# Impact of Short-selling Restrictions on Futures Pricing:

# Evidence from China

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**ABSTRACT**

This study examines the impact of short-selling restrictions on the pricing efficiency of CSI 300 index futures contract, using intraday trading data in the Chinese capital market. In mid-2015, the Chinese regulator imposed short-selling restrictions to curb stock market volatility. Evidence indicates that restrictions over the access to stock short-selling services led to significant stock index futures mispricing, in terms of frequency and magnitude. Further, significant under-pricing of futures contracts relative to its underlying stock index is observed. This change in regulation appears to have led to the deterioration in futures market efficiency after the implementation of short-selling restrictions.

*Keywords*: CSI 300 Index Futures Contract; Index arbitrage; Short-selling restrictions

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## 1. INTRODUCTION

This study investigates the pricing efficiency of stock index futures in relation to short-selling restrictions in Chinese capital markets. Numerous empirical studies discover that index futures mispricing exists and persists in worldwide capital markets (Cronell and French, 1983; Harris, 1989; Brennan, 1990; Chung, 1991; Yadav and Pope, 1994). The continuous trading in futures and spot instruments exerts pressure on the price of the futures contracts, tending to close out any mispricing. The relative pricing relationship is maintained by arbitrageurs, who profit from any misalignment between those two instruments (MacKinlay and Ramaswamy, 1988). However, various obstacles against arbitrage trading strategies allow mispricing to persist in the market. Large volume of research examines the impact of these obstacles, such as transaction costs, restrictions on short-selling, execution risks, difficulties in implementing trading strategies, and other market variables (such as interest rate, dividend yield and tax). Among them, short-selling restrictions are considered to be one significant barrier (Puttonen and Martikainen, 1991; Pope and Yadav, 1994; Fung and Draper, 1999). When the short-selling scheme is prohibited or restricted in the stock market, "long futures" trading strategies (long position in futures contract and short position in underlying stocks) cannot be implemented by arbitrageurs. As a result, the restriction contributes to an asymmetric futures mispricing with more negative mispricing over positive (Cummings and Frino, 2011). In addition, this analysis incorporates the impact of futures market price volatility, futures contract trading volume and daily futures price movements.

China has a relatively short history of short-selling scheme (starting from 31 March 2010) and a newly introduced index futures market (the first CSI 300 index futures contract was traded from 16 April 2010). The short-selling scheme in China refers to the securities lending service, which experiences a significant growth in the past 5 years. The number of stocks which are eligible for securities lending is 10 times larger than that when the scheme was initially introduced. However, in mid-2015, restrictions on securities lending were imposed by the regulator after a tremendous stock market decline. The effect of such events on the futures market attracts significant attention. Unlike US index futures contract, few empirical studies on the pricing efficiency of the CSI 300 index futures contract are available.

The objective of this study is to examine the impact of the short-selling restrictions on the index futures pricing efficiency in China. An event study is undertaken based on the recent short-selling restriction policy imposed in the Chinese stock market. As an extension of previous research, this study incorporates three futures market factors as control variables, which are market volatility, contract trading volume and market daily price trend.

Richie et al. (2008) examine the frequency, magnitude and persistence of mispricing of the S&P 500 futures contract, with 5 levels of pre-assumed transaction costs.[1] They conclude that mispricing exists and persists in the US market, especially during high market volatility periods. Mispricing may not turn to be profitable arbitrage opportunities, taking market liquidity into consideration. Our research further investigates the relationship between short-selling restriction policy and futures market efficiency in China. The analysis is performed with 7 levels of pre-assumed transaction costs, ranging from 0 to 1.50%. In addition, Chang et al. (2014) measure the impact of short-selling restrictions on the Chinese stock market efficiency. They conclude that price efficiency improves, while stock return volatility reduces, after the short-selling ban is lifted. In our paper, we extend the investigation into the relative pricing efficiency between futures and stock markets. We find that futures mispricing exists within Chinese markets. After the short-selling restriction is imposed, the frequency of mispricing surges significantly, with a larger magnitude. Further, asymmetric distribution of futures mispricing is discovered. Under-pricing of futures contract overwhelms the overpricing in the market, especially after the short-selling restriction is imposed. This result

[1] Richie et al use 5 levels of transaction costs, namely 0.00%, 0.05%, 0.10%, 0.15% and 0.20%.

is consistent with the findings in Cummings and Frino (2011). However, unlike Richie's paper (2008), we do not observe a strong relationship between futures market liquidity and relative price efficiency. Moreover, we find mispricing occurs more frequently and with a larger relative magnitude during the periods of downward futures market price changes.

The remainder of this paper is structured as follows. Section 2 provides institutional details of the CSI 300 Index and its futures contract, as well as the short-selling scheme in China. Section 3 reviews related literatures. Section 4 discusses the possible effects of short-selling restrictions on futures market pricing efficiency. Section 5 presents the data used in this study. Section 6 outlines the research design. Section 7 reports the empirical results and Section 8 concludes.

## 2. INSTITUTIONAL DETAILS

### 2.1 CSI300 Index

China's two stock exchanges, the Shanghai Securities Exchange ("SSE") and the Shenzhen Securities Exchange ("SZSE"), were established in 1990 and 1991, respectively. China Securities Index 300 ("CSI 300 Index") is a market capitalisation weighted index that consists of 300 A-share stocks listed on the SSE and SZSE. The index represents approximately 70% of the total market capitalisation of both stock exchanges. CSI 300 Index was created by China Securities Index Company Ltd on 8 April 2005. As the first equity index covering the two exchanges together, CSI 300 index aims to reflect the price movements and performance of China A-share market.[2] It is designed for use as performance benchmarks and as a basis for derivatives innovation and indexing. The index is

[2] China Securities Index Co., Ltd, "CSI 300," http://www.csindex.com.cn/sseportal_en/csiportal/zs/jbxx/report.do?code=000300&subdir=1, accessed on 15 November 2015.

a free-float weighted index, with a base level of 1000 on 31 December 2004.[3] Both the SSE and SZSE open from 9:30 am to 11:30 am (Beijing time; GMT + 8) and from 1:00 pm to 3:00 pm (a call auction of 9:15 to 9:25 am each trading day). The active hours of CSI 300 Index are the same with above.

**2.2 CSI300 Index Futures**

The CSI 300 Index futures contract was established for domestic investors initially as a tool to manage risks in the stock market. The CSI 300 Index futures contract is traded on China Financial Futures Exchange (CFFEX), which was established in Shanghai in 2006. Later it launched CSI 300 Index futures mock trading system which provided a practical simulation of index futures to regulators and participants. The first stock index futures contract began to formally trade on 16 April 2010. The expiration date of the futures contract is the third Friday (last trading day) of the contract delivery month, postponing to the next business day if it falls on a public holiday. The contract size is the underlying index value multiplied by RMB 300. The trading time of CSI 300 index futures market is from 9:15 am to 11:30 am (Beijing time; GMT + 8) and from 1:00 pm to 3:15 pm. For last trading day (third Friday), the futures market closes at 3:30 pm[4]. The futures contracts are cash settled on the settlement date. The delivery settlement price is calculated based on the average index points in last two trading hours of that day. According to the term of maturity, there are two kinds of futures contracts, which are quarterly and non-quarterly contracts. Quarterly contract expires in the month of March, June, September and December. The contract lasts for 8 months since its inception. In addition, non-quarterly contract, which lasts for 2 months, expires in months other than the above four. At any trading day, there are four futures contracts that are actively traded in the market. They are referred to the “current month”, “next month” and the “final months” of the



[3] Bloomberg, “Shanghai Shenzhen CSI300,” http://www.bloomberg.com/quote/SHSZ300:IND, accessed on 15 November 2015.
[4] China Financial Futures Exchange, “CSI 300 Index Futures,” http://www.cffex.com.cn/en_new/sspz/hs300zs/, accessed on 15 November 2015.

next two quarters, with expiration dates in current month, next month, next quarter and next second quarter respectively.[5]

### 2.3 Short-selling Scheme in China

Short-selling scheme in China's stock market has a relatively short history. The short-selling is achieved through securities lending. On 8 January 2010, the State Council of China approved in-principle the trail launch of securities lending and margin borrowing (Bryan et al, 2010). On 12 February 2010, the China Securities Regulatory Commission ("CSRC") announced the launch of the short-selling and margin trading pilot program, which was implemented on 31 March 2010 (Shariff et al, 2013). Under this programme, 90 stocks were allowed to be sold short and bought on margin. Those stocks are constituent stocks of the Shanghai Stock Exchange 50 Index ("SSE-50") and Shenzhen Stock Exchange Component Index ("SZSE-40") (Bryan et al, 2010).[6] On 25 November 2011, the CSRC announced the abolition of the pilot program and move into normal operation. The stock list increased to 278, of which 260 stocks are the CSI 300 constituent stocks. This announcement came into effect on 5 December 2011 (Chang et al, 2014). Those stocks in the updated short-sell stock list are constituents of SSE-180 and SZSE-100 indices. In 31 January 2013, that number increased to 500, which includes all 300 constituent stocks in the CSI 300 index (Fabozzi et al, 2014). Further, in April 2015, the type of stocks that investors can borrow increased from 900 to 1,100.[7] In 2 March 2015, foreign investors were allowed to short Chinese shares for the first

[5] For instance, in January before expiration date, the four active trading contracts are January contract ("current month"), February contract ("next month"), March contract ("next quarter") and June contract ("second next quarter"). Once the January contract expires, the "current month" contract turns to be February contract, the March contract is the "next month" contract, the June contract becomes the "next quarter" contract and a new futures contract expires by September (September contract) starts trading as the "second next quarter" contract. In March before expiration, March, April and June, September contracts are trading. In March after expiration, April, May and June, September contracts are trading.

[6] This stock list was revised once in July 2010 due to changes in the composition of SSE-50 and SZSE-40 indices.

[7] CNBC, "Why China's rule changes are hitting US market?" http://www.cnbc.com/2015/04/17/why-chinas-rule-changes-are-hitting-us-markets.html, 17 April 2015, accessed on 18 November 2015.

time under the Shanghai-Hong Kong Stock Connect program. 414 shares listed on SSE are eligible for short-selling through the stock connect.[8]

### 2.4 Recent Event: Short-selling Restriction

In mid of 2015, China’s stock market experienced a tremendous drop, which evaporated almost $4 trillion in market value. On 3 August 2015, Chinese regulators imposed restrictions on the short-selling in stock markets. SSE and SZSE modified the implementation rule of margin trading and securities lending that investors who borrow shares shall wait one day to pay back their loans, which took effect immediately after announcement.[9] Under the new rule, investors are not able to close their intraday short position; instead they have to wait till the next trading day as the earliest. That rule discourages short-selling scheme that short-sellers now have to leave their position overnight, therefore are exposed to any public information disclosure before the market re-opens the next morning.[10] Some brokerage companies in China temporarily suspended their short-selling service after this restriction; Citic Securities and Huatai Securities suspended their securities lending services since that day.[11]



[8] Securities Lending Times, “Plans to boost Chinese securities lending revealed,” http://www.securitieslendingtimes.com/securitieslendingnews/article.php?article_id=219876#.VnaA6n4rKc0, 24 April 2015, accessed on 18 November 2015.

[9] SSE, “Notice on modifying Article 15 of ‘SSE Detailed Rules for Implementation of Margin Trading and Securities Lending (Revised in 2015)’,” http://english.sse.com.cn/aboutsse/news/c/c_20150804_3959339.shtml, 3 August 2015, accessed on 15 November 2015.
SZSE, “SZSE Amends Rules for Margin Trading and Securities Lending,” http://www.szse.cn/main/en/AboutSZSE/SZSENews/SZSENews/39756431.shtml, 3 August 2015, accessed on 15 November 2015.

[10] Bloomberg, “China limits Stock Market Short selling to curb volatility,” http://www.bloomberg.com/news/articles/2015-08-03/china-s-stock-markets-restrict-short-selling-to-curb-volatility, 4 August 2015, accessed on 17 November 2015.

[11] Bloomberg, “China Stocks Rise as Brokerage ban short-selling to sterm losses,” http://www.bloomberg.com/news/articles/2015-08-04/china-s-stock-futures-rise-on-more-measures-to-stabilize-markets, 4 August 2015, accessed on 17 November 2015; Huaitai Securities, “Disclosure about the modification of exchange rule,” http://www.htsc.com.cn/browser/view/commonNewsPage.jsp?&docId=16284630, 4 August 2015, accessed on 18 November 2015.

## 3. RELATED LITERATURE

The futures contract is theoretically priced based on spot price of underlying asset and affected by other economic factors. The pricing scheme, known as “cost-of-carry” model, was firstly introduced by Cronell and French in 1983. In that paper, the actual price is compared with the theoretical price for NYSE composite index futures contract and S&P 500 index futures contract (Cronell and French, 1983). Since then, a number of studies are undertaken on this topic (Harris, 1989; Brennan, 1990; Chung, 1991; Yadav and Pope, 1994). In early years after the introduction of index futures contract, it is observed that significant deviations of futures price from its theoretical futures price persist (Chung, 1991). While, index futures mispricing attracts index arbitrage trading, which is a strategy adopted by institutions or other large investors to profit from the mispricing between prices in the spot and futures markets for stock indices (Chung, 1991). Therefore, any mispricing will be ultimately eliminated by the actions of market participants in an efficient market (Richie et al., 2008). Figlewski (1984) argues that the index-futures mispricing can be the “noise” in the market and such mispricing usually disappears shortly after its occurrence. However, in real world, various market environments can result in persisted index futures mispricing. Those market factors differentiate between futures mispricing and index arbitrage.

Transaction cost is a significant driver for the index futures mispricing. The impacts of transaction costs are widely considered in existing literatures (Modest and Sundaresan, 1983; Modest, 1984; MacKinlay and Ramaswamy, 1988; Gould, 1988; Puttonen and Martikainen, 1991). Stoll and Whaley (1986) examine the pricing model by taking into account the transaction costs. They find that no arbitrage profits can be exploited when the actual futures price are within a certain deviation away from its theoretical value. Futures mispricing can be explained by transaction costs faced by market participants. Similarly, Chung discovers that hidden costs or impediments to arbitrageurs are not capture by the theoretical “cost-of-carry” model (1991). In his paper, Chung lists transaction costs involved in an index arbitrage strategy including: (1) round-trip commissions to long and short the stocks in the spot market; (2) one commission to open a position in the futures market; (3) one "market impact" cost in the stock market, which is the bid-ask spread; and (4) one "market impact" cost in the futures market. Then he performs the index-futures mispricing test based on 3 pre-set levels of transaction costs (i.e. 0.5%, 0.75% and 1%).

Regulatory constraints in the capital market can also impose a structural persistence of mispricing. Short-selling restrictions, for example, are widely implemented in many regional markets. A number of researchers have examined the impact of short-selling restrictions on index futures mispricing. Pope and Yadav (1994) investigate the London market and find that short-selling restrictions and costs are significant factors resulting in index futures mispricing. Similar findings are discovered in Finnish (Puttonen and Martikainen, 1991) and German markets (Kempf, 1998). Further, Fung and Draper (1999) observe that the removal of short-selling restrictions in Hong Kong market reduces the size and frequency of mispricing, especially the underpricing of futures contract, and speeds up the price adjustments. In addition, Cummings and Frino (2011) point out that the index-futures mispricing (SFE SPI 200) is not symmetric, with more negative mispricing over positive. This asymmetry attributes to the high cost involving short-selling transaction in Australian stock market. Those negative mispricing cannot be captured by arbitrage strategies, which requires a short position in underlying stocks. Similar results are discovered in Korean market by Gay and Jung (1999), they find that transaction cost alone is not sufficient to explain the persistence of futures underpricing and they attribute those to restrictions of short sales. In contrast, Neal (1996) argues that short-selling restrictions do not exert a significant impact on the futures mispricing because a large portion of arbitrage trades are conducted by institutions, which already owns the stocks and are not affected by the policy.

Other capital market variables, which contribute to the index futures mispricing, are covered in previous studies, such as taxation difference between stocks and futures instruments (Cornell and French, 1983); variability of dividend (Peters, 1984; Cummings and Frino, 2011); interest rate volatility (Cummings and Frino, 2011); time to maturity of index futures contract (Merrick, 1989; Cummings and Frino, 2011); and liquidity constraints of both futures contract and its underlying market (Roll et al, 2007).

Moreover, since the index itself is not tradable, arbitrage strategies are more complicated than the "cost-of-carry" model. MaKinlay and Ramaswamy (1988) argue that asset in the replicating portfolio of index futures contract is only a close substitute of underlying asset in theory. In capital market, a basket of stocks may be closely related to the index. However, the transaction costs and liquidity issues turn to be a strict barrier. Some past studies used Exchange Traded Fund (ETF) as the proxy for the index (Switzer et al., 2000; Richie et al., 2008). Richie et al (2008) adopt the S&P 500 Standard and Poor's Depository Receipt (SPDR) Exchange-Traded Fund (ETF) as the "underlying cash assets" for the S&P 500 cash index. It is argued that although some ETFs replicate the index, ETF and index are not perfectly correlated. Up to 2012, there are no ETF that completely replicates the CSI 300 index in China. As an alternative, a combination of two ETFs (i.e. ETF 180 and SI 100) can cover 93% of the 300 constituent stocks in the CSI 300 index. The correlation between that ETF portfolio and CSI 300 index is 0.9994, with tracking error of 0.188% (Slivka, 2012).

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## 4. THE EFFECTS OF SHORT-SELLING RESTRICTIONS

As an extension of previous literature that measures how the short-selling restrictions influence the futures pricing efficiency, this section discusses possible effects in Chinese index futures market. With the implementation of short-selling restrictions, the futures price becomes relatively lower than its underlying assets value. Miller (1977) states that stocks, which are restricted for short-sale, tend to be overpriced since pessimists in the market are restricted from acting on their predictions. Instead, those traders can take a short position in index futures market to reflect their beliefs. Futures price faces a downward pressure with more orders crowding on the sell side, therefore futures contracts are more under-priced than the underlying index. However, as discussed in Neal's study (1996), if arbitrage strategies are mostly undertaken by those participants who already own the stocks, the restrictions do not exert a significant impact on futures mispricing. Therefore, whether the relative pricing between market index and its futures contract is affected by short-selling restrictions is ultimately an empirical question.

In addition, one significant obstacle for index futures arbitrage is the transaction cost. However, transaction cost is not the only reason for futures mispricing. Richie et al (2008) discovers that arbitrage opportunities exist in the S&P 500 index futures market after taking into account the transaction cost. Those opportunities can be exploited by arbitrage strategies, which force the futures price towards its theoretical value. Consequently, those arbitrage opportunities will be ultimately eliminated from the market. In average, those opportunities persist in the market for less than 5 minutes (described by Richie et al, 2008). Comparatively, arbitrage opportunities may exist in CSI 300 index futures market and those are expected to be eliminated shortly after occurrence.

There is possibility that the occurrence of over-pricing and under-pricing is asymmetric in futures market. Cummings and Frino (2011) find that futures price is expected to be asymmetric around its theoretical value derived from underlying assets. With a higher stock borrowing cost than the financing cost of margin trading, arbitrageurs face larger costs in a long futures strategy (i.e. take a long position in futures contract and short position for the underlying stocks simultaneously) than the short futures strategy (i.e. take a short position in futures contract and long position for the underlying stocks at the same time). As a result, underpricing of futures is expected to occur more frequently and persist longer in the market. After the implementation of short-selling restrictions, futures contract will be more underpriced, with little or no impact on the overpricing side. Arbitrageurs are not able to exploit the opportunities of that underpricing due to the trading constraint.

Further, the futures market volatility and trading volume may contribute to futures mispricing. It is found that market volatility is associated with the existence and size of futures mispricing in US market (Richie et al, 2008). However, the direction of impact is not obvious in that research. For CSI 300 index futures, it is expected that the futures market volatility is positively related to futures mispricing. When the market is highly volatile, it is more likely that market futures price will deviate from its theoretical value derived from the underlying stock market. In addition, liquidity constraints can drive the actual futures price away from equilibrium price. Richie et al (2008) discover that mispricing occurs more when the volume of underlying assets is much smaller than that of futures. Arbitrage trading strategies may fail to be implemented due to insufficient trading volume. Therefore, it is possible that futures mispricing occurs more when the trading volume is low.

Lastly, futures market trend may also influence the mispricing. Futures and index markets do not usually move simultaneously in real practise. In a bearish futures market, the futures price is more likely to be overvalued compared to its underlying securities. Similarly, the contract may be more underpriced if the futures market is bearish.

## 5. DATA

The sample period in this study is from 30 April 2015 to 10 November 2015. All intraday analysis is partitioned into one-minute observation intervals. To minimise infrequent trading problems, only the most actively traded contracts (largest trading volume within a day) are examined. In addition, the rollover of futures contract for each month is observed.[12] In rollover period, the trading behaviour may significantly differ from the normal trading period (Alampieski and Lepone, 2009). Hence the trading day data in rollover period is eliminated from the sample.[13] As a result, the futures contract for a specific day used in this study is both the nearest-to-expiry and the daily most actively traded contract (largest trading volume).[14] Moreover, the short-selling restriction rules are announced after the market close on 3 August 2015 and take into effect since promulgation; 4 trading days before and after the implementation of the policy are excluded from our study.[15] Our sample contains 110 trading days, with 55 days on both sides of the event. For each day, the trading hours of stock index market and futures market are not the same. Therefore, for analytical purposes, futures price and its underlying stock index before either markets opens or after either of them closes are excluded from the sample. To minimise the effect of irregular trading behaviour before the market close, 10 minutes prior to the close of each market session are eliminated.



[12] The rollover effect is observed in the CSI 300 Index futures market. That effect refers to that the trading volume "rolls" into the next expired contract (regardless of monthly or quarterly contract) as approaching the expiration date. More specifically, the current month futures contract (nearest expiry contract) has the largest trading volume among four contracts on a specific day. However, before the monthly expiration date (third Friday of the month), the most actively traded contract turns to be the next nearest-to-expiry futures contract. In another word, the next nearest-to-expiry futures contract has the largest trading volume among all four contracts. For CSI 300 Index Futures Contract, the rollover effect occurs every month, 2-5 trading days before the futures contract's expiration.

[13] The rollover periods in the sample are 14 May 2015, 15 May 2015, 18 June 2015, 19 June 2015, 16 July 2015, 17 July 2015, 20 August 2015, 21 August 2015, 17 September 2015, 18 September 2015 and 16 October 2015. 9 July 2015 is eliminated due to data incompleteness.

[14] The CSI 300 index futures contracts in this analysis are CIFK5, CIFM5, CIFN5, CIFQ5, CIFU5, CIFV5, and CIFX5.

[15] 4 days before the event are 29 July 2015, 30 July 2015, 31 July 2015 and 3 August 2015; 4 days after the event are 4 August 2015, 5 August 2015, 6 August 2015 and 7 August 2015.

Consequently, the intraday trading data examined in this study is from 9:31 am to 11:20 am and from 1:01 pm to 2:50 pm, totally 220 minutes.

The CSI 300 stock index futures prices and the underlying stock index values are sourced from the Thomson Reuters Tick History (TRTH), which is provided by the Securities Industry Research Centre of Asia Pacific (SIRCA). The data set contains: (1) the last price of CSI 300 futures contracts in one minute intervals; (2) the last price of CSI 300 index in one minute intervals; (3) the open, last, highest and lowest prices of CSI 300 index futures contracts for each day; (4) the open, last, highest and lowest prices of CSI 300 index points for each day; (5) the trading volume of CSI 300 index futures contract for each day and (6) the best bid and ask price of all constituent stocks of CSI 300 Index in one minute interval. The dividend yield for CSI 300 Index is obtained from Bloomberg. The interest rate in this study is the one year benchmark lending rate in China. The rate is issued and maintained by the People's Bank of China (PBoC, the central bank of China).

## 6. METHODS

Our empirical method includes: (i) observing two measures of futures market pricing efficiency, which are the frequency of mispricing occurrence and its magnitude, relative to its underlying stock market using intraday data; (ii) relating those two measures to short-selling restriction event and other market variables. The pricing of futures contract is built on the "cost-of-carry" model (used in Cronell and French, 1983; Harris, 1989; Brennan, 1990; Chung, 1991; Yadav and Pope, 1994) as follows:

$$TFP = Ie^{[(R_f - d)\tau/365]} \quad (1)$$

The parameters in this model are: the theoretical futures price (*TFP*); the CSI 300 index point (*I*); time to expiry ($\tau$); dividend yield (*d*); and risk-free interest rate ($R_f$).

The theoretical futures price is calculated in one minute time interval for each trading day during the sample period. Then a futures price band which consists of an upper and lower bounds around a theoretical price is simulated (Chung, 1991; Richie et al, 2008). As a further extension of the analysis conducted by Richie et al (2008), the mispricing in our study is measured against 7 pre-assumed levels of transaction costs. They are 0, 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50%. Then the upper and lower theoretical futures price boundary is built.[16]

The market futures price is compared with the theoretical futures price band created above for each minute. If the market futures price is larger than the upper boundary, the futures contract is considered to be "Overpriced". Arbitrageurs may take a short position of futures contract and long the underlying stocks (refers to short futures strategy). In contrast, if the market futures price is below the lower boundary, the futures contract is considered to be "Underpriced". In order to exploit this opportunity, investors take a long position in futures contract and short the underlying stocks (refers to long futures strategy). Lastly, if the theoretical futures price locates within the futures price band, the status is regarded as being "correctly priced".

To isolate the impact of short-selling restriction, this study uses a regression-based approach to control the relevant factors that may lead to the mispricing. Our regression analysis, which is performed on daily basis, is as follows:

$$\mathrm{MIS\_FREQ_t} = \beta_0 + \beta_1 \mathrm{EVENT_t} + \beta_2 \mathrm{VOLATILITY_t} + \beta_3 \ln(\mathrm{VOLUME_t}) + \beta_4 \mathrm{DAILY\_TREND_t} + \varepsilon_t \quad (2)$$

[16] Upper Price Boundary: $UPB = TFP \times (1 + trans\_cost)$ Lower Price Boundary: $LPB = TFP \times (1 - trans\_cost)$; TFP refers to the Theoretical Futures Price via cost-of-carry model.

"$MIS\_FREQ_t$" is the frequency of futures mispricing as a percentage of total observations (i.e. 220 observations) in the day t. "$EVENT_t$" denotes the implementation of short-selling restriction from 4 August 2015. It is a dummy variable, which equals 0 for the period before the event (between 30 April 2015 and 28 July 2015) and 1 for the period after the event (between 10 August 2015 and 10 November 2015). "$VOLATILITY_t$" measures the volatility of futures market at day t. In this study, market volatility is measured as the natural logarithm of the daily highest futures price divided by lowest futures price (high-low volatility; Frino et al, 2011).[17] "$Ln(VOLUME_t)$" represents the futures contract trading volume in natural logarithm term for day t. $DAILY\_TREND_t$ represents the futures price movement in day t. It is a dummy variable, which equals 0 if the futures market price moves upwards during the trading day (the last price of futures contract at is larger than the opening price) and equals 1 if the futures market price move downwards during the day. To minimise the effects of outliers, we winsorise both dependent and independent variables (i.e. mispricing frequency, market volatility and trading volume) in the regression analysis. Extreme values are set to the 1st and 99th percentile values. In addition, the regression analysis also examines the frequency of futures overpricing ($OVER\_FREQ_t$), as well as the underpricing ($UNDER\_FREQ_t$), as the dependent variable.

Similar analysis is performed against the magnitude of futures mispricing as follows:

$$\mathrm{MIS\_MAG_t} = \beta_0 + \beta_1 \mathrm{EVENT_t} + \beta_2 \mathrm{VOLATILITY_t} + \beta_3 \ln(\mathrm{VOLUME_t}) + \beta_4 \mathrm{DAILY\_TREND_t} + \varepsilon_t \qquad (3)$$

"$MIS\_MAG_t$" measures the average relative size of futures mispricing in absolute terms for day t. The relative mispricing is calculated as absolute size of deviation of futures price away

[17] The formula is $\mathrm{Market\_volatility_t} = \ln(\mathrm{High_t} / \mathrm{Low_t})$

from the upper/lower price boundary divided by futures price for each minute. The four independent variables in formula (2) are measured in the same way as the regression analysis for the frequency of mispricing. Similar to above, regression analysis is performed on the overpricing ($OVER\_MAG_t$) and underpricing ($UNDER\_MAG_t$) separately.

## 7. RESULTS

### 7.1 Descriptive Statistics

Table 1 reports the descriptive statistics for the CSI 300 index futures contract during our sample period. We find that the futures market is less volatile after the event, which is statistically significant at 5% level. The average market volatility decreases from 5.53% to 4.23%. The trading volume of futures contracts drops significantly after the implementation of short-selling restrictions in China. After the event, the average daily volume of futures contract is 467,784, which is less than one third of that before the event (1,660,043). In addition, the average daily closing price of the futures contract reduces from 4,600 before event to 3,395 for the period after the event, which is statistically significant at 1% level. It shows that the futures market experiences a huge decline in terms of market value within the sample period.

**Table 1 here**

Table 2 presents the correlation coefficient matrix for four independent variables, which are the short-selling restriction event, daily futures price volatility, daily futures contract trading volume and futures market price trend. Consistent to previous discussion, we observe that after the short-selling restriction is implemented, both market volatility and trading volume reduce. Moreover, a positive relationship is discovered between market volatility and trading volume.

**Table 2 here**

### 7.2 Frequency of Mispricing

Table 3 reports the number and percentage of observations that the futures contract is mispriced in the period before and after the short-selling event. There are seven levels of pre-assumed transaction costs, ranging from 0 to 1.50%. From the table, futures contracts are frequently mispriced against its underlying index. For 0.25% transaction cost level, approximately 83% of observations fall out of the theoretical futures price boundary before the event. During the same period, there are still 30% of observations recorded as mispricing with a 1.50% transaction cost assumption. This implies that the transaction cost alone is insufficient to explain the futures mispricing in Chinese market. In addition, after the short selling restriction is implemented, more violations of the price boundary are observed. To illustrate, in 0.25% transaction cost level, approximately 99% of the total observations are reported as mispricing while the frequency of futures mispricing remains high at 75% at the cost level of 1.50%. Further, asymmetric futures mispricing distribution is observed in both periods. At all transaction cost levels, futures contracts have significantly more negative price violations than positive. This outcome is consistent with the theory that long futures arbitrage strategy (long position in futures contract and short position in underlying stocks) is more costly to be implemented than short futures arbitrage strategy (short position in futures contracts and long position in underlying stocks), since it is easier to short futures than underlying stocks. After the short selling event, the asymmetric distribution of mispricing is more significant, with underpricing dominating in the futures market. From 0.75% to 1.50% transaction cost levels, all of the mispricing recognised is below the lower price boundary and no overpricing is observed. This further confirms the theory that the short-selling restriction imposes a higher barrier to implement the long futures strategy for arbitrageurs.

**Table 3 here**

Table 4 presents the regression results of the daily frequency of futures mispricing against four independent variables. The dependent variable measures the percentage of observations that fall out of the non-mispricing boundary on a daily basis. The coefficient of the event variable is positive and statistically significant for all pre-assumed transaction cost levels. It implies that futures contracts are more frequently mispriced after the short-selling restriction is implemented, reducing the futures market pricing efficiency relative to its underlying stock market. In addition, futures market volatility and trading volume do not exert a significant impact on the price efficiency. However, a positive relationship between daily market movement and mispricing is observed. It shows that mispricing occurs more frequently during the periods of downward futures price changes.

**Table 4 here**

We then separate the effect of positive and negative violations of theoretical price boundaries. According to Table 5, we find that the event exerts a negative impact on the overpricing occurrence. It suggests that futures are less overpriced against its underlying index after the restriction is implemented. However, such effect is only statistically significant at a lower transaction cost levels (lower than 0.50% inclusively). No strong relationship is observed between the overpricing occurrence and other 3 futures market factors, which are market volatility, trading volume and market trend.

**Table 5 here**

Table 6 presents the regression analysis outcome for futures underpricing as the dependent variable. The short-selling restriction imposes a strong positive impact on the futures underpricing at all transaction cost levels. It suggests that lower theoretical price boundary is more frequently violated after the event. In addition, the coefficient of futures market volatility is positive and significant at 5% level, under the 1.25% and 1.50% transaction cost levels. Under these two levels of transaction cost assumption, futures contracts are more frequently underpriced when the futures market is in volatile. Similarly, a positive impact of daily price trend on futures underpricing is found at those two cost levels as well. In a bearish market, relatively more futures underpricing is discovered. However, the trading volume does not have a strong impact on the price efficiency. Further, combined with the results in Table 4 and 5, we find that the short-selling restriction policy does not influence the futures mispricing distribution symmetrically. The frequency of futures underpricing is more affected by the event. This is consistent with the theory that short-selling restriction in stock market will limit the long futures arbitrage strategies (long position in futures contracts and short position in underlying stocks), leaving more futures underpricing persisting in the market. While, the short futures trading strategy (short position in futures contracts and long position in underlying stocks) is less influenced by the regulatory policy. In addition, we do not observe the evidence that futures market illiquidity (low trading volume) is a driving factor for futures mispricing within the sample period.

**Table 6 here**

### 7.3 Magnitude of Futures Mispricing

Table 7 reports the average size of the futures mispricing before and after the short-selling restriction event. The relative magnitude of futures mispricing measures the size of deviation of market futures price away from the upper (if the futures are overpriced) or lower (if the futures are underpriced) theoretical futures price boundary relative to the market futures price.

According to the table, the relative size of mispricing is significant even with a high level of pre-assumed transaction cost. In addition, with a same level of transaction cost, the relative size of underpricing is higher than that of overpricing. It is consistent to the theory that long futures arbitrage strategy (long position in futures contract and short position in underlying stocks) is more costly to be implemented, leaving sizable underpricing in the market. The short-selling restriction further pushes up the cost of long futures trading strategy. As a result, the average relative size of mispricing after the event is significantly higher than that before the event at all transaction cost levels. It concludes that larger mispricing, in terms of magnitude, exists in the futures market, especially when there are short-selling restrictions.

**Table 7 here**

Table 8 presents the regression analysis of the daily average magnitude of futures mispricing against four independent variables. The analysis is performed with seven levels of pre-assumed transaction costs, ranging from 0 to 1.50%. As in the table, after the short-selling restriction event, the relative magnitude of mispricing increases at the transaction cost levels below 0.50% inclusive. This is consistent with our previous discussion. Market volatility imposes a positive impact on the magnitude of mispricing. When the futures market is more volatile, the larger magnitude of mispricing occurs. Moreover, for the futures market price trend, the coefficient is positive and statistically significant at 5% level at the transaction cost below 0.75% inclusive. It suggests that the deviation of the market futures price away from its theoretical price boundary is larger when the futures price decreases within the day. In addition, the impact of futures contract trading volume is not statistically significant. It illustrates that the futures market liquidity does not influence the magnitude of futures mispricing.

**Table 8 here**

Further, we focus on overpricing and underpricing separately. After the short-selling restriction event, the relative size of futures overpricing drops at all transaction cost levels (Table 9). All other three factors do not show a strong impact on the magnitude of overpricing. In Table 10, we see that the relative magnitude of underpricing increases after the event, at the transaction cost levels below 0.75% inclusive. The market volatility imposes a positive impact on the relative magnitude of futures underpricing at all cost levels. Moreover, a positive relationship between daily market trend and size of underpricing is discovered at the transaction costs below 0.25%. It indicates that when futures market is in bearish, larger underpricing is more likely to occur in the futures market. Market trading volume again does not exert a significant impact on underpricing magnitude.

**Table 9&10 here**



## 8. CONCLUSION

This study examines the impact of short-selling restrictions on the pricing efficiency of index futures market in China. It is based on a short-selling restriction event introduced by the Chinese market regulator in mid-2015. A mispricing series using one-minute contemporaneous observations from the CSI 300 index and its futures contract is constructed and analysed. Seven levels of transaction costs, ranging from 0 to 1.50%, are employed to simulate the costs faced by arbitrageurs. Mispricing is recognised when the market futures price falls outside of the theoretical futures price boundary, which is built by stock index value via the cost-of-carry model and those pre-assumed transaction costs. Mispricing is measured by its frequency and magnitude. The impact of short-selling restrictions event on those two measures is examined through regression analysis. As an extension, this study incorporates three market factors as control variables, which are futures market volatility, futures contract trading volume and futures market trend.

Results indicate that mispricing occurs frequently in the futures market, even under a high pre-assumed transaction cost level. This is consistent with findings in previous literature. With a symmetric transaction cost band over the theoretical futures price, the CSI 300 index futures contract presents an asymmetric distribution of mispricing, with more under-priced than over-priced. In addition, the magnitude of under-pricing is larger than that of overpricing before the short-selling restriction is imposed.

Results also reveal that short-selling restrictions are a significant driver for futures mispricing. After implementing a high barrier of securities lending, more mispricing occurs, with a larger magnitude. Futures overpricing becomes less prevalent and under-pricing dominates in the market in the post-event period. A positive relationship between short-selling restrictions and the futures under-pricing is observed and is statistically significant, whereas futures overpricing is less influenced by the restriction. Further, it is found that futures market daily price movement exerts a positive impact on the occurrence of futures under-pricing (and hence total mispricing) at high pre-assumed transaction cost levels, while the daily movement imposes a positive impact on the relative magnitude of futures under-pricing (and hence total mispricing) at low pre-assumed transaction cost levels. In addition, the results show that futures market trading volume does not impose significant impacts on the index futures mispricing, indicating that the futures mispricing is not driven by the futures market illiquidity.

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**Table A**

**Contract Specifications for the CSI 300 index futures contract**

| | **CSI 300 Index futures** |
|---|---|
| Underlying instrument | CSI 300 Index |
| Contract unit | CNY 300 per index point |
| Minimum price variation | 0.2 point |
| Settlement months | Monthly: current month, next month, next two calendar quarters (four total) |
| Last trading day | Third Friday of the contract month, postponed to the next business day if it falls on a public holiday |
| Limit Up/Down | +/- 10% of settlement price on the previous trading day |
| Trading hours | 9:15 – 11:30, 13:00 – 15:15 (9:15 – 11:30, 13:00 – 15:00 on last trading day) |

**Table 1**

Descriptive Statistics

| | | Pre-event | Post-event |
|---|---|---|---|
| N | | 55 | 55 |
| Volatility | Mean | 5.53%* | 4.23%* |
| | Standard Deviation | 3.21% | 2.72% |
| | Min | 1.49% | 1.49% |
| | Median | 4.58% | 2.83% |
| | Max | 13.17% | 11.85% |
| Trading Volume | Mean | 1,660,043** | 467,784** |
| | Standard Deviation | 410,401** | 768,997** |
| | Min | 414,476 | 11,664 |
| | Median | 1,642,710 | 16,232 |
| | Max | 2,594,682 | 2,425,793 |
| Daily Closing Price | Mean | 4,600** | 3,395** |
| | Standard Deviation | 546** | 310** |
| | Min | 3,463 | 2,822 |
| | Median | 4,674 | 3,377 |
| | Max | 5,335 | 4,033 |

Table 1 reports the descriptive statistics for the CSI 300 index futures contract for the sample period before and after the Short-selling Restriction is imposed. "Volatility" is the average daily volatility of the futures market. The daily volatility is calculated as the natural logarithm of daily highest price divided by lowest price ("ln(High/Low)"). "Trading Volume" is the average daily trading volume of the futures contract (number of contracts traded) during the sample period. Daily Closing Price is the average daily close price of futures contract (index points). The table presents the descriptive statistics for the 110 trading days across the implementation of the short-selling restriction, with 55 trading days on each side. The restriction takes effective from 4 August 2015. 4 trading days before and after the event are excluded from the sample. Pre-event period is between 30 April 2015 and 28 July 2015, inclusive. Post-event period is between 10 August 2015 and 10 November 2015, inclusive. Futures rollover days within the periods are eliminated. * (**) denote statistical significance at the 95% (99%) level for the mean and standard deviation before and after the event.

**Table 2**

Correlation Coefficient Matrix

| | $EVENT_t$ | $VOLATILITY_t$ | $ln(VOLUME)_t$ | $DAILY\_TREND_t$ |
|---|---|---|---|---|
| $EVENT_t$ | 1 | -0.2150* | -0.7450** | -0.1093 |
| | | (0.0241) | (<0.0001) | (0.2559) |
| $VOLATILITY_t$ | -0.2150* | 1 | 0.4098** | 0.1370 |
| | (0.0241) | | (<0.0001) | (0.1536) |
| $ln(VOLUME)_t$ | -0.7450** | 0.4098** | 1 | 0.1381 |
| | (<0.0001) | (<0.0001) | | (0.1503) |
| $DAILY\_TREND_t$ | -0.1093 | 0.1370 | 0.1381 | 1 |
| | (0.2559) | (0.1536) | (0.1503) | |

This table presents the correlation coefficient among four independent variables within the sample period. "EVENT" refers to the short-selling restriction event, which is a dummy variable. It equals 0 for the period before the event (between 30 April 2015 and 28 July 2015, inclusive) and 1 after the event (between 10 August 2015 and 10 November 2015, inclusive). $VOLATILITY_t$ is the volatility of the futures market for day t. The daily volatility is calculated as the natural logarithm of daily highest price divided by lowest price ("ln (High/Low)"). Ln $(VOLUME)_t$ is the trading volume of futures contract in natural logarithm terms at day t. $DAILY\_TREND_t$ is the futures market trend, which is a dummy variable. It equals 0 if the last price is higher than the opening price in day t, and equals 1 if the last price is lower than the opening price in day t. In the table, the first row is the correlation coefficient. * (**) denote statistical significance at the 95% (99%) level. The p-values are reported in parenthesis.

**Table 3**

**Frequency of Mispricing**

| | Pre-event | | | | Post-event | | | |
|---|---|---|---|---|---|---|---|---|
| Transaction Costs (%) | N | -1 Signal | 0 Signal | +1 Signal | N | -1 Signal | 0 Signal | +1 Signal |
| 0 | 12,100 | 7,458 | 0 | 4,642 | 12,100 | 12,089 | 0 | 11 |
| | | 62% | 0% | 38% | | 100% | 0% | 0% |
| 0.25 | 12,100 | 6,341 | 2,060 | 3,699 | 12,100 | 11,951 | 148 | 1 |
| | | 52% | 17% | 31% | | 99% | 1% | 0% |
| 0.50 | 12,100 | 5,198 | 4,061 | 2,841 | 12,100 | 11,539 | 560 | 1 |
| | | 43% | 34% | 23% | | 95% | 5% | 0% |
| 0.75 | 12,100 | 4,237 | 5,766 | 2,097 | 12,100 | 10,952 | 1,148 | 0 |
| | | 35% | 48% | 17% | | 91% | 9% | 0% |
| 1.00 | 12,100 | 3,419 | 6,996 | 1,685 | 12,100 | 10,491 | 1,609 | 0 |
| | | 28% | 58% | 14% | | 87% | 13% | 0% |
| 1.25 | 12,100 | 2,879 | 7,850 | 1,371 | 12,100 | 9,803 | 2,297 | 0 |
| | | 24% | 65% | 11% | | 81% | 19% | 0% |
| 1.50 | 12,100 | 2,615 | 8,447 | 1,038 | 12,100 | 9,055 | 3,045 | 0 |
| | | 22% | 70% | 9% | | 75% | 25% | 0% |

This table reports the number and percentage of non-mispricing (*0 Signal*), overpricing (*+1 Signal*), and underpricing (*-1 Signal*) of CSI 300 index futures contract before and after the event, with 7 levels of pre-assumed transaction costs (ranging from 0 to 1.50%). If the market futures price is above (below) the upper (lower) price boundary of theoretical futures price, it is recognised as overpricing (underpricing), otherwise it is correctly priced. The above table is based on 110 trading days, with 220 minutes of observations per day. The restriction takes effective from 4 August 2015. 4 days before and after the event are excluded from the sample. Pre-event period is between 30 April 2015 and 28 July 2015, inclusive. Post-event period is between 10 August 2015 and 10 November 2015, inclusive. Futures rollover days within the periods are eliminated. For each period, there are 12,100 observations, comprising of 3 signals. The first row is the number of observation (both in number and minute). The second row the proportion of signals within each period. The proportions of +1 signal and -1 signal are statistically different using a binomial test.

**Table 4**

Regression of Daily Mispricing Occurrence

| Transaction Cost (%) | Constant | $EVENT_t$ | $VOLATILITY_t$ | $\ln(VOLUME)_t$ | $DAILY\_TREND_t$ | Adj. $R^2$ | N |
|---|---|---|---|---|---|---|---|
| 0.25 | 0.8131** | 0.1610** | 0.8430 | -3.238 | 0.02850 | 0.1885 | 110 |
| | (<0.0001) | (<0.0001) | (0.1442) | (0.5186) | (0.3068) | | |
| 0.50 | 0.5221** | 0.3206** | 1.596 | 0.6526 | 0.07744 | 0.2268 | 110 |
| | (0.0019) | (<0.0001) | (0.1215) | (0.9582) | (0.0859) | | |
| 0.75 | 0.2331* | 0.4466** | 2.051 | 8.024 | 0.1071* | 0.2570 | 110 |
| | (0.4022) | (<0.0001) | (0.0949) | (0.6909) | (0.0484) | | |
| 1.00 | 0.1966 | 0.4950** | 2.138 | 3.076 | 0.1084* | 0.2869 | 110 |
| | (0.5101) | (<0.0001) | (0.1058) | (0.8884) | (0.0456) | | |
| 1.25 | 0.3529 | 0.4556** | 2.539 | -14.92 | 0.1223* | 0.2865 | 110 |
| | (0.3286) | (<0.0001) | (0.0704) | (0.5685) | (0.0243) | | |
| 1.50 | 0.5611 | 0.3832* | 2.954 | -34.59 | 0.1231* | 0.2743 | 110 |
| | (0.2423) | (0.0116) | (0.0660) | (0.3205) | (0.0281) | | |

This table presents the regression analysis of the daily average frequency of futures mispricing occurrence against four independent variables: $MIS\_FREQ_t = \beta_0 + \beta_1 EVENT_t + \beta_2 VOLATILITY_t + \beta_3 \ln(VOLUME_t) + \beta_4 DAILY\_TREND_t + \varepsilon_t$. "$MIS\_FREQ_t$" is the percentage of observation of futures price that beyond/below the upper/lower of theoretical futures non-mispricing boundaries at day t. "EVENT" refers to the short-selling restriction event, which is a dummy variable. It equals 0 for the period before the event (between 30 April 2015 and 28 July 2015, inclusive) and 1 after the event (between 10 August 2015 and 10 November 2015, inclusive). $VOLATILITY_t$ is the volatility of the futures market for day t. The daily volatility is calculated as the natural logarithm of daily highest price divided by lowest price ("ln (High/Low)"). Ln $(VOLUME)_t$ is the trading volume of futures contract in natural logarithm terms at day t. $DAILY\_TREND_t$ is the futures market trend, which is a dummy variable. It equals 0 if the last price is higher than the opening price in day t, and equals 1 if the last price is lower than the opening price in day t. In the table, the first row is the correlation coefficient. * (**) denote statistical significance at the 95% (99%) level. The p-values are reported in parenthesis. The regression adopts the Newy-West estimators. In addition, the table contains the Constant, Adjusted $R^2$ and Sample size of the regression. The sample size for each analysis is 110 (trading days). The regression analysis is performed with 7 levels of pre-assumed transaction cost, ranging from 0 to 1.50%. 0 transaction cost is not presented in the table. Under that condition, futures are mispriced at each trading minute regardless of those four independent variables.

**Table 5**

Regression of Daily Overpricing Occurrence

| Transaction Cost (%) | Constant | $EVENT_t$ | $VOLATILITY_t$ | $\ln(VOLUME)_t$ | $DAILY\_TREND_t$ | Adj. $R^2$ | N |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.3746** | -0.3792** | 0.04322 | 2.678 | -0.05434 | 0.2640 | 110 |
| | (<0.0001) | (<0.0001) | (0.9724) | (0.7526) | (0.2111) | | |
| 0.25 | 0.3044** | -0.3041** | 0.2948 | 0.7813 | -0.04497 | 0.2030 | 110 |
| | (0.0004) | (0.0011) | (0.8132) | (0.9224) | (0.2913) | | |
| 0.50 | 0.2319** | -0.2336** | 0.3982 | -0.7438 | -0.01456 | 0.1388 | 110 |
| | (0.0043) | (0.0081) | (0.6974) | (0.9108) | (0.6720) | | |
| 0.75 | 0.1609* | -0.1706 | 0.3241 | -0.7428 | 0.008835 | 0.0862 | 110 |
| | (0.0200) | (0.0332) | (0.7033) | (0.8966) | (0.7046) | | |
| 1.00 | 0.1099* | -0.1327 | -0.05054 | 1.839 | 0.01005 | 0.0562 | 110 |
| | (0.0495) | (0.0684) | (0.9440) | (0.7189) | (0.6418) | | |
| 1.25 | 0.07496 | -0.1047 | -0.2751 | 3.162 | 0.01410 | 0.0437 | 110 |
| | (0.1342) | (0.1073) | (0.6352) | (0.4746) | (0.5487) | | |
| 1.50 | 0.05238 | -0.07751 | -0.2215 | 2.352 | 0.01845 | 0.0321 | 110 |
| | (-0.1974) | (0.1381) | (0.6118) | (0.4931) | (0.4863) | | |

This table presents the regression analysis of the daily average frequency of futures overpricing occurrence against four independent variables: $OVER\_FREQ_t = \beta_0 + \beta_1 EVENT_t + \beta_2 VOLATILITY_t + \beta_3 \ln(VOLUME_t) + \beta_4 DAILY\_TREND_t + \varepsilon_t$. "$OVER\_FREQ_t$" is the percentage of observation of futures price that beyond the upper of theoretical futures non-mispricing boundary at day t. "EVENT" refers to the short-selling restriction event, which is a dummy variable. It equals 0 for the period before the event (between 30 April 2015 and 28 July 2015, inclusive) and 1 after the event (between 10 August 2015 and 10 November 2015, inclusive). $VOLATILITY_t$ is the volatility of the futures market for day t. The daily volatility is calculated as the natural logarithm of daily highest price divided by lowest price ("ln (High/Low)"). Ln $(VOLUME)_t$ is the trading volume of futures contract in natural logarithm terms at day t. $DAILY\_TREND_t$ is the futures market trend, which is a dummy variable. It equals 0 if the last price is higher than the opening price in day t, and equals 1 if the last price is lower than the opening price in day t. In the table, the first row is the correlation coefficient. * (**) denote statistical significance at the 95% (99%) level. The p-values are reported in parenthesis. The regression adopts the Newy-West estimators. In addition, the table contains the Constant, Adjusted $R^2$ and Sample size of the regression. The sample size for each analysis is 110 (trading days). The regression analysis is performed with 7 levels of pre-assumed transaction cost, ranging from 0 to 1.50%.

## Table 6

Regression of Daily Underpricing Occurrence

| Transaction Cost (%) | Constant | $EVENT_t$ | $VOLATILITY_t$ | $\ln(VOLUME)_t$ | $DAILY\_TREND_t$ | Adj. $R^2$ | N |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.6254** | 0.3792** | -0.04322 | -2.678 | 0.05434 | 0.2640 | 110 |
| | (<0.0001) | (<0.0001) | (0.9747) | (0.7526) | (0.2111) | | |
| 0.25 | 0.5084** | 0.4654** | 0.5502 | -4.036 | 0.07375 | 0.3506 | 110 |
| | (<0.0001) | (<0.0001) | (0.6871) | (0.6420) | (0.0892) | | |
| 0.50 | 0.2903 | 0.5542** | 1.198 | 1.369 | 0.09199 | 0.3912 | 110 |
| | (0.0899) | (<0.0001) | (0.4054) | (0.9144) | (0.0599) | | |
| 0.75 | 0.07224 | 0.6172** | 1.727 | 8.767 | 0.09827 | 0.3949 | 110 |
| | (0.7943) | (<0.0001) | (0.2046) | (0.6612) | (0.0625) | | |
| 1.00 | 0.08669 | 0.6277** | 2.188 | 1.236 | 0.09822 | 0.4222 | 110 |
| | (0.7725) | (<0.0001) | (0.0812) | (0.9545) | (0.0546) | | |
| 1.25 | 0.2778 | 0.5604** | 2.816* | -18.10 | 0.1083* | 0.4029 | 110 |
| | (0.4366) | (<0.0001) | (0.0183) | (0.4767) | (0.0332) | | |
| 1.50 | 0.5079 | 0.4619** | 3.188* | -37.09 | 0.1062* | 0.3587 | 110 |
| | (0.2826) | (0.0022) | (0.0216) | (0.2741) | (0.0405) | | |

This table presents the regression analysis of the daily average frequency of futures underpricing occurrence against four independent variables: $UNDER\_FREQ_t = \beta_0 + \beta_1 EVENT_t + \beta_2 VOLATILITY_t + \beta_3 \ln(VOLUME_t) + \beta_4 DAILY\_TREND_t + \varepsilon_t$. "$UNDER\_FREQ_t$" is the percentage of observation of futures price that below the lower of theoretical futures non-mispricing boundary at day t. "EVENT" refers to the short-selling restriction event, which is a dummy variable. It equals 0 for the period before the event (between 30 April 2015 and 28 July 2015, inclusive) and 1 after the event (between 10 August 2015 and 10 November 2015, inclusive). $VOLATILITY_t$ is the volatility of the futures market for day t. The daily volatility is calculated as the natural logarithm of daily highest price divided by lowest price ("ln (High/Low)"). Ln $(VOLUME)_t$ is the trading volume of futures contract in natural logarithm terms at day t. $DAILY\_TREND_t$ is the futures market trend, which is a dummy variable. It equals 0 if the last price is higher than the opening price in day t, and equals 1 if the last price is lower than the opening price in day t. In the table, the first row is the correlation coefficient. * (**) denote statistical significance at the 95% (99%) level. The p-values are reported in parenthesis. The regression adopts the Newy-West estimators. In addition, the table contains the Constant, Adjusted $R^2$ and Sample size of the regression. The sample size for each analysis is 110 (trading days). The regression analysis is performed with 7 levels of pre-assumed transaction cost, ranging from 0 to 1.50%.

**Table 7**

Descriptive Statistics of Relative Mispricing Magnitude

| Transaction cost (%) | N | Pre- Mispricing (%) | Post- Mispricing (%) | Pre- Overpricing (%) | Post- Overpricing (%) | Pre- Underpricing (%) | Post- Underpricing (%) |
|---|---|---|---|---|---|---|---|
| 0.00 | 110 | 1.339** | 2.969** | 0.571** | 0.142** | 1.278** | 2.969** |
| 0.25 | 110 | 1.148** | 2.717** | 0.545 | 0.413 | 1.187** | 2.717** |
| 0.50 | 110 | 1.015** | 2.470** | 0.506 | 0.164 | 1.139** | 2.470** |
| 0.75 | 110 | 0.959** | 2.276** | 0.432 | 0.000 | 1.178** | 2.276** |
| 1.00 | 110 | 1.001** | 2.172** | 0.445 | 0.000 | 1.234* | 2.172* |
| 1.25 | 110 | 1.015** | 1.986** | 0.391 | 0.000 | 1.271 | 1.986 |
| 1.50 | 110 | 0.957** | 1.803** | 0.320 | 0.000 | 1.225 | 1.803 |

This table reports the daily average of the relative magnitude of futures mispricing. 7 levels of pre-assumed transaction costs are adopted (ranging from 0 to 1.50%). The relative magnitude of futures mispricing measures the absolute size of the deviation of market futures price away from the upper (if overpricing) or lower (if underpricing) theoretical futures price boundary relative to the market futures price in one minute interval. That for futures over/underpricing measures the absolute size of the deviation of market futures price away from the upper/lower theoretical futures price boundary relative to the market futures price in one minute interval. Those measures are compared before (30 April 2015 – 28 July 2015, inclusive) and after (10 August 2015 – 10 November 2015, inclusive) the event. * (**) denote statistical significance at the 95% (99%) level for the mean before and after the event (refers to the "t-test"). The unit of relative magnitude is in %.

## Table 8

Regression of Average Daily Mispricing Magnitude

| Transaction Cost (%) | Constant | $EVENT_t$ | $VOLATILITY_t$ | $\ln(VOLUME)_t$ | $DAILY\_TREND_t$ | Adj. $R^2$ | N |
|---|---|---|---|---|---|---|---|
| 0.00 | -0.0184 | 0.0236* | 0.1547 | 1.4682 | 0.0038* | 0.2897 | 110 |
| | (0.5845) | (0.0382) | (0.0522) | (0.5373) | (0.0271) | | |
| 0.25 | -0.0202 | 0.0230* | 0.1551* | 1.4649 | 0.0037* | 0.2857 | 110 |
| | (0.5464) | (0.0422) | (0.0489) | (0.5362) | (0.0311) | | |
| 0.50 | -0.0215 | 0.0221* | 0.1539* | 1.4535 | 0.0034* | 0.2793 | 110 |
| | (0.5182) | (0.0488) | (0.0483) | (0.5374) | (0.0395) | | |
| 0.75 | -0.0223 | 0.0210 | 0.1522* | 1.4296 | 0.0031* | 0.2714 | 110 |
| | (0.4992) | (0.0585) | (0.0476) | (0.5411) | (0.0499) | | |
| 1.00 | -0.0225 | 0.0197 | 0.1561* | 1.3669 | 0.0028 | 0.2686 | 110 |
| | (0.4855) | (0.0696) | (0.0366) | (0.5496) | (0.0657) | | |
| 1.25 | -0.0235 | 0.0187 | 0.1498* | 1.3952 | 0.0027 | 0.2616 | 110 |
| | (0.4569) | (0.0800) | (0.0377) | (0.5326) | (0.0631) | | |
| 1.50 | -0.0249 | 0.0177 | 0.1411* | 1.4680 | 0.0026 | 0.2538 | 110 |
| | (0.4189) | (0.0886) | (0.0392) | (0.4993) | (0.0639) | | |

This table presents the regression analysis of the daily average magnitude of futures mispricing against four independent variables: $MIS\_MAG_t = \beta_0 + \beta_1 EVENT_t + \beta_2 VOLATILITY_t + \beta_3 \ln(VOLUME_t) + \beta_4 DAILY\_TREND_t + \varepsilon_t$. "$MIS\_MAG_t$" is the relative size of futures mispricing, which is the deviation of futures price to the upper/lower of theoretical futures non-mispricing boundaries at day t in average. "EVENT" refers to the short-selling restriction event, which is a dummy variable. It equals 0 for the period before the event (between 30 April 2015 and 28 July 2015, inclusive) and 1 after the event (between 10 August 2015 and 10 November 2015, inclusive). $VOLATILITY_t$ is the volatility of the futures market for day t. The daily volatility is calculated as the natural logarithm of daily highest price divided by lowest price ("ln (High/Low)"). Ln $(VOLUME)_t$ is the trading volume of futures contract in natural logarithm terms at day t. $DAILY\_TREND_t$ is the futures market trend, which is a dummy variable. It equals 0 if the last price is higher than the opening price in day t, and equals 1 if the last price is lower than the opening price in day t. In the table, the first row is the correlation coefficient. * (**) denote statistical significance at the 95% (99%) level. The p-values are reported in parenthesis. The regression adopts the Newy-West estimators. In addition, the table contains the Constant, Adjusted $R^2$ and Sample size of the regression. The sample size for each analysis is 110 (trading days). The regression analysis is performed with 7 levels of pre-assumed transaction cost, ranging from 0 to 1.50%. 0 transaction cost is not presented in the table. Under that condition, futures are mispriced at each trading minute regardless of those four independent variables.

**Table 9**

Regression of Average Daily Overpricing Magnitude

| Transaction Cost (%) | Constant | $EVENT_t$ | $VOLATILITY_t$ | $\ln(VOLUME)_t$ | $DAILY\_TREND_t$ | Adj. $R^2$ | N |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.0047** | -0.0040** | 0.0090 | -0.0824 | -0.0001 | 0.1793 | 110 |
| | (0.0013) | (0.0028) | (0.5457) | (0.5096) | (0.8211) | | |
| 0.25 | 0.0043** | -0.0033** | 0.0120 | -0.1361 | 0.0000 | 0.1456 | 110 |
| | (0.0047) | (0.0055) | (0.3573) | (0.2954) | (0.9565) | | |
| 0.50 | 0.0031** | -0.0025** | 0.0093 | -0.0975 | 0.0001 | 0.1216 | 110 |
| | (0.0073) | (0.0097) | (0.3542) | (0.3334) | (0.7980) | | |
| 0.75 | 0.0022** | -0.0018* | 0.0077 | -0.0681 | 0.0001 | 0.1087 | 110 |
| | (0.0099) | (0.0145) | (0.3032) | (0.3586) | (0.7851) | | |
| 1.00 | 0.0021 | -0.0015* | 0.0069 | -0.0907 | 0.0002 | 0.0867 | 110 |
| | (0.0555) | (0.0261) | (0.3316) | (0.3158) | (0.4977) | | |
| 1.25 | 0.0016 | -0.0011* | 0.0054 | -0.0711 | 0.0002 | 0.0782 | 110 |
| | (0.0663) | (0.0336) | (0.3393) | (0.3055) | (0.4595) | | |
| 1.50 | 0.0011 | -0.0007* | 0.0042 | -0.0504 | 0.0001 | 0.0749 | 110 |
| | (0.0705) | (0.0393) | (0.3260) | (0.3005) | (0.3796) | | |

This table presents the regression analysis of the daily average magnitude of futures overpricing against four independent variables: $OVER\_MAG_t = \beta_0 + \beta_1 EVENT_t + \beta_2 VOLATILITY_t + \beta_3 \ln(VOLUME_t) + \beta_4 DAILY\_TREND_t + \varepsilon_t$. "$OVER\_MAG_t$" is the relative size of futures mispricing, which is the deviation of futures price to the upper theoretical futures non-mispricing boundary at day t in average. "EVENT" refers to the short-selling restriction event, which is a dummy variable. It equals 0 for the period before the event (between 30 April 2015 and 28 July 2015, inclusive) and 1 after the event (between 10 August 2015 and 10 November 2015, inclusive). $VOLATILITY_t$ is the volatility of the futures market for day t. The daily volatility is calculated as the natural logarithm of daily highest price divided by lowest price ("ln (High/Low)"). Ln $(VOLUME)_t$ is the trading volume of futures contract in natural logarithm terms at day t. $DAILY\_TREND_t$ is the futures market trend, which is a dummy variable. It equals 0 if the last price is higher than the opening price in day t, and equals 1 if the last price is lower than the opening price in day t. In the table, the first row is the correlation coefficient. * (**) denote statistical significance at the 95% (99%) level. The p-values are reported in parenthesis. The regression adopts the Newy-West estimators. In addition, the table contains the Constant, Adjusted $R^2$ and Sample size of the regression. The sample size for each analysis is 110 (trading days). The regression analysis is performed with 7 levels of pre-assumed transaction cost, ranging from 0 to 1.50%. 0 transaction cost is not presented in the table. Under that condition, futures are mispriced at each trading minute regardless of those four independent variables.

**Table 10**

Regression of Average Daily Underpricing Magnitude

| Transaction Cost (%) | Constant | $EVENT_t$ | $VOLATILITY_t$ | $\ln(VOLUME)_t$ | $DAILY\_TREND_t$ | Adj. $R^2$ | N |
|---|---|---|---|---|---|---|---|
| 0.00 | -0.0200 | 0.0261* | 0.1657* | 1.3533 | 0.0038* | 0.3296 | 110 |
| | (0.5462) | (0.0220) | (0.0308) | (0.5637) | (0.0298) | | |
| 0.25 | -0.0214 | 0.0250* | 0.1640* | 1.3694 | 0.0036* | 0.3193 | 110 |
| | (0.5171) | (0.0271) | (0.0315) | (0.5581) | (0.0362) | | |
| 0.50 | -0.0223 | 0.0236* | 0.1624* | 1.3676 | 0.0032 | 0.3068 | 110 |
| | (0.4979) | (0.0348) | (0.0320) | (0.5570) | (0.0515) | | |
| 0.75 | -0.0229 | 0.0222* | 0.1588* | 1.3639 | 0.0029 | 0.2929 | 110 |
| | (0.4842) | (0.0455) | (0.0343) | (0.5560) | (0.0656) | | |
| 1.00 | -0.0232 | 0.0207 | 0.1577* | 1.3385 | 0.0028 | 0.2829 | 110 |
| | (0.4720) | (0.0579) | (0.0319) | (0.5565) | (0.0727) | | |
| 1.25 | -0.0241 | 0.0193 | 0.1499* | 1.3830 | 0.0027 | 0.2714 | 110 |
| | (0.4462) | (0.0701) | (0.0354) | (0.5356) | (0.0670) | | |
| 1.50 | -0.0252 | 0.0181 | 0.1410* | 1.4597 | 0.0026 | 0.2600 | 110 |
| | (0.4121) | (0.0810) | (0.0384) | (0.5013) | (0.0682) | | |

This table presents the regression analysis of the daily average magnitude of futures mispricing against four independent variables: $UNDER\_MAG_t = \beta_0 + \beta_1 EVENT_t + \beta_2 VOLATILITY_t + \beta_3 \ln(VOLUME_t) + \beta_4 DAILY\_TREND_t + \varepsilon_t$. "$UNDER\_MAG_t$" is the relative size of futures underpricing, which is the deviation of futures price to the lower of theoretical futures non-mispricing boundary at day t in average. "EVENT" refers to the short-selling restriction event, which is a dummy variable. It equals 0 for the period before the event (between 30 April 2015 and 28 July 2015, inclusive) and 1 after the event (between 10 August 2015 and 10 November 2015, inclusive). $VOLATILITY_t$ is the volatility of the futures market for day t. The daily volatility is calculated as the natural logarithm of daily highest price divided by lowest price ("ln (High/Low)"). Ln $(VOLUME)_t$ is the trading volume of futures contract in natural logarithm terms at day t. $DAILY\_TREND_t$ is the futures market trend, which is a dummy variable. It equals 0 if the last price is higher than the opening price in day t, and equals 1 if the last price is lower than the opening price in day t. In the table, the first row is the correlation coefficient. * (**) denote statistical significance at the 95% (99%) level. The p-values are reported in parenthesis. The regression adopts the Newy-West estimators. In addition, the table contains the Constant, Adjusted $R^2$ and Sample size of the regression. The sample size for each analysis is 110 (trading days). The regression analysis is performed with 7 levels of pre-assumed transaction cost, ranging from 0 to 1.50%. 0 transaction cost is not presented in the table. Under that condition, futures are mispriced at each trading minute regardless of those four independent variables.