Credit quality or liquidity?
Crisis-period evidence from the American sovereign bond market

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ABSTRACT

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Treasury bond yields are affected by credit and liquidity. This paper determines the extent to which Treasury bond holders are concerned about liquidity and quality during times of market distress. Using data from the American sovereign bonds market, we find that investors increasingly demand liquidity whereas credit quality continues to be an important determinant of Treasury bond yields when the market is not favorable. Specifically, credit quality accounts for the majority of the variation in bond yields while liquidity plays a substantially smaller role during times of financial crisis. Furthermore, credit quality has a larger and stronger effect on bonds with a longer time to maturity, suggesting that changes in credit quality are a long-term concern that may be associated with changes in fiscal discipline and political policy.

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1. Introduction

Flight to quality is a feature of financial market during times of financial crisis, when some market participants decrease their high-risk investments in their portfolio and purchase safer products, such as gold or US Treasury bonds. The flight to quality phenomenon is frequently monitored in times of market distress. Diamond and Dybvig (1983) and Bernanke and Gertler (1995) suggest that bank runs and panics, credit crunches, and sudden declines in the market values of corporate bonds are all examples of flight to quality.

On the other hand, flight to liquidity is a distinct phenomenon that has been observed in recent financial markets. Some market investors prefer to hold securities with greater liquidity when markets are distressed. The 1998 Russian default is a typical example of flight to liquidity. During that time, prices of Treasury bonds surprisingly and suddenly climbed relative to less-liquid debt, resulting in the widening of credit spreads and large losses in the long term capital market.

Flights to quality and liquidity may both happen during times of financial distress. Duffie, Pedersen, and Singleton (2003) and Longstaff, Mithal, and Neis (2005) document that both credit and liquidity determinants are important to bond yields. Following their research findings, this study concentrates on the effects of credit quality and liquidity capability on bond yields and how they affect the behavior of market participants and their investment strategies. Specifically, we examine the credit differentials between long-term and short-term bonds and the liquidity differentials between on-the-run and off-the-run bonds in the US Treasury bond market. Next, we study the relationship between U.S. sovereign bond yields and their corresponding credit and liquidity measures for 3 different maturity categories in both an univariate and multivariate context.

Our findings suggest that investors chase both credit and liquidity during financial crises. We further find that credit quality accounts for the majority of the variation in bond yields whereas liquidity has a considerably smaller effect on bond yields across all maturity horizons

in times of market distress. Moreover, fluctuations in credit and liquidity are more pronounced for long-term bonds, and credit quality has both a larger and stronger effect for bonds with a longer time to maturity. Our results are consistent with investors perceiving that modifications in credit quality are a long-run concern associated with changes in fiscal discipline, which in turn are related to changes in the political and governmental landscape.

The motivations for investigating whether investors are more concerned about credit quality or liquidity in times of market crises are threefold. First, our paper attempts to explain the relationship between credit, liquidity, and bond yields, in an attempt to provide a better understanding of cross-temporal bond market dynamics. Second, we aim to provide insights to explain the behavior of market participants during periods of financial turmoil. The insights we draw from this analysis should provide important information for regulators and policy makers, thereby allowing them to make better informed decisions aimed at stabilizing the financial market. Third, understanding the implications of credit quality and liquidity capability should allow investors to adjust their trading decisions and investment strategies.

Our study proceeds as follows. Section 2 presents the related literature. Section 3 describes the data and variables used in this study. Section 4 documents and discusses our empirical results. Section 5 concludes.

2. Related Literature

2.1 Determinants of Sovereign bond yields

Our study relates to three different strands of the finance literature. First, our empirical analyses build on prior research that examines the sovereign bond market in U.S.. Thus, our literature review in this section focuses compilation of work has mainly on the determinants of sovereign bond yields. Bernoth, Hagen, and Schuknecht (2004) document that the yields of EU countries and the U.S. are affected by international risk factors. To price sovereign debt,

Duffie, Pedersen, and Singleton (2003) construct a model that accounts for the risks of both default and restructuring, and allows for compensation for illiquidity. Geyer, Kossmeier, and Pichler (2004) use factor models to capture the main features of the sovereign bond market. In a similar vein, Codogno, Favero, and Missale (2003) and Favero, Pagano, and Von Thadden (2005) explore the determinants of yield spreads in Europe. In our study, we employ the simplified cross-sectional framework proposed by Beber, Brandt, and Kavajecz (2009), and focus on the extent to which credit and liquidity affect the bond yields in U.S. sovereign bond market.

2.2 Credit risk and proxy

Our study also relates to prior research on credit quality. Credit risk reflects the possibility that a debtor will not meet his or her obligation in full at the time of maturity. Hull, Predescu, and White (2004), Blanco, Brennan, and Marsh (2005), Longstaff, Mithal, and Neis (2005), Beber, Brandt, and Kavajecz (2009), and Ang and Longstaff (2013) use information from sovereign credit default swaps to examine the credit risk of sovereign bonds. A close relationship between CDS spreads and bond spreads has been confirmed by Hull, Predescu, and White (2004), Blanco, Brennan, and Marsh (2005), Houweling and Vorst (2005), and Zhu (2006). Specifically, Ang and Longstaff (2013) suggest that a key advantage of using CDS data is that it provides a much more direct method to measure the credit risk of sovereign bonds. They argue that sovereign debt yields are driven not only by sovereign credit risk, but also by interest rate movements and changes in the supply of underlying bonds. Meanwhile, Hull, Predescu, and White (2004), Blanco, Brennan, and Marsh (2005), and Zhu (2006) conclude that CDS provide a good proxy of the underlying credit risk. Because CDS prices are more reactive to new information, they are also more likely to lead the bond market in terms of price discovery.

2.3 Liquidity risk and premium

Finally, our study relates to the growing strand of the finance literature that explores the importance of liquidity. Liquidity risk describes the risk that market participants will not be

able to liquidate their portfolios in time or with small transaction costs. Flight to liquidity is a recently observed phenomenon in the world's financial markets. Investors' demand for liquidity was first identified by Holmstrom and Tirole (1996), who examine the role of public sectors in providing liquidity to the financial markets. Interestingly, according to standard asset pricing theory, the flight to liquidity phenomenon is invalid and should not exist. Under that theory, the value of a security should be equal to the present value of its cash all flows in the future, which should not rely on how popular the security is in the market.

Posing a challenge to traditional asset pricing theory, Longstaff (2002) finds that there have been large and significant liquidity premia in Treasury bond prices during the past decade and that the liquidity premium can be more than fifteen percent for some Treasury bonds. Additionally, Favero, Pagano, and Von Thadden (2010) summarize two main views to clarify why liquidity should be priced by financial markets: first, illiquidity can create a trading cost; second, it can generate additional risk. Amihud and Mendelson (1986) first developed the trading cost view. They suggest that illiquid securities must offer a higher expected return to control for fundamental risk and to compensate for their increased transaction costs. Pastor and Stambaugh (2003) propose and test the liquidity risk view, emphasizing that liquidity is priced not only because it creates trading costs, but also because it exposes investors to additional uncertainties over time.

3. Data and Variables

3.1 Data

We use trading data for sovereign bonds from Bloomberg to conduct our empirical analyses. Bloomberg contains a wide range of security identification information, such as the issue currency, the bond's coupon, and its maturity. In addition, it provides a wealth of trading information, such as a bond's daily bid price, ask price, and bond yield based on the mid price. Additionally, we obtain daily prices of Sovereign Credit Default Swaps, quoted in basis points

from Bloomberg's Sovereign CDS Monitor. These data allow us to construct yield quotes, credit proxies, as well as liquidity measures. Finally, we complement our dataset with quotes for short-term (1 month) Treasury bills from WRDS.

In this study, we examine the effect of liquidity and credit risk on the American sovereign bond market from January 1, 2008 to June 30, 2014. Please note that CDS daily price quotes in pre-crisis period are not available because Bloomberg's coverage of U.S. sovereign bond CDS data only dates back to 2008. We separate our sample period into three parts in order to better capture and compare the influence of market distress. Specifically, we differentiate among the crises period (from January 1, 2008 to September 30, 2009), the recovery period (from October 1, 2009 to December 31, 2012), and the stagnant period (from January 1, 2013 to June 30, 2014). According to Grigor and Salikhov (2009), there are three stages for the recent financial crises: the mortgage crises from July 2007 to August 2008, the liquidity crises that followed the bankruptcy of Lehman Brothers in September 2008, and third the credit paralysis stemming from the distrust within the banking system. The U.S. President Barack Obama declared on January 27, 2010 that, "the markets are now stabilized, and we have recovered most of the money we spent on the banks."[1] On the other hand, according to the National Bureau of Economic Research (NBER), the U.S. recession began in December 2007 and ended in September 2009.[2] In this paper, we take the average of these dates and consider September 30, 2009 as the ending of financial crisis. Thus the recovery period is followed from October 1, 2009 to December 31, 2012. However, in September 2013, the USA Today comments ,"Five years after Lehman Brothers collapsed and the ensuing financial crises set off the Great Recession, the aftershocks of the historic upheaval are still being felt in nearly every corner of the economy."[3] Mark Zandi, chief economist of Moody's Analytics, views the after-crisis recovery as "with no credit, no growth or slow growth"[4]. Later in November, the IMF warns that do not expect fast crisis recovery.[5] SRSrocco Report even suggests that another U.S. economy recession is coming. Then we consider the extreamly slow recovery

[1] http://en.wikipedia.org/wiki/Financial_crisis_of_2007–08
[2] http://en.wikipedia.org/wiki/Financial_crisis_of_2007–08
[3] http://www.usatoday.com/story/money/business/2013/09/10/economy-2008-financial-crisis-lehman/2789841/
[4] http://www.usatoday.com/story/money/business/2013/09/10/economy-2008-financial-crisis-lehman/2789841/
[5] http://www.euronews.com/2013/10/11/imf-warns-don-t-expect-fast-crisis-recovery-reform-must-prevent-recurrence/

stage between January 1, 2013 and June 30, 2014 as the stagnant period.[6]

Finally, we construct a dataset of daily quotes for 2004 U.S. sovereign bonds. Based on data provided by World Bank[7], America experienced its highest annual GDP growth rate during the last decades in 2004. Thus we choose the year 2004 as a good year against which we compare the 2008-2009 financial crises. Comparing these two time periods should allow for a direct comparison of how liquidity and credit affect Treasury bond yields during booming and distressed market periods.

For each year (i.e. 2004 and 2008), we collect both on-the-run and off-the-run sovereign bond trading quote. In essence, on-the-run bonds are very actively traded and have greater liquidity than off-the-run bonds. According to Barclay, Hendershott, and Kotz (2006), the trading volume drops by more than 90% when Treasury securities go off-the-run. Interestingly, Akay, Cyree, Griffiths, and Winters (2012) note that there is more than one definition for the on-the-run period in the literature. One definition is that of Most Recently Auctioned bonds used by Fleming (2003), and Barclay, Hendershott, and Kotz (2006). Another definition used is Most Recently Issued bonds as suggested by Furfine and Remolona (2002) and Pasquariello and Vega (2009). In the process of reexamining Barclay, Hendershott, and Kotz (2006)，Pasquariello and Vega (2009), and Moore and Winters (2014) find that Treasury notes are different in terms of trading activity and observe that Treasury bills do not align well with the Most Recently Auctioned definition of on-the-run bonds. In our study, we use the Most Recently Issued definition to decide whether a bond is on-the-run or off-the-run. In line with the prior literature in this area, we employ the remaining time to maturity of off-the-run bonds to sort Treasury bonds into different maturity groups. For example, a 10-year Treasury bond issued in 2003, which in 2008 would have five more years until it matures, is considered a 5-year off-the-run Treasury bond in 2008.

[6] http://srsroccoreport.com/get-prepared-the-u-s-economic-collapse-is-still-coming/get-prepared-the-u-s-economic-collapse-is-still-coming/

[7] http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?page=1

I exclude floating rate coupon securities, bonds issued in currencies other than the U.S. dollar, non-government securities, and structured securities. To minimize the sometimes complicated effects of special fixed-income features, we only concentrate on fixed coupon Treasury bonds.

To conclude, our dataset has two parts. The first part contains the daily yields of on-the-run and off-the-run U.S. Treasury bonds and bills in both 2004 and 2008, which we employ in our credit and liquidity differential analysis; the second part contains U.S. sovereign bonds quotes well as corresponding daily CDS trading prices from January 1, 2008 to June 30, 2014, which we use in our unconditional regression.

3.2 Variables

We separate sovereign bonds along three different dimensions. The first dimension, which we employ in our credit and liquidity differential analysis, identifies the state of each bond: on-the-run or off-the-run. The second dimension is maturity: Here we differentiate between bill with 1-month to maturity and bonds with 3-year, 5-year or 10-year to maturity. We apply the same classification to the corresponding sovereign bond CDS. The third dimension continues the time line of the recent financial crisis: Here we distinguish among the crisis period (from January 1, 2008 to September 30, 2009), the recovery period (from October 1, 2009 to December 31, 2012), and the stagnant period (from January 1, 2013 to June 30, 2014).

In order to study the impact of credit quality and liquidity on sovereign bond yields, we employ three essential sets of variables for each maturity group: sovereign bond yields, credit variables, and liquidity variables. First, we use the Mid Price Yield, which can be retrieved directly from Bloomberg, as a proxy for the sovereign bond yield. According to Bloomberg, the Mid Price Yield is defined as the lowest yield (based on the mid price) for all possible redemption date scenarios. For bonds, the mid price yield is the internal rate of return used in the present value formula that solves for the mid price. Second, following the extant literature in this area, we employ the corresponding daily sovereign CDS prices to represent the credit

variable. Third, because there is no universally accepted definition for liquidity, we consider the dollar bid-ask spread, the percentage bid- ask spread, the effective spread, and γ as liquidity proxies. Detailed definitions for all the variables are provided in the next section.

Table1 and 2 provide summary statistics for our credit/liquidity differential analysis and for unconditional regression. Specifically, they list our sample averages for sovereign bond yields, several credit measures, our liquidity proxies, and other supplementary information. Note that daily price quotes for 2004 are not available because Bloomberg's coverage of U.S. sovereign bond CDS data only dates back to 2008.

3.3 Correlations

Before engaging in our empirical analyses, we present cross-temporal correlation coefficients between bond yields and our credit (liquidity) measures for on-the-run sovereign bonds from January 1, 2008 to June 30, 2014 (see Table 3). We anticipate positive correlations because an increase in CDS prices or liquidity measures, indicating poorer credit quality or liquidity, should result in an increase in bond yields.

Nevertheless, unexpected negative correlations between bond yields and our credit risk proxy suggest a unique behavior of the U.S. sovereign bond market during the recent financial crisis. We will explore this phenomenon in more detail by examining the determinants of sovereign bonds in the next section.

4. Empirical Results

Having examined the correlation between credit, liquidity and bond yields, we now examine which attribute of bond investors care most about. We accomplish this by investigating credit differentials between long- and short-term bonds as well as liquidity differentials between on-the-run and off-the-run bonds. Afterwards, we examine the impact of credit and liquidity

on bond yields and derive additional insights about the relationship between these variables using a series of unconditional regression.

4.1 Movements between bond yields and corresponding CDS prices

Guaranteed by the U.S. federal government, U.S. Treasury bonds are normally assumed as "risk-free". However, history proves that even U.S. Treasury bonds may sometimes go wrong. Zivney and Marcus (1989) suggest that the U.S. government has already default once in May 1979 due to delays on several institutional and technical factors. Whereas Nippani, Liu, and Schulman (2001) show that the U.S. comes close to default again between October 1995 and March 1996 because of a disagreement between the White House and Congress over an increase of the federal debt ceiling. The market charges a default risk premium on Treasury bills this time. In addition, Nippani and Smith (2010) conclude that the lower spread for long-term Treasury bond is consistent with greater default risk in 2008 financial crisis. They address that the increasing default risk of Treasury bonds is due to greater government involvement in times of market distress.

The time-series behavior of 3-year, 5-year, and 10-year sovereign bond CDS (in basis points) and sovereign bond yields during the crisis period (from January 1, 2008 to September 30, 2009) are documented in Figures 1 to 3. The rapid rise of sovereign CDS prices in these graphs clearly reflects the economy uncertainties during that period. However, regardless of the unfavorable developments in credit quality, we observe a surprising reduction in sovereign bond yields, which reflects higher prices and growing demand. Similarly, when CDS price drops and credit quality improves, the corresponding bonds are less sought after and have a higher yield.

This unique negative relationship between sovereign bond yields and CDS prices is consistent with our expectation. It may be explained by flight to quality situation that the prices for Treasury bonds are bidded up and the yields decrease relative to other securities. Unlike corporate bonds, US sovereign bonds are desired when the economy is doing poorly as was

the case during the 2008 financial crisis. Treasury bonds could become riskier but still look favorable when they are compared to others. In addition, slight variations in sovereign bond yields appear to cause dramatically opposite reactions in corresponding CDS prices, suggesting that the market was under great tension during that time.

4.2 Credit and liquidity differentials

4.2.1 Hypotheses

Normally, a bond with a shorter maturity is safer than one with a longer maturity, if other conditions hold. Although the likelihood of U.S. federal government default is almost nil, Treasury bonds with shorter maturity are generally considered to have better credit quality than those with longer maturity due to future uncertainties, such as political risk, inflation, and the potential failure to uphold the loan terms. Thus we expect to observe yield differentials between long-term and short-term Treasury bonds due to their diverse credit characteristics. Moreover, the yield differential is likely to grow if bond holders attach more importance to credit quality in times of market distress. We denote this kind of differential as credit differential (CD), measured by the spread between short-term and long-term Treasury bond yields.

As discussed before, if market participants during financial crisis cared more about credit quality, short-term Treasury bonds should have become more desirable resulting in a drop in yields, while long-term treasury bonds should have become less attractive, leading to an increase in yields. Thus, compared to the boom year of 2004, the 2008 credit differential should be widening, if the flight to quality phenomenon exists. Thus our first hypothesis is as follows:

$$\text{Let } \mathrm{CD}_{2004} = \text{long-term bond yield}_{2004} - \text{short-term bond yield}_{2004}$$

$$\mathrm{CD}_{2008} = \text{long-term bond yield}_{2008} - \text{short-term bond yield}_{2008}$$

$$\Delta\mathrm{CD} = \mathrm{CD}_{2008} - \mathrm{CD}_{2004} \quad \text{(Equation I)}$$

H1: $\Delta CD > 0$, i.e., bond holders chased bonds with greater credit quality during the 2008 financial crisis. Alternatively, if $\Delta CD \leq 0$, bond holders did not chase bonds with greater credit quality during the 2008 financial crisis.

Usually, on-the-run bonds are more liquid than off-the-run bonds due to their larger trading volume. Hence, if market participants are concerned about liquidity when markets are in distress, they should target the on-the-run Treasury bond market, causing yields to fall and prices to augment. Meanwhile, because of shrinking demand, off-the-run Treasury bond prices should decline and their yields should increase. Thus if bond holders value liquidity, liquidity differential (LD), measured as the yield spread between off-the-run and on-the-run Treasury bonds, should have increase during the financial crisis. We thus postulate our second hypothesis as follows:

$$\text{Let} \quad \text{LD}_{2004} = \text{off-the-run bond yield}_{2004} - \text{on-the-run bond yield}_{2004}$$
$$\text{LD}_{2008} = \text{off-the-run bond yield}_{2008} - \text{on-the-run bond yield}_{2008}$$
$$\Delta\text{LD} = \text{LD}_{2008} - \text{LD}_{2004} \quad \text{(Equation II)}$$

H2: $\Delta LD > 0$, i.e., bond holders chased bonds with higher liquidity during the financial crisis. Alternatively, if $\Delta LD \leq 0$, bond holders did not chase bonds with higher liquidity.

4.2.2 Movements of CD and LD

Next, Figures 4 to 6 show the credit differentials, namely the yield differentials between long-term on-the-run Treasury bonds (with 3 years, 5 years and 10 years to maturity, respectively) and short-term on-the-run Treasury bills (with 1 month to maturity) for both 2004 and 2008. The graphs clearly show large gaps in the credit differentials between 2004 and 2008, suggesting that market participants pursue bond credit quality during financial crises. The widening gaps in the credit differentials support our first hypothesis.

Further, we plot the movements of the liquidity differentials in 2004 and 2008. Figures 7 to 9 demonstrate the yield differentials between off-the-run and on-the-run Treasury bonds with

3-year, 5-year or 10-year maturity, respectively. The spreads in the liquidity differentials do not change significantly between 2004 and 2008, except the 3-year bonds. We believe that the inconsistency at 3-year horizon may be resulted from interventions by the federal government. Since May 15, 2007, no 3-year Treasury bond was issued. After a delay of more than 15 months, the federal government finally put a new 3-year bond on the market with a relatively low coupon rate on November 10, 2008. The abnormally high yield of the newly-issued bond causes a nosedive jump in the liquidity differential, which is visible on trading day 217 in Figure 7. The 3-year bond liquidity differentials are untypical on account of these institutional factors. However, it is still difficult to judge whether the spreads of the liquidity differentials are enlarged by simply observing Figures 8 and 9. No strong evidence is found to support our second hypothesis and further quantity analysis (as provided below) is required to examine the demand for liquidity in financial market turmoil.

4.3 Unconditional regression

4.3.1 Model and variables

We now perform regression analysis to better understand the relative importance of credit quality and liquidity to bondholders. In our study, we employ the simplified cross-sectional framework proposed by Beber, Brandt, and Kavajecz (2009). Equation III below details the regression model.

$$\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$$

(Equation III)

$\text{Sovereign Bond Yield}_t$ is the internal rate of return in the present value formula that solves for the mid price on day t. Credit_t is the credit quality variable and we use the mid price of Treasury CDS on day t to measure this variable; the higher the CDS price, the lower the credit quality. Liquidity_t is the liquidity variable and we use four measures to quantify this variable: the dollar bid-ask spread, the percentage bid- ask spread, the effective spread, and γ.

The dollar bid-ask spread is defined as the difference between the daily ask and bid prices. And the percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price.

$$\text{Dollar bid-ask spread} = \text{ask price} - \text{bid price}$$

$$\text{Percentage bid- ask spread} = \frac{\text{ask price} - \text{bid price}}{(\text{ask price} + \text{bid price})/2}$$

The third measure we employ to measure liquidity is the effective spread (Roll (1984)). Roll (1984) notes that if the fundamental value of a security fluctuates randomly, a negative serial dependence can be observed in successive market. Thus our effective liquidity measurement is as follows:

$$\text{Effective spread} = 2\sqrt{-\text{cov}}$$

where "cov" is the first-order auto covariance of security returns.

A problem using effective spread is that the first-order auto covariance can sometimes be positive, rendering the measure meaningless. Similar to Lesmond, Ogden, and Trizcinka (1999), I also adopt Harris's (1990) approach to convert all positive auto covariances to negative to solve the problem.

Our fourth measure of liquidity γ, was introduced by Ban, Pan, and Wang (2011). It measures the transitory component of price movements. When the value of γ is high, the bond is considered to have low liquidity. We provide the estimation of γ as follows:

$$\gamma = -\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$$

where $p_t = \ln P_t$ and P_t denotes the clean price at day t.

4.3.2 Estimation results

We estimate the regression in Equation III for the 3-, 5- and 10-year maturity Treasury bonds

in our sample periods. Table 4 demonstrates the relationship between credit, liquidity, and bond yields during the entire sample period of 1676 trading days. The table shows that the Treasury bond yields and Treasury bond CDS prices are significantly negatively related. This may seem a bit strange because associate higher yields with low credit quality. However, in the case of Treasury CDS spreads, larger spreads imply that the government is having difficulty meeting its obligations (at least in the short term), which in turn implies that the economy is rather shaky. As a result, funds flow into investments that relatively safe during these times. Treasury bonds being the safest of all investments, there is a greater demand for them and consequently their yields fall. As expected, the coefficients of all the liquidity measures are significantly positive, indicating that poor liquidity is associated with higher bond yields. The explanatory power of the regressions for bonds of various maturities, as measured by the adjusted R^2, ranges from 0.2717 to 0.6126. These results show that credit quality and liquidity explain Treasury bond yields fairly well.

The estimation results of Equation III for the crisis period (from January 1, 2008 to September 30, 2009) are shown in Table 5. Consistent with our prior analyses, the credit proxy has a strong negative impact on Treasury bond yields in times of financial crises. As noted above, more capital was injected into the Treasury bonds market, causing higher prices and lower yields due to increased demand, although their credit quality was diminishing. The negative coefficients provide strong evidence for the flight to quality phenomenon. Additionally, the market is quite sensitive during this period so even a tiny change in credit quality would cause a tremendous opposite bounce in bond yields. For every 100 basis points increase in Treasury CDS price, the yields of Treasury bonds of various maturities drop between 108 basis points and 192 basis points. On the other hand, we find that for most liquidity measures, the coefficients remain significantly positive, suggesting that a poor liquidity results in a greater yield. However, the significance of liquidity is not as strong as credit quality, indicating that credit quality has a greater influence on Treasury bond yields than liquidity in times of distress.

We report the estimation for the recovery period (from October 1, 2009 to December 31,

2012). Interestingly, the credit proxy for 3-year Treasury bond changes to positive, indicating that a bad credit quality would increase its price when the economy is slowly recovering. Further, we observe that the values of all liquidity coefficients surge dramatically compared to table 5, showing that bond holders may attach more importance on Treasury bond liquidity when the market suffers from less tension.

Finally, we repeat the above analysis one last time when the economy is not slipping deeper into a crisis but is stagnant (from January 1, 2013 to June 30, 2014). This is to compare the relative influence of credit and liquidity variable on Treasury bond yields in slightly different economic states. The results are presented in Table 7. The results indicate that the investors continue to give more importance to credit quality than liquidity in a stagnant economy, just as they do in a declining economy.

4.4 Bond yield decomposition

4.4.1 Contribution and proportion

In the unconditional regression analysis, we saw that credit quality plays a more dominant role in liquidity in determining Treasury bond yields during times of crises. In this section, we wish to quantity what was qualitatively inferred earlier. We use two measures to do this, credit proportion and liquidity proportion. The credit proportion for day t is the ratio of the absolute value of the credit contribution to the sum of the absolute value of the credit contribution and the liquidity contribution in day t. The liquidity proportion is calculated analogously. The sum of the credit and liquidity proportions should be 1.

$$\text{Credit Proportion}_t = \frac{|\text{Credit Contribution }_t|}{|\text{Credit Contribution }_t| + |\text{Liquidity Contribution }_t|}$$

$$\text{Liquidity Proportion}_t = \frac{|\text{Liquidity Contribution }_t|}{|\text{Credit Contribution }_t| + |\text{Liquidity Contribution }_t|}$$

The credit (liquidity) contribution in day t is determined by taking the credit (liquidity) spread over the average for the sample period and multiplying it by the corresponding credit

(liquidity) coefficients shown in tables 4 to 7.

$$\text{Credit Contribution}_{t} = \beta'(\text{Credit}_{t} - \text{Credit}_{ave})$$

$$\text{Liquidity Contribution}_{t} = \delta'(\text{Liquidity}_{t} - \text{Liquidity}_{ave})$$

where Credit_{ave} is the arithmetic average of CDS prices and Liquidity_{ave} is the arithmetic average for each liquidity measurement. β' (δ') is the credit (liquidity) coefficient in the corresponding sample period and maturity group.

The results are shown in tables 8 to 11. The proportion figures offer complementary information on the relationships between credit quality, liquidity status, and sovereign bond yields. They indicate the relative importance of credit and liquidity in determining bond yields. Notice that the proportion figures capture the effects of credit and liquidity on the variation in yields estimated in Equation III, rather than the actual bond yields.

4.4.2 Credit and liquidity proportions

Figures 10 to 12 illustrates the liquidity proportions over the entire sample period of our four liquidity variables for each maturity group. Their sharp decrease in the crisis period demonstrates that credit quality accounts for most of Treasury bond yields whereas liquidity plays a considerably smaller role. Tables 8 to 11 show the proportions of credit and liquidity for all three maturity groups at different stages in the economy. During the entire sample period, credit quality contributes accounts for 78% of the yield, whereas liquidity accounts for only 22%. In the following recovery period, the liquidity proportion climbs to an average 56% as an anxiety in the market begins to lessen. Finally, during the stagnant period, the liquidity proportion goes down again due to the post-crisis sluggish recovery. In combining these figures and tables together, a shock of massive financial distress is clearly observable and these trends significantly influenced behavior of market participants.

A review of tables 8 to 11 shows that the fluctuations in the proportions are more pronounced for long-term bonds than for short-term bonds. We observe that in the crisis period (Table 9), the 10-year bond liquidity proportion drops sharply to an average of 7% while the 3-year bond holds a relatively high liquidity proportion of 44%. But in the following recovery period (Table 10), the 10-year bond liquidity proportion surges enormously to 48% with an increase of more than 550%, whereas the 3-year bond liquidity proportion goes up only to 66%. In the final period when the economy is stagnant, the 10-year bond experiences a larger reduction rate of 65% than the 3-year bond (61%). We reach a similar conclusion when we look at credit proportions. For instance, the 5-year bond average credit proportion drops by 40% from the crisis period to the recovery period; however the 3-year bond average credit proportion decreases by only 22%.

An interesting observation from these tables is that liquidity proportions are smaller for longer maturities. We find that bonds with 3-year maturity have the largest liquidity proportions compared to bonds with 5-year and 10-year maturities. Conversely, the credit proportions are bigger for long-term bonds than for short term bonds in all sample periods. This makes sense because credit quality is generally not a big concern for bonds near maturity as the likelihood of the issuer not meeting its obligations during a short period of time is low; however, for longer term bonds, this likelihood is high and therefore credit quality is more important.

In summary, our empirical results show that for Treasury bonds credit quality is more important than liquidity during time of crises. Also, the importance of credit quality increases with the maturity of the bonds. In times of crises, investors seek safe investment opportunities, and therefore there is an increase in the flow of funds into the Treasury bond market. As a consequence, we see a decrease in Treasury bond yields during times of crises. This is in direct contrast to the behavior of corporate bonds; as the credit quality decreases, the yields increase.

Although Treasury bonds are routinely mentioned as “risk-free”, they actually suffer from an increasing default rate in the recent financial crisis based on prior literature. However,

Treasury bonds with shorter maturity have a lower probability of a technical default. So credit quality is smaller in determining the yields of these bonds; liquidity gains in importance for these bonds. The situation reverses for longer term bonds. The probability of a technical default is higher and the government's economic policies and steps being taken to push the economy out of the slump have a larger impact on long-term bonds.

5. Conclusions, Limitations, and Avenues for Future Research

In this study, we empirically study the extent to which Treasury bond holders are concerned about liquidity and quality during times of market distress. We accomplish this by first investigating credit differentials between long-term and short-term bonds as well as liquidity differentials between on-the-run and off-the-run bonds. Second we examine the impact of credit and liquidity on bond yields in a multivariate regression context.

Our findings suggest that investors increasingly chase liquidity during financial crises while credit quality continues to occupy a vital place in determining Treasury bond yields. We further find that credit quality accounts for the majority of the variation in bond yields whereas liquidity has a considerably smaller effect on bond yields across all maturity horizons in times of market distress.

Moreover, fluctuations in credit and liquidity are more pronounced for long-term bonds, and credit quality has both a larger and stronger effect for bonds with a longer time to maturity. Our results are consistent with investors perceiving that modifications in credit quality are a long-run concern associated with changes in fiscal discipline, which in turn are related to changes in the political and governmental landscape.

Authors who conduct future research in this area may want to explore other commercially available data sources that contain daily quotes for U.S. Treasury bonds and corresponding CDS information to resolve some of the data limitations we encountered in this study. Hopefully, this will allow for the definition of more liquidity variables, which measure

different aspects of trading activity and their price impact, such as quoted depth and inter-quartile range. In addition, the daily quotes for Sovereign CDS before 2008 may be complemented with the assistance of other databases. This will allow for the construction of a broader pre-crisis dataset, thus allowing for more convincing conclusions by comparing crisis results to pre- and post- periods of market distress.

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Table 1: Sample summary statistics for credit and liquidity differentials

This table provides sample summary statistics for measures we use in our credit and liquidity differential analysis. Number of bonds in the table is the sum of qualified bonds monitored in each group. Bond yield (%) is the average of the internal rate of return used in the present value formula that solves for a bond's mid price. CDS price (bps) represents the average mid price of Sovereign CDS (quoted in basis points). Please note that the 2004 CDS trading quotes are not available in Bloomberg. Thus, the resulting figures are omitted. The dollar bid-ask spread is the average gap between the daily bid and ask prices.

Maturity	Number of bonds	Bond yield (%)	CDS price (bps)	Dollar bid-ask spread
		2004 on-the-run bonds		
3 Years	4	2.7255	-	0.0226
5 Years	13	3.4148	-	0.0158
10 Years	5	3.6437	-	0.0345
		2004 off-the-run bonds		
3 Years	6	2.7928	-	0.0607
5 Years	4	1.9949	-	0.0508
10 Years	3	3.4674	-	0.0625
		2008 on-the-run bonds		
3 Years	3	1.9640	17.3785	0.0561
5 Years	13	2.7937	19.6853	0.0183
10 Years	5	3.6438	23.2753	0.0349
		2008 off-the-run bonds		
3 Years	14	2.2079	30.3300	0.0597
5 Years	4	2.7394	33.8338	0.0625
10 Years	2	3.8508	36.4040	0.0625

Table 2: Sample summary statistics for unconditional regression

This table presents sample summary statistics for all variables we use in our regression analysis. Maturity measures the time to maturity of our sample bonds. Trading days reflect the number of trading monitored in each group. Bond yield (%) is the average of the internal rate of return used in the present value formula that solves for a bond's mid price. CDS price (bps) represents the average mid price of Sovereign CDS (quoted in basis points). The dollar bid-ask spread is the average gap between the daily bid and ask prices. The percentage bid-ask spread is the average dollar bid-ask spread divided by the corresponding mid price. The effective spread is the average of $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is the average of $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price.

Maturity	Trading days	Bond yield (%)	CDS price (bps)	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ (0.0001)
				Full sample period			
3 Years	1675	0.9941	29.4896	0.0218	0.0214	0.1048	0.0039
5 Years	1675	1.7002	36.4745	0.0141	0.0141	0.1872	0.0126
10 Years	1672	2.8070	48.0255	0.0251	0.0251	0.3260	0.0234
				Crisis Period			
3 Years	438	1.7226	29.5459	0.0515	0.0502	0.2120	0.0121
5 Years	438	2.5050	32.9174	0.0184	0.0183	0.3550	0.0360
10 Years	438	3.4330	35.3628	0.0340	0.0337	0.3616	0.0309
				Recovery Period			
3 Years	847	0.7871	32.9668	0.0127	0.0127	0.0772	0.0016
5 Years	847	1.4630	42.0675	0.0142	0.0142	0.1243	0.0039
10 Years	844	2.6463	56.1281	0.0247	0.0247	0.3878	0.0280
				Stagnant Period			
3 Years	390	0.6256	21.8746	0.0082	0.0082	0.0441	-0.0005
5 Years	390	1.3113	28.3226	0.0091	0.0092	0.1355	0.0053
10 Years	390	2.4517	44.7831	0.0161	0.0163	0.1523	0.0049

Table 3: Correlation coefficients between bond yields and credit (liquidity) measures

The table provides the correlation coefficients between bond yields and our credit (liquidity) measures from January 1, 2008 to June 30, 2014. The bond yield is the internal rate of return used in the present value formula that solves for a bond's mid price in percentage. CDS price (bps) represents the mid price of Sovereign CDS (quoted in basis points). The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\mathrm{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\mathrm{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price.

Variable	Bond yields for bonds with different maturities		
	3 years	5 years	10 years
CDS price (bps)	-0.1725	-0.3991	-0.6222
Dollar bid-ask spread	0.7575	0.3365	0.4987
Percentage bid-ask spread	0.7532	0.3355	0.5148
Effective spread	0.4798	0.6535	0.4417
γ (0.0001)	0.4368	0.6105	0.5674

Table 4: Relation between bond yields, credit, and liquidity (full sample period)

This table provides the regression results for a model in which we regress the yield of our sample bonds on each bond's CDS quoted mid price (credit) and our four liquidity measures during the full sample period (from January 1, 2008 to June 30, 2014). Specifically, we estimate the following equation:

$$\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$$

$\text{Sovereign Bond Yield}_t$ is the internal rate of return used in the present value formula that solves for a bond's mid price in percentage. Credit_t represents the mid price of Sovereign CDS. Liquidity_t stands for our four liquidity measures. The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. P-values are shown in parentheses below each coefficient. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. P-values of model's F-test are shown in the parentheses under adjusted R^2.

Variables	Liquidity variables			
	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ (0.0001)
	3-year bonds (number of observations=1675)			
Constant	0.7208***	0.7314***	0.9437***	1.1689***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-67.5781***	-73.4255***	-125.0331***	-120.3426***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	21.6712***	22.3037***	3.9789***	46.1046***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Adjusted R^2	0.6033	0.6017	0.3160	0.2717
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	5-year bonds (number of observations=1675)			
Constant	2.0980***	2.0988***	1.4669***	1.8100***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-201.3783***	-201.4277***	-108.4239***	-105.4213***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	23.7696***	23.7474***	3.3466***	21.6051***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Adjusted R^2	0.2774	0.2768	0.4697	0.4117
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	10-year bonds (number of observations= 1672)			
Constant	3.3683***	3.3329***	3.4182***	3.6934***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-221.9180***	-219.2179***	-253.1906***	-226.3118***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	20.0958***	20.9831***	1.8525***	8.5627***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Adjusted R^2	0.5200	0.5285	0.5680	0.6126
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Table 5: Relation between bond yields, credit, and liquidity (crisis period)

This table provides the regression results for a model in which we regress the yield of our sample bonds on each bond's CDS quoted mid price (credit) and our four liquidity measures during the crisis period (from January 1, 2008 to September 30, 2009). Specifically, we estimate the following equation:

$$\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$$

$\text{Sovereign Bond Yield}_t$ is the internal rate of return used in the present value formula that solves for a bond's mid price in percentage. Credit_t represents the mid price of Sovereign CDS. Liquidity_t stands for our four liquidity measures. The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. P-values are shown in parentheses below each coefficient. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. P-values of model's F-test are shown in the parentheses under adjusted R^2.

Variables	Liquidity variables			
	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ (0.0001)
	3-year bonds (number of observations=438)			
Constant	1.8252***	1.8254***	2.6461***	2.3455***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-150.2407***	-153.0378***	-108.0173***	-124.5279***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	6.5758***	6.8988***	-2.8545***	-21.2355***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Adjusted R^2	0.5880	0.5910	0.6519	0.5959
	5-year bonds (number of observations=438)			
Constant	3.0916***	3.0894***	2.9421***	3.0194***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-192.1803***	-192.1974***	-183.1141***	-182.1712***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	2.4390	2.5699	0.4609***	2.3248***
	(0.1736)	(0.1501)	(0.0003)	(0.0022)
Adjusted R^2	0.6624	0.6625	0.6709	0.6682
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	10-year bonds (number of observations=438)			
Constant	3.9338***	3.8682***	4.0572***	4.0202***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-168.7573***	-167.2896***	-169.5314***	-169.0509***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	2.7948**	4.6041***	-0.0707	0.3092
	(0.0383)	(0.0005)	(0.4250)	(0.3262)
Adjusted R^2	0.6238	0.6305	0.6206	0.6209
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Table 6: Relation between bond yields, credit, and liquidity (recovery period)

This table provides the regression results for a model in which we regress the yield of our sample bonds on each bond's CDS quoted mid price (credit) and our four liquidity measures during the recovery period (from October 1, 2009 to December 31, 2012). Specifically, we estimate the following equation:

$$\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$$

$\text{Sovereign Bond Yield}_t$ is the internal rate of return used in the present value formula that solves for a bond's mid price in percentage. Credit_t represents the mid price of Sovereign CDS. Liquidity_t stands for our four liquidity measures. The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. P-values are shown in parentheses below each coefficient. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. P-values of model's F-test are shown in the parentheses under adjusted R^2.

Variables	Liquidity variables			
	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ (0.0001)
	3-year bonds (number of observations=847)			
Constant	0.0905**	0.0891**	0.5504***	0.5609***
	(0.0417)	(0.0452)	(0.0000)	(0.0000)
Credit	31.7672***	32.2581***	52.5802***	59.3074***
	(0.0042)	(0.0036)	(0.0002)	(0.0000)
Liquidity	46.7849***	46.7233***	0.8207**	19.0632***
	(0.0000)	(0.0000)	(0.0113)	(0.0004)
Adjusted R^2	0.3912	0.3915	0.0224	0.0295
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	5-year bonds (number of observations=847)			
Constant	1.8697***	1.8679***	1.6864***	2.0996***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-149.5164***	-149.4076***	-133.8729***	-173.9697***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	15.6550***	15.7547***	2.7340***	24.2880***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Adjusted R^2	0.1280	0.1289	0.1033	0.0635
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	10-year bonds (number of observations=844)			
Constant	4.0507***	4.0033***	3.0098***	3.6164***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-318.0862***	-314.5396***	-256.7747***	-231.5185***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	15.4523***	16.5448***	2.7793***	11.7550***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Adjusted R^2	0.4049	0.4146	0.5768	0.7426
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Table 7: Relation between bond yields, credit, and liquidity (stagnant period)

This table provides the regression results for a model in which we regress the yield of our sample bonds on each bond's CDS quoted mid price (credit) and our four liquidity measures during the stagnant period (from January 1, 2012 to June 30, 2014). Specifically, we estimate the following equation:

$$\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$$

$\text{Sovereign Bond Yield}_t$ is the internal rate of return used in the present value formula that solves for a bond's mid price in percentage. Credit_t represents the mid price of Sovereign CDS. Liquidity_t stands for our four liquidity measures. The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. P-values are shown in parentheses below each coefficient. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. P-values of model's F-test are shown in the parentheses under adjusted R^2.

Variables	Liquidity variables			
	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ (0.0001)
	3-year bonds (number of observations=390)			
Constant	0.8299***	0.8304***	0.4770***	0.6105***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-113.7819***	-113.7405***	-82.4229***	-83.5014***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	5.4261	5.3465	7.4499***	-376.7082 ***
	(0.1800)	(0.1857)	(0.0000)	(0.0000)
Adjusted R^2	0.2170	0.2169	0.4700	0.4902
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	5-year bonds (number of observations=390)			
Constant	2.2441***	2.2421***	1.3975***	1.6227***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-352.1094***	-352.0129***	-210.4970***	-229.2001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	7.0529**	7.2107***	3.7631***	63.2641***
	(0.0101)	(0.0083)	(0.0000)	(0.0000)
Adjusted R^2	0.5916	0.5920	0.7919	0.8091
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	10-year bonds (number of observations=390)			
Constant	3.5607***	3.5308***	3.5038***	3.2235***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Credit	-252.6529***	-252.3090***	-244.9837***	-189.9052***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Liquidity	1.3951	3.1129	0.2954	16.0494***
	(0.6955)	(0.3768)	(0.2601)	(0.0000)
Adjusted R^2	0.5411	0.5418	0.5424	0.6188
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Table 8: Credit and liquidity proportions (full sample period)

This table provides information on the explanatory power of credit (liquidity) on the yields of 3-year, 5-year and 10-year bonds. We calculate the proportion of credit and liquidity as the average weights of the impact of credit and liquidity on the bond yields:

$$\text{Credit Contribution}_t = \beta'(\text{Credit}_t - \text{Credit}_{ave})$$

$$\text{Liquidity Contribution}_t = \delta'(\text{Liquidity}_t - \text{Liquidity}_{ave})$$

$$\text{Credit Proportion}_t = \frac{|\text{Credit Contribution}_t|}{|\text{Credit Contribution}_t| + |\text{Liquidity Contribution}_t|}$$

$$\text{Liquidity Proportion}_t = 1 - \text{Credit Proportion}_t$$

Where Credit_{ave} is the arithmetic average of daily CDS prices and Liquidity_{ave} is the arithmetic average of our liquidity measures. Credit_t represents the mid price of Sovereign CDS. Liquidity_t stands for our four liquidity measures. The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. β' (δ') is the credit (liquidity) coefficient of the regression: $\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$.

Variable	Liquidity Variable			
	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ(0.0001)
		3-year bonds		
Credit	0.1910	0.2382	0.3978	0.4064
Liquidity	0.8090	0.7618	0.6022	0.5936
		5-year bonds		
Credit	0.6171	0.6187	0.3763	0.3379
Liquidity	0.3829	0.3813	0.6237	0.6621
		10-year bonds		
Credit	0.5887	0.5806	0.5664	0.5521
Liquidity	0.4113	0.4194	0.4336	0.4479

Table 9: Credit and liquidity proportions (crisis period)

This table provides information on the explanatory power of credit (liquidity) on the yields of 3-year, 5-year and 10-year bonds. We calculate the proportion of credit and liquidity as the average weights of the impact of credit and liquidity on the bond yields:

$$\text{Credit Contribution}_t = \beta'(\text{Credit}_t - \text{Credit}_{ave})$$

$$\text{Liquidity Contribution}_t = \delta'(\text{Liquidity}_t - \text{Liquidity}_{ave})$$

$$\text{Credit Proportion}_t = \frac{|\text{Credit Contribution}_t|}{|\text{Credit Contribution}_t| + |\text{Liquidity Contribution}_t|}$$

$$\text{Liquidity Proportion}_t = 1 - \text{Credit Proportion}_t$$

Where Credit_{ave} is the arithmetic average of daily CDS prices and Liquidity_{ave} is the arithmetic average of our liquidity measures. Credit_t represents the mid price of Sovereign CDS. Liquidity_t stands for our four liquidity measures. The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. β' (δ') is the credit (liquidity) coefficient of the regression: $\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$.

Variable	Liquidity Variable			
	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ(0.0001)
		3-year bonds		
Credit	0.6503	0.6523	0.5345	0.4133
Liquidity	0.3497	0.3477	0.4655	0.5867
		5-year bonds		
Credit	0.9423	0.9394	0.7908	0.8118
Liquidity	0.0577	0.0606	0.2092	0.1882
		10-year bonds		
Credit	0.9228	0.8993	0.9421	0.9404
Liquidity	0.0772	0.1007	0.0579	0.0596

Table 10: Credit and liquidity proportions (recovery period)

This table provides information on the explanatory power of credit (liquidity) on the yields of 3-year, 5-year and 10-year bonds. We calculate the proportion of credit and liquidity as the average weights of the impact of credit and liquidity on the bond yields:

$$\text{Credit Contribution}_t = \beta'(\text{Credit}_t - \text{Credit}_{ave})$$

$$\text{Liquidity Contribution}_t = \delta'(\text{Liquidity}_t - \text{Liquidity}_{ave})$$

$$\text{Credit Proportion}_t = \frac{|\text{Credit Contribution}_t|}{|\text{Credit Contribution}_t| + |\text{Liquidity Contribution}_t|}$$

$$\text{Liquidity Proportion}_t = 1 - \text{Credit Proportion}_t$$

Where Credit_{ave} is the arithmetic average of daily CDS prices and Liquidity_{ave} is the arithmetic average of our liquidity measures. Credit_t represents the mid price of Sovereign CDS. Liquidity_t stands for our four liquidity measures. The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. β' (δ') is the credit (liquidity) coefficient of the regression : $\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$.

Variable	Liquidity Variable			
	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ(0.0001)
		3-year bonds		
Credit	0.1132	0.1149	0.5569	0.5502
Liquidity	0.8868	0.8851	0.4431	0.4498
		5-year bonds		
Credit	0.5434	0.5420	0.3445	0.4767
Liquidity	0.4566	0.4580	0.6555	0.5233
		10-year bonds		
Credit	0.6088	0.5930	0.4562	0.4081
Liquidity	0.3912	0.4070	0.5438	0.5919

Table 11: Credit and liquidity proportions (stagnant period)

This table provides information on the explanatory power of credit (liquidity) on the yields of 3-year, 5-year and 10-year bonds. We calculate the proportion of credit and liquidity as the average weights of the impact of credit and liquidity on the bond yields:

$$\text{Credit Contribution}_t = \beta'(\text{Credit}_t - \text{Credit}_{ave})$$

$$\text{Liquidity Contribution}_t = \delta'(\text{Liquidity}_t - \text{Liquidity}_{ave})$$

$$\text{Credit Proportion}_t = \frac{|\text{Credit Contribution}_t|}{|\text{Credit Contribution}_t| + |\text{Liquidity Contribution}_t|}$$

$$\text{Liquidity Proportion}_t = 1 - \text{Credit Proportion}_t$$

Where Credit_{ave} is the arithmetic average of daily CDS prices and Liquidity_{ave} is the arithmetic average of our liquidity measures. Credit_t represents the mid price of Sovereign CDS. Liquidity_t stands for our four liquidity measures. The dollar bid-ask spread is the gap between the daily bid and ask prices. The percentage bid-ask spread is the dollar bid-ask spread divided by the corresponding mid price. The effective spread is measured as $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is measured as $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. β' (δ') is the credit (liquidity) coefficient of the regression: $\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$.

Variable	Liquidity Variable			
	Dollar bid-ask spread	Percentage bid-ask spread	Effective spread	γ(0.0001)
		3-year bonds		
Credit	0.9475	0.9484	0.5429	0.5265
Liquidity	0.0525	0.0516	0.4571	0.4735
		5-year bonds		
Credit	0.8528	0.8508	0.3864	0.5593
Liquidity	0.1472	0.1492	0.6136	0.4407
		10-year bonds		
Credit	0.9738	0.9540	0.8688	0.5299
Liquidity	0.0262	0.0460	0.1312	0.4701

Figure 1: 3-year sovereign bond yields and corresponding CDS prices

This figure displays daily movements in the yield of 3-year U.S. sovereign bonds and the price of 3-year Credit Default Swaps (CDS) from January 1, 2008 to September 30, 2009. The U.S. sovereign bonds yield is measured as the internal rate of return in the present value formula that solves for the daily mid price. The Sovereign CDS price, measured in 10 basis points for reading easily, is the daily quoted mid price for the corresponding Treasury bond.

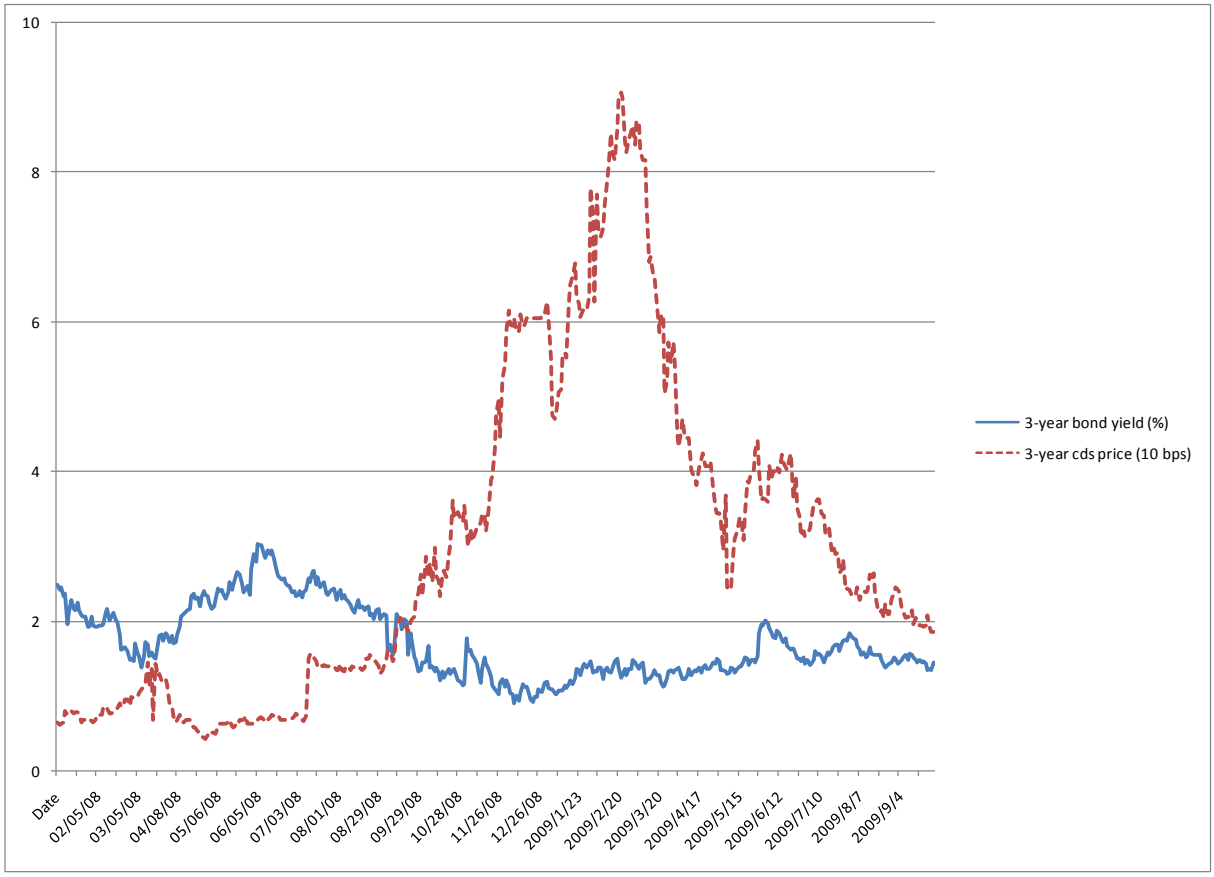

Figure 2: 5-year sovereign bond yields and corresponding CDS prices

This figure displays daily movements in the yield of 5-year U.S. sovereign bonds and the price of 5-year Credit Default Swaps (CDS) from January 1, 2008 to September 30, 2009. The U.S. sovereign bonds yield is measured as the internal rate of return in the present value formula that solves for the daily mid price. The Sovereign CDS price, measured in 10 basis points for reading easily, is the daily quoted mid price for the corresponding Treasury bond.

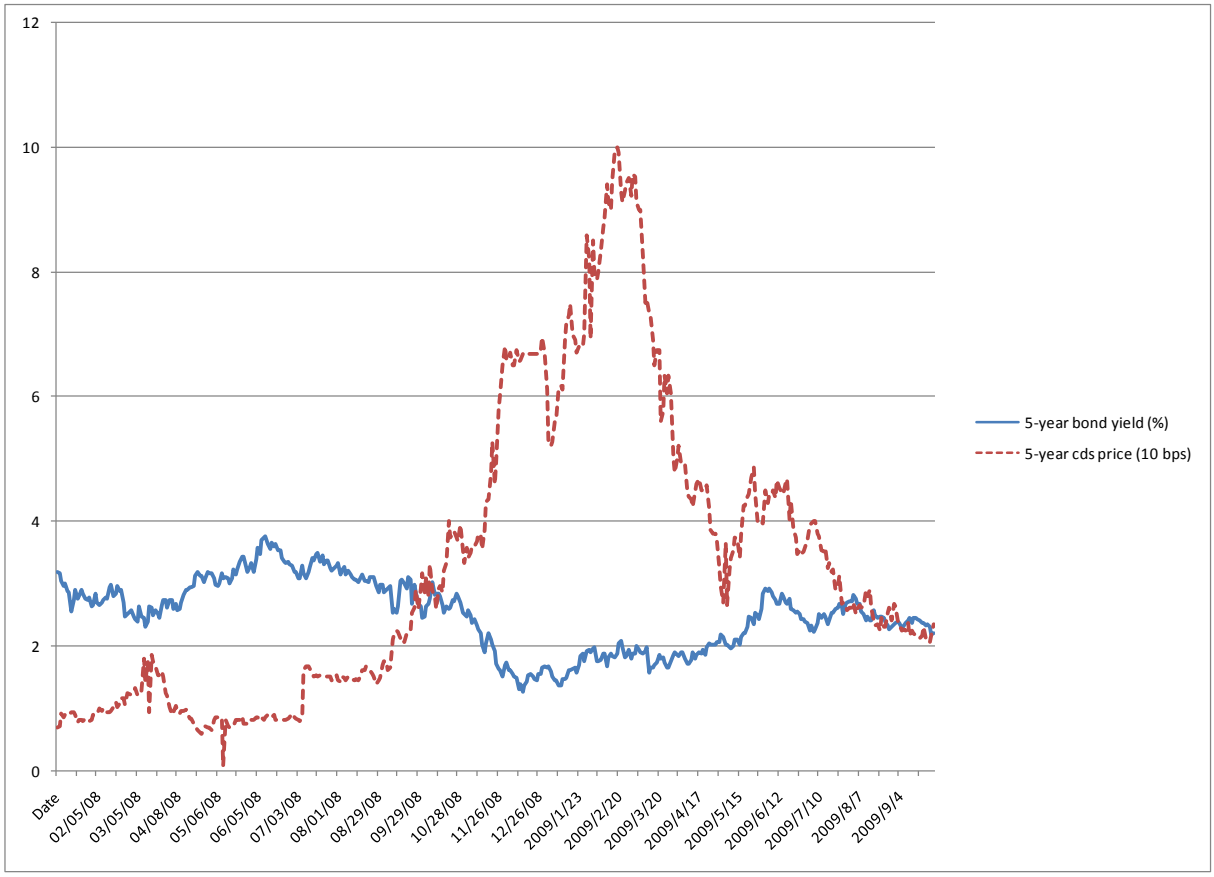

Figure 3: 10-year sovereign bond yields and corresponding CDS prices

This figure displays daily movements in the yield of 10-year U.S. sovereign bonds and the price of 10-year Credit Default Swaps (CDS) from January 1, 2008 to September 30, 2009. The U.S. sovereign bonds yield is measured as the internal rate of return in the present value formula that solves for the daily mid price. The Sovereign CDS price, measured in 10 basis points for reading easily, is the daily quoted mid price for the corresponding Treasury bond.

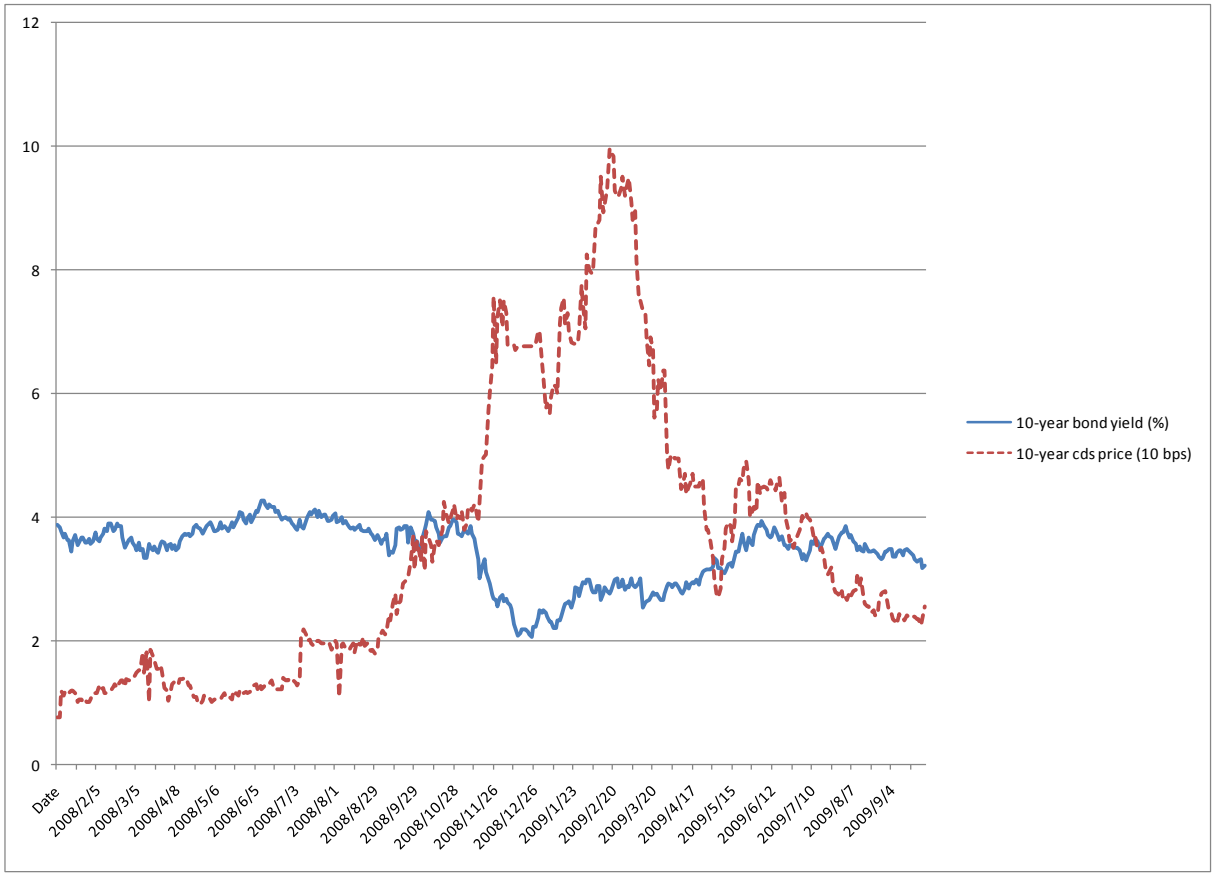

Figure 4: Credit differentials for 3 year Treasury bonds

The credit differential (CD) is defined as the spread between short-term and long-term Treasury bond yields. Specifically, the 3y credit differential in 2004 (2008) equals the yield of the 3-year on-the-run Treasury bond minus that of the 1-month Treasury bill in 2004 (2008).

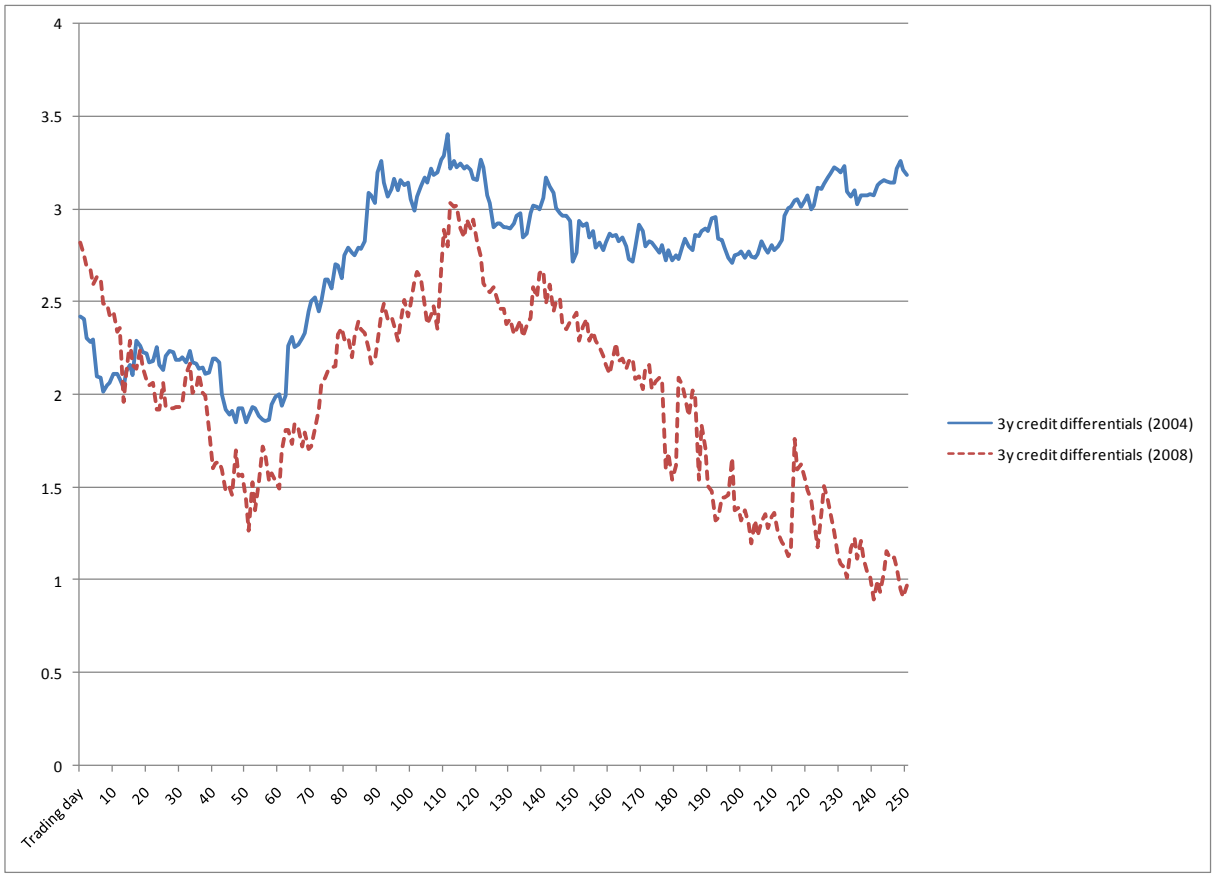

Figure 5: Credit differentials for 5 year Treasury bonds

The credit differential (CD) is defined as the spread between short-term and long-term Treasury bond yields. Specifically, the 5y credit differential in 2004 (2008) equals the yield of the 5-year on-the-run Treasury bond minus that of the 1-month Treasury bill in 2004 (2008).

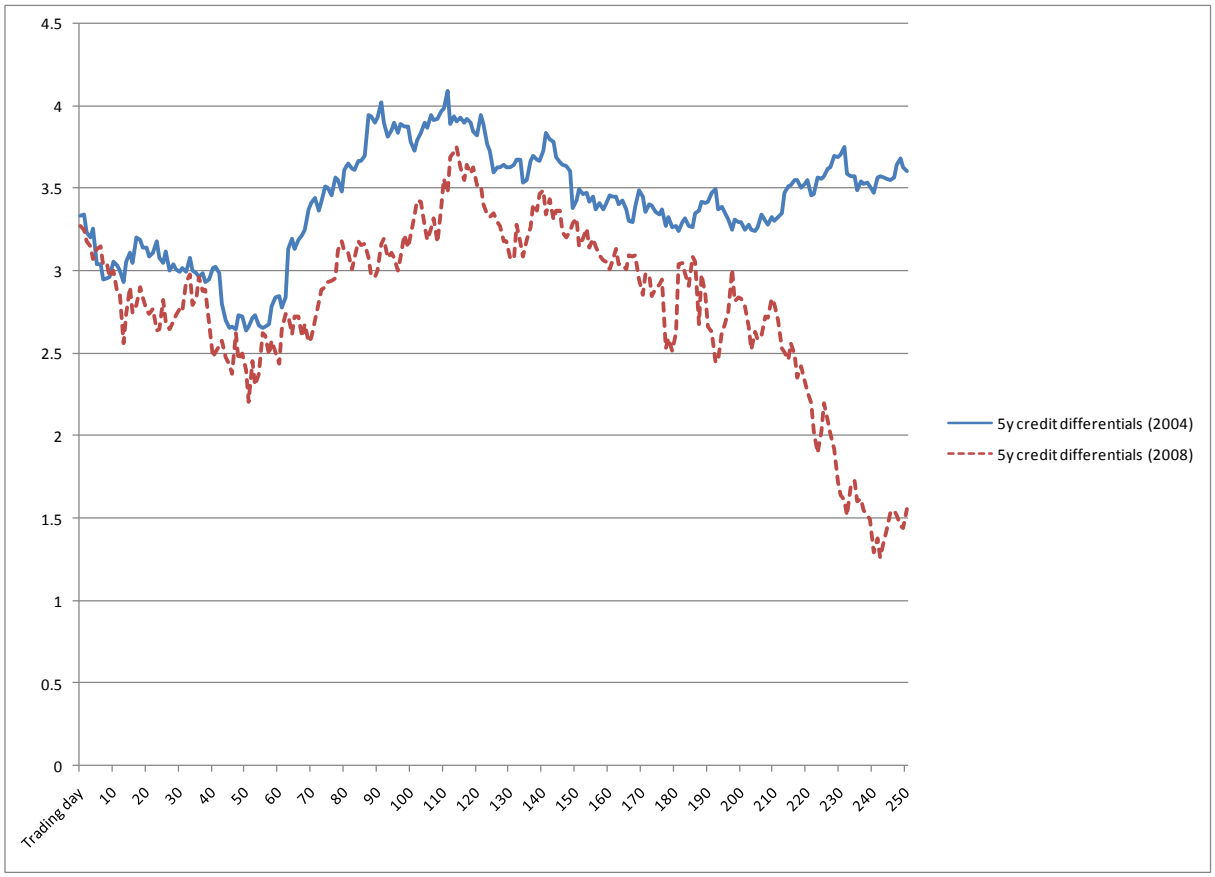

Figure 6: Credit differentials for 10 year Treasury bonds

The credit differential (CD) is defined as the spread between short-term and long-term Treasury bond yields. Specifically, the 10y credit differential in 2004 (2008) equals the yield of the 10-year on-the-run Treasury bond minus that of the 1-month Treasury bill in 2004 (2008).

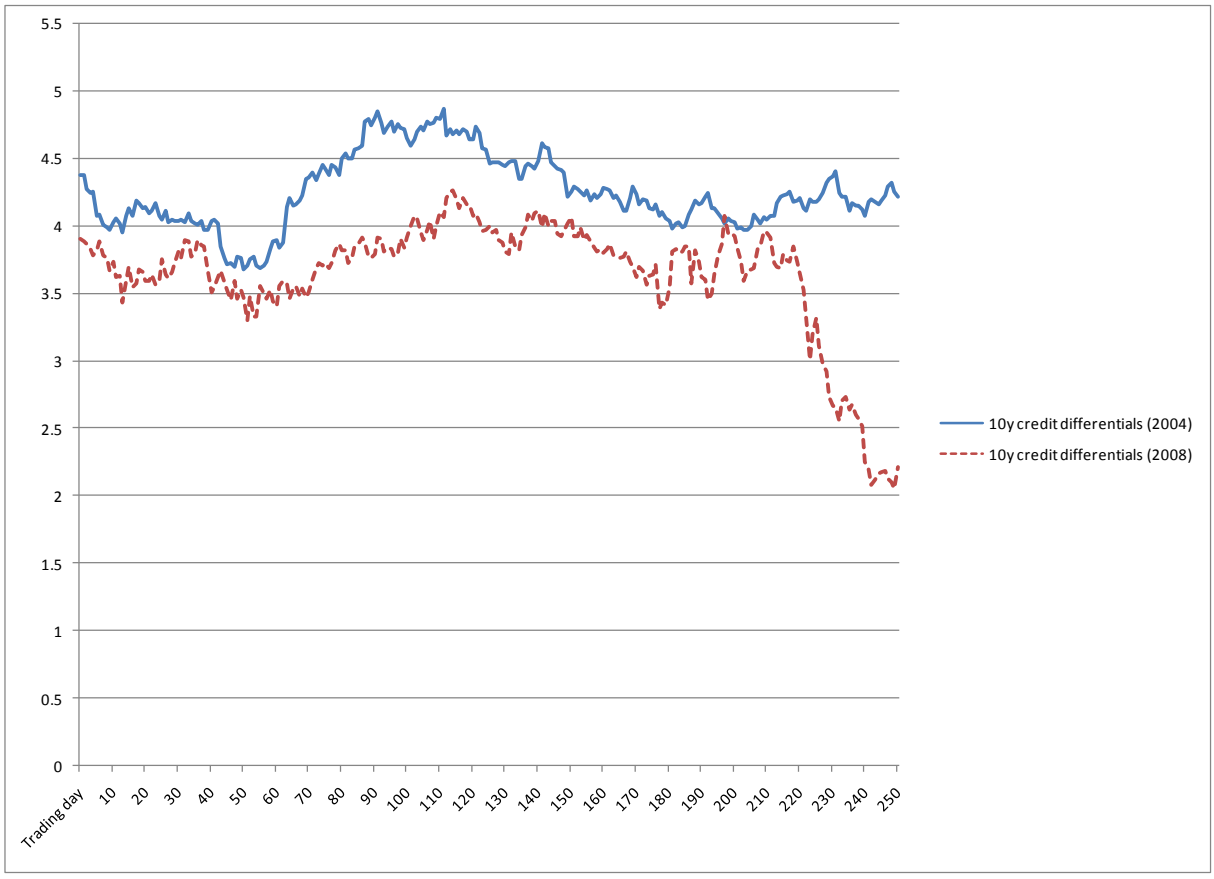

Figure 7: Liquidity differentials for 3-year Treasury bonds

The liquidity differential (LD) is defined as the yield spread between off-the-run and on-the-run Treasury bonds. Specifically, the 3y liquidity differential in 2004 (2008) equals the yield of the 3-year off-the-run Treasury bond minus that of the corresponding on-the-run Treasury bond in 2004 (2008). The 3-year liquidity differentials are untypical due to interventions by the federal government.

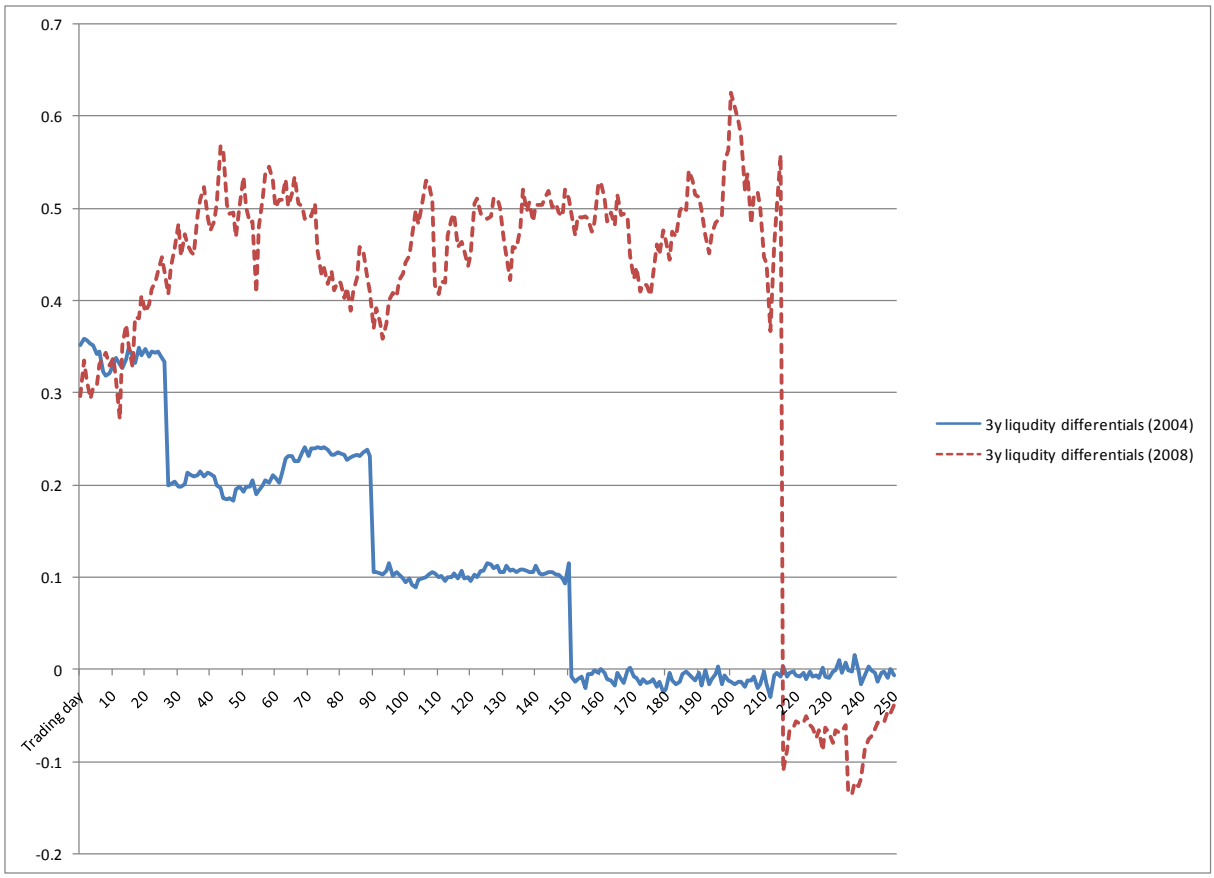

Figure 8: Liquidity differentials for 5-year Treasury bonds

The liquidity differential (LD) is defined as the yield spread between off-the-run and on-the-run Treasury bonds. Specifically, the 5y liquidity differential in 2004 (2008) equals the yield of the 5-year off-the-run Treasury bond minus that of the corresponding on-the-run Treasury bond in 2004 (2008).

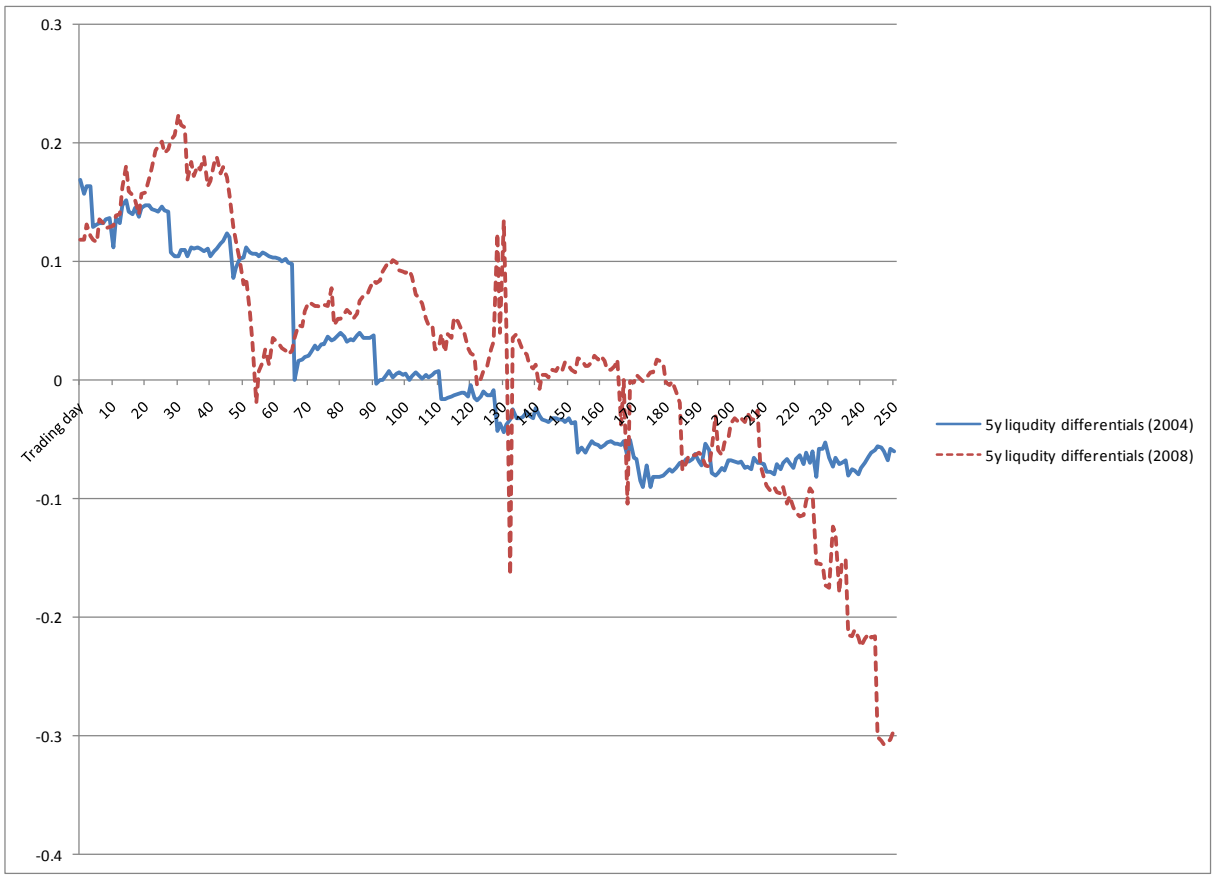

Figure 9: Liquidity differentials for 10-year Treasury bonds

The liquidity differential (LD) is defined as the yield spread between off-the-run and on-the-run Treasury bonds. Specifically, the 10y liquidity differential in 2004 (2008) equals the yield of the 10-year off-the-run Treasury bond minus that of the corresponding on-the-run Treasury bond in 2004 (2008).

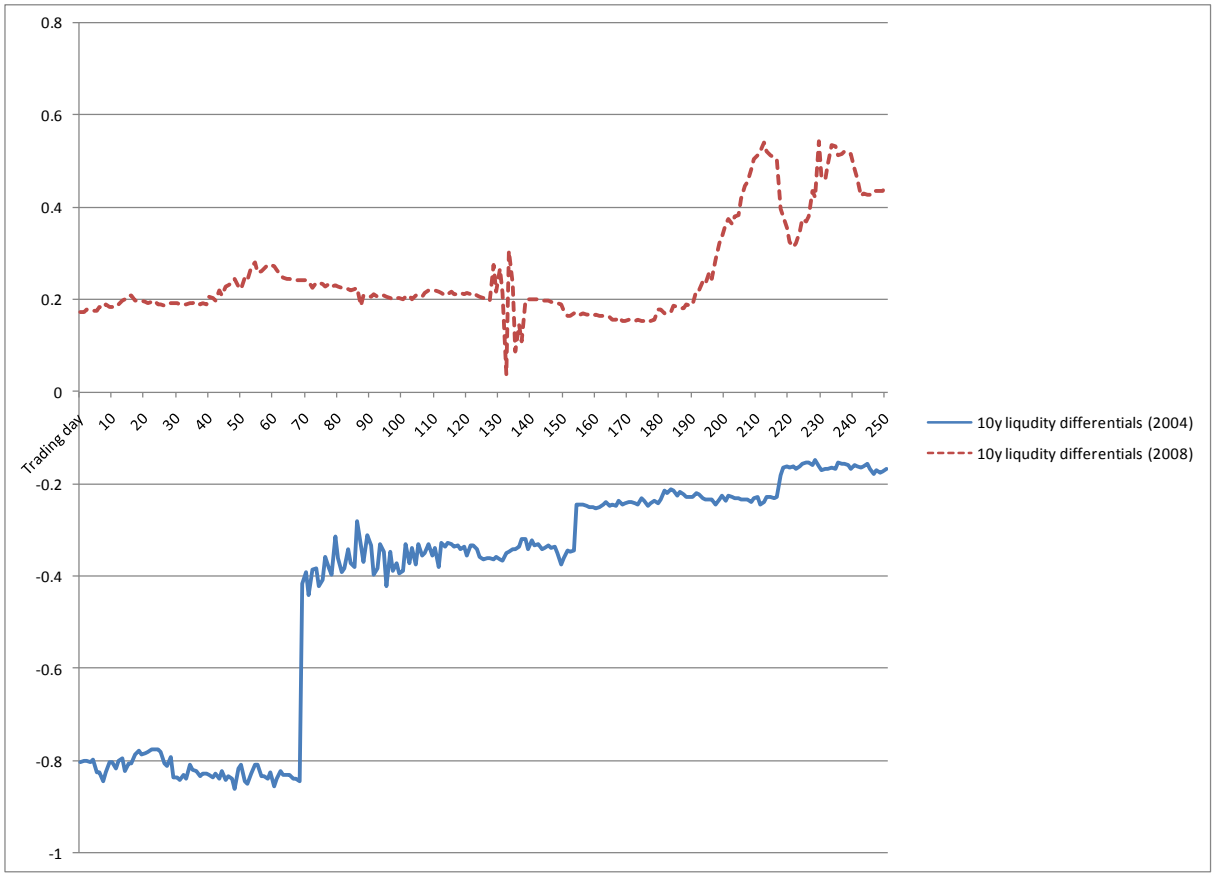

Figure 10: Liquidity proportions for Treasury bonds with 3 year maturity

This figure displays the impact of liquidity on bonds with 3 years to maturity during different periods. Specifically, we define a bond's liquidity proportions as follows:

$$\text{Credit Contribution}_t = \beta'(\text{Credit}_t - \text{Credit}_{ave})$$

$$\text{Liquidity Contribution}_t = \delta'(\text{Liquidity}_t - \text{Liquidity}_{ave})$$

$$\text{Credit Proportion}_t = \frac{|\text{Credit Contribution}_t|}{|\text{Credit Contribution}_t| + |\text{Liquidity Contribution}_t|}$$

$$\text{Liquidity Proportion}_t = 1 - \text{Credit Proportion}_t$$

Where Credit_{ave} is the arithmetic average of daily CDS prices and Liquidity_{ave} is the arithmetic average of liquidity measures. We employ four liquidity measures. The dollar bid-ask spread is the average gap between the daily bid and ask prices. The percentage bid-ask spread is the average dollar bid-ask spread divided by the corresponding mid price. The effective spread is the average of $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is the average of $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. β' (δ') is the credit (liquidity) coefficient of the regression: $\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$.

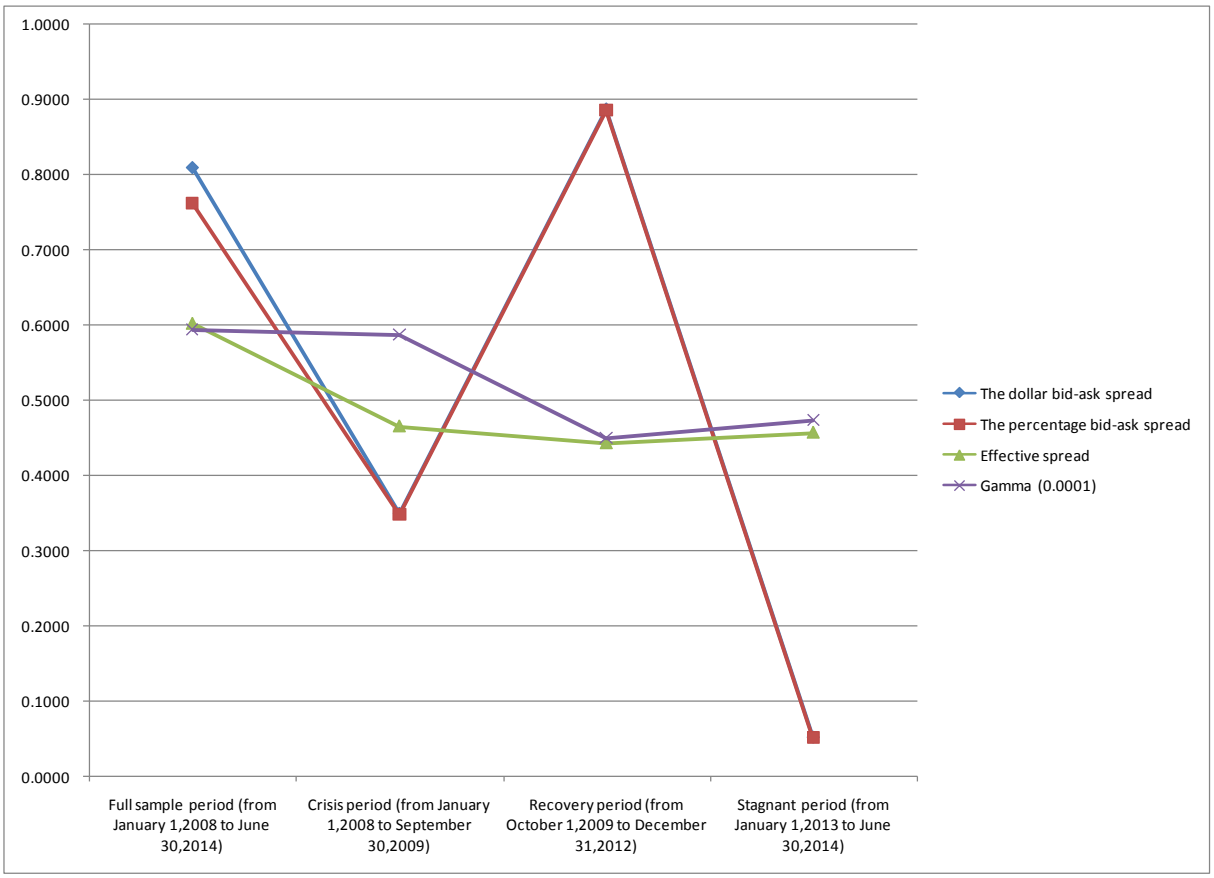

Figure 11: Liquidity proportions for Treasury bond with 5 year maturity

This figure displays the impact of liquidity on bonds with 5 years to maturity during different periods. Specifically, we define a bond's liquidity proportions as follows:

$$\text{Credit Contribution}_t = \beta'(\text{Credit}_t - \text{Credit}_{ave})$$

$$\text{Liquidity Contribution}_t = \delta'(\text{Liquidity}_t - \text{Liquidity}_{ave})$$

$$\text{Credit Proportion}_t = \frac{|\text{Credit Contribution}_t|}{|\text{Credit Contribution}_t| + |\text{Liquidity Contribution}_t|}$$

$$\text{Liquidity Proportion}_t = 1 - \text{Credit Proportion}_t$$

Where Credit_{ave} is the arithmetic average of daily CDS prices and Liquidity_{ave} is the arithmetic average of liquidity measures. We employ four liquidity measures. The dollar bid-ask spread is the average gap between the daily bid and ask prices. The percentage bid-ask spread is the average dollar bid-ask spread divided by the corresponding mid price. The effective spread is the average of $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is the average of $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. β' (δ') is the credit (liquidity) coefficient of the regression: $\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$.

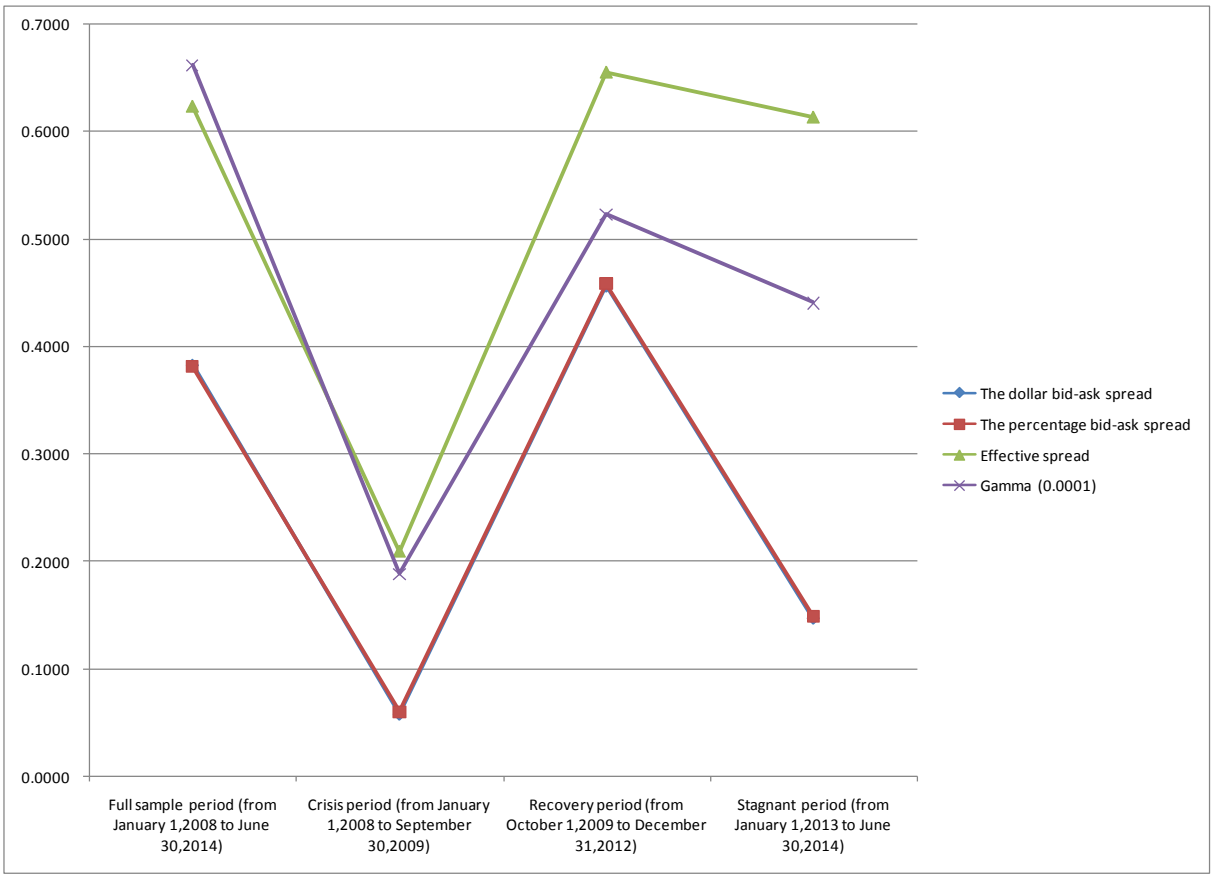

Figure 12: Liquidity proportions for Treasury bond with 10 year maturity

This figure displays the impact of liquidity on bonds with 10 years to maturity during different periods. Specifically, we define a bond's liquidity proportions as follows:

$$\text{Credit Contribution}_t = \beta'(\text{Credit}_t - \text{Credit}_{ave})$$

$$\text{Liquidity Contribution}_t = \delta'(\text{Liquidity}_t - \text{Liquidity}_{ave})$$

$$\text{Credit Proportion}_t = \frac{|\text{Credit Contribution}_t|}{|\text{Credit Contribution}_t| + |\text{Liquidity Contribution}_t|}$$

$$\text{Liquidity Proportion}_t = 1 - \text{Credit Proportion}_t$$

Where Credit_{ave} is the arithmetic average of daily CDS prices and Liquidity_{ave} is the arithmetic average of liquidity measures. We employ four liquidity measures. The dollar bid-ask spread is the average gap between the daily bid and ask prices. The percentage bid-ask spread is the average dollar bid-ask spread divided by the corresponding mid price. The effective spread is the average of $2\sqrt{-\text{cov}}$, where "cov" is the first-order auto covariance of a bond's returns. γ is the average of $-\text{Cov}(p_t - p_{t-1}, p_{t+1} - p_t)$, where $p_t = \ln P_t$ and P_t denotes the clean price. β' (δ') is the credit (liquidity) coefficient of the regression: $\text{Sovereign Bond Yield}_t = \alpha + \beta * \text{Credit}_t + \delta * \text{Liquidity}_t + \varepsilon_t$.