Online Appendix to "Regulation and Market Liquidity"

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A Brief History of the Volcker Rule

In this section, we discuss the rulemaking process of the Volcker Rule as a most salient example of post-crisis financial regulations to illustrate the empirical challenges that we need to address in this study.

The Volcker Rule refers to Section 619 Title VI of the 2010 Dodd-Frank Act, originally proposed by former Federal Reserve Chairman Paul Volcker to restrict U.S. banks from proprietary trading and investing in hedge funds and private equities. As a long-time skeptic of financial innovation, Volcker argued that such speculative activity played a central role in the financial crisis of 2008--2009.

The Volcker Rule first appeared in a January 2009 Group of Thirty Report, but was not embraced at the time (Krawiec and Liu, 2015). Influential members of the Obama Administration, including former Treasury Secretory Timothy Geithner and Director of the National Economic Council Larry Summers, actively opposed the Volcker Rule, which they believed to be overly restrictive for banks. As a result, the Volcker Rule was not even part of the initial financial reform legislation proposed by the Treasury Department[1].

Throughout the summer and fall of 2009, the initial Treasury proposal was hammered by critics as one catering to Wall Street. As discontent brewed, the Obama administration started to shift towards Paul Volcker's proposal (Skeel, 2010). On January 21, 2010, President Obama, with Paul Volcker by his side, publicly announced his support for the rule. On July 21, 2010, the Volcker Rule, together with other provisions of the Dodd-Frank Act, was signed into law.

Like many other provisions of the Dodd-Frank Act, the Volcker Rule was highly incomplete when the legislation was passed. The specific rulemaking was delegated to five federal agencies, including the Federal Reserve Board, FDIC, OCC, CFTC and SEC. Given the substantial incompleteness of the legislative statute, the rulemaking process ignited a heated debate among regulators and industry special interest groups: over 17,000 public comments were filed. Big banks such as Bank of America, Goldman Sachs, and JP Morgan expressed concerns about the rule. Conservative politicians such as the Chairman of the House Financial Services Committee, Representative Spencer Bachus, vowed to limit the effect of the Volcker Rule[2]. Industry lobbyists were also pushing for loosening the restrictions or extending the compliance deadlines.

Due to all the above controversies, the implementation of the Rule was delayed multiple times. Congress originally mandated that the Volcker Rule become effective in July 2012, two years after Dodd-Frank passed. However, during his report to Congress on February 29, 2012, Federal Reserve Chairman Ben Bernanke said that the central bank and other regulators would not meet that deadline. After missing the first deadline, regulators estimated that the rule would be finished during the first few months of 2013. Again, this second deadline was missed. On December 10, 2013, all five of the necessary regulatory agencies approved a version of the Volcker Rule which had a longer compliance period and fewer metrics than earlier proposals[3]. However, the approval was immediately followed by an emergency lawsuit filed by the American Bankers Association, bringing the five regulatory agencies back to the reviewing process. On January 14, 2014, revised

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[1] Department of The Treasury, Financial Regulatory Reform: A New Foundation: Rebuilding Financial Supervision and Regulation (2009), available at http://www.treasury.gov/initiatives/Documents/FinalReport_web.pdf.

[2] See "Bachus Urges Regulators Not to Rigidly Implement Volcker Rule", by Deborah Solomon, The Wall Street Journal, November 4, 2010

[3] See "Volcker Shrugged", PwC Financial Services Regulatory Practice, December, 2013.

final regulations were approved by all five regulatory agencies. The effective date was set on April 1, 2014 and the deadline of conformance was extended to July 21, 2015. By that time, the Volcker Rule had grown into a 953-page document, adding to the 2,400 page Dodd-Frank Act. In contrast, the Federal Reserve Act of 1913 which created the Federal Reserve System was only 31 pages long, and the Glass-Steagall Act of 1933, the most important regulatory legislation post the Great Depression, was only 37 pages.

Anticipating tighter regulation, big banks started to gradually retreat from businesses prohibited by the Rule well before details were finalized. In September 2010, two months after the passage of Dodd-Frank, JP Morgan first announced the closing of its proprietary trading desks[4]. Two days later, Goldman Sachs followed[5]. Several other banks such as Morgan Stanley, Bank of America, Citi Group, and RBC announced the shutdown of their proprietary trading desks one after another from January 2011 to April 2014, spanning the whole rulemaking period[6].

With banks retreating from proprietary trading due to the anticipation of tighter regulation, market participants started to worry about unintended consequences of the Volcker Rule on banks' market making capacity. Although the Volcker Rule exempts market-making related trading activities, critics argued that the proposed metrics of exemption would nevertheless substantially discourage the use of market making discretion (Duffie, 2012). Supporting this claim, there seemed to be evidence that banks started shedding their corporate bond inventories. Figure 2 shows one of the most cited stylized facts: the amount of corporate bonds held by dealer banks declined by nearly 80% since their peak of $235 billion in 2007 according to Federal Reserve data[7]. In terms of the percentage of the total corporate bond outstanding, the decline is from more than 5% in 2007 to less than 1% in 2014. Because the corporate bond market relies heavily on the banks to make market, this dramatic decline of dealer inventories has fed concerns about deteriorating market liquidity under Dodd-Frank and the Volcker Rule.

As the above discussion should have made clear, the protracted rulemaking process and complicated anticipatory response by market participants posit a daunting challenge for researchers trying to pin down when the regulations started to take effect on market liquidity, or if it had any effect at all. To address this challenge, we employ statistical methods which allow us to estimate the dates of breaks in liquidity without requiring a priori knowledge of the exact timing.

The Volcker Rule is by no means the only regulation that may affect market liquidity. Basel III and other post-crisis financial regulations could also constrain banks' market making ability. The implementation process of various regulations overlaps each other, adding another layer of complexity. In this study, we are mostly interested in the cumulative effect of post-crisis regulations. Nevertheless, the estimated timing of the breaks and the heterogeneous effects on different types of securities can shed some light on which regulation might be the most relevant.

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[4] See "J.P. Morgan to Close Proprietary-Trading Desks" by Matthias Rieker, The Wall Street Journal, Sep 1, 2010.

[5] See "Goldman shutting proprietary trading", The Globe and Mail, September 3, 2010.

[6] See "Morgan Stanley Team to Exit In Fallout From Volcker Rule" by Aaron Lucchetti, The Wall Street Journal, January 11, 2011; "Bank Of America Is Shutting Down Merrill's Bond Prop Trading Desk" by Katya Wachtel, Business Insider, June 10, 2011; "Citigroup to Close Prop Trading Desk" by Kevin Roose, The New York Times, January 27, 2012; "RBC to Close Proprietary-Trading Desk", by Rob Copeland, The Wall Street Journal, April 15, 2014.

[7] See "Markets: The Debt Penalty" by Tracy Alloway, Financial Times, September 10, 2013. See also "Investors Raise Alarm Over Liquidity Shortage" by Christopher Whittall and Juliet Samuel, The Wall Street Journal, March 18, 2015.

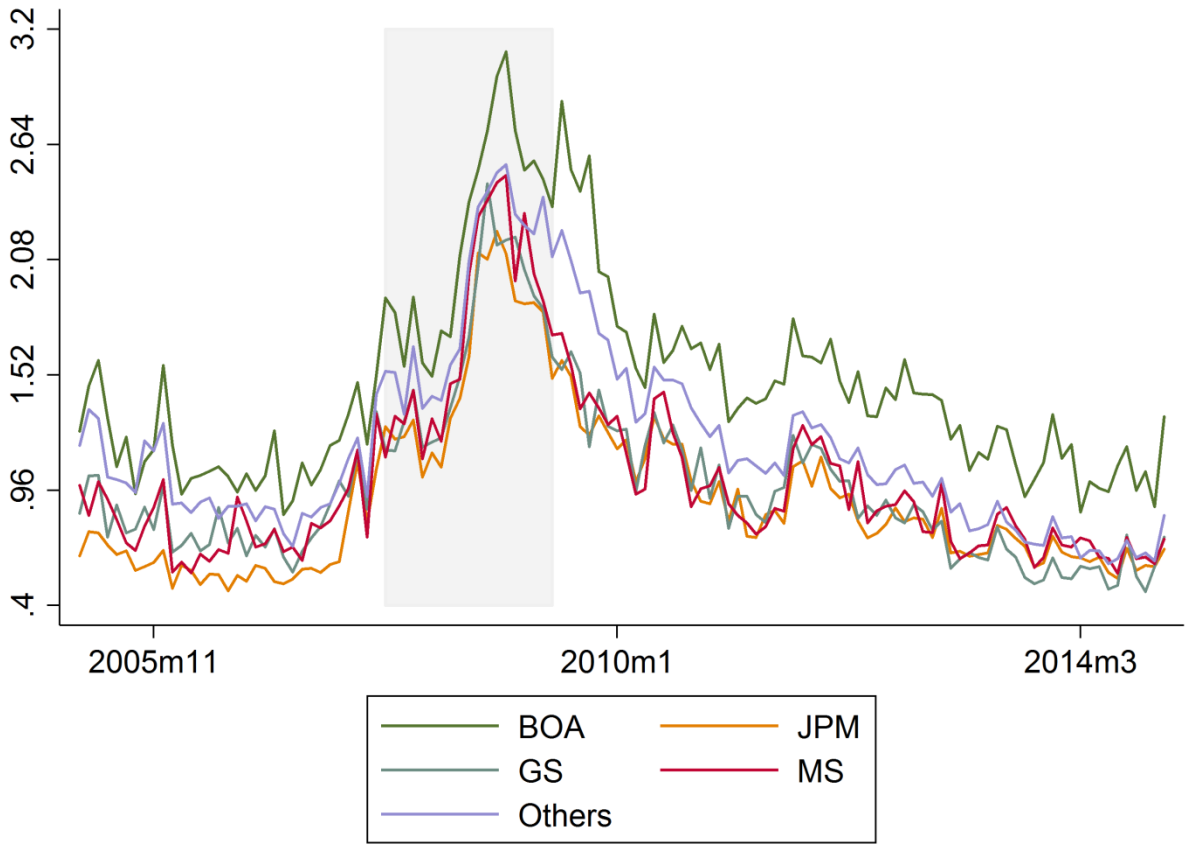

Figure 1. Time Series of Liquidity Measures (Underwriter-Level): Amihud

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

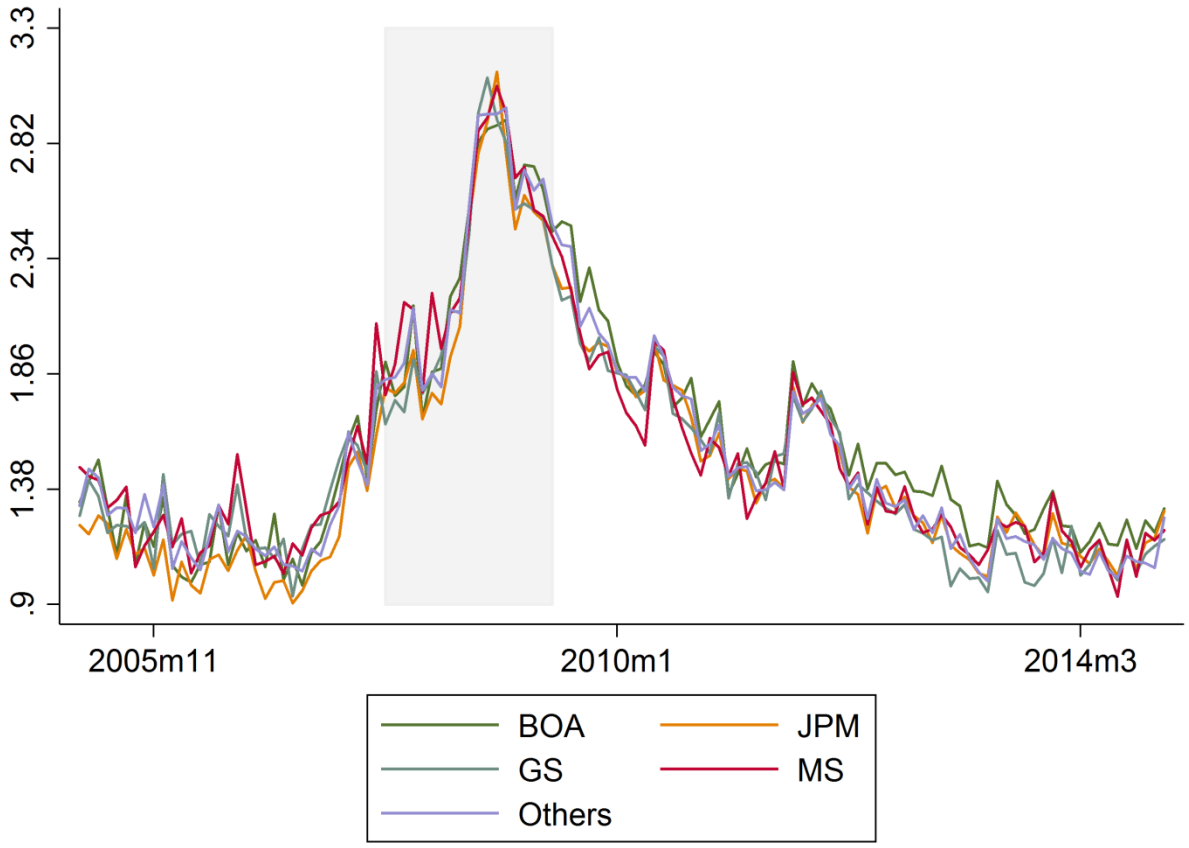

Figure 1 (continued). Time Series of Liquidity Measures (Underwriter-Level): Amihud (sd)

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

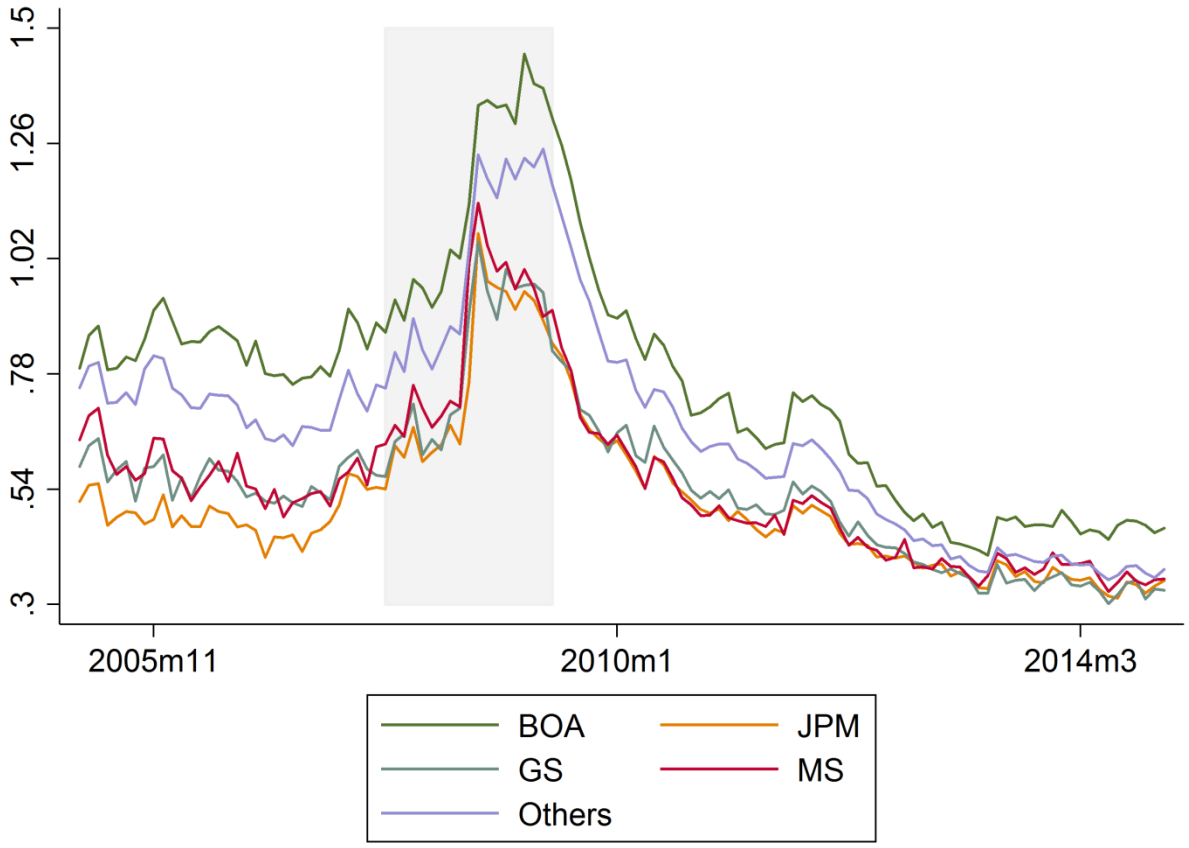

Figure 1 (continued). Time Series of Liquidity Measures (Underwriter-Level): IRC

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

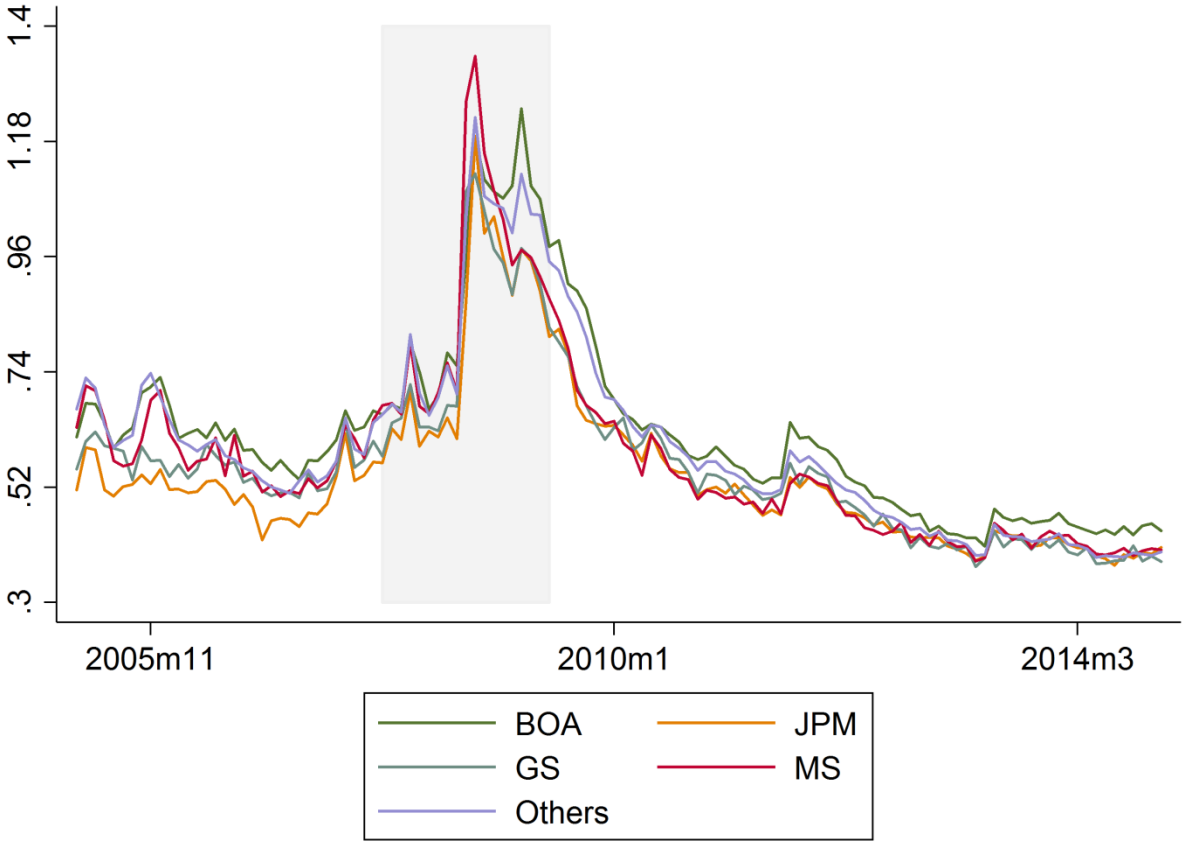

Figure 1 (continued). Time Series of Liquidity Measures (Underwriter-Level): IRC (sd)

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

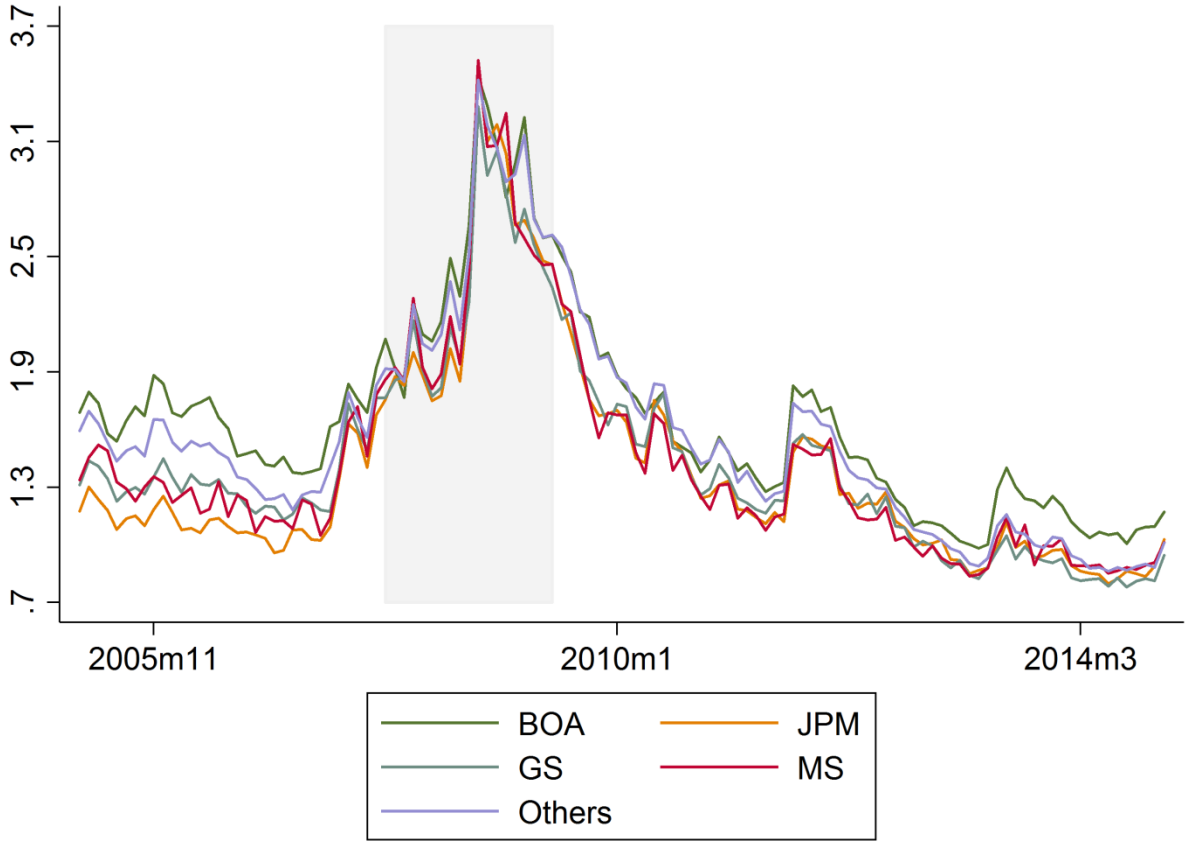

Figure 1 (continued). Time Series of Liquidity Measures (Underwriter-Level): Roll

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

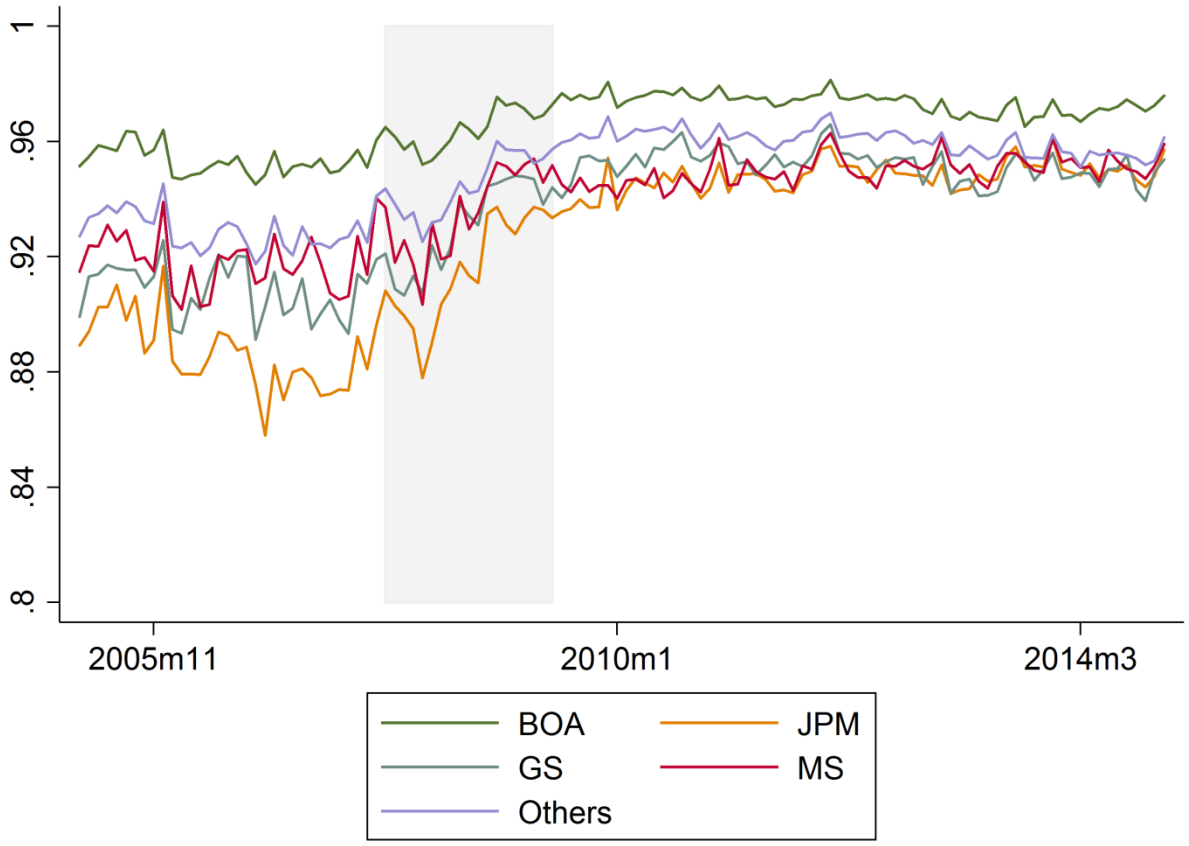

Figure 1 (continued). Time Series of Liquidity Measures (Underwriter-Level): Non-block Trade

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

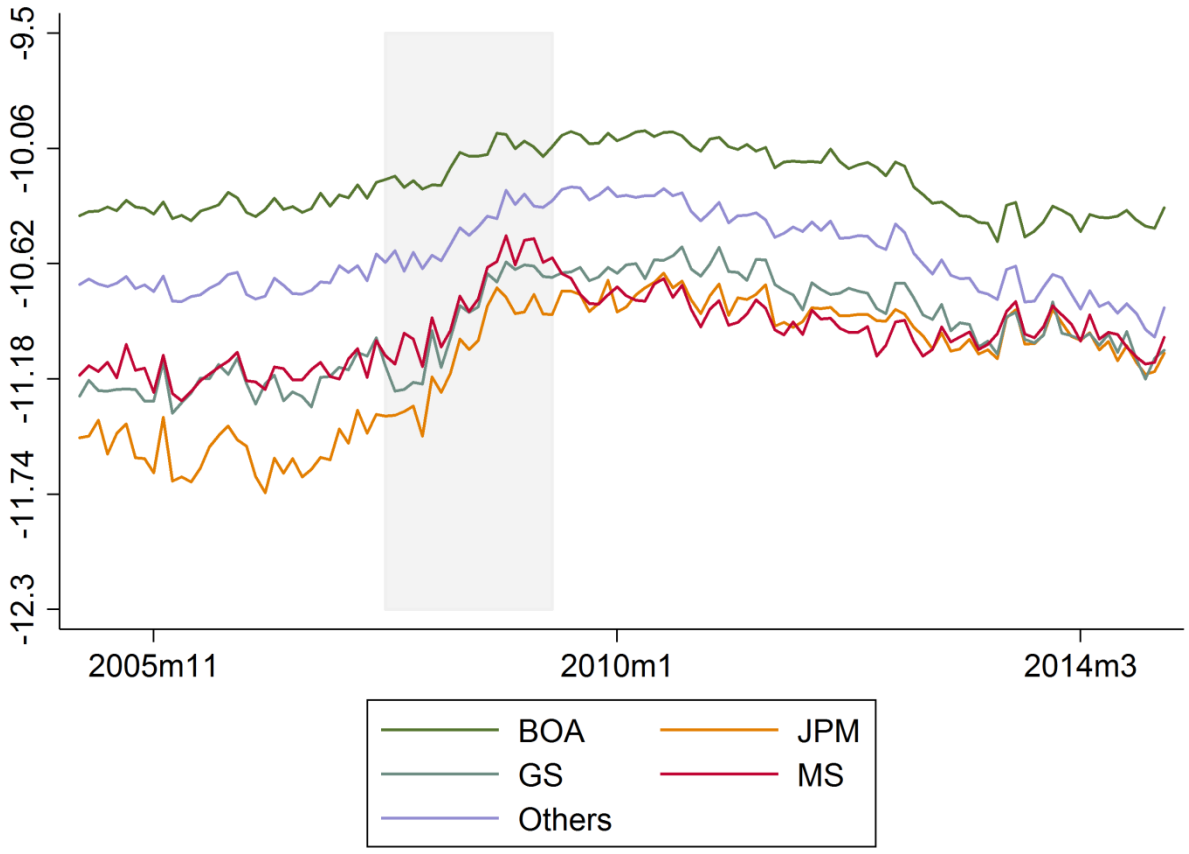

Figure 1 (continued). Time Series of Liquidity Measures (Underwriter-Level): Size (negative)

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

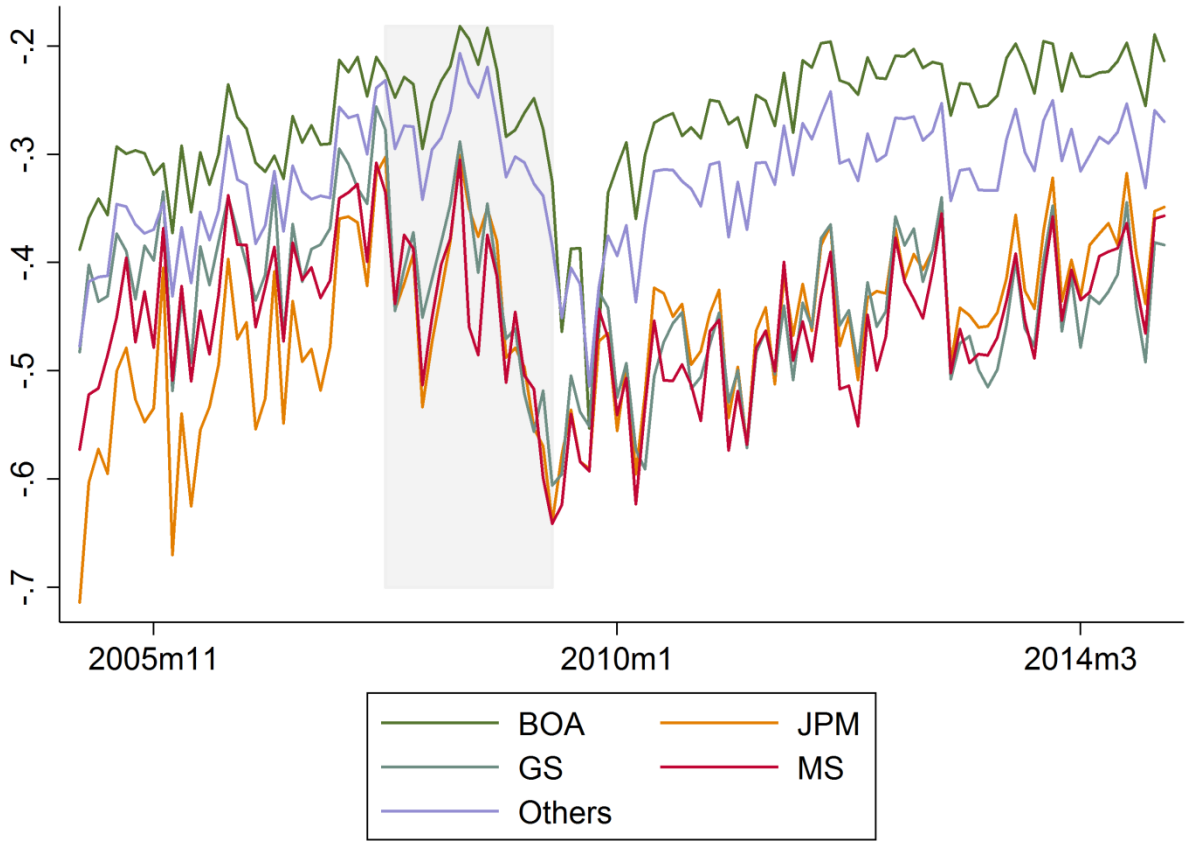

Figure 1 (continued). Time Series of Liquidity Measures (Underwriter-Level): Turnover (negative)

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

Figure 1 (continued). Time Series of Liquidity Measures (Underwriter-Level): Zero-trading Days

Notes: This graph shows the time series of liquidity measures of U.S. corporate bonds underwritten by four big banks and all the other underwriters combined. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

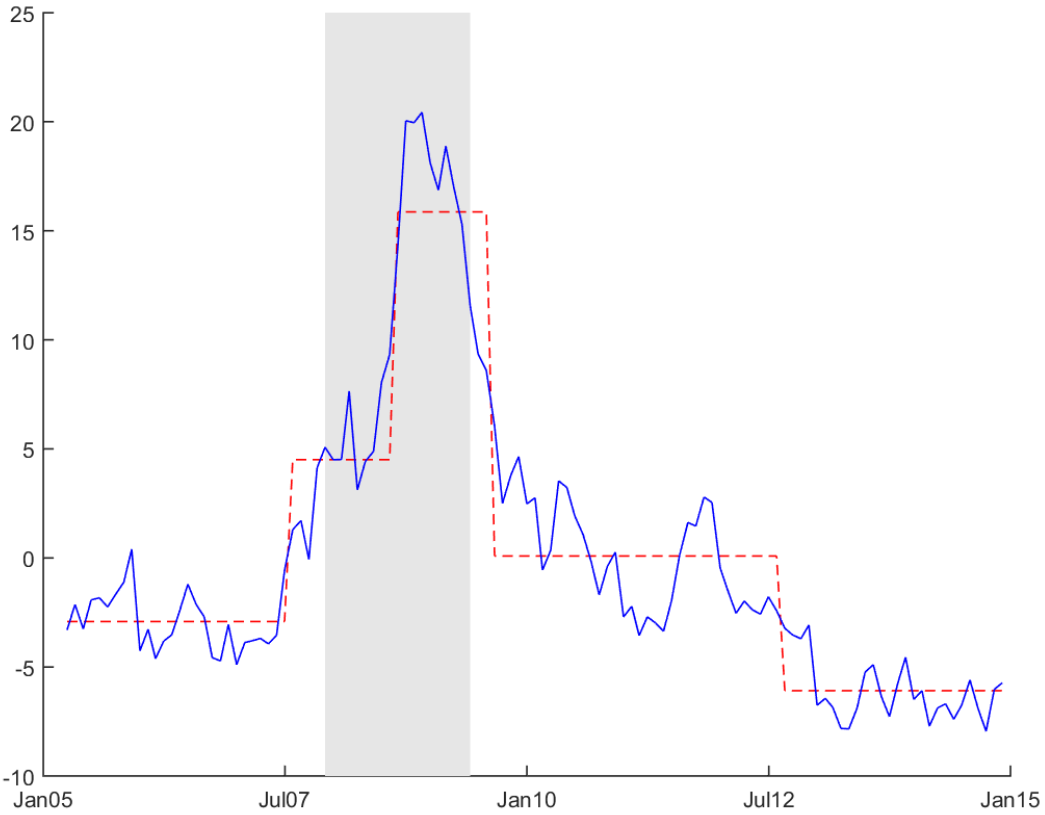

Figure 2. Time Series of Aggregate Liquidity Index of U.S. Corporate Bonds

Notes: This graph shows the time series of aggregate liquidity index of U.S. corporate bond market (blue line), and the estimated mean for each sub-period (red dashed line). The break dates (dates with a shift in the level of the red dashed line) are estimated by the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from April 2005 to December 2014. The data frequency is monthly. The grey area indicates recession.

Figure 3. Corporate Bond Turnover from 2002 to 2014

Notes: This graph shows the aggregate bond turnover from 2002 to 2014. The solid line is the raw turnover, and the dashed line is the turnover adjusted by including corporate bond ETFs. The vertical line indicates the passage of Dodd-Frank Act (July, 2010). The corporate bond data is from SIFMA and the ETF data is from Bloomberg.

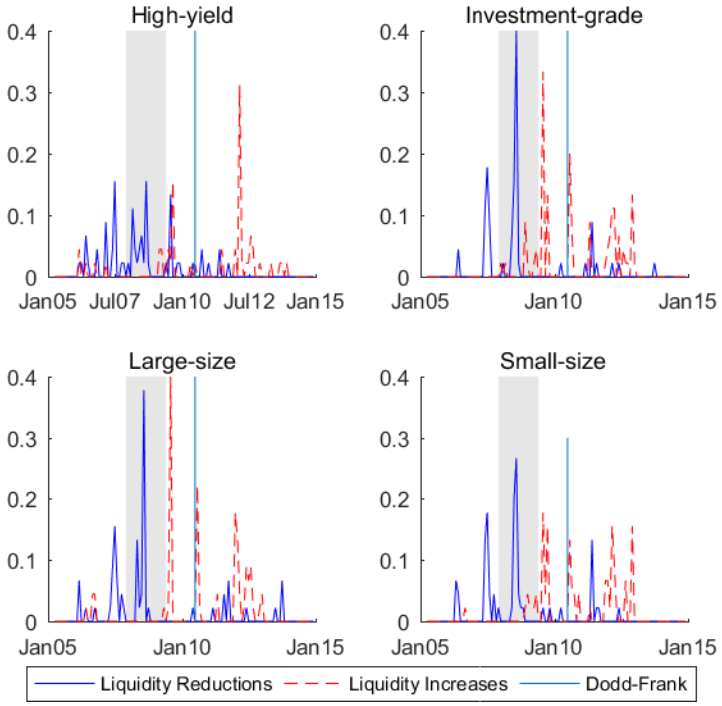

Figure 4. Breaks in the Means of Liquidity by Bond Type (Disaggregate-level)

Notes: This graph shows the decomposition of break dates by bond type. The x-axis shows the dates and the y-axis shows the corresponding fraction of the 45 (=9×5) liquidity measures of each bond type which have a break at this date. The break dates are estimated using the Bai and Perron (1998-2003) approach with 5 percent significance level. The solid vertical line indicates the passage of Dodd-Frank Act (July, 2010). The sample period is from April 2005 to December 2014. The data frequency is monthly.

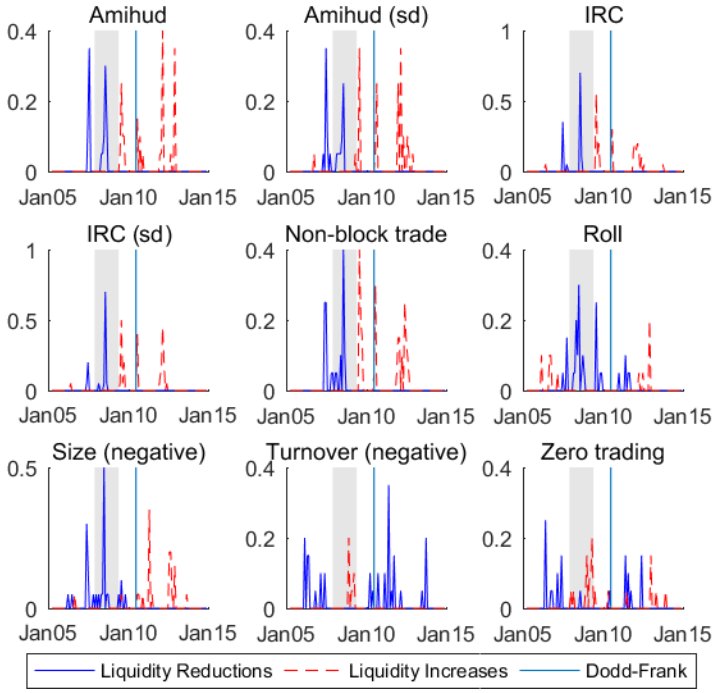

Figure 5. Breaks in the Means of Liquidity by Measure (Disaggregate-level)

Notes: This graph shows the decomposition of break dates by liquidity measure. The x-axis shows the dates and the y-axis shows the corresponding fraction of the 20 (=5×2×2) series of each liquidity measure which have a break at this date. The break dates are estimated using the Bai and Perron (1998-2003) approach with 5 percent significance level. The solid vertical line indicates the passage of Dodd-Frank Act (July, 2010). The sample period is from April 2005 to December 2014. The data frequency is monthly.

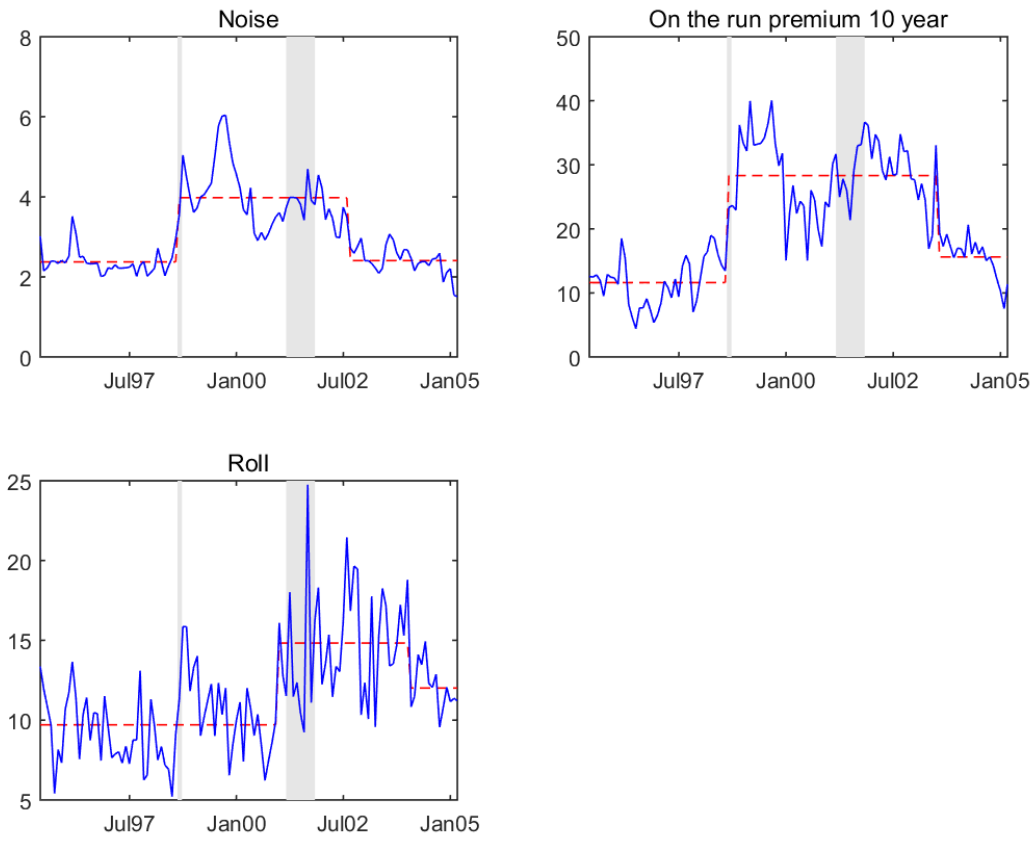

Figure 6. Time Series of Liquidity of the U.S. Treasury Bonds (June 1995 to March 2005)

Notes: This graph shows the time series of liquidity measures of U.S. Treasury market (blue line), and the estimated mean for each sub-period (red dashed line). The break dates (dates with a shift in the level of the red dashed line) are estimated by the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from June 1995 to March 2005. The data frequency is monthly. The first grey area indicates LTCM crisis, and the second grey area indicates the recession in 2001.

Table 1. Sample Mean and Standard Deviation of Liquidity (Disaggregate-level)

Bank	Bond Type	Amihud	Amihud (sd)	IRC	IRC (sd)	Roll	Non-block trade	Size (negative)	Turnover (negative)	Zero-trading
B	High-yield	0.71	1.21	0.48	0.52	1.33	0.70	-11.87	-0.36	0.63
		(0.26)	(0.32)	(0.15)	(0.16)	(0.4)	(0.09)	(0.52)	(0.12)	(0.05)
B	Investment-grade	1.58	1.63	0.79	0.63	1.68	0.98	-10.14	-0.26	0.78
		(0.53)	(0.51)	(0.26)	(0.18)	(0.54)	(0.01)	(0.15)	(0.06)	(0.03)
B	Large-size	0.88	1.52	0.57	0.65	1.28	0.93	-10.98	-0.65	0.18
		(0.49)	(0.55)	(0.24)	(0.25)	(0.59)	(0.02)	(0.2)	(0.17)	(0.04)
B	Small-size	1.58	1.60	0.78	0.63	1.68	0.97	-10.18	-0.25	0.79
		(0.51)	(0.48)	(0.26)	(0.18)	(0.52)	(0.01)	(0.15)	(0.06)	(0.03)
GS	High-yield	0.83	1.32	0.55	0.58	1.51	0.74	-11.55	-0.32	0.66
		(0.33)	(0.46)	(0.17)	(0.17)	(0.51)	(0.07)	(0.47)	(0.08)	(0.07)
GS	Investment-grade	1.02	1.54	0.55	0.56	1.42	0.96	-10.86	-0.45	0.51
		(0.43)	(0.5)	(0.17)	(0.16)	(0.53)	(0.02)	(0.21)	(0.08)	(0.09)
GS	Large-size	0.86	1.54	0.59	0.67	1.26	0.94	-10.74	-0.75	0.15
		(0.58)	(0.56)	(0.27)	(0.28)	(0.59)	(0.02)	(0.24)	(0.16)	(0.05)
GS	Small-size	1.02	1.52	0.54	0.55	1.46	0.94	-10.94	-0.39	0.57
		(0.39)	(0.47)	(0.15)	(0.14)	(0.51)	(0.02)	(0.24)	(0.06)	(0.08)

Notes: This table shows the sample mean and standard deviation (in brackets) of 180 underwriter-level liquidity measures for the U.S. corporate bond market. The list of underwriters includes Bank of America (B), Goldman Sachs (GS), JP Morgan (JPM), Morgan Stanley (MS), and all the other underwriters (OT). The sample period is from April 2005 to December 2014. The data frequency is monthly. The unit of Amihud, Amihud (sd), IRC, IRC (sd), and Roll is percentage point. The unit of Non-block trade, Turnover (negative) and Zero-trading is 1.

Bank	Bond Type	Amihud	Amihud (sd)	IRC	IRC (sd)	Roll	Non-block trade	Size (negative)	Turnover (negative)	Zero-trading
JPM	High-yield	0.78	1.34	0.53	0.56	1.41	0.70	-11.79	-0.39	0.61
		(0.29)	(0.4)	(0.15)	(0.16)	(0.42)	(0.1)	(0.61)	(0.09)	(0.05)
JPM	Investment-grade	0.94	1.51	0.51	0.54	1.39	0.95	-11.01	-0.47	0.49
		(0.42)	(0.51)	(0.17)	(0.16)	(0.57)	(0.02)	(0.29)	(0.08)	(0.07)
JPM	Large-size	0.72	1.38	0.51	0.61	1.20	0.93	-10.89	-0.69	0.16
		(0.49)	(0.5)	(0.22)	(0.22)	(0.57)	(0.02)	(0.23)	(0.14)	(0.04)
JPM	Small-size	0.96	1.51	0.52	0.54	1.42	0.93	-11.11	-0.43	0.54
		(0.39)	(0.48)	(0.16)	(0.15)	(0.55)	(0.03)	(0.32)	(0.08)	(0.06)
MS	High-yield	0.94	1.51	0.58	0.62	1.58	0.75	-11.47	-0.37	0.63
		(0.34)	(0.38)	(0.17)	(0.19)	(0.49)	(0.06)	(0.35)	(0.09)	(0.05)
MS	Investment-grade	1.03	1.55	0.55	0.58	1.42	0.96	-10.90	-0.46	0.48
		(0.46)	(0.51)	(0.18)	(0.19)	(0.56)	(0.01)	(0.17)	(0.08)	(0.08)
MS	Large-size	0.86	1.43	0.55	0.63	1.18	0.94	-10.96	-0.72	0.16
		(0.55)	(0.53)	(0.25)	(0.27)	(0.57)	(0.02)	(0.19)	(0.17)	(0.04)
MS	Small-size	1.06	1.58	0.56	0.57	1.48	0.94	-10.95	-0.41	0.55
		(0.42)	(0.48)	(0.16)	(0.16)	(0.55)	(0.02)	(0.18)	(0.06)	(0.07)
OT	High-yield	0.77	1.32	0.53	0.56	1.43	0.72	-11.70	-0.36	0.66
		(0.24)	(0.3)	(0.14)	(0.14)	(0.41)	(0.08)	(0.49)	(0.11)	(0.04)
OT	Investment-grade	1.26	1.57	0.69	0.61	1.58	0.97	-10.48	-0.32	0.71
		(0.51)	(0.54)	(0.24)	(0.19)	(0.58)	(0.01)	(0.19)	(0.05)	(0.04)
OT	Large-size	0.73	1.37	0.51	0.61	1.18	0.93	-10.97	-0.65	0.18
		(0.46)	(0.51)	(0.23)	(0.24)	(0.56)	(0.02)	(0.16)	(0.14)	(0.05)
OT	Small-size	1.27	1.58	0.69	0.60	1.60	0.95	-10.54	-0.30	0.73
		(0.48)	(0.5)	(0.23)	(0.18)	(0.56)	(0.02)	(0.2)	(0.05)	(0.03)

Table 2. Break Dates in the Levels of Liquidity (Aggregate-level)

Measure	Break Dates			
Amihud	Aug07	Aug08	Dec09	Dec12
Amihud (sd)	Mar12			
IRC	Aug08	Oct09	Mar12	
IRC (sd)	Aug08	Oct09	Mar12	
Roll	Feb08	Oct09	Jun12	
Non-block trade	Oct07	Oct08	Dec12	
Size (negative)	Jun07	Jul08	May11	Oct12
Turnover (negative)	Jan07			
Zero trading	Jun06	Jun07	May09	

Notes: This table lists break dates in the levels of 9 aggregate-level liquidity measures of the U.S. corporate bond market. The dates are estimated by the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from April 2005 to December 2014. The data frequency is monthly.

Table 3. Double Maximum Test Statistics of Breaks in the Levels of Liquidity (Aggregate-level)

Measures	WDmax	5% critical value of WDmax	UDmax	5% critical value of UDmax
Amihud	75.81	10.39	44.74	9.52
Amihud (sd)	62.02	10.39	36.60	9.52
IRC	278.58	10.39	184.60	9.52
IRC (sd)	97.20	10.39	58.38	9.52
Roll	55.66	10.39	32.84	9.52
Non-block trade	231.80	10.39	152.66	9.52
Size (negative)	214.44	10.39	126.54	9.52
Turnover (negative)	76.27	10.39	45.01	9.52
Zero trading	86.06	10.39	50.78	9.52

Notes: This table lists the Dmax statistics of break dates in the levels of 9 aggregate-level liquidity measures of the U.S. corporate bond market. The dates are estimated by the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from April 2005 to December 2014. The null hypothesis is that there is no break, and the alternative hypothesis is that there is at least one break. The data frequency is monthly. The critical values are obtained from Bai and Perron (1998) with 10% of trimming rates.

Table 4: Sequential Test Statistics of Multiple Breaks in the Means of Liquidity (Aggregate-level)

Measure	F(2|1)	5% critical value of F(2|1)	F(3|2)	5% critical value of F(3|2)	F(4|3)	5% critical value of F(4|3)	F(5|4)	5% critical value of F(5|4)
Amihud	14.63	10.55	35.57	11.36	20.61	12.35	10.76	12.97
Amihud (sd)	3.46	10.55						
IRC	23.01	10.55	16.25	11.36	5.86	12.35		
IRC (sd)	20.89	10.55	25.83	11.36	3.00	12.35		
Roll	18.29	10.55	24.25	11.36	5.97	12.35		
Non-block trade	11.63	10.55	29.91	11.36	5.07	12.35		
Spread	29.82	10.55	109.60	11.36	49.79	12.35	11.29	12.97
Turnover (negative)	3.18	10.55						
Zero trading	22.35	10.55	38.24	11.36	6.00	12.35		

Notes: This table lists the sequential test statistics of break dates in the levels of 9 aggregate-level liquidity measures of the U.S. corporate bond market. The dates are estimated by the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from April 2005 to December 2014. The data frequency is monthly. The critical values are obtained from Bai and Perron (1998) with 10% of trimming rates.

Table 5. Number of Dynamic Factors (Disaggregate-level)

Method	Number of Estimated Factors
Ahn & Horenstein (2013) ER	3
Ahn & Horenstein (2013) GR	3
Bai & Ng (2002) IC1	10
Bai & Ng (2002) IC2	8
Bai & Ng (2002) IC3	10
Bai & Ng (2002) PC1	10
Bai & Ng (2002) PC2	9
Bai & Ng (2002) PC3	10
Bai & Ng (2002) AIC3	10
Bai & Ng (2002) BIC3	4

Notes: This graph shows the estimated number of factors in 180 underwriter-level liquidity measures for the U.S. corporate bond market. The sample period is from April 2005 to December 2014. The liquidity measures are differenced and standardized. The data frequency is monthly. The maximum number of possible breaks is 10.

Table 6. Number of Factors Before and After Break: Single Break Test

Notes: This graph shows the estimated number of factors before and after the break dates in a panel of underwriter-level liquidity measures for the U.S. corporate bond market. The break dates are estimated using the sup-Wald test from Chen et al. (2014), and the numbers of factors before and after break are estimated using the eigenvalue ratio estimator from Ahn and Horenstein (2013). The sample period is from April 2005 to December 2014. The liquidity measures are differenced and standardized. The data frequency is monthly.

	# of Factors		
Whole Sample	Before Break	After Break	Break Dates
2	1	1	Jul08
3	2	2	Jun10
4	2	1	Sep08
5	2	1	Sep08
6	2	1	Sep08
7	2	1	Sep08
8	2	1	Sep08
9	2	1	Sep08
10	2	3	Oct08

Table 7: Break Dates of Liquidity Factor Structure (Disaggregate-level)

	Break Dates				
2	Aug08	Sep09			
3	Aug08	Sep09			
4	Aug08	Sep09			
5	Sep08	Dec09			
6	Aug06	Sep07	Sep08	Nov09	Aug11
7	May06	Sep07	Sep08	Nov09	Sep11
8	Aug06	Sep07	Sep08	Sep09	Sep10
9	Aug06	Sep07	Sep08	Mar10	Mar11
10	May06	Sep07	Sep08	Jul10	Sep11

Notes: This table shows the break dates in factor structure of the U.S. corporate bond market liquidity employing the Chen, Dolado, and Gonzalo (2014) and Bai and Perron (1998-2003) approach with 5 percent significance level. Liquidity measures are in underwriter-level. The sample period is from April 2005 to December 2014. We estimate the top 10 principal components from the differenced and standardized liquidity measures, then run the tests iteratively assuming that there are k principal factors, where k = 2 to 10.

Table 8: Double Maximum Test Statistics of Breaks in the Liquidity Factor Structure (Disaggregate-level)

Number of factors	WDmax	5% critical value of WDmax	UDmax	5% critical value of UDmax
2	22.51	10.39	19.59	9.52
3	51.15	13.66	44.17	12.59
4	400.32	16.07	314.23	14.85
5	172.29	18.38	125.93	17.00
6	546.64	20.30	399.88	18.91
7	1325.34	22.55	935.27	21.01
8	7.12E+13	24.34	5.08E+13	22.80
9	2.98E+04	26.10	2.45E+04	24.56
10	1.37E+14	27.99	1.00E+14	26.48

Notes: This table shows the double maximum test statistics of break in factor structure of the U.S. corporate bond market liquidity employing the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from April 2005 to December 2014. The data frequency is monthly. We estimate the top 10 principal components from the differenced and standardized liquidity measures, then run the tests iteratively assuming that there are k principal factors, where k = 2 to 10. The null hypothesis is that there is no break, and the alternative hypothesis is that there is at least one break. The critical values are obtained from Bai and Perron (1998) with 10% of trimming rates.

Table 9: Sequential Test Statistics of Multiple Breaks in the Liquidity Factor Structure (Disaggregate-level)

Number of factors	F(2|1)	5% critical value of F(2|1)	F(3|2)	5% critical value of F(3|2)	F(4|3)	5% critical value of F(4|3)	F(5|4)	5% critical value of F(5|4)
2	21.26	10.55	1.35	11.36				
3	32.37	13.83	7.36	14.73				
4	43.43	16.53	15.20	17.43				
5	22.11	18.56	7.38	19.53				
6	39.27	20.57	40.46	21.60	59.75	22.55	59.75	23.00
7	69.01	23.01	102.09	24.14	102.09	24.77	92.12	25.48
8	91.88	24.64	435.28	25.57	435.28	26.54	83.63	27.04
9	3752.16	26.42	1554.46	27.66	1554.46	28.25	36.52	28.99
10	1350.01	28.23	4688.40	29.44	12381.97	30.31	12381.97	30.77

Notes: This table shows the sequential test statistics of break in factor structure of the U.S. corporate bond market liquidity employing the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from April 2005 to December 2014. The data frequency is monthly. We estimate the top 10 principal components from the differenced and standardized liquidity measures, then run the tests iteratively assuming that there are k principal factors, where k = 2 to 10. The critical values are obtained from Bai and Perron (1998) with 10% of trimming rates.

Table 10: Number of Factors of Each Subperiod: Multiple Break Test

Whole sample	Subperiod 1	Subperiod 2	Subperiod 3	Subperiod 4	Subperiod 5	Subperiod 6
2	1	1	3			
3	1	1	3			
4	1	1	3			
5	2	1	3			
6	1	3	2	1	3	2
7	1	3	2	1	2	2
8	1	3	2	1	3	2
9	1	3	2	1	1	2
10	1	3	2	1	2	2

Notes: This graph shows the estimated number of factors of each subperiod in a panel of underwriter-level liquidity measures for the U.S. corporate bond market. The break dates are estimated using Bai and Perron (1998-2003) approach with 5 percent significance level, and the number of factors of each subperiod is estimated using the eigenvalue ratio estimator from Ahn and Horenstein (2013). The sample period is from April 2005 to December 2014. The liquidity measures are differenced and standardized. The data frequency is monthly.

Table 11: Liquidity Principal Components and Determinants

	(1) Factor 1	(2) Factor 2	(3) Factor 3	(4) Factor 4	(5) Factor 5
VIX	0.0413***	-0.0136	0.0148	0.0120	0.0247**
	[0.0124]	[0.0124]	[0.0102]	[0.0131]	[0.0106]
BBB	0.00669	-0.00282	0.0274	0.0104	0.0385*
	[0.0155]	[0.0165]	[0.0211]	[0.0150]	[0.0198]
FFR	-0.0108	0.00787	0.0224**	-0.00425	0.0146
	[0.00905]	[0.00998]	[0.0111]	[0.0136]	[0.0110]
Term	-0.00268	-0.0158	0.0463***	0.000163	-0.00361
	[0.0128]	[0.0128]	[0.0149]	[0.00934]	[0.0107]
Breakeven	-0.00246	0.0183	-0.00784	-0.000244	0.0301*
	[0.0145]	[0.0146]	[0.0210]	[0.0159]	[0.0164]
QE	-0.0140	0.0136	-0.0565***	-0.00634	0.0114
	[0.0103]	[0.00935]	[0.0169]	[0.0112]	[0.0155]
TED	0.0231	0.0104	-0.00973	-0.0379***	-0.00689
	[0.0195]	[0.00999]	[0.0205]	[0.0102]	[0.0142]
Bond Fund	0.00458***	-0.00874***	-0.00703***	0.00203*	-0.00596***
	[0.000973]	[0.00122]	[0.000963]	[0.00104]	[0.00113]
inventory	0.0119	0.00871	0.00241	-0.00464	0.0113
	[0.00716]	[0.00829]	[0.00639]	[0.00837]	[0.00696]
Observations	117	117	117	117	117
Adjusted R-squared	0.369	0.019	0.207	0.071	0.152

Notes: This table shows multivariate regression of principal components of 180 liquidity measures on potential determinants that affect liquidity.

Table 11 (continued): Liquidity Principal Components and Determinants

	(6) Factor 6	(7) Factor 7	(8) Factor 8	(9) Factor 9	(10) Factor 10
VIX	-0.0239**	-0.0131	-0.0191	-0.0129	0.00293
	[0.0119]	[0.0145]	[0.0177]	[0.0164]	[0.0114]
BBB	-0.00272	-0.00905	0.0212	0.0116	0.0144
	[0.0161]	[0.0251]	[0.0207]	[0.0205]	[0.0198]
FFR	0.0150	-0.00218	-0.00127	0.0141	0.0147
	[0.0111]	[0.0136]	[0.0122]	[0.0141]	[0.0121]
Term	0.0113	0.00329	-0.0120	0.0314*	0.000697
	[0.0120]	[0.0134]	[0.0161]	[0.0163]	[0.0117]
Breakeven	0.0124	-0.00728	-0.0312**	-0.00667	0.0193
	[0.0158]	[0.0133]	[0.0149]	[0.0133]	[0.0169]
QE	0.0210	0.000757	-0.0268**	0.0217*	0.0111
	[0.0132]	[0.0114]	[0.0117]	[0.0125]	[0.0134]
TED	0.0134	0.0422***	0.00195	-0.0166	0.0152
	[0.0185]	[0.0124]	[0.00964]	[0.0142]	[0.0104]
Bond Fund	-0.00481***	-0.00178	-0.00189	-0.00470***	0.00130
	[0.00115]	[0.00123]	[0.00129]	[0.00125]	[0.000943]
inventory	-0.0122	-0.00921	0.000989	-0.00457	-0.0104
	[0.0130]	[0.00810]	[0.00806]	[0.00882]	[0.00820]
Observations	117	117	117	117	117
Adjusted R-squared	0.042	0.090	0.133	0.063	-0.001

Notes: This table shows multivariate regression of principal components of 180 liquidity measures on potential determinants that affect liquidity.

Table 12: Break Dates of the U.S. Treasury Liquidity

Measure	Break Dates			
Noise	Jun07	Jun08	Jun09	
On the run premium 10 year	Jan11			
Roll	Aug07	Jun09	Nov11	
Turnover (negative)	Mar06	Oct08	Apr10	Nov11

Notes: This table lists break dates in the levels of liquidity measures of U.S. Treasury market. The dates are estimated by the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from April 2005 to December 2014. The data frequency is monthly.

Table 13: Double Maximum Test Statistics of Multiple Breaks in the Means of the U.S. Treasury Liquidity

Measure	WDmax	5 percent critical value of WDmax	UDmax	5 percent critical value of UDmax
Noise	12.10	10.39	7.14	9.52
On the run premium	54.14	10.39	35.88	9.52
Roll	119.05	10.39	87.48	9.52
Turnover (negative)	276.59	10.39	276.59	9.52

Notes: This table lists the double maximum statistics of break dates in the levels of liquidity measures of U.S. Treasury market. The dates are estimated by the Bai and Perron (1998-2003) approach with 5 percent significance level. The sample period is from April 2005 to December 2014. The data frequency is monthly. The null hypothesis is that there is no break, and the alternative hypothesis is that there is at least one break. The critical values are obtained from Bai and Perron (1998).

Table 14: Sequential Test Statistics of Multiple Breaks in the Means of the U.S. Treasury Liquidity

Measure	F(2|1)	5% critical value of F(2|1)	F(3|2)	5% critical value of F(3|2)	F(4|3)	5% critical value of F(4|3)	F(5|4)	5% critical value of F(5|4)
Noise	10.56	10.55	21.63	11.36	9.65	12.35		
On the run premium 10 year	5.65	10.55						
Roll	25.12	10.55	31.19	11.36	1.26	12.35		
Turnover (negative)	34.26	10.55	16.50	11.36	16.50	12.35	12.23	12.97

Notes: This table lists the double maximum statistics of break dates in the levels of liquidity measures of U.S. Treasury market. The dates are estimated by the Bai and Perron (1998-2003) approach with 5percent significance level. The sample period is from April 2005 to December 2014. The data frequency is monthly. The critical values are obtained from Bai and Perron (1998).