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Futures mispricing, order imbalance, and short-selling constraints

Emily Lin [a,b,*], Cheng-Few Lee [c,d], Kehluh Wang [c]

[a] Department of Int'l Business, St. John's University, 499, Sec. 4, Tam King Rd. Tamsui, New Taipei City, Taiwan
[b] Department of Management Science, National Chiao Tung University, 1001 University Road, Hsinchu, Taiwan
[c] Graduate Institute of Finance, National Chiao Tung University, 1001 University Road, Hsinchu, Taiwan
[d] Department of Finance & Economics, Newark and New Brunswick, Rutgers University, Piscataway, NJ, USA

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ABSTRACT

The aim of the research is to determine how the lifting of price restrictions on short sales and security-lending sales affects market efficiency, liquidity and arbitrage opportunities. The study examines trading behaviors of large and small traders separated by their transaction costs and shows the lifting of price restrictions strengthens the correlation between extreme order imbalance and extreme mispricing. Also, autocorrelations of the underpricing and overpricing persist longer, in particular for big traders, and so do those of buy-side and sell-side order imbalances. However, the outcomes for the post-lifting market efficiency are mixed. This paper provides evidence that lifting price restrictions enhances informed trading and the lead–lag relationship between mispricing and order imbalance in the cash and futures markets.

1. Introduction

Although short selling[1] has existed for years in major financial markets around the world, its effects on market efficiency, especially pricing efficiency, remain of interest to financial researchers. Governments often restrict short selling in an attempt to keep security prices high, but how short selling impacts capital markets is highly controversial, with regulation varying widely across countries and capital markets. A variety of empirical or theoretical studies over the past decades point to impediments associated with short sales as possibly creating arbitrage opportunities. The measure of these opportunities is mispricing. We are interested in examining whether lifting short-sale price restrictions on the underlying component stocks improves the mispricing, and whether increased liquidity in the stock market caused by eliminating price restrictions spills into the futures market.

The price restrictions on short sales or securities lending sales[2] in Taiwan come from a trading rule stipulating that the prices of short selling or security lending selling (lending selling afterwards) must be equal to or above the previous closing price. Short sales differ from lending sales in several ways. Shares for lending sales come from the Security Lending Center, securities finance

* Corresponding author at: St. John's University, 499, Sec. 4, Tam King Road, Tamsui District, New Taipei City, 25135 Taiwan. Tel.: +886 2 2801 3131x6754; fax: +886 2 2801 3131x6773.
E-mail address: mlin@mail.sju.edu.tw (E. Lin).

[1] Short selling refers to the ability of an investor to sell a borrowed security to a third party.

[2] Securities lending, or stock lending, refers to the lending of securities by one party to another. Security-lending sale thus refers to a transaction in which the seller borrows the stocks for sale.

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companies, and brokerage firms. Shares for short selling come from securities finance companies and brokerage firms. The initial margin is around 140% for lending sales but only 90% for short sales. The borrowing fee is fixed at 0.08% for short sales, but is based on each day's closing price for lending sales.

Throughout this study, we used two types of transaction costs (low for large traders and high for small traders) to explore futures mispricing and emphasize situations in which different traders face different kinds of short selling or lending selling restrictions. As around 95% of short sellers are individuals and around 95% of lending sellers are from institutions, we can track their different effects on the misalignment of index futures and cash index during different market events, as well as on signed order imbalances. Therefore, this study also investigates the price pressure exerted by arbitrageurs and speculators in the futures market, both before and after price restrictions are lifted.

The Taiwan Stock Exchange Corporation (TWSE) removed price restrictions on short sales or lending sales based on a subset of stocks listed in the Taiwan Weighted Average Stock Index (TAIEX). They did so because price restrictions may have different effects on stocks with different sizes of market capitalization. TWSE removed price restrictions on short sales in May 2005 on all stocks listed in the Taiwan 50 index, which consists of the top 50 stocks traded in the Taiwan Stock market (defined by market capitalization), then lifted price restrictions on lending sales on stocks listed in the same index in May 2007, and then relaxed price restrictions on short sales and lending sales on the same day for all stocks listed in the Taiwan mid-cap 100 index in November 2007. The Taiwan mid-cap 100 index consists of stocks ranked in size from 51 to 150. The first lifting of price restrictions on short sales exempted around 67% of market capitalization of the TAIEX, the second lifting of price restrictions on lending sales exempted around the same percentage of market capitalization of the TAIEX, and the third lifting on short sales and lending sales exempted 17.40% more market capitalization to equal to around 84% of the TAIEX (the exact percentage is shown in Table 1). For the entire market or individual stock, however, the volume of short sales plus the volume of security lending for selling purpose is limited to 25% of the total number of shares outstanding.

According to a survey conducted by Charoenrook and Daouk (2004) for short-selling regulations and feasibility from 111 countries, more than 55% of all the financial markets in the world prohibit short selling from WWII through 2002. A similar study done by Bris, Goetzmann, and Zhu (2007) notes short sales are typically allowed in major markets that encourage financial innovation—particularly with respect to capital structure and new security developments. Generally, theoretical models predict that short-sale constraints can cause stocks to be either overvalued or undervalued. Diamond and Verrecchia (1987) maintain that restricting short selling slows the downward adjustment of securities prices to reflect bearish information. This evidence supports the following insights that short-sale prohibitions make short selling more costly for investors who have a negative opinion about stock prices since their views may register less in the prices than if short sales are allowed. If such costs are significant, we would expect the removal of price restrictions to cause short selling to increase or, if the restrictions are not costly, remain the same. As price restrictions may impose costs on short sellers in the form of lower fill rates and execution delays, Alexander and Peterson (2008) report that eliminating price tests benefits traders by allowing them to trade more aggressively with orders that could be executed more quickly. The effect of transaction costs on the index-futures price relationship under a setting of prohibition from short selling has been explored quite a few in the literature. For example, Abhyankar (1995) documents that

Table 1

Descriptive statistics for mispricing and futures order imbalance.

This table presents summary statistics for overpricing (Mis^+), underpricing (Mis^-), order imbalance of buy-side ($Foib^+$) and sell-side ($Foib^-$) of Taiwan stock index futures during six-month period, three months before and three months after the four market events, SS50, SS100, LS50 and LS100 spanned from Feb, 2005 through Feb, 2008. SS50 and SS100 (LS50 and LS100) denotes lifting TWSE uptick rule which regulates prices of short sales (security lending sales) be equal or above the previous closing price for component stocks of Taiwan 50 or Taiwan mid-cap 100 indices respectively. Note events SS100 and LS100 occurred on the same day. Panel A consists of two sub-panels, 1) low transaction costs category applied to large traders and 2) high transaction costs category applied to small traders. Mis^+ and Mis^- are measured over a 5-minute interval. Std. Dev. denotes standard deviation.

Event (Exempt market capitalization %)	Pre-SS50 *(67.04)*		Post-SS50 *(67.38)*		Pre-LS50 *(66.87)*		Post-LS50 *(66.69)*		Pre-SS/LS100 *(83.76)*		Post-SS/LS100 *(84.76)*	
Panel A: Mispricing	Mis^+	Mis^-	Mis^+	Mis^-	Mis^+	Mis^-	Mis^+	Mis^-	Mis^+	Mis^-	Mis^+	Mis^-
1) Low transaction costs												
No of observations	14	1088	15	2425	29	1159	19	2539	185	1351	84	1164
Mean	0.0021	−0.0019	0.0017	−0.0049	0.0016	−0.0027	0.0025	−0.0037	0.0014	−0.0047	0.0041	−0.0022
Median	0.0007	−0.0015	0.0009	−0.0040	0.0007	−0.0022	0.0016	−0.0024	0.0007	−0.0033	0.0029	−0.0015
Std. Dev.	0.0023	0.0016	0.0020	0.0038	0.0024	0.0022	0.0027	0.0038	0.0027	0.0045	0.0048	0.0032
2) High transaction costs												
No of observations	5	242	3	1440	5	391	4	1016	18	716	42	257
Mean	0.0018	−0.0012	0.0021	−0.0039	0.0025	−0.0020	0.0040	−0.0040	0.0046	−0.0047	0.0040	−0.0025
Median	0.0016	−0.0009	0.0020	−0.0030	0.0007	−0.0015	0.0029	−0.0028	0.0028	−0.0037	0.0015	−0.0014
Std. Dev.	0.0007	0.0012	0.0003	0.0034	0.0038	0.0020	0.0026	0.0042	0.0053	0.0043	0.0054	0.0053
Panel B: Futures order imbalance												
	$Foib^+$	$Foib^-$	$Foib^+$	$Foib^-$	$Foib^+$	$Foib^-$	$Foib^+$	$Foib^-$	$Foib^+$	$Foib^-$	$Foib^+$	$Foib^-$
No of observations	1701	1825	1814	1901	1536	1694	1901	1921	1686	1919	1572	1928
Mean	0.3585	−0.3607	0.3474	−0.3614	0.2459	−0.2526	0.2391	−0.2476	0.2118	−0.2278	0.1761	−0.2050
Median	0.3392	−0.3333	0.3191	−0.3436	0.2234	−0.2337	0.2222	−0.2314	0.1948	−0.2134	0.1566	−0.1914
Std. Dev.	0.2252	0.2299	0.2206	0.2266	0.1661	0.1631	0.1575	0.1644	0.1389	0.1532	0.1222	0.1333

changes in transaction-cost policies and short-sale restrictions alter the lead–lag relationship between index futures prices and spot prices on the London market. MacKinlay and Ramaswamy (1988) suggest that if differences in the transaction costs between spot and futures markets are large, new information incorporates more quickly in one market than in the other; such differences are reflected in the variability of the price series, especially if the intervals are short.

Short-sale constraints limit the arbitrage on the lower bounds of mispricing which results in underpricing and larger arbitrage bounds. The effects can be substantial, and there are serious impediments to short sales in real markets. These include transaction costs, transaction lags, index tracking errors, and nonsynchronous trading. Factors that can affect arbitrage opportunities when futures are underpriced relative to the cash index include, for example, the severity of the regulatory restrictions on short sales, the level of institutional participation in the market, the possibility of early unwinding, the difficulty and the cost of identifying willing stock lenders, the differences in borrowing and lending rates, and the risk associated with taking short stock positions. The adverse effect of short-sale constraints on the index-futures pricing relationship is supported by a variety of studies in US, H.K., and European markets. For example, Jiang, Fung, and Cheng (2001) find that restrictions on short sales weaken the contemporaneous relationship between futures and the cash market, especially when the market is falling and futures are underpriced. Fung and Jiang (1999) examine the error-correction dynamics between the Hang Seng index and index futures, concluding those which heighten constraints on short sales associated with an increase in the price difference between futures and spot index. Fung and Draper (1999) show that lifting price restrictions on short selling reduces the frequency and magnitude of underpricing in Hang Seng index futures, and it affects how quickly the underpricing is eliminated. Fung and Draper (1999, p707) report "Futures are generally overpriced in Hong Kong (in contrast to the results of similar studies for other exchanges), and the magnitude of overpricing is greater than that of underpricing", which Draper and Fung (2003) reaffirm using data from the same market. We find the opposite to be the case in Taiwan, which conforms to the results in most literature.[3]

Grossman (1988) and Fung (2007) document that index arbitrageurs are important providers of liquidity in the futures market when the stock market is in disequilibrium. This observation sheds light on how the order imbalance in the stock market is responsible for the misalignment of index futures and the cash index. Therefore, another purpose of our investigation is to determine whether lifting price restrictions can affect extreme order imbalances and to look for evidence concerning the effect of price restrictions on the misalignment and illiquidity (defined as order imbalance). Our analysis differs from previous ones in three respects. First, the study separates large from small traders by their transaction costs to explore pricing relationship between spot index and index futures without really identifying them. Second, although the literature is focused on order imbalance in the stock market, we choose to explore the different effects of order imbalance that are triggered by informed trading in the index futures market; therefore, we propose that lifting the price restrictions reduces extreme order imbalance. Third, whereas it is assumed in the literature that mispricing is caused by investors' misreactions to information or friction in the market, we hypothesize that mispricing is caused by informed trading combined with the controlled transaction costs faced by different types of traders.

The remainder of this paper is organized as follows. In Section 2, we describe the data, define variables and events, and summarize signed mispricing and signed order imbalance. In Section 3, we test and interpret the trading impact reported in Section 2 and compare market quality surrounding the initiation of removing price restrictions. In Section 4, we detect reversals or momentums for underpricing and overpricing, and for buy-side and sell-side order imbalances, and examine the correlation patterns of extreme observations between underpricing and sell-side order imbalance, as well as between overpricing and buy-side order imbalance. In Section 5, we discuss the determinants of the mispricing and order imbalance of index futures, and simultaneously examine how the behaviors of large and small informed and uninformed traders affect the excess buying and excess selling of index futures. Finally, we summarize our conclusions in Section 6.

2. Data and event description

We select the Taiwan Weighted Average Stock Index as our representative stock market index because it is unaffected by nonsynchronous trading and the concomitant nuisance of spurious serial dependence.[4] As described more fully below, the examination of the four different periods when price restrictions on short selling or lending selling are lifted allows us to track trader behavior and analyze it by taking into account differences in the market capitalization of pilot stocks and the different channels for selling them. Our data sources are the Taiwan Stock Exchange Corporation (TWSE) and the Taiwan Futures Exchange (TAIFEX). To avoid thin market and expiration effects, we use only the futures contracts that expired the earliest. We select them

[3] In contrast to Fung and Draper (1999), Draper and Fung (2003), and Chu and Hsieh (2002), who show futures are overpriced, we find the opposite to be the case in Taiwan, which actually conforms to most of the literature as shown in the results of the following studies. Cornell and French (1983) find S&P contracts to be under-priced, yet Chu and Hsieh (2002) find S&P 500 become overpriced after the issue of Standard and Poor's Depositary Receipts (SPDRs). Modest and Sundaresan (1983) study both the S&P 500 and NYSE composite contracts and attribute the discount to the inability of the trader to fully use the proceeds from short selling stocks. Chung (1991) examines the Major Market Index (MMI) and finds the deviations smaller than those of the previous studies. However, the MMI consists of only 20 stocks. Cakici and Chatterjee (1991) find observations from earlier contracts showing that when futures prices are mispriced with respect to model price, such mispricing is usually negative, i.e., the futures sell at a discount from the model price, although the market interest rates historically exceed the dividend yields on common stocks, from which one might expect the futures price to be at a premium compared with the price of the spot index. Outside the U.S., Brenner, Subrahmanyam, and Uno (1989) find the Nikkei contracts to be generally underpriced, and Yadav and Pope (1994) observe that the FTSE 100 contracts are more frequently underpriced with the average magnitude of underpricing exceeding that of overpricing.

[4] The serial correlation for TAIEX returns is −0.01, compared to −0.02 for S&P 500 returns. The mean return of TAIEX futures is 0.06, compared to 0.26 for S&P 500. The periods covered for both indexes are from April 1, 1999 to September 30, 2005.

using the rolling-over method, because trading activity is more active with short-term contracts than with long-term contracts. The data provided by the TWSE and the TAIFEX cover the period from February, 2005 to February, 2008.

We define two events, SS50 and SS100, as the lifting of short-sale price restrictions on stocks listed in the Taiwan 50 index and the Taiwan mid-cap 100 index, respectively. Two other events, LS50 and LS100, are defined as the lifting of price restrictions on security lending sales on the same two indices. We define the event day as the day on which the restrictions are formally lifted. SS100 event and LS100 event happen on the same day. Each event window represents a 6-month period including the 3 months before and the 3 months after the event day. The pre-lifting (post-lifting) refers to the period before (after) the price restrictions are lifted.

2.1. Mispricing variables

Following the cost-of-carry relationship proposed by Klemkosky and Lee (1991), the upper (lower) no-arbitrage bound of the futures price $F^U_{d_t}(F^L_{d_t})$ at time t on day d is:

$$F^U_{d_t} = S_{d_t}(1+r)^{T-d} - \sum_{j=d}^{T-d-1} \sum_{i=1}^{n} W_{ij} D_{ij} \left(1+r_j\right)^{T-j} + TC$$

$$F^L_{d_t} = S_{d_t}(1+r)^{T-d} - \sum_{j=d}^{T-d-1} \sum_{i=1}^{n} W_{ij} D_{ij} \left(1+r_j\right)^{T-j} - TC,$$

where S_{d_t} represents the TAIEX value, r the riskless rate of interest, D_{ij} the dividend payout rate of stock i in the index portfolio on day j, TC the transaction costs (including commissions, impact costs, and taxes), and T-d the time to maturity of the arbitrage portfolio. W_{id}, the weight for stock i on day d based on its market value, is computed as follows:

$$W_{id} = \left(S_{d-1} / \sum_{i=1}^{n} N_{id} P_{id-1}\right) * N_{id-1} \quad \text{for non} - \text{ex} - \text{dividend days}$$

$$W_{id} = \left(S_{d-1} / \sum_{i=1}^{n} N_{id} P^*_{id}\right) * N_{id-1} \quad \text{for ex} - \text{dividend days},$$

where P^*_{id} is the reference price on an ex-dividend day, P_{id-1} is the closing price of stock i on day $d-1$, N_{id} is the number of outstanding shares of stock i on day d, S_{d-1} is the closing index value of the TAIEX on the previous trading day, and n is the number of stocks in the index portfolio. The TAIEX value is calculated as the ratio of the current market value of all the index stocks divided by their total market value at the close of the previous day, multiplied by the TAIEX value at the previous close. We examine the mispricing relative to the corresponding upper and lower boundaries of the futures price. There is no arbitrage opportunity if $F^L_{d_t} < F_{d_t} < F^U_{d_t}$. The higher the transaction costs TC, the farther apart the bounds, and the less binding the arbitrage relationship on possible prices. Most studies view commissions as fixed costs, although fees vary by trader type and order size. In this study, we emphasize situations in which different traders face different kinds of short-selling restrictions and transaction costs. To build upper and lower bounds, we used a 30-day Treasury bill rate and two types of transaction costs. Because the assumed transaction costs can be a large part of futures mispricing, below is a detailed description of how the transaction costs are developed. To build the upper and lower no-arbitrage bounds, we use the 30-day Treasury bill rates and consider two types of transaction costs. The distinction between large and small traders is based on their different levels of commission which is negotiable between a brokerage firm and its client traders and can be reduced to almost zero for large-volume traders. Therefore, we assume zero commission for large-volume traders in both stock and futures markets. The round trip commission for a futures contract ranges from Taiwan dollars $400 to $160 during our sample period, which equals to 2 (=NT$400/200) to 0.8 (=NT$160/200) on a per-index basis. The one-way market impact cost for buying or selling a contract of futures is 0.5 (half of the tick size 1 on a per-index basis), but for buying or selling a share of stock is NT$0.025 (or 0.000125[5] on a per-index basis) in that the average stock price during our sample period ranges from NT$20 to $30 with tick size NT$0.05. Since market-on-close orders are not available in Taiwan, investors incur two-way impact costs in the stock market. The sales tax for futures is 0.025% during our sample period, but for stocks it is 0.3%. The round-trip commission for buying and selling stocks amounts to 0.285%. The transaction costs in the futures and stock markets (C_f and C_s) are detailed as follows.

For large traders

$$C_f = \mathbf{0.5} + \mathbf{0.00025} * (\text{futp} + \text{Fut\_settle});$$

$$C_s = \mathbf{0.000125} * 2 + \mathbf{0.003} * \text{Fut\_settle};$$

[5] Previous studies have shown that the average percentage effective spread in the Taiwan stock market is about 0.5%. If selling (buying) pressure results in all stocks being pushed to trade at the bid (ask) price upon expiration of the futures, the index will fall (rise) by half the spread, or approximately 0.25%. Brockman, Chung, and Perignon (2009) report an average relative spread of 0.53% for the top 289 firms in Taiwan computed over the period October 1, 2002 to June 30, 2004. Relative Effective Spread is the effective spread (i.e., twice the absolute trading price deviation from the bid-ask midpoint) divided by the bid-ask midpoint. Ke, Jiang, and Huang (2004) report respective spreads of 0.34% and 0.97% for stocks traded in two different tick-size categories over the 2-year period of 1998–1999. Nevertheless, Taiwan stock market cuts tick size of equity to half on March 1, 2005, but a bit more for block trading.

For small traders

$$C_f = \mathbf{0.5} + \mathbf{0.00025}^*(\text{futp} + \text{Fut\_settle}) + (\text{CM}^*\mathbf{2})/\mathbf{200};$$

$$C_s = \mathbf{0.000125}^*2 + \mathbf{0.003}^*\text{Fut\_settle} + \mathbf{0.001425}^*(\text{index} + \text{Fut\_settle});$$

where futp and index denote index futures price and the value of stock index at time *t* respectively, Fut_settle futures final settlement price at expiration, and CM futures commission.

For each 5-minute interval, we calculate the following:

- Mis^+ the magnitude of overpricing of the TAIEX futures relative to the upper no-arbitrage bound, defined as $(F_{d_t} - F^U_{d_t})/F^U_{d_t}$;
- Mis^- the magnitude of underpricing of the TAIEX futures relative to the lower no-arbitrage bound, defined as $(F_{d_t} - F^L_{d_t})/F^L_{d_t}$;
- Std_fut the volatility of the TAIEX futures, defined as the standard deviation of its 5-minute returns;
- Std_ind the volatility of the TAIEX, defined as the standard deviation of its 5-minute returns;
- TO the average daily turnover, calculated by averaging the daily trading share volume scaled by the number of outstanding shares of stocks listed in the TAIEX.

For each daily interval, we calculate the following:

- Std_cross_comp the cross-sectional volatility of the component stocks listed in the Taiwan 50 (Taiwan mid-cap 100) index during events SS50 and LS50 (SS100 and LS100), defined as the standard deviation of its daily returns;
- TO_comp the average daily turnover, calculated by averaging the daily trading share volume scaled by the number of outstanding shares of stocks listed in the Taiwan 50 (Taiwan mid-cap 100) index during events SS50 and LS50 (SS100 and LS100);
- Ss_TO_comp the average daily short-sale turnovers, calculated by averaging the daily sold short shares scaled by the number of outstanding shares of stocks listed in the Taiwan 50 (Taiwan mid-cap 100) index during events SS50 and LS50 (SS100 and LS100);
- Lendingsale_TO_comp the average daily lending-sale turnovers, calculated by averaging the daily lending selling shares scaled by the number of outstanding shares of stocks listed in the Taiwan 50 (Taiwan mid-cap 100) index during events SS50 and LS50 (SS100 and LS100);
- PIN_fut probability of informed trading for index futures, calculated by our modified Easley, Hvidkjaer, and O'Hara (2002) model[6] (we allow the arrival rate of informed buyers to be different from the arrival rate of informed sellers to match the empirical environment);
- PIN_ind probability of informed trading for stock index, calculated by our modified Easley et al. (2002) model (we allow the arrival rate of informed buyers to be different from the arrival rate of informed sellers to match the empirical environment);
- ETF50_nav (ETF100_nav) the value of the market price for the exchange-traded Taiwan 50 (Taiwan mid-cap 100) fund minus the aggregate net asset value of its 50 (100) constituent stocks.

2.2. Order imbalance variables

Trading activity has usually been represented by volume, but order imbalance can be a better predictor of the direction and magnitude of price changes. Unlike volume, which employs a functional form, order imbalance can be a direct measure of the asymmetry of liquidity. In earlier studies, order imbalance has been defined as the net purchases by active participants, while there are other representations of order imbalance, e.g. Blume, MacKinlay, and Terker (1989), Locke and Sayers (1993), Stoll (2000), and Fung (2007).[7] Furthermore, order imbalance has been found to be positively associated with returns in many kinds of

[6] We modify the likelihood function from Easley et al. (2002) as follows:

$$L(\theta|B,S) = (1-\alpha)e^{-\varepsilon_b}\frac{\varepsilon_b^B}{B!}e^{-\varepsilon_s}\frac{\varepsilon_s^S}{S!} + \alpha\delta e^{-\varepsilon_b}\frac{\varepsilon_b^B}{B!}e^{-(\mu_s+\varepsilon_s)}\frac{(\mu_s+\varepsilon_s)^S}{S!} + \alpha(1-\delta)e^{-(\mu_b+\varepsilon_b)}\frac{(\mu_b+\varepsilon_b)^B}{B!}e^{-\varepsilon_s}\frac{\varepsilon_s^S}{S!}$$

$$V = L(\theta|M) = \prod_{i=1}^{I} L(\theta|B_i, S_i, Z_i)$$

[7] Blume et al. (1989) define the order imbalance of an individual stock as equal to its dollar volume at the ask price minus the dollar volume at the bid price within a particular time interval. Locke and Sayers (1993) define order imbalance as the absolute value of the difference between all the contracts bought and sold in 1 min by floor traders for their own accounts. Stoll (2000) defines order imbalance as the difference between the daily share volume on the ask side and the bid side, expressed as a percentage of daily volume. Fung (2007) defines order imbalance as buyer-initiated trading volume (trades executed at ask prices) minus seller-initiated trading volume (trades executed at bid prices).

markets, including equity, bond, futures, and foreign exchange markets. One popular interpretation of this relationship is that active participants have superior information, which motivates them to initiate the transaction. Other interpretations[8] are found in Blume et al. (1989), Lee and Ready (1991), Chordia, Roll, and Subrahmanyam (2002, 2008), Huang and Chou (2007), and Kao (2011).

Motivated by Jones, Kaul, and Lipson (1994) observation that the number of trades, rather than the total volume, is most closely associated with the magnitude of price changes, we define order imbalance in terms of number of transactions, the same as Chordia and Subrahmanyam (2004) and Huang and Chou (2007). To calculate order imbalance, each transaction of index futures is first designated as either buyer-initiated or seller-initiated according to the Lee and Ready (1991) algorithm,[9] which requires that each transaction be matched to a bid-ask quote. Following the findings of Bessembinder (2003), we do not use a time lag for matching quotes with trades. In other words, for each trade we use the best bid and ask prices available at the time of the trade. Nevertheless, each stock index transaction is computed using the tick test.[10] For each 5-minute interval, we calculate the following:

Foib (Soib) the number of buyer-initiated orders minus the number of seller-initiated orders scaled by total orders during interval t for the index futures (stock index);

$Soib^+$ ($Soib^-$) the positive (negative) Soib over interval t, representing buy-side (sell-side) order imbalance in the stock index market;

$Foib^+$ ($Foib^-$) the positive (negative) Foib over interval t, representing buy-side (sell-side) order imbalance in the index futures market.

2.3. Descriptive statistics

Although different traders in the markets generally face different transaction costs and it results in quasi-arbitrage,[11] whether this is true when there are short-sale restrictions is questionable, particularly for institutional investors. Panel A of Table 1 consists of two sub-panels representing low and high transaction costs. These categories allow us to distinguish the behavior of large traders with low transaction costs from small traders with high transaction costs.

Table 1 reports summary statistics of futures mispricing and order imbalance for both categories of low and high transaction costs over 5-minute intervals for the market events, SS50, LS50, SS100, and LS100. Sub-panels 1 and 2 of Panel A presents overpricing (Mis^+) and underpricing (Mis^-), while Panel B reports the buy-side order imbalance ($Foib^+$) and the sell-side order imbalance ($Foib^-$). In Table 1, the high frequencies of underpricing and the untabulated negative means of mispricing in the post-lifting period suggest an overwhelming underpricing of index futures. When traders face excessive restrictions on short selling, they have little opportunity to do short stocks and long futures arbitrage. Although the restriction on short selling increases the no-arbitrage bound, it affects not only the strategy of long futures and short stocks, but also the strategy of short futures and long stocks. A comparison between low and high transaction cost categories from sub-panels 1 and 2 of Panel A in Table 1 highlights the impact of lifting short-sale constraints on the pricing efficiency of the index futures. First, the magnitude of the lower-bound violations is greater in the post-SS50 (post-LS50) period than in the pre-SS50 (pre-LS50) period, but it is smaller in the post-SS/LS100 period than in the pre-SS/LS100 period. Second, comparing the pre-lifting and post-lifting periods, we find the frequencies of the lower-bound violations to be consistently larger than those of the upper-bound violations. Third, the volatility (represented by the realized standard deviation) of the lower-bound violations is higher in the post-lifting periods with the exception of post-SS/LS100, but the volatility of the upper-bound violations is higher in the post-lifting periods with the exception of post-SS50 for the big and small traders. The frequency and magnitude of underpricing for the post-SS50 and post-LS50 periods contradict our expectation that underpricing declines after price restrictions are relaxed. In addition, boundary violations occur asymmetrically, with fewer violations at the upper bound than at the lower bound, signaling the lower-bound violations persist slightly longer than the upper-bound violations. When transaction costs exceed 0.15%, there are no upper-bound violations; however, there are lower-bound violations, suggesting that the market tends to underprice futures during our sample period.

In Panel B of Table 1, the frequency of sell-side order imbalance ($Foib^-$) is consistently larger than that of buy-side order imbalance ($Foib^+$) between the pre-lifting and post-lifting periods. In addition, the average absolute magnitude of the sell-side order imbalances is larger in the post-lifting periods than in the pre-lifting periods during our sample period. In contrast, the

[8] Blume et al. (1989) find a strong contemporaneous relationship between order imbalance and price changes on October 19 and 20, 1987. Lee and Ready (1991) show that prices tend to respond to order imbalance even during periods of normal trading. Chordia et al. (2002) split order imbalance into positive and negative components in examining the relationship between returns and the signed order imbalances, the purpose being to allow for the different effects of excessive buy and sell orders. Chordia et al. (2008) note that the returns from lagged order flows can be predicted from the unexpected component of order flow in any given period. Huang and Chou (2007) compares the impact of order imbalance on market performance, liquidity and volatility under two different market structures: order-driven and quote driven, and Kao (2011) exhibits significant reversal following periods of extreme low trading imbalance, and momentum following periods of extreme high trading imbalance.

[9] A trade is classified as buyer-(seller-)initiated if the trade price equals the ask (bid) price. If the trade price is in between these two prices, we record the trade as buyer-(seller-)initiated if the trade price is closer to the ask (bid) price than to the bid (ask) price. If the trade occurs at exactly the midpoint, we employ a tick test by comparing the current trade price with the preceding trade price(s).

[10] A trade is classified as buyer-(seller-)initiated if it occurs on an uptick (downtick) or a zero uptick (downtick). If a trade occurs on consecutive zero ticks more than three times, it is not classified.

[11] A quasi-arbitrage is a potential arbitrage of short futures and long stocks or long futures and short stocks, with relatively low transaction costs.

buy-side order imbalance is lower in the post-lifting periods than in the pre-lifting periods, while sell-side order imbalance does not show this pattern in the post-SS50 period. The volatilities of the buy-side and sell-side order imbalances are smaller in the post-lifting periods than in the pre-lifting periods, but these results are reversed in the post-LS50 period for sell-side order imbalance. Some descriptive statistics worth mentioning but not shown in the tables include the positive correlation between lagged order imbalances and mispricing, the autocorrelation of mispricing, and that of order imbalance for the 5-minute interval at the aggregate level (without splitting trader types) three months before and after the four market events, SS50, SS100, LS50 and LS100. The autocorrelation of order imbalance is less than 0.18, and persists for less than 10 min, whereas the autocorrelation of mispricing exceeds 0.96, suggesting arbitrage activity might not be effective. Nevertheless, no conclusions should be drawn until the differences are tested in Table 2.

3. Trading impact on the lifting of price restrictions

Short-sale restrictions impede the arbitrages that are associated with short stocks and long futures (short arbitrage) and result in the costs and inconvenience involved in short selling the entire index portfolio. In theory, the lifting of price restrictions should reduce the friction in arbitrage and therefore shrink the underpricing of futures. Nevertheless, it also makes the arbitrage that involves longing stocks and shorting futures (long arbitrage) more difficult to establish. This is because the early unwinding of an initial short arbitrage portfolio prevents futures prices from drifting too far above their fair value and thus decreases the profits from taking advantage of long arbitrage opportunities. We should observe reduction in either the magnitude or the occurrences for both underpricing and overpricing after the lifting of price restrictions.

In this study, we adopt two empirical approaches to compare market quality during the post-lifting periods with market quality during the pre-lifting periods for the four market events. The two approaches are t-test as presented in this session and semi-autoregression described in session 4. Table 1 summarizes the percentage pricing errors for large traders and small traders, as well as the order imbalance of index futures. Table 2 provides the test results to interpret what is found in Table 1. Other variables consisting of market quality are also considered. The results in Table 2 motivate the hypotheses that signed order imbalances and signed mispricing are both persistent, which are shown in Table 3. The relationship between the degree of mispricing and future liquidity is discussed in both Tables 4 and 5.

3.1. Effects on the pricing of index futures

Results in Table 1 seem not consistent with theoretical predictions. One possibility is that there might be other constraints inversely affect the pricing relationship between spot index and index futures much more strongly. Other explanation might be that different traders face different restrictions on short sales or lending sales, or use different financing sources in Taiwan. Unlike the uptick rules in the US[12] and other financial markets, investors in Taiwan must obey a rule that inhibits short selling or lending selling at a price below the previous closing. We refer to this rule as the "TWSE uptick rule."

Reduced post-lifting underpricing suggests that price restrictions cause stocks to be slightly overvalued, whereas the opposite outcome suggests that factors other than price restrictions cause futures to be underpriced. In Panel A of Table 2, we observe that the lower-bound and upper-bound violations surrounding SS50 and LS50 persist for both large and small traders, but only the lower-bound violations surrounding SS/LS100 reversed for both traders. Although the evidence for post-SS/LS100 is consistent with the hypothesis that price restrictions facilitate the underpricing of index futures, the evidence for post-SS50 and post-LS50 contradicts it. A similar contradiction is also found for increased upper-bound violations for large traders in the post-lifting periods than in the pre-lifting periods. It is possible that the small sample size for the overpricing does not create sufficient power to detect the effect of the changes resulting from the removal of price restrictions. We are curious whether the elimination of price restrictions has a discernible effect on stock prices due to the trading strategies from different types of traders. This is why we separate large traders from small ones. As the result shows, there seems no difference between the large and small traders except the overpricing in the post-SS/LS100 period. The observed overpricing between pre-SS/LS100 and post-SS/LS100 period is greater for large traders, but lower for small traders in the same period.

3.2. Effects on market quality

The previous evidence of price restrictions gives us insights into how price restrictions can affect the level of market quality. In this study, market quality is represented by all the variables presented in Table 2, and these variables come from different frequencies, either on a 1-minute basis, on a 5-minute basis, or on a daily basis. It's surprising that the buy-side and sell-side order imbalances are both insignificant in the post-SS50 and post-LS50 periods. This suggests liquidity asymmetry becomes significant only during the post-SS/LS100 period. The returns of the stock index and index futures seem to have been more volatile in the post-lifting periods than in the pre-lifting periods, except a declined stock return volatility in the post-SS50 period. Although it is statistically significant, the size of reduction is minor. Note an increase of volatility in the stock market raises the demand for hedging.

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[12] The U.S. Securities and Exchange Commission (SEC) summarized the rule as follows: "a listed security may be sold short (A) at a price above the price at which the immediately preceding sale effected (plus tick), or (B) at the last sale price if it is higher than the last different price (zero-plus tick)." Short sales are not permitted on minus ticks or zero-minus ticks.

Table 2

Effects of short sales and security lending sales.

This table reports pre- and post-lifting mean values, mean difference (△) and p-values of t-test 3 months before and after market events. Events SS50 and SS100 (LS50 and LS100) denote lifting TWSE uptick rule which regulates prices of short selling (security lending sales) be equal or above the previous closing price for component stocks of the Taiwan 50 or Taiwan mid-cap 100 indices respectively. Panel A exhibits overpricing (Mis^+) vs. underpricing (Mis^-) on a 1-minute basis for low and high transaction cost categories. Panel B displays buy-side vs. sell-side order imbalance, futures trading volume (Volume), spot return volatility (Std_ind), and futures return volatility (Std_fut) on a 5-minute basis. Panel B also presents aggregate turnover in TAIEX (TO) and turnover (TO_comp), short-sale turnover (Ss_TO_comp), Security-lending-sale turnover (Lendingsale_TO_comp), and cross-sectional return volatility (Std_cross_comp) of component stocks in the Taiwan 50 or Taiwan mid-cap 100, probabilities of informed trading for stock index (PIN_ind) and index futures (PIN_fut), and the value of the market price of the Taiwan 50 (Taiwan mid-cap 100) minus the net asset value of its 50 (100) component stocks,ETF50_nav (ETF100_nav), on a daily basis.

Variables	Pre-SS50	Post-SS50	△	p-value	Pre- LS50	Post-LS50	△	p-value	Pre-SS/LS100	Post-SS/LS100	△	p-value
Panel A: Mispricing measured on a 1-minute basis												
1) Low transaction costs												
Mis^+	0.0011	0.0016	0.0005	(0.3356)	0.0009	0.0019	0.0010	(0.0008)	0.0009	0.0030	0.0021	(0.0000)
Mis^-	−0.0019	−0.0049	−0.0030	(0.0000)	−0.0026	Q	−0.0010	(0.0000)	−0.0046	−0.0020	0.0026	(0.0000)
2) High transaction costs												
Mis^+	0.0020	0.0022	0.0003	(0.5272)	0.0025	0.0032	0.0008	(0.7305)	0.0040	0.0021	−0.0019	(0.0147)
Mis^-	−0.0011	−0.0039	−0.0028	(0.0000)	−0.0020	−0.0039	−0.0019	(0.0000)	−0.0047	−0.0017	0.0030	(0.0000)
Panel B: Market quality												
1) On a 5-minute basis												
$Foib^+$	0.1676	0.1625	−0.0051	(0.3442)	0.1143	0.1163	0.0020	(0.6102)	0.0974	0.0779	−0.0195	(0.0000)
$Foib^-$	−0.1809	−0.1772	0.0038	(0.5006)	−0.1295	−0.1217	0.0078	(0.0518)	−0.1192	−0.1112	0.0080	(0.0243)
Std_fut	0.0009	0.0187	0.0178	(0.0000)	0.0011	0.0014	0.0003	(0.0000)	0.0019	0.0026	0.0007	(0.0000)
Std_ind	0.0010	0.0009	−0.00005	(0.0000)	0.0010	0.0013	0.0003	(0.0000)	0.0018	0.0024	0.0006	(0.0000)
Volume	376	433	57	(0.0001)	569	798	229	(0.0000)	704	1009	305	(0.0000)
2) On a daily basis												
Std_cross_comp	0.0126	0.0142	0.0015	(0.0000)	0.0146	0.0164	0.00184	(0.0000)	0.0234	0.0247	0.00136	(0.0000)
TO	0.0079	0.0089	0.0009	(0.0000)	0.0106	0.0149	0.0044	(0.0000)	**0.0091**	**0.0061**	−0.0030	(0.0000)
TO_comp	0.0038	0.0046	0.0008	(0.0000)	0.0040	0.0048	0.0008	(0.0000)	0.0102	0.0103	0.0001	(0.0019)
Ss_TO_comp	0.00008	0.00014	0.00005	(0.0000)	0.00006	0.00004	−**0.00002**	(0.0000)	0.00015	0.00042	0.00027	(0.0000)
Lendingsale_TO_comp	0	0.000007	0.000007	(0.0000)	0.000021	0.000024	0.000003	(0.0000)	0.000015	0.000016	0.000002	(0.0000)
PIN_fut	0.3184	0.3268	0.0084	(0.0000)	0.2400	0.2475	0.0075	(0.0000)	0.2075	0.1859	−0.0216	(0.0000)
PIN_ind	0.3959	0.4166	0.0207	(0.0000)	0.4069	0.4513	0.0444	(0.0000)	0.5018	0.5367	0.0350	(0.0000)
ETF50_nav (ETF100_nav)	−0.0110	−0.0550	−0.0445	(0.0000)	−0.0260	−0.0420	−0.0165	(0.0000)	−0.0800	0.0958	0.1760	(0.0000)

Table 3
Reversals/momentums of futures mispricing and order imbalance.
This table presents regression coefficients of mispricing on lagged overpricing and lagged underpricing during the six-month period, three months before and three months after the start of each lifting as described in Table 1. The coefficients are the mean coefficients estimated over the designated periods. $\text{Mismin}_t = \min(\text{Mis}_t, 0)$, and $\text{Mismax}_t = \max(\text{Mis}_t, 0)$, where Mis_t denotes the mispricing in interval t. Panel A reports results for low transaction costs category applied to large traders, while Panel B reports results for high transaction cost category applied to small traders. The missing coefficients are due to small observations of overpricing. MI-25% (MI+75%) denotes the serial correlation of intervals below the 25th (above the 75th) percentile, i.e., the large underpricing(overpricing) intervals accompanied by large sell-side (buy-side) imbalances. P-value of t-test is in parenthesis.

Independent variables	Pre-SS50		Post-SS50		Pre-LS50		Post-LS50		Pre-SS/LS100		Post-SS/LS100	
Panel A: Mispricing												
1) Low transaction costs												
Mismin_{t-1}	0.50	(0.00)	**0.83**	(0.00)	0.54	(0.00)	0.44	(0.00)	0.43	(0.00)	0.16	(0.00)
Mismin_{t-2}	0.14	(0.00)	**0.05**	(0.07)	0.17	(0.00)	0.18	(0.00)	0.17	(0.00)	0.11	(0.00)
Mismin_{t-3}	0.12	(0.01)	0.02	(0.38)	0.04	(0.37)	0.11	(0.00)	0.12	(0.00)	0.13	(0.00)
Mismin_{t-4}	0.01	(0.84)	0.01	(0.76)	0.08	(0.04)	0.10	(0.00)	0.14	(0.00)	0.11	(0.00)
Mismin_{t-5}	0.10	(0.01)	0.03	(0.12)	0.07	(0.04)	0.11	(0.00)	0.09	(0.00)	0.11	(0.00)
Mismax_{t-1}	-0.02	(0.95)	**-0.26**	(0.25)	0.05	(0.86)	-0.37	(0.16)	-0.24	(0.01)	0.43	(0.03)
Mismax_{t-2}	10.57	(0.33)	**0.07**	(0.77)	1.40	(0.21)	0.17	(0.53)	-0.08	(0.41)	0.27	(0.16)
Mismax_{t-3}	-0.21	(0.39)	-0.45	(0.04)	0.13	(0.82)	0.04	(0.88)	-0.10	(0.30)	0.08	(0.56)
Mismax_{t-4}	-0.18	(0.47)	0.21	(0.32)	0.12	(0.83)	-0.18	(0.55)	0.02	(0.80)	0.33	(0.05)
Mismax_{t-5}	-0.01	(0.96)	0.23	(0.31)	0.01	(0.99)	0.02	(0.96)	0.12	(0.20)	0.11	(0.25)
R^2/DW	0.60	(1.79)	0.88	(1.95)	0.66	(2.07)	0.75	(1.93)	0.70	(1.91)	0.18	(2.01)
2) High transaction costs												
Mismin_{t-1}	0.20	(0.04)	0.85	(0.00)	0.32	(0.00)	0.37	(0.00)	0.33	(0.00)	0.05	(0.54)
Mismin_{t-2}	0.15	(0.13)	0.00	(0.91)	0.20	(0.00)	0.16	(0.00)	0.18	(0.00)	0.00	(0.95)
Mismin_{t-3}	0.22	(0.03)	0.07	(0.05)	0.06	(0.41)	0.11	(0.00)	0.06	(0.19)	0.03	(0.68)
Mismin_{t-4}	-0.12	(0.22)	-0.03	(0.39)	0.09	(0.18)	0.14	(0.00)	0.15	(0.00)	0.03	(0.68)
Mismin_{t-5}	-0.02	(0.83)	0.05	(0.05)	0.16	(0.01)	0.12	(0.00)	0.14	(0.00)	0.01	(0.90)
Mismax_{t-1}	0.00		0.00		0.00		0.00		-0.98	(0.00)	0.88	(0.55)
Mismax_{t-2}	0.00		0.00		0.00		0.00		-0.52	(0.02)	-0.07	(0.97)
Mismax_{t-3}	0.00		-0.08	(0.87)	0.00		0.00		-0.22	(0.16)	0.48	(0.76)
Mismax_{t-4}	0.00		0.00		0.00		0.00		-0.44	(0.06)	0.17	(0.93)
Mismax_{t-5}	0.00		0.00		0.00		0.00		-0.22	(0.35)	0.88	(0.64)
R^2/DW	0.09	(1.91)	0.88	(1.96)	0.45	(2.21)	0.66	(1.95)	0.55	(1.93)	0.02	(2.04)
Panel B: Order imbalance												
Foibmin_{t-1}	0.17	(0.00)	0.13	(0.00)	0.18	(0.00)	0.06	(0.05)	0.15	(0.00)	0.12	(0.00)
Foibmin_{t-2}	−0.09	(0.01)	−0.01	(0.65)	0.00	(0.95)	−0.01	(0.82)	−0.01	(0.67)	−0.03	(0.31)
Foibmin_{t-3}	−0.01	(0.88)	−0.06	(0.09)	−0.03	(0.45)	−0.03	(0.35)	−0.05	(0.10)	0.07	(0.03)
Foibmin_{t-4}	0.00	(1.00)	−0.05	(0.18)	−0.08	(0.03)	0.01	(0.67)	−0.01	(0.87)	−0.05	(0.16)
Foibmin_{t-5}	0.01	(0.88)	−0.03	(0.34)	−0.07	(0.05)	0.00	(0.91)	−0.01	(0.84)	0.00	(0.99)
Foibmax_{t-1}	0.19	(0.00)	0.14	(0.00)	0.07	(0.06)	0.15	(0.00)	0.10	(0.01)	0.13	(0.00)
Foibmax_{t-2}	0.05	(0.16)	−0.11	(0.00)	−0.05	(0.13)	−0.09	(0.01)	−0.04	(0.22)	−0.07	(0.06)
Foibmax_{t-3}	0.00	(0.98)	0.04	(0.21)	0.00	(0.90)	0.01	(0.82)	0.02	(0.54)	−0.04	(0.33)
Foibmax_{t-4}	−0.02	(0.65)	0.05	(0.14)	0.10	(0.01)	−0.02	(0.59)	0.01	(0.78)	0.03	(0.42)
Foibmax_{t-5}	0.03	(0.37)	0.01	(0.82)	0.03	(0.38)	−0.03	(0.34)	0.01	(0.89)	0.02	(0.69)
R^2/DW	0.03	(2.00)	0.02	(2.00)	0.02	(2.00)	0.01	(2.00)	0.02	(1.99)	0.02	(2.00)
Panel C: Extreme observations												
Mispricing vs. Foib	$\text{MI}^{+75\%}$	$\text{MI}^{-25\%}$	$\text{MI}^{+75\%}$	$\text{MI}^{-25\%}$	$\text{MI}^{+75\%}$	$\text{MI}^{-25\%}$	$\text{MI}^{+75\%}$	$\text{MI}^{-25\%}$	$\text{MI}^{+75\%}$	$\text{MI}^{-25\%}$	$\text{MI}^{+75\%}$	$\text{MI}^{-25\%}$
No of observations	20	1	4	214	7	10	8	53	33	57	7	4
Autocorrelation	−0.256	0	−0.024	0.050	−0.074	−0.071	−0.557	−0.202	−0.122	−0.119	−0.515	−0.431

The removal of price restrictions should cause an increase in short arbitrage opportunities, which in turn should induce a large turnover of short sales in the constituent index stocks. In Panel B of Table 2, we find increased post-lifting daily aggregate turnover (TO_comp), short-sale turnover (Ss_TO_comp), and lending-sale turnover (Lendingsale_TO_comp) of component stocks listed in the Taiwan 50 and Taiwan mid-cap 100 indices. We find that the daily aggregate turnover of component stocks listed in the TAIEX (TO) declined from 0.91% in the pre-SS/LS100 period to 0.61% in the post-SS/LS100 period, yet the daily aggregate turnover, short-sale turnover, and lending-sale turnover of the component stocks listed in the Taiwan mid-cap 100 index increase from 1.02%, 0.015%, and 0.0015% in the pre-SS/LS100 period to 1.03%, 0.042%, and 0.0016% in the post-SS/LS100 period. We also find a significant higher volatility for cross-sectional returns of component stocks in the post-lifting periods than in the pre-lifting periods for the four market events. This evidence implies a higher divergent opinion among traders after the price restrictions are lifted.

Lifting the price restrictions leads to an increased post-lifting volume of index futures for all the four events, whereas the aggregate short-sale shares of the Taiwan 50 index stocks, short-sale turnover, in the post-LS50 period decrease. This may have resulted from the fact that investors replace short selling with lending selling in this period. As suggested in the literature, an increase in the volume of futures for underpricing without a commensurate increase in the short-sale turnover of index stocks may lead to a greater underpricing. To examine this possibility, we examine the correlation between the futures order imbalance

Table 4
Determinants of signed mispricing.
The table reports the factors which determines overpricing (Mis^+) or underpricing (Mis^-) of index futures. UNFoib (UNSoib) refers to daily uninformed order imbalance of index futures (stock index), while INFoib (INSoib) refers to daily informed order imbalance of index futures (stock index). The decomposition of estimates of daily order imbalance is obtained using revised Easley et al. (2002) model. SS is one (zero) if an observation appeared on or after (before) the lifting date of each event. The dependent variable of the regressions is overpricing or underpricing. The independent variables are interaction terms Soib∗SS and Mis_{t-1}∗SS, lagged mispricing (Mis_{t-1}), lagged order imbalance of stock index ($Soib_{t-1}$), lagged order imbalance on buy side ($Foib^+_{t-1}$) and sell side ($Foib^-_{t-1}$) of index futures, and return volatility of index futures (Std_fut). For some periods, there is no overpricing. P-value of t-test is in parenthesis.

Independent variables	Low transaction costs						High transaction costs					
	SS50		LS50		SS/LS100		SS50		LS50		SS/LS100	
	Mis^+	Mis^-	Mis^+	Mis^-	Mis^+	Mis^-	Mis^+	Mis^-	Mis^+	Mis^-	Mis^+	Mis^-
UNFoib		0.012		−0.012	0.197	0.093		0.003		0.015		0.191
		(0.030)		(0.325)	(0.082)	(0.014)		(0.906)		(0.623)		(0.020)
INFoib		−0.008		−0.002	−0.047	−0.121		−0.001		0.032		−0.161
		(0.093)		(0.796)	(0.351)	(0.000)		(0.986)		(0.194)		(0.000)
UNSoib		−0.005		0.002	0.034	−0.023		0.017		0.000		−0.027
		(0.175)		(0.832)	(0.308)	(0.238)		(0.692)		(0.989)		(0.354)
INSoib		−0.004		0.008	0.045	0.032		−0.009		−0.005		−0.011
		(0.318)		(0.368)	(0.268)	(0.121)		(0.592)		(0.860)		(0.692)
SS		0.019		−0.080	−0.337	0.170		0.024		−0.112		0.509
		(0.058)		(0.000)	(0.020)	(0.000)		(0.552)		(0.011)		(0.000)
UNFoib∗SS		−0.008		0.004	0.000	0.039		−0.001		−0.038		0.118
		(0.077)		(0.532)		(0.043)		(0.979)		(0.023)		(0.009)
INFoib∗SS		0.005		−0.008	0.000	0.036		0.001		−0.108		−0.017
		(0.214)		(0.141)		(0.027)		(0.900)		(0.000)		(0.721)
UNSoib∗SS		0.010		−0.003	−0.294	0.009		−0.015		0.003		−0.058
		(0.012)		(0.814)	(0.074)	(0.718)		(0.699)		(0.920)		(0.415)
INSoib∗SS		0.000		0.001	0.000	0.001		0.007		0.037		−0.026
		(0.937)		(0.860)		(0.979)		(0.608)		(0.147)		(0.728)
Soib		0.000		−0.001	0.054	0.004		0.000		−0.007		0.002
		(0.935)		(0.910)	(0.024)	(0.709)		(0.979)		(0.637)		(0.928)
$Soib_{t-1}$		−0.038		−0.037	−0.088	−0.036		−0.040		−0.036		−0.037
		(0.000)		(0.000)	(0.000)	(0.000)		(0.000)		(0.000)		(0.012)
$Soib_{t-1}$∗SS		0.004		0.006	−0.022	0.012		0.004		0.019		0.017
		(0.262)		(0.273)	(0.465)	(0.333)		(0.480)		(0.088)		(0.519)
$Foib^+$		−0.001		0.005	−0.003	−0.022		0.001		−0.001		−0.022
		(0.783)		(0.344)	(0.938)	(0.108)		(0.657)		(0.945)		(0.339)
$Foib^-$		0.001		−0.002	−0.044	0.001		0.002		0.001		0.015
		(0.660)		(0.752)	(0.280)	(0.955)		(0.537)		(0.911)		(0.529)
$Foib^+_{t-1}$		0.010		0.039	0.074	0.070		0.013		0.025		0.089
		(0.003)		(0.000)	(0.079)	(0.000)		(0.075)		(0.157)		(0.001)
$Foib^+_{t-1}$∗SS		0.007		0.002	0.195	−0.014		0.010		0.022		0.015
		(0.084)		(0.840)	(0.007)	(0.385)		(0.192)		(0.139)		(0.726)
$Foib^-_{t-1}$		0.022		0.044	0.039	0.060		0.020		0.036		0.063
		(0.000)		(0.000)	(0.505)	(0.000)		(0.008)		(0.071)		(0.017)
$Foib^-_{t-1}$∗SS		0.007		0.003	−0.017	0.000		0.005		0.027		−0.004
		(0.094)		(0.647)	(0.734)	(0.997)		(0.472)		(0.081)		(0.917)
Mis_{t-1}		1.086		1.091	−0.193	0.526		0.985		0.727		0.294
		0.000		0.000	(0.052)	(0.000)		(0.000)		(0.000)		(0.000)
Mis_{t-1}∗SS		0.050		−0.103	0.553	−0.162		0.077		−0.127		−0.124
		(0.000)		(0.000)	(0.000)	(0.000)		(0.035)		(0.023)		(0.000)
Std_fut		−0.001		−1.150	1.464	−1.957		−0.274		−2.303		−2.951
		(0.043)		(0.000)	(0.085)	(0.000)		(0.080)		(0.000)		(0.000)
R^2		0.979		0.835	0.927	0.599		0.981		0.716		0.598
DW		(2.072)		(1.923)	(2.167)	(1.627)		(2.021)		(1.705)		(1.640)

and short-sale turnover of index stocks, as well as the correlation between futures mispricing and the short-sale turnover. Brenet, Morse, and Stice (1990) and Senchack and Starks (1993) observe that short selling takes place not only for speculation but also for arbitrage and argue that index futures arbitrage accounts for a considerable proportion of short selling. The implication of this observation is that the lack of a price reaction following short selling may be attributed to an arbitrage transaction involving the underlying security. For this reason, we expect to find a higher correlation between the futures and the stock index when an increased underpricing corresponds to a decrease in short sales of index stocks by speculators, or when a decreased underpricing corresponds to a higher level of short sales in index stocks by index and risk arbitrageurs. Based on the results in Table 2, we conjecture that arbitrage activity increases during the post-SS/LS100 period because of a higher trading volume, a lower underpricing, and a lower order imbalance relative to the pre-SS/LS100 period.

We find that the exchange traded fund ETF50 (its underlying securities are the Taiwan top 50 stocks) is slightly undervalued relative to its net asset value, that is, the value of ETF50_nav is less than zero. Because the ETF50 is not subject to the TWSE uptick rule and can be used for short arbitrage, the small discount of the ETF50 may simply reflect a short-selling pressure. If the undervaluation is

Table 5
Determinants of signed order imbalance.
The table reports the factors which determine buy-side ($Foib^+$) or sell-side ($Foib^-$) order imbalance of index futures, which is the dependent variable. UNFoib (UNSoib) refers to daily uninformed order imbalance of index futures (stock index), while INFoib (INSoib) refers to daily informed order imbalance of index futures (stock index). The decomposition of estimates of daily order imbalance is obtained using revised Easley et al. (2002) model. SS is one (zero) if an observation appeared on or after (before) the lifting date of each event. The other independent variables are lagged order imbalance of stock index ($Soib_{t-1}$), lagged order imbalance of index futures ($Foib_{t-1}$), contemporaneous and lagged Mismax and Mismin, and futures return volatility (Std_fut). Interaction terms include UNFoib∗SS, INFoib∗SS, UNSoib∗SS, INSoib∗SS, Soib∗SS, Mismin∗SS, and Mismax∗SS, where Mismin = min(Mis_t,0) and Mismax = max(Mis_t,0).

Independent variables	Low transaction costs/high transaction costs					
	SS50		LS50		SS/LS100	
	$Foib^+$	$Foib^-$	$Foib^+$	$Foib^-$	$Foib^+$	$Foib^-$
UNFoib	0.090	0.068	0.063	−0.058	−0.043	−0.026
	(0.003)	(0.013)	(0.057)	(0.042)	(0.239)	(0.471)
INFoib	0.016	0.033	0.028	0.001	0.021	0.045
	(0.591)	(0.204)	(0.120)	(0.961)	(0.264)	(0.012)
UNSoib	0.010	0.012	0.017	0.007	−0.001	0.040
	(0.675)	(0.574)	(0.561)	(0.797)	(0.967)	(0.034)
INSoib	−0.001	−0.016	−0.016	−0.012	0.007	0.022
	(0.981)	(0.475)	(0.448)	(0.530)	(0.696)	(0.227)
SS	−0.010	−0.033	0.022	0.053	−0.088	−0.042
	(0.816)	(0.395)	(0.498)	(0.064)	(0.005)	(0.174)
UNFoib∗SS	−0.050	−0.073	−0.033	0.078	0.028	0.014
	(0.172)	(0.026)	(0.117)	(0.000)	(0.128)	(0.430)
INFoib∗SS	0.012	0.005	0.001	0.018	0.015	0.017
	(0.665)	(0.853)	(0.973)	(0.214)	(0.334)	(0.260)
UNSoib∗SS	−0.017	−0.025	−0.039	0.000	−0.011	−0.045
	(0.568)	(0.343)	(0.258)	(0.987)	(0.645)	(0.056)
INSoib∗SS	−0.013	0.049	0.003	0.002	0.008	0.014
	(0.636)	(0.053)	(0.912)	(0.908)	(0.662)	(0.436)
Soib	0.434	0.380	0.297	0.313	0.297	0.279
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Soib∗SS	−0.008	0.022	−0.018	−0.037	−0.068	−0.039
	(0.677)	(0.222)	(0.194)	(0.003)	(0.000)	(0.001)
$Soib_{t-1}$	0.016	0.019	0.036	−0.001	−0.057	−0.013
	(0.548)	(0.420)	(0.059)	(0.941)	(0.001)	(0.439)
$Foib_{t-1}$	0.086	0.034	−0.046	−0.002	−0.121	−0.304
	(0.156)	(0.535)	(0.475)	(0.966)	(0.070)	(0.000)
$Foib_{t-1}$∗SS	−0.175	−0.137	−0.218	−0.046	−0.162	−0.058
	(0.036)	(0.069)	(0.013)	(0.554)	(0.121)	(0.572)
Mismax	0.000	0.000	−0.207	1.281	−0.001	0.295
			(0.821)	(0.107)	(0.995)	(0.111)
Mismin	−0.431	−0.132	0.015	0.038	−0.118	0.003
	(0.008)	(0.367)	(0.836)	(0.548)	(0.001)	(0.940)
$Mismax_{t-1}$	−0.190	0.149	−0.044	0.184	−0.008	0.053
	(0.284)	(0.352)	(0.673)	(0.047)	(0.750)	(0.023)
$Mismin_{t-1}$	0.210	0.028	−0.003	−0.033	0.028	−0.004
	(0.137)	(0.828)	(0.955)	(0.524)	(0.298)	(0.883)
Mismax∗SS	−0.500	0.145	−0.001	−0.098	−0.040	−0.098
	(0.168)	(0.658)	(0.989)	(0.269)	(0.567)	(0.150)
Mismin∗SS	0.151	0.031	0.014	−0.018	0.018	−0.064
	(0.027)	(0.613)	(0.702)	(0.569)	(0.405)	(0.003)
Std_fut	0.001	0.004	−0.636	0.352	−0.665	−0.098
	(0.829)	(0.256)	(0.144)	(0.351)	(0.001)	(0.614)
R^2	0.119	0.116	0.124	0.151	0.166	0.168
DW	(2.001)	(2.002)	(2.002)	(2.003)	(1.974)	(2.035)

due to price restrictions, it should decline after the TWSE uptick rule is relaxed. However, we find this pattern only during the post-SS/LS100 period. This may result from undervalued ETF50 which underestimates the theoretical futures price and hence underestimates the boundaries. Because there are no futures whose underlying securities are the component stocks listed in the Taiwan mid-cap 100 index, this might be the reason why ETF100 is not undervalued in the post-SS/LS100 period, but EFT50 is in the post-SS50 and post-LS50 periods. In fact, boundary violations are not uncommon when new information induces a temporary mispricing error between futures and cash index. A large boundary violation after lifting price restrictions may simply reflect the consequences of more information. It does not necessarily reflect poor pricing efficiency. We discover increased post-lifting information, measured by probability of informed trading (PIN), in both the cash and futures markets except in the futures market during the post-SS/LS100 period. In addition, the increase in PIN in the stock market is stronger than that in the futures markets. This evidences more information may flow into the cash market by speculators or hedgers after removing price restrictions. This inference comes from the argument in Senchack and Starks (1993) that it is unlikely that the short sales form part of an arbitrage transaction will precipitate a price reaction. If price changes result from something other than information, we expect to observe subsequent reversals in mispricing or in order imbalance caused by price manipulation.

4. Autoregression methodology for assessing reversals

To measure the impact of price restrictions on reversals in mispricing or in order imbalance, we employ a methodology similar to autoregression and estimate the parameters of the following model:

$$V_t = \sum_{n=1}^{5} \kappa_n V\min_{t-n} + \sum_{n=1}^{5} \gamma_n V\max_{t-n}, \quad V_t = \text{Mis}_t \text{ or Foib}_t$$

where V_t represents the index-futures mispricing Mis_t (futures order imbalance $Foib_t$) in interval t, and the regressors are the positive and negative components of lagged mispricing (lagged order imbalance), noted respectively as

$$V\min_t = \min(0, V_t) \text{ and } V\max_t = \max(0, V_t), \quad V = \text{Mis or Foib}$$

The number of lags is determined by the Akaike and Schwarz information criteria. When these two criteria indicate different lag lengths, the lesser lag length is chosen for the sake of parsimony. The estimated autocorrelation coefficients κ_n and γ_n measure the extent to which the underpricing (sell-side order imbalance) and overpricing (buy-side order imbalance) reverse or continue in the same direction during subsequent intervals. If in a world where mispricing (order imbalance) follows a random-walk process, the true coefficients would be zero. Unlike in ordinary autoregression, this specification allows the degrees of reversal, due to the buying or selling shock, to differ between the overpricing (buy-side order imbalance) and underpricing (sell-side order imbalance). In either case, a positive coefficient indicates that mispricing (order imbalance) exhibits a short-term momentum, whereas a negative coefficient indicates a short-term reversal. Table 3 reports the autoregression coefficients for the lagged terms of overpricing and underpricing (the lagged order imbalance on buy side and sell side) before and after the lifting of the price restrictions. The coefficients reported in the table are estimated over the designated period.

4.1. Reversals/momentums of arbitrage spread

In sub-panel 1 (sub-panel 2) of Panel A in Table 3, we show the effect of momentum or reversal in mispricing for large traders (small traders) during the pre-lifting and post-lifting periods. The coefficients γ_1 and γ_2 are estimated to be around −0.26 and 0.07 respectively over the post-SS50 period. This means that an overpricing of 1% would, on average, be followed by an underpricing of 26 basis points in the next period and an overpricing of 7 basis points in the period after that. The coefficients κ_1 and κ_2 are estimated to be around 0.83 and 0.05 respectively over the same period. This indicates that the 1% underpricing is, on average, followed by an underpricing of 83 and then 5 basis points in the next two periods. We are interested in comparing these coefficients for both large and small traders and for both the pre-lifting and post-lifting periods, as well as for both the overpricing and underpricing intervals. If such restrictions help prevent short-term negative price manipulation, we would expect to see the κ coefficients lower in the post-lifting period than in the pre-lifting period, regardless of whether futures mispricing continues in the same direction or reverses.

In the post-lifting period, the autocorrelations of the lower-bound violations and upper-bound violations persist longer and are more pronounced for big traders than small traders. Specially, in the post-SS/LS100 period the autocorrelation of the upper-bound violations seems to persist for 25 min for large traders. Furthermore, the autocorrelation of the lower-bound violations are much more pronounced than upper-bound violations. We observe from Panel A of Table 3 that for large traders the aggregate autocorrelation (the sum of the significant coefficients) is surprisingly higher in the post-SS50 and post-LS50, but is lower in the post-SS/LS100 as our expectation, whereas the duration represented by the autocorrelation with significant coefficients is longer in all the post-lifting periods. These findings support the argument that the post-SS50 and post-LS50 periods might be dominated by speculators, while the post-SS/LS100 might be dominated by arbitrageurs. As remarked in Chu and Hsieh (2002), the reduction in magnitude and shorter duration represented by the autocorrelations are two indicators of efficiency. Therefore, the above results are mixed because a low autocorrelation indicates improvement in efficiency, whereas an autocorrelation with a longer duration indicates a decrease in efficiency. For small traders, the pattern is similar to big traders' except the results are reversed in the post-LS50 period. The lower-bound violations for big traders tend to persist for longer periods than small traders. Moreover, these violations are followed by new violations, suggesting that the market is slow to react to lower-bound violations. This result conforms to our preliminary finding that index futures tend to be underpriced. The asymmetry in mispricing and the response time may be due to the TWSE uptick rule, as well as other short-sale constraints that impede short arbitrages.

4.2. Reversals/momentums of futures order imbalance

Theoretically, the buy-side order imbalance of index futures should decrease after lifting price restrictions because the friction in short arbitrage is reduced and therefore decreases the buy-side order imbalance. Relaxing price restrictions also makes the long arbitrage that involves longing stocks and shorting futures more difficult to establish, and thus decreases the sell-side order imbalance of index futures. As expected, in Panel B of Table 3 the aggregate significant coefficients of the buy-side and sell-side order imbalances are consistently lower in the post-lifting periods than in the pre-lifting periods. We observe the sums of significant autocorrelation coefficients on the buy-side in the post-SS50, post-LS50 and post-SS/LS100 periods are 0.03, 0.06, and 0.06, while they are 0.13, 0.06, and 0.12 on the sell-side in the same periods. The implication of the observation is that the buy-side order imbalance is more weakly auto-correlated than the sell-side order imbalance in the pre- and post-lifting periods, with an exception in the pre-SS50 period. Our findings are similar to Ning and Tse's (2009), which demonstrates that both excess buying and excess selling reduce liquidity and excess buy orders have no impact on prices but sell orders do, as suggested by the fact that the buy-side order imbalance was more strongly auto-correlated than the sell-side order imbalance.

4.3. The autocorrelations on extreme observations

The relationship between order imbalance and arbitrage spreads has been examined in previous studies (see, for example, Fung, 2007; Stoll & Whaley, 1987, and Roll, Schwartz, & Subrahmanyam, 2007). We consider it more important to know the different effects of the buy/sell-side order imbalance on underpricing and overpricing for the extreme observations. Stoll and Whaley (1987) argue that if the unwinding of index arbitrage leads to a temporary order imbalance that drives the price away from the equilibrium level, the index tends to reverse at the next opening, when the price pressure has dissipated. Roll et al. (2007) find evidence that dynamics of the absolute futures-cash basis and liquidity are jointly determined and indicate that arbitrage transactions themselves can reduce liquidity by creating order imbalances although liquid markets facilitate arbitrage transactions. The evidence contradicts the common conjecture that improving the trading mechanism can increase market liquidity. Roll et al. (2007) calculate basis as Eq. (2) in MacKinlay and Ramaswamy (1988). Their measure of basis is equivalent to our measure of mispricing but is expressed differently as $(Fe^{-(r-\delta)t}-S)/S$shown in Eq. (1). Fung (2007) calculates order imbalance by volume and examines how such imbalance in cash market affects the arbitrage spread between the futures and the underlying index. In this study, we gauge order imbalance by order flow and seek to understand how the imbalance in the index futures market affects the arbitrage spread under a lead–lag framework in the predictive regressions in the next session.

Intuition suggests that mispricing should be more strongly affected by more extreme order imbalances, and the more extreme of the observations represents the greater possibility of profitability. To determine whether the pattern of correlations between order imbalance and mispricing is different for extreme and non-extreme observations, and whether the correlation between large sell-side imbalance and large underpricing is asymmetric with that between large buy-side imbalance and large overpricing, we sorted all 5-minute intervals by the order imbalance and by the mispricing of the TAIEX futures separately. Then, for time intervals during the pre-lifting (post-lifting) period above the 75th and below the 25th percentiles, we calculate two serial correlations for both the order imbalance and mispricing sorts in Panel C of Table 3. The serial correlation for the −25% intervals in the pre-SS50, pre-LS50, and pre-SS/LS100 (post-SS50, post-LS50, and post-SS/LS100) periods are 0, −0.071, −0.119 (0.050, −0.202, −0.431), with $N=1$, 10, 57 (214, 53, 4). The corresponding figures for the +75% intervals are −0.256, −0.074, −0.122 (−0.024, −0.557, and −0.515), with $N=20$, 7, 33 (4, 8, 7). Hence, there is evidence of weak momentums for large underpricing intervals accompanied by large sell-side imbalances, and evidence of strong reversals for large overpricing intervals accompanied by large buy-side imbalances in the post-SS50 period, whereas there is evidence of relatively weak momentum for large underpricing intervals accompanied by large negative imbalances, and evidence of strong momentums for large overpricing intervals accompanied by large buy-side imbalances in the post-LS50 period. Furthermore, there is evidence of strong momentums for large underpricing intervals accompanied by large sell-side imbalances and large overpricing intervals accompanied by large buy-side imbalances in the post-SS/LS100 period. It is surprising to find that for the four types of events, the correlation between extreme imbalance and extreme mispricing increases consistently after the removal of price restrictions because improvements in arbitrage enhance the correlation.

5. Informed trading and lead–lag relationship

In Tables 4 and 5, we decompose estimates of daily order imbalance into informed and uninformed components to proxy for trading with and without information. We do so by modifying Easley et al. 's (2002) model to assess whether trader reaction to mispricing or order imbalance depends upon private information. An estimation of intraday informed and uninformed order imbalance is unavailable due to the limitation of the likelihood function from Easley et al. (2002). We apply two hypotheses based on ideas presented in previous studies, such as those of Chordia and Subrahmanyam (2004) and Fung (2007). For the purpose of comparison and to address the relationship between signed mispricing and signed order imbalance, we refer to them as the *substitution* hypothesis and the *arbitrage enforcement* hypothesis. Before we draw a distinction between the sensitivity of order imbalance during overpricing and underpricing periods, we assume responses to mispricing are linear and the responses predict the buy-side and sell-side measures of illiquidity for the pre- and post-lifting periods.

Based on the above analysis, we propose the following bi-directional lead–lag regression models:

$$\begin{aligned}\mathrm{Mis}_t^+(\mathrm{Mis}_t^-) = {} & \beta_0+\beta_1\,\mathrm{Foib}_t^+ +\beta_2\,\mathrm{Foib}_t^- +\beta_3\,\mathrm{Foib}_{t-1}^+ +\beta_4\,\mathrm{Foib}_{t-1}^- +\beta_5\,\mathrm{SS}_t+\beta_6\,\mathrm{Foib}_{t-1}^{+}{}^*\,\mathrm{SS}_t \\ & +\beta_7\,\mathrm{Foib}_{t-1}^{-}{}^*\,\mathrm{SS}_t+\beta_8\,\mathrm{Soib}_{t-1}{}^*\,\mathrm{SS}_t+\beta_9\,\mathrm{Mis}_{t-1}+\beta_{10}\,\mathrm{Mis}_{t-1}{}^*\,\mathrm{SS}_t+X_t\end{aligned} \tag{1}$$

$$\begin{aligned}\mathrm{Foib}_t^+(\mathrm{Foib}_t^-) = {} & \alpha_0+\alpha_1\,\mathrm{MisMax}_t+\alpha_2\,\mathrm{MisMin}_t+\alpha_3\,\mathrm{MisMax}_{t-1}+\alpha_4\,\mathrm{MisMin}_{t-1}+\alpha_5 SS_t+\alpha_6 Foib_{t-1} \\ & +\alpha_7\,\mathrm{Foib}_{t-1}{}^*\,\mathrm{SS}_t+\beta_8\,\mathrm{Soib}_t{}^*\,\mathrm{SS}_t+\beta_9\,\mathrm{MisMax}_{t-1}{}^*\,\mathrm{SS}_t+\beta_{10}\,\mathrm{MisMin}_{t-1}{}^*\,\mathrm{SS}_t+X_t\end{aligned} \tag{2}$$

where Mis_t^+ (Mis_t^-) denotes overpricing (underpricing) at time *t*, $Foib_t^+$ ($Foib_t^-$) denotes buy-side (sell-side) order imbalance of index futures at time *t*, SS_tdenotes the lifting dummy, $Soib_t(Soib_{t-1}) * SS_t$ denotes the interaction between lifting dummy and order imbalance of spot index at time t ($t-1$), $Mis\ \min_t = \min(0, Mis_t)$, $Mis\ \max_t = \max(0, Mis_t)$, and X_t denotes the common variables listed in Tables 4 and 5.

The proposed models come from a conjecture that contemporaneous order imbalances bear little relation to contemporaneous mispricing, so lagged signed order imbalance of index futures is included to determine whether mispricing declines during the time interval following the occurrence of imbalance. Table 4 presents the determinants of the underpricing and overpricing, while Table 5 reports the determinants of the buy-side and sell-side order imbalances with respect to index futures. The dependent variables are predicted by 11 common variables including the daily uninformed and informed order imbalances in the stock index and index futures markets (UNSoib, INSoib,UNFoib, INFoib), their interaction with lifting dummy (UNSoib∗SS, INSoib∗SS, UNFoib∗SS, INFoib∗SS), 5-min volatility of the index futures returns (std_fut) , and contemporaneous and lagged 5-min order imbalance of spot index ($Soib_t$,$Soib_{t-1}$), as well as the specific 5-min independent variables listed in either (1) or (2). Lifting dummy (*SS*) represents the pre- and post-SS50 (post-LS50, post-SS/LS100) periods to test for the structural break in the regressions.

5.1. Determinants of mispricing

In Table 4, we find liquidity, defined by order imbalance, during the preceding 5-minute in both the stock and futures markets affects underpricing and overpricing (if overpricing exists), but in opposite directions, the contemporaneous order imbalance in both markets has no effects on overpricing and underpricing. The lagged order imbalance in the stock market significantly and negatively associated with underpricing and overpricing, but the extent of negative relation is insignificantly smaller after removing the price restrictions. However, the buy-side and sell-side components of lagged order imbalance in the futures market are positively related to underpricing and overpricing. The positive relationship between lagged signed futures imbalance and mispricing becomes evident after we control for contemporaneous order imbalance and other variables in the regressions. The coefficients between lagged buy-side futures imbalance and underpricing is positive, indicating investors buy the futures to increase the buy-side order imbalance and sell stocks to reduce underpricing in the subsequent 5 min. This behavior is called arbitrage enforcement. However, the negative relationship between lagged stock imbalance and underpricing encourages investors to substitute selling futures for selling stocks in their trading (because of lower transaction costs) to increase sell-side order imbalance and widen underpricing in the next 5 min. This is called substitution hypothesis.

The private information in the index futures market seems to affect underpricing more than overpricing for both large and small traders. The results in Table 4 show that informed traders have a negative effect on underpricing, but uninformed traders associate positively with it. The explanation is that uninformed traders enforce arbitrage to lessen the magnitude of overpricing, whereas informed traders substitute selling futures for selling stocks and increase the magnitude of underpricing, as suggested by the substitution hypothesis. Across the four events, we find uninformed traders in the futures market (indicated by UNFoib) have a positive impact on underpricing and they expand underpricing in the post-SS50 and post-LS50 periods, but lessen it in the post-SS/LS100 period for large and small traders. On the other hand, informed traders (indicated by INFoib) increase the size of underpricing prior to the lifting of price restrictions. Nonetheless, large informed traders shrink underpricing in the post-SS/LS100 period, while small informed traders widen underpricing in the post-LS50 period (as indicated by the coefficients of INFoib∗SS). The significant impact of informed traders on underpricing supports our main hypothesis in this session that lifting price restrictions enhances informed trading in the futures market. In the post-lifting period, large uninformed traders in the stock market (indicated by UNSoib∗SS) lower the size of underpricing in the post-SS50 period and the size of overpricing in the post-SS/LS100 period, but it is not the case for informed traders in the same market. Relative to the traders in the futures market, informed and uninformed traders in the stock market have less impact on signed mispricing and fail to conclude that lifting price restrictions enhances informed trading in the stock market.

The underpricing and overpricing on post-lifting days is significantly smaller than on pre-lifting days (as indicated by the coefficient of the lifting dummy) for both large and small traders, but they are not the case in the post-LS50 period regardless of whether they are large or small. Prior to the lifting of price restrictions, an increase (a decrease) in the mispricing in the previous 5 min is strongly related to a decrease (an increase) in underpricing and overpricing, while this momentum effect is significantly greater on the post-lifting days than on the pre-lifting days except in the post-SS50 period for large and small traders. For all traders regardless of whether they are large or small, futures return volatility consistently increases the level of overpricing and the level of underpricing surrounding the lifting of price restrictions for the four market events. Fung (2007) investigates the link between futures mispricing and signed order imbalance in the stock market and find that negative order imbalance has a greater impact than positive imbalance on mispricing, and that violations of the upper (lower) no-arbitrage bound are related to positive (negative) order imbalance. Similarly, we find a significant and positive link between upper-bound violations and lagged buy-side order imbalance of index futures for large traders, but we find that violations of the lower no-arbitrage bound are significant and positively related to the lagged buy-side and lagged sell-side order imbalances for all traders. It seems that arbitrage activity occurs when an increased magnitude of mispricing can be detected from order flow.

5.2. Determinants of futures order imbalance

In Table 5, we examine the results for buy-side and sell-side order imbalances in the index futures market, which may have different effects. We control for the volatility of index futures return because of the evidence in Chan and Fong (2000) that the volatility-volume relationship becomes much weaker after controlling for the impact of order imbalance. In addition, including return volatility as a control variable can account for the results of possible trading activity associated with portfolio rebalancing.

To detect differences in the momentum effect for the buy-side and sell-side imbalances, we include lagged order imbalances of stock index and index futures in the regressions. The contemporaneous order imbalance in the stock market strongly affects both buy-side and sell-side order imbalances in the futures market, given that its lagged term $Soib_{t-1}$ significantly spills over into the buy-side imbalance in the futures market in the post-LS50 and post-SS/LS100 periods.

On the post-lifting days, the futures momentum effect is higher than spillover effect for both buy- and sell-side order imbalances, yet the aggregate spillover effect (as indicated by the sum of the coefficients on the Soib and Soib∗SS) is stronger than the aggregate momentum effect (as indicated by the sum of the coefficients on the $Foib_{t-1}$ and $Foib_{t-1}{}^{*}SS$). Furthermore, we observe an increase in underpricing (indicated by*Mis* min) expands the buy-side order imbalance, but an increase in the lagged overpricing (indicated by *Mis* max $_{t-1}$) reduces the sell-side order imbalance. The relationship between underpricing and the buy-side order imbalance in the periods before and after SS50 indicates that investors long futures instead of buying stocks. Likewise, the relationship between the lagged overpricing and the sell-side order imbalance surrounding SS/LS100 implies that short futures substitutes for selling stocks, as predicted by the substitution hypothesis. However, the cause of the relationship between underpricing and buy-side order imbalance is the intensified arbitrage that follows from the lifting of price restrictions, supporting the arbitrage enforcement hypothesis. Because the underpricing impacts on the buy-side order imbalance are greater than the lagged overpricing on the sell-side order imbalance in the index futures market, we can infer that the substitution hypothesis has more support than the arbitrage enforcement hypothesis. Whereas, we find underpricing narrows the buy-side order imbalance to a greater extent after SS50 than before it, and underpricing also narrows the sell-side order imbalance after SS/LS100, signaling lifting price restrictions improves liquidity in the futures market.

The behavior of informed traders in the stock market does not significantly increase the futures imbalance on either the buy side or the sell side; on the other hand, the behavior of uninformed traders in the stock market increases the liquidity in the futures market by decreasing the imbalance on the sell side. As for the index futures market, the behavior of uninformed traders increases the sell-side liquidity before lifting price restrictions on short selling the Taiwan 50 stocks, but lower both the buy- and sell-side liquidities before lifting price restrictions on lending selling the same stocks. Moreover, uninformed traders in the futures market decrease the sell-side liquidity by 7.3% in the post-SS50 period than in the pre-SS50 period, but increase the liquidity by 7.8% in the post-LS50 period than in the pre-LS50 period. Although uninformed traders in the stock market enhance the sell-side liquidity by 4.9% in the post-SS50 period, the extent of increased liquidity is less than the decreased 7.3% lessened by uninformed traders in the futures market. On the other hand, the behavior of informed traders in the futures market reduced the sell-side liquidity by 4.5%, regardless of whether before or after SS/LS100. These results fail to support our hypothesis that lifting price restrictions causes informed traders to lessen the liquidity in the futures market. Nevertheless, the elimination of price restrictions (as indicated by the coefficients of the lifting dummy SS) significantly reduces the sell-side order imbalance in the post-LS50 period and the buy-side order imbalance in the post-SS/LS100 period, suggesting an improved sell- and buy-side liquidities in the post-LS50 and post-SS/LS100 periods respectively.

Our results show that if mispricing deteriorates during any 5-minute interval, the arbitrage transactions in the subsequent 5-minute interval yield an increase in buy or sell orders, which strains liquidity. Overall, our results are consistent with the hypothesis that deviations from no-arbitrage bounds can predict liquidity, and vice versa. Our finding documents a bi-directional lead–lag relationship between signed mispricing and signed order imbalance in the futures market. If market efficiency is defined as the degree to which the law of one price is satisfied, then our results suggest that liquidity plays a significant role in moving markets toward an efficient outcome. On the other hand, our results also suggest that deviation from the law of one price on a given interval can help predict market liquidity on subsequent intervals when the upper no-arbitrage bounds are violated, but it cannot when the lower no-arbitrage bounds are violated. As revealed in Grossman (1988), the prediction indicates that arbitrageurs affect liquidity in the futures market by their trading.

We conclude with a discussion on the inclusion of real-time 5-minute order imbalance and daily order imbalance. If markets are efficient in disseminating all publicly available information, the regression coefficients for the two types of order imbalance should be different. Because 5-minute order imbalances in the index and index futures are identified through publicly available trade data, both can be observed essentially in real time. As a result, prices associated with real-time 5-minute order imbalances should be efficient, and real-time order imbalances should not predict future returns or mispricing. Even if such predictions are possible (or available), they should be so only for a short period of time because of the noise caused by the bid-ask bounce and potential thin trading. The real-time contemporaneous order imbalance data in Table 5 supports this argument. Because daily informed and uninformed order imbalances are not publicly observed, the associated order flow can predict future returns as long as it is not collinear with the real-time 5-minute order imbalance.

6. Conclusions

This study analyzes the effects of removing price restrictions on the pricing of index futures, the excess buy and sell orders in the index futures market, and how violations of the upper and lower no-arbitrage bounds are related to excess buy and sell orders in the index futures market. The price pressure exerted by arbitrageurs and speculators in the futures market, both before and after relaxing price restrictions, is explored by arbitrage enforcement and substitution hypotheses. The literature has focused mainly on the impact of market derivatives on the spot market, whereas our study is focused on the impact of the spot market on market derivatives. As reported in other studies, in the presence of short-sale constraints, stock prices tend to be upwardly biased and index futures overvalued, which widens the no-arbitrage window if there are price restrictions. We find that after the price restrictions are lifted, the degree of misalignment between the stock index and index futures varies for different groups of stocks classified by their market capitalization and for different kinds of traders classified by their transaction costs involved. During the post-lifting period, the autocorrelations for underpricing and overpricing persist longer and are more pronounced for big traders, while the autocorrelations for the buy- and sell-side order imbalances are consistently lower and persist longer. Meanwhile, the order imbalance on the buy side is more weakly auto-correlated than that on the sell side. The outcomes for the post-lifting market efficiency are mixed for all the lifting of price restrictions explored in this study. We find deviations from no-arbitrage bounds can predict liquidity, and vice versa. Our findings not only document a bi-directional lead–lag relationship between signed mispricing and signed order imbalance in the futures market, but also uncover the impact of informed and uninformed trading on these relationships. This study evidences lifting price restrictions enhances informed trading in the futures market, but not the case in the stock market. In addition, this study finds no evidence to support that lifting price restrictions causes informed traders to lessen the liquidity in the futures market. Previous studies underscore the importance of order imbalance as an asymmetric measure of liquidity, and only focus on the impact of both positive and negative illiquidity on short-term overpricing and underpricing. Our results, from a practical standpoint, suggest that access to information about order imbalance can be valuable for the design of trading strategies.

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