The Impact of Market Fluctuations on Financial Bond Liquidity

Tianyi He

***Abstract*—The global financial crises often strongly affect the decisions of investors. This paper studies whether domestic and foreign institutional investors change their investment strategies during crisis periods by shifting from high-risk and high-yield investment products to more conservative bond-related securities. In particular, this paper focuses mainly on financial bonds in the interbank market. This paper examines the causes of pricing discrepancies of financial bonds between financial crisis periods and normal market conditions. In addition, as China's bond market is still at its developing phase, this paper studies whether some widely used liquidity measures in the US and European markets play a significant role in the pricing of China's financial bonds. The result shows that liquidity explains an additional 28% of bond yield spread during normal market conditions, while it increases the R-squared from 7.58% to 45.93% during the three crisis periods.**

***Index Terms*—Interbank market, financial bonds, yield to maturity, liquidity, financial crisis.**

I. Introduction

Affected by the global financial crisis, investors inevitably change their investment behaviors in high-risk and high-yield investment products and conservative bond-related products. Liquidity, commonly viewed as an important feature of the investment environment, refers to the ability of an asset in the market to be quickly converted into other assets at a reasonable price and at a lower transaction cost. During the 2008 global financial crisis, the 2010-2012 European debt crises, and the 2015 China's stock market crash, large fluctuations in the liquidity levels of stock market had caused investors to pay more attention to the bond market, usually considered as a much safer market.

Financial bonds are securities issued by banks and other financial institutions for individuals to raise funds. Under the assumption that all bonds are reasonably priced, the yields of government bonds, which have no default risk, are usually used as the risk-free rate. As corporate bonds and enterprise bonds are largely researched in many literatures, this paper focuses on financial bonds as the research object, one of the largest three bonds in the China interbank market. Moreover, the transaction volume of financial bonds is of the same magnitude to that of corporate bonds and enterprise bonds. In addition, I use a variety of liquidity measures to study whether liquidity of China's financial bonds is more pronounced during market downturns. My hypothesis is that, if the liquidity of the bond market is more significant during crisis periods, it can be shown that investors gradually change their investment decisions by re-allocating high-risk and high-yield stock products to safer low-risk and low-yield bond products, when the stock market is not promising.

The Chinese bond market is well known to be largely segmented and can be divided into two major markets: the exchange market and the interbank market. Market participants in the interbank market are mostly large institutions and enterprises, while the exchange market is flooded with household and retail investors with a much smaller trading scale. The vast difference in the customer type triggers large difference in demand, resulting in different market prices of financial bonds even with the same credit risk. Although the issuances of financial bonds in the two primary markets are almost the same, in the secondary market, the interbank bond transaction volume accounts for almost 99% of the entire market. Therefore, this paper will take the interbank market transaction data as the main body, based on the changes of bond yield spreads during different market conditions, and systematically measure and analyze the liquidity changes of financial bonds in the interbank market.

At present, many widely used liquidity measures have appeared in related literatures in the United States and Europe. The emergence of these liquidity proxies fully reflects the efficiency of the US and European bond markets. However, China's bond market is still in its infancy, and the trading system and data reservoirs remain imperfect. Therefore, whether these widely used liquidity measures play a significant role in the pricing of China's financial bonds is also one of the main research contents of this paper.

The data in this paper comes from the WIND database and the China Central Depository & Clearing Co., Ltd. (CCDC). I mainly employ several famous liquidity measures proposed in the literature, including the high-low spread measure, the bid-ask spread measure, the Amihud ratio and the zero-return measure. Since China officially allowed overseas investors to trade in the Chinese interbank bond market in August 2010, I expect that the liquidity contribution to yield spread to be small during the 2008 financial crisis, to increase during the 2010-2012 European debt crisis, and to be conspicuously lower than the impact of China's 2015 stock market crash on the liquidity of the bond market. The results show that the speculation is in line with the empirical evidence.

The remainder of this paper is organized as follows. Section II presents the survey of some related research papers in the literature. Sections III provide the descriptive

Manuscript received October 9, 2018; revised March 18, 2019.

Tianyi He is with Nanjing University of Science of Technology, Jiangsu, China (e-mail: hetianyi@njust.edu.cn).

doi:10.18178/joebm.2019.7.4.597

statistics of the dependent variable, independent variables, data and liquidity measures used for the empirical tests. Section IV then discusses the empirical methodology and introduces the models used. Section V reports the empirical results and robustness test. Section VI concludes this paper.

II. Literature

There exist vast research papers on liquidity related topics in the literature, especially from developed capital markets. Amihud and Mendelson (1986, 1989) are the first to set up the liquidity measures of price impact. [1] Lately, numerous liquidity measures, which had been effectively used in the stock and bond markets in the US and Europe, began to appear in research papers in Chinese publications. They include the "effective spread measure" from Bao, Pan, Wang (2007), [2] the "price dispersion measure" and "zero return measure" from Jankowitsch (2011), [3] and the "high-low spread measure" from Corwin and Schultz (2012). [4]

The early stage of liquidity research focused on direct influence from liquidity level to asset estimation. Amihud and Mendelson (1986, 1991) propose that the reduction in liquidity level would result in the increase of expected market yield as well as the decrease of future market price, displaying a negative correlation between liquidity level and expected yield rate. [5] In the later stage of research on influence to asset estimation, Acharya and Pedersen (2005) mention that the risk of liquidity refers to the risk of price and trade changes under uncertain liquidity impacts. [6] Particularly, in the over-the-counter market, Duffie, Garleanu and Pedersen (2007) reckon that the transaction costs are primarily determined by search friction, inventory holding cost and bargaining power. [7] In addition, Amihud and Bharath (2009) advocate that such friction elements can change by time and can be significantly amplified during economy crisis due to the increase in capital constraint and holding cost. [8] Lin and Wang (2011) believe that the risk of liquidity decisively influences the immediate profit of American corporate bonds. [9] Relation between the two was significant to some bond information, including defaults, beta and liquidity levels, as well as various liquidity measures.

Apparently, the liquidity in bond market is crucial during fluctuation periods, especially during financial crises. As the liquidity level in the bond market is much smaller to that in the stock market, it is expected to be a more important bond pricing factor during crisis periods. Friewald, Jankowitsch and Subrahmanyam (2012) carefully study whether liquidity played a vital role in price determination of American corporation bonds and discover that the influence of liquidity is much more pronounced in financial crises, particularly to bonds with high credit risk. [10] In addition, by using various liquidity measurements, they conclude that the effect of liquidity could explain 14% of the yield spread change.

As recent Chinese capital market is gradually opening for the overseas, the liquidity of Chinese bond market has gained prime focus from variety of scholars and the professionals. In decades, mountains of research papers regarding the liquidity of Chinese bond market have shown up. An early study of liquidity in Chinese market from Zhu (2004), starting from the trading cost, choosing national debt price gap between buyer and seller as the measure of liquidity, elaborate the periodic feed back and influencing factor of loan transaction to national debt market between banks. [11] Wang (2012) analyzes the influencing factor of corporation bond liquidity and confirmed that the keys to the corporation bond liquidity were circulation, remaining maturity and coupon interest rate. [12] Specifically, first two factors are negatively correlated to liquidity whereas last one is positively related. Wang and In (2016), using the liquidity measurements from Amihud (2002), Bao, Pan and Wang (2011), Corwin and Schultz (2012), comprehensively analyze the influence from the risk of bond market liquidity to price determination of corporate bonds. However, they failed to ignore the variation of zero-risk interest in calculation, which would result in minor error in their conclusion. In addition, the sample selected was between January 2008 to December 2014，which is relatively short and of early development stage as compared to the time frame discussed in this article.

Schestag, Schuster and Uhrig-Homburg (2016) and Ba and Yao (2013) measure the percentage of liquidity between banks and financial markets while applying the concept of bond market liquidity and standard liquidity measures and made further efforts to estimate and conclude overall liquidity level. [13], [14]. They separately study liquidity measures of American and Chinese bond markets. Based on daily data from American corporate bond market, the former comprehensively compares some frequently applied measures for the first time. They discover that those frequently used measures are highly correlated, which would contribute to notable expected results. Some less frequently applied proxies also successfully fit to estimation of cost. The three dominant measures are high-low spread from Corwin and Schultz (2012), measure from Roll (1984) and Gibbs measure from Hasbrouck (2009). Ba and Yao (2013) considered turnover rate and liquidity ratio as the criteria to measure bond market between banks and fundamentally analyzed and calculated the overall liquidity of Chinese bond market. [15] According to their research, recent Chinese bond market has been undergoing rapid growth. The overall liquidity level kept increasing and during crisis; as price fluctuation enlarged, liquidity dropped.

This paper contributes to the literature in the following aspects. First, this paper is unprecedented, as there has been no research on domestic bond market liquidity before and after the entry of overseas investors. The liquidity under different scale of financial crisis has also never been studied before. Second, the article explores the liquidity of financial bond, which is different from frequently discussed types of bonds. Third, the article applies several liquidity measures from western countries in the domestic market. Their practical value is explicitly examined and will be the foundation for further research.

III. Descriptive Statistics

A. Data and Dependent Variables

This paper selects financial bonds traded in the interbank market as the research objects. There are two main reasons. First, the Chinese interbank bond market is the mainstay of the bond market, accounting for more than 99% of the total trading volume. The other reason is that there has been research on corporate bonds in academia but very few studies on financial bonds. Therefore, I select the sample period from January 2006 to June 2017 to study the changes in bond liquidity before and after several financial crises from 2008 to the present. The data comes from Wind Database (WIND) and China Central Depository & Clearing Co., Ltd. (CCDC), containing 1583 financial bonds. Before processing the data, this paper has excluded data that would interfere with the results of the study.

First, I found that during the period when Chinese bond market has not been opened, the bond transaction data is sparse and transaction frequency is relatively low. Therefore, data before January 1, 2007 is removed. Secondly, I screen out the low-frequency bonds of the remaining bonds. Those low-frequency bonds have less than 30 days of interval between the first transaction and the last transaction and the transaction number is less than 10 times during the trading period. Finally, I obtain 1153 financial bonds with a total transaction record of 214102. Table I shows the distribution of the number of financial bonds of different trading frequencies. Consequently, 42% of the 1153 financial bonds are traded between 100 and 400 times, 29% of them are traded within 50 times, and only 4% are traded more than 600 times. The number of bond transactions decreases as trading frequency increases, indicating that China's interbank bond market has extreme low liquidity. In contrast, it is not uncommon that developed markets, such as the United States, have a large number of bonds which are traded for more than 1000 times. Those markets even have very few bonds traded for less than 1000 times. Thus, China's interbank market still needs time to grow to reach the same scale as those in developed markets.

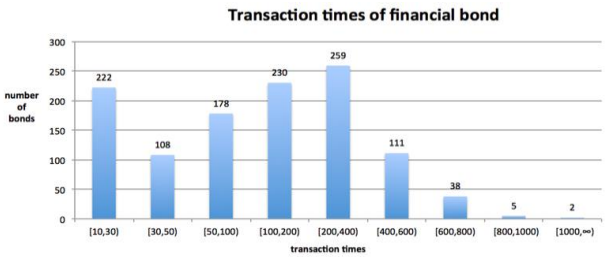

Fig. 1. Transaction times of financial bond.

Fig. 1 shows the number of financial bonds of different trading frequencies. I set the frequency scale to 10, 30, 50, 100, 200, 400, 600, 800, 1000, and count the numbers of the bonds with different frequencies. 42% of the 1153 financial bonds are traded between 100 and 400 times; 29% are traded within 50 times, and only 4% are traded more than 600 times. The frequency of bond transactions is declining, indicating that China's interbank bond market is of extremely low liquidity. In contrast, it is not uncommon that developed markets, such as the United States, have a large number of bonds which are traded for more than 1000 times. Those markets even have nearly few bonds trading less than 1000 times. Thus, China's interbank market still needs time to grow up and reach the same scale of developed markets.

Furthermore, the data shows an inappropriate gap with minimum of 0.0078% and maximum of 195.7%. Therefore, I choose the data with yield to maturity and closing price between 0.5% and 99.5% to process, and finally obtain 208,182 remaining transaction records. After the above data screening steps, the maximum and minimum yields are 1.63% and 8.19%. The maximum and minimum closing prices are 92.57 and 115.40. They all lie within a reasonable range.

In order to analyze the impact of the financial crisis on bond liquidity, this paper mainly studies whether the impact of liquidity measures on bond yield becomes more significant during the financial crisis. The dependent variable selected in this paper is yield spread, which can reflect the change of liquidity. It is obtained by subtracting zero-risk interest rate from bond yield. The zero-risk interest rate is defined as the yield of the government bond.

$$(\text{yield spread})_{i,t} = (\text{Yield})_{i,t} - (\text{risk free})_t$$

The independent variables selected in this paper can be divided into three categories: 1. basic information of bonds; 2. bond trading activities; 3. liquidity measurement.

1) Bond information

Bond information variables contain the most intuitive data that can present the information of bonds. They can also initially detect the liquidity of the bond. Bond information variables can be divided into bond age, remaining time, maturity, and coupon rate.. Specifically, bond age refers to the time from issuance to the present. If the data shows that the transaction volume of the bonds just issued is much larger than the bonds issued for a long time, the smaller the bond age is (on the run), the stronger the liquidity will be. Theoretically, it will result in a lower yield to maturity. The remaining variables are positively correlated with the yield spread. The longer the remaining period is, the higher the compensation on the yield will be. Besides, the higher the coupon rate, the higher the yield to maturity. It clearly shows a positive correlation. Additionally, duration is the weighted average of the time required to pay the cash flow of each period, that is, the cash flows generated by future events are converted into the present value according to the current yield. After adding up all the numbers that are obtained by multiplying each cash value by the time period of the cash flow, I divide this sum by the sum of the discounted limits of each period and finally obtain the duration. Long duration means it takes long time to receive the principal balance. Therefore, the longer the duration is, the higher the compensation and yield to maturity will be. Duration variable is also positively correlated with the yield spread. Besides, because the liquidity of the Chinese bond market is very low, whether our theoretical predictions are consistent with the facts need to be analyzed by the results according to the research design.

2) Trading variables

Trading variables can be divided into daily volume, trade

interval, zero return, and zero trade. First, the larger the daily trading volume is, the lower the yield to maturity would be. They are negatively correlated. Second, trading interval is defined as the date interval between the trading day and the previous trading date. The longer the interval, the worse the liquidity, results in a higher yield to maturity. Next, the zero-return period refers to the trading days with constant transactions but no return. Buyer's bid is equal to the seller's asking price, that is, the yield to maturity is zero, and the zero-return period is 1. When the zero return period is high, it indicates that the demand is small, the liquidity is low, and the yield is high. Zero-return and yield spread are positively correlated. Finally, zero trade is the ratio of zero trading days in one week divided by five trading days a week. When the number of zero trades is large, the liquidity will be low and yield spread will be high. However, the above are theoretical predictions, and the opposite result has been detected in the bond market in some countries. For example, when the buyer dominates the market and the transaction volume is large, the liquidity is strong, the price is depressed, and the yield will increase. Another example is that bondholders can choose to pledge AAA bonds and re-invest in the bonds they hold. The yield is high, but it will lead to a decrease in liquidity in the financial bond market. Thus, whether these measures prove to be consistent with theoretical predictions in the inter-bank financial bond market remains to be explored.

3) Liquidity measures

The four liquidity measures used in this paper are Amihud ratio (Amihud 2002), bid-ask spread, Price Dispersion measure (Jankowitsch *et.al* 2012), and high-low spread measure (Corwin & Schultz 2012).

The Amihud ratio is a well-known measure of illiquidity used in most studies domestically and internationally. This liquidity proxy for a certain bond over a particular time period with *N* observed returns is defined as the average ratio between the absolute value of these returns and its trading volumes,

$$(Amihud\ ratio)_{i,t} = \frac{1}{N_{i,t}} \sum_{j=1}^{N_{i,t}} \frac{|return_j|}{Volume_j}$$

As the Amihud ratio variable increases, trading a bond causes its price to move more in response to a given volume of trading, in turn, reflecting lower liquidity. The expected impact on yield to maturity is positively correlated.

The Bid-ask spread is measured by the bid-ask spread divided by the weighted average price. It is used in almost all literature and the formula is

$$(bid - ask)_{i,t} = \frac{High_{i,t} - Low_{i,t}}{2 * weighted_{i,t}}$$

Basically, the larger the bid-ask spread is, the higher the yield to maturity would be. Thus, I estimate that this liquidity proxy is positively correlated with the yield spread. Due to the imperfection of the data, I cannot see every transaction detail. If the highest price equals to the lowest price, the bid-ask spread may deliver the opposite result.

The price dispersion measure，presented by Jankowitsch, Nashikkar and Subrahmanyam (2012), is based on the dispersion of traded prices in the market's general valuation range:

$$(pd)_{i,t} = \sqrt{\frac{1}{\sum_j Volume_j} \sum_j \left(Closing_{i,j} - weighted_{i,t}\right)^2 Volume_j}$$

A low dispersion around the valuation indicates that the bond can be purchased at a price approaching its fair value, thus representing low transaction costs and high liquidity. In contrast, a high dispersion means high transaction costs, large spreads, and low liquidity. It would be difficult for buyers to unload after buying the bonds, so they demand attractive returns. In short, the price dispersion measure is also positively correlated with yield spread.

Corwin and Schultz (2012) designed the High-low spread measure. They believe that the buyer's price is the highest price in daily transactions, and the seller's price is the lowest, so the highest and lowest prices can reflect bid-ask information in bond transactions. The formula is

$$(high - low\ spread)_{i,t} = \frac{2(\exp(\alpha) - 1)}{\exp(\alpha) + 1}$$

$$\alpha = \frac{\sqrt{2\beta} - \sqrt{\beta}}{3 - 2\sqrt{2}} - \sqrt{\frac{\gamma}{3 - 2\sqrt{2}}}, \beta = \log\left(\frac{H_{t+1}}{L_{t+1}}\right) + \log\left(\frac{H_t}{L_t}\right), \gamma = \left[\log\left(\frac{H_{t,t+1}}{L_{t,t+1}}\right)\right]^2$$

When the HL spread is large, the volatility of the bid-ask spread is large, the non-liquidity of the bond is strong, and the yield to maturity is greater. Hence, the HL spread measure is positively correlated with yield spread.

The above measures have been tested for various times in American and European stock market and bond market. However, whether they are effective measures in the Chinese bond market remains to be studied. This paper will conduct an in-depth discussion in the next section.

TABLE I: THE CROSS-SECTIONAL DESCRIPTIVE STATISTICS

	Q5%	Q25 %	Median	Q75 %	Q95 %	Mean	SD
Yield spread (%)	1.629	3.134	3.800	4.310	8.189	3.825	0.967
Coupon (%)	1.53	3.33	3.94	4.52	6.5	3.91	0.889
Time to maturity	0.04	1.550	3.240	5.730	9.92	3.833	2.720
Age	0.033	0.496	1.162	2.392	9.411	1.716	1.602
Duration	0.099	1.564	3.081	5.147	8.423	3.460	2.238
Volume	10	130	400	1000	11260	993.8	1365.95
Interval (day)	0.003	0.0027	0.0027	0.0082	0.4027	0.018	0.051
Intensity	0.018	0.2	0.4	1	1	0.523	0.051
Zero return	0	0	0	1	1	0.366	0
Zero trade	0	0.4	0.6	0.8	0.8	0.611	0.187
Amihud	0	0.00008	0.0003	0.0017	4.636	0.004	0.010
Price dispersio	0	0	0.004	0.061	1.483	0.098	1.483

n							
BA	0	0.000002	0.00008	0.0021	1.004	0.003	0.0098
HL spread	0	0.13	0.19	0.26	0.04	0.22	0.01

Table I report the cross-sectional descriptive statistics (5th, 25th, 50th, and 95th quantiles, mean, and standard deviation) for the dependent variable (yield spread) and independent variables (bond information, trading, and liquidity proxies). The data comes from the WIND database, and the total number of the data after screening out is 208,182. The time period that data covers is from January 2006 to June 2017.

TABLE II: THE CORRELATION MATRIX OF VARIABLES

	Amount issued	Coupon	Maturity	Age	Volume	Trades	Interval	Amihud	Price.Dis	Zero- return	High-Low	BA
Amount issued	1											
Coupon	0.379	1										
Maturity	0.214	0.044	1									
Age	-0.113	-0.101	0.358	1								
Volume	-0.116	-0.105	-0.009	-0.105	1							
Trades	0.003	0.304	-0.142	0.044	0.073	1						
Interval	0.058	0.03	0.091	0.16	-0.068	-0.015	1					
Amihud	0.044	0.015	0.043	0.007	-0.053	-0.034	-0.017	1				
Price.Dis	0.065	0.037	0.162	-0.11	0.056	-0.038	-0.086	0.13	1			
Zero-return	0.056	0.004	0.035	0.142	-0.201	-0.07	0.164	0.123	-0.1	1		
High-Low	0.066	0.241	0.41	0.039	0.028	0.099	-0.017	0.016	0.117	-0.03	1	
BA	-0.005	-0.0024	0.124	-0.124	0.253	0.006	-0.042	-0.011	0.24	-0.18	0.089	1

Table II shows the correlation matrix of the main variables. Among them, the bond information variables contain basic information of the bond, including coupon interest and bond age; the trading variables represent the trading activity, containing trading volume, trading day interval, and zero return period; the liquidity measures variables representing the liquidity measure are Amihud ratio, Price Dispersion, High-low spread and Bid-ask spread.

TABLE III: THE AVERAGE YIELD FINANCIAL BONDS IN DIFFERENT ECONOMIC PERIODS

Interbank Financial Bonds							
Maturity	Mean	SD	Minimum	25%	50%	75%	Maximum
0.5-[0.25~0.75]	3.295	0.889	1.63	2.573	3.175	3.9	8.186
1-[0.75~1.5]	3.493	0.887	1.629	2.751	3.435	4.159	7.772
2-[1.5~2.5]	3.764	0.912	1.629	3.073	3.68	4.298	8.106
3-[2.5~3.5]	3.825	0.855	1.632	3.209	3.787	4.32	7.73
4-[3.5~4.5]	3.87	0.895	1.631	3.2	3.782	4.3	7.882
5-[4.5~5.5]	3.962	0.869	1.641	3.377	3.948	4.340	8.188
6-[5.5~6.5]	4.03	0.953	1.645	3.417	3.987	4.321	8.189
7-[6.5~7.5]	4.255	1.1	1.745	3.615	4.108	4.597	8.185
8-[7.5~8.5]	4.387	1.209	1.894	3.561	4.143	4.546	8.188
9-[8.5~9.5]	4.194	1.045	1.643	3.258	4.096	4.521	8.188
10-[9.5-10]	4.258	1.03	1.928	3.57	4.126	4.673	8.088

Table III shows the average yields of financial bonds with different remaining time in different economic periods. Yields steadily increased from the first year to the eighth year, but declined in the 9th and 10th years. The probable reason is that buyers in China's interbank market have more demand for long-term bonds than medium-term bonds. Many investors only purchase bonds with fixed yield to maturity, especially those of approximately 10 years. Hence, the greater the demand is, the greater the seller's pricing power would be, and making the yield becomes lower than the medium-term bonds. In addition, during the period of the financial crises, the average yield spread is lower than that in normal period. The main reason is that investors will shift their focus from high-risk and high-yield financial products to low-risk, low-yield bonds in the event of a financial crisis. The demand is high and the price is high, resulting in a lower yield.

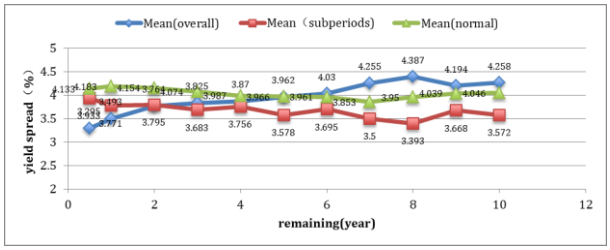

Fig. 2. The average yield spreads of financial bonds with different remaining.

Fig. 2 shows the average yields of financial bonds with different remaining time in different economic periods. Yields steadily increased from the first year to the eighth year, but declined in the 9th and 10th years. The probable reason is that buyers in China's interbank market have more demand for long-term bonds than medium-term bonds. Many investors only purchase bonds with fixed yield to maturity, especially those of approximately 10 years. Hence, the greater the demand is, the greater the seller's pricing

power would be, making the yield become lower than the medium-term bonds. In addition, during the period of the financial crises, the average yield spread is lower than that in normal period. The main reason is that investors will shift their focus from high-risk and high-yield financial products to low-risk, low-yield bonds in the event of a financial crisis. The demand is high and the price is high, resulting in a lower yield.

IV. Empirical Methodology

In order to study whether liquidity has more significant explanatory power to change in yield to maturity during the financial crisis than other periods, I divide the time period from January 2006 to June 2017 into four segments, respectively. They are classified as: 2008 global financial crisis (August 2008-October 2009), European debt crisis (January 2010-December 2011), China stock market crash (June 2015-February 2016) and ten year-time collection of non-financial crisis (January 2006-August 2008, October 2009-2010 January, December 2011-June 2015, February 2016-June 2017). Due to the fact that the Chinese bond market has been opened to foreign investors in 2010, I conclude that foreign capital has not yet entered the bond market during the 2008 financial crisis. Additionally, the market gradually opened up during the 2010 European debt crisis, and it developed rapidly in 2015 stock crash time period.

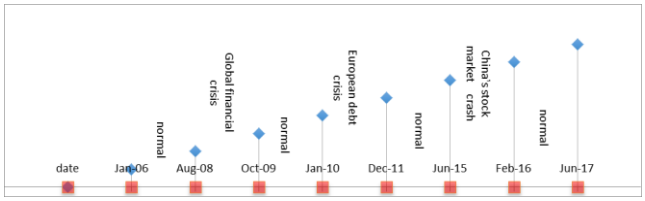

Fig. 3. The timeline of financial crises from 2006 to 2017.

Fig. 3 shows three large-scale financial crises during the period from 2006 to 2017. Specifically, they are classified as the 2008 global financial crisis (August 2008-October 2009), European debt crisis (January 2010-December 2011), China stock market crash (June 2015-February 2016) and ten-year-time collection of non-financial crisis (January 2006-August 2008, October 2009-2010 January, December 2011-June 2015, February 2016-June 2017).

I apply linear regression to analyze the impact of bond information, trading activities and liquidity variables on bond yield to maturity. The following two models are established. First, model 1 is used to regress the independent variable of the bond information to observe the impact on the yield spread. Model 2 is a regression model that I add trading activities and liquidity measures, aiming to explore the impact of liquidity on yield spread.

Model 1:

$$(\text{Yield spread})_{i,t} = a_0 + a_1\text{Age} + a_2\text{Remaining} + a_3\text{Coupon} + e_{i,t}$$

Model 2:

$$(\text{Yield spread})_{i,t} = a_0 + a_1\text{Age} + a_2\text{Remaining} + a_3\text{Coupon} + a_4\text{Volume} + a_5\text{Interval} + a_6\text{Zero.Return} + a_7\text{Zero.Trade} + a_8\text{Amihud} + a_9\text{BAspread} + a_{10}\text{Price.Disp} + a_{11}\text{HLspread} + e_{i,t}$$

Model 3:

$$(\text{Liq.Measure})_{i,t} = a_0 + a_1\text{Age} + a_2\text{Remaining} + a_3\text{Coupon} + a_4\text{Volume} + e_{i,t}$$

I also conduct a robustness test. Since the processed data and the dependent variable (yield spread) are measured in terms of trading days while some liquidity measures created are measured by week, I also apply weekly variables and data to observe the reliability of the results, preventing interference caused by excessive daily data.

V. Results

A. Regression Results

Table IV shows the regression results of the independent variables on the yield spread of Chinese financial bonds. First of all, the variables of the bond information (coupon interest, bond age, remaining time) have a significant impact on the yield spread of financial bonds, and have a positive correlation with it. The results show that the coupon rate and the remaining period are also positively correlated with the yield spread, which is consistent with our expectations. This is mainly due to the fact that when the coupon rate is small or the remaining period is long, the bonds need to promote more successful transaction through high compensation and high returns. The regression results show that when the coupon rate increase by 1%, the yield spread will increase by 29bp. However, for each additional year of bond age, the yield spread will increase by 1 bp. The fact is inconsistent with our expectations because the demand for long-term bonds in China's banking market is greater than that of short-term or medium-term bonds. Many investors only purchase bonds with fixed yield, so when the bonds are young, and the demand is small, the buyers will have more buying power. The transaction price will decline, and the yields will increase. This is different from the results in American research that the yield spread of bonds on the run will be much lower than those off the run.

TABLE IV: The Regression Results of Independent Variables on the Yield Spread

	Estimate	Std. Error	t-statistic	p-value
Coupon	1.649e-03***	7.287e-03	175.615	2e-16
Age	1.088e-02***	175.615	11.658	2e-16
Maturity	2.065e-02 ***	6.296e-04	32.800	2e-16
Volume	-6.002e-06***	7.212e-07	-8.323	2e-16
Interval	3.736e-01***	2.216e-02	16.860	2e-16
NTD	1.287e-01***	5.977e-03	21.534	2e-16
ZPM	2.961e-02***	3.962e-03	7.472	7.93e-14
Bid-ask	-1.632e+00***	1.623e-01	-10.059	2e-16
Amihud	6.233e-01***	7.667e-02	8.129	4.35e-16
PD	4.608e-03	5.482e-03	0.841	0.401
High-low	5.808e-01***	8.432e-03	-68.873	2e-16

Note: Significance at 10% level is marked*, at 5% marked **, and at 1% marked ***

Table IV shows each regression results of independent variables on the yield spread. NTD means no trade days.

ZPM stands for zero price movement. PD represents price dispersion measure. According to Table IV, except for the price dispersion measure variable, all other variables are significantly correlated. The trading volume and BA spread measure are negative correlations while the rest are positive correlations.

Second, the results show that all the trading activity variables are statistically significant in explaining the changes in bond yield spreads. Among them, the transaction volume and the yield spread are negatively correlated, which is in line with the expectations. Specifically, for every additional 10,000 volume, the yield spread will reduce by 0.06 bp. The main reason is that large transaction volume means large demand and seller dominated market, which would lead to high transaction prices and low yield spread. The trading interval, zero return and zero trade variables are also positively correlated with the yield spread. These three measures can be classified as illiquidity measures. When liquidity weakens, it would be more difficult to find the appropriate counterparty to trade, thus requiring higher yields to compensate investors for liquidity risk. For each additional day of the bond's trading interval, the yield spread will increase by 37bp; for each additional week of zero return, or each additional day of zero trade variables, the yield to maturity will increase by 13 bp and 3 bp, respectively.

Third, all liquidity measures have the expected significant correlation except for the price dispersion measure. The bid-ask difference is a significant negative correlation, and for every 1 bp increase, the yield spread reduces by 163 bp. This opposite result is mainly due to the defects of the data. Because of the limitation of data, WIND can only provide the total transaction data of one day but are inaccessible to every transaction detail, so I believe that there may be many transactions that have different highest and the lowest prices, while a single transaction leads to the equal highest and the lowest price. The bid-ask is large, but the liquidity increases, thus resulting in a lower yield spread.

The Amihud ratio is significantly and positively correlated with the dependent variables, which is under expectation. Specifically, an increase of 1 bp per million units will increase the yield to maturity by 62 bp. Price dispersion also displays positive correlation. For every unit of increase in volume, the yield to maturity will increase by 0.046 bp. High-low spread is also significantly and positively correlated with yield spread. For each unit increase in spread, the yield spread will increase by 58bp.

TABLE V: R SQUARED AND INCREASES IN THE FOUR TIME PERIODS

	2008 daily	2008 weekly	2010 daily	2010 weekly	2015 daily	2015 weekly	Normal daily	Normal weekly
R^2(%)	35.98	50.6	13.56	31.35	13.39	20.82	11.32	15.18
R^2	38.71	52.66	19.25	35.85	19.54	28.56	14.57	20.07
Absolute	2.73	2.06	5.69	4.5	6.15	7.74	3.25	4.89
Relative	7.58	4.7	42	14.4	45.93	37.18	28.71	32.2

Table V shows R Squared and increases during the financial crisis and non-financial crisis period. Meanwhile, I added the weekly variables and data on the basis of the daily data. The results show that the reliability of the data is consistent with the daily data. The absolute increase is the difference between the models two R SQUARED minus the model one R squared; the relative increase is the model two R SQUARED divided by the value of the model one R squared minus one.

In terms of R squared, when I only perform model regression on the bond information variables, R squared is 11.97%. When regression is performed on all dependent variables, R squared is 15.05%. It presents an absolute improvement of about 3.08% and a relative improvement of 27.65% in the explanatory power of the model when I add the liquidity variables. When exploring whether liquidity significantly affects the dependent variables, I divide the time period from January 2006 to June 2017 into four segments, namely three financial crises time periods and one accumulated normal time period, to analyze the changes in R squared.

The first period was the 2008 global financial crisis. When I only perform model regression on the bond information, R squared is 35.98%. When regression is performed on all dependent variables, R squared is 38.71%. I found an absolute improvement of about 2.73% and a relative improvement of 38.71% in the explanatory power of the model when I added the liquidity to Regression 1. During this period, the opening of China's bond market was not yet mature. Foreign capitals had not yet entered the Chinese inter-bank bond market. The impact of the global financial crisis on liquidity existed while was not significant.

The second period is the 2010 European debt crisis. In the study of this financial crisis, when I only perform regression on the bond information, R squared is 13.56%. When regression is performed on all dependent variables, R squared is 19.25%. I find an absolute improvement of about 5.69% and a relative improvement of 42% in the explanatory power of the model when I add the liquidity information. At this stage, foreign investors have gradually entered the Chinese bond market. Although foreign investors only hold about 1% of Chinese bonds, they have a great influence on bond pricing. Therefore, the European debt crisis has begun to have a significant impact on the liquidity of China's domestic bond market.

The third period is the 2015 China stock market crash. I conduct the same regression and found that R squared changed from 13.39% to 19.54%, presenting an absolute increase of 6.15%, and a relative increase of 45.93%. This financial crisis happened in China, which was most relevant to China and had a greater impact on China. At this stage,

foreign capital had entered the Chinese bond market for five years. As a result, compared with the previous two financial crises, liquidity in the 2015 China stock market crash changed the most drastically. The impact of the 2015 financial crisis on liquidity was the most significant.

The fourth time period is a collection of time periods in which no financial crisis has occurred. In the study of this period, when I only perform the regression on the bond information, R squared is 11.32%. When the liquidity measure and trading variables are added, R2 becomes 14.57%. This documents an absolutely increasing by 3.25% and a relatively increasing by 28.71%.

B. Robustness Test

Some independent variables are measured on a weekly basis, which means that the data of these measures for each week are equal to our empirical test. To avoid concerns in data quality and confirm that liquidity can still significantly affect the yield to maturity, I perform the regression model again on a weekly basis. By splitting the daily data that has been screened out for five steps in the previous section, I take a weighted average of the trading volume data for the same bond every five days and obtain 76907 weekly data, which is about one third of the daily data (208182). This shows that on average, each bond trades about 1.7 times a week. When I perform the model only on the bond information, R squared is 17.72%. When the liquidity measure and trading variables are added, R squared becomes 21.73%, absolutely increasing by 4%, and relatively increasing by 22.57%. In the 2008 financial crisis, I conduct the same model regression and found that R squared changed from 50.6% to 52.66%, presenting an absolute increase of 2.06%, and a relative increase of 4.7%. In the 2008 financial crisis, the added model regression make R squared change from 31.35% to35.85%, showing an absolute increase of 4.5%, and a relative increase of 14.4%. In 2015 China's stock market crash, the increase in liquidity measurement and trading variables made R squared change from 20.82% to 28.56%. R squared absolutely increases by 7.74%, and relatively increases by 37.18%. In the normal period, liquidity variables made R squared change from 15.18% to 20.07%, an absolute increase of 4.89%, and relatively increase of 32.21%. The results are similar to the regression results on a daily basis. Overall, the impact of the three financial crises on liquidity has gradually increased, and liquidity is far more important in times of crisis. In addition, it shows that the weekly result of the relative increase in the yield spread of the 2010 European debt crisis, being 14% only, is much smaller than the daily result at 42%. This can be attributed to the fact that China had just opened the interbank market in 2010, and the daily data had some noise at the beginning. Conducting the weekly robustness test renders my conclusion more reliable.

In Model 3, when Amihud measure is regressed on bond information and trading activities, R squared is 0.557%. This indicates that only 0.557% of the information in the Amihud measure is included in other variables, so it is reasonable to add the Amihud measure variable to Model 2. Similarly, when price dispersion becomes the independent variable, R squared is 5.1%, indicating that 94.9% of the information is not included in bond information and trading activities. When the bid-ask spread measure is related to bond information and trading activities for regression test, R squared is 10.42%. Last, R squared is 22.84% when the high-low measure is correlated. Overall, more than 70% of the information that four liquidity measures explain is not included in the bond information and trading activities variables. Additionally, according to Table II, the correlation between these liquidity measures is weak, and the information contained is almost completely different. Thus, adding four liquidity measure variables to the design of Model 2 can be considered reasonable.

VI. Conclusion

This paper establishes regression models to explore the pricing factors of financial bonds in the Chinese interbank market. By controlling all independent variables, including bond information, trading activities and four liquidity variables, this paper analyzes the change in explanatory power of liquidity proxies to bond yield spread during different market conditions. The empirical results show that market participants adjust their investment strategies during financial crises. The empirical results show that bond information and trading activities both have a significant impact on the yield spread of financial bonds, and all these variables are positively correlated with each other. The four low-frequency liquidity measures are also significantly related to the yield spread, except for the price dispersion measure. Specifically, the bid-ask spread shows a significant negative correlation, while the Amihud ratio, price dispersion and high-low spread measures are positively correlated with financial bonds' yield spread.

One contribution of this paper is that it analyzes the performance of several commonly used liquidity measures and examines their applicability in the domestic bond market, which helps future research on Chinese bond markets. More importantly, this paper examines the changes in liquidity of financial bonds before and after foreign investment took place in the interbank market and the impact of liquidity during different crises periods. To do so, it systematically analyzes the impact of three different subperiods on the liquidity of financial bonds in the interbank market. The empirical results demonstrate that nearly all liquidity proxies exert significantly higher impact on the change of yield spreads during market downturns. This proves the conjecture at the beginning of this paper that investors gradually change their investment decisions by shifting high-risk and high-yield stock products to low-risk and low-yield bond products, when the stock market is not promising.

References

[1] Y. Amihud and H. Mendelson, "Asset pricing and the bid-ask spread," *Journal of Financial Economics*, vol. 17, pp. 223-249, 1986.

[2] J. Bao, J. Pan, and J. Wang, "The illiquidity of corporate bonds," *Journal of Finance*, vol. 66, pp. 911-946, 2011.

[3] N. Friewald, R. Jankowitsch, and M. G. Subrahanyam, "Illiquidity or credit deterioration: A study of liquidity in the US corporate bond market during financial crises," *Journal of Financial Economics*, vol. 105, pp. 18-36. 2012.

[4] S. Corwin and P. Schultz, "A simple way to estimate bid-ask spreads from daily high and low prices," *Journal of Finance*, vol. 67, pp. 719-60, 2012.

[5] Y. Amihud and H. Mendelson, "Liquidity, maturity and the yields on U.S. government securities," *Journal of Finance*, vol. 46, pp. 1411-1426, 1991a.
[6] V. Acharya and L. H. Pedersen, "Asset pricing with liquidity risk," *Journal of Financial Economics*, vol. 77, pp. 275-410.
[7] D. Duffie, N. Garleanu, and L. H. Pedersen, "Valuation in over-the-counter markets," *The Review of Financial Studies*, vol. 20, pp. 1865-1900, 2007.
[8] Y. Amihud, "Illiquidity and stock returns: Cross-section and time-series effects," *Journal of Financial Markets*, vol. 5, pp. 31-56, 2002.
[9] H. Lin, J. Wang, and C. Wu, "Liquidity risk and expected corporate bond returns," *Journal of Financial Economics*, vol. 99, pp. 628-650, 2011.
[10] R. Jankowitsch, A. Nashikkar, and M. Subrahmanyam, "Price dispersion in OTC markets: A new measure of liquidity," *Journal of Banking and Finance*, vol. 35, pp. 343-357. 2012.
[11] S. Zhu and K. Xu, "An empirical study on the liquidity of interbank market," *Statistical Research*, no. 11, pp. 41-46, 2004.
[12] X. Wang, B. Zhang, and Z. He, "An empirical analysis of factors to impact the liquidity of corporate bonds," *Finance Forum*, vol. 17, no. 06, pp. 59-65, 2012.
[13] Y. Wang and Z. Wen, "The effect of liquidity risks on the bond pricing," *Review of Investment Studies*, vol. 25, no. 5, pp. 76-90, 2016.
[14] R. Schestag, P. Schuster, and M. Uhirig-Homburg, "Measuring liquidity in bond markets," *SSRN Electronic Journal*, vol. 29, no. 5, pp. 1170-1219, 2016.
[15] Shusong Ba, Fei Yao, "The liquidity measurement of China bond market," *Statistical Research*, no. 30, pp. 95-99, 2013.

Tianyi He was born in 1997, in Shaoxing, China. She is an undergraduate student at Nanjing University of Science and Technology of China, and she will complete a double major in Japanese and Accounting in June, 2019.

In 2018, she interned at Deloitte as an analyst in the Research Center of Consulting Department. She also interned as an assistant researcher in Department of Real Estate Research at Shanghai Head Office of Noah Holdings Limited. In addition, she has joined the research workshop of Real Estate Law and Transactions for five weeks, led by the professor of the Wharton School, University of Pennsylvania.

Ms. Tianyi's research interests include real estate, law and finance. She has published the research paper in *Oriental Enterprise Culture*, named "The Impact of Using WeChat on Interpersonal Relationship of University Students from the Perspective of Interpersonal Face-Taking WeChat Moments as Example". The paper won the Outstanding Award with Academic Research Reward of Innovation Cup-NJUST Extracurricular Academic Competition.