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DISSECTING THE SEGMENTATION OF CHINA'S REPO MARKETS

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Abstract

China repos trade in the over-the-counter interbank market as well as the stock exchange. This paper examines the behaviours, sources, and drivers of the spread between China's exchange and interbank repo rates from December 2006 to June 2018. After adjusting for different day-count quoting methods, I dissect the exchange to interbank repo spread into two components: cross-market segmentation between exchange and interbank markets for non-depository institutions (NDIs), and within-market counterparty segmentation between NDIs and depository institutions (DIs) in the interbank market. The 1-day repo markets are found to be more segmented, with the spread mainly driven by the cross-market segmentation for NDIs, reflecting the two different market mechanisms and trading frictions that prevent NDIs from effectively arbitraging across the two markets in the shorter tenor. On the other hand, the 7-day repo markets are found to be less segmented, with the spread mainly driven by the counterparty segmentation between NDIs and DIs within the interbank market, reflecting greater counterparty credit and liquidity risks for NDIs relative to DIs. Further analysis uncovers the impacts of quarter-end effect, monetary policies, and shadow banking activities on the cross-market and within-market segmentations in China's repo markets.

Keywords: Repo; Segmentation; Liquidity; Interbank; Exchange
JEL classification: G15, G21, G28

Dissecting the Segmentation of China's Repo Markets

1. Introduction

Repurchase agreements, or repos, are pivotal to the efficient functioning of global financial markets. In a repo, one counterparty borrows money from another counterparty while pledging securities as collateral. The security serves as collateral to mitigate the lender's credit risk exposure and reduce the borrower's interest cost. In essence, a repo is a short-term and highly liquid collateralized debt instrument.

A well-functioning repo market channels the efficient allocation of secured short-term funds among banks, nonbank institutions, and investors, serves a major execution platform for central bank open market operations, and reduces the systemic risk resulting from unsecured lending. Although China's informal repo trading did not begin until 1991 and had not fully taken off until 2006, it has grown at a remarkable pace and effectively become China's largest money market and the most important liquidity engine in China's financial markets. Based on annual statistics provided by the People's Bank of China (PBOC) and Bloomberg, trading volume in China's repo markets totalled RMB908 trillion in 2018, increasing by 20 times in the last decade.

A unique feature of China's repo market is that its repos trade in the interbank market as well as stock exchanges. China's national exchange repo market formally started in 1995 with the exchange providing centralized counterparty guarantee for repo buyers and sellers. In 1997, the PBOC initiated the interbank repo market to insulate both depository institutions (DIs) from funding non-depository institutions (NDIs) in equity and real estate investments through the

exchange repo market.[1] To encourage broader participation in the interbank market of spot and repo bond trading, PBOC expanded the list of eligible interbank repo market participants to include nonbank financial institutions and also nonbank enterprises. Although both DIs and NDIs have been able to participate in interbank repos since 2005, DIs are still strictly prohibited from participating in the exchange repo market. In addition, the PBOC frequently conducts open market operations (OMO) to either inject or take away liquidity in the interbank repo market. The key advantage of the interbank market lies in its large trading volume and rich source of funding supply from DIs and the PBOC, while the strength of exchange repo market is the counterparty guarantee and standardization of terms provided by the exchange.

Fan and Zhang (2007) study the segmentation and linkage between the interbank and exchange repo markets in China using weekly data on 7-day (and longer) repos from 2000 to 2005. They show that the exchange repo rates were significantly higher than the interbank repo rates, especially during the 2000-2002 period. However, the study was based on the earlier period when China's repo market was still in its infancy and uses only long-dated tenors. During the last 11 years (2007 to 2018), annual trading volume of repos in China increased 16 times (RMB44 trillion to RMB709 trillion) in the interbank market and 111 times (RMB1.8 trillion to RMB200 trillion) in the exchange market. In addition, China's 1-day repo, which was not previously studied, delivers the most remarkable growth and accounts for over 80% of the trading volume in both markets. Furthermore, NDIs have been permitted to participate in both the interbank repo and exchange repo markets. Finally, the explosive growth of money market mutual funds, wealth management products, and Peer-to-Peer (P2P) lending in China have led to far more supply and

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[1] Depository Institutions (DIs) refer to deposit-based banks. Non-Depository Institutions (NDIs) refer to nonbank financial institutions (such as securities firms, investment funds, real estate investment firms, insurance companies, and finance companies) as well as nonfinancial enterprises.

demand of short-term market-based funding (see Elliott, Kroeber, and Qiao (2015), Funke, Mihaylovski, and Zhu (2015), Perry and Weltewitz (2015), and McLoughlin and Meredith (2017)). The highly liquid and fully standardized exchange repo market has become an integral part of such market finance system (see Shevlin and Chang (2015)).

Using ten years of monthly highest rate data between October 2006 and October 2016, Xu (2018) documents a sizeable and persistent positive spread between the exchange and interbank repo rates, for both 1-day and 7-day tenors. The continued segmentation between the interbank and exchange repo markets is puzzling. Theoretically speaking, since NDIs can participate in both repo markets, a much higher rate spike in exchange repos should quickly motivate arbitrage activities across the two markets. During periods of liquidity shortage in the exchange repo market, if NDIs can borrow at lower rates in the interbank market (where DIs and the PBOC serve as key liquidity providers) and lend at higher rates in the exchange repo market, funds should flow from the interbank repo market to exchange repo market to lessen the funding shortage and reduce the rate spikes. However, monthly highest repo rates of the two markets can occur on different days of the month, so whether there are unexploited arbitrage opportunities should be examined at more frequent intervals using daily volume-weighted data, and after controlling different quoting methods (actual/360 vs. nominal/365 day-count conventions), different market trading mechanisms across two markets (exchange vs. interbank), and different counterparties (NDIs vs. DIs) within the interbank market.

To address this segmentation puzzle, I develop a comprehensive framework that thoroughly dissects the repo rate spread between China's interbank and exchange repo markets. In particular, my framework decomposes the exchange to interbank repo rate spread into three key components: (1) a quoting method component due to different day-count quoting conventions, (2) a cross-

market segmentation component to reflect the two different trading mechanisms for NDIs in the exchange and interbank repo markets, and (3) a within-market segmentation component to reflect different counterparty credit and liquidity risks between NDIs and DIs in the interbank repo market.

To use the framework to examine the degree and sources of segmentation, I compile daily volume-weighted interbank repo rates by DIs and NDIs, as well as exchange repo rates. I also perform rigorous adjustment on exchange repo rates to account for the impact of different day-count quoting conventions. I find that China's 1-day repo markets are more segmented, and the total spread is strongly driven by the cross-market spread for NDIs, reflecting various frictions that prevent NDIs from effectively arbitraging across the two market mechanisms in the 1-day tenor. Additional analysis demonstrates that the exchange to interbank spread on 1-day repos, although statistically significant and sizeable, does not generate economically significant arbitrage opportunities in most scenarios after considering trade size, cross-market transaction costs and additional trading frictions.

On the other hand, the counterparty spread within the interbank repo market is much larger and more dominating for the 7-day repos, reflecting higher counterparty credit and liquidity risks for NDIs relative to DIs in the longer tenor. Although both DIs and NDIs may trade in the interbank repo market, PBOC injects liquidity through open market operations by exclusively trading with DIs in the longer tenor.

Regression analysis indicates that calendar factors, monetary policies, and shadow banking activities that increase the demand or reduce the supply of liquidity to NDIs more than the DIs tend to heighten the segmentation between exchange and interbank repos. This effect is most

pronounced on the cross-market segmentation of NDIs for 1-day repos, and the within-market segmentation between NDIs and DIs in the interbank market for 7-day repos.

The main contribution of this paper is on addressing the segmentation puzzle of China's repo markets through the formulation and execution of the decomposition framework to dissect the exchange to interbank repo total spread. By compiling the most detailed and comprehensive dataset on China repo rates and variables that capture calendar factors, monetary policies, and shadow banking activities, and conducting thorough empirical analysis using the decomposition framework, this study contributes to the financial market literature by illuminating the sources and drivers of the cross-market and within-market segmentations in China's repo markets.

The rest of this paper is organised as follows. Section 2 characterizes the institutional background and development of China's Interbank vs. Exchange Repo Markets. Section 3 presents the hypotheses and data. Section 4 formulates and analyses the decomposition framework for the Exchange to Interbank Repo Rate Spread, while Section 5 offers additional analysis on the spread components. Section 6 presents regression analysis on the determinants of the spread and its cross-market as well as within-market segmentation components. Section 7 concludes the paper.

2. Institutional Background of China's Interbank and Exchange Repo Markets

Early development of China's repo trading can be traced to non-standardized, informal, and fragmented repo trading at the local exchange centres since 1991 (see Xu (2007)). In 1995, China reformed the repo market by shutting down risky local repo centres and standardizing the national exchange repo market at the Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE), signifying the official entry of exchange repos into China's financial market. Initial participants of the exchange repo market included commercial banks as well as nonbank financial

institutions. On the other hand, at centre stage of China's money market was the interbank unsecured lending as a venue for banks to manage their excess reserves and credit imbalances. However, it was often exploited by banks to circumvent credit ceilings and channel credit to securities firms and real estate developers. Before 1996, the unsecured interbank lending was mostly unregulated and highly fragmented. In January 1996, the PBOC embarked on the unification and modernization of the national interbank lending market through the development of the China Foreign Exchange Trading System & National Interbank Funding Center (CFETS). In 1997, interbank repos (with bonds as collateral) emerged as the PBOC removed depository-based banks from the exchange repo market and launched the national interbank repo market exclusively for banks. Over time, the PBOC has expanded the interbank repo market to allow for the participation of nonbank financial institutions (such as securities firms, investment funds, real estate investment firms, insurance companies, and finance companies) and nonfinancial enterprises. Following the promulgation of three PBOC official releases (2000, No. 5; 2002, No. 5; 2005, No. 13), all NDIs may participate in China's interbank repo market since 2005.[2] As a result, NDIs can trade repos in the interbank and exchange repo markets, while DIs can only trade repos in interbank market and retail investors can only trade repos in the exchange market. Appendix A summarizes a timeline of the development of China's repo markets, while Appendix B presents a brief comparison of China's Interbank and Exchange Repo Markets.

Panel A of Table 1 summarizes the monthly trading volumes of China's interbank repos, exchange repos, as well as the interbank unsecured lending and interbank spot bond trading, from

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[2] The expansion of eligible interbank repo market participants to nonbank financial institutions and nonfinancial enterprises was initiated by a PBOC official release (2000, No. 5), which stated that the nonbank financial institutions may trade directly in the interbank market, and nonfinancial enterprises may participate using financial institutions as their settlement agents. Detailed coverage and procedures were further clarified through by PBOC's official release (2002, No. 5) regarding nonbank financial institutions and another official release (2005, No. 13) regarding nonfinancial enterprises.

December 2006 to June 2018. The statistics in Panel A show that the average monthly volumes are RMB19.705 trillion and RMB6.368 trillion for the interbank repo and exchange repo markets, respectively. It should be noted that the interbank repo market has been the dominating fixed income market, representing 4.27 times the interbank lending volume, and 2.44 times the interbank spot bond trading volume. Figure 1 shows that China's exchange repo market, initially the smallest of the four markets, has surpassed its interbank unsecured lending and interbank spot bond markets in trading volume since 2013.

With repo tenors ranging from 1-day to 1-year, the 1-day and 7-day tenors are most popular. Panel B of Table 1 presents the average trading volumes by tenor for the interbank and exchange repo markets. During the sample period, 1-day repos on average account for 75.9% and 72.8% of the monthly trading volumes in the interbank and exchange repo markets, followed by 7-day repos, which account for 16.8% and 22.3% of interbank and exchange repo trading volumes, respectively. Panel C of Table 1 shows the annual distribution of trading volumes by tenor for the interbank and exchange repo markets in 2007 and 2018 (i.e., the first and last years of the sample period). Although the 1-day tenor only accounts for 29.7% of the exchange repo trading volume in 2007, its share has risen to a dominating 86.9% in 2018. The percentage of 1-day tenor in the interbank repo market also shows a sharp increase from 52.2% in 2007 to 81.6% in 2018.[3] In 2018, the 7-day tenor, which accounts for about 10% of the annual trading volumes in the interbank and exchange repo markets, is much less active than the 1-day tenor.[4] While earlier studies on China's

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[3] Since the shorter-tenor repos could effectively magnify trading volume due to rolling of borrowing and lending, the amount outstanding should better represent the relative importance of repo tenors. Even after adjusting for the term of repo, the 1-day repos amount outstanding has surpassed that of the 7-day repos since 2012 in the exchange market and since 2015 in the interbank market.

[4] Repos also trade for additional terms of maturities such as 14 days, 21 days, 1 month, 3 months, 6 months, etc. However, as of 2018, the combined trading volume of these other tenors only account for 5.2% and 3.2% of the interbank and exchange repo trading volumes, respectively. As a result, this study only examines the 1-day and 7-day repos.

repo markets (such as Fan and Zhang (2007) and Porter and Xu (2009)) focus on the 7-day tenor, this study examines both 1-day and 7-day repos. I include the 1-day repo in the analysis because it is by far the most actively traded tenor in both the interbank and exchange repo markets during the sample period. Also included in this study is the 7-day repo because it is the second most active repo tenor, the most popular money market benchmark indicator in China, and the most studied China repo rate in earlier studies on China's repo markets.

Appendix B presents a brief comparison of China's Interbank and Exchange Repo Markets. Interbank repos are traded over-the-counter through the National Interbank Funding Center's CFETS platform with terms and conditions negotiated between counterparties, while exchange repos are traded on Shanghai Stock Exchange (SSE) or Shenzhen Stock Exchange (SZSE) with counterparty guarantees and standardized terms provided by the exchange.[5]

Interbank repo trading is not anonymous, with rates reflecting counterparty risks, similar to the bilateral repos in the US. Although both DIs and NDIs can participate in the interbank market, NDIs typically carry greater credit and liquidity risks than DIs. In addition, the PBOC frequently conducts open market operations by trading in the interbank repo market with primary dealers that are mostly DIs, providing additional liquidity support to DIs. With greater credit risk and more liquidity constraints, NDIs face higher rates than DIs in the interbank repo market.

Unlike interbank repos, exchange repos are traded anonymously based on standardized terms and conditions at rates quoted by the Stock Exchange which also provides the counterparty guarantee. Both NDIs and retail investors may participate in the exchange repo market, but DIs are strictly prohibited. As a result, although exchange repo trading is essentially free of

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[5] See Shevlin and Chang (2015) for a detailed description of the differences in operations and trading mechanisms between China's interbank and exchange repo markets, and Ross and Lees (2017) for a focused discussion on China's interbank repo market.

counterparty credit risk, it comes with greater liquidity risk due to the absence of participation by major liquidity providers such as DIs and PBOC.

Another key difference between the interbank and exchange repo markets is the day-count quoting convention. While interbank repo rates have always been quoted on an actual/365 basis, the exchange repo rates have been quoted on a nominal/360 basis until May 22, 2017, when the SSE reformed the exchange repo quoting method to the actual/365 basis.[6] The *nominal number of days* only counts the number of trading days in the repo period, while the *actual number of days* counts all calendar days (including weekend and exchange holidays) in the repo period. In addition, interbank repos are settled on the same day (t+0), while exchange repos are settled on the next trading day (t+1), making it harder for NDIs to arbitrage across the two markets.

3. Hypotheses and Data

The observed spread between China's exchange and interbank repo rates could be due to different day-count quoting methods (nominal/360 vs. actual/365), different trading mechanisms across the exchange and interbank markets, or different counterparties (NDIs vs. DIs) within the interbank market. After adjusting for differences in the day-count quoting conventions, this study employs the methodology of Bartolini, Hilton, and Prati (2006) to examine the cross-market segmentation between China's interbank and exchange repo markets, and the within-market counterparty segmentation between NDIs and DIs in the interbank market.

Given the same-day settlement for interbank repos and next-day settlement for exchange repos, NDIs who arbitrage between the two markets will face the risk of uncertain next-day market conditions, which is a key barrier to effective cross-market arbitrage in the shortest-tenor (1-day)

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[6] See CSRC and SSE (2017).

repo markets. The first hypothesis is that the 1-day repo markets to be more segmented than the 7-day repo markets, and the segmentation of the 1-day repo markets to be mainly driven by cross-market segmentation between the exchange and interbank markets for NDIs.

Since NDIs can more effectively arbitrage across the exchange and interbank markets for longer tenor (such as 7-day), the cross-market segmentation for NDIs should be less severe for the 7-day repos than the 1-day repos. Within the interbank market, the lower credit risk and deeper liquidity source for DIs (especially from the PBOC's 7-day OMO) should lead to greater counterparty segmentation within the interbank 7-day repo market. The second hypothesis is the exchange to interbank repo rate spread for NDIs to be smaller for 7-day repos than 1-day repos, and the segmentation of the 7-day repo markets to be mainly driven by the within-market counterparty segmentation between NDIs and DIs in the interbank market.

To conduct the analysis, I obtain daily data on the volume-weighted interbank pledged repo rates and SSE exchange repo rates from Wind Financial,[7] and daily closing and highest rates for both markets from Bloomberg. Volume-weighted SSE exchange repo rates have an inception date of December 5, 2006 from Wind Financial, while closing and highest of SSE exchange repo rates start from May 8, 2006. Although data on the interbank repo rates have a much longer history, this study focuses on the period from December 5, 2006 to June 29, 2018 to ensure availability of volume-weighted repo rates from both interbank and exchange repo markets.

To capture the day-count quoting method spread, I obtain the SSE exchange calendar during the sample period and count all the weekends and exchange holidays to determine the number of actual days between the exchange repo settlement date (the next trading day t+1) and expiration

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[7] I ignore the interbank outright repos because its volume is less than 5% of the interbank pledged repo volume. Similarly, I ignore the SZSE exchange repos because SSE is the main exchange for the trading of bonds and repos in China.

date (t+2 for 1-day repos, and t+8 for 7-day repos). Before the exchange repo reform on May 22, 2017, the SSE exchange repo rates (ER) are converted from a nominal/360 basis to the adjusted exchange repo rates (ER$_a$) on an actual/365 basis using the following equations: [8]

$$ER_{a\_}1D = ER\_1D \times \frac{1}{360} \div \frac{ADJUST\_1D}{365} \qquad (1)$$

$$ER_{a\_}7D = ER\_7D \times \frac{7}{360} \div \frac{ADJUST\_7D}{365} \qquad (2)$$

where ADJUST_1D and ADJUST_7D are two calendar factor variables that are equal to the actual number of days for the 1-day and 7-day repos prior to the exchange reform date of May 22, 2017, respectively. This adjustment is especially important for exchange repos before weekends and before long national holidays. No adjustment is required after the reform because both repo markets use the same actual/365 day-count quoting method after May 22, 2017.

Table 2 presents descriptive statistics of the exchange and interbank repo rates for the full sample period (12/05/2006-06/29/2018), and the subperiods before and after the exchange repo rate quoting method reform of 05/22/2017. The daily mean (standard deviation) of the volume-weighted 1-day repo rates is 3.689% (3.790%) in the exchange repo market and 2.386% (0.963%) in the interbank repo market, with a daily average exchange to interbank total spread of 1.303% and a standard deviation ratio of 3.523%. After adjusting for the quoting method spread which averages 0.669%, the daily average of the adjusted exchange to interbank spread drops to 0.633%. This confirms the importance of adjustment for different day-count quoting methods for 1-day repos. For the 7-day repos, the daily mean (standard deviation) of the volume-weighted rates is 3.415% (2.593%) in the exchange repo market and 3.018% (1.172%) in the interbank repo market, with a daily average exchange to interbank total spread of 0.397% and a standard deviation ratio of 2.114%. Unlike the 1-day tenor, the quoting method spread for 7-day repos is small and

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[8] See Appendix C for symbols and definitions of repo rates, spreads, and other variables used in this paper.

insignificant. This is intuitive since the net effect of exchange repos' (t+1) settlement and the day-count quoting method adjustment should be much less for the longer tenor.

Table 2 also summarizes the repo rates and spreads based on daily closing and highest rates. It should be noted that the daily closing repo rates tend to underestimate repo rates due to low volume toward the end of trading days,[9] while daily highest rates only capture the spikes that may be associated with a short period of intraday volatility or small volume during the day. This observation is consistent with the much lower daily closing rates and much higher daily highest rates (relative to the daily volume-weighted rates) for both interbank and exchange repo markets, as shown in both Panels of Table 2. Since volume-weighted rates are more representative of the daily repo rates than the closing or highest rates, the rest of this study uses daily volume-weighted rates for both interbank and exchange repo markets in the analysis.

Subsample analysis in Table 2 shows that the exchange to interbank repo spread has not decreased after the removal of day-count quoting spread on May 22, 2017. This could be due to additional sources of segmentation or time-varying factors that drive the spread between the interbank and exchange repo markets.

Although both DIs and NDIs can participate in the interbank repo market, DIs have lower counterparty credit risk than NDIs. In addition, the PBOC frequently conducts open market operations by trading exclusively with DIs in the interbank repo market, leading to lower liquidity risk for DIs. The higher credit and liquidity risks of NDIs relative to DIs within the interbank market could be an important source of the observed spread between exchange and interbank repos.

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[9] After the exchange repo reform on May 22, 2017, the daily closing repo rate on SSE has been changed to the volume-weighted rate during last hour of the trading day, instead of the last minute of the trading day.

Since December 15, 2014, the PBOC has compiled daily interbank volume-weighted repo rates exclusively for DIs (IR_{DI}), in addition to the general repo rates covering all institutions in the interbank market (IR).[10] Although interbank repo rates for NDIs (IR_{NDI}) are not directly available, they can be inferred from the daily interbank repo rates for all institutions (IR) and DIs (IR_{DI}), along with the monthly volumes of DIs and NDIs in the interbank market:[11]

$$VOLUME_{ALL} = VOLUME_{DI} + VOLUME_{NDI} \qquad (3)$$

$$PVOLUME_{DI} = \frac{VOLUME_{DI}}{VOLUME_{ALL}} \qquad (4)$$

$$IR = IR_{DI} \times PVOLUME_{DI} + IR_{NDI} \times (1 - PVOLUME_{DI}) \quad (5)$$

$$IR_{NDI} = \frac{IR - IR_{DI} \times PVOLUME_{DI}}{1 - PVOLUME_{DI}} \qquad (6)$$

where $VOLUME_{DI}$, $VOLUME_{NDI}$, and $VOLUME_{ALL}$ refer to the interbank repo trading volumes for DIs, NDIs, and all institutions, respectively, and $PVOLUME_{DI}$ refers to percentage of DI trading volume in the interbank repo market.

4. A Framework for the Decomposition of Exchange to Interbank Repo Rate Spread

To dissect the sources of segmentation between the interbank and exchange repo markets in China, I develop a comprehensive framework that decomposes the exchange to interbank repo rate spread (ST) into three components: an exchange repo rate quoting method spread (S1), a cross-market spread component for NDIs between the exchange and interbank repo markets (S2), and a within-market counterparty spread component between NDIs and all institutions in the interbank market (S3). Figure 1 illustrates this decomposition framework while Panel C1 of Appendix C defines the repo rates and spreads in details.

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[10] Although the PBOC has not officially publicized the IR_{DI} data until May 31, 2017, daily data on IR_{DI} are available from Wind Financial with an inception date of December 15, 2014.
[11] Monthly volumes on interbank repos by institutional types are obtained from the CFETS.

Prior to the exchange reform date of May 22, 2017, exchange repos were quoted on a nominal/360 basis, which is different from the actual/365 basis quoted by interbank repos. The rigorous conversion of the exchange repo rates (ER) to the adjusted exchange repo rates (ER_a), as illustrated in Section 2, allows for the calculation of S1, the spread component that purely reflects the impact of different day-count conventions on repo rate quotes. If this day-count quoting method spread S1 is not adjusted for, the degree of segmentation in China's repo market could be highly overestimated before the exchange reform date. After the exchange reform on May 22, 2017, the quoting method S1 is set to zero because both markets are quoting repos on an actual/365 basis.

The availability of derived NDI interbank repo rates since December 15, 2014 enables the calculation of S2, the spread between adjusted exchange repo rates (ER_a) and NDI interbank repo rates (IR_{NDI}), to capture the pure effect of different market mechanisms (exchange vs. interbank) for NDIs. As discussed in Section 2 and illustrated in Appendix B, the exchange market provides standardization of terms and conditions along with the exchange's counterparty guarantee, but faces greater liquidity risks than the interbank market due to lack of funding supply from DIs and PBOC. The net effect of higher liquidity risk and counterparty guarantee in the exchange relative to the interbank repo market results in S2, which is the cross-market segmentation component in the spread decomposition framework.

Finally, S3, the spread between interbank NDI repo rates (IR_{NDI}) and general interbank repo rates for all institutions (IR), captures the pure effect due to different counterparties inside the interbank repo market. In general, DIs are more creditworthy and use safer government bonds as collateral, while NDIs are less creditworthy and use riskier corporate/enterprise bonds as collateral, leading to higher counterparty credit risk relative to DIs. On the other hand, PBOC frequently conducts open market operations to inject liquidity into the interbank market by exclusively trading

with DIs, leading to more liquidity supply for DIs. Since NDIs are subject to higher counterparty credit and liquidity risks than DIs inside the interbank repo market, S3 represents the within-market counterparty segmentation component in the spread decomposition framework.

Table 3 presents a summary decomposition of the *Daily Exchange to Interbank Repo Rate Total Spread* from December 15, 2014 (inception date of data on interbank repo rates for DIs) to June 29, 2018 using daily volume-weighted data on interbank general repo rates for all institutions, interbank repo rates for NDIs, as well as raw and adjusted SSE exchange repo rates. In addition to the full-history summary of 864 daily observations, Table 3 also presents additional summaries before the reform (592 daily observations), after the reform (272 daily observations), and the matched period right before the reform (272 daily observations). Panel A presents the mean, standard deviation, and skewness of the 1-day repo rates and spreads, while Panel B presents summary statistics for the 7-day tenor.

Panel A of Table 3 shows that the mean total spread (ST_1D) is 1.30% between the 1-day exchange and interbank repo rates, which is equivalent to a 53.78% percentage spread above the interbank repo rate, and much greater than its counterpart in the 7-day repo markets. For the 53.78% percentage total spread for the full history of 1-day repos, 21.83%, 26.74%, and 5.21% are due to different quoting methods (S1_1D), different market mechanisms for NDIs (S2_1D), and different counterparties within the interbank market (S3_1D), respectively. The exchange quoting method spread (S1_1D) represents the largest source of spread before the exchange repo reform, and declines to zero after the reform. Panel A also shows that the spread between adjusted exchange repo rate and NDI interbank repo rate (S2_1D) is sizeable and persistent for the 1-day tenor, indicating the presence of cross-market segmentation between the exchange and interbank repo markets for NDIs. For the short 1-day tenor, the higher liquidity risk clearly outweighs the

benefit of counterparty guarantee in exchange repos relative to interbank repos, and is further intensified by the difficulty for NDIs to arbitrage the difference between 1-day exchange and interbank repos due to the exchange repos' next-day settlement delay. As a result, there is a sizeable and positive cross-market spread (S2_1D) for NDIs in 1-day repos. Intuitively, with greater counterparty credit risk and liquidity risk, NDIs face higher repo rates than DIs within the interbank repo market. Because the concerns for counterparty risk should be much less for the 1-day tenor, we observe a relatively small counterparty spread (S3_1D) between NDIs and all institutions in the interbank market. These results from Panel A support the first hypothesis that the 1-day repo markets are more segmented than the 7-day repo markets, and the segmentation of the 1-day repo markets is mainly driven by cross-market segmentation between the interbank and exchange repo markets for NDIs.

For the 7-day repos, Panel B of Table 3 shows that the mean total spread (ST_7D) is 0.39% between the exchange and interbank repo rates, which is equivalent to an 11.23% percentage spread above the interbank repo rate. This total spread for the 7-day repos is much smaller than that for the 1-day repos, confirming that the 7-day repo markets are less segmented than the 1-day markets. For the 11.23% percentage total spread for the full history of 7-day repos, -0.07%, -6.17%, and 17.47% are due to different quoting methods (S1_7D), different market mechanisms for NDIs (S2_7D), and different counterparties within the interbank market (S3_7D), respectively. Consistent with observations from Table 2, the quoting method spread (S1_7D) is small and insignificant for 7-day repos because of the net effect of the exchange repo's t+1 settlement and the smaller day counting difference for longer tenors. There is a small but negative spread for NDIs between the exchange and interbank markets (S2_7D) for 7-day repos, contrary to the large and positive spread for 1-day repos. In the longer tenor, the counterparty credit risk concern plays a

more important role while the liquidity concern is less dominant. For 7-day repos, the benefit of counterpart guarantee from the exchange tends to outweigh the higher liquidity risk in the exchange repo market, and it is much more feasible for NDIs to arbitrage the difference between the 7-day exchange and interbank repo markets. These led to a smaller and mostly negative cross-market spread for NDIs in 7-day repos. Finally, the interbank counterparty spread (S3_7D) is the dominating component of the 7-day exchange to interbank total spread, reflecting strong presence of the within-market counterparty segmentation between NDIs and DIs inside the interbank repo market. It should be noted that the PBOC frequently conducts open market operations in the interbank repo market through the trading of 7-day repos with DIs. The large and persistent S3_7D is indicative of the higher counterparty credit and liquidity risks of NDIs relative to DIs in the interbank repo market for 7-day repos. In sum, empirical results from Panel B of Table 3 support the second hypothesis that the exchange to interbank repo rate spread for NDIs is smaller for 7-day repos than 1-day repos, and the segmentation of the 7-day repo markets is mainly driven by the within-market counterparty segmentation between NDIs and DIs in the interbank market.

While the quoting method spread (S1) in Table 3 adjusts for the differences in repo rate quoting methods, it should be noted that some market participants may not rationally adjust for such an impact in their decision making process. This could lead to distortion in the spread decomposition prior to the exchange repo reform. To ensure pure decomposition of exchange and interbank repo rate total spread (ST) into the cross-market spread for NDIs across the exchange and interbank repo markets (S2) and within-market counterparty spread between NDIs and all institutions in the interbank repo market (S3), Table 4 focuses on the post-exchange repo reform period to conduct tests on the cross-market and within-market spread components.

Results from both the t-test on the mean and the Wilcoxon signed rank test on the median demonstrate that the total spreads and their cross-market and within-market components are all statistically significant for 1-day repos (Panel A) and 7-day repos (Panel B). In Panel C, the Satterthwaite-Welch t-test on mean comparison and the Mann-Whitney test on median comparison indicate that the cross-market spread component (S2_1D) is significantly higher than the within-market counterparty spread component (S3_1D) for 1-day repos, while the within-market counterparty spread component (S3_7D) is significantly higher than cross-market spread component (S2_7D) for 7-day repos. In Panel D, the tests confirm that the exchange to interbank total spread (ST) and its cross-market spread component (S2) are both larger for 1-day repos relative to 7-day repos, while the within-market counterparty spread component (S3) is larger for the 7-day repos relative to 1-day repos. In sum, both parametric and nonparametric tests confirm that the 1-day repo markets are more segmented, with the exchange to interbank total spread mainly driven by the cross-market segmentation for NDIs. They also confirm that the 7-day repo markets are less segmented, with the total spread mainly driven by within-market counterparty segmentation between NDIs and DIs inside the interbank market.

5. Additional Analysis of the Spread Components

5.1 Calendar Patterns of the Day-count Quoting Method Spread

Prior to the exchange reform date of May 22, 2017, exchange repos were quoted on a nominal/360 basis, which is different from the actual/365 basis quoted by interbank repos. Due to the next day (t+1) settlement of exchange repos, trading of 1-day exchange repos two days before weekends or holidays should be most affected by this difference due to day-count convention. While the nominal number of days for 1-day repos is always 1 day (from t+1 to t+2), the actual

number of days could be longer than 1 day. For example, exchange-traded 1-day Repos on a Thursday (t) will have 3 actual days of funding from the starting settlement on Friday (t+1) to the ending settlement on the following Monday (t+2), while those traded 2 days before a 7-day holiday will have 8 actual days of funding for the 1-day repo.

Appendix D presents the calendar pattern of these variables for Period #1 (after 12/05/2006 before 12/15/2014) in Panel A and Period #2 (after 12/15/2014 before 05/22/2017) in Panel B. Both Period #1 and Period #2 are prior to the exchange repo reform date of May 22, 2017, and therefore require adjustment for the difference in day-count quoting convention, as measured by the Day-count Quoting Method Spread (S1_1D). Appendix D shows that the averages of S1_1D in Panel A and Panel B are 3.24% and 2.86% on Thursdays, and 6.88% and 7.17% in two days before Holidays. On the other hand, Fridays and the other trading days do not show any sizeable S1_1D because the number of actual days is the same as the nominal day for 1-day repos traded on those days.

Even if not all traders understand this difference in repo rate quoting methods as measured by the first spread component (S1_1D), the observed Exchange to Interbank 1-Day Repo Rate Total Spread (ST_1D) clearly reflects similar calendar patterns as demonstrated in both Panel A and Panel B. In addition, for Panel B, with the availability of NDI interbank repo rates in Period #2, the Unadjusted Exchange to NDI Interbank 1-Day Repo Rate Spread (S1_1D+S2_1D) also confirms the calendar patterns of large spread size for NDIs two days before the weekend, and even larger size two days before holidays.

In Panel C of Appendix D, I present the correlation of the Exchange to Interbank 1-Day Repo Rate Total Spread (ST_1D) with the calendar dummy variables (Thursday, Friday, One Day before Holiday, Two Days before Holiday) and the Calendar Factor Variable (ADJUST_1D). The

correlations are presented for Periods #1 and Period #2 prior to the exchange reform date of May 22, 2017, and for Period #3 after the reform. During the pre-reform periods, total spread has positive and significant correlation with the dummy variables that captures *Thursdays* and *Two Days before Holidays,* but not with the dummy variables that capture *Fridays* and *One Day before Holidays*. In the meantime, the total spread has the highest positive correlation with the Calendar Factor Variable *ADJUST_1D*, which counts the actual number of days between t+1 and t+2 in the 1-day repo, and incorporates all the calendar patterns shown in Panels A and B. During the post-reform Period #3, the correlations between the repo spread and the calendar variables all become insignificant, confirming that the difference due to day-count convention disappears when both exchange and interbank repos are quoted using the same actual/365 day-count convention after the exchange repo reform.

5.2 Is the Cross-market Repo Spread for NDIs Economically Significant?

Although NDIs can participate in both exchange and interbank repo markets, a sizeable spread still exists between the exchange and interbank repo rates for NDIs in the 1-day tenor. At first glance, if NDIs can borrow at lower rates in the interbank repo market and lend at higher rates in the exchange repo market to conduct an effective cross-market arbitrage, such a persistent and sizeable spread between the two repo markets should have disappeared. To avoid the issue of market adjustments for different quoting conventions, I analyse the economic significance of cross-market arbitrage by NDIs based on the 13-month period from June 2017 to June 2018, when repo rates from both markets are based on the same day-count quoting convention after the exchange repo reform. The return on the cross-market arbitrage by NDIs is not only depending on

the exchange to interbank repo spread for NDIs (S2_1D), but also on the trade size, the transaction costs, and any additional trading frictions.

As shown in Appendix E, the average trade size of 1-day repos is RMB240.33 million for NDIs in the interbank market, more than 100 times the RMB2.13 million average trade size of 1-day repos in the exchange market, leading to additional liquidity risks for NDIs to arbitrage across the exchange and interbank repo markets. Regarding the transaction costs as shown in Appendix F, 1-Day repos are subject to 0.00005% surcharge in the interbank market and 0.001% brokerage commission in the exchange repo market, resulting in 0.3833% annualized transaction costs for cross-market arbitrage; 7-day repos are subject to 0.00015% surcharge in the interbank market and 0.005% brokerage commission in the exchange market, resulting in 0.2678% annualized transaction costs.

The simulated returns of cross-market arbitrage between exchange and interbank 1-day repos are presented in the Table 5.[12] Based on the frequency distribution of the exchange to interbank cross-market 1-day spread for NDIs (S2_1D), Table 5 starts with the following percentiles: first quartile (0.28%), median (0.68%), third quartile (1.29%), 90 percentile (2.52%), 95 percentile (3.90%), and 99 percentile (10.16%). In addition, I also include scenarios when S2_1D is equal to its mean (-0.26%), the transaction costs (0.38%), 1%, and 2%. Building on these scenarios of S2_1D, I simulate the cross-market arbitrage profit associated with three different trade sizes: RMB100,000 (minimum exchange repo trade size), and RMB2.13 million (the average exchange 1-day repo trade size), and RMB240.33 million (the average interbank 1-day repo trade size). In the case of 1% spread and the minimum exchange repo trade size of RMB100,000, the exchange

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[12] As shown in Table 3, the mean (median) exchange to interbank 7-day repo spread for NDIs is only -0.26% (-0.23%), which is not even large enough to compensate the cross-market arbitrage cost of 0.27%, indicating that the exchange and interbank markets at the 7-day tenor are well integrated.

to interbank 1-day repo arbitrage will generate gross profit of RMB2.74 before transaction costs, and net profit of RMB1.69 after adjusting for the RMB1.05 transaction costs, which is trivial in absolute dollar amount and in percentage return (0.00169% for one-day, 0.62% annualized). Even in the case of a 99 percentile cross-market spread of 10.16%, only RMB570.60 of net arbitrage profit can be generated based on the average SSE exchange repo trade size of RMB2.13 million. In the case of a median spread of 0.68%, only RMB1,923 of net arbitrage profit (or 0.0008%) can be generated based on the average interbank repo trade size of RMB240.33 million. With less cross-market segmentation and small or even negative exchange to interbank NDI repo rate spread, cross-market arbitrage opportunities in 7-day repos are even less economically significant.[13]

If NDIs were to borrow at lower rates in the interbank repo market and lend at higher rates in the exchange repo market, additional trading frictions could further prevent the realization of cross-market arbitrage profit as shown in the Table 5. For example, interbank repos are settled on the same day but exchange repos are settled the next day, subjecting the cross-market arbitrage to additional uncertainty of the next day.

In sum, this additional analysis demonstrates that the exchange to interbank spread for NDIs on 1-day repos, although statistically significant and sizeable, does not generate economically significant cross-market arbitrage opportunities in most scenarios after considering the sizes of the spread, trade size, cross-market transaction costs, and additional trading frictions.

5.3 Within-market Segmentation between NDIs and DIs in the Interbank Market

With greater credit risk and more liquidity constraints, NDIs face higher rates than DIs within the interbank repo market. Because of varying degrees of counterparty risks, different repo rates

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[13] Simulated returns of cross-market arbitrage of 7-day repos for NDIs are available upon request.

may be charged on different borrowers in the interbank market. The third component in this paper's spread decomposition model, which is the difference between the interbank repo rates for NDIs and all institutions (denoted as $S3=IR_{NDI} - IR$), reflects higher counterparty credit and liquidity risks associated with NDIs in the interbank market. As shown in Table 3 from December 2014 to June 2018, this component has an average size of 0.591% in the 7-day tenor, more than three times the 0.132% average size in the 1-day tenor. The larger and more persistent counterparty spread for 7-day repos could be attributed to the following: first, NDIs' credit and liquidity risks are of greater concern to lenders who commit funding for 7 days instead of 1 day; second, the PBOC frequently conducts open market operations in the interbank market via 7-day (or longer) reverse repos with DIs, which substantially reduces the liquidity risk of DIs in the 7-day tenor. During the period from December 2014 to June 2018, the average monthly liquidity injection from PBOC's open market operations is RMB850 billion, equivalent to over 3% of the interbank repo market's monthly trading volume during the same period. As illustrated in the regression analysis in the next section, the degree of segmentation between NDIs and DIs within the interbank market at the 7-day tenor is positively driven by factors that increase the liquidity for DIs, such as liquidity injections from PBOC's open market operations and lower required reserve ratios on banks.

6. Determinants of the Exchange to Interbank Repo Rate Spread and Its Components

Figure 2A and Figure 2B illustrate the decomposition of China's exchange to interbank repo rate spread for the 1-day and 7-day repos, respectively. The time series variations shown in the decomposition charts motivate further examinations into the determinants of cross-market spread (exchange vs. interbank) for NDIs and within-market counterparty spread (NDIs vs. DIs) in the interbank market.

Using weekly data on the 7-day exchange to interbank repo rate spread from 2000 to 2005, Fan and Zhang (2007) show that the spread is highly persistent, and that the IPO activities, central bank interest rate, and difference in conditional variances between the two markets have strong explanatory power for the spread. Porter and Xu (2009) examine the drivers of the 7-day interbank repo rate using daily data from October 2003 to August 2008 and show that the daily repo rate is highly persistent, and strongly driven by the PBOC's benchmark interest rates and calendar-related liquidity factors, but not its monetary policy actions such as changes in the required reserve ratio or open market operations. Using monthly data from October 2006 to October 2016, Xu (2018) shows that shadow banking financing is a key driver of repo rate spikes in China.

Building on previous studies, the time series regressions in this study incorporate the autoregressive term and a list of daily explanatory variables that reflect the calendar effects, PBOC's monetary policies, shadow banking activities, stock market return, margin trading activities, IPO issuance, and volatility ratio between the two markets. Due to the mathematical nature of day-count quoting method adjustment from raw to adjusted exchange repo rates, I do not include quoting method spread component (S1) in the regression analysis. This section focuses on the adjusted exchange to interbank repo rate total spread (ST_a) and its two segmentation components (S2 for the cross-market exchange to interbank spread for NDIs, and S3 for the within-market counterparty spread between NDIs and all institutions in the interbank market). The sample period of the regression includes 864 trading days from December 15, 2014 (the starting date with available cross-market and within-market spread components) to June 29, 2018.

The coefficient of the *first-order autoregressive term* (AR1) is expected to be positive and significant on S2 to reflect persistent differences across the exchange and interbank repo trading mechanisms for NDIs, and on S3 to reflect persistent differences in the counterparty credit and

liquidity risk exposures between NDIs and DIs within the interbank market. *An indicator of the post-exchange repo reform date of May 22, 2017* (REFORM) is included to see if the cross-market spread due to different trading mechanisms (S2) and within-market spread due to different counterparties (S3) have increased after the elimination of differences in quoting methods between the two markets. *A quarter-end indicator* (QEND) is included to capture the impact of quarter-end liquidity shortages, as results of quarter-end regulatory inspections and maturing time deposits for DIs and quarter-end tax payments and maturing wealth management products for NDIs. I expect QEND to have a positive and significant coefficient on the cross-market spread (S2) due to absence of any liquidity injection from PBOC in the exchange repo market to alleviate quarter-end liquidity shortage. I also expect QEND to have positive and significant coefficients on the within-market spread (S3) because PBOC injects liquidity through trading repos with DIs, not NDIs, in the interbank repo market.

The PBOC has a variety of direct and indirect monetary policy tools, including setting the policy rates, setting bank deposit and lending benchmark rates, setting the required reserve ratio for banks, and conducting open market operations. To examine whether the repo rate spreads are affected by monetary policy actions, I include the *PBOC's 12-month lending benchmark rate* (CLR), *major banks' required reserve ratio* (CRR), and *PBOC's open market operations* (OMO). While higher CLR tends to worsen liquidity and drive up rates for all participants in the repo markets, cross-market repo spread (S2) for shorter tenor repos and within-market repo spread (S3) for longer tenor repos are expected to widen. With regard to the impact of bank reserve requirement, higher CRR implies less supply of funds from DIs to the interbank repo market, which could increase the interbank repo rate for DIs and reduce the within-market counterparty spread (S3). Finally, the daily OMO, which best captures the net liquidity injection from PBOC to

the banking sector, is expected to increase the liquidity supply to DIs in the interbank market, reduce the repo rate for DIs, and hence increase the within-market counterparty spread (S3).

Demand for financial intermediation outside of the highly regulated banking sector has propelled the rise in China's shadow banking system, which heavily relies on the repo markets as a source of liquidity to balance funding shortage or maturity mismatching between "shadow deposits" and "shadow lending". Due to full liberalization of banks' deposit and lending interest rates after 2014 and the regulatory efforts to crack down on bank shadow banking activities, DIs have lessened their involvement in shadow banking in recent years, while NDIs have intensified their engagement in shadow banking, especially through marketplace lending. To account for the potential impact of shadow banking activities on repo spread, I use *China's daily P2P Lending Amount Index* (P2PA), an indicator of marketplace lending in China, as a daily proxy of shadow banking.[14] Higher P2PA is expected to drive up the cross-market and within-market repo spreads because shadow banking activities exert more liquidity stress on NDIs than DIs during the sample period.

The *Return on Shanghai Composite Index* (CS) serves as an indicator of China's stock market performance, while the *SSE margin trading volume as a % of SSE total trading volume* (MTV) captures the potential funding demand shocks due to stock market margin trading activities. I also incorporate the *IPO Issuance in the next 10 trading days* (IPOV) to capture the impact of funding needs for subscriptions to upcoming IPOs.[15] Although lower CS, higher MTV, and higher IPOV

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[14] Xu (2018) uses the monthly amount of *China shadow banking financing* (CSB) provided by the PBOC and Bloomberg to capture shadow banking activities. However, CSB figures are only available on a monthly basis. In this daily study, I use the daily *China P2P Lending Amount Index* (P2PA), which is an indicator of marketplace lending in China. At the monthly level, CSB and P2PA have a correlation of 0.8. Since marketplace lending is an important component of shadow banking activities during the sample period, and P2PA has a high explanatory power for CSB, I use P2PA as a daily proxy for shadow banking financing in the regression.

[15] Fan and Zhang (2007) show that funds tied up during stock IPOs represent a key credit demand in the exchange repo market and therefore drive up the cross-market difference between exchange and interbank repo rates.

in the stock market could lead to greater demand for liquidity by NDIs and higher repo spreads, these variables may not be significant considering that China's stock trading volume and IPO activities have grown at a much slower pace than the growth of repo trading volume over the last two decades. Finally, I include the *Exchange to Interbank ratio of last 10 days of standard deviations* (SRATIO) to see if the time-series variation in repo spreads could be explained by the volatility ratio between the two repo markets.

Table 6 reports the regression estimates for the Adjusted Exchange to Interbank total spread (ST_a) and its cross-market (S2) and within-market (S3) spread components from December 15, 2014 to June 29, 2018. Panel A presents the results for the 1-day tenor, while Panel B presents results for the 7-day tenor. All the spread dependent variables are standardized as a % of the corresponding interbank repo rate. All explanatory variables are demeaned.

The constant term indicates the predicted spread variable when all the demeaned explanatory variables are set to zero. In the Panel A for 1-day repos, the constant terms are positive and significant with significantly larger size in the cross-market spread (S2_1DP) regressions relative to those in the within-market counterparty spread (S3_1DP) regressions. In the Panel B for 7-day repos, the constant terms are significantly positive in the within-market counterparty spread (S3_7DP) regressions and slightly negative in the cross-market spread (S2_7DP) regressions.

The positive and significant AR1 coefficient in both panels shows that the total spread and its two segmentation components are highly persistent. REFORM has been shown to be a positive driver of the total spread and the within-market spread in the longer tenor, suggesting that counterparty segmentation within the interbank market has not been eased in the post-exchange repo reform period. The *quarter-end indicator* (QEND) shows a highly significant and positive

effect on the total spread and its components for both tenors, indicating more severe segmentation at quarter-end due to liquidity shortages.

As for monetary policy variables, the *12-month lending benchmark rate* (CLR) is a positive driver of the cross-market spread for NDIs for 1-day repos (S2_1D) and the within-market counterparty spread for 7-day repos (S3_7D), indicating more segmentation in the higher rate environment. The *required reserve ratio* (CRR) shows a significantly negative effect on S3_7D, suggesting that more liquidity constraints on banks (due to higher required reserve ratio) narrow the interbank repo spread between NDIs and DIs. Consistent with previous studies (e.g., Porter and Xu (2009) and Xu (2018)) that do not find a significant impact of *PBOC's open market operations* (OMO) on repo rates, results from both Panels of Table 6 show that OMO has no significant effect on the total spread. However, OMO has shown a positive and significant effect on the within-market spread (S3) for both tenors, suggesting that PBOC's liquidity injections to DIs in the interbank market lead to more severe counterparty segmentation between NDIs and DIs within the interbank market.

The *P2P Lending Amount Index* (P2PA) has been shown to be a positive driver of the total spread (ST_a) and its components for both tenors, consistent with the impact of liquidity pressure from shadow banking activities on the repo market segmentation. *Stock market return* (CS), *margin trading activities* (MTV), the *IPO Issuance* (IPOV), and *the exchange to interbank volatility ratio* (SRATIO) have no significant effect on the total spread or its components.

The above analyses are based on the regression setting (1) which includes the first-order autoregressive term (AR1) and all the explanatory variables. In the regression setting (2) where I remove the autoregressive term, the R-squared is lower but all the explanatory variables still show robust signs and significance as those in the regression setting (1). In regression setting (3), I

remove the four variables (CS, MTV, IPOV, SRATIO) that have not shown significance in the regression settings (1) and (2), and find robust signs and significance on the remaining explanatory variables (REFORM, QEND, CLR, CRR, OMO, P2PA).

In sum, the empirical results indicate that even after adjusting for persistence and time-varying factors, the 1-day repo markets still show sizeable exchange to interbank spread that is mainly driven by the cross-market segmentation for NDIs, while the 7-day repo markets show smaller spread mostly driven by the counterparty segmentation between NDIs and DIs within the interbank market. Our robustness regression analysis across various specifications demonstrate that calendar factors, monetary policies, and shadow banking activities that increase the demand or reduce the supply of liquidity to NDIs more than the DIs tend to heighten the segmentation between exchange and interbank repos. This effect is most evident on the cross-market segmentation of NDIs for 1-day repos, and the within-market segmentation between NDIs and DIs in the interbank market for 7-day repos.

7. Conclusions

China repos trade in the interbank market as well as stock exchanges, but repo rates in these two markets are associated with large and persistent spreads that indicate market segmentation instead of integration. In this paper, I develop a comprehensive decomposition framework to dissect the exchange to interbank repo total spread into three components that reflect different day-count quoting methods (nominal/360 vs. actual/365), different trading mechanisms across markets (exchange vs. interbank) for NDIs, and different counterparties (NDI vs. DIs) within the interbank market.

The day-count quoting method spread represents an important source of the total spread for 1-day repos before the exchange repo reform of May 22, 2017, especially on trading days that are two days before weekends or holidays. Although NDIs can participate in both markets, the exchange to interbank cross-market spread for NDIs is large and positive for 1-day repos. However, this cross-market spread for NDIs on 1-day repos does not generate economically significant arbitrage opportunities in most scenarios after considering trade size, cross-market transaction costs, and additional trading frictions. On the other hand, the average exchange to interbank spread for NDIs is small and negative for 7-day repos, reflecting the outcome of less barriers for cross-market arbitrage in the longer tenor and benefit of the exchange's counterparty guarantee. Finally, the within-market counterparty spread in the interbank repo market is much larger and more dominating for the 7-day repos. With greater counterparty credit risk and more liquidity constraints, NDIs face higher rates than DIs in the interbank repo market. This is most evident for the 7-day repos due to the PBOC's frequent liquidity injection to DIs through open market operations in the 7-day tenor.

Further analysis uncovers the impacts of quarter-end effect, monetary policies, and shadow banking activities on the degree of cross-market segmentation between the exchange and interbank repo rates for non-depository institutions, and within-market segmentation between depository and non-depository institutions in the interbank repo market.

This study sheds light on the sources and drivers of the segmentation between exchange and interbank repos in China. It contributes to the financial market literature by addressing this segmentation puzzle and more importantly, provides an important basis for the formulation of macroprudential policies to mitigate systematic risk in China's financial sector. From a policy perspective, the persistent repo rate differences for NDIs across the two market mechanisms, the

exclusion of DIs in the exchange market, and the PBOC's exclusive open market operations with DIs in the interbank market, could be well-intended measures to reduce systemic risk in China's financial system. Given the explosive growth and frequent liquidity shortages of the nonbank financial sector, such partially segmented market structure allows for China's repo markets to serve the volatile liquidity needs of NDIs while still ensuring a more orderly market for DIs that are subject to tighter regulations.

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Figure 1. A Decomposition Framework for the Exchange to Interbank Repo Rate Total Spread

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SSE
Exchange Repo
Rate (ER)

Adjusted SSE
Exchange Repo
Rate (ER$_a$)

Interbank Repo Rate
for Non-Depository
Institutions (IR$_{NDI}$)

Interbank Repo
Rate for All
Institutions (IR)

First Component:
S1 ≡
Day-count Quoting
Method Spread for
Exchange Repos
= ER - ER$_a$

Second Component:
S2 ≡
Cross-market Spread for
NDIs between Exchange
and Interbank Repos
= ER$_a$ - IR$_{NDI}$

Third Component:
S3 ≡
Within-market Counterparty
Spread between NDIs and
All Institutions in the
Interbank Repo Market
= IR$_{NDI}$ - IR

Exchange to Interbank Repo Rate Total Spread (ST)
can be decomposed into three components (S1, S2, and S3):
$ST = ER - IR = (ER - ER_a) + (ER_a - IR_{NDI}) + (IR_{NDI} - IR) = S1 + S2 + S3$
For 1-day Repos: $ST\_1D = ER\_1D - IR\_1D = S1\_1D + S2\_1D + S3\_1D$;
For 7-day Repos: $ST\_7D = ER\_7D - IR\_7D = S1\_7D + S2\_7D + S3\_7D$

Adjusted Exchange to Interbank Repo Rate Total Spread (ST$_a$)
can be decomposed into the cross-market (S2) and within-market (S3) segmentation components:
$ST_a = ER_a - IR = (ER_a - IR_{NDI}) + (IR_{NDI} - IR) = S2 + S3$
For 1-day Repos: $ST_a\_1D = ER_a\_1D - IR\_1D = S2\_1D + S3\_1D$;
For 7-day Repos: $ST_a\_7D = ER_a\_7D - IR\_7D = S2\_7D + S3\_7D$

Note: See Panel C1 of Appendix C for definitions of repo rates and spreads.

Table 1. Summary of Trading Volume Statistics for China Interbank and Exchange Repos

Panel A. Summary of Monthly Volume during the Sample Period (December 2006 to June 2018)

Variable	Mean	Min	First Quartile	Median	Third Quartile	Max
Monthly Volume in RMB Billion						
Interbank Repos	19,705	2,239	5,964	11,369	35,775	61,151
Exchange Repos	6,368	93	353	2,963	10,009	23,945
Interbank Unsecured Lending	3,720	273	1,651	2,863	5,326	11,745
Interbank Spot Bond Trading	5,347	538	3,055	4,883	7,254	13,445
Monthly Volume Ratio						
Interbank Repos / Exchange Repos	4.27	1.87	2.81	3.88	15.42	40.13
Interbank Repos / Interbank Unsecured Lending	4.27	2.53	3.20	4.66	6.11	9.13
Interbank Repos / Interbank Spot Bond Trading	2.44	1.09	1.65	2.73	5.24	10.35

Panel B. Average Monthly Trading Volumes by Tenors during the Sample Period (December 2006 to June 2018)

Tenor	Avg. Monthly Volume in RMB Billion				% of Average Monthly Volume for all Tenors		
	1 Day	1 Week	Others	ALL	1 Day	1 Week	Others
Interbank Repos	15,939	2,635	1,131	19,705	75.9%	16.8%	7.3%
Exchange Repos	5,464	551	354	6,368	72.8%	22.3%	4.9%

Panel C. Annual Trading Volumes by Tenors in 2007 and 2018

Year / Tenor		Annual Volume in RMB Billion				As a % of Annual Volume for all Tenors		
		1 Day	1 Week	Others	ALL	1 Day	1 Week	Others
2007	Interbank Repos	22,999	15,842	5,227	44,067	52.2%	35.9%	11.9%
	Exchange Repos	534	1,144	120	1,797	29.7%	63.6%	6.7%
2018	Interbank Repos	578,266	71,219	37,139	708,673	81.6%	10.0%	5.2%
	Exchange Repos	173,701	19,628	6,474	199,802	86.9%	9.8%	3.2%
Geometric Average Annual Growth Rate (2007-2018)	Interbank Repos	34.1%	14.6%	19.5%	28.7%			
	Exchange Repos	69.2%	29.5%	43.7%	53.5%			

Source: Bloomberg, Wind Financial, PBOC

Table 2. Descriptive Statistics of the Exchange and Interbank Repo Rates and Spreads

Daily Repo Rates and Spreads Variables			Full Sample (12/05/2006-06/29/2018): 2814 Obs			Before Exchange Repo Reform Date of 05/22/2017: 2542 Obs			After Exchange Repo Reform Date of 05/22/2017: 272 Obs		
Tenor	**Repo Market**	**Repo Rates and Spreads Specifications**	**Mean**	**StdDev**	**Skewness**	**Mean**	**StdDev**	**Skewness**	**Mean**	**StdDev**	**Skewness**
1 Day	Exchange Repo	Volume-weighted (ER_1D)	3.689	3.790	6.938	3.642	3.936	6.846	4.124	1.910	3.318
	Exchange Repo	Adjusted VW (ER$_a$_1D)	3.019	3.389	9.362	2.901	3.490	9.500	4.124	1.910	3.318
	Exchange Repo	Closing (ERC_1D)	2.794	3.488	10.161	2.656	3.580	10.401	4.078	2.058	3.465
	Exchange Repo	Highest (ERH_1D)	4.986	6.198	6.802	4.957	6.424	6.720	5.258	3.424	3.306
	Interbank Repo	Volume-weighted (IR_1D)	2.386	0.963	1.770	2.344	1.002	1.853	2.778	0.220	1.531
	Interbank Repo	Closing (IRC_1D)	2.370	0.946	1.635	2.338	0.988	1.681	2.670	0.212	0.364
	Interbank Repo	Highest (IRH_1D)	3.066	1.630	4.207	3.014	1.674	4.240	3.544	1.021	4.747
	Exchange-Interbank	ER_1D-IR_1D	1.303	3.523	7.798	1.298	3.660	7.660	1.346	1.807	3.609
	Exchange	ER_1D-ER$_a$_1D	0.669	2.012	4.644	0.741	2.105	4.395	0.000	0.000	.
	Exchange-Interbank	ER$_a$_1D-IR_1D	0.633	3.174	10.420	0.557	3.278	10.458	1.346	1.807	3.609
	Exchange-Interbank	ERC_1D-IRC_1D	0.423	3.392	10.817	0.318	3.492	10.962	1.407	2.001	3.567
	Exchange-Interbank	ERH_1D-IRH_1D	1.920	5.792	7.318	1.942	5.999	7.223	1.714	3.273	3.543
7 Days	Exchange Repo	Volume-weighted (ER_7D)	3.415	2.593	5.464	3.329	2.684	5.494	4.222	1.231	3.281
	Exchange Repo	Adjusted VW (ER$_a$_7D)	3.420	2.718	7.437	3.334	2.818	7.432	4.222	1.231	3.281
	Exchange Repo	Closing (ERC_7D)	3.147	2.587	6.221	3.033	2.660	6.370	4.213	1.375	3.945
	Exchange Repo	Highest (ERH_7D)	3.930	3.267	5.487	3.846	3.373	5.492	4.712	1.852	4.485
	Interbank Repo	Volume-weighted (IR_7D)	3.018	1.172	1.196	2.977	1.214	1.250	3.400	0.522	2.483
	Interbank Repo	Closing (IRC_7D)	2.973	1.179	1.300	2.961	1.227	1.225	3.083	0.560	7.647
	Interbank Repo	Highest (IRH_7D)	3.608	1.744	3.203	3.582	1.794	3.148	3.854	1.155	4.807
	Exchange-Interbank	ER_7D-IR_7D	0.397	2.114	6.688	0.352	2.201	6.590	0.822	0.890	3.934
	Exchange	ER_7D-ER$_a$_7D	-0.005	1.486	-17.099	-0.006	1.563	-16.251	0.000	0.000	.
	Exchange-Interbank	ER$_a$_7D-IR_7D	0.402	2.317	10.019	0.357	2.416	9.809	0.822	0.890	3.934
	Exchange-Interbank	ERC_7D-IRC_7D	0.175	2.200	6.681	0.073	2.253	6.901	1.130	1.286	3.787
	Exchange-Interbank	IRH_7D-IRH_7D	0.322	2.645	5.750	0.264	2.734	5.717	0.858	1.490	5.346

Note: See Panel C1 of Appendix C for definitions of repo rates and spreads. All rates and spreads are in %.

Source: Bloomberg, Wind Financial

Table 3. Decomposition of the Daily Exchange to Interbank Repo Rate Spread (12/15/2014-06/29/2018)

	Full History (12/15/2014-06/29/2018): 864 Observations			Before the Reform Date of 05/22/2017: 592 Observations			272 Trading Days before the Reform Date of 05/22/2017			272 Trading Days after the Reform Date of 05/22/2017		
	Mean	**StdDev**	**Skew-ness**	**Mean**	**StdDev**	**Skew-ness**	**Mean**	**StdDev**	**Skew-ness**	**Mean**	**StdDev**	**Skew-ness**
Panel A. 1-Day Repo Rate Spreads												
Exchange to Interbank Repo Rate Total Spread	**1.303**	**2.413**	**4.00**	**1.284**	**2.647**	**3.92**	**1.669**	**2.671**	**3.57**	**1.346**	**1.807**	**3.61**
$ST\_1D / IR\_1D = (ER\_1D - IR\_1D) / IR\_1D$	53.78%	98.24%	3.66	56.95%	110.94%	3.36	70.17%	110.34%	3.50	46.89%	61.83%	3.81
Day-count Quoting Method Spread for Exchange Repos	0.487	1.727	5.37	0.711	2.049	4.38	0.865	2.400	4.23	0.000	0.000	.
$S1\_1D / IR\_1D = (ER\_1D - ER_a\_1D) / IR\_1D$	21.83%	74.44%	5.12	31.87%	88.15%	4.17	36.89%	100.30%	4.13	0.00%	0.00%	.
Exchange to Interbank Cross-market Spread for NDIs	0.684	1.922	4.75	0.481	1.983	5.26	0.674	1.693	3.12	1.127	1.704	3.92
$S2\_1D / IR\_1D = (ER_a\_1D - IR_{NDI}\_1D) / IR\_1D$	26.74%	76.71%	3.75	20.91%	82.82%	3.76	27.85%	71.56%	3.15	39.42%	59.53%	4.12
Counterparty Spread within the Interbank Market	0.132	0.168	6.46	0.092	0.090	5.12	0.131	0.118	3.99	0.220	0.247	4.99
$S3\_1D / IR\_1D = (IR_{NDI}\_1D - IR\_1D) / IR\_1D$	5.21%	4.79%	5.06	4.17%	3.02%	4.07	5.43%	3.84%	3.41	7.47%	6.76%	4.12
Panel B. 7-Day Repo Rate Spreads												
Exchange to Interbank Repo Rate Total Spread	**0.391**	**1.111**	**2.41**	**0.193**	**1.147**	**2.55**	**0.303**	**0.958**	**2.76**	**0.822**	**0.890**	**3.93**
$ST\_7D / IR\_7D = (ER\_7D - IR\_7D) / IR\_7D$	11.23%	33.46%	1.71	5.76%	36.45%	1.93	9.98%	33.20%	2.76	23.11%	21.45%	3.04
Day-count Quoting Method Spread for Exchange Repos	0.002	0.679	-3.55	0.003	0.821	-2.94	-0.016	0.927	-5.81	0.000	0.000	.
$S1\_7D / IR\_7D = (ER\_7D - ER_a\_7D) / IR\_7D$	-0.07%	23.15%	-6.40	-0.10%	27.98%	-5.30	-0.61%	34.46%	-6.35	0.00%	0.00%	.
Exchange to Interbank Cross-market Spread for NDIs	-0.202	1.001	2.22	-0.173	1.034	2.96	-0.277	1.005	3.91	-0.264	0.922	-0.11
$S2\_7D / IR\_7D = (ER_a\_7D - IR_{NDI}\_7D) / IR\_7D$	-6.17%	31.00%	3.41	-6.16%	34.14%	3.58	-8.48%	34.35%	5.67	-6.21%	22.74%	1.08
Counterparty Spread within the Interbank Market	0.591	0.735	3.40	0.363	0.471	3.40	0.596	0.602	2.41	1.086	0.937	3.00
$S3\_7D / IR\_7D = (IR_{NDI}\_7D - IR\_7D) / IR\_7D$	17.47%	16.28%	1.81	12.02%	12.14%	2.33	19.06%	14.17%	1.77	29.32%	17.79%	1.50

Note: See Figure 1 for *the Exchange to Interbank Repo Spread Decomposition Framework*, and Panel C1 of Appendix C for definitions of repo rate spreads.

All spreads are in %.

Source: Bloomberg, Wind Financial

Table 4. Parametric and Nonparametric Tests of Components of the Daily Exchange to Interbank Repo Rate Spread (after the Reform Date of 05/22/2017)

	Parametric Statistics				Nonparametric Statistics				
	Mean	t Test Statistic on Mean	Standard Deviation	Skewness	Median	Wilcoxon Signed Rank Test on Median	No. of Days with Positive (Negative) Spread	First Quartile	Third Quartile
Panel A. 1-Day Repos									
Exchange Repo Rate (ER_1D)	4.124		1.910	3.318	3.595			3.069	4.389
Interbank Repo Rate for NDIs (IR$_{NDI}$_1D)	2.998		0.446	3.483	2.872			2.736	3.125
Interbank Repo Rate for All Institutions (IR_1D)	2.778		0.220	1.531	2.724			2.614	2.910
Exchange to Interbank Repo Rate Spread: Total Spread (ST_1D)	**1.346 (12.29)**		1.807	3.609	**0.871 (14.18)**		262 (10)	0.419	1.514
ST_1D / IR_1D = (ER_1D - IR_1D) / IR_1D	**46.89% (12.51)**		0.618	3.812	**30.44% (14.18)**			15.84%	53.75%
Cross-market Spread for NDIs between Exchange and Interbank Markets (S2_1D)	**1.127 (10.90)**		1.704	3.925	**0.675 (13.79)**		247 (25)	0.283	1.291
S2_1D / IR_1D = (ER$_a$_1D - IR$_{NDI}$_1D) / IR_1D	**39.42% (10.92)**		0.595	4.116	**24.27% (13.79)**			10.82%	43.98%
Within-market Spread between NDIs and All in the Interbank Market (S3_1D)	**0.220 (14.67)**		0.247	4.993	**0.147 (14.30)**		272 (0)	0.116	0.215
S3_1D / IR_1D = (IR$_{NDI}$_1D - IR_1D) / IR_1D	**7.47% (18.22)**		0.068	4.125	**5.55% (14.30)**			4.42%	7.49%
Panel B. 7-Day Repos									
Exchange Repo Rate (ER_7D)	4.222		1.231	3.281	3.934			3.469	4.571
Interbank Repo Rate for NDIs (IR$_{NDI}$_7D)	4.486		1.455	2.835	4.042			3.553	5.017
Interbank Repo Rate for All Institutions (IR_7D)	3.400		0.522	2.483	3.284			3.057	3.599
Exchange to Interbank Repo Rate Spread: Total Spread (ST_7D)	**0.822 (15.23)**		0.890	3.934	**0.616 (14.29)**		271 (1)	0.332	0.946
ST_7D / IR_7D = (ER_7D - IR_7D) / IR_7D	**23.11% (17.77)**		0.215	3.037	**18.69% (14.29)**			10.33%	28.37%
Cross-market Spread for NDIs between Exchange and Interbank Markets (S2_7D)	**-0.264 (-4.72)**		0.922	-0.107	**-0.231 (6.72)**		83 (188)	-0.594	0.069
S2_7D / IR_7D = (ER$_a$_7D - IR$_{NDI}$_7D) / IR_7D	**-6.21% (-4.50)**		0.227	1.083	**-7.25% (6.72)**			-17.62%	2.34%
Within-market Spread between NDIs and All in the Interbank Market (S3_7D)	**1.086 (19.13)**		0.937	3.000	**0.769 (14.30)**		272 (0)	0.521	1.423
S3_7D / IR_7D = (IR$_{NDI}$_7D - IR_7D) / IR_7D	**29.32% (27.18)**		0.178	1.496	**24.00% (14.30)**			17.07%	39.69%
Panel C: Tesing Difference between Cross-market and Within-market Spread Components	Difference in Mean (Satterthwaite-Welch t-tes				Difference in Median (Mann-Whitney Test)				
Difference for 1-Day Repos: S2_1D - S3_1D	**0.907 (8.69)**				**0.528 (11.86)**				
Difference for 7-Day Repos: S2_7D - S3_7D	**-1.351 (-16.94)**				**-0.999 (17.44)**				
Panel D: Tesing Difference between the 1-Day Repo Spread and 7-Day Repo Spread	Difference in Mean (Satterthwaite-Welch t-tes				Difference in Median (Mann-Whitney Test)				
Difference in Total Spread: ST_1D - ST_7D	**0.524 (4.29)**				**0.255 (3.76)**				
Difference in % Total Spread: ST_1D / IR_1D - ST_7D / IR_7D	**23.78% (5.99)**				**11.75% (6.24)**				
Difference in Cross-market Spread: S2_1D - S2_7D	**1.391 (11.84)**				**0.906 (15.63)**				
Difference in % Cross-market Spread: S2_1D / IR_1D - S2_7D / IR_7D	**45.63% (11.81)**				**31.52% (15.87)**				
Difference in Within-market Spread: S3_1D - S3_7D	**-0.867 (-14.75)**				**-0.621 (18.22)**				
Difference in % Within-market Spread: S3_1D / IR_1D - S3_7D / IR_7D	**-21.85% (-18.93)**				**-18.45% (18.23)**				

Note: See Figure 1 for *the Exchange to Interbank Repo Spread Decomposition Framework* , and Panel C1 of Appendix C for definitions of repo rates and spreads.

All rates and spreads are in %. Exchange Repo Rates (ER) are equal to the Adjusted Exchange Repo Rates (ER$_a$) during the post-exchange reform period, when the two markets have the same day-count quoting methods.

Bold -- Significant at 5%

Source: Bloomberg, Wind Financial

Table 5. Arbitraging between Exchange and Interbank 1-Day Repos for NDIs based on Various Trade Sizes (June 2017-June 2018)

| | Cross-Market (Exchange to Interbank) Repo Rate Spread for NDIs (S2_1D) | | Profit (in RMB) on the Interbank (borrow) and Exchange (lend) 1-Day Repo Arbitrage for NDIs based on Different Trade Sizes | | | | | | Arbitrage Return (in %) after adjusting for the Cost of Arbitrage | |
| | | | Shanghai Stock Exchange Repo Minimum Trade Size: RMB100K | | Shanghai Stock Exchange 1-Day Repo Average Trade Size: RMB2.13 Million | | Interbank 1-Day Repo Average Trade Size for NDIs: RMB240.33 Million | | | |
	Percentile	Size of Spread in % (Annualized)	Gross Profit	Profit after adjusting for transaction costs	Gross Profit	Profit after adjusting for transaction costs	Gross Profit	Profit after adjusting for transaction costs	1 Day Return	Annualized Return
Top 1% Spread	99%	10.16%	27.84	26.79	592.97	570.60	66,905.24	64,381.77	0.02679%	9.78%
Top 5% Spread	95%	3.90%	10.69	9.64	227.60	205.24	25,680.41	23,156.95	0.00964%	3.52%
Top 10% Spread	90%	2.52%	6.91	5.86	147.21	124.84	16,609.77	14,086.30	0.00586%	2.14%
Third Quartile Spread	75%	1.29%	3.54	2.49	75.31	52.94	8,497.15	5,973.68	0.00249%	0.91%
Median Spread	50%	0.68%	1.85	0.80	39.41	17.04	4,446.43	1,922.97	0.00080%	0.29%
First Quartile Spread	25%	0.28%	0.78	-0.27	16.52	-5.85	1,863.71	-659.76	-0.00027%	-0.10%
2% Spread	87.5%	2.00%	5.48	4.43	116.71	94.35	13,168.77	10,645.30	0.00443%	1.62%
Mean Spread	70.2%	1.13%	3.09	2.04	65.74	43.38	7,417.85	4,894.38	0.00204%	0.74%
1% Spread	67.3%	1.00%	2.74	1.69	58.36	35.99	6,584.38	4,060.92	0.00169%	0.62%
Breakeven point that covers the cost of arbitrage	36.0%	0.38%	1.05	0.00	22.37	0.00	2,523.47	0.00	0.00000%	0.00%
Cost of Arbitrage in One Day				1.05		22.37		2,523.47		
Cost of Arbitrage in One Day (%)	0.00105%									
Annualized Cost of Arbitrage (%)	= 0.00105% X 365 = 0.38325%									
Source: CFETS; Shanghai Stock Exchange										

Table 6. Determinants of the Adjusted Exchange to Interbank Repo Rate Spread and Its Components (12/15/2014-06/29/2018)

Panel A. 1-Day Repos

Explanatory Variables / Dependent Variable		$ST_a\_1DP = S2\_1DP+S3\_1DP$ 1-Day Repos: Adj. Exchange to Interbank Repo Rate Total Spread			S2_1DP 1-Day Repos: Cross-market (Exchange to Interbank) Spread for NDIs			S3_1DP 1-Day Repos: Within-Market Counterparty Spread (between NDIs and All) in the Interbank Market		
Regression Specification		First	Second	Third	First	Second	Third	First	Second	Third
Intercept	CONSTANT	**0.163**	**0.315**	**0.163**	**0.139**	**0.265**	**0.139**	**0.025**	**0.050**	**0.025**
Autoregressive lag 1	AR1	**0.482**		**0.482**	**0.472**		**0.473**	**0.498**		**0.505**
Indicator of post-exchange repo reform	REFORM	0.007	0.020	0.001	0.002	0.012	-0.005	0.005	0.009	0.005
Quarter-end indicator	QEND	**0.320**	**0.505**	**0.323**	**0.316**	**0.494**	**0.320**	*0.007*	**0.011**	*0.007*
PBOC's 12-month lending benchmark rate	CLR	**0.491**	**0.918**	**0.480**	**0.495**	**0.916**	**0.478**	0.006	0.002	0.011
Major banks' required reserve ratio	CRR	-0.161	-0.276	**-0.161**	-0.158	-0.272	**-0.156**	-0.005	-0.004	-0.007
PBOC's open market operations	OMO	1.4E-04	2.6E-05	1.4E-04	9.8E-05	-2.5E-05	9.3E-05	**4.3E-05**	**5.1E-05**	**4.3E-05**
China P2P lending amount index	P2PA	**2.5E-02**	**5.4E-02**	**2.4E-02**	**2.4E-02**	**5.1E-02**	**2.3E-02**	**1.3E-03**	**2.9E-03**	**1.5E-03**
Stock Return on the Shanghai Composite Index	CS	-9.7E-03	1.8E-03		-9.9E-03	1.4E-03		3.6E-04	4.7E-04	
Margin trading volume as a % of SSE trading volume	MTV	1.0E-04	1.2E-04		1.5E-04	3.5E-04		-3.2E-05	-2.3E-04	
IPO issuance in the next 10 trading days	IPOV	7.4E-05	9.0E-04		2.0E-05	6.9E-04		6.7E-05	2.1E-04	
Exchange to Interbank Ratio of 1-day repo rate std. deviations (based on the last 10 trading days)	SRATIO_1D	1.9E-04	1.0E-03		2.5E-04	1.1E-03		**-3.5E-05**	**-7.0E-05**	
R-squared		32.7%	11.9%	32.7%	31.3%	11.2%	31.2%	43.6%	26.2%	43.5%
Adjusted R-squared		31.7%	10.8%	32.0%	30.3%	10.1%	30.6%	42.8%	25.3%	42.9%
F-statistic		**34.36**	**10.55**	**54.16**	**32.17**	**9.86**	**50.68**	**54.68**	**27.72**	**85.73**

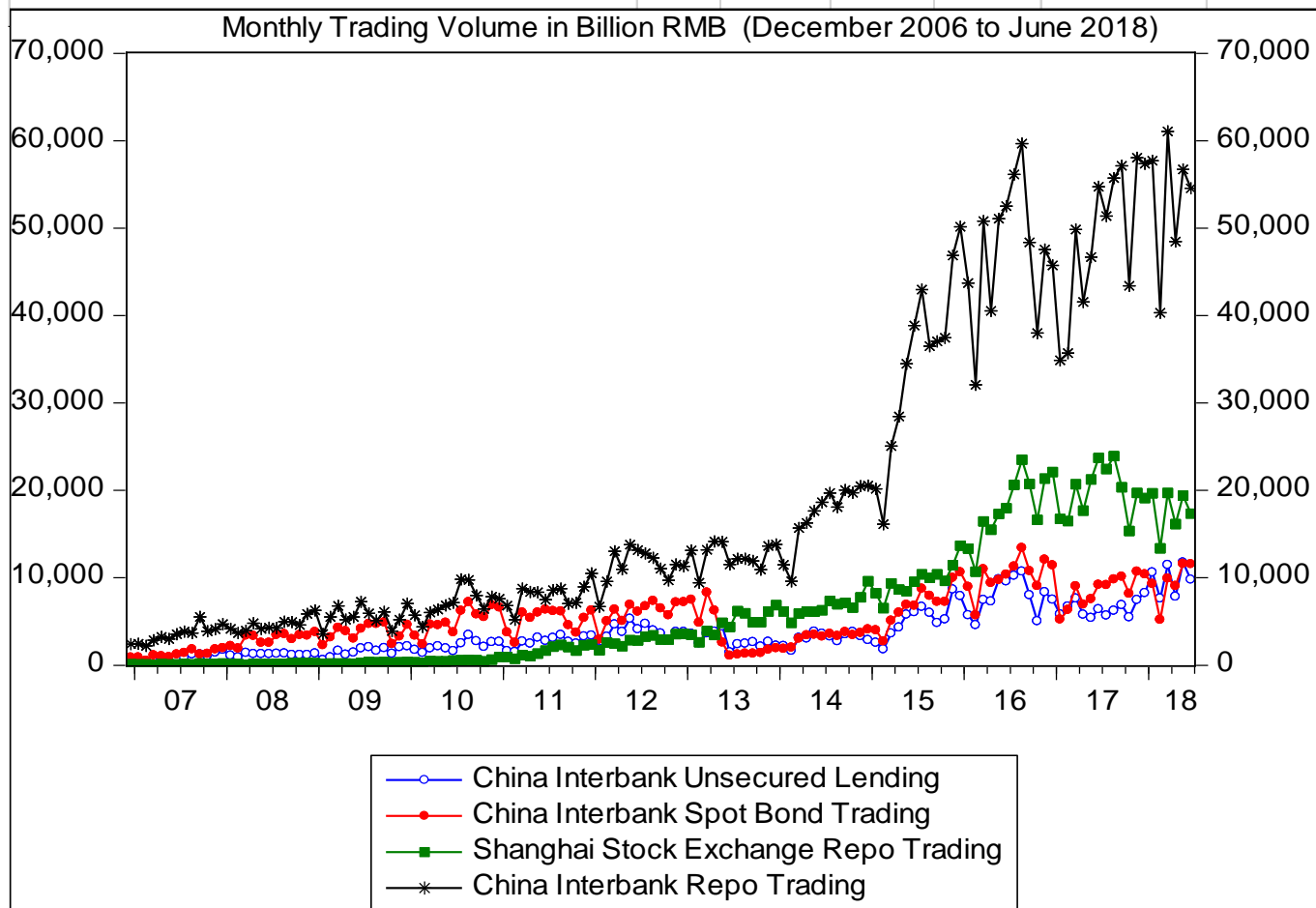Panel B. 7-Day Repos

Explanatory Variables / Dependent Variable		$ST_a\_7DP = S2\_7DP+S3\_7DP$ 7-Day Repos: Adj. Exchange to Interbank Repo Rate Total Spread			S2_7DP 7-Day Repos: Cross-market (Exchange to Interbank) Spread for NDIs			S3_7DP 7-Day Repos: Within-Market Counterparty Spread (between NDIs and All) in the Interbank Market		
Regression Specification		First	Second	Third	First	Second	Third	First	Second	Third
Intercept	CONSTANT	**0.047**	**0.114**	**0.047**	**-0.026**	**-0.057**	**-0.026**	**0.049**	**0.172**	**0.049**
Autoregressive lag 1	AR1	**0.591**		**0.593**	**0.564**		**0.568**	**0.715**		**0.717**
Indicator of post-exchange repo reform	REFORM	**0.043**	**0.096**	*0.036*	0.022	0.040	0.009	*0.015*	**0.056**	0.018
Quarter-end indicator	QEND	**0.102**	**0.218**	**0.104**	*0.061*	**0.127**	**0.066**	**0.036**	**0.091**	**0.034**
PBOC's 12-month lending benchmark rate	CLR	0.135	**0.384**	**0.153**	0.089	0.285	0.093	**0.045**	*0.099*	**0.047**
Major banks' required reserve ratio	CRR	-0.034	**-0.119**	*-0.050*	-0.013	-0.071	-0.027	**-0.024**	**-0.047**	**-0.020**
PBOC's open market operations	OMO	-6.0E-06	2.0E-05	-7.0E-06	*-1.2E-04*	-1.1E-04	*-1.2E-04*	1.1E-04	1.3E-04	1.1E-04
China P2P lending amount index	P2PA	**9.4E-03**	**2.5E-02**	**8.3E-03**	1.0E-03	5.0E-03	-6.8E-04	**5.9E-03**	**2.0E-02**	**6.2E-03**
Stock Return on the Shanghai Composite Index	CS	-5.2E-03	-5.2E-03		-4.0E-03	-4.3E-03		-1.3E-03	-9.1E-04	
Margin trading volume as a % of SSE trading volume	MTV	-2.7E-04	1.9E-03		-5.6E-04	1.9E-03		4.1E-04	-7.1E-05	
IPO issuance in the next 10 trading days	IPOV	8.3E-04	6.2E-04		8.3E-04	2.4E-04		-2.0E-04	3.8E-04	
Exchange to Interbank Ratio of 7-day repo rate std. deviations (based on the last 10 trading days)	SRATIO_7D	2.0E-04	5.2E-04		3.7E-04	*8.6E-04*		-1.1E-04	-3.4E-04	
R-squared		46.9%	18.0%	46.7%	36.5%	6.9%	36.2%	77.8%	52.0%	77.7%
Adjusted R-squared		46.1%	17.0%	46.2%	35.6%	5.7%	35.6%	77.5%	51.4%	77.5%
F-statistic		**62.45**	**17.12**	**97.82**	**40.67**	**5.77**	**63.23**	**247.33**	**84.32**	**387.91**

Note:
 1. The dependent variables are the adjusted exchange to interbank repo rate spread (ST_a),
   and its cross-market and within-market components (S2 and S3), all standardized by the interbank repo rate (IR).
 2. All explanatory variables (REFORM QEND CLR CRR OMO P2PA CS MTV IPOV SRATIO) have been demeaned.
 3. See Appendix C for definitions of the dependent and independent variables.
 4. **Bold** -- Significant at 5%; ***Bold and Italic*** -- Significant at 10%

Figure 1. Monthly Trading Volume (in RMB Billion) of China's Interbank Lending, Interbank Repos, Interbank Bond Trading, and Exchange Repos (Dec. 2006-June 2018)

Monthly Trading Volume in Billion RMB (December 2006 to June 2018)

Legend:
- China Interbank Unsecured Lending
- China Interbank Spot Bond Trading
- Shanghai Stock Exchange Repo Trading
- China Interbank Repo Trading

Figure 2. Monthly Decomposition of China's Exchange to Interbank Repo Rate Spreads (January 2015 - June 2018)

Figure 2A. Decomposition of China's 1-Day Exchange to Interbank Repo Rate Spread

S3_1D/IR_1D: Interbank Counterparty Spread between Non-depository Institutions and All Institutions / Interbank Repo Rate

S2_1D/IR_1D: Exchange to Interbank Cross-market Spread for Non-depository Institutions / Interbank Repo Rate

S1_1D/IR_1D: Day-count Quoting Method Spread / Interbank Repo Rate

Figure 2B. Decomposition of China's 7-Day Exchange to Interbank Repo Rate Spread

S3_7D/IR_7D: Interbank Counterparty Spread between Non-depository Institutions and All Institutions / Interbank Repo Rate

S2_7D/IR_7D: Exchange to Interbank Cross-market Spread for Non-depository Institutions / Interbank Repo Rate

S1_7D/IR_7D: Day-count Quoting Method Spread / Interbank Repo Rate

Note: The three spread components illustrated in the figures are all standardized as a percentage of the coresponding volume-weighted interbank repo rate.
See Figure 1 for *the Exchange to Interbank Repo Spread Decomposition Framework* , and Panel C1 of Appendix C for variable definitions.

Appendix A. A Timeline of the Development of China's Repo Markets

1990	Shanghai Stock Exchange (SSE) was launched in 1990 and Shenzhen Stock Exchange (SZSE) was launched in 1991.
1991	Non-standardized, informal, and fragmented repo trading started at local exchange centres.
1995	China shut down risky local repo centres and standardized the national exchange repo market at SSE and SZSE.
1996	National Interbank Lending Market was launched by PBOC in 1996. Trading through the China Foreign Exchange Trading System & National Interbank Funding Centre (CFETS).
1997	PBOC launched the interbank repo market exclusively for banks, and prohibited depository institutions (banks) from participating in the exchange repo market.
2000	PBOC issued an official release (2000, No. 2) to expand eligible interbank repo market participants to include nonbank financial institutions and nonfinancial enterprises.
2002	PBOC issued an official release (2002, No. 5) to further clarify the exact coverage of all financial institutions that may participate in the interbank repo market.
2005	PBOC issued an official release (2005, No. 13) to formally authorize nonfinancial enterprises to participate in spot bond trading and conduct reverse repos with financial institutions in the interbank market.
12/15/2014	PBOC started compiling the daily interbank repo rates exclusively for depository institutions (DIs), in addition to the general repo rates covering all institutions in the interbank market.
5/22/2017	CSRC and SSE reformed the exchange repo rate quotes from the nominal/360 day-count method to the actual/365 day-count method.[1]

Note:

[1] See China Securities Regulatory Commission and Shanghai Stock Exchange (2017).

Appendix B. A Brief Comparison of the Interbank and Exchange Repo Markets in China

Features	Interbank Repo Market	Exchange Repo Market
Regulator	People's Bank of China (PBOC)	China Securities Regulatory Commission (CSRC)
Trading Platform	Interbank Trading through the China Foreign Exchange Trading System (CFETS) of the National Interbank Funding Centre	Shanghai Stock Exchange (SSE, main exchange for the trading of bonds and repos); Shenzhen Stock Exchange (SZSE)
Participants	**Depository Institutions (DIs, also referred to as banks), PBOC,** Non-Depository Institutions (NDIs, including Nonbank Financial Institutions and Enterprises)	Non-Depository Institutions (NDIs, including Nonbank Financial Institutions and Enterprises), **Retail Investors**
Counterparty	Bond collateral provider (repo seller, borrower) vs. Cash provider (repo buyer, lender). Counterparties negotiate terms and conditions of the repo transaction to reflect credit risk and liquidity risk.	Exchange serves as the counterparty for all repo buyers and sellers; repo buyers and sellers are anonymous.
Counterparty Credit Risk	Depends on the creditworthiness of the counterparty, and the quality and haircut of the collateral. With less creditworthiness and lower quality collateral, NDIs' counterparty credit risk is generally perceived to be higher than that of DIs.	Zero. The stock exchange bears all the counterparty credit risk.
Liquidity Risk	Liquidity supply from PBOC and DIs reduces the risk of liquidity shortage in the interbank repo market. PBOC only trades with DIs in the interbank market.	More liquidity risk due to lack of funding supply from PBOC and DIs.
Eligible Collaterals and Haircuts	Negotiated between repo counterparties	Standardized, set by the Exchange
Repo Rate	Counterparties negotiate terms, conditions, and repo rates to reflect counterparty credit risk and liquidity risk.	Quotes are set by the exchange based on supply & demand
Day-count Quoting Method for Repo Rates	Actual/365 (actual number of days as a ratio of 365 days in a year)	Nominal/360 (Number of trading days as a ratio of 360 days in a year) method before 05/22/2017; actual/365 (actual number of days as a ratio of 365 days in a year) method after the exchange repo reform date of 05/22/2017
Settlement	Same day (t+0)	Next trading day (t+1)
Annual Trading Volume in 2018	709 Trillion RMB	200 Trillion RMB
Annual Growth Rate in Trading Volume from 2007 to 2018	28.7%	53.5%

Appendix C. Variable Definitions and Data Sources

Panel C1. China Repo Rates and Spreads [1]

Variable Symbol for 1-Day Tenor	Variable Symbol for 7-Day Tenor	Variable Name	Source
ER_1D	ER_7D	Exchange Repo Rate (daily volume-weighted from the Shanghai Stock Exchange)	Wind (Inception date: 12/5/2006)
ER_a_1D	ER_a_7D	Adjusted exchange repo rate (ER_a). ER_a is converted from the volume-weighted exchange repo rate (ER) on a nominal/360 basis to an actual/365 basis before the Exchange Repo Reform of 05/22/2017.	See equations (1) and (2) in the paper for the conversion formulas
ERC_1D	ERC_7D	Exchange Repo Rate (based on daily closing from SSE)	Bloomberg
ERH_1D	ERH_7D	Exchange Repo Rate (based on daily highest from SSE)	Bloomberg
IR_1D	IR_7D	Interbank Repo Rate (daily volume-weighted for all institutions)	Wind
IR_{DI}_1D	IR_{DI}_7D	Interbank Repo Rate for DIs (daily volume-weighted for depository institutions)	Wind (Inception Date: 12/15/2014)
IR_{NDI}_1D	IR_{NDI}_7D	Interbank Repo Rate for NDIs (daily volume-weighted for non-depository institutions)[2]	Estimated from daily IR, daily IR_{DI}, and monthly DI and NDI volumes; See equations (3)-(6) in the paper for the estimation formulas.
IRC_1D	IRC_7D	Interbank Repo Rate (based on daily closing)	Bloomberg
IRH_1D	IRH_7D	Interbank Repo Rate (based on daily highest)	Bloomberg
ST_1D	ST_7D	Exchange to Interbank Repo Rate Total Spread	ST_1D=ER_1D-IR_1D; ST_7D=ER_7D-IR_7D
S1_1D	S1_7D	Day-count Quoting Method Spread	S1_1D=ER_1D-ER_a_1D; S1_7D=ER_7D-ER_a_7D
ST_a_1D	ST_a_7D	Adjusted Exchange to Interbank Repo Rate Total Spread	ST_a_1D=ER_a_1D-IR_1D; ST_a_7D=ER_a_7D-IR_7D
S2_1D	S2_7D	Exchange (Adjusted) to Interbank Repo Rate Spread for NDIs	S2_1D=ER_a_1D-IR_{NDI}_1D; S2_7D=ER_a_7D-IR_{NDI}_7D
S3_1D	S3_7D	Interbank Counterparty Spread between NDIs and All Institutions	S3_1D=IR_{NDI}_1D-IR_1D; S3_7D=IR_{NDI}_7D-IR_7D
ST_1DP	ST_7DP	Exchange to Interbank Repo Rate Total Spread as a % of the Interbank Repo Rate	ST_1DP=ST_1D / IR_1D; ST_7DP=ST_7D / IR_7D
S1_1DP	S1_7DP	Quoting Method Spread as a % of the Interbank Repo Rate	S1_1DP=S1_1D / IR_1D; S1_7DP=S1_7D / IR_7D
ST_a_1DP	ST_a_7DP	Adjusted Exchange to Interbank Repo Rate Total Spread as a % of the Interbank Repo Rate	ST_a_1DP=ST_a_1D / IR_1D; ST_a_7DP=ST_a_7D / IR_7D
S2_1DP	S2_7DP	Exchange (Adjusted) to Interbank Repo Rate Spread for NDIs as a % of Interbank Repo Rate	S2_1DP=S2_1D / IR_1D; S2_7DP=S2_7D / IR_7D
S3_1DP	S3_7DP	Interbank Counterparty Spread between NDIs and All as a % of Interbank Repo Rate	S3_1DP=S3_1D / IR_1D; S3_7DP=S3_7D / IR_7D

Note:

[1] The Exchange Repo Rates (ER, ERC, ERH) are quoted using the nominal/360 day-count convention before the exchange repo reform date of 05/22/2017, and changed to the actual/365 day-count convention after the reform. Interbank Repo rates are quoted using the actual/365 day-count convention through the sample period.

[2] The daily volume-weighted interbank repo rates for non-depository institutions (IR_{NDI}) are estimated using the daily interbank general repo rates for all institutions (IR), daily interbank repo rates for depository institutions (IR_{DI}), and monthly interbank repo volume data for DIs and NDIs from the CFETS.

See Figure 1 for *the Exchange to Interbank Repo Spread Decomposition Framework*.

Appendix C. Variable Definitions and Data Sources (Continued)

Panel C2. Definitions and Sources of Other Variables (by alphabetical order of the variable symbol)

Variable Symbol	Variable Name	Source
ADJUST_1D	*Calendar factor for 1-day exchange repo's day-count quoting method adjustment.* Equals the number of actual days from the next trading day (t+1) to the (t+2) trading day for the period before May 22, 2017, and 0 otherwise	Calculated based on the SSE Exchange Calendar; Bloomberg
ADJUST_7D	*Calendar factor for the 7-day exchange repo's day-count quoting method adjustment.* Equals the number of actual days from the next trading day (t+1) to the (t+8) trading day for the period before May 22, 2017, and 0 otherwise	Calculated based on the SSE Exchange Calendar; Bloomberg
AR1	Lag one-day autoregressive term of the dependent variable	Calculation
CLR	PBOC's 12-month lending benchmark rate	Bloomberg; PBOC
CRR	Major banks' required reserve ratio	Bloomberg; PBOC
CS	China stock return as calculated from the Shanghai Composite Index	Bloomberg; SSE
IPOV	Initial public offerings in the next 10 trading days (in billion RMB)	Bloomberg; Calculation
MTV	Margin trading volume as a % of SSE trading volume	Bloomberg; Wind
OMO	PBOC's net injection to market from open market operations (in billion RMB)	Bloomberg; PBOC
P2PA	China P2P Lending Amount Index (in billion RMB)	Wind
QEND	Quarter-end indicator. Equals 1 during last two weeks of Mar., June, Sep., Dec., and 0 otherwise	Calculation
REFORM	Indicator of post-exchange repo reform date of 05/22/2017	Equals 1 after 5/22/2017, and 0 before 5/22/2017
SRATIO_1D	Exchange to Interbank ratio of 1-day repo rate standard deviations (based on last 10 trading days)	$SRATIO\_1D = STDEV (ER\_1D) / STDEV (IR\_1D)$
SRATIO_7D	Exchange to Interbank ratio of 7-day repo rate standard deviations (based on last 10 trading days)	$SRATIO\_7D = STDEV (ER\_7D) / STDEV (IR\_7D)$

Appendix D. Calendar Patterns of Repo Spreads for 1-Day Repos

Group	Number of Trading Days	% of Trading Days	Mean of Calendar Factor Variable ADJUST_1D	Mean of Day-count Quoting Method Spread (in %) for Exchange Repos S1_1D	Mean of Exchange to Interbank Repo Rate Total Spread (in %) ST_1D	Mean of Unadj. Exchange to Interbank Repo Spread (in %) for NDIs S1_1D+S2_1D
Panel A: Average in Period #1 (Before 12/15/2014)						
(1950 Trading Days: before the availability of DI vs. NDI Interbank Repo Rates)						
All Trading Days	1950	100%	1.49	0.75	1.30	
Thursday (Two Days before Weekend)	**357**	**18%**	**3.00**	**3.24**	**2.49**	
Two Days before Holiday	**18**	**1%**	**5.72**	**6.88**	**6.57**	
Two Days before Holiday Weekend	**30**	**2%**	**6.27**	**8.40**	**7.12**	
Friday	391	20%	1.00	-0.05	1.23	
Other Trading Days	1154	59%	1.00	-0.04	0.73	
Panel B: Average in Period #2 (After 12/15/2014 before 05/22/2017)						
(592 Trading Days: after the availability of DI vs. NDI Interbank Repo Rates and before the Exchange Repo Reform of May 22, 2017)						
All Trading Days	592	100%	1.49	0.71	1.28	1.19
Thursday (Two Days before Weekend)	**106**	**18%**	**3.00**	**2.86**	**2.16**	**2.06**
Two Days before Holiday	**8**	**1%**	**5.88**	**7.17**	**6.32**	**6.25**
Two Days before Holiday Weekend	**9**	**2%**	**5.44**	**8.82**	**8.77**	**8.64**
Friday	116	20%	1.00	-0.04	0.91	0.83
Other Trading Days	353	60%	1.00	-0.04	0.84	0.74

Panel C: Correlations between Calendar Variables and ST_1D (the Exchange to Interbank 1-Day Repo Rate Spread)

	Period #1 (1950 Trading Days) After 12/05/2006	Period #2 (592 Trading Days) After 12/15/2014 Before 05/22/2017	Period #3 (292 Trading Days) After 05/22/2017 Before 06/28/2018
Dummy - Thursday	**0.195**	**0.271**	0.036
Dummy - Friday	-0.010	*-0.070*	0.047
Dummy - One Day before Holiday	0.055	0.055	-0.043
Dummy - Two Days before Holiday	**0.148**	**0.215**	0.084
Calendar Factor Variable (ADJUST_1D)	**0.288**	**0.430**	0.085

Note:

ADJUST_1D: Calendar factor variable for 1-Day Exchange Repos. Equal to the actual number of days from t+1 to t+2 for 1-day repos.

See Figure 1 and Appendix C1 for detailed spread variable definitions.

Correlations: **Bold** -- Significant at 5%; ***Bold and Italic*** -- Significant at 10%

Appendix E. Average Trade Size (in RMB Million) of Interbank and Exchange Repos (June 2017-June 2018)

Month	Participants	Interbank Repos								Shanghai Stock Exchange Repos		
		All Institutions: Banks and Non-bank Institutions			Large Commercial Banks	Joint Stock Commercial Banks	Non-bank Institutions			Non-bank Institutions and Retail Investors		
	Tenor	All	1-Day	7-Day	All	All	All	1-Day	7-Day	All	1-Day	7-Day
201706		302.22	337.25	206.56	675.81	839.72	225.91	252.10	154.41	2.07	2.31	1.42
201707		283.81	318.09	190.20	630.97	775.79	215.22	241.21	144.23	2.18	2.44	1.46
201708		264.76	296.27	178.43	571.43	666.11	199.28	223.00	134.30	1.88	2.10	1.27
201709		284.30	322.30	187.49	645.72	748.59	206.25	233.82	136.02	1.73	1.96	1.14
201710		282.57	316.19	194.77	643.59	702.00	207.56	232.25	143.07	1.71	1.92	1.18
201711		280.26	310.86	185.21	631.73	664.43	212.89	236.13	140.69	1.81	2.00	1.19
201712		296.51	332.88	201.68	738.14	767.94	215.30	241.71	146.44	1.73	1.94	1.18
201801		298.12	332.83	192.83	764.70	761.95	214.43	239.39	138.69	1.93	2.16	1.25
201802		331.17	393.08	222.31	745.19	849.25	228.30	270.98	153.26	2.11	2.51	1.42
201803		295.60	337.27	186.97	721.89	712.37	210.81	240.53	133.34	1.90	2.16	1.20
201804		261.58	304.38	180.45	661.41	704.99	191.32	222.63	131.98	1.63	1.89	1.12
201805		284.22	328.60	179.22	690.33	701.98	208.40	240.94	131.41	1.87	2.16	0.01
201806		285.94	330.76	194.76	647.68	683.97	215.83	249.65	147.01	1.82	2.11	1.24
Mean		288.54	327.75	192.38	674.51	736.85	211.65	240.33	141.14	1.87	2.13	1.16

Source: CFETS; Shanghai Stock Exchange

Appendix F. Transaction Costs of Cross-market Arbitrage between Interbank and Exchange Repos

Transaction Costs \ Tenor			1-Day Repos	7-Day Repos
Interbank Repo - Transaction Costs			0.00005%	0.00015%
Exchange Repo - Transaction Costs			0.00100%	0.00500%
Sum of transaction costs in Interbank and Exchange Repos			0.00105%	0.00515%
Cross-market Arbitrage -- Transaction Costs (Annualized)			0.38325%	0.26780%

Source: CFETS; Shanghai Stock Exchange