Macro Factors in Corporate Bond Credit and Liquidity Spreads

Biao Guo∗Songtao Wang†‡

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Abstract

This paper studies the macroeconomic determinants of the term structures of Treasury yields, corporate bond credit spreads, and corporate bond liquidity spreads in a unified no-arbitrage framework. Four economic factors, monetary conditions, inflation, real output, and financial market volatility, are extracted from a set of macroeconomic and financial data series. During the pre-crisis period, volatility shocks decrease Treasury yields and widen both credit spreads and liquidity spreads for all rating classes, and credit spreads widen as monetary conditions tighten, but the effects of inflation and real output are insignificant. In times of stress, financial market volatility has a similar impact and the impacts of inflation and real output become significant as well. Ignoring the liquidity component of corporate yield spreads is shown to lead to inaccurate estimation of the impacts of economic factors on corporate credit spreads. The paper also provides evidence of “flight-to-liquidity” behavior which strengthens in bad times and sheds light on the negative correlation between the risk-free rate and corporate yield spreads as well as on the positive correlation between credit spreads and liquidity spreads.

Keywords: Affine Models, Credit Default Swaps, Macroeconomic Variables, Credit Risk, Liquidity.
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∗Renmin University of China. E-mail: biao.guo@outlook.com
†Shanghai Jiaotong University. E-mail: wangsongtao@sjtu.edu.cn
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I Introduction

It is widely known that credit risk alone cannot explain corporate yield spreads. For instance, Collin-Dufresne, Goldstein, and Martin (2001) and Huang and Huang (2012) show that credit risk only accounts for a small fraction of the observed yield spreads on investment-grade bonds and a larger fraction for speculative-grade bonds. A large number of papers have been dedicated to studying this issue and find that the nondefault component of yield spreads is mainly related to the illiquidity of corporate bonds (see, e.g., Longstaff, Mithal, and Neis (2005), Chen, Lesmond, and Wei (2007), Martell (2008)).

While previous studies have examined the dynamics of corporate bond credit spreads across maturities, little is known about corporate bond liquidity spreads. What is the term structure of corporate bond liquidity spreads? What determines variations in this term structure? According to Basel III, corporate bonds are included in the Level 2 assets whose liquidity needs to be monitored quantitatively\(^1\). Thus, understanding these issues is of fundamental importance from a risk management perspective. Also important for risk management is to understand the co-movement between credit spreads and liquidity spreads of corporate bonds. Ericsson and Renault (2006) and Buhler and Trapp (2009) find that credit spreads and liquidity spreads are positively correlated, however, they do not provide an explanation for this stylized fact.

This paper studies these and other related issues by investigating in a unified framework the impacts of macroeconomic and financial factors on Treasury yields, corporate credit spreads, corporate liquidity spreads, and their term structures. Specifically, building on Ang and Piazzesi (2003), Wu and Zhang (2008), and others, we develop a no-arbitrage term structure model to link four economic factors representing monetary condition,

\(^1\) Basel III defines two categories of assets as high-quality liquid: Level 1 and Level 2. The Level 1 assets can be included into a bank’s portfolio without limit while the Level 2 assets can only comprise up to 40%.
macroeconomic fundamentals, and financial market volatility to the pricing of Treasury bonds, Credit Default Swaps (CDS), and corporate bonds by assuming that the instantaneous Treasury yield and the instantaneous corporate bond credit and liquidity spreads are affine in the four economic factors\(^2\). Compared to the regression approach, the no-arbitrage term structure model has some advantages. First, it generates more interpretable and more stable results than those from regressions. Second, it allows us to make an internally consistent analysis of the impacts of macroeconomic and financial factors on Treasury yields, corporate bond credit and liquidity spreads across the whole spectrum of maturities. Moreover, the estimation results from the no-arbitrage term structure model not only show how the factors affect the term structure but also reveal the reasons behind it. These advantages serve in part as our motivation for using the no-arbitrage framework to study the macroeconomic determinants of the credit and liquidity spreads.

As in Longstaff, Mithal, and Neis (2005), Ericsson and Renault (2006), and Buhler and Trapp (2009), corporate yield spreads are divided into default and nondefault components, and the nondefault component represents the compensation for illiquidity of corporate bonds. We use the information in credit default swap premia to dissect the default and liquidity components of corporate yield spreads. Credit default swaps are the most common type of credit derivative. In a credit default swap, the party buying protection pays the seller a fixed premium each period until either default occurs or the swap contract matures. In return, if the underlying firm defaults on its debt, the protection seller is obligated to buy back from the buyer the defaulted bond at its par value or to pay the buyer the cash difference between par value and the market price of the bond. Thus, credit default swaps provide information about the default component of corporate yield spreads.

The empirical analysis first focuses on the sample period from July 2002 to November 2007. We extract four economic factors of monetary condition, inflation, real output, and financial market volatility from a set of 12 macroeconomic and financial data series using the Principal Component Analysis (PCA) approach. With the extracted economic factors, we estimate the parameters for Treasury bonds, and using these estimated parameters as given, we then estimate the parameters for CDS and corporate bonds for each rating class. The main results can be summarized as follows:

First, variations in Treasury yields and corporate credit and liquidity spreads are mainly related to shocks in the monetary condition, real output, and financial market volatility factors. Specifically, increases in financial market volatility lower Treasury yields and widen credit spreads and liquidity spreads, and the impact of financial market volatility on both credit spreads and liquidity spreads increases as the credit rating declines. Expansionary monetary policies reduce credit spreads, and the reduction is stronger at lower rating classes. In addition, the impact of the financial market volatility factor on credit spreads of investment-grade bonds and on liquidity spreads of bonds with ratings below A persists across maturities. The inflation factor is not important in corporate credit and liquidity spreads during the pre-crisis period. The finding of the opposite responses of Treasury yields and corporate liquidity spreads to shocks of financial market volatility is in line with the "flight-to-liquidity" phenomenon. The results on the determinants of variations in Treasury yields and corporate bond credit and liquidity spreads also suggest that the negative correlation between the interest rates and corporate yield spreads (see, e.g., Longstaff and Schwartz (1995), Duffee (1999)) is mainly driven by the responses in opposite directions of these two rates to exogenous shocks in the financial market volatility factor while the positive correlation between the credit and liquidity components of corporate yield spreads (see, e.g., Ericsson and Renault (2006), Buhler and Trapp (2009)) is mainly driven by their similar responses to exogenous shocks in the financial market volatility factor.
Second, the ratio of the implied liquidity spread to the observed yield spread decreases as the rating declines and exceeds 50% for investment-grade bonds (71.74% for bonds with ratings above AA), consistent with the findings of Elton et al. (2001), Huang and Huang (2012), etc. that credit risk accounts for only a small fraction of the yield spreads for investment-grade bonds. In addition, the ratio of the implied liquidity spread to the observed yield spread is a first decreasing and then increasing function of the bond maturity across all rating classes, with the lowest ratio occurring for bonds that expire in around seven years. This result is different from the findings of Amihud and Mendelson (1991) and Ericsson and Renault (2006) that the liquidity spread is a decreasing and convex function of the bond maturity.

Alternatively, we estimate an otherwise similar model assuming that yield spreads are only due to credit risk and do not contain the compensation for illiquidity (as in Amato and Luisi (2006), Mueller (2007), Wu and Zhang (2008), and Specker (2011)). The relationships between the economic factors and credit spreads estimated in the alternative model are different, indicating that ignoring the liquidity component of yield spreads may lead to inaccurate estimation of the impacts of the economic factors on credit spreads. This finding justifies the importance of dissecting liquidity spreads and credit spreads of corporate bonds.

Then, we extend the empirical analysis to the period from July 2002 to June 2010, which nests the recent financial crisis. The ”flight-to-liquidity” phenomenon strengthens, and again both credit spreads and liquidity spreads response positively to shocks in the financial market volatility factor. Accommodative monetary policies undertaken by the Federal Reserve Board in times of stress change the relationship between the monetary condition factor and credit spreads. In addition, our results show that in times of stress, the inflation factor is also important in liquidity spreads: a higher inflation increases liquidity spreads at all rating classes. In times of stress, the impacts of the economic factors on credit spreads are persistent.
Finally, we find that the nondefault component of CDS spreads defined as the market observed CDS spreads minus the model-implied CDS spreads has weak correlations with three market and CDS-specific liquidity proxies: 1) the on/off-the-run 5-year Treasury yield spread; 2) the flows into money market mutual funds; and 3) the number of CDS quote providers. The three liquidity proxies only explain a very small portion of variations in the nondefault component of CDS spreads. This result justifies the assumption made in this study that CDS spreads are mainly due to credit risk and do not contain the compensation for the illiquidity of CDS contracts.

Many of this paper’s findings are new while others reinforce and clarify previous results. This paper is the first empirical work that studies in a no-arbitrage framework the determinants of the term structure of corporate bond liquidity spreads. Goyenko, Subrahmanyam, and Ukhov (2011) study the joint time-series of illiquidity for different maturities and the determinants of on-the-run and off-the-run illiquidity, but their analysis focuses on Treasury bonds and is based on the regression approach. Ericsson and Renault (2006) study the term structure of corporate bond liquidity spreads without investigating the determinants of the term structure. Different from many previous studies such as Longstaff (2004) and Acharya, Amihud, and Bharath (2013), this paper finds ”flight-to-liquidity” also in non-stress times. Furthermore, this paper provides economic explanations for the negative correlation between the risk free interest rates and corporate yield spreads and the positive correlation between the credit and liquidity components of corporate yield spreads.

The rest of this paper is organized as follows: Section II shows the extraction of four economic factors from a set of 12 macroeconomic and financial data series; Section III derives the closed-form pricing formulas for Treasury bonds, CDS, and corporate bonds; Section IV discusses the data used in this study and the method of estimating the model parameters;
Section V presents the empirical results; Section VI examines whether and how the relationships between the economic factors and the Treasury yield, corporate bond credit and liquidity spreads change in times of stress; Section VII analyzes the residuals of CDS spreads; Section VIII concludes this paper with further comments.

II No-Arbitrage Pricing Model

We develop a no-arbitrage model to link the four economic factors to the pricing of Treasury bonds, CDS, and corporate bonds\(^3\), and Treasury yield is used as the riskless interest rate. The instantaneous Treasury yield, corporate bond credit and liquidity spreads are assumed to be affine in the four economic factors to derive closed-form pricing formulas. Let \(X \in \mathbb{R}^4\) be a vector of Markov processes for the four factors governing an economy, and the mean-reverted dynamics for the economic factors under the physical measure \(P\) are

\[
dX_{i,t} = -k_iX_{i,t}dt + \sigma_i dW_t
\]

for \(i = 1, 2, 3, 4\), and under the equivalent martingale measure \(Q\) are

\[
dX_{i,t} = k_i^Q \left( \theta_i^Q - X_{i,t} \right) dt + \sigma_i dW_t^Q
\]

where \(k_i \left( k_i^Q \right)\) determines the mean reversion speed, \(\theta_i^Q\) is the long run mean of the factor \(i\), \(\sigma_i\) measures the volatility of the factor \(i\), \(W_t \left( W_t^Q \right)\) is an independent standard Brownian motion vector under the measure \(P \left( Q \right)\), \(k^Q \theta^Q = -\gamma_0\) and \(k^Q = k + \gamma_1\) such that the market price of risk \(\gamma(X_t) = \Omega^{-\frac{1}{2}} \left[ \gamma_0 + \gamma_1 X_t \right]\) is a deterministic function of the factor levels associated with \(W_t^Q\), here \(\gamma_0\) and \(\gamma_1\) affect the mean value and the time variation of risk.

\(^3\)Some macro-finance papers also use three other unobserved latent factors (i.e. the level, slope, and curvature factors). These latent factors are not used in this study due to the following reasons. First, incorporating them into our model will dramatically enlarge the set of parameters that need to be estimated, making the estimation very difficult. Second, it is ambiguous what the level, slop, and curvature factors stand for, making it difficult to explain the empirical results associated with these factors. Third, as Ang and Piazzesi (2003) show, the macroeconomic factors such as inflation and real output can indeed explain a significant part of variations in the three latent factors.

\(^4\)This specification of market price of risk is commonly used in literature, for example, by Ang and Piazzesi (2003), Wu and Zhang (2008).
premia. For the sake of parsimony and closed-form solutions, \( k^Q \) is restrained to be a diagonal matrix so the four factors are independent and the time variation in the compensation for shocks to factors is only driven by the factors themselves. 

\[
\Omega = \begin{bmatrix}
\sigma_1^2 & 0 & 0 & 0 \\
0 & \sigma_2^2 & 0 & 0 \\
0 & 0 & \sigma_3^2 & 0 \\
0 & 0 & 0 & \sigma_4^2 \\
\end{bmatrix}
\]

is the covariance matrix of the four factors.

A Treasury Bond

Assume that instantaneous Treasury interest rate \( r_t \) is a function of \( X_t \)

\[
r_t = a_r + b_r^T X_t
\]

(3)

A zero-coupon treasury bond with time to maturity \( T \) can be priced under \( Q \) measure as

\[
B(0, T) = E^Q \left[ \exp \left( - \int_0^T r_t dt \right) \right]
\]

(4)

As shown in Appendix, Eq. (4) has a closed-form solution as

\[
B(0, T) = \exp \left( a_B + b_B^T X_0 \right)
\]

(5)

where \( a_B \) and \( b_B \) are solutions of the following ordinary differential equations (ODEs)

\[
\dot{a}_B = a_r + b_B^T \gamma_0 - \frac{1}{2} b_B^T \Omega b_B
\]

(6)

\[
\dot{b}_B = b_r + (k^Q)^T b_B
\]

(7)

subject to the boundary conditions \( a_B = 0 \) and \( b_B = 0 \) at time \( T \), the subscript \( T \) denotes the transpose of a matrix.

The continuous compounded spot interest rates can be expressed as an affine function of the economic factors by taking the log of Eq. (5)

\[
s(0, T) = - \frac{\log (B(0, T))}{T} = - \left( \frac{a_B}{T} \right) - \left( \frac{b_B^T}{T} \right) X_0
\]

(8)
B CDS valuation

A Credit Default Swap (CDS) is a swap contract and agreement in which the protection buyer of the CDS makes a series of payments to the protection seller and in exchange, receives a payoff in the event of default. Let $w$ represent the CDS spread that is paid continuously, the present value of the premium leg of a CDS at a certain credit rating class can be written under $Q$ measure as:

$$P(0, T) = E^Q \left[ w \int_0^T \exp \left( - \int_0^t (r_s + \lambda_s) \, ds \right) \, dt \right]$$  \hspace{1cm} (9)

where $r$ is the Treasury yield and $\lambda$ is the credit spread\(^5\). Similarly, if a default event occurs then the protection seller pays the buyer the par value and in return gets a bond issued by the same reference entity\(^6\), the present value of the protection leg of a CDS under $Q$ measure is

$$PR(0, T) = E^Q \left[ \delta \int_0^T \exp \left( - \int_0^t (r_s + \lambda_s) \, ds \right) \, dt \right]$$  \hspace{1cm} (10)

with $\delta$ being the loss rate of the par value in the event of default. Equating the values of both legs returns the CDS spread

$$w = \frac{E^Q \left[ \delta \int_0^T \exp \left( - \int_0^t (r_s + \lambda_s) \, ds \right) \, dt \right]}{E^Q \left[ \int_0^T \exp \left( - \int_0^t (r_s + \lambda_s) \, ds \right) \, dt \right]}$$  \hspace{1cm} (11)

To price CDS contracts with the four economic factors, we assume that the instantaneous credit spread for each rating is an affine function

$$\lambda_t = a_\lambda + b_\lambda X_t$$  \hspace{1cm} (12)

\(^5\)Longstaff, Mithal, and Neis (2005) argue that the contractual nature of credit default swaps makes them far less sensitive to liquidity effects. Following these authors, we assume that the CDS spread does not contain liquidity premium. Another reason for us to make such an assumption is to avoid the identification problem that will be otherwise met in the estimation of the model parameters. In Section 7, we will examine whether the implied non-default component of the CDS spread is associated with the illiquidity of CDS.

\(^6\)Or in cash settlement case, the protection seller pays the buyer the cash difference between par value and the market price of the bond.
Given the dynamic process for the factors in Eq. (2) and the affine structure in Eq. (12), it is shown in Appendix that the value of the denominator of Eq. (11) is

$$\int_0^T \exp \left( a_{CDS} + b_{CDS}^T X_0 \right) dt$$

(13)

with $a_{CDS}$ and $b_{CDS}$ being solutions to the following ODEs:

$$\dot{a}_{CDS} = a_r + a_\lambda + b_{CDS}^T \gamma_0 - \frac{1}{2} b_{CDS}^T \Omega b_{CDS}$$

(14)

$$\dot{b}_{CDS} = b_r + b_\lambda + (k_Q)^T b_{CDS}$$

(15)

subject to the boundary conditions $a_{CDS} = 0$ and $b_{CDS} = 0$ at time $T$.

Similarly, the value of the nominator of Eq. (11) is

$$\delta \int_0^T \exp \left( a_{CDS} + b_{CDS}^T X_t \right) \left( a_\lambda + A_{CDS} + B_{CDS}^T X_0 \right) dt$$

(16)

with $A_{CDS}$ and $B_{CDS}$ satisfying the following ODEs:

$$\dot{A}_{CDS} = B_{CDS}^T \gamma_0 - b_{CDS}^T \Omega B_{CDS}$$

(17)

$$\dot{B}_{CDS} = (k_Q)^T B_{CDS}$$

(18)

subject to the boundary conditions $A_{CDS} = 0$ and $B_{CDS} = b_\lambda$ at time $T$, $b_{CDS}$ is the same as the one in Eq. (15).

C Corporate Bond

Following Longstaff, Mithal, and Neis (2005) and Buhler and Trapp (2009), we incorporate liquidity spreads into the term structure model of defaultable bonds under a reduced-form pricing framework. The price of a zero-coupon corporate bond $CB(0,T)$ at a certain credit rating class under $Q$ measure equals

$$CB(0, T) = E^Q \left[ \exp \left( - \int_0^T (r_t + \lambda_t + l_t) dt \right) \right]$$

$$+ E^Q \left[ (1 - \delta) \int_0^T \lambda_t \exp \left( - \int_0^t (r_s + \lambda_s + l_s) ds \right) dt \right]$$

(19)
where \( \lambda_t \) is the default spread equaling to that for CDS spread, and \( l_t \) is the liquidity spread. The first term is the present value of the promised principal payment at a par value $1, the second term is the present value of recovery payments upon default. Assume the instantaneous liquidity spreads are affine functions of the four economic factors:

\[
l_t = a_l + b_l^T X_t
\]

Thus

\[
r_t + \lambda_t + l_t = (a_r + a_\lambda + a_l) + (b_r^T + b_\lambda^T + b_l^T) X_t
\]

Therefore, Eq. (19) can be re-casted as

\[
CB(0, T) = CB(\text{Part1}_T) + (1 - \delta) \int_0^T CB(\text{Part2}_t) dt
\]

Closed-form solutions for \( CB(\text{Part1}) \) and \( CB(\text{Part2}) \) are derived in Appendix.

\[
CB(\text{Part1}_T) = \exp \left( a_{CB} + b_{CB}^T X_0 \right)
\]

where \( a_{CB} \) and \( b_{CB} \) are solutions to the following ODEs

\[
\dot{a}_{CB} = a_r + a_\lambda + a_l + b_{CB}^T \gamma_0 - \frac{1}{2} b_{CB}^T \Omega b_{CB}
\]

\[
\dot{b}_{CB} = b_r + b_\lambda + b_l + (k Q)^T b_{CB}
\]

subject to the boundary conditions \( a_{CB} = 0 \) and \( b_{CB} = 0 \) at time \( T \), and

\[
CB(\text{Part2}_t) = CB(Part1_t) \left( a_\lambda + A_{CB} + B_{CB}^T X_0 \right)
\]

where \( A_{CB} \) and \( B_{CB} \) satisfy the following ODEs

\[
\dot{A}_{CB} = B_{CB}^T \gamma_0 - b_{CB}^T \Omega B_{CB}
\]

\[
\dot{B}_{CB} = (k Q)^T B_{CB}
\]

subject to the boundary conditions \( A_{CB} = 0 \) and \( B_{CB} = b_\lambda \) at time \( t \), and \( b_{CB} \) is computed the same as in Eq. (25).
III Data and Estimation

In this section, we first discuss the data and explain how to calculate corporate bond yields and CDS spreads and extract economic factors used in the following empirical analysis. Then, we present the method of estimating the no-arbitrage term structure model.

A Data

A.1 Treasury yields, CDS spreads, and corporate bond yields

We obtain the month-end 1-, 2-, 3-, 5-, 7-, and 10-year constant maturity Treasury yields from the Federal Reserve Bank of St. Louis\textsuperscript{7}; the corporate bond trading data from TRACE (the Trade Reporting and Compliance Engine)\textsuperscript{8}; the bond information data such as coupon rates and credit rating from the Mergent FISD dataset of WRDS (the Wharton Research Data Services); and the corporate CDS data from the Markit database in WRDS. we exclude any bond with callable, puttable or other embedded option features, and any bond or CDS with trading history less than one year (12 observations) to avoid the firm that disappears soon after listing or is of recent issue. we calculate the trading volume weighted daily yield since TRACE reports intraday trading data. we use the data of the last transaction day of each month and in the case that there exists no transaction in the last trading day of the month, we compute the month-end yield by linear interpolating the yield of the last transaction day of the month and the first transaction day of the following month.

\textsuperscript{7}Yields on Treasury nominal securities at constant maturity are interpolated by the U.S. Treasury from the daily par yield curve for non-inflation-indexed Treasury securities. So we bootstrap the par yields to provide a discount curve.

\textsuperscript{8}TRACE is a vehicle that facilitates the mandatory reporting of over-the-counter secondary market transactions in eligible fixed income securities. All brokers/dealers who are from Financial Industry Regulatory Authority member firms have an obligation to report transactions in corporate bonds to TRACE under an SEC approved set of rules.
a simple approach as in Jarrow and Yildirim (2003). For each rating (AA, A, BBB and BB\(^9\)), we include all bonds at that rating class, compute the mean yield \( \mu_y \) and the standard deviation \( \sigma_y \), and remove any yield observation \( y_i \) from our sample if it violates the inequality

\[
\left| \frac{y_i - \mu_y}{\sigma_y} \right| \leq 3
\]

(29)

The algorithm does not remove many observations, it finds 201 outliers out of 17,691 quotes for AA-rated bonds; 77 outliers out of 29,367 quotes for A-rated bonds; 14 outliers out of 14,377 quotes for BBB-rated bonds and 107 outliers out of 8,411 quotes for BB-rated bonds.

After obtaining the month-end individual corporate bond and CDS yields, we do the following to construct month-end 1-, 2-, 3-, 5-, 7- and 10-year constant maturity corporate bond and CDS yields at all rating classes. For CDS, we simply compute the average of CDS yields of each maturity for each rating as Markit provides CDS quotes for all the interested maturities; for corporate bond, since not many traded bonds have exactly those maturities, we first bootstrap coupon-bearing corporate bond yields to zero-coupon yields for each rating, then we fit and estimate rates for all interested maturities using the Nelson and Siegel (1987) model.

The sample period is from July 2002 to November 2007. Table 1 summarizes the number of corporate bonds and CDSs left after the above screening at each rating class. There are more corporate bonds at high rating classes than at low rating classes. The total number of corporate bonds for AA and A ratings is 1,781, compared with 827 for BBB and BB ratings, which is in a stark contrast with the number of CDSs: 266 vs. 764, indicating that investors are more willing to trade CDSs to hedge against the default risk of low-rated corporate bonds. On average, the sample includes 27 months of trading history for a corporate bond and 40 months for a CDS. Table 2 reports, for each maturity of 1, 2, 3, 5, 7, and 10 years, Treasury yield, CDS spread and corporate bond yield spread defined as the difference between

\(^9\)Rating classes are categorized as AA (AA- ~ AAA), A (A- ~ A+), BBB (BBB- ~ BBB+), BB (below BBB-), bonds with NR(not rated) rating are excluded.
corporate bond yield and Treasury yield at each rating class, and the ratio of CDS spread to corporate bond yield spread. Long-term Treasury yields are larger than short-term yields, for example, the 10-year Treasury yield is 1.41 times larger than the 1-year yield. CDS spread increases as the rating declines, suggesting investors require a higher return for bearing higher default risk. The percentage of the corporate bond yield spread explained by the model-independent CDS default spread is 29% for AA-rated bonds, 41% for A-rated bonds, 48% for BBB-rated bonds, and 90% for BB-rating bonds, indicating that high grade corporate bond yield spreads consist of a large component unexplained by default risk\textsuperscript{10}.

Figures 1 and 2 plot the evolution of Treasury yields, corporate bond yields and CDS spreads for three maturities of 2, 5, and 10 years. The Treasury yield shapes were inverted from the end of 2005 to the middle of 2007 and were normal during other periods. Regardless of ratings, both corporate bond yields and CDS spreads started at a high level from 2002 to 2003, known as the accounting scandal periods initiated by the Enron Company, then became stable and low from 2003 to 2007 and started to increase after the beginning of 2007. A similar pattern is found for the empirical bond liquidity spreads estimated approximately as the differences between corporate bond yields and the sum of CDS spreads and Treasury yields, demonstrating an illiquid bond market even before the beginning of the financial crisis.

\section*{A.2 Economic Factors}

In this study, our analysis relies on four groups of variables that have been previously shown to affect corporate bond yields.

The first group includes three monetary policy related series: monetary base (MB), federal funds rate (FED), and non-borrowed reserves ratio (NRR). MB is controlled by a

\footnote{Longstaff, Mithal, and Neis (2005) use a smaller sample at different periods (03.2001 $\sim$ 10.2002) and find the ratio is 49\%, 53\%, 68\% and 84\%, respectively.}
central bank for a loose or a tight policy. FED is used by the Federal Reserve Board as an open market operation to adjust the money supply. NRR is defined as the portion of non-borrowed reserves to the total reserves of depository institutions, and it has been shown to resolve the price puzzle as well as the liquidity puzzle, see for example, Strongin (1995).

The second group contains four inflation related series: the consumer price index (CPI), the producer price index (PPI), the personal consumption expenditure (PCE) deflator, and the spot market commodity prices (PCOM). CPI is a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services. PPI measures the average change in prices received by domestic producers for their output. PCE deflator is an indicator of the average increase in prices for all domestic personal consumption. PCOM is traditionally treated as an indicator of inflation.

The third group consists of four real output related series: the industrial production index (IPI), nonfarm payrolls (NP), the real PCE (RPCE), and unemployment (UE). IPI measures real production output that includes manufacturing, mining, and utilities. NP is an influential statistic and economic indicator meant to represent the number of jobs created or lost over the last month, not including jobs relating to the farming industry due to its seasonal nature. In contrast to PCE, RPCE is inflation adjusted. UE reflects the labor force in market and is hence closely related to real production output.

The fourth group contains only one series – the CBOE Volatility Index (VIX) computed from options on the S&P 500 index. The VIX is often referred to as the fear index or the fear gauge and represents one measure of the market’s expectation of stock market volatility over the next 30-day period.

All the above 12 series except for the VIX are available at a monthly frequency. To obtain one monthly VIX series, we calculate the average of the daily VIX in each month to reduce
noise and take logs on the average. We convert the four inflation related series and the four real output related series into the year-over-year percentage changes, and then normalize all the 12 series.

To reduce the number of variables used in estimating the no-arbitrage pricing model described in Section II, we follow the Principal Component Analysis (PCA) approach to extract the first principal component of each group of variables, separately, and use it as a measure of the underlying economic factor.\textsuperscript{11} Panel A of Table 3 reports the loading estimates. The first principal component of the monetary policy series loads positively on MB and negatively on FED and NRR, meaning that positive shocks to this variable represent positive monetary policy shocks. The first principal component of the inflation series loads positively on CPI, PPI, PCE, and PCOM, and the similar magnitude of the loading estimates suggests the alike importance of these series to reflect the inflation of an economy. The first principal component of the real output series loads positively on IPI, NP, and RPCE and negatively on UE, so positive shocks to this variable can be interpreted as positive real output shocks. As shown in Panel A of Table 3, about 53% (84% and 86%) of the variance of monetary policy (inflation and real output) series is explained by the first principal component. We use the normalized monthly VIX series as the financial market volatility measure. Panel B of Table 3 reports the correlations among the extracted economic factors: monetary policy is positively correlated with financial market volatility which in turn is negatively correlated with both inflation and real output; inflation and real output are positively correlated.

Fig. 3 plots the time series dynamics over the time period July 2002 through December 2015 of the monetary policy, inflation, real output, and financial market volatility factors extracted using the PCA approach. It is clear that as a response to the weak economy, the \textsuperscript{11}Alternatively, we also extract the economic factors using the Kalman Filter approach that imposes some restrictions on the processes governing the dynamics of the economic factors. The corresponding empirical results are similar to what are shown in the text, and they are available upon request.
Federal Reserve dramatically loosened monetary policy during the subprime mortgage crisis. After the crisis, monetary policy became much less loose. Inflation was at a high level before the crisis, but then fell sharply during the crisis. The post-crisis inflation on average is lower than the pre-crisis one. Similarly, real output also declined a lot during the crisis, but it recovered to the pre-crisis level in the middle of 2010. As expected, the financial markets were very volatile around late 2002 and early 2003 due to the dot.com bubble burst and during the subprime mortgage crisis.

B Estimation Method

We use a three-step estimation procedure. In the first step, we use the ordinary least square regression (OLS) approach to estimate the annualized parameters \( \{ k_i, \sigma_i \} \) in the physical measure \( P \) equation

\[
dX_{i,t} = -k_i X_{i,t} dt + \sigma_i dW_t,
\]

which are the same regardless of assets and ratings. In the second step, the parameters \( \{ k^Q_i, \theta^Q_i, a_r, b_r \} \) for Treasury bonds are jointly estimated by minimizing the following sum of squared errors,

\[
\min_{k^Q_i, \theta^Q_i, a_r, b_r} \sum_{t=1}^{162} \sum_{j=1}^{6} \left[ s_{jt} - \hat{s}_{jt} \left( k^Q_i, \theta^Q_i, a_r, b_r \right) \right]^2
\]

(30)

where \( s_{jt} \) is the market observed Treasury yield and \( \hat{s}_{jt} \) is the model-implied Treasury yield from Eq. (5). Squared pricing errors are summed along time series for 162 months and cross-section for 6 maturities. \( \gamma_0, \gamma_1 \), and thus the market price of risk for Treasury bonds can be computed once the values of \( k_i, k^Q_i \) and \( \theta^Q_i \) are known. In the third step, since the default information of corporate bonds is restrained to be fully captured in the CDS spread of the same rating, the parameters on the instantaneous default and liquidity functions for each rating can be estimated simultaneously. Holding \( a_r \) and \( b_r \) estimated in the second step fixed, the remaining parameters \( \{ k^Q_i, \theta^Q_i, a_\lambda, b_\lambda, a_l, b_l \} \) for CDS and corporate bonds can be estimated by minimizing the sum of squared errors

\[
\min_{k^Q_i, \theta^Q_i, a_\lambda, b_\lambda, a_l, b_l} \sum_{t=1}^{162} \sum_{j=1}^{12} \left[ y_{jt} - \hat{y}_{jt} \left( k^Q_i, \theta^Q_i, a_\lambda, b_\lambda, a_l, b_l \right) \right]^2
\]

(31)
where $y_{jt}$ is the market observed CDS spread or corporate bond yield, $\hat{y}_{jt}$ denotes the model-implied CDS spread from Eq. (11) or corporate bond yield\(^{12}\) from Eq. (22). Squared pricing errors are summed for 162 months and for 6 maturities of CDS and 6 maturities of corporate bonds. We repeat this procedure and estimate the default and liquidity dynamics for all the rating classes. This optimization algorithm is basically a nonlinear least square regression and is used in the valuation of fixed-income securities (see Longstaff, Mithal, and Neis (2005) for CDS and bond pricing and Longstaff and Rajan (2008) for CDX pricing). Asymptotic statistics are calculated as in Gallant (1975).

## IV Estimated Results

### A Impacts of Economic Factors on Instantaneous Treasury Yield and Instantaneous Credit and Liquidity Spreads

In this subsection, we discuss the impacts of the economic factors on the instantaneous Treasury yield and instantaneous corporate bond credit and liquidity spreads, measured by the estimates of the coefficients $b_r$, $b_\lambda$, and $b_l$ in Eqs. (3), (12), and (20).

#### A.1 Instantaneous Treasury Yield

As shown in Panel A of Table 4, monetary policy, real output, and financial market volatility have significantly negative impacts on the instantaneous Treasury yield: a 1-standard deviation increase in the three factors reduces the instantaneous Treasury yield by 1.44%/year, 0.75%/year, and 0.34%/year, respectively. Loose monetary policy reduces the Treasury yield by lowering interest rates. If we interpret the volatility of stock markets as a proxy for financial stress, the negative relationship between the instantaneous Treasury yield and the

\(^{12}\)We convert bond prices to yields to be consistent with CDS spreads when fitting parameters.
financial market volatility is consistent with the phenomenon of “flight-to-liquidity” in the financial markets, which claims that in times of financial stress, to avoid large losses, investors rebalance their portfolios toward less risky and more liquid securities like the Treasury bills whose prices are then pushed up.\textsuperscript{13} The inflation factor has an expectedly positive but smaller impact on the instantaneous Treasury yield.

A.2 Instantaneous Credit Spread

The coefficient estimates in Panel B of Table 4 show how the economic factors impact the instantaneous credit spread at each rating class.

By increasing the money supply, loose monetary policies such as increases in MB and declines in FED and NRR may yield more investment, boost the economy, and then reduce default risk. Therefore, we expect the monetary policy factor to have a negative impact on the instantaneous credit spread. This is exactly the case at the rating classes of A, BBB, and BB. However, the coefficient estimates in the third column of Panel B of Table 4 show that the impact of monetary policy on the instantaneous credit spread is significantly negative only at the BBB rating class and does not exhibit pattern across rating classes.

The ability of a firm to repay the debt positively depends on its profitability, and thus it is reasonable to conjecture that the real output factor has a negative impact on the instantaneous credit spread because a firm is likely able to make more profits when the real output grows. This is exactly the case: the coefficient estimate for the real output factor is negative across all rating classes, and its absolute value is larger at lower rating class, meaning that the real output factor has a stronger impact on the instantaneous credit spread of corporate bonds with lower ratings.

\textsuperscript{13} The volatility of stock markets is high in times of financial stress. Refer to Longstaff (2004), Fontaine and Garcia (2012), and Acharya, Amihud, and Bharath (2013) for more discussions about the “flight-to-liquidity” phenomenon.
The impact of financial market volatility is positive and statistically significant. Previous studies such as Merton (1974) and Leland (1994) show that all other things being equal, increased volatility increases the probability for firm values to hit the default threshold and thus widens credit spreads. The distance to default on average is smaller for firms with lower ratings, hence financial market volatility ought to have a larger impact on bonds issued by those firms. Indeed, the coefficient estimate for the financial market volatility factor is larger at lower rating class. The impact of financial market volatility is larger compared to those of the other economic factors, this result confirms previous findings about the strong impact of financial market volatility on credit spreads in Campbell and Taksler (2003), Zhang et al. (2009), etc.

The inflation factor has the smallest impact on the instantaneous credit spread, which is significantly positive at the AA rating class and negative at the other rating classes.

A.3 Instantaneous Liquidity Spread

It is noticeable in Panel C of Table 4 that the impacts of real output and financial market volatility on the instantaneous liquidity spread are similar to those on the instantaneous credit spread: real output growth reduces and increased volatility increases the instantaneous liquidity spread. Nevertheless, the channels are different:

- The real output factor may impact bond market liquidity through the wealth effect: real output growth makes individuals wealthier, who are then willing to invest more, the higher demand will increase trading activity in the bond markets, increasing market liquidity.

- Previous studies (e.g., Ho and Stoll (1983), O’Hara and Oldfield (1986)) in the market microstructure literature show that increased volatility, by increasing inventory risk,
tend to reduce market liquidity. Brunnermeier and Pedersen (2009) argue that increased volatility tightens “funding liquidity” by increasing the expectations of financiers about future volatility, who will then raise margin requirements for traders. Tight funding liquidity forces traders to de-lever their positions, leading to lower market liquidity.\footnote{Fontaine and Garcia (2012) construct a new measure of funding liquidity and show how it affects bond pricing. Aragon and Strahan (2012) show that shocks to hedge funds’ funding liquidity caused by the failure of Lehman Brothers in 2008 reduce the market liquidity of the stocks that they trade.}

Loose monetary policy tends to reduce financing costs and then improve market liquidity through adding money to the system and lowering interest rates. However, this is true only at the AA and A rating classes. A potential explanation for this result is that the Federal Reserve loosens monetary policy in times of financial distress when traders switch their positions towards low-risk assets, hence the money added to the bond markets through loose monetary policy may mainly go to highly-rated bonds, leading to higher liquidity for those bonds.

The impact of inflation on the instantaneous liquidity spread is very different from the one on the instantaneous credit spread: increasing inflation significantly widens the instantaneous liquidity spread across all rating classes. Positive inflation shocks may reduce real wealth and hence drain trading activity out of the bond market, reducing liquidity. Such shocks may also signal a shift in future monetary policy (i.e., the expectation that the Federal Reserve may raise interest rates to dampen inflation) and thus can adversely affect liquidity by portending a shift in inventory financing costs.

\section*{B Economic Determinants of Term Structures}

The dynamic model in Section II also allows us to quantify the contemporaneous responses of the Treasury yield curve and term structures of corporate bond credit and liquidity spreads to shocks in the economic factors. The loading term \(- \left( \frac{b_T}{T} \right)\) in the linear Eq. (8) measures the
response of the T-year Treasury yield. We follow Koop et al. (1996) to calculate numerically the nonlinear responses of credit and liquidity spreads as shown in Eqs. (11) and (22).\footnote{Specifically, we first simulate the economic factors 10,000 times based on their historical mean and variance-covariance matrix assuming they are Gaussian distributed and then calculate the credit spreads $w_{\text{original}}$ as in Eq. (11) and liquidity spreads (the difference between yield spreads as in Eq. (22) and credit spreads) using the simulated value. We increase each factor’s simulated values by one standard deviation and keep other factors’ simulated values unchanged and recalculate the credit spreads $w_{\text{re}}$, the averaged difference between $w_{\text{re}}$ and $w_{\text{original}}$ captures the contemporaneous response of credit spreads to a unit shock on that factor. The response of liquidity spreads is computed similarly.}

**B.1 Economic Determinants of Treasury Yield Curve**

Fig. 3 shows the contemporaneous responses of the Treasury yield curve to unit shocks in the economic factors. Evidently, monetary policy has the strongest impact, particularly at the short end of the Treasury yield curve. For example, the response of the 3-month Treasury yield to a 1-standard deviation monetary policy shock is around 1.39\%, almost one time higher than the second highest response to a 1-standard deviation real output shock. The impact of inflation on the Treasury yield, albeit small in magnitude, persists across maturities, while those of the other economic factors, particularly monetary policy, dissipate as the maturity increases.

**B.2 Economic Determinants of Credit Spread Term Structure**

The top row of graphs in Fig. 4 show the contemporaneous responses of the credit spread term structure to unit shocks in the economic factors, and each graph corresponds to one rating class.

The solid line in each graph denotes the response to monetary policy shocks. The response is highly positive and increases with the maturity at the BB rating class: a 1-standard deviation monetary policy shock increases the 1-year credit spread by 0.86\% and the 10-year credit spread by 1.03\%. Monetary policy shocks mainly move short credit spreads at the BBB
rating class, while their impacts are small across maturities at the AA and A rating classes.

The dashed line in each graph denotes the response to inflation shocks, which declines with the maturity at the AA rating class but persists across maturities at the other rating classes. The impact of inflation shocks on the credit spread term structure is small relative to those of shocks in the other economic factors.

The dotted line in each graph denotes the response to real output shocks. Credit spreads across the whole spectrum of maturities are negatively impacted by real output shocks, and the impact is larger at lower rating class. At the AA, A, and BBB rating classes, short credit spreads are more sensitive to real output shocks than long credit spreads, but at the BB rating class, it is the other way around.

The dash-dotted line in each graph denotes the response to financial market volatility shocks, which is positive across maturities and all rating classes and increases as the rating declines. The impact of financial market volatility shocks on credit spreads increases with the maturity at the AA and A rating classes and decreases with the maturity at the BB rating class.

### B.3 Economic Determinants of Liquidity Spread Term Structure

The contemporaneous responses of the liquidity spread term structure to unit shocks in the economic factors are shown by the bottom row of graphs in Fig. 4.

The impact of monetary policy shocks on liquidity spreads is negative only for short term corporate bonds at the AA and A rating classes. The opposite impacts of monetary policy shocks on liquidity spreads at the short and long ends of the liquidity spread term structure imply that the liquidity spread term structure at the AA and A rating classes flattens in the episodes of loose monetary policy.\(^{16}\) At the BBB and BB rating classes, the impact of

\(^{16}\)Amihud and Mendelson (1991) and Ericsson and Renault (2006) find that the liquidity spread term structure
monetary policy shocks is positive across maturities and slowly dies off as the maturity increases.

The response to inflation shocks is positive and the strongest at the short end of the liquidity spread term structure across all rating classes. As the maturity increases, the response declines and becomes negligible at the long end.

Similarly, short liquidity spreads also response more aggressively to real output shocks than long liquidity spreads, particularly at low rating classes.

At the BB rating class, the impact of financial market volatility shocks on liquidity spreads declines from highly positive at short maturities to slightly negative at long maturities. However, at the other rating classes, financial market volatility shocks have a persistent positive impact on liquidity spreads.

The empirical results shown in Section IV.D imply that the determinants of movements in the term structures of credit and liquidity spreads are different. Movements in the credit spread term structure are mainly driven by financial market volatility shocks, and shocks to the other economic factors, particularly inflation shocks, are less powerful in explaining the movements. Real output shocks are the main determinant of movements in the liquidity spread term structure. It is also worth noting that shocks in the economic factors primarily move liquidity spreads at the short end of the liquidity spread term structure, while they have much more persistent impacts on credit spreads across the whole spectrum of maturities.

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is downward sloping, our results in Section IV.F confirm this finding.
C No Liquidity Premia

Previous papers (Amato and Luisi (2006), Wu and Zhang (2008), etc) study the impacts of the economic factors on the term structure of credit spreads by assuming that corporate bond yield spreads are only due to credit risk and do not contain the compensation for illiquidity. We perform a similar analysis. Precisely, we remove the instantaneous liquidity spread \( l_t \) from Eq. (19) to drive the valuation formula of a zero-coupon corporate bond and use only the corporate bond yields data in Eq. (31) to estimate the model parameters.

Table 5 reports the estimates of the parameters on the instantaneous credit spread function, which show that the impacts of monetary policy and inflation on the instantaneous credit spread are changed. For instance, the impact of monetary policy becomes significantly negative at the AA rating class and significantly positive at the BBB rating class, and except at the AA rating class, the impact of inflation changes from negative to positive. It is noticeable in Fig. 5 that assuming no liquidity premia in corporate bond yield spreads also significantly changes the responses of the credit spread term structure to shocks in the economic factors. First, financial market volatility shocks are not the main determinant of movements in the credit spread term structure any more. Second, the impacts of shocks to monetary policy, inflation, and real output on credit spreads become less persistent across maturities.

So, the assumption of no liquidity premia in corporate bond yield spreads leads to an inaccurate estimation of the impacts of the economic factors on credit spreads. This finding is consistent with other studies on the fallacy of default models for short-term defaultable assets, for example, by Huang and Huang (2012). Thus, decisions of credit risk management and portfolio management made on the analysis without accounting for bond liquidity may be inappropriate and generate undesirable results. For policy makers, ignoring liquidity component of yield spreads will make them wrongly evaluate the impact of monetary policies.
on business conditions.

D Implied Liquidity Spread

The 2-7 columns of Table 6 report the implied liquidity spread calculated as the model implied corporate bond yield spread minus the model implied CDS spread and the ratio of the implied liquidity spread to the observed yield spread for corporate bonds with the maturities of 1, 2, 3, 5, 7, and 10 years across the rating classes of AA, A, BBB, and BB, and the average values are in the last column.

The implied liquidity spread strictly increases from 95.62 bps for corporate bonds in the AA rating class to 211.44 bps for corporate bonds in the BB rating class. In contrast, the ratio of the implied liquidity spread to the observed corporate bond yield spread decreases as the rating declines: for investment-grade bonds, it exceeds 55%, and for speculative-grade bonds, it is below 31%. This result is in line with the finding of Bao et al. (2011) that changes in the market level of illiquidity explain a substantial part of the time variation in yield spreads of highly-rated (AAA ~ A) bonds. Huang and Huang (2012) also find that once the structural models are calibrated to be consistent with historical default rates and losses, and the equity risk premium, credit risk only accounts for a small fraction of observed yield spreads on investment-grade bonds. Furthermore, similar to Amihud and Mendelson (1991) and Ericsson and Renault (2006), we find that the ratio of the implied liquidity spread to the observed yield spread is a decreasing function of time to maturity.
V Robustness Checks

A The 2007-2009 Subprime Mortgage Crisis

Above, the empirical analysis of how the economic factors impact the Treasury yield and corporate bond credit and liquidity spreads is for the sample period July 2002 through December 2015 that nests the 2007-2009 subprime mortgage crisis. We see in Figures 1 and 2 that movements in corporate bond yield spreads, CDS spreads, and the economic factors are highly correlated over the period 2007-2009. Recent studies such as Filipova et al. (2013) and Li et al. (2013) find that the impacts of the economic fundamentals on bond pricing are regime-switching in nature and stronger when the economy is in stress. It is thus possible that the empirical results shown above are driven by the event of subprime mortgage crisis. In this section, we address this issues by excluding the data observed over the period from December 2007 to June 2009.

We re-estimate the parameters in Eqs. (3), (12), and (20), and the estimates are reported in Table 7. The absolute values of the estimates of the coefficients $b_r$, $b_\lambda$, and $b_l$ become smaller in most of cases, meaning that the economic factors have less strong impacts on the instantaneous Treasury yield and instantaneous credit and liquidity spreads in normal times. Nevertheless, the signs and statistical significance of the coefficient estimates are similar as in the full sample case, hence the conclusions about the impacts of the economic factors on the instantaneous Treasury yield and instantaneous credit and liquidity spreads stated in Section V.C again hold. One notable exception is that the impact of financial market volatility on AA liquidity spreads becomes statistically negative, indicating the existence of the “flight-to-quality” phenomenon. Similarly, Beber et al. (2008) find that in the Euro-area government bond market, investors care about credit quality in normal times, but chase liquidity in times of market distress.
As shown by the intercept estimates, the long-term mean of the instantaneous corporate bond yield spread induced by credit risk is lower in normal times across all rating classes. The average corporate default probability is lower in normal times, and as a consequence, the return on corporate bonds that investors require should also be lower. The decline in the compensation for illiquidity is also significant and the strongest for speculative-grade bonds (from 6.31%/year to 3.71%/year). Dick-Nielsen et al. (2012) find that the effect of illiquidity is much stronger for high-yield bonds during the subprime mortgage crisis.

The top (bottom) row of graphs in Fig. 6 show the contemporaneous responses of the credit spread (liquidity spread) term structure to unit shocks in the economic factors, calculated with the re-estimated parameters. The responses of the credit spread term structure change little, and financial market volatility shocks are again the main determinant of movements in the credit spread term structure. Except at the AA rating class, the responses of the liquidity spread term structure change with the exclusion of the data observed over the subprime mortgage crisis: first, the impact of inflation shocks on long term liquidity spreads are now strongly negative; second,

B Lagged Economic Factors

The real economy and the financial sector have been shown to affect each other. Then, a relevant question arises: do the above-presented empirical results really reflect the impacts of the economic factors on the credit risk and illiquidity of corporate bonds? Or are they driven by the reverse causality arising from the impacts of changes in the credit risk and illiquidity of corporate bonds on the economy? To address such an endogeneity issue, we use the lagged economic factors as explanatory variables in Eqs. (3), (12), and (20).

The coefficient estimates in Table 8 show that using the lagged values does not change the
impacts of the economic factors on the instantaneous corporate bond credit and liquidity
spreads. Also, as shown in Fig. 7, the responses of the term structures of credit and liquidity
spreads to shocks in the economic factors are similar to those obtained with the
contemporaneous economic factors used as explanatory variables. These results suggest that
our results shown in previous section are not driven by the reverse causality arising from the
impacts of changes in the credit risk and illiquidity of corporate bonds on the economy.

VI Analysis of CDS Spread Residuals

So far, in order to avoid the identification issue in the estimation, we assume that CDS spreads
only represent the compensation for default risk. Previous studies have found that liquidity is
also a determinant of CDS spreads. For example, Pu, Wang, and Wu (2011) show that
liquidity related variables determine CDS spreads, and Guo and Newton (2013) discover a
regime-dependent liquidity component of CDS spreads. In this section, we examine the
validity of this assumption.

For this purpose, we regress the average of the CDS spread residuals defined as the
differences between the market observed CDS spreads and the model implied CDS spreads
across all ratings on some liquidity proxies. Since the CDS spread residuals are the
non-default component that cannot be explained by default risk, if the coefficient estimates for
liquidity proxies are statistically significant, we may then agree that CDS spreads also contain
the compensation for illiquidity. The first liquidity proxy is the on/off spread in percentage –
the difference between the on-the-run 5-year Treasury yield and the off-the-run 5-year generic
Treasury yield – obtained from the Bloomberg. The on/off spread reflects the liquidity of
Treasury bonds and affects the liquidity of other fixed-income assets as a consequence
(Duffie, 1996); the second liquidity proxy is the monthly flows (in billions of U.S. dollars)
to money market mutual funds obtained from the Federal Reserve Board. An increase in the
flows may be associated with a lack of liquidity in risky asset markets (Longstaff, 2004); the third liquidity proxy is CDS-specific and is the average number of quote providers for the 5-year CDS provided by Markit. Intuitively, a larger number of providers indicates a higher liquidity for the CDS market.

Table 9 shows the univariate and multivariate regression results. In the univariate regressions, the coefficient estimates for the three liquidity proxies are all statistically insignificant, and the explanatory power is low, with adjusted $R^2$ less than 4%. The multivariate regression yields similar results except that the coefficient estimate for the monthly flows into money market mutual funds is marginally significant at the 10% level. These results imply that it is appropriate to assume that CDS spreads only represent the compensation for default risk.

**VII Conclusions**

Liquidity management had never been such crucial, FDIC (Federal Deposit Insurance Corporation) highlights “contingency funding plans should incorporate events that could rapidly affect an institution’s liquidity” in a letter to financial institutions in 2008; Basel III in 2010 proposes an international framework for liquidity measurement and requires institution supervisors to implement its standard consistently. So in this paper we try to address the following questions: 1) are liquidity spreads significant for corporate bonds? 2) how do macro factors affect corporate bond credit and liquidity spreads quantitatively? and 3) what might determine the joint movement of the term structures of Treasury yields, credit spreads and liquidity spreads?

In order to answer these questions, we construct four economic factors, namely monetary condition, inflation, real output, and financial market volatility, from 12 observed
macroeconomic and financial data series. We build a no-arbitrage link between these economic factors and the term structures of Treasury yields, credit and liquidity spreads of corporate bonds. This linkage enables us to quantify the impacts of the economic factors on the dynamics of these curves. We find liquidity spreads account for a major fraction of investment-grade corporate bond spreads. A model without dissecting credit spreads and liquidity spreads in corporate bonds delivers inaccurate results, and the inaccuracy is more severe for bonds of short maturities, indicating the fallacy of default models on short-term defaultable assets. Our results show that the inflation factor has insignificant impacts on Treasury yields, credit and liquidity spreads during the period from July 2002 to November 2007. Positive shocks of the monetary condition factor decrease Treasury yields and widen corporate credit spreads. The impact of the financial market volatility factor is negative on Treasury yield and positive on both corporate credit and liquidity spreads, and the impact is stronger at lower rating classes, a phenomenon associated with “flight-to-liquidity”, which strengthens during the extended period from July 2002 to June 2010 nesting the mortgage subprime crisis. These different responses also explain the negative correlation between the risk-free interest rates and corporate bond yield spreads as well as the positive correlation between credit spreads and liquidity spreads. Furthermore, the macro factors impact the term structures of Treasury yields, credit and liquidity spreads differently, and their interplay determines the joint movement of these spreads.
A Appendix

In this appendix, we derive the pricing formulas for Treasury bond, CDS, and corporate bond. Suppose a stochastic differential equation for $X_t$ is

$$dX_t = \mu (X_t) \, dt + \sigma (X_t) \, dW_t$$

(32)

where $W_t$ is a vector of standard Brownian motions,

$$\mu (X_t) = K_0 + K_1 X_t, \quad \left( \sigma (X_t) \sigma (X_t)^T \right)_{ij} = (H_0)_{ij} + (H_1)_{ij} X_t.$$  Duffie, Pan, and Singleton (2000) prove that under some technical regularity conditions, when $R (X_t) = \rho_0 + \rho_1 X_t$, the solution for

$$F (X_t, t, T) = E \left[ \exp \left( - \int_t^T R (X_s) \, ds \right) \right]$$

(33)

is given by

$$F (X_t, t, T) = \exp (\alpha + \beta X_t)$$

(34)

where $\alpha$ and $\beta$ satisfy the complex-valued ordinary differential equations (ODEs)

$$\dot{\alpha} = \rho_0 - K_0 \beta - \frac{1}{2} \beta^T H_0 \beta$$

(35)

$$\dot{\beta} = \rho_1 - K_1^T \beta - \frac{1}{2} \beta^T H_1 \beta$$

(36)

subject to boundary conditions $\alpha = \beta = 0$ at time $T$.

Now turning to the expectation

$$F (v, X_t, t, T) = E \left[ v X_T \exp \left( - \int_t^T R (X_s) \, ds \right) \right]$$

(37)

Duffie, Pan, and Singleton (2000) show that this type of extended transform has a closed-form solution as

$$F (v, X_t, t, T) = (A + BX_t) F (X_t, t, T)$$

(38)
where $F(X_t, t, T)$ is as in Eq. (34), $A$ and $B$ satisfy the following ODEs

\[
\dot{A} = -K_0B - \beta^T H_0 B \tag{39}
\]

\[
\dot{B} = -K_1^T B - \beta^T H_1 B \tag{40}
\]

$\beta$ is calculated as in Eq. (36), with the boundary conditions $B = v$ and $A = 0$ at time $T$.

In my setting where $dX_t = k^Q (\theta^Q - X_t) \, dt + \sigma^Q dW^Q_t$, $K_0 = k^Q \theta^Q$, $K_1 = k^Q$, $H_1$ is a null matrix, and $H_0 = \begin{bmatrix} \sigma_1^2 & 0 & 0 & 0 \\ 0 & \sigma_2^2 & 0 & 0 \\ 0 & 0 & \sigma_3^2 & 0 \\ 0 & 0 & 0 & \sigma_4^2 \end{bmatrix}$, we can derive the pricing formulas for Treasury bond, CDS, and corporate bond simply by replacing relevant parameters in Eqs. (34)∼(36) or (38)∼(40):

- Replace $\rho_0$ with $a_r$ and $\rho_1$ with $b_r$ in Eqs. (34)∼(36) to obtain the Treasury bond valuation formula;

- Replace $\rho_0$ with $a_r + a_\lambda$ and $\rho_1$ with $b_r + b_\lambda$ in Eqs. (34)∼(36) to obtain the denominator of the CDS spread valuation formula;

- Replace $v$ with $b_\lambda$, $\rho_0$ with $a_r + a_\lambda$, and $\rho_1$ with $b_r + b_\lambda$ in Eqs. (38)∼(40) to obtain the nominator of the CDS spread valuation formula;

- Replace $\rho_0$ with $a_r + a_\lambda + a_l$ and $\rho_1$ with $b_r + b_\lambda + b_l$ in Eqs. (34)∼(36) to obtain the first term of the corporate bond valuation formula;

- Replace $v$ with $b_\lambda$, $\rho_0$ with $a_r + a_\lambda + a_l$, and $\rho_1$ with $b_r + b_\lambda + b_l$ in Eqs. (38)∼(40) to obtain the second term of the corporate bond valuation formula.
References


1207–1254.


Fig 1. The times series of month end 2-, 5-, and 10-year constant maturity Treasury yields (the top row), corporate bond yield spreads (the middle row), and CDS spreads (the bottle row) over the period July 2002 through December 2015. Corporate bond yields are calculated using the Nelson-Siegel (1987) model.
Fig 2. The time series of the four economic factors, namely monetary policy, inflation, real output, and financial market volatility, extracted using the Principal Component Analysis (PCA) approach from a set of 12 monetary policy, macroeconomic, and financial series over the period July 2002 through December 2015.
Fig 3. The contemporaneous responses of the Treasury yield curve to unit shocks in the four economic factors, namely monetary policy, inflation, real output, and financial market volatility.
Fig 4. The contemporaneous responses of the term structures of corporate bond credit and liquidity spreads to unit shocks in the four economic factors, namely monetary policy, inflation, real output, and financial market volatility across the rating classes of AA, A, BBB, and BB.
Fig 5. The contemporaneous responses of the credit spread term structure to unit shocks in the four economic factors, namely monetary policy, inflation, real output, and financial market volatility across the rating classes of AA, A, BBB, and BB. Corporate bond yield spreads are assumed to only represent default premia.
Fig 6. The contemporaneous responses of the term structures of corporate bond credit and liquidity spreads to unit shocks in the four economic factors, namely monetary policy, inflation, real output, and financial market volatility across the rating classes of AA, A, BBB, and BB. The data observed over the period from December 2007 to June 2009 are excluded in estimating the parameters in Eqs (30)-(31), which are used to calculate the contemporaneous responses.
Table 1
Descriptive Statistics

This table reports the numbers of reference entities and trading observations of corporate bonds and Credit Default Swaps (CDS) used in this study across the rating classes of AA, A, BBB, and BB. The sample covers the period July 2002 through December 2015.

<table>
<thead>
<tr>
<th></th>
<th>Corporate Bond</th>
<th>CDS</th>
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<td># of Trades</td>
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<td>54,442</td>
</tr>
<tr>
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<td>103,350</td>
</tr>
<tr>
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<td>985</td>
<td>38,423</td>
</tr>
<tr>
<td>BB</td>
<td>904</td>
<td>23,788</td>
</tr>
<tr>
<td>Total</td>
<td>6,137</td>
<td>220,003</td>
</tr>
</tbody>
</table>
Table 2
CDS Spread and Corporate Bond Yield Spread

This table reports the average CDS spread, the average corporate bond yield spread, and the ratio of the two spreads for corporate bonds with the maturities of 1, 2, 3, 5, 7, and 10 years and across the rating classes of AA, A, BBB, and BB. Corporate bond yield spread is the difference between corporate bond yield and Treasury yield. The sample covers the period July 2002 through December 2015.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>10</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: CDS Spread (bps)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AA</td>
<td>42.94</td>
<td>49.96</td>
<td>56.79</td>
<td>70.41</td>
<td>79.92</td>
<td>87.48</td>
<td>64.58</td>
</tr>
<tr>
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<td>42.14</td>
<td>49.82</td>
<td>58.62</td>
<td>75.86</td>
<td>85.12</td>
<td>93.96</td>
<td>67.59</td>
</tr>
<tr>
<td>BBB</td>
<td>83.30</td>
<td>93.24</td>
<td>106.35</td>
<td>132.30</td>
<td>144.04</td>
<td>153.71</td>
<td>118.83</td>
</tr>
<tr>
<td>BB</td>
<td>391.37</td>
<td>412.22</td>
<td>436.61</td>
<td>469.30</td>
<td>478.34</td>
<td>476.06</td>
<td>443.98</td>
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<tr>
<td><strong>Panel B: Corporate Bond Yield Spread (bps)</strong></td>
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<td></td>
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<td>120.91</td>
<td>131.65</td>
<td>153.31</td>
<td>159.76</td>
</tr>
<tr>
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<td>159.49</td>
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<td>153.26</td>
<td>164.57</td>
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</tr>
<tr>
<td>BBB</td>
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<td>285.66</td>
<td>291.96</td>
<td>307.58</td>
<td>290.15</td>
</tr>
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<td>676.96</td>
<td>613.02</td>
<td>579.28</td>
<td>570.18</td>
<td>655.83</td>
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<td><strong>Panel C: Ratio of CDS Spread to Corporate Bond Yield Spread (%)</strong></td>
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<tr>
<td>AA</td>
<td>16.42</td>
<td>30.91</td>
<td>43.86</td>
<td>58.24</td>
<td>60.71</td>
<td>57.06</td>
<td>40.43</td>
</tr>
<tr>
<td>A</td>
<td>21.10</td>
<td>31.24</td>
<td>38.89</td>
<td>49.50</td>
<td>51.72</td>
<td>50.14</td>
<td>39.95</td>
</tr>
<tr>
<td>BBB</td>
<td>28.75</td>
<td>33.00</td>
<td>37.53</td>
<td>46.31</td>
<td>49.33</td>
<td>49.98</td>
<td>40.95</td>
</tr>
<tr>
<td>BB</td>
<td>50.41</td>
<td>57.31</td>
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<td>76.55</td>
<td>82.57</td>
<td>83.49</td>
<td>67.70</td>
</tr>
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</table>
Panel A reports the factor loadings defining the first principal component for four groups of variables. The first group includes three monetary policy related series: monetary base (MB), Federal funds rate (FED), and non-borrowed reserves ratio (NRR). The second group includes four inflation related series: the consumer price index (CPI), the producer price index (PPI), the personal consumption expenditure (PCE) deflator, and the spot market commodity price (PCOM). The third group includes four real output related series: the industrial production index (IPI), nonfarm payrolls (NP), the real PCE (RPCE), and unemployment (UE). The fourth group includes the CBOE Volatility Index (VIX). Panel B reports the correlations among the four factors. The sample covers the period July 2002 through December 2015.

### Panel A: Factor Loadings

<table>
<thead>
<tr>
<th>Series</th>
<th>Monetary Policy</th>
<th>Inflation</th>
<th>Real Output</th>
<th>Volatility</th>
</tr>
</thead>
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<td></td>
<td></td>
</tr>
<tr>
<td>FED</td>
<td>-0.4838</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NRR</td>
<td>-0.5165</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPI</td>
<td>0.5243</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPI</td>
<td>0.5265</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCE</td>
<td>0.5259</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCOM</td>
<td>0.4140</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPI</td>
<td>0.4960</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NP</td>
<td>0.4961</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPCE</td>
<td>0.4788</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UE</td>
<td>-0.5279</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIX</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% of variance explained: 53% 84.28% 85.74% 100%

### Panel B: Correlations

<table>
<thead>
<tr>
<th></th>
<th>Monetary Policy</th>
<th>Inflation</th>
<th>Real Output</th>
<th>Volatility</th>
</tr>
</thead>
<tbody>
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<td></td>
</tr>
<tr>
<td>Inflation</td>
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</tr>
<tr>
<td>Real Output</td>
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<tr>
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<td>0.6559</td>
<td>-0.1478</td>
<td>-0.6672</td>
<td>1.0000</td>
</tr>
</tbody>
</table>
Table 4

dicontemporaneous Effects of Economic Factors

This table reports the coefficient estimates for the instantaneous Treasury yield process $r_t = a_r + b'_r X_t$ and for the instantaneous corporate credit and liquidity spread processes $\lambda_t = a_\lambda + b'_\lambda X_t$ and $l_t = a_l + b'_l X_t$ respectively, where $X_t$ is the vector of four economic factors, namely monetary policy, inflation, real output, and financial market volatility. These estimates are obtained by minimizing the sum of squared errors in Eqs. (30) – (31). The t-statistics in parentheses are calculated using the method of Gallant (1975). ***, **, and * denote the significance at the 1%, 5%, and 10% levels.

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>Monetary Policy</th>
<th>Inflation</th>
<th>Real Output</th>
<th>Volatility</th>
</tr>
</thead>
<tbody>
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<td><strong>Panel A: $r_t = a_r + b'_r X_t$</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AA</td>
<td>0.0106***</td>
<td>-0.0144***</td>
<td>0.0026***</td>
<td>-0.0075***</td>
<td>-0.0034***</td>
</tr>
<tr>
<td></td>
<td>(13.3)</td>
<td>(-9.78)</td>
<td>(6.55)</td>
<td>(-11.7)</td>
<td>(-4.96)</td>
</tr>
<tr>
<td>A</td>
<td>0.0082***</td>
<td>-0.0011</td>
<td>-0.0049**</td>
<td>-0.0004</td>
<td>0.0043***</td>
</tr>
<tr>
<td></td>
<td>(7.46)</td>
<td>(-0.72)</td>
<td>(-2.51)</td>
<td>(-0.18)</td>
<td>(4.04)</td>
</tr>
<tr>
<td>BBB</td>
<td>0.0244***</td>
<td>-0.0133***</td>
<td>-0.0090***</td>
<td>0.0053***</td>
<td>0.0120***</td>
</tr>
<tr>
<td></td>
<td>(61.4)</td>
<td>(-11.5)</td>
<td>(-6.48)</td>
<td>(2.87)</td>
<td>(9.48)</td>
</tr>
<tr>
<td>BB</td>
<td>0.0526***</td>
<td>-0.0593***</td>
<td>-0.0230***</td>
<td>-0.0173***</td>
<td>0.0321***</td>
</tr>
<tr>
<td></td>
<td>(6.38)</td>
<td>(-5.50)</td>
<td>(-5.40)</td>
<td>(-3.66)</td>
<td>(8.05)</td>
</tr>
<tr>
<td><strong>Panel B: $\lambda_t = a_\lambda + b'_\lambda X_t$</strong></td>
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</tr>
<tr>
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<td>0.0046***</td>
<td>0.0025*</td>
<td>-0.0044**</td>
<td>0.0011***</td>
</tr>
<tr>
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<td>(3.83)</td>
<td>(1.92)</td>
<td>(-6.69)</td>
<td>(4.01)</td>
</tr>
<tr>
<td>A</td>
<td>0.0082***</td>
<td>-0.0011</td>
<td>-0.0049**</td>
<td>-0.0004</td>
<td>0.0043***</td>
</tr>
<tr>
<td></td>
<td>(7.46)</td>
<td>(-0.72)</td>
<td>(-2.51)</td>
<td>(-0.18)</td>
<td>(4.04)</td>
</tr>
<tr>
<td>BBB</td>
<td>0.0244***</td>
<td>-0.0133***</td>
<td>-0.0090***</td>
<td>0.0053***</td>
<td>0.0120***</td>
</tr>
<tr>
<td></td>
<td>(61.4)</td>
<td>(-11.5)</td>
<td>(-6.48)</td>
<td>(2.87)</td>
<td>(9.48)</td>
</tr>
<tr>
<td>BB</td>
<td>0.0526***</td>
<td>-0.0593***</td>
<td>-0.0230***</td>
<td>-0.0173***</td>
<td>0.0321***</td>
</tr>
<tr>
<td></td>
<td>(6.38)</td>
<td>(-5.50)</td>
<td>(-5.40)</td>
<td>(-3.66)</td>
<td>(8.05)</td>
</tr>
<tr>
<td><strong>Panel C: $l_t = a_l + b'_l X_t$</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.0135***</td>
<td>-0.0210***</td>
<td>0.0036***</td>
</tr>
<tr>
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<td>(10.9)</td>
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<td>(13.7)</td>
</tr>
<tr>
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<td>0.0176***</td>
<td>-0.0148***</td>
<td>0.0042***</td>
</tr>
<tr>
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<td>(10.8)</td>
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<td>0.0262***</td>
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<td>0.0028***</td>
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<td>(23.4)</td>
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<td>(4.10)</td>
</tr>
<tr>
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<td>0.0098</td>
<td>-0.0026</td>
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<td>(6.75)</td>
<td>(0.92)</td>
<td>(-0.65)</td>
<td>(2.35)</td>
</tr>
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</table>
## Table 5

### No Compensation for Bond Illiquidity

This table reports the coefficient estimates for the instantaneous credit spread process \( \lambda_t = a + b_t X_t \) obtained by assuming that corporate bond yield spreads only represent the compensation for default risk, where \( X_t \) is the vector of four economic factors, namely monetary policy, inflation, real output, and financial market volatility. Only are the corporate bond yields data used to estimate the model parameters. The t-statistics in parentheses are calculated using the method of Gallant (1975). ***, **, and * denote the significance at the 1%, 5%, and 10% levels.

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>Monetary Policy</th>
<th>Inflation</th>
<th>Real Output</th>
<th>Volatility</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.0195**</td>
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<td>(2.09)</td>
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<tr>
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<td>0.0300***</td>
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<td>0.0176***</td>
</tr>
<tr>
<td></td>
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<td>(0.82)</td>
<td>(-2.65)</td>
<td>(3.84)</td>
</tr>
<tr>
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<td>0.0628**</td>
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<td>-0.0378**</td>
<td>0.0669***</td>
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<tr>
<td></td>
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<td>(2.26)</td>
<td>(0.00)</td>
<td>(-2.54)</td>
<td>(3.04)</td>
</tr>
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</table>
This table reports the implied liquidity spread defined as the difference between the model implied corporate bond yield spread and the model implied CDS spread and the liquidity ratio calculated as the implied liquidity spread divided by the observed corporate bond yield spread for corporate bonds with the maturities of 1, 2, 3, 5, 7, and 10 years across the rating classes of AA, A, BBB, and BB.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
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<th>5</th>
<th>7</th>
<th>10</th>
<th>All</th>
</tr>
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<tbody>
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<td><strong>Panel A: Implied Liquidity Spread (bps)</strong></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>77.91</td>
<td>50.87</td>
<td>45.30</td>
<td>70.24</td>
<td>94.84</td>
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<td>115.75</td>
<td>96.80</td>
<td>77.34</td>
<td>76.85</td>
<td>91.48</td>
<td>101.13</td>
</tr>
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<td>163.01</td>
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</tr>
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<td>298.75</td>
<td>227.58</td>
<td>139.06</td>
<td>96.81</td>
<td>90.89</td>
<td>212.62</td>
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<tr>
<td><strong>Panel B: Liquidity Ratio (%)</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>68.55</td>
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<td>34.41</td>
<td>45.82</td>
<td>55.46</td>
</tr>
<tr>
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<td>72.57</td>
<td>64.23</td>
<td>50.46</td>
<td>46.70</td>
<td>48.82</td>
<td>59.53</td>
</tr>
<tr>
<td>BBB</td>
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<td>65.93</td>
<td>63.35</td>
<td>57.06</td>
<td>51.63</td>
<td>47.65</td>
<td>59.28</td>
</tr>
<tr>
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<td>41.54</td>
<td>33.62</td>
<td>22.68</td>
<td>16.71</td>
<td>15.94</td>
<td>30.82</td>
</tr>
</tbody>
</table>
Table 7
Excluding the Effect of Subprime Mortgage Crisis

This table reports the coefficient estimates for the instantaneous Treasury yield process \( r_t = a_r + b'_r X_t \) and for the instantaneous corporate credit and liquidity spread processes \( \lambda_t = a_\lambda + b'_\lambda X_t \) and \( l_t = a_l + b'_l X_t \), where \( X_t \) is the vector of four economic factors, namely monetary policy, inflation, real output, and financial market volatility. These estimates are obtained by minimizing the sum of squared errors in Eqs. (30)-(31). The t-statistics in parentheses are calculated using the method of Gallant (1975). ***, **, and * denote the significance at the 1%, 5%, and 10% levels. The data observed during the subprime mortgage crisis from December 2007 to June 2009 are excluded in the estimating process.

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>Monetary Policy</th>
<th>Inflation</th>
<th>Real Output</th>
<th>Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A:</strong> ( r_t = a_r + b'_r X_t )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0106***</td>
<td>-0.0145***</td>
<td>0.0024***</td>
<td>-0.0048***</td>
<td>-0.0052***</td>
</tr>
<tr>
<td></td>
<td>(13.2)</td>
<td>(-14.6)</td>
<td>(6.53)</td>
<td>(-10.2)</td>
<td>(-4.94)</td>
</tr>
<tr>
<td><strong>Panel B:</strong> ( \lambda_t = a_\lambda + b'_\lambda X_t )</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
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<td>0.0032***</td>
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<td>-0.0029**</td>
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<td>0.0318***</td>
<td>-0.0039***</td>
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<td>(2.32)</td>
<td>(19.6)</td>
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<td>-0.0046***</td>
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<td>(-3.20)</td>
<td>(3.88)</td>
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Table 8
Analysis of Non-Default Component of CDS Spreads

This table reports the regression results of the averaged CDS spread residuals on three liquidity proxies across all the credit ratings: the on-/off-the-run spread (the difference between the on-the-run 5-year Treasury yield and the off-the-run 5-year generic Treasury yield), MMMF (the monthly flows into total money market mutual funds), and the number of CDS quote providers (the average number of quote providers for the 5-year CDS provided by Markit). Associated t-statistics (in parentheses) and adjusted $R^2$ are reported. N denotes the number of observations, and ***, **, and * denote the significance at the 1%, 5%, and 10% levels.

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<td>(1.43)</td>
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<td></td>
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<td># of CDS quote providers</td>
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<td>-0.42%</td>
<td>0.29%</td>
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<tr>
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<td>(-0.78%)</td>
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<tr>
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<td>4.69%</td>
<td>3.29%</td>
</tr>
<tr>
<td></td>
<td>(-1.09%)</td>
<td>(-2.61%)</td>
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### Table 9
Regression of Changes in Average Nondefault Component of the Spread on Bond Market Liquidity Measures

This table reports the regression results of the averaged CDS spread residuals on three liquidity proxies across all the credit ratings: the on-/off-the-run spread (the difference between the on-the-run 5-year Treasury yield and the off-the-run 5-year generic Treasury yield), MMMF (the monthly flows into total money market mutual funds), and the number of CDS quote providers (the average number of quote providers for the 5-year CDS provided by Markit). Associated t-statistics (in parentheses) and adjusted $R^2$ are reported. N denotes the number of observations, and ***, **, and * denote the significance at the 1%, 5%, and 10% levels.

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<td>t-statistic</td>
<td>$\beta$ coefficient</td>
<td>t-statistic</td>
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<tr>
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<td>Price Dispersion</td>
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<td>-0.78%</td>
<td>4.69%</td>
<td>1.09%</td>
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