Cognitive Biases and Asset Prices:

Evidence from the Exchange-traded Repo Market in China

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Abstract

Prior to May 22, 2017, actual daily interest rates of Chinese exchange-traded repos on certain days of the week and on trading days prior to market-closed holidays exhibited remarkable seasonalities. On May 22, 2017, the exchanges changed the way in which rates were displayed such that investors need no longer infer actual repo maturities. Thereafter, the seasonalities disappeared. We interpret the seasonalities and their disappearance as being due to investors employing an ease-of-processing heuristic that was not required after May 22, 2017. An implication is that a cognitive bias on the part of investors caused the seasonalities in asset prices.

JEL Classification: G12, G14

Keywords: Cognitive Biases, Ease-of-processing Heuristic, Seasonalities, Exchange-traded Repo

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1. Introduction

The past half dozen years has witnessed phenomenal growth in the exchange-traded repurchase agreement (henceforth, exchange-traded repo) market in China, with daily trading volume on the Shanghai Stock Exchange (SSE) increasing six-fold, from $21.38 billion in 2012 to $127.62 billion in 2018. Unlike the U.S. exchange market, which is dominated by institutional investors, the exchange market in China is dominated by retail investors who, in 2017, accounted for more than 82% of the dollar trading volume according to the SSE Statistics Annual (2018).

A peculiarity of the Chinese exchange-traded repo market is that prior to May 22, 2017, actual daily repo interest rates on certain days of the week and on days prior to market-closed holidays exhibited remarkable seasonalities. For example, during the period of January 1, 2012, through May 21, 2017, the annualized actual daily rates of one-day repos on Thursdays and on trading days prior to market-closed holidays were 1.50% *lower* than the rates on surrounding days (henceforth, all interest rates reported in this study are annualized).

A further peculiarity is that on certain days of the week and prior to market-closed holidays, the Chinese financial press frequently cited to *higher* repo rates on such days as signals of a liquidity crisis or a looming economic problem. In citing to rates that were "too high" the financial press was citing to quoted repo rates rather than to actual repo rates. The quoted repo rates were displayed as daily rates based on the quoted number of days to maturity (henceforth, quoted maturity) rather than the actual number of days to maturity (henceforth, actual maturity). For example, the quoted repo rate of a "one-day" repo initiated on Thursday was a daily rate based on the quoted maturity of one day even though the actual maturity was three days as the repo extended

across the weekend. Thus, to a naïve reader, the quoted rates on "one-day" repos initiated on Thursdays could appear to be extraordinarily high.

Indeed, examination of the quoted "one-day" repo rates on Thursdays and prior to market-closed holidays shows that the quoted repo rates prior to May 22, 2017, were significantly higher than the quoted repo rates on surrounding days. For example, over the period of January 1, 2012, through May 21, 2017, the average *quoted* one-day repo rate on Thursdays and prior to market-closed holidays was 2.79% *higher* than the average quoted rate on surrounding days. That is not surprising as the "one-day" repos on Thursdays and prior to market-closed holidays actually spanned more than one day. What is peculiar is that the *actual* daily repo rates were *lower* than surrounding actual daily rates. Subsequent to May 22, 2017, the seasonalities in actual daily repo rates disappeared. Additionally, concerns expressed in the financial press about quoted rates being "too high" also all but disappeared. Why?

On May 22, 2017, as directed by the China Securities Regulatory Commission (CSRC), the SSE changed the way in which rates were quoted for exchange-traded repos.[2] In terms of the execution of trades and in terms of the cash flows associated with exchange-traded repos, nothing changed. What changed is the way in which the quoted repo rates were displayed. In placing an order, the display presented to an investor gives quoted maturity of the repo, the closing quoted repo rate of the prior day for repos with that quoted maturity, and the quoted repo rate of the most recent trade of that repo on the day in question. The repo rates are quoted as annual rates, and investors offer the repo rate to place their trades. Prior to May 22, 2017, the quoted repo rates displayed were based on the quoted maturities of the repos. Subsequent to May 22, 2017, the

[2] The stated intent of the CSRC was to reduce volatility in repo rates put forth as a need "to eliminate the drastic volatility in the repo rates caused by holidays and weekends." http://english.sse.com.cn/aboutsse/news/newsrelease/c/4314726.shtml.

quoted repo rates displayed were based on the actual maturities of the repos. For example, prior to May 22, 2017, on Thursdays, the quoted repo rate for a "one-day" repo was displayed as a one-day rate when in actuality the interval covered by the rate encompassed three days. Subsequent to May 22, 2017, on Thursdays, the quoted repo rate for a "one-day" repo is displayed as the rate per day over a three-day interval. The consequence of the CSRC mandated change is that, post-May 22, 2017, the quoted rate is the actual daily rate.

We propose that it was the change in the way in which quoted repo rates are displayed that eliminated the seasonalities in rates that we noted above and that we elaborate upon below. In particular, we propose that prior to May 22, 2017, a likely explanation for the pattern of actual daily one-day repo rates being too low and media representations of the quoted one-day repo rates being too high is that retail investors and the media were subject to a form of cognitive bias. The formal name for the cognitive bias that we have in mind is "ease-of-processing" information whereby individuals tend to use information in the form displayed and ignore or discount information that must be inferred from the explicit display (Slovic (1972), Payne, Bettman, and Johnson (1993), Hirshleifer (2001), and Hirshleifer and Teoh (2003)).

In the case of Chinese exchange-traded repos, the information that had to be inferred prior to May 22, 2017, was the actual maturity of the repo. We propose that subsequent to May 22, 2017, the change in the way in which quoted repo rates are displayed eliminated the need to infer the actual maturity of the repos and, thereby, eliminated the seasonalities in rates. Further, the pre-May 22, 2017, seasonalities that we observe in one-day repo rates are also apparent in two-, three-, four-, and seven-day repos when the actual maturity of the repo exceeds the quoted maturity. And, as with one-day repos, the seasonalities in the rates of these repos disappeared after May 22, 2017.

To make our argument a bit more concrete, consider an example. Assume that prior to the change in the quotation practice on May 22, 2017, an investor requires an interest rate of 3% per day. On Thursday, in order to earn that rate, the investor should offer a rate of 9% for a "one-day" repo. Observing that rate and the closing rate of the prior day (i.e., 3%), an investor employing an ease-of-processing heuristic might well conclude that the displayed rate of the current day's most recent trade for this apparent one-day repo rate is unusually high in comparison with immediately prior one-day repo rates. Such an investor might decide to over-allocate funds to this exceptionally good opportunity. In doing so, the investor, or a group of similarly afflicted investors, might well drive the "one-day" Thursday-initiated repo rate to be far less than the required 9% with the upshot that the actual daily rate for Thursday repos would be far less than the required 3% per day. Subsequent to May 22, 2017, and enactment of the CSRC mandate, the quoted repo rate displayed is 3% rather than the apparently attractive 9%, and the cognitively biased investor need not infer the actual maturity when submitting a bid. If so, the prediction is that prior to May 22, 2017, actual rates for one-day repos on Thursdays would be "too low" and they would be "just right" thereafter.

As it turns out, in some instances, the quoted maturities of the repos are greater than the actual maturities. What we discover is that prior to May 22, 2017, for such repos, the seasonality goes in the other direction - - when the quoted number of days covered by the repo is greater than the actual number of days encompassed by the repo, the actual rates were *too high* relative to surrounding rates of similar repos. In particular, a "two-day" or "three-day" repo initiated on Friday actually encompasses only one day and a "four-day" repo initiated on Friday actually encompasses only two days. Prior to May 22, 2017, for these repos, the actual daily rates were systematically too high in comparison with rates of similar repos on surrounding days. After May 22, 2017, the difference between the actual daily rates of "two-day," "three-day," and "four-day"

repos initiated on Fridays and the rate for such repos initiated on other days of the week disappeared.

The exchange-traded repo market also offers repos with quoted maturities of 14, 28, 91, and 182 days. For these, the actual maturities of the repos are always the same as the quoted maturities. We do not observe any seasonalities in these repo rates.

We then undertake various further considerations. First, prior to market-closed holidays, the actual maturities of some repos exceed the quoted maturities even more than during a non-holiday week. For example, in some cases a one-day repo could encompass a four-day market-closed holiday. Consider the implication for a "one-day" repo that encompasses four days. An investor requiring a daily rate of 3% should offer a bid of 12%. To a cognitively biased investor, this rate could appear to be even more attractive than the 9% rate cited above for the Thursday-initiated "one-day" repo. As such, the investor, and similarly biased investors, might well over-allocate even further. If so, we conjecture that the actual daily "one-day" repo rate would be even lower relative to surrounding rates than would the actual daily repo rate for the Thursday-initiated "one-day" repos. That is, the longer the actual maturity of the repo relative to the quoted maturity, the lower the actual daily repo rates relative to surrounding rates.

To consider this conjecture, we estimate regressions separately using pre- and post-May 22, 2017, data with the dependent variable being the actual daily repo rate and the key independent variable being the actual maturity of the repo. With the pre-May 22, 2017, data, in each regression, the coefficient is significantly negative. In none of the regressions using post-May 22, 2017, data is the coefficient significantly different from zero. Consistent with our conjecture, pre-May 22, 2017, the longer the actual maturity of the repo, the lower the actual daily rate. Also consistent with our conjecture, the relationship disappears after May 22, 2017.

Second, the smaller Shenzhen Stock Exchange (SZSE) also trades repos. We replicate our analyses using closing rates of repos from the SZSE with data from January 1, 2013, through December 31, 2018. The seasonalities and their disappearance are also present in these rates.

Third, starting from 1997, commercial banks were not permitted to trade in the exchange-traded repo markets. At the same time, a parallel interbank repo market was created in which trades take place by negotiation between banks or by anonymous clearing through the China Central Depository and Clearing Corporation (CCDC). Among other repos, that market trades one- and seven-day repos, which, in terms of quoted maturities, are the only repos in the interbank repo market that are comparable with repos in the exchange-traded market. From its inception, the display given to traders in the interbank market presented participants with actual daily repo rates. Thus, traders did not need to infer the number of days encompassed by the repo to determine the actual daily rate. Consistent with the proposition that it was the rate display that gave rise to the seasonalities in exchanged-traded repo rates, we find no seasonalities in these rates.

To give some indication of the amount of opportunity losses associated with the apparent repo pricing errors, using the coefficient of the regression for one-day repos and their average daily volume, the estimated daily loss for one-day repos initiated on Thursdays is $703 million. Recognizing that each such repo encompasses three days and that the sample period covers 5.5 years, the total estimated loss is $703 million × 3 days × 52 Thursdays per year × 5.5 years = $603 billion for one-day repos initiated on Thursdays. Further, recognizing that one-day repos represent approximately 87% of the total exchange-traded repo volume, the estimated loss for one-day repo mispricing is reflective of total mispricing losses.

Our paper contributes to studies that investigate the effect of investors' tendency to employ ease-of-processing heuristics in asset pricing. The novelty of the study is that we examine an

exogenous shock that removed a potential barrier to information processing. We find that the seasonalities in asset prices disappear along with the barrier. We interpret the findings to be consistent with investors employing an ease-of-processing heuristic prior to the removal of the barrier. An implication of the findings is that a cognitive bias on the part of investors caused the observed seasonalities in repo rates. Of course, we recognize that this study covers only one type of asset in one market, and that the apparent mispricing has disappeared. Caution should be used in generalizing these findings.

The paper is organized as follows. Section 2 sets forth the institutional background of the exchange-traded repo market in China. Section 3 provides a brief review of related literature on cognitive biases and asset prices. Section 4 more fully develops the ideas underlying our proposed explanation of seasonalities in exchange-traded repo rates. Section 5 presents the data and the primary empirical results. Section 6 presents extensions of the main empirical results. Section 7 concludes.

2. Institutional background

2.1. Exchange-traded repo markets in China

The Chinese exchange-traded repo market was initiated in 1991 by the SSE, China's largest stock exchange. The SZSE, the second largest Chinese stock exchange, followed suit in 1993. Initially, although all investors were permitted to trade exchange-traded repos, commercial banks were the dominant traders (Fan and Zhang (2007)). In 1997, the CSRC disallowed commercial banks from trading in the exchange-traded repo market. At the same time, the CSRC initiated the interbank repo market with the stated intent of separating commercial bank repo trading from repo trading by other market participants. Thus, commencing in 1997, trading in the exchange-traded

repo market has been restricted to retail investors, operating companies, and non-bank financial institutions including security firms, insurance companies, and mutual funds.

The repos traded on the exchange-traded market are collateralized repos in which qualified bonds are pledged as collateral in exchange for a cash loan.[3] As is customary with repo transactions generally, the loan is less than the dollar amount of treasuries pledged based on margin requirements. The two parties agree to return the cash and release the bonds at the maturity of the repo. In the Chinese exchange-traded repo market, the exchange acts as the counterparty to both sides of the transaction and, thus, bears the default risk on both sides. As a result, interest rates of exchange-traded repos are close to risk-free rates (Chen, Chen, He, Liu and Xie (2018)). In an exchange-traded repo transaction, the China Securities Depository & Clearing Corporation (CSDCC), an entity fully owned by the SSE and the SZSE and regulated by the CSRC, serves as the clearing agent and holds the collateral. An important feature of the Chinese market is that participants are not permitted to borrow bonds for the purpose of entering into exchange-traded repo transactions. This feature has the effect of limiting arbitrage opportunities in the repo market. That feature is, of course, potentially consequential in allowing the observed seasonalities to persist.

Panel A of Table 1 reports, by year, the average daily trading volume by dollar amount of exchange-traded repos during 2012–2018 for both the SSE and the SZSE. As shown, the SSE is the dominant exchange accounting for over 90% of the dollar volume of exchange-traded repo transactions. Panel B of Table 1 presents the annual trading volume by contract maturity. One-day repos account for 87% of the repo volume. Two-, three-, four-, and 14-day repos each account for roughly 1% of the volume with seven-day repos accounting for roughly 7%.

[3] Qualified bonds include treasury bonds and AAA-rated municipal and corporate bonds.

2.2. Placing an order on the SSE repo market

As we describe above, in placing a repo order the display presented to an investor gives the quoted maturity of the repo, the prior day's closing interest rate for repos with the same quoted maturity, and the interest rate of the most recent transaction in repos of that maturity. Prior to May 22, 2017, on Thursday, for a one-day repo, the prior day's closing rate might be displayed as 3%. The interest rate of the most recent trade for repos of that maturity might be 7%. An investor employing an ease-of-processing heuristic might fail to infer that the actual maturity of the repo is three days. If so, the 7% appears to be an especially attractive rate for a one-day repo. Such an investor might place an order at a rate close to 7% or, perhaps, place a market order that would clear at the closing rate for the day. If the market is populated with a sufficient number of such investors, the closing daily rate for Thursday might well end up far below the actual market-clearing rate of the preceding days with the consequence that a Thursday-seasonality would appear in one-day repo rates.

In this example, subsequent to May 22, 2017, the information displayed to the investor would still be one day for the quoted maturity of the repo and the closing rate for the prior day would still be 3%, but the rate for the most recent transaction would be converted to a daily rate. Thus, in this example, the rate displayed for the most recent transaction would be $(100\% + 7.0\%)^{1/3} - 100\% = 2.28\%$. An investor employing an ease-of-processing heuristic would not need to infer the actual maturity of the repo to learn that the actual daily rate of the most recent transaction is far below the market-clearing rate of the prior day. The investor, now aware of the actual daily rate, would no longer view that rate as extraordinarily attractive. He or she would quite reasonably pass up the opportunity to bid at that rate or to place an order at the implied closing market rate for the day. Rather, the investor would, perhaps, withhold funds or place an order at a rate closer to

the prior day's actual closing rate. If so, the post-May 22, 2017, market closing rate for the day is likely to be in line with those of surrounding days and the Thursday-seasonality would disappear. At least, that is the idea that we have in mind.

A counter-argument is that the market must be populated to some extent by astute market participants. Such participants would notice the seasonality and place orders to take advantage of it. Doing so would require that the astute investor have access to bonds that can be used as collateral to borrow at the low repo rate. But such investors may be limited in access to such bonds. And, importantly, such investors are prohibited by law from borrowing bonds to pledge as collateral in the exchange-traded repo market. Thus, if potential arbitrageurs do not own an adequate amount of bonds to counter-act the trading of cognitively impaired repo retail investors and the arbitrageurs cannot borrow such bonds, the seasonalities could endure.

2.3. The repo market clearing and settlement procedure

The exchange-traded repo market operates with a clearance and settlement practice whereby the first clearance date is the transaction date and the first settlement date is the next trading day after the first clearance date at which time the lender provides cash and the borrower deposits collateral. The due clearance date is the maturity date of the repo, which is N calendar days after the first clearance date where N is the quoted number of days of the repo maturity. If the maturity date would have occurred on a market-closed weekend day or market-closed holiday, the due clearance date is the next trading day after the maturity date. The due settlement date is the next trading day after the due clearance date, at which time the agreed upon funds are returned to the lender and the collateral is released to the borrower. Under our proposed explanation of the seasonalities, it is the clearance and settlement practice coupled with the way in which rates were displayed before May 22, 2017, that gave rise to the seasonalities in repo rates.

To give an example of the clearance and settlement procedure, assume a one-day repo is initiated on Thursday, January 11, 2018. Then the first clearance date is Thursday, January 11, and the first settlement date is Friday, January 12. Funds are transferred to the borrower on Friday, the first settlement date. Because the market is closed for the weekend of January 13–14, the due settlement date is Monday, January 15. The funds are returned to the lender on Monday, the due settlement date. Thus, although the quoted maturity of the repo is one day, the actual maturity is three days.

For two-, three-, and four-day repos initiated on Friday, the actual maturity of the repo is less than the quoted maturity. For example, assume a three-day repo is initiated on Friday, March 3, 2017. The first settlement date is Monday, March 6, the day on which funds are advanced to the borrower. Because the market is closed for the weekend of March 4–5, the due clearance date is Monday, March 6, three calendar days after the first clearance date. The due settlement date is Tuesday, March 7, and funds are returned to the lender on that day. In this case, although the quoted maturity of the repo is three days, the actual maturity is one day (that is, the funds are on loan for only one day). Panel A of Table 2 reports the actual maturities of repos with various quoted maturities during non-holiday weeks. So, for example, the actual maturity of a four-day repo initiated on Monday or Tuesday is six days while the actual maturity of a four-day repo initiated on Wednesday is five days.

If the repo transaction is initiated prior to a market-closed holiday, the difference between the quoted maturity and the actual maturity could be even larger than shown in Panel A of Table 2. For example, assume a two-day repo is initiated on January 25, 2017, two days prior to the Chinese New Year holiday. The first clearance date is January 25 and the first settlement date is January 26. The due clearance date is February 6 because the market is closed for the holidays

from January 27 to February 5, and the due settlement date of the repo is Tuesday, February 7. Thus, although the quoted maturity of the repo is two days, the actual maturity is 12 days.

Panel B of Table 2 reports the average actual maturities of repos with various quoted maturities prior to market-closed holidays during the period of January 1, 2012– December 31, 2018. So, for example, the average actual number of days to maturity for one-day repos varies across holidays ranging from 4.2 days for the New Year's Day (i.e., January 1) to 9.0 days for the National Day. And, of course, these are averages with variation in the maturity within each holiday interval. Such variation allows for cross-sectional analysis within each maturity of repo.

2.4. The Chinese financial press on "too high" of repo rates

As we noted, prior to market-closed holidays, and prior to May 22, 2017, the Chinese financial press frequently cited to high repo rates as being signals of a liquidity crisis and/or an impending economic problem. As one example, in 2013, New Year's Day occurred on Tuesday, January 1 and the market was closed that day. On the prior Monday, December 31, 2012, the quoted one-day repo rate was 7.16%. Because the actual maturity of the repo was two days, the actual daily rate was $(100\% + 7.16\%)^{1/2} - 100\% = 3.52\%$. This compares with the much higher quoted (and actual) average rate of 5.89% for one-day repos over other days of the previous week.

Nevertheless, on December 31, 2017, the *China Securities Journal*, the newspaper designated by the CSRC, the China Banking Regulatory Commission, and the China Insurance Regulatory Commission as the official media outlet for corporate information, published an article titled "One-day Repo Rate Soars!" and reported the event as "Exchange-traded repo rates soared tremendously, especially in the case of the one-day repo rate that closed at 7.16%. The high rate reflects the instability of liquidity in the market."[4]

[4] The *China Securities Journal*, December 31, 2017, Page 7.

As a second example, in 2017, New Year's Day occurred on Sunday, January 1. Because January 1 was a Sunday, the security markets were closed on Monday, January 2. On the prior Thursday, December 29, 2016, the quoted one-day repo rate was 11.20%, meaning that the actual daily rate for this four-day market-closed holiday was $(100\% + 11.20\%)^{1/4} - 100\% = 2.69\%$. This compares with the much higher average quoted and average actual daily rate of 5.87% for one-day repos over other days of the same week. Nonetheless, on that Thursday, the *China Industrial Economy News*, the first economics-oriented newspaper established in modern China,[5] published an article with the headline "Liquidity Dries Up, Worries of Funding Shortage Arise" and went on to say "[t]he high [quoted one-day repo] rate shows that liquidity dried up at the end of year, partially because asset managers demanded more funds to enhance their year-end performance evaluations."[6]

How frequently did such accounts appear in major financial newspapers? Over the 19 months prior to May 22, 2017, a search of *China Stock Market & Accounting Research (CSMAR)* financial news database yields 40 articles by 12 different newspapers relating to seven different holidays in which the Chinese financial press pointed to repo rates as being "too high" prior to market-closed holidays. In each instance, the actual daily rate over the holiday was *less* than the average actual daily rates over the week preceding the article. In comparison, over the 19 months following May 22, 2017, our search of the same news source identifies four articles in three different newspapers relating to two holidays in which the press pointed to rates as being too high. On each of these occasions, the actual rate was, in fact, higher than the average actual daily rate over the week preceding the article.

[5] In this instance, we are referring to the People's Republic of China.
[6] The *China Industrial Economy News*, December 29, 2016, page 3.

A similar search of *Sina Finance*, the largest financial news website in China that accounts for more than one-third of the "traffic" of financial news websites, yielded 21 news articles noting repo rates as being too high in 2012, 73 articles in 2013, 170 articles in 2014, 104 articles in 2015, 52 articles in 2016, and 185 articles in 2017 prior to the change of the rate quotation display. And, again, in each instance the actual daily rate was *less* than the average actual daily rate over the week preceding the holiday. The frequency of such stories declined to eight during the last six months of 2017 and to three during all of 2018. In each instance, the actual rate was higher than the average actual daily rate during the preceding week.

3. Related literature

Cognitive biases refer to systematic patterns in which decision-makers deviate from what would customarily be considered rational decision-making.[7] An underlying cause of cognitive biases is thought to be limited human information processing capacity which refers to the tendency for individuals to apply simple strain-reducing strategies or heuristics for processing information when making certain judgments or decisions (Slovic (1972)). One form of the limited information processing capacity is referred to as an "ease-of-processing" heuristic. Underlying the ease-of-processing heuristic is the "concreteness principle" which is the idea that a "decision maker tends to use only the information that is explicitly displayed in the stimulus object and will use it only in the form in which it is displayed. Information that has to be stored in memory, inferred from the explicit display, or transformed tends to be discounted or ignored."[8]

[7] Various cognitive biases have been examined in the finance and economics literature. These include, for example, overconfidence (Daniel, Hirshleifer, and Subrahmanyam (1998), Odean (1998), and Barber and Odean (2000)), the loss aversion or prospect theory (Kahneman and Tversky (1979)), the limited attention bias (Barber and Odean (2008)), the exponential growth bias (Stango and Zinman (2009)), the stale-information processing bias (Tetlock (2011)), the confirmatory bias (Pouget, Sauvagnat and Villeneuve (2017)), and the contrast effects bias (Hartzmark and Shue (2018)).

[8] Slovic (1972), p. 8.

The effect of investors' tendency to employ ease-of-processing heuristics on asset prices has been examined in the finance and accounting literature. Two lines of studies have considered this topic. The first uses market data to form a benchmark that attempts to capture the fundamental value of the asset and to link the deviation of the asset's returns from the benchmark with investors' ease-of-processing heuristic. The second conducts laboratory experiments in which information given to subjects is modified and the effect of the modification on investors' behavior is observed.

The first category includes, for example, Engelberg (2008) who distinguishes quantitative earnings news, labeled as easier to process, from qualitative earnings news, labeled as more difficult to process. You and Zhang (2009) who distinguish between firms with simple and complex 10-Ks. Lee (2012) who distinguishes between easier-to-read and more-difficult-to-read 10-Qs and links those to concurrent earnings announcements. And Hwang and Kim (2017) who distinguish funds on the basis of the "readability" of the fund's annual reports. Each study uses a market-based benchmark of equity returns, usually based on matching firm characteristics, to study the effect of ease-of-processing on security prices or performance. Each study attributes the observed pricing difference to a cognitive bias that emanates from an ease-of-processing heuristic.

The second category includes, for example, Bertrand and Morse (2011) who conduct a field trial where they randomly provide easier-to-read information on the cost of payday loans to customers entering 77 stores of a large national payday lending chain. They find that borrowers are less likely to use payday loans when given easier-to-read information. Rennekamp (2012) who recruited 234 participants from Amazon's Mechanical Turk platform and finds that more readable disclosures increase participants' belief in the reliability of the disclosure. He concludes that the "easier-to-process information reduces cognitive effort and facilitates the ability [of investors] to

envision how companies perform." Both studies conclude that, in a laboratory setting, easier-to-digest information alters market-participant behavior.

Our study complements these prior studies. As with the prior studies, we document a pattern of returns that is consistent with the existence of a cognitive bias that influences asset prices (or use of an asset). In particular, as with the prior studies, the asset prices (or use) deviate from a benchmark in a way that suggests the deviations derive from an ease-of-processing heuristic. The novelty of our study is the disappearance of the pattern when the barrier to information processing is removed in a capital market setting. The results support the existence, at least in some circumstances, of a causal relation between investors' cognitive biases and asset prices.

4. Proposed explanation of seasonalities and their demise

As outlined above, we propose that, prior to May 22, 2017, repos with quoted maturities that were less than their actual maturities would have had actual daily rates that were *less* than the surrounding actual daily rates of repos with the same quoted maturities and for which the quoted maturities were the actual maturities. Further, repos with quoted maturities that were greater than their actual maturities would have had actual daily rates that were *greater* than the surrounding actual daily rates of repos with the same quoted maturities and for which the quoted maturities were the actual maturities. Given that, prior to May 22, 2017, repos initiated on certain days of the week and prior to market-closed holidays had actual maturities that were greater than their quoted maturities, we propose that such repos would have had lower actual daily rates than similar maturity repos initiated on other days of the week. If so, such repos would have exhibited weekly and holiday seasonalities.

To be specific, we predict that, prior to May 22, 2017, for one-day repos initiated on Thursdays, the actual repo rates would have been less than the actual rates for repos initiated on

other days of the week. For two- and three-day repos initiated on Wednesdays and Thursdays, the actual repo rates would have been less than the actual rates for two- and three-day repos initiated on other days of the week. For four-day repos, initiated on Mondays, Tuesdays and Wednesdays, the actual repo rates would have been less than the actual rates for four-day repos initiated on other days of the week. On the other side of the coin, for two-, three-, and four-day repos initiated on Fridays, the actual repo rates would have been greater than the actual rates for two-, three- and four-day repos initiated on other days of the week.

As regards market-closed holidays, for one-, two-, three-, and four-day repos initiated prior to market-closed holidays in which the duration of the market-closed period exceeded the quoted maturity of the repo, we predict that the actual repo rates would have been less than actual rates of repos with similar quoted maturities on which the quoted maturity was the same as the actual maturity. To give an example, for a three-day repo initiated prior to a six-day market-closed holiday, we expect that the actual daily rate would have been less than the actual daily rate of preceding three-day repos for which the quoted maturities and the actual maturities were the same.

Seven-day repos are a special case. In a non-holiday week, the quoted maturity and the actual maturity of a seven-day repo are always seven days. However, prior to some market-closed holidays, the quoted maturity of a seven-day repo was less than the actual maturity. Thus, for non-holiday weeks, we predict that seven-day repos exhibited no weekly seasonality. But, for market-closed holidays in which the actual maturity of a seven-day repo exceeded seven days, we predict that the actual rates would have been *less* than the actual rates of surrounding seven-day repos.

There are, of course, repos with maturities greater than seven days. These include repos with maturities of 14, 28, 91 and 182 days. For these, the quoted maturities and the actual

maturities are always the same. Ergo, we expect not to observe weekly or market-closed holiday seasonalities in these repo rates either before or after May 22, 2017.

Conditional on observing weekly and holiday seasonalities in actual daily rates for one-, two-, three-, four-, and seven-day repos, we further predict that, prior to May 22, 2017, for each quoted maturity of repo, there would have been a negative relation between the actual daily repo rates and the actual maturities of the repos.

Finally, and importantly, conditional on observing weekly and holiday seasonalities in repo rates prior to May 22, 2017, we propose that these were caused by a cognitive bias that derived from an ease-of-processing heuristic on the part of retail investors, that was, in turn, caused by the way in which repo quotes were displayed. Further, and equally importantly, once the quotation display was changed (on May 22, 2017), we predict that the seasonalities in rates would have disappeared as would the negative relation between the actual daily repo rates and the actual maturities of the repos. We now turn to the data.

5. Data and empirical results

5.1. Data

The data used in our analyses are from *Wind Information*, a major provider of detailed financial information in China. The key data of interest are the time series of repo interest rates for repos traded on the SSE, the SZSE, and the Chinese interbank repo market.[9] Our primary analyses use the closing quoted repo interest rates from the SSE for the time period of January 1, 2012, through December 31, 2018. For the SSE, for repos with a quoted maturity of seven days or less, a closing rate is available for every trading day over this time period. For repos with a

[9] The specific time-series obtained from *Wind Information* include GC001, GC002, GC003, GC004, GC007, GC014, GC028, GC091, GC182 for the SSE, R001, R002, R003, R004, R007 for the SZSE, and IB001 and IB007 for the interbank repo market.

quoted maturity greater than seven days, a closing rate is available for 98% of the trading days.[10] Data from the SZSE and the Chinese interbank repo market are used in certain secondary analyses. Data from the SZSE encompass the time period of January 1, 2013, through December 31, 2018. Data from the interbank repo market encompass the time period of January 1, 2012, through December 31, 2018.

For each repo for each day, we retrieve the *Quoted Maturity*, the *Actual Maturity*, the *Quoted Rate,* and the *Actual Rate*. Specifically, *Quoted Maturity* is the quoted maturity of the repo. *Actual Maturity* is the actual maturity of the repo, computed as the number of days between the first settlement date (i.e., the day on which funds are advanced) and the due settlement date of the repo (i.e., the day on which funds are returned). The *Quoted Rate* is the reported closing quoted interest rate of the repo. The quoted rate is reported as an annual rate of interest. Prior to May 22, 2017, the *Actual Rate* is the annualized actual daily rate of return on the repos calculated as $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. Subsequent to May 22, 2017, it is calculated as $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$.

5.2. Univariate analysis

We present results of the analysis of repo rates in bar charts and tables for each quoted maturity of repo according to days of the week and for market-closed holidays - - first for days of the week and, then, for market-closed holidays. We present results separately for the time period of January 1, 2012 – May 21, 2017 (the pre-May 22, 2017 period), the period of May 22, 2017 – December 31, 2018 (the post-May 22, 2017 period), and the period of January 1, 2017 – May 21, 2017.

5.2.1. Weekdays

[10] Prior to 2012, closing rates of repos are available for roughly 39% of the trading days.

Panel A of Figure 1 presents bar charts of the average actual daily repo rates for each quoted maturity of repo for each day of the week for non-holiday weeks for the pre-May 22, 2017, time period. As predicted, compared with rates on surrounding days, the actual daily rates are lower on Thursday for the one-day repos, on Wednesday and Thursday for two-day and three-day repos, and on Monday, Tuesday, and Wednesday for four-day repos. Further, as predicted, we do not observe any weekly seasonalities in actual rates for any of the repos with quoted maturities of seven or more days.

Results of the tests of the statistical significance of weekly seasonalities for the pre-May 22, 2017, time period are given in Panel A of Table 3. As shown in row 4 of Panel A, for repos in which the quoted maturity is less than the actual maturity, the average actual daily rate is statistically significantly less than the average actual daily rate on days on which the quoted maturity is the same as the actual maturity. The differences range from -1.52% to -0.50% (all p-values < 0.01). As shown in row 5, for repos in which the quoted maturity is greater than the actual maturity, the average actual daily rate is statistically significantly greater than the average actual daily rate on days on which the quoted maturity is the same as the actual maturity. The differences range from 0.27% to 0.85% (all p-values < 0.02).

Critically, for our proposition, neither the bar charts of Panel B of Figure 1 nor the statistics in Panel B of Table 3 give any indication of seasonalities in rates in the post-May 22, 2017, time period. The differences in average actual rates for this time period range from -0.13% to 0.15% (all p-values > 0.45). The seasonalities in rates disappear in the post-May 22, 2017, time period.

Panel C of Table 3 shows results for the time period of January 1, 2017, through May 21, 2017 - - a more restricted time period that immediately precedes the change in the display of repo rates. This time period includes 91 trading days encompassing roughly 18 weekly observations.

As in row 4 of Panel A, for repos in which the quoted maturities are less than the actual maturities, the actual rates are significantly less than the actual rates on days on which the quoted maturities are the same as the actual maturities. As shown in row 4, the differences range from -1.88% to -0.32% (all p-values < 0.05). As shown in row 5, for repos in which the quoted maturities are greater than the actual maturities, the actual daily rates are significantly greater than the actual daily rates on days on which the quoted maturities are the same as the actual maturities. The differences range from 0.82% to 1.49% (all p-values < 0.05). Not shown in the table are the results for the more restricted post-change-in-display time period of May 22, 2017, through December 31, 2017. As with the full post-May 22, 2017, time period, the seasonalities are absent in the May 22, 2017 – December 31, 2017, time period (all p-values > 0.38).

5.2.2. Holidays

Panel A of Figure 2 presents bar charts of the average actual daily repo rates for each quoted maturity of repo initiated on days prior to market-closed holidays and on days on which the quoted maturity is the same as the actual maturity for the pre-May 22, 2017, time period. As predicted, compared with rates on surrounding days, the average actual daily rates are lower prior to market-closed holidays for the one-, two-, three-, four-, and seven-day repos. Further, in comparison, for none of the repos in which the quoted maturities are greater than seven days are the average actual rates less than the rates on surrounding days (recall that for these repos, the quoted maturities and the actual maturities are the same).

Results of the tests of the statistical significance of holiday seasonalities in repo rates are given in Panel A of Table 4. As shown in row 3, for repos in which the quoted maturity is less than the actual maturity, the average actual rate is statistically significantly less than the average

actual rate on days on which the quoted maturity is the same as the actual maturity. The differences range from -1.71% to -0.21% (all p-values < 0.01).

Critically, for our proposition, neither the bar charts of Panel B of Figure 2 nor the statistics in Panel B of Table 4 give any indication of holiday seasonalities in rates in the post-May 22, 2017, time period. The differences in the average actual rates range from 0.00% to 0.38% (all p-values > 0.33).

The presence of weekly and holiday seasonalities prior to May 22, 2017, and, more importantly, their disappearance subsequently are consistent with our proposition that the observed seasonalities in exchange-traded repo market in China are caused by investors subject to a cognitive bias that derives from the use of an ease-of-processing heuristic in which the information that must be inferred is the actual maturity of the repos.

5.3. Regression analysis

The univariate analyses document the presence and the subsequent disappearance of seasonalities in the exchanged-traded repo rates. To alleviate the concern that the seasonalities derive from macroeconomic events confounded with days of certain weeks or holidays in certain years prior to May 22, 2017, we estimate regressions that control for year-week fixed effects. Specifically, for each of the one-, two-, three-, four- and seven-day repos, we estimate the following OLS regression:

$$Actual\ Rate_t = \alpha + \beta_1 Quoted < Actual_t + \beta_2 Quoted > Actual_t + Year - Week\ Fixed\ Effects + \varepsilon_t \quad (1)$$

where $Quoted < Actual_t$ $(Quoted > Actual_t)$ is an indicator that takes the value of one if the repo was initiated on trading days where the *Quoted Maturity* is less (more) than the *Actual Maturity*. The sample used to estimate the model for each maturity repo includes all repos with

that quoted maturity including repos that encompass market-closed holidays. The regression includes year-week fixed effects. Standard errors are clustered at the year-week level.

Our interest is the coefficient of *Quoted* < *Actual* ($i.e., \beta_1$) and *Quoted* > *Actual* ($i.e., \beta_2$) for each of the five maturities of repos. If the observed seasonalities and their subsequent disappearance in exchange-traded repo market in China are caused by investors subject to a bias that derives from the use of an ease-of-processing heuristic, β_1 is predicted to be negative prior to May 22, 2017, in each regression and β_2 is predicted to be positive prior to May 22, 2017, in the regressions for two-, three-, and four-day repos. With post-May 22, 2017, data, both β_1 and β_2 are expected not be different from zero in any regression.[11]

Panel A of Table 5 reports the coefficient estimates for the pre-May 22, 2017, time period. In each regression, the sign of β_1 is negative and statistically significantly less than zero. The coefficient estimates are -1.765 for one-day, -0.568 for two-day, -0.319 for three-day, -0.190 for four-day, and -0.166 for seven-day repos (all p-values < 0.01). Additionally, the sign of β_2 is statistically significantly positive in the regressions of two-, three-, and four-day repos. The coefficient estimates are 0.221 for two-day, 0.101 for three-day repo, and 0.179 for four-day repos (all p-values < 0.01). (Regressions cannot include β_2 for one- and seven-day repos.)

To help interpret these estimates, for one-day repos initiated on days on which the quoted maturity is less than the actual maturity, the actual daily rates are 1.765% lower than those of one-day repos initiated on days on which the quoted maturity is the same as the actual maturity. This difference compares with the sample average actual daily rate for one-day repos of 3.40%.

The results for the post-May 22, 2017, time period are presented in Panel B of Table 5. In clear contrast to the results for the pre-May 22, 2017, period, in none of the regressions for the

[11] *Quoted* > *Actual* always equals zero in the regressions of one- and seven-day repos because the quoted maturity is either equal to or less than the actual maturity for one- and seven-day repos.

post-May 22, 2017, time period is the coefficient estimate of β_1 or β_2 significantly different from zero (all p-values > 0.28).

Panel C of Table 5 gives results for the narrower time period of January 1, 2017, through May 21, 2017. The sign of β_1 is significantly negative in each of the five regressions with coefficient estimates -1.724 for one-day, -0.589 for two-day, -0.283 for the three-day, -0.162 for four-day, and -0.065 for seven-day repos (all p-values < 0.01). The sign of β_2 is positive in regressions of two-, three-, and four-day repos. The coefficient estimates are 0.317 for two-day, 0.229 for three-day, and 0.188 for four-day repos, respectively, with p-values of 0.06, 0.06, and < 0.01. Not shown in the table are the results for the more restricted time period of May 22, 2017, through December 31, 2017. In each case, the coefficient estimates are modest in magnitude and not statistically different from zero (all p-values > 0.38).

6. Further considerations

6.1. The relation between actual maturities and actual repo rates

As an extension of our proposed explanation of the seasonalities in repo rates and their disappearance, we further conjecture that, prior to May 22, 2017, the greater the extent to which the actual maturities of the repos exceed the quoted maturities the lower the actual daily rates. Of course, for instances in which the actual maturities were less than the stated maturities, the greater the extent to which the actual maturities of the repos fall short of the quoted maturities the higher the actual daily rates. That is, we conjecture that, prior to May 22, 2017, for any given quoted maturity repo, the relationship between the actual maturity of the repo and the actual daily rate would have been negative.

To examine that conjecture, we estimate regressions in which the dependent variable is the actual daily repo rate and the independent variable is the actual maturity of the repos. We estimate

five regressions, one each for repos of one-, two-, three-, four-, and seven-day quoted maturities. The results are given in Table 6. Panel A of the table reports the coefficient estimates of *Actual Maturity* for the pre-May 22, 2017, time period. In each regression, the sign of the coefficient estimate is negative and statistically significantly less than zero. The coefficient estimates are -0.635 for one-day, -0.211 for two-day, -0.094 for three-day, -0.044 for four-day, and -0.020 for seven-day repos (all p-values < 0.01). To help interpret these estimates, for one-day repos, a one day increase in actual maturity is associated with 0.635% decrease in the actual daily rate.

The results for the post-May 22, 2017, time period are presented in Panel B of Table 6. In clear contrast to the results for the pre-May 22, 2017, period, in none of the regressions for the post-May 22, 2017, time period is the coefficient estimate of *Actual Maturity* significantly different from zero (all p-values > 0.28).

One additional observation of the results in Table 6 merits consideration. A comparison of the coefficients across quoted maturities shows that they increase monotonically (i.e., becomes less negative) as the quoted maturities of the repos increase. This monotonic increase further supports the proposition that the observed seasonalities in repo rates are caused by the use of an ease-of-processing heuristic on the part of investors in the Chinese exchange-traded repo market.

To illustrate this conjecture, consider two repos, one with a quoted maturity of one day and the other with a quoted maturity of seven days, both of which were initiated on the trading day prior to the 2016 Chinese New Year Day. The actual maturity of the one-day repo would be nine days. A "sophisticated" investor who requires an annualized interest rate of 3% per day would offer a rate of 27%. The actual maturity of the seven-day repo would be 10 days. The same investor would offer a rate of 30% for a seven-day repo.

According to our proposition, in the eyes of a cognitively impaired investor who fails to adjust for the difference between the quoted and actual maturities, the one-day repo appears to offer a return of 27% for one day in comparison with the seven-day repo that appears to offer a return of 30% for seven days. As a result, under our proposition, the cognitively impaired investor would allocate relatively more funds to the one-day repo. If so, for a given stated maturity repo, the implication is that the longer the quoted maturities of the repos, the less attractive the quoted repo rates appear to be to the cognitively impaired investor with the consequence that the mispricing will be less the longer the quoted maturity of the repo prior to May 22, 2017.

The monotonically increasing coefficient estimates of Table 6 are consistent with this prediction.

6.2. Repo rate seasonalities on the Shenzhen Stock Exchange

We also investigate whether our results are restricted to repos traded on the SSE. In particular, we repeat the analyses in Table 5 with an alternative sample that consists of the daily closing rates of one-, two-, three-, four- and seven-day repos traded on the SZSE during the period of January 1, 2013 to December 31, 2018. Like the SSE, the SZSE changed the way in which quoted repo rates are displayed on May 22, 2017.

As reported in Panel A of Table 7, for the pre-May 22, 2017, period, in each of the five regressions, the coefficient estimate of *Quoted* < *Actual* is negative and statistically significant (all p-values < 0.05), and the coefficient estimate of *Quoted* > *Actual* is positive with p-values of 0.10, 0.09, and <0.01. And the magnitudes of the coefficient estimates are similar to those in Table 5. For the post-May, 22, 2017, time period, none of the coefficients are statistically different from zero (all p-values > 0.19). The results in Table 7 indicate that the pre-May 22, 2017, seasonalities and their subsequent disappearance in exchange-traded repo rates are not unique to the SSE.

6.3. The absence of seasonalities in Chinese interbank repo rates

As one further consideration, we examine actual daily repo rates in the interbank repo market for the time period of January 1, 2012, through December 31, 2018. Trading in the interbank repo market is confined to commercial banks. Trading takes place either through bank-to-bank negotiations or through anonymous trades cleared by the China Central Depository and Clearing Corporation (CCDC). In any event, all trades are reported to the CCDC. The data used in our analysis of the interbank repo market are the closing trades according to the CCDC. We consider one- and seven-day repos, which, in terms of quoted maturities, are the only interbank repos comparable to repos traded on the exchange-traded market. Of particular importance for our analysis is that the repo rates displayed in the interbank market have always been presented as actual daily rates. Thus, traders in the market did not need to infer the repo maturity to know the actual daily repo rate.

Panels A and B of Figure 3 present bar charts of the average actual daily rates by day of the week for non-holiday weeks for one- and seven-day repos, respectively, before and after May 22, 2017. Neither before nor after May 22, 2017, do the figures give any indication of weekly seasonalities in actual daily rates for either one-day or seven-day repo rates. Across days of the week, the bars are of equal height.

Panels C and D of Figure 3 present bar charts of average actual daily rates for one-day and seven-day repos, respectively, initiated prior to market-closed holiday periods and on other days of the same weeks for the pre- and post-May 22, 2017, periods. As the bar charts illustrate, in the interbank repo market, actual daily interest rates of one- and seven-day repos during holiday periods were definitively not lower than actual rates of one- and seven-day repos on other days during the weeks leading up to the holidays either before or after May 22, 2017. The seasonalities

in the SSE and the SZSE repo rates do not appear in the interbank repo market. Given that traders in the interbank market did not need to infer the actual repo maturity to know the actual daily repo rate, the absence of seasonalities in the interbank repo market lends further credence to the proposition that their appearance and later disappearance in the retail market is due to a cognitive bias that disappeared after May 22, 2017, when retail investors were no longer required to infer the actual maturity of repos traded on the SSE and the SZSE.

6.4 Other CSRC rulings during 2017

We attribute the pre-May 22, 2017, seasonalities in the interest rates of exchange-traded repos to the way in which repo rates were displayed to investors. The form of this display was created by the CSRC in 1997. We attribute the disappearance of the seasonalities to a CSRC mandated change in the way in which rates were displayed on May 22, 2017. The seasonalities were common to both the SSE and the SZSE. It is certainly possible that some other factor or event common to both exchanges caused the appearance and disappearance of such seasonalities. The year-week fixed effects in the regression models should control for such factors. Nevertheless, we reviewed the CSRC website for all rule-making announcements during 2017 that affected stock exchange practices. We identified 64 pronouncements and orders. Of these, 12 related to equity trading, six related to bond trading, nine related to futures trading, and 37 related to corporate disclosure practices and procedures. Other than the May 22nd pronouncement relating to the way in which repo quotes are displayed, none related to exchange-traded repurchase transactions.

7. Conclusion

This study undertakes to investigate the existence, prior to May 22, 2017, of marked seasonalities in interest rates of exchange-traded repurchase agreements (repos) on the Shanghai Stock Exchange and the disappearance of these seasonalities subsequent to May 22, 2017. Prior

to May 22, 2017, the repo display shown to investors presented the quoted term to maturity of the repo, the prior day's closing quoted daily interest rate of repos with the same maturity, and the quoted daily interest rate of the most recent trade in repos of that maturity. On certain days of the week and prior to market-closed holidays, the actual term to maturity of certain repos exceeded the quoted term to maturity; on certain other days of the week, the actual term of maturity of certain repos was less than the quoted term to maturity. In each of these instances, investors would have been required to infer the actual maturities of the repos so as to adjust their bids - - which were (and are) submitted in the form of annual interest rates. In instances wherein the actual term to maturity of the repos exceeded the quoted maturity, we document that actual rates were significantly lower than the rates on surrounding days for repos of the same maturity. Contrarily, in instances wherein the actual term to maturity of the repos was less than the quoted maturity, we document that actual rates were significantly higher than the rates on surrounding days for repos of the same maturity.

On May 22, 2017, the China Securities Regulatory Commission mandated that the display shown to repo investors be changed such that investors no longer needed to infer the actual maturity of the repos when submitting their bids. Following the change in the display, the seasonalities in rates disappeared.

We interpret this evidence to imply that when placing bids in the Chinese exchange-traded repo market, investors employed an ease-of-processing heuristic in which they tended to use information in the form displayed and downplayed information that had to be inferred. Such behavior falls under the general rubric of a cognitive bias on the part of investors. In this case, the bias gave rise to the seasonalities in rates. Once the need to infer information from the display

was removed, the seasonalities in asset prices disappeared. The implication is that, at least in this circumstance, a cognitive bias on the part of investors influenced asset prices.

References

Barber, B.M., Odean, T., 2000. Trading is hazardous to your wealth: The common stock investment performance of individual investors. *Journal of Finance* 55, 773-806.

Barber, B.M., Odean, T., 2008. All that glitters: The effect of attention and news on the buying behavior of individual and institutional investors. *Review of Financial Studies* 21, 785-818.

Bertrand, M., Morse, A., 2011. Information disclosure, cognitive biases, and payday borrowing. *Journal of Finance* 66, 1865-1893.

Chen, H., Chen, Z., He, Z., Liu, J., Xie, R., 2018. Pledgeability and asset prices: Evidence from the Chinese corporate bond markets. Working Paper.

Daniel, K., Hirshleifer, D., Subrahmanyam, A., 1998. Investor psychology and security market under-and overreactions. *Journal of Finance* 53, 1839-1885.

Engelberg, J., 2008. Costly information processing: Evidence from earnings announcements. Working paper.

Fan, L., Zhang, C., 2007. Beyond segmentation: The case of China's repo markets. *Journal of Banking and Finance* 31, 939-954.

Hartzmark, S.M., Shue, K., 2018. A tough act to follow: Contrast effects in financial markets. *Journal of Finance* 73, 1567-1613.

Hirshleifer, D., 2001, Investor psychology and asset pricing. *Journal of Finance* 56, 1533-1597.

Hirshleifer, D., Teoh, S.H., 2003, Limited attention, information disclosure, and financial reporting. *Journal of Financial Economics* 36, 337-386.

Hwang, B.H., Kim, H.H., 2017. It pays to write well. *Journal of Financial Economics* 124, 373-394.

Kahneman, D., Tversky, A., 1979. Prospect theory: An analysis of decision under risk. *Econometrica* 47, 263-292.

Lee, Y.J., 2012. The effect of quarterly report readability on information efficiency of stock prices. *Contemporary Accounting Research* 29, 1137-1170.

Odean, T., 1998. Volume, volatility, price, and profit when all traders are above average. *Journal of Finance* 53, 1887-1934.

Payne, J.W., Bettman, J.R., Johnson, E.J., 1993. The Adaptive Decision-maker. Pergamon, Oxford.

Pouget, S., Sauvagnat, J., Villeneuve, S., 2017. A mind is a terrible thing to change: Confirmatory bias in financial markets. *Review of Financial Studies* 30, 2066-2109.

Rennekamp, K., 2012. Processing fluency and investors' reactions to disclosure readability. *Journal of Accounting Research* 50, 1319-1354.

Slovic, P., 1972. From Shakespeare to Simon: speculations—and some evidence about man's ability to process information. Oregon Research Institute Monograph, Vol. 12, No. 2.

Stango, V., Zinman, J., 2009. Exponential growth bias and household finance. *Journal of Finance* 64, 2807-2849.

Tetlock, P.C., 2011. All the news that's fit to reprint: Do investors react to stale information?. *Review of Financial Studies* 24, 1481-1512.

You, H., Zhang, X.J., 2009. Financial reporting complexity and investor underreaction to 10-K information. *Review of Accounting studies* 14, 559-586.

Figure 1. Average actual daily repo rates across different quoted maturity repos by day of the week

This figure presents average actual daily repo rates across different quoted maturities of repos by day of the week. The sample consists of the actual daily closing interest rates of repos traded on the Shanghai Stock Exchange during the period of January 1, 2012 – December 31, 2018. Prior to May 22, 2017, the *Actual Rate* is calculated as $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. After May 22, 2017, the *Actual Rate* is calculated as $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$. *Quoted Rate* is the quoted closing rate of the repo, *Quoted Maturity* is the quoted maturity of the repo, and *Actual Maturity* is the number of days between the first settlement date and the due settlement date of the repo. Panel A reports the average rates for the January 1, 2012 – May 21, 2017, time period. Panel B reports the average rates for the May 22, 2017 – December 31, 2018, time period. The heights of the bars represent the average *Actual Rate* by day of the week during non-holiday weeks.

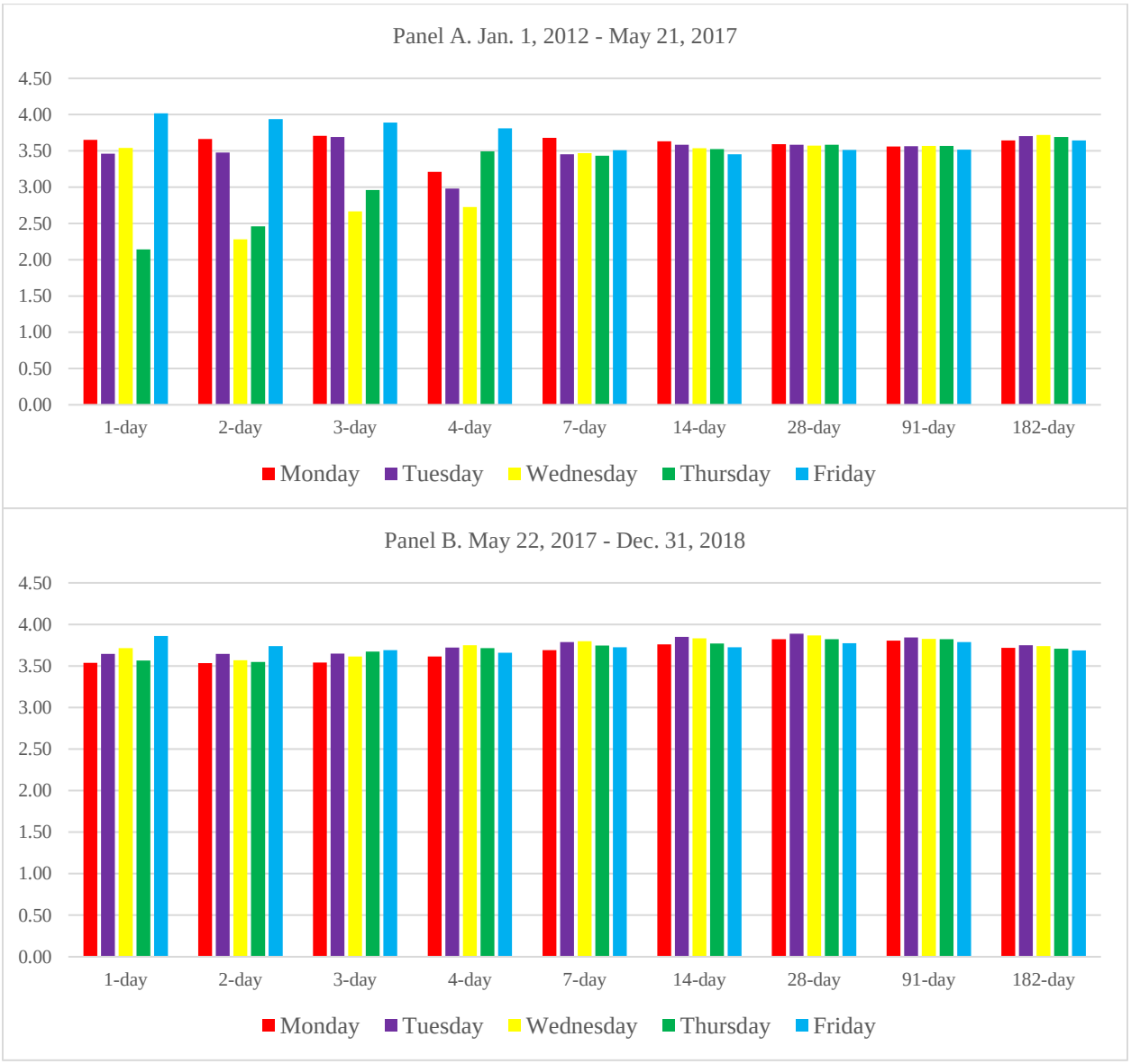

Figure 2. Average actual daily repo rates across different quoted maturity repos for pre-holiday days and other days

This figure presents average actual daily repo rates across different quoted maturities of repos for pre-holiday days on which the quoted maturities are less than the actual maturities and for other days on which the quoted maturities are the same as the actual maturities. The sample consists of the actual pre-holiday and other days closing interest rates of repos traded on Shanghai Stock Exchange during the period of January 1, 2012−December 31, 2018. Prior to May 22, 2017, the *Actual Rate* is calculated as $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. After May 22, 2017, the *Actual Rate* is calculated as $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$. *Quoted Rate* is the quoted closing rate of the repo, *Quoted Maturity* is the quoted maturity of the repo, and *Actual Maturity* is the number of days between the first settlement date and the due settlement date of the repo. Panel A reports the average rates for the January 1, 2012 – May 21, 2017, time period. Panel B reports the average rates for the May 22, 2017 – December 31, 2018, time period. The heights of the bars represent the average *Actual Rate* on trading days prior to market-closed holidays and on other days on which the quoted maturity of the repo equals the actual maturity.

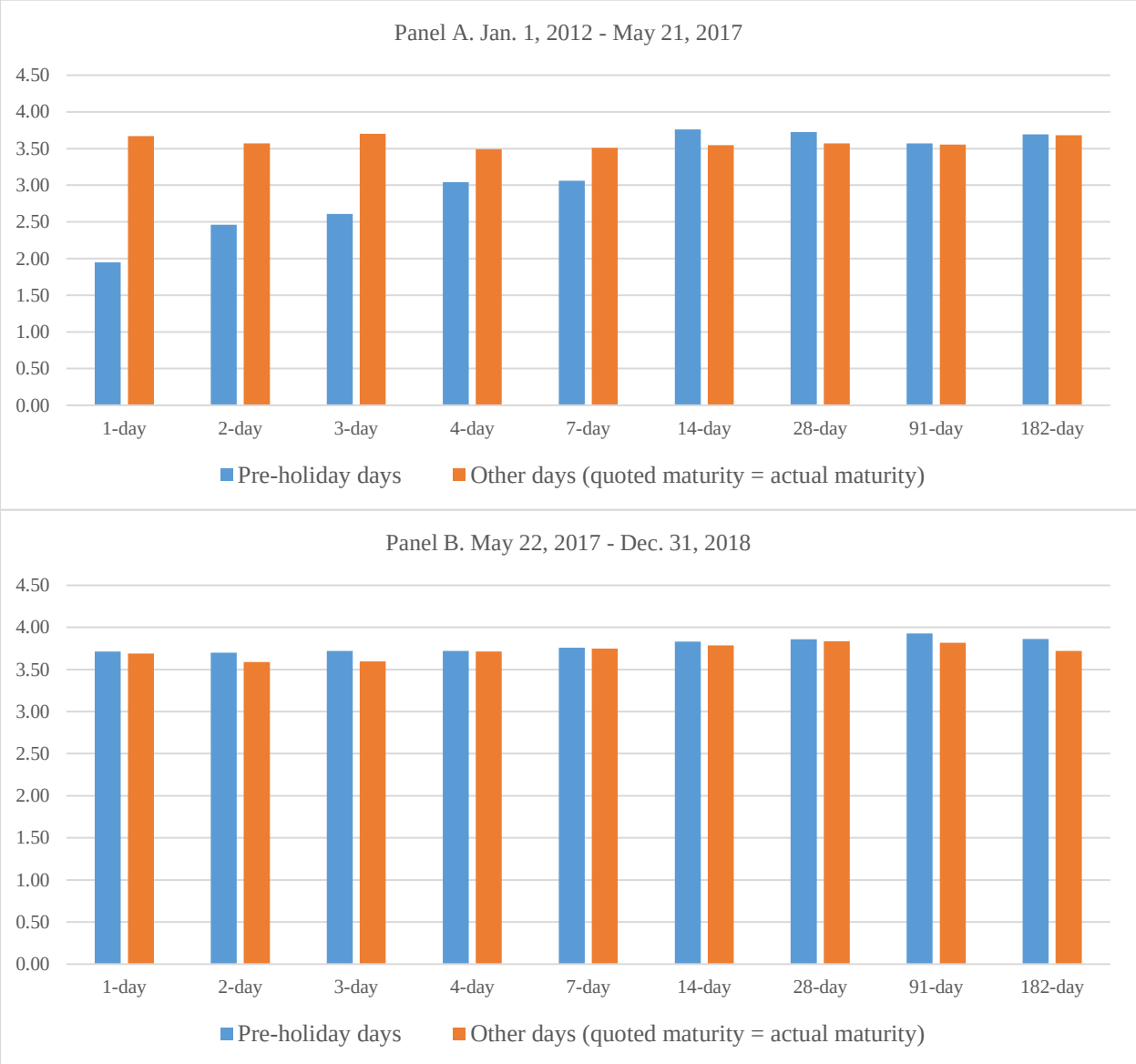

Figure 3. Average actual daily repo rates for one- and seven-day repos traded on the interbank repo market

This figure presents average actual daily repo rates by day of the week for one-day and seven-day repos traded on the Chinese interbank repo market. The sample consists of the actual daily closing interest rates of repos traded on the Chinese interbank repo market during the period of January 1, 2012−December 31, 2018. Prior to May 22, 2017, the *Actual Rate* is calculated as $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. After May 22, 2017, the *Actual Rate* is calculated as $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$. *Quoted Rate* is the quoted closing rate of the repo, *Quoted Maturity* is the quoted maturity of the repo, and *Actual Maturity* is the number of days between the first settlement date and the due settlement date of the repo. Panels A and B reports the average rates for one- and seven-day repos, respectively, by day of the week. Panels C and D report the average rates for one- and seven-day repos, respectively, for pre-holiday days on which the quoted maturity is less than the actual maturity and other days on which the quoted maturity equals the actual maturity. The heights of the bars represent the average *Actual Rate*.

Figure 3. Continued

Table 1. Trading volume of exchange-traded repos in China

This table reports trading volumes of exchange-traded repos in China. The sample consists of repos traded on the Shanghai Stock Exchange and the Shenzhen Stock Exchange during the period of January 1, 2012−December 31, 2018. Panel A reports the average daily repo trading volumes by year and by exchange. For 2017, the sample is partitioned into the pre-May 22, 2017 period (i.e., January 1, 2017−May 21, 2017) and the post-May 22, 2017 period (i.e., May 22, 2017−December 31, 2017). The trading volumes are reported in billions of U.S. dollars where the currency exchange rate is as of 12/31/2018. Panel B reports the proportion of total trading volume according to exchange for each quoted repo maturity.

Panel A. Average daily trading volume (in billion $)

Year	Shanghai Stock Exchange	Shenzhen Stock Exchange
2012	21.38	--
2013	36.57	3.18
2014	49.77	4.02
2015	71.73	5.18
2016	133.08	8.15
2017	146.21	10.65
- Pre-May 22, 2017	142.50	9.70
- Post-May 22, 2017	148.41	11.21
2018	127.62	11.88

Panel B. Percentage of total trading volume across repo maturities

Quoted Maturity	Shanghai Stock Exchange	Shenzhen Stock Exchange
1-day	86.72%	89.00%
2-day	0.97%	1.09%
3-day	1.47%	2.02%
4-day	1.26%	1.19%
7-day	7.52%	5.58%
14-day	1.48%	0.78%
28-day	0.57%	0.31%
91-day	0.01%	0.02%
182-day	0.00%	0.01%

Table 2. Actual maturities of exchange-traded repos

This table gives the actual maturities of one-, two-, three-, four- and seven-day exchange-traded repos. The actual maturity is the number of days between the first settlement date and the due settlement date of the repo. Panel A reports the actual maturities of repos initiated on weekdays of non-holiday weeks. Panel B reports the average actual maturities of repos initiated on trading days prior to market-closed holidays.

Panel A. Actual maturities of repos by day of the week for repos of various quoted maturities

Quoted Maturity	Monday	Tuesday	Wednesday	Thursday	Friday
1-day	1	1	1	3	1
2-day	2	2	4	4	1
3-day	3	3	5	4	1
4-day	6	6	5	4	2
7-day	7	7	7	7	7

Panel B. Average actual maturities for repos of various quoted maturities sorted by market-closed holidays

Holiday	1-day	2-day	3-day	4-day	7-day
Chinese New Year's Day	8.9	10.2	11.1	11.6	12.5
International Labor Day	4.7	5.7	6.4	6.9	8.9
Mid-autumn Festival	4.5	5.5	6.0	6.3	9.2
National Day	9.0	10.2	10.9	11.4	12.3
New Year's Day	4.2	4.9	5.9	6.6	9.5
Dragon Boat Festival	4.6	5.6	6.2	6.7	8.8
Tomb-sweeping Festival	4.7	5.7	6.3	6.8	9.0
Victory over Japan Day	5.0	6.0	6.5	6.5	10.0

Table 3. Analysis of actual daily repo rates for non-holiday weekdays

This table reports the results of univariate analysis of actual daily interest rates during non-holiday weeks of repos traded on the Shanghai Stock Exchange during January 1, 2012 – December 31, 2018. The data are the average *Actual Rate* of one-, two-, three-, and four-day repos where the *Actual Rate* prior to May 22, 2017 is calculated as $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. After May 22, 2017, the *Actual Rate* is calculated as $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$. The *Quoted Rate* is the reported closing repo rate, the *Quoted Maturity* is the quoted maturity of the repo, and the *Actual Maturity* is the number of days between the first settlement date and the due settlement date of the repo. The data are classified into three groups: repos initiated on trading days on which [1] the *Actual Maturity* is greater than the *Quoted Maturity*, [2] the *Actual Maturity* is the same as the *Quoted Maturity*, and [3] the *Actual Maturity* is less than the *Quoted Maturity*. Panels A, B, and C report the results for the period of January 1, 2012 – May 21, 2017, the period of the May 22, 2017 – December 31, 2018 period, and the period of January 1, 2017 - May 21, 2017, respectively. t-statistics are shown in parentheses. $*$, $**$, and $***$ denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Jan. 1, 2012 – May 21, 2017

	Actual Rates [%]			
	1-day	2-day	3-day	4-day
[1] *Quoted Maturity* < *Actual Maturity*	2.14	2.60	2.96	2.46
[2] *Quoted Maturity* = *Actual Maturity*	3.66	3.47	3.62	2.96
[3] *Quoted Maturity* > *Actual Maturity*		3.74	4.09	3.81
[4] Difference: [1] - [2]	-1.52***	-0.87***	-0.66***	-0.50***
	(-10.15)	(-9.34)	(-8.40)	(-4.46)
[5] Difference: [3] - [2]		0.27***	0.47**	0.85***
		(3.00)	(2.37)	(8.66)

Panel B. May 22, 2017 – Dec. 31, 2018

[1] *Quoted Maturity* < *Actual Maturity*	3.56	3.56	3.60	3.65
[2] *Quoted Maturity* = *Actual Maturity*	3.69	3.59	3.54	3.53
[3] *Quoted Maturity* > *Actual Maturity*		3.74	3.69	3.66
[4] Difference: [1] - [2]	-0.13	-0.03	0.06	0.12
	(-0.61)	(-0.23)	(0.36)	(0.75)
[5] Difference: [3] - [2]		0.15	0.15	0.13
		(0.72)	(0.59)	(0.48)

Panel C. Jan. 1, 2017 – May 21, 2017

[1] *Quoted Maturity* < *Actual Maturity*	2.18	2.39	2.60	2.55
[2] *Quoted Maturity* = *Actual Maturity*	4.05	3.75	3.68	2.87
[3] *Quoted Maturity* > *Actual Maturity*		4.56	4.51	4.36
[4] Difference: [1] - [2]	-1.88***	-1.35***	-1.08***	-0.32**
	(-4.04)	(-5.76)	(-4.77)	(-2.51)
[5] Difference: [3] - [2]		0.82**	0.83**	1.49***
		(2.49)	(2.14)	(2.72)

Table 4. Analysis of actual daily repo rates prior to market-closed holidays

This table reports the results of the univariate analysis of the actual daily interest rates of repos traded on the Shanghai Stock Exchange during January 1, 2012 – December 31, 2018. The data are average *Actual Rate* of one-, two-, three-, and four-day repos where the *Actual Rate* prior to May 22, 2017 is calculated as $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. After May 22, 2017, the *Actual Rate* is calculated as $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$. The *Quoted Rate* is the daily closing rate of the repo as reported in the repo quote, the *Quoted Maturity* is the quoted maturity of the repo, and the *Actual Maturity* is the number of days between the first settlement date and the due settlement date of the repo. The data are classified into two groups: [1] repos initiated on trading days prior to market-closed holidays on which the *Actual Maturity* is greater than the *Quoted Maturity* and [2] repos initiated on other days on which the *Actual Maturity* is the same as the *Quoted Maturity*. Panels A and B report the results for the period of January 1, 2012 – May 21, 2017 and the period of May 22, 2017 – December 31, 2018, respectively. t-statistics are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Jan. 1, 2012 – May 21, 2017

	Actual Rates [%]				
	1-day	2-day	3-day	4-day	7-day
[1] *Quoted Maturity* < *Actual Maturity*	1.95	2.42	2.62	2.46	3.45
[2] *Quoted Maturity* = *Actual Maturity*	3.66	3.47	3.62	2.96	3.66
[3] Difference: [1] - [2]	-1.71***	-1.05***	-1.00***	-0.50***	-0.21***
	(-3.61)	(-4.00)	(-3.16)	(-5.16)	(-2.70)
Panel B. May 22, 2017 – Dec. 31, 2018					
[1] *Quoted Maturity* < *Actual Maturity*	3.75	3.80	3.92	3.53	3.81
[2] *Quoted Maturity* = *Actual Maturity*	3.69	3.59	3.54	3.53	3.72
[3] Difference: [1] - [2]	0.06	0.21	0.38	-0.00	0.09
	(0.47)	(0.14)	(0.51)	(-0.09)	(0.97)

Table 5. Regressions of actual daily repo rates across quoted maturities of repos

This table presents the results of OLS regressions of actual daily repo rates against actual repo maturities for repos with quoted maturities of one-, two-, three-, four- and seven-days. The dependent variable is the actual daily closing rates of repos on the Shanghai Stock Exchange during January 1, 2012–December 31, 2018. Prior to May 22, 2017, the dependent variable *Actual Rate* is $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. After May 22, 2017, *Actual Rate* is $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$. *Quoted Rate* is the quoted closing rate of the repo, *Quoted Maturity* is the quoted maturity of the repo, and *Actual Maturity* is the number of days between the first settlement date and the due settlement date of the repo. The independent variables are *Quoted < Actual* (*Quoted > Actual*), an indicator that takes the value of one if the repo was initiated on trading days on which the *Quoted Maturity* is less (more) than the *Actual Maturity*. Panels A, B, and C report the results for the period of January 1, 2012 – May 21, 2017, the period of May 22, 2017 – December 31, 2018, and the period of January 1, 2017 - May 21, 2017. Year-week fixed effects are included with standard errors clustered at the year-week level. t-statistics are in parentheses. $*$, $**$, and $***$ denote statistical significance at the 10%, 5%, and 1% levels.

Panel A. Jan. 1, 2012 – May 21, 2017

Quoted Maturity	*Quoted < Actual*	*Quoted > Actual*	Obs.	Adjusted R^2
1-day	-1.765***		1,305	0.558
	(-18.70)			
2-day	-0.568***	0.221***	1,305	0.640
	(-12.24)	(2.59)		
3-day	-0.319***	0.101**	1,305	0.659
	(-11.06)	(2.74)		
4-day	-0.190***	0.179***	1,305	0.703
	(-4.18)	(15.88)		
7-day	-0.166***		1,305	0.826
	(-2.81)			

Panel B. May 22, 2017 – Dec. 31, 2018

Quoted Maturity	*Quoted < Actual*	*Quoted > Actual*	Obs.	Adjusted R^2
1-day	0.107		396	0.636
	(0.67)			
2-day	0.192	0.029	396	0.647
	(1.00)	(0.56)		
3-day	0.147	0.028	396	0.694
	(1.49)	(0.55)		
4-day	0.051	-0.092	396	0.780
	(1.49)	(-0.95)		
7-day	0.002		396	0.779
	(0.00)			

Table 5. Continued

Panel C. Jan. 1-May 21, 2017

Quoted Maturity	*Quoted < Actual*	*Quoted > Actual*	Obs.	Adjusted R^2
1-day	-1.724***		91	0.599
	(-9.89)			
2-day	-0.589***	0.317*	91	0.572
	(-4.53)	(1.92)		
3-day	-0.283***	0.229*	91	0.531
	(-3.26)	(1.91)		
4-day	-0.162**	0.188***	91	0.511
	(-2.57)	(4.96)		
7-day	-0.065***		91	0.741
	(-2.79)			

Table 6. Actual daily repo rates and actual maturities

This table presents the results of OLS regressions of actual daily repo rates against actual repo maturities for repos with quoted maturities of one-, two-, three-, four- and seven-days. The dependent variable is the actual daily closing rates of repos on the Shanghai Stock Exchange during January 1, 2012–December 31, 2018. Prior to May 22, 2017, the dependent variable *Actual Rate* is $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. After May 22, 2017, *Actual Rate* is $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$. *Quoted Rate* is the quoted closing rate of the repo, and *Quoted Maturity* is the quoted maturity of the repo. The independent variable is *Actual Maturity*, defined as the number of days between the first settlement date and the due settlement date of the repo. Panel A reports the results for the period of January 1, 2012–May 21, 2017. Panel B reports results for the period of May 22, 2017–December 31, 2018. Year-week fixed effects are included with standard errors clustered at the year-week level. t-statistics are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels.

Panel A. Jan. 1, 2012 – May 21, 2017

Quoted Maturity	*Actual Maturity*	Obs.	Adjusted R^2
1-day	-0.635***	1,305	0.548
	(-13.54)		
2-day	-0.211***	1,305	0.632
	(-14.81)		
3-day	-0.094***	1,305	0.638
	(-10.14)		
4-day	-0.044***	1,305	0.681
	(-5.82)		
7-day	-0.020***	1,305	0.835
	(-3.43)		

Panel B. May 22, 2017 – Dec. 31, 2018

Quoted Maturity	*Actual Maturity*	Obs.	Adjusted R^2
1-day	0.035	396	0.636
	(0.61)		
2-day	0.037	396	0.646
	(0.94)		
3-day	0.031	396	0.692
	(1.09)		
4-day	0.003	396	0.777
	(0.05)		
7-day	-0.008	396	0.779
	(-0.26)		

Table 7. Actual daily repo rate and actual maturities of repos on Shenzhen Stock Exchange

This table presents the results of OLS regressions of actual daily repo rates against actual repo maturities for repos with quoted maturities of one-, two-, three-, four- and seven-days. The dependent variable is the actual daily closing rates of repos on the Shenzhen Stock Exchange during January 1, 2013–December 31, 2018. Prior to May 22, 2017, the dependent variable *Actual Rate* is $(100\% + Quoted\ Rate \times Quoted\ Maturity)^{1/Actual\ Maturity} - 100\%$. After May 22, 2017, *Actual Rate* is $(100\% + Quoted\ Rate \times Actual\ Maturity)^{1/Actual\ Maturity} - 100\%$. *Quoted Rate* is the quoted closing rate of the repo, *Quoted Maturity* is the quoted maturity of the repo, and *Actual Maturity* is the number of days between the first settlement date and the due settlement date of the repo. The independent variables are *Quoted* < *Actual* (*Quoted* > *Actual*), an indicator that takes the value of one if the repo was initiated on trading days on which the *Quoted Maturity* is less (more) than the *Actual Maturity*. Panels A, B, and C report the results for the period of January 1, 2012 – May 21, 2017, the period of May 22, 2017 – December 31, 2018, and the period of January 1, 2017 - May 21, 2017. Year-week fixed effects are included with standard errors clustered at the year-week level. t-statistics are in parentheses. ∗, ∗∗, and ∗∗∗ denote statistical significance at the 10%, 5%, and 1% levels.

Panel A. Jan. 1, 2013 – May 21, 2017

Quoted Maturity	*Quoted < Actual*	*Quoted > Actual*	Obs.	Adjusted R^2
1-day	-1.804***		1,062	0.549
	(-17.48)			
2-day	-1.200***	0.740***	1,062	0.630
	(-11.49)	(14.41)		
3-day	-0.997***	0.216***	1,062	0.651
	(-10.82)	(2.49)		
4-day	-0.211**	0.104**	1,062	0.716
	(-2.42)	(2.02)		
7-day	-0.360***		1,062	0.830
	(-2.51)			

Panel B. May 22, 2017 – Dec. 31, 2018

Quoted Maturity	*Quoted < Actual*	*Quoted > Actual*	Obs.	Adjusted R^2
1-day	0.074		396	0.651
	(0.53)			
2-day	0.132	-0.022	396	0.661
	(0.80)	(-0.11)		
3-day	0.186	-0.022	396	0.714
	(1.31)	(-0.11)		
4-day	0.060	-0.083	396	0.800
	(0.87)	(-1.05)		
7-day	0.063		396	0.788
	(0.21)			

Table 7. Continued

Panel C. Jan. 1-May 21, 2017

Quoted Maturity	*Quoted < Actual*	*Quoted > Actual*	Obs.	Adjusted R^2
1-day	-1.739***		91	0.613
	(-10.15)			
2-day	-1.214***	0.320*	91	0.580
	(-5.42)	(1.65)		
3-day	-0.887***	0.370*	91	0.541
	(-3.80)	(1.68)		
4-day	-0.445**	0.722***	91	0.527
	(-2.30)	(5.11)		
7-day	-0.436***		91	0.734
	(-3.97)			