonds also have been taken into account to let us estimate individual market shares for each issue. Because the availability of trading volume information, the dataset used is a subsample,

[10] Fabozy and Fleming (2005) argue that about 70% of total trading volume is concentrated in the section on-the-run.

11 As example Brandt, Kavaiecz and Underwood (2007), Mizrach and Neely (2008), and Pasquariello and Vega (2009).

which covers the period January 1996 to April 2001. From May 2001, interdealer brokers leave to report information to GovPx about volume activity. Since we need this measure to quantify individual market share, we can only use data from January 1996 to April 2001.

The U.S. Treasury securities are identified by an identification number referred as CUSIP (Committee on Procedures Uniform Securities Identification). Each of outstanding issues have a different identification number, thus each outstanding issues have different characteristics. Only on a few cases the U.S. Treasury has issued notes with the same CUSIP if coupon rate of new issuance is the same as for existing notes with the same maturity. Therefore, all bonds are identified by a CUSIP code which is the same over time.

To complement the dataset, we use official information about amount outstanding and auction date obtained from the official website of U.S. Treasury.

In our work, we use data from January 1996 to April 2001, related to all Treasury notes and Treasury bonds outstanding. For this period, there are 1357 trading days, thus we have 304,256 observations. We have data of all outstanding issues for each day, whether traded on the secondary market, as those with no trade, such as illiquid securities. 2-year notes are issued monthly and on regular basis, so each day there are available observations of 24 outstanding issues. 5-year notes are also issued monthly and regularly, so each day there are 60 observations of outstanding securities with 5 years to maturity. In the case of 10-year notes, although the issue has been ongoing, there have been years where have been more specific issues because of funding needs, so that the number of shares outstanding each day is not constant across the sample. 3- and 7-year notes and 20- and 30-year bonds have no continuous issuance during this time period, thus we don't have the same number of securities outstanding for each day in the subsample. On this period, the 7-year notes and 20-year bonds available information is from outstanding notes and bonds and during the study period no new issuances take place. Therefore, trading activity for this notes and bonds is low. The most actively traded is 2-year notes and 10-year notes, and the lower trading activity corresponds to 7-year notes.

Table II shows the total number of outstanding issues and its traded volume.

Table II. Summary of Data

Range of observations	02/01/1996 a 30/04/2001		
Observation days	1357		
	Number of outstanding securities	Traded Volume	Average Traded Volume
2-years bond	88	9.284.304	105.503,455
3-years bond	22	2.205.348	100.243,091
5-years bond	95	6.248.506	65.773,7474
7-years bond	18	128.718	7.151
10-years bond	50	4.422.426	88.448,52
20-years bond	16	3.027	189,1875
30-years bond	57	1.480.687	25.976,9649
Total	346	23.773.016	

Table II shows the total traded volume in $ million, for each of the issues include in the period analyzed. The average trades volume is the average traded by each of the types of issues.

In the case of 5-year notes, they have an additional feature; on a certain number of outstanding 5-year notes, three years after their issuances, when they are two years to maturity, there is a reissue of the same notes with the same CUSIP that causes a rebound in trading. We have controlled for this feature, because this bonds continue being 5-year notes, and no new 2-year notes issuances

5 Methodology. Empirical Results

The empirical analysis in this study takes into account medium, longer and much longer term to maturity securities issued by the U.S. Treasury. Liquidity in short, medium and long term bonds is very different. This securities also have differences in taxation[12], and the markets in which are traded may have different characteristics that can influence the determinants of liquidity. Therefore it is desirable to separate and analyze liquidity of each type of issue separately.

We analyze spread yields between U.S Treasury securities yields and securities with the same term to maturities that were the most liquid in the market yields, and we do this distinguishing by issue. These differences in yield may be explained by differences in liquidity. To that purpose we include both current liquidity and expected future liquidity that we obtain using a bond liquidity 'life cycle' function. We assume that newer securities have higher security-level liquidity and the older ones have lower security-level liquidity, so we establish a link between bond's age and bond liquidity.

[12] Tax differences may influence when measuring the effect of liquidity, (Strevulaev (2002)). The analysis of each issue separately, can avoid the tax differentials between short-term securities and securities in the medium and long term.

Firstly we specify a proxy to measure liquidity in U.S. debt market. As we have seen above, there are many liquidity measures in previous literature to quantify liquidity securities and its use depends on the analysis and on the availability data.

In this work we are going to use the daily average market share of the total daily volume traded on market one day for measuring U.S. Treasuries individual liquidity. The average market share over the bond's life cycle reflects the bond status, ie if it is a newly issued bond or if some time has gone since its issuance. The most recent issues, referred as the on-the-run, are considered the benchmark, and they are the most traded securities on markets and the most liquid. The other issues at the same maturity are referred as the off-the-run and they are less liquid. If any security has security-level liquidity at any moment through its life, this security-level liquidity will go through a 'life cycle' too. We can follow liquidity over time, through the bond's age, in what is referred as liquidity 'life cycle'.

To determine individual securities market share, we have included all observations of all outstanding issues (2-, 3-, 5-, 7- and 10-year notes and 20- and 30-year bonds) in the period analyzed. Securities data from phase *when-issued* have not been taken into account. In this issues are set out all the trades after the auction announcement and prior to auction purchases. Also we have not included data from older bonds because it has not been possible to obtain information, particularly 30-year bond issues with issuance date before 1980. This is a small number of titles (approximately 2% of total bonds sample) and they are extremely illiquid.

Once we have measured current liquidity with our individual market share measure, we are able to estimate future liquidity through our liquidity bond 'life cycle' function. We will relate these measures with the yield spreads between securities and other securities considered the most liquid in markets, in time-series regressions, besides other liquidity and status measures. We have time-series cross-sectional observations, including some quantitative and qualitative measures. Distinguishing by issues, we avoid any potentially cross-sectional differences between notes and bonds, like differences in coupon, different tax treatments, etc. because it is being compared between securities with the same features. Therefore the analysis of yield spreads over the bond 'life cycle' is not affected.

5.1 Market Share

First we determine the market share of each issue, distinguishing by term to maturity. For the period analyzed, we used the following expression:

$$MS_{i,t} = \frac{TV_{i,t}}{TTV_t} \qquad for\ t = 0,1, \ldots 1357 \tag{1}$$

where:

$MS_{i,t}$ is the market share for security *i* on day *t*; $TV_{i,t}$ is the total volume traded for security *i* on *t*, and TTV_t is the total traded volume of all securities traded on the market on day *t*. Market share is estimated individually for each security on each day, and after then differentiated by age and type of issue.

We estimate the age for security *i* at any moment *t* as the time elapsed from its issuance date to the day considered:

$$Age_{i,t} = D.issue_{i,t} - D.traded_{i,t} \tag{2}$$

Additionally, we use weekly sections that have been divided from 0 to 6 days, 7 to 13 days, etc. To determine an average market share measure according to age, we summarize all individual market share measures sorted by age ranges, and average them for number of securities at the same age range:

$$\overline{MS}_{i,t} = \frac{\sum_{t=1}^{n} MS_{i,t}}{N_{i,t}} \tag{3}$$

Where $N_{i,t}$ is the number of issues for each maturity and age range. Thus we have an average market share for bonds in tranche from 0 to 6 days, another average measure for bonds in tranche from 7 to 13 days, and so on.

The following figure shows the behavior of the 2-year notes average market share through the note cycle life:

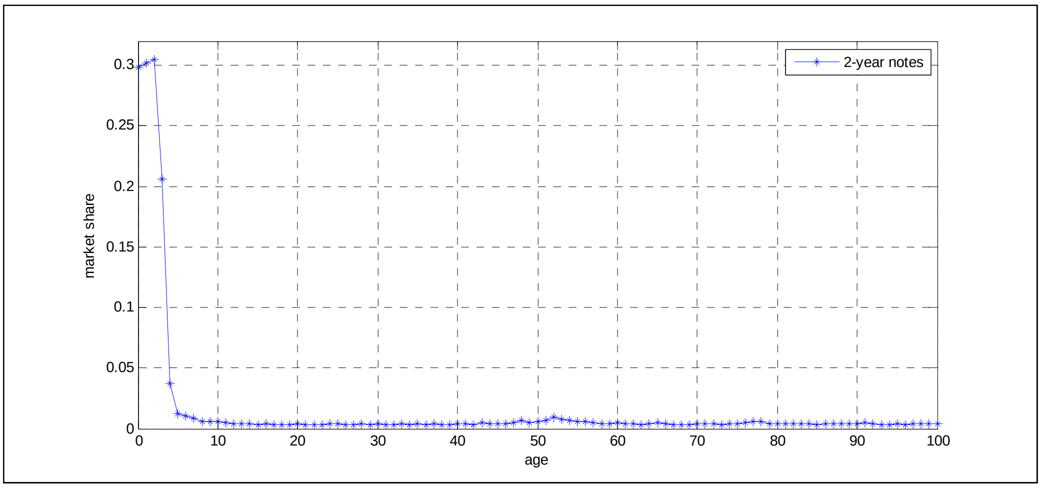

Figure 3. 2-year notes market share. It represents the average market share in terms of the age in weeks, for 2-year notes.

We observe that the newer issues for 2-year notes are the mostly traded on market and are the most liquid. However the older issues, from week 4 to maturity date, have a lower trading and are much more illiquid.

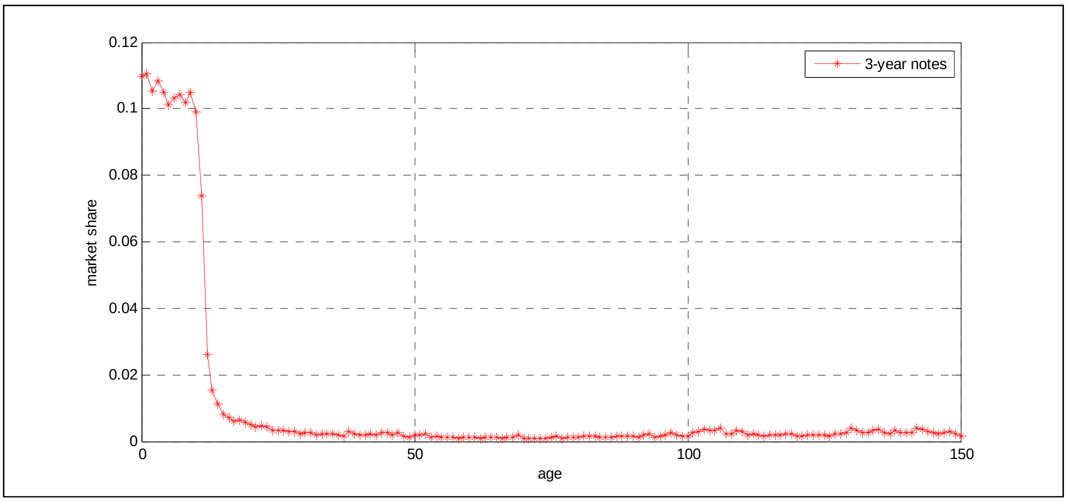

Figure 4. 3-year notes market share. It represents the average market share in terms of the age in weeks, for 3-year notes.

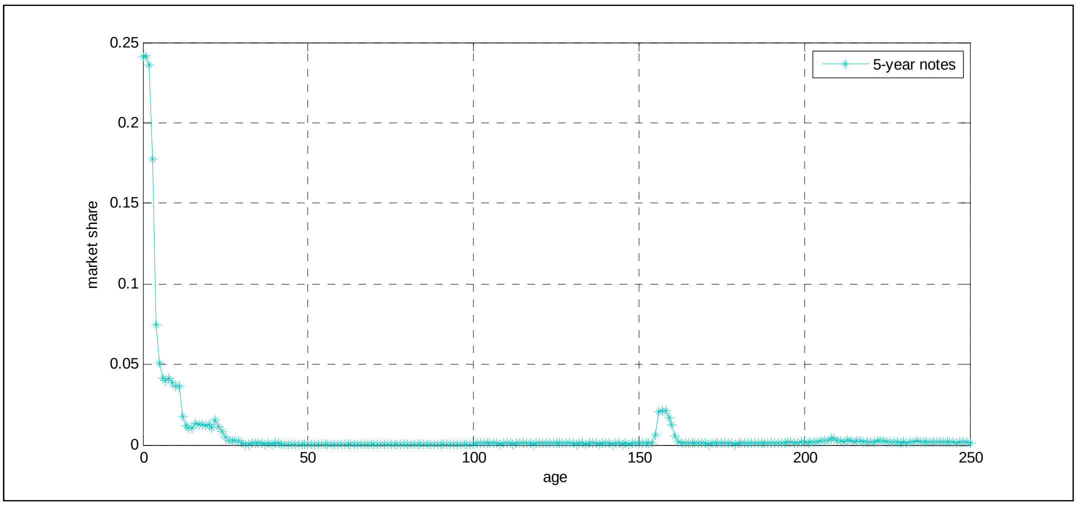

Figure 5. 5-year notes market share. It represents the average market share in terms of the age in weeks, for 5-year notes.

Furthermore, the other issues have the same behavior over the time, and the moment when they become off-the-run depends on the different issuance cycles across securities. 5-year notes are issued monthly, thus since week 4 they become off-the-run notes. 3- and 10-year notes are issued four times a year, so from week 12 go on status off-the-run, and the same for 30-year bonds. 5-year notes has a spike around week 156 from issue, which corresponds with new issues on the same reference but with a term to maturity of 2 years. It's a new issue, which attracts investor’s interest again, which makes large market share measure at that time as shown in figure (5).

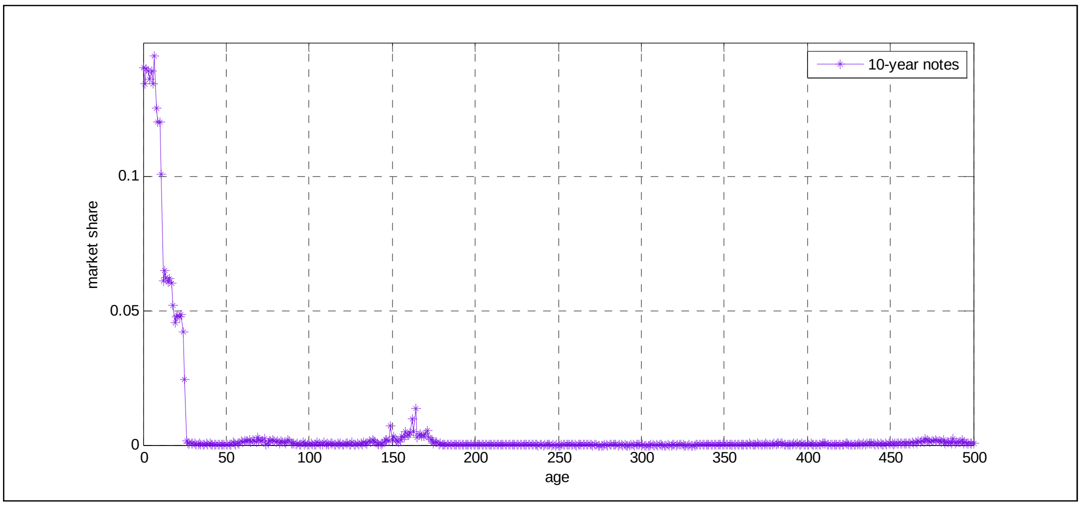

Figure 6. 10-year notes market share. It represents the average market share in terms of the age in weeks, for 10-year notes.

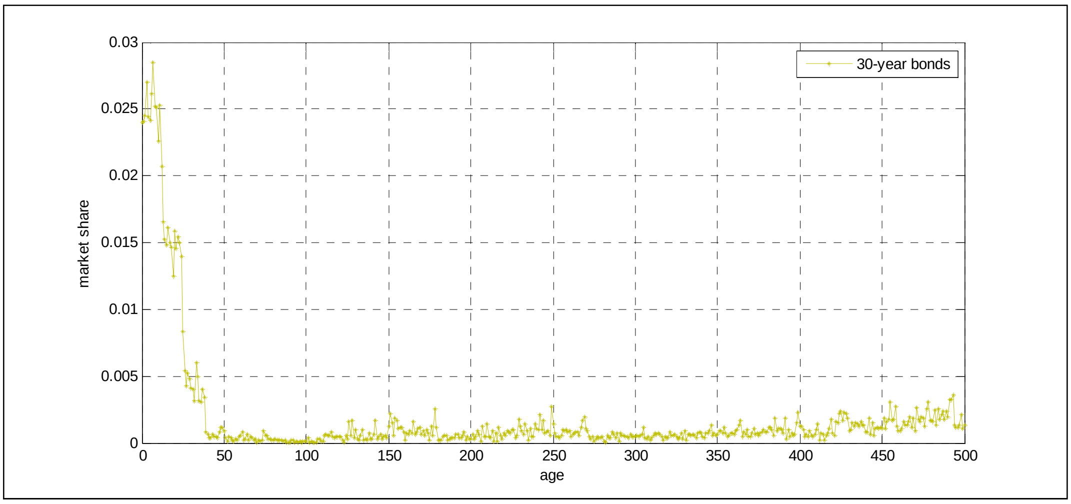

Figure 7. 30-year bonds market share. It represents the average market share in terms of the age in weeks, for 30-year notes.

If we set the average market share of all issues by term to maturity, for the first 100 weeks of the security's life, we can observe that 2-years bond and 5-years bond go on status on-the-run faster than the other issues:

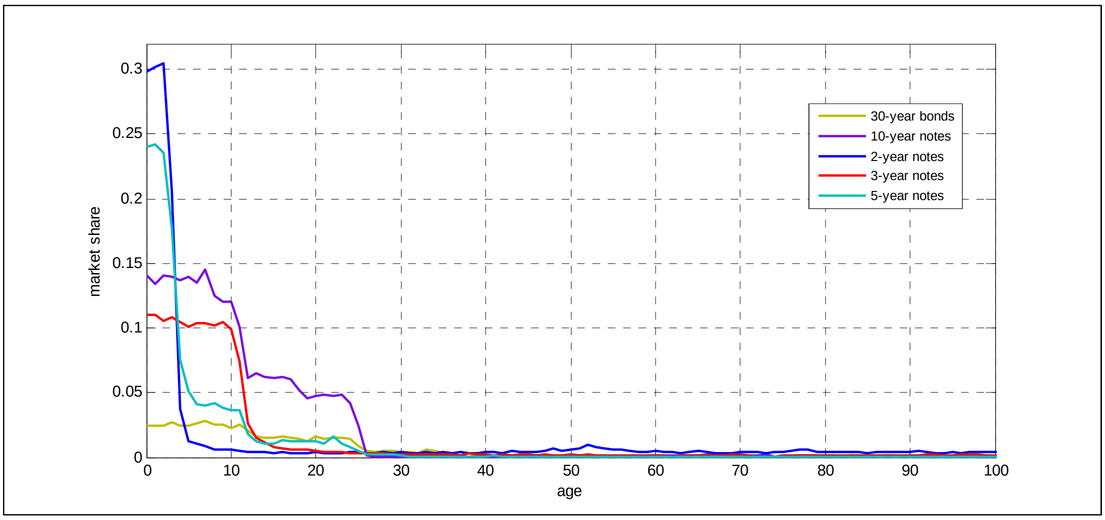

Figure 8. 2-, 3-, 5- and 10-year notes and 30-year bond market share. It represents the average market share in terms of security's age measures in weeks, for securities with original maturities of 2, 3, 5, 10, and 30 years.

What we can see is that there is a similar behavior of the average market share for all types of issues. The newly issued bonds, the on-the-run bonds, are the ones that attract market trading, and are therefore those with greater liquidity. When there are new issues with the same term to maturity, these bonds don't trade actively and go to the status off-the-run, which remain relatively illiquid until maturity date. This phenomenon referred as 'on-the-run phenomenon' has been observed in the U.S.

Treasury bonds, and widely studied in previous literature, Brandt, Kavaiecz and Underwood (2007), Mizrach and Neely (2008), and Pasquariello and Vega (2009), among others.

It is also possible to see in figures below that the securities which represent the vast of market share and that are the most widely traded are the 2- and 5-year notes, and are also the greatest number of securities issuances.

5.2 Current Liquidity

Liquidity, measured by market share becomes predictable over time. As shown in figures below, liquidity follows a pattern quite regular, although each specific type of issue has particular characteristics. This result suggests that we may model security market share as a function of security age. A valid functional form to reflect this behavior would be from an exponential function[13]. 2-, 3- and 5-year notes market share measure have a very similar behavior, while 10-year notes and 30-year bonds have a different behavior. So we will apply different functions for different issues. The following exponential expression measures the average market share depending on the bond age:

$$MS_{i,t} = c + \beta_1 \exp\left(-\beta_2 \cdot age_{i,t}^2\right) + \beta_3 \cdot \beta_4^{age} + u_{i,t} \qquad (4)$$

For example, for 2-, 3- and 5-year notes we apply equation (4). In case of 5-year notes we include a dummy variable that would reflect the effect of 5-year notes reissuance three years after the original issue. This dummy variable takes value 1 if notes are aged between 156 weeks and 160 weeks and 0 otherwise.

In the case of 10-year notes, the liquidity behavior is different, and the equation that we will estimate is as follows:

$$MS_{i,t} = c + \beta_1 dummy_1 + \beta_2 dummy_2 + \beta_3 dummy_3 + \beta_4 dummy_4 + u_{i,t} \qquad (5)$$

[13] The original exponential form was proposed by Heligman and Pollard (1980) on their seminal work about human mortality, where they establish a relationship between mortality and age. Díaz, Merrick y Navarro (2006) use an equation inspired in their actuarial research, and here we use a version of this exponential form for the U.S. Treasury securities.

where $dummy_i$ are dummy variables that reflected this effect: $dummy_1$ takes value 1 for 10-year notes aged between 0 and 7 weeks, and 0 otherwise; $dummy_2$ takes value 1 for bonds with aged between 8 and 11 weeks, and 0 otherwise; $dummy_3$ takes value 1 for bonds aged between 12 and 25 weeks, and 0 otherwise; and $dummy_4$ takes value 1 for bonds aged 26 weeks and 1560 weeks, and 0 otherwise.

And in the case of 30-year bonds, which behave differently from other bonds, the estimated equation is given by the following expression:

$$MS_{i,t} = c + \beta_1 \, exp\left(-\beta_2 \cdot age_{i,t}\right) + u_{i,t} \qquad (6)$$

The estimation results of equations (4) to (6), presented in Table III shows the results for each issue, and the equations applied in each case:

Table III.

2-year note	$MS_{i,t} = c + \beta_1 exp(-\beta_2 \cdot age_{i,t}^2) + \beta_3 \cdot \beta_4^{age_{i,t}} + u_{i,t}$	
Estimated coefficients		
c	0.003892	(0.0025, 0.005284)
$\boldsymbol{\beta_1}$	−1.285	(-1.532, -1.039)
$\boldsymbol{\beta_2}$	1.098	(1.042, 1.155)
$\boldsymbol{\beta_3}$	1.58	(1.334, 1.827)
$\boldsymbol{\beta_4}$	0.4582	(0.4284, 0.488)
$\mathbf{R^2}$	0.9837	
3-year note	$MS_{i,t} = c + \beta_1 exp(-\beta_2 \cdot age_{i,t}^2) + \beta_3 \cdot \beta_4^{age_{i,t}} + u_{i,t}$	
Estimated coefficients		
c	0.00122	(4.354e-005, 0.002396)
$\boldsymbol{\beta_1}$	-0.2035	(-0.2515, -0.1554)
$\boldsymbol{\beta_2}$	0.07664	(0.06504, 0.08824)
$\boldsymbol{\beta_3}$	0.3351	(0.2813, 0.3889)
$\boldsymbol{\beta_4}$	0.8452	(0.8306, 0.8598)
$\mathbf{R^2}$	0.9378	
5-year note	$MS_{i,t} = c + \beta_1 exp(-\beta_2 \cdot age_{i,t}^2) + \beta_3 \cdot \beta_4^{age_{i,t}} + \beta_5 dummy\_re + u_{i,t}$	
Estimated coefficients		
c	0.002131	(0.001486, 0.002777)
$\boldsymbol{\beta_1}$	−0.2794	(-0.3298, -0.229)
$\boldsymbol{\beta_2}$	0.9636	(0.835, 1.092)
$\boldsymbol{\beta_3}$	0.5176	(0.4678, 0.5673)
$\boldsymbol{\beta_4}$	0.672	(0.6524, 0.6916)
$\boldsymbol{\beta_5}$	0.0184	(0.0144, 0.0225)
$\mathbf{R^2}$	0.9724	
10-year note	$MS_{i,t} = c + \beta_1 dummy_1 + \beta_2 dummy_2 + \beta_3 dummy_3 + \beta_4 dummy_4 + u_{i,t}$	
Estimated coefficients		
c	0.00044672	(0.0002557, 0.0006378)
$\boldsymbol{\beta_1}$	0.13838003	(0.1369002, 0.1398599)
$\boldsymbol{\beta_2}$	0.11639718	(0.1143131, 0.118481,)
$\boldsymbol{\beta_3}$	0.05157218	(0.504466, 0.0526978)
$\boldsymbol{\beta_4}$	0.00368476	(0.0028163, 0.0045533)
$\mathbf{R^2}$	0.99023729	
30-year bond	$MS_{i,t} = c + \beta_1 exp(-\beta_2 \cdot age_{i,t}) + u_{i,t}$	
Estimated coefficients		
c	0.0005666	(0.0005107, 0.0006224)
$\boldsymbol{\beta_1}$	0.03185	(0.03092, 0.03277)
$\boldsymbol{\beta_2}$	0.05491	(0.05257, 0.05726)
$\mathbf{R^2}$	0.8536	

In parenthesis, the confidence intervals for the 95% level.

Figure (9) represents the current and estimated average market share for 2-year notes:

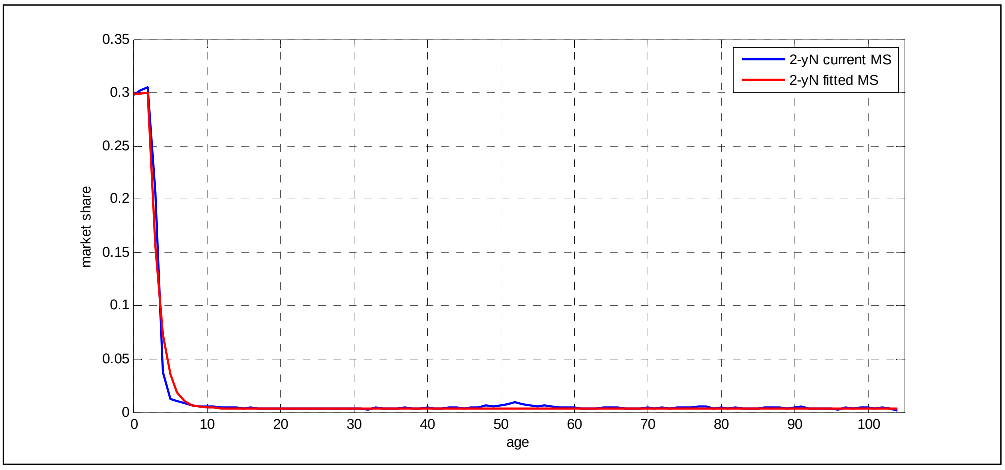

Figure 9. 2-year notes current and estimated average market share. It represents the current and estimated average market share from the exponential form described in the table (III), depending on note age. The note age is measured in weeks elapsed from its issue.

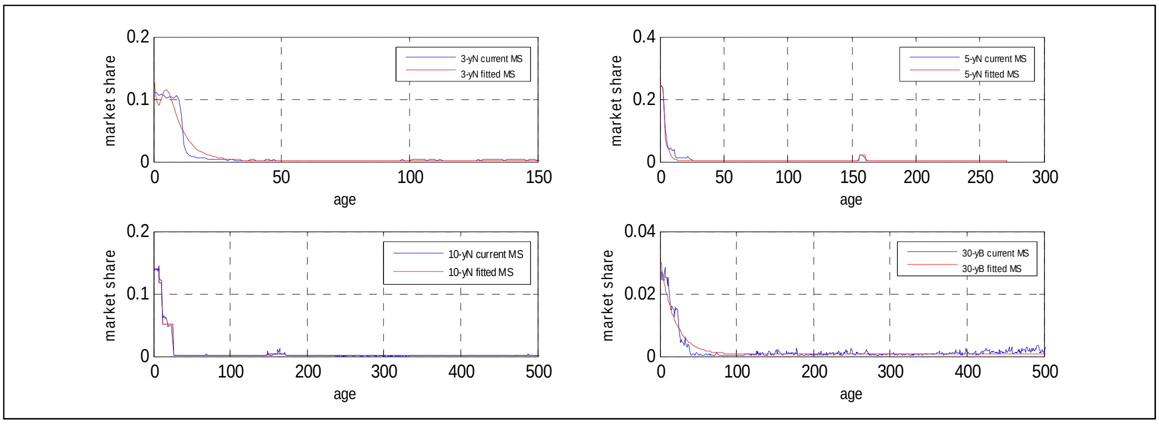

Figure 10. 3-, 5- and 10-year notes and 30-year bonds current and estimated average market share measures. It represents the current and estimated average market share from the exponential forms described in the table (III), depending on notes and bonds age. Age is measured in weeks elapsed from its issue.

5.3 Future Liquidity

Next we are going to use functions estimated on previous section to estimate a future liquidity measure. At any time during the liquidity life cycle, there is a security-level liquidity that is its current-level liquidity and there is a future-level liquidity remaining until maturity date. Because of this pattern, we can estimate expected future liquidity for the remaining time to maturity of the security. With estimated coefficients of each function set according to table (III), we estimate the expected value of the market share for security i at time $t + j$:

$$E[MS_{i,t+j}] = \hat{c} + \hat{\beta}_1\, exp(-\hat{\beta}_2 \cdot age^2_{i,t+j}) + \hat{\beta}_3 \cdot \hat{\beta}_4^{age_{i,t+j}} \tag{7}$$

This is the 2-year notes expected market share for bond i from week $t+1$ to $t+m_{it}$, where m_{it} is the number of days until maturity. For each term to maturity we estimate an expected value of future liquidity. The expected average market share for each bond at time t, would be the average over m_{it} of the total expected future market share by issue:

$$\overline{MS}_{i,t,t+m_{it}} = \frac{1}{m_{it}} \sum_{j=1}^{m_{it}} E[MS_{i,t+j}] \tag{8}$$

This average expected future market share reflects the average expected future liquidity for each security by issue. The following figure shows how expected future liquidity is lower at any time than the current liquidity, as this measure is the average of liquidity remaining to maturity:

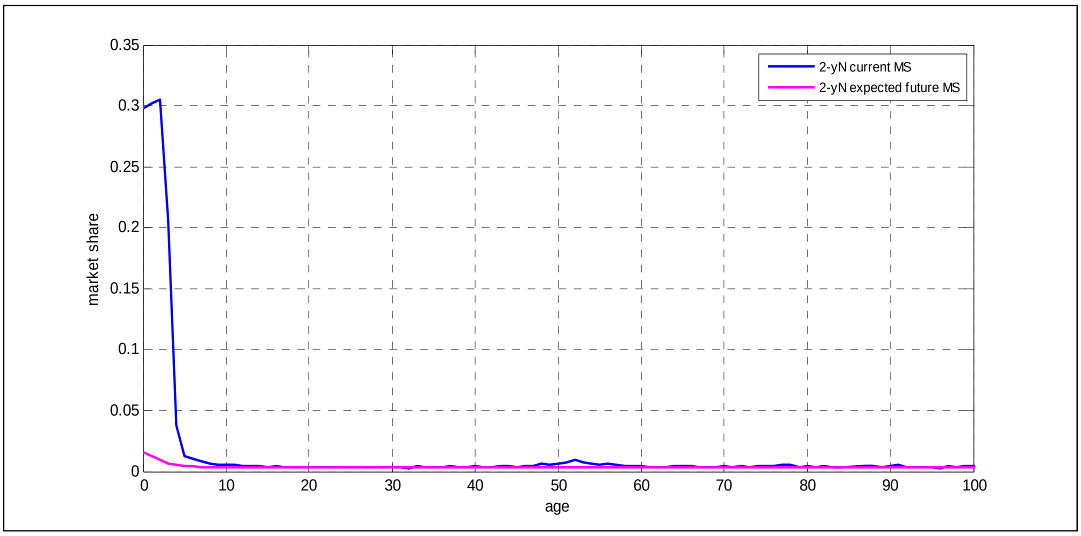

Figure 11. 2-years bond current market share and expected future market share. The expected future market share is the average of expected future liquidity remaining until the maturity date. Age is measured in weeks from securities issuance date.

5.4 Analysis of yield spreads

In this section we analyze yield spreads between securities[14]. We calculate yield spreads as the differences between an outstanding security yield and another most liquid and theoretical security yield with the same term to maturity. We want to see the differences in yields between assets with the same characteristics in terms of maturity and coupon payments.

To do this, we first calculate, at a time *t*, the yield that has a security maturating at *T* and that pays *c* coupons at interest rates prevailing in *t*. Additionally, we calculate the yield that would have another theoretical security that were issued on *t*, with maturity date at *T* and with the same number of coupons equal to *c*, discounted at spot interest rates. The difference between these yields is equal to our yield spreads.

We get the spot interest rates used from the U.S. Department of Treasury (DoT). The data consist on daily series of zero coupon interest rates from January 1996 to December 2006, for periods of 1m, 3m, 6m, 1y, 2y, 3y, 5y, 7y, 10y, 20y and 30y. We have an interest rate on each observation data for each term to maturity. Now, to calculate the theoretical price, and therefore the theoretical yield, we discount each of the remaining security cash flows until its maturity, to the interest rate on each data for each term.

In our daily data, time to maturity mismatch in most of the cases to the deadlines of spot rates series provided by the U.S. DoT. Sometimes we have cash flows to discount with a number of days to maturity that differs from the number of days included on periods provided by the U.S. DoT. In these cases, to discount remaining cash flows at right rates, we have use cubic interpolation that allows us to obtain the right interest rate to apply for days remaining. We have done this for all those outstanding securities cash flows that differ their maturities in number of days, during the period analyzed.

[14] The empirical literature propose different measures to yield spreads. As example Amihud and Medelson (1991), Strebulaev (2001), Goldreich, Hanke and Nath (2005) or Díaz, Navarro and Merrick (2006).

Knowing current security yield at time t and theoretical security yield also at t, we calculate, for each of securities, the yield spreads as:

$$YS_{i,t} = y_{curr_{i,t}} - y_{theo_{i,t}} \tag{9}$$

where:

$y_{curr_{i,t}}$ is the current yield for security i on t, and $y_{theo_{i,t}}$ is the theoretical yield for security i on t, whose price we have get discounting bond cash flows to spot interest rate.

Yield spreads for older notes and bonds are greater than those observed for the newer notes and bonds. For new securities, as they are the most liquid on-the-run securities, we are comparing the yield from a new bond with the theoretical yield for another bond that would be too new. So yield spreads are quite small. In the case of older securities, less liquid off-the-run securities, they have a higher yield respect to a security with similar characteristics in term to maturity and coupon payments. Thus yield spread is greater than on-the-run yield spreads.

The so-called 'liquidity premium' bond measures the yield spread between less liquid and more liquid bonds. Investors demand a higher return or a lower price as the lower the liquidity of a title.

In some cases, we have obtained yield spreads too high, because the DoT Term Structure of Interest Rates has provided very high rates. This is possibly due to data errors, and in any case we haven't included these bonds. Likewise, bonds for which bid-ask spreads have proved negative, possibly because brokers have not updated the data or due to errors, have not been taken into account. Other observations that are not included in this part of the analysis are those relating to bonds to 7 and 20 years, since during the period of analysis there are not new issues to these maturities. Moreover, the available data from outstanding securities mostly quite illiquid have also been omitted for the study. It has not been possible to obtain theoretical prices, because there are no rates in the Term Structure of Interest Rates series provided by the U.S. DoT[15].

Furthermore, to remove extreme values of yield spreads series, we have included only those observations for which the difference in yield exceeds mean ± two-twice standard deviation, i.e., and thus we include those observations for which the yield spread is into the range:

$$[\overline{YS} - 2\sigma_{YS}\,, \overline{YS} + 2\sigma_{YS},] \tag{10}$$

.

Therefore, in this second part of the analysis, the sample has been reduced to 204,024 observations, from 304,256 available firstly. The following table shows the main statistics for the series of observed yield spread for each of the maturities:

Table IV. Main statistics yield spreads series.

	2-years bond	3-years bond	5-years bond	10-years bond	30-years bond
Mean	0.021986	0.010690	-0.019901	-0.023799	0.135827
Median	0.012762	-0.007520	-0.037816	-0.038290	0.070316
Maximum	0.927623	0.922444	0.929693	0.907394	0.930061
Minimum	-0.691605	-0.691690	-0.691468	-0.685281	-0.343540
Std. Dev.	0.118077	0.126723	0.111110	0.083423	0.222859
Skewness	0.673346	0.951088	0.595589	1.312734	1.982085
Kurtosis	10.65315	9.511751	12.43822	15.11735	6.613909
# Observations	30514	11769	69600	43740	48401

Main statistics yield spreads series by issues.

In addition, to analyze the yield spreads observed in U.S. Treasuries, we will consider to the current liquidity and expected future liquidity, besides other important measures in explaining yield spreads, such as duration, that would be reflecting observed differences in term to maturity; price premiums that would reflect the impact due to differences in coupon; amount outstanding by issue, bonds age, and other control variables to control for interest rates, such as level, slope and curvature for spot interest rate. Coupon is important because different coupons securities have different taxes. High coupon bonds are subject to higher taxation in U.S. Age is also important in yield spreads, like we have seen in previous sections.

[15] There are trading days in the market for which the DoT does not provide data for spot interest rate.

The following table shows the correlation matrix of these variables:

Table V.Correlations Matrix.

	YIE_SPR	E_FUT_MS	CURR_MS	DUR	PRI_PRE	A_OUTST	AGE	LEVEL	SLOPE	CURVAT.	S_BIDASK	AGR_VOL	CUPON	TIM_T_MAT
YIE_SPR	1	-0.177426	-0.075953	0.2166	0.411275	-0.209931	0.492874	-0.174278	0.129306	-0.051353	0.286257	-0.038269	0.390703	0.366769
E_FUT_MS	-0.177426	1	0.211987	-0.642147	-0.463535	0.216473	-0.595045	-0.007744	0.008097	0.002048	-0.36127	0.111228	-0.578953	-0.711843
CURR_MS	-0.075953	0.211987	1	-0.073674	-0.11178	0.143763	-0.188404	0.03354	-0.102129	-0.000757	-0.08902	0.135584	-0.12079	-0.138735
DUR	0.2166	-0.642147	-0.073674	1	0.584957	-0.137792	0.360036	-0.009265	-0.017507	-0.013399	0.573165	-0.019618	0.430998	0.93228
PRI_PRE	0.411275	-0.463535	-0.11178	0.584957	1	-0.24387	0.658148	-0.176231	0.025559	-0.148481	0.461423	-0.04722	0.790738	0.705293
A_OUTST	-0.209931	0.216473	0.143763	-0.137792	-0.24387	1	-0.407601	-0.033583	-0.087875	-0.028562	-0.230229	0.11917	-0.388204	-0.258435
AGE	0.492874	-0.595045	-0.188404	0.360036	0.658148	-0.407601	1	0.031865	-0.009365	0.005525	0.377155	-0.090863	0.756769	0.64478
LEVEL	-0.174278	-0.007744	0.03354	-0.009265	-0.176231	-0.033583	0.031865	1	-0.110662	0.660433	0.240193	-0.018731	0.041847	0.015625
SLOPE	0.129306	0.008097	-0.102129	-0.017507	0.025559	-0.087875	-0.009365	-0.110662	1	-0.055008	0.338875	0.00284	0.11781	-0.01217
CURVAT.	-0.051353	0.002048	-0.000757	-0.013399	-0.148481	-0.028562	0.005525	0.660433	-0.055008	1	0.058718	-0.004007	0.003685	-0.000227
S_BIDASK	0.286257	-0.36127	-0.08902	0.573165	0.461423	-0.230229	0.377155	0.240193	0.338875	0.058718	1	-0.063291	0.489392	0.626865
AGR_VOL	-0.038269	0.111228	0.135584	-0.019618	-0.04722	0.11917	-0.090863	-0.018731	0.00284	-0.004007	-0.063291	1	-0.078756	-0.053731
CUPON	0.390703	-0.578953	-0.12079	0.430998	0.790738	-0.388204	0.756769	0.041847	0.11781	0.003685	0.489392	-0.078756	1	0.623366
TIM_T_MAT	0.366769	-0.711843	-0.138735	0.93228	0.705293	-0.258435	0.64478	0.015625	-0.01217	-0.000227	0.626865	-0.053731	0.623366	1

Correlations matrix for different liquidity measures taken into account.

Yield spreads correlation is high with other variables: age, price premium, term to maturity and coupon. In turn, yield spreads correlation is also high but in opposite sign, between expected future market share, and coupon and term to maturity. This is indicating that the longer-term is the lower expected future liquidity is, and that the higher coupon is the lower expected future liquidity is.

The regression estimated by issue includes variables to control for interest rates: level, slope and curvature. Also includes as explanatory variables: duration, to take into account the influence term to maturity and age; price premium, which reflects the influence of coupon; and a *dummy* variable to control for the status impact in yield spreads. This *dummy* variable takes value 1 if bond is on-the-run and 0 otherwise. The equation to be estimated and the results obtained are shown below:

$$YS_{i,t} = c + \beta_1 CURR\_MS_{i,t} + \beta_2 E\_FUT\_MS_{i,t} + \beta_3 LEVEL_{i,t} + \beta_4 SLOPE_{i,t} + \beta_5 CURVAT_{i,t} + \beta_6 DUR_{i,t} + \beta_7 PRI\_PRE_{i,t} + \beta_8 DUMMY\_ONTR_{i,t} + u_{i,t} \tag{11}$$

where $YS_{i,t}$ measures yield spread for each security i on day t; $CURR\_MS_{i,t}$ is the current market share of security i on day t ; $E\_FUT\_MS_{i,t}$ is the average expected future liquidity of the bond i at time t; $DUR_{i,t}$ is the Macaullay duration for bond i on t; $PRI\_PRE_{i,t}$ is the security i price premium at t, calculated as the difference between bond current price and the spot price; $DUMMY\_ONTR_{i,t}$ is a *dummy* variable that reflects bond status. It takes value 1 if is an on-the-run bond, and 0 otherwise.

Table VI. Current market share and expected future market share impacts on yield spreads controlling for variables like interest rates, status, duration and price premiun.

	Estimated coefficients	***t-statistics***	***Probability***	***R^2***	***R^2 Adjusted***
C	*0.213411*	*24.92642*	*0.0000*	*0.208605*	*0.208574*
CURR_MS	*-0.034915*	*-5.946470*	*0.0000*		
E_FUT_MS	*-0.984047*	*-3.066001*	*0.0022*		
LEVEL	*-4.404049*	*-28.49079*	*0.0000*		
SLOPE	*5.515993*	*23.24420*	*0.0000*		
CURVAT	*27.36188*	*50.28938*	*0.0000*		
DURATION	*-0.000862*	*-4.819399*	*0.0000*		
PRI_PRE	*0.005666*	*30.99102*	*0.0000*		
DUMMY_ONTR	*-0.064879*	*-35.88658*	*0.0000*		

Regression estimated for a number of observations equal to 204,024. In regression we have applied Newey-West correction for heteroscedasticity estimators.

The regression results reflect that both, the current liquidity, measured by market share, and future liquidity, measured by expected future market share, explain the observed yield spreads on U.S. Treasury notes and bonds, including other control variables in regressions. The R-squared is near 20%, and all the variables include add explanatory power for observed yield spreads to a 99% confidence level. Coefficients signs for the liquidity-related variables are negative, as we expected. This result implies that the lower liquidity is, both current and expected future, the greater U.S. debt securities yield spread is. In terms of size, expected future liquidity seems to be most important rather than current liquidity. Duration and status variables coefficients are negative. This result indicates, firstly, that the longer duration is, the lower yield spread is; and subsequently, the new bonds have lower yield spreads and are bonds on status on-the-run, so the longer duration is, the less yield spread is. On the other hand, the negative sign for the status variable would indicate that bonds in status on-the-run have lower yield spread, than bonds in the off-the-run status. The positive sign of price premium coefficient premium implies that the higher the price premium is, the lower the current price related to the spot price is. So its yield is greater than the benchmark yield, making the spreads widen.

We have made the analysis for all terms to maturity of the bonds considered (2-, 3-, 5- 10- and 30-years). If we separate them by security term to maturity, the regressions estimated are the following:

- For 2-year notes:

$$YS_{i,t}^{2a} = c + \beta_1 CURR\_MS_{i,t}^{2a} + \beta_2 E\_FUT\_MS_{i,t}^{2a} + \beta_3 LEVEL_{i,t}^{2a} + \beta_4 SLOPE_{i,t}^{2a} + \beta_5 CURVAT_{i,t}^{2a} + \beta_6 DUR_{i,t}^{2a} + \beta_7 PRI\_PRE_{i,t}^{2a} + \beta_8 DUMMY\_ONTR_{i,t}^{2a} + u_{i,t} \quad (12)$$

- For 3-year notes:

$$YS_{i,t}^{3a} = c + \beta_1 CURR\_MS_{i,t}^{3a} + \beta_2 E\_FUT\_MS_{i,t}^{3a} + \beta_3 LEVEL_{i,t}^{3a} + \beta_4 SLOPE_{i,t}^{3a} + \beta_5 CURVAT_{i,t}^{3a} + \beta_6 DUR_{i,t}^{3a} + \beta_7 PRI\_PRE_{i,t}^{3a} + \beta_8 DUMMY\_ONTR_{i,t}^{3a} + u_{i,t} \quad (13)$$

- For 5-year notes:

$$YS_{i,t}^{5a} = c + \beta_1 CURR\_MS_{i,t}^{5a} + \beta_2 E\_FUT\_MS_{i,t}^{5a} + \beta_3 LEVEL_{i,t}^{5a} + \beta_4 SLOPE_{i,t}^{5a} + \beta_5 CURVAT_{i,t}^{5a} + \beta_6 DUR_{i,t}^{5a} + \beta_7 PRI\_PRE_{i,t}^{5a} + \beta_8 DUMMY\_ONTR_{i,t}^{5a} + u_{i,t} \quad (14)$$

- For 10-year notes:

$$YS_{i,t}^{10a} = c + \beta_1 CURR\_MS_{i,t}^{10a} + \beta_2 E\_FUT\_MS_{i,t}^{10a} + \beta_3 LEVEL_{i,t}^{10a} + \beta_4 SLOPE_{i,t}^{10a} + \beta_5 CURVAT_{i,t}^{10a} + \beta_6 DUR_{i,t}^{10a} + \beta_7 PRI\_PRE_{i,t}^{10a} + \beta_8 DUMMY\_ONTR_{i,t}^{10a} + u_{i,t} \quad (15)$$

- And for 30-year bonds:

$$YS_{i,t}^{30a} = c + \beta_1 CURR\_MS_{i,t}^{30a} + \beta_2 E\_FUT\_MS_{i,t}^{30a} + \beta_3 LEVEL_{i,t}^{30a} + \beta_4 SLOPE_{i,t}^{30a} + \beta_5 CURVAT_{i,t}^{30a} + \beta_6 DUR_{i,t}^{30a} + \beta_7 PRI\_PRE_{i,t}^{30a} + \beta_8 DUMMY\_ONTR_{i,t}^{30} + u_{i,t} \quad (16)$$

The results obtained from each regression are shown in the following table (VII):

Table VII. Current market share and expected future market share impact yield spreads and other control variables and liquidity measures.

	Estimated coefficients	t-statistics	Probability	R^2	R^2 Adjusted
2-years bond					
C	0.483680	46.67543	0.0000	0.165911	0.165692
CURR_MS	0.003982	0.642403	0.5206		
E_FUT_MS	-2.685353	-9.621493	0.0000		
LEVEL	-7.616546	-45.72542	0.0000		
SLOPE	-4.183814	-14.49630	0.0000		
CURVAT	39.36962	30.94064	0.0000		
DURATION	-0.036900	-12.17002	0.0000		
PRI_PRE	-0.019396	-16.05138	0.0000		
DUMMY_ONTR	-0.067355	-26.35363	0.0000		
3-years bond					
C	0.535563	33.46066	0.0000	0.281156	0.280667
CURR_MS	-0.073513	-4.829590	0.0000		
E_FUT_MS	-3.176693	5.989212	0.0000		
LEVEL	-8.832227	-30.14547	0.0000		
SLOPE	0.121382	0.239067	0.8111		
CURVAT	65.08687	23.95450	0.0000		
DURATION	-0.067360	-24.04294	0.0000		
PRI_PRE	0.002929	3.202859	0.0014		
DUMMY_ONTR	-0.001171	-0.418282	0.6757		
5-years bond					
C	0.555315	44.87578	0.0000	0.194359	0.194267
CURR_MS	-0.024473	-2.123135	0.0337		
E_FUT_MS	-85.17954	-55.99831	0.0000		
LEVEL	-6.442159	-32.04623	0.0000		
SLOPE	-1.079891	-7.164619	0.0000		
CURVAT	27.11034	36.57081	0.0000		
DURATION	-0.009989	-16.29780	0.0000		
PRI_PRE	-0.000191	-0.265590	0.7906		
DUMMY_ONTR	0.229246	34.94764	0.0000		
10-years bond					
C	0.425409	68.82237	0.0000	0.266142	0.266008
CURR_MS	-0.157194	23.24127	0.0000		
E_FUT_MS	-6.275210	-5.316544	0.0000		
LEVEL	-7.524968	-81.70184	0.0000		
SLOPE	1.657129	13.54118	0.0000		
CURVAT	24.10872	36.30173	0.0000		
DURATION	-0.009557	-27.78697	0.0000		
PRI_PRE	-0.000850	-7.043464	0.0000		
DUMMY_ONTR	-0.019461	-4.659376	0.0000		
30-years bond					
C	2.833040	50.41777	0.0000	0.557693	0.557620
CURR_MS	-1.374734	-13.84843	0.0000		
E_FUT_MS	-1034.779	-19.96021	0.0000		
LEVEL	-14.26114	-48.26992	0.0000		
SLOPE	13.74632	28.58096	0.0000		
CURVAT	0.553261	0.569196	0.5692		
DURATION	-0.127385	-49.81802	0.0000		
PRI_PRE	-0.003372	-27.76462	0.0000		
DUMMY_ONTR	0.297650	17.91993	0.0000		

Regressions for a number of observations equal to 204,024. In all regressions we have applied Newey-West correction for heteroscedasticity estimators.

In all regressions current and future market share variables coefficients have negative sign. This result indicates the inverse relationship that exists between yield spreads and security-level liquidity. Only for 2-year notes current market share coefficient has positive sign, although in this case it is not significant. Also in all regressions duration coefficient has negative sign that would indicate the inverse relationship between yield spreads and bond age: the longer duration is, the lower yield spread is. Moreover, control variables for interest rates coefficients are statistically significant in almost all cases.

6 Conclusions

In this paper we have analyzed the observed yield spreads U.S. Treasury notes and U.S. Treasury bonds for the period from January 1996 to April 2001. Changes in yield are interpreted like changes in current and expected future market share. It is possible to model liquidity measured by market share since it has a regular pattern. We use bond liquidity 'life cycle' function that allows us to express changes in yield spreads through changes in liquidity 'life cycle'.

Our results for the yield spreads analysis for bonds and notes with maturities of 2, 3, 5, 10 and 30 years, reveal that the whole liquidity life cycle explain the yield spreads of U.S. Treasuries studied. The role of the liquidity 'life cycle' has allowed us to collect the liquidity over the entire life of the bond, not only the current liquidity. In terms of size, expected future liquidity has proved to be more important in all cases than current liquidity. Taking each issue individually distinguishing by term to maturity, the results show that both current and future liquidity, in addition to other variables, explain the observed yield spread for the period considered. In these cases, also expected future liquidity is more important in magnitude than current liquidity.

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