Market Efficiency, Stability and Short-Sale Constraints: Evidence from Taiwan

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Abstract

How efficient is the market under the superimposed short sale constraint has long been debated in the recent literature. We disentangle the related efficiency adjustment issues by examining the put-call parity defined equilibrium deviations. By taking advantage of the natural experiments from several policy changes of short-sale constraints in Taiwanese stock market from 2002 to 2009, we document that stronger short-sale constraints induce heavier asymmetric adjustment between upward and downward convergence to equilibrium. After examining across different hypotheses, we also find that short sale constraints in general hinder negative information into price; therefore the convergence rate of upward adjustment is faster than that of downward adjustment within our entertained threshold error correction model (TECM). This is true even we controlled for market conditions and liquidity. Moreover, we find evidence supporting that exercising tighter short sale constraints help restoring the market confidence via our conducted counterfactual analysis, albeit against the claim that a tighter short sale constraint stabilize the market. Instead, we find both volatility and downside risk increases after tightening up the short sale restrictions.

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1. Introduction

The concept of market efficiency is the building block of modern financial theory; market stability, nonetheless, is the core concern among policy makers who are in charge of trading mechanism designs. Given the recent experienced financial crises in 2008, academic researchers, market practitioners, and regulators are increasingly interested in understanding the highly contentious impact of short sales on the price efficiency and stability in capital markets. Without a consensus about the effects of short selling, stock exchanges and government regulators find it difficult to agree on a consistent set of short-sale guidelines. As a result, short-sale regulations continue to vary widely across countries and capital markets (Bris et al., 2007).

This article studies empirically the impacts of short-sale restrictions on price efficiency (the price discovery process) and market stabilization policy by examining the characteristics of the index returns distribution from the emerging Taiwanese market across different regimes of short-sale regulations. The short-selling policies that has been implemented and changed over the past decade have given rise to a unique chance for research since they provided academics the perfect "natural experiment."

The first goal of this paper is to explore the effects of short sale constraints pressure changes on the speed of price adjustment toward new equilibrium. We define price efficiency as the degree to which prices reflect all available information in terms of speed and accuracy. Set aside the efficiency issues, we also attempt to resolve what is the impact of short-selling constraints on stabilizing the financial markets? Do they make markets more or less volatile?

A short sale refers to a trading strategy involving borrowing and selling shares in the open market and then buying back and returning at some point in the future that aims to capitalize on anticipated declines in the price of a security. Both academicians and practitioners have long been interested in studying the benefits and costs of short sales. In the presence of short-sale constraints, security prices tend to reflect a more optimistic valuation than the average opinion of potential investors and thus tend to be upward biased (Miller 1977, Figlewski 1981). Recently, Danielsen and Sorescu (2001), Jones and Lamont (2002), Ofek and Richardson (2003), Chang et al. (2007), and Diether et al. (2009a) all test Miller's (1977) conjecture that short-sale constraints result in overpriced securities and low subsequent returns. However, an alternative argument is that in a rational market, traders will recognize the existence of short-sale constraints and will therefore adjust their beliefs such that no overpricing of securities will exist, on average (Diamond and Verrecchia 1987). In addition, Franklin and Gale (1991) find that short sales can potentially destabilize an economy.

As the short sale constraints produce asymmetric magnitude of price changes and asymmetric speed of price adjustment, the majority of past studies focus on the former aspect, particularly on the relation between short sales and stock overvaluation, see through (Miller, 1997, Jones and Lamont, 2002, Bris et al., 2007, Ofek et al., 2004, Boulton and Braga-Alves, 2010, and Autore et al., 2011). There appeared only a few works that examine the speed of price adjustment to new information till recently due to the lack of transaction data and the difficulties characterizing the speed of price adjustment in earlier years. Diether et al. (2009b) find that the suspension of short sales constraints improves the symmetric price transmission process without significantly sacrificing volatility and liquidity when examining the trading activities under the SEC pilot program in NYSE and Nasdaq. Fung and Draper (1999) demonstrate that relaxing short selling constraints reduces the mispricing of index futures contracts and speeds up the market price adjustments. Bris et al. (2007) show that the ability to short sell facilitates an efficient price discovery process by comparing the cross-autocorrelations between weekly lagged market returns and individual stock returns in 46 equity markets for dually listed stocks. Chen and Rhee (2010) present empirical evidence for Hong Kong that short sales contribute to market efficiency by increasing the speed of price adjustment to not only private/public firm-specific information but also market-wide information. Shortable equities are characterized by weaker trade continuity and stronger quote reversals. While Chen and Rhee (2010) also disentangle the speed of adjustment issue under short sale constraints, they focus more on the firm level evidence.

Specifically, this paper focuses on both parts but emphasizes on the speed of price adjustment to new equilibrium, where we define a path of implied equilibrium prices from various option contracts by using the put-call parity. As an alternative to short selling with an even lower cost, the introduction of option/future trading enhances the price efficiency by improving the speed of price adjustment to a new equilibrium, see, for example, Diamond and Verrecchia (1987), Patell and Wolfson (1984), Jennings and Starks (1986), Senchack and Starks (1993), and Figlewski and Webb (1993). From a price discovery point of view, if the restriction on short sales hinders price discovery in the underlying spot index, then short sales in terms of writing puts or shorting calls in the option market should play a more important price discovery role for the fundamental value in equilibrium. Therefore, we posit that option implied index (return) will be more informative about market returns if the underlying index is restricted from being sold short in the spot market.

We use the put-call parity to recover the averaged implied Taiwan indices from 7 near month option contracts. The no-arbitrage-condition implied index prices alleviate the potential issues from model misspecifications and biased volatility inputs, see Chiou et al. (2007) among many others. In particular, with the shared cointegration relationship between the spot/implied indices, the natural equilibrium explanation allows us to disentangle specifically on the speed of mispricing adjustment toward a new equilibrium, instead of merely on the speed of price adjustment to new information. We explore the picture of the adjustment procedure by looking unconditionally into and conditionally by implementing the threshold error correction models (TECM) to the adjusting duration of mispriced equilibrium deviations. As we know, this piece is the first that uses the comprehensive TECM approach that allows for the endogenous entry barriers from concerns such as transaction cost and market frictions in analyzing the effect of short sale constraints for an aggregate index.

Our main findings are as follows. First, short sale constraints lead to a less efficient market by creating the asymmetric patterns in both the magnitude as well as the speed of price adjustment in the presence of mispricing. We find that short sale constraints in general hinder negative information into price, therefore the convergence rate of upward adjustment is faster than that of downward adjustment within our entertained threshold error correction model (TECM), even controlled for market conditions and liquidity. Second, we document that short sale constraints influences adjusting period and the speed of adjustment—markets with short sale ban are associated with lower efficiency. The speed for downward adjustment improved after relaxing short sale constraints.

We find that tightening short sale constraints rescues investors' confidence from executing more fire sales and saves the market from further liquidity dry-ups, though it helps little in stabilizing the market from fluctuations. By contrast, we find that heavier short sale restrictions are associated with greater downside risk and higher volatility. The results hold true even we control for investors' fear gauge that is proxy by VIX.

This paper provides direct evidence on the effects of short sell constraint on market efficiency. Despite that our results are consistent with Miller's hypothesis about over valuation, subsequent lower returns, and higher market volatility; the realized equilibrium adjustments via our counterfactual analysis also indicate that the short sale constraint rescues the investors' confidence from executing more fire sales and save the market from further liquidity dry-ups. This said, given the tremendous social cost incurred from previous experiences financial market crises as has been estimated and shown in Veronesi and Zingales (2010), Hoshi and Kashyap (2010), and Diamond and Rajan (2009), short sale constraint strikes a fine balance in exchange for future systematic liquidity costs (hedging future systemic liquidity frozen) that is non-assessable with the price of (un)intended current partial market inefficiency and illiquidity. Interestingly, although these findings do not support the view expressed by regulators that restraining short sales can stabilize prices, they do patronize academic findings that short-sale restrictions generally lead to less efficient markets.

This paper proceeds as follows. Section II documents the related hypothesis with literature review. Section III describes the data and the short sale policy changes in Taiwan. Section IV specifies the threshold error correction model and testable implications. Section V shows the empirical results and Section VI summarizes and concludes our findings.

2. Hypotheses and Literature Review

2.1 Asymmetric Period of Adjustment

Most theory and empirical evidence suggests that short sales constraints have an evil effect on efficiency, particularly when the news is bad. Diamond and Verrecchia (1987) suggest short sale restrictions hinder efficiency especially for negative information. The constraints reduce information content of the stock price, such as Miller (1977), Duffie et al. (2002), and Autore et al. (2011). Saffi and Sigurdsson

(2011) find price adjust quickly with lower short-sale constraints and there is no evidence to support relaxing constraints lead to price fluctuation and extreme negative return. Jiang et al. (2001) find information efficiency increase both in stock market and futures market after lifting short sale constraints in Hong Kong. Autore et al. (2011) examine the cross-sectional impact of the 2008 short sale ban on the returns of US financial stocks. The results show the shock with short sale ban bring about decreasing price information and support illiquidity effect by Amihud and Mendelson (1986) and overvaluation effect by Miller (1997). Jones and Lamont (2002), Bris et al. (2007), Ofek et al. (2004), and Boulton and Braga-Alves (2010) also support overvaluation effect which constraints result in overvaluation and sequent return decrease.

Another issue we keep an eye on whether we can profit from short sale strategy or not. Jones and Lamont (2002) show investors could short the stocks which enter lending market and profit 1%-2% after cost per month relative to than other stocks of similar size. Diether et al. (2009a) document the monthly average abnormal return of the strategy is 1.4% as we buy a low short sale activity portfolio and sell a high short sale activity portfolio. Diether et al. (2009a) claim investors may not earn the profit unless a trader managed her costs very effectively.

Most literature cited above suggests that short sales constraints have an adverse effect on efficiency, particularly when the news is bad—the only question is how long will prolong the price deviation. We address this gap in the literature below. Mørck, Yeung, and Yu (2000) compute the amount of private information incorporated into prices, but not the adjusting period for new information arrival. Few work model the time-spent of price adjustment. Adjusting period is denoted by calculating unconditional minutes accounting. We also exploit the potential asymmetry in price adjustment with different short sale constraints pressures. If only the price adjustment to bad news is constrained, one would expect longer adjusting period to new equilibrium while deviations are positive, and in particular, in regimes which short sales are prohibited. We test the following hypothesis:

Hypothesis 1: If short sale constraints hinder negative information into price, downward adjustments toward equilibrium need more much time than upward. In other words, adjusting period of downward adjustments reduce during relaxing constraints versus during strict constraints.

2.2 Proxy for Short Sale Constraints

There are some proxies for higher short sales constraints or higher short sale cost such as lower lending supply or higher loan fee (Saffi and Sigurdsson, 2011), lower rebate rate (Bargeron et al., 2011, D'Avolio, 2002, Geczy et al., 2002), negative rebate rate spread (Ofek et al, 2004), and low daily short interest (Diether et al., 2009a). Other proxies present relaxing short sale restrictions have the presence of stock options (Phillips, 2011, Danielsen and Sorescu, 2001, Charoenrook and Daouk, 2005), the introduction of stock futures (Danielsen et al., 2009), the allowance of short-selling (Chen and Rhee, 2010), the percent of proceeds available to short-sellers (Kamara and Miller, 1995), and the policy changes short sales constraints (Jiang et al., 2001, Autore et al., 2011, Boulton and Braga-Alves, 2010, Bris et al., 2007, Diether et al., 2009b). Jones and Lamont (2002) think rebate rate is a good proxy for the difficulty of short sale, since rebate rate is equilibrium where short sale demand meets supply.

However, most of literatures cited above rely on indirect measures of short-sale constraints or on restricted samples of lending data. For example, Geczy et al. (2002) use one year of data (November 1998 through October 1999) from a U.S. custody bank to study borrowing costs for IPOs. Ofek et al. (2004) rely on rebate rate from one of the largest dealer-brokers. We never know whether individual custodians might have different pricing strategies and therefore the data might not be equilibrium for lending price. Saffi and Sigurdsson (2011) claim the loan fee using is a representative of average lending price since averaged loan fee is computed by 10 custodians for each 12621 firms from 26 countries.

There is some weaknesses for denote monthly short interest as the proxy for short sale constraints. First, Saffi and Sigurdsson (2011) and Diether et al. (2009a) suggest it is difficult to distinguish whether high short interest reflects investors' negative views about the stock or lower short-sale constraints. Second, Diether et al. (2009a) suggest short sellers cover their position rapidly, and therefore the monthly short interest does not allow us to study short-term trading strategy. These shortcomings are avoided through the use of better proxies for short-selling constraints.

In Taiwan, the database for loan rate is not complete enough and the loan rate is formed under price limitations and short sales constraints. It may not be appropriate that we serve the loan rate as equilibrium in short sale market in Taiwan. Fortunately, several policy changes for short sale restrictions during 2002 to 2009 in Taiwan provide us treat them as the natural proxy to examine how the stock market response on different short sale constraints regimes.

2.3 Improved Speed of Price Adjustment

Little research has illustrated what impede or improve the speed of adjustment toward equilibrium, except Chen and Rhee (2010), Bris et al. (2007) and Saffi and Sigurdsson (2011). The latter two serve higher cross-autocorrelation as higher adjustment speed and find price adjust quickly with lower short-sale constraints. Chen and Rhee (2010) employ Jones and Lipson's (1999) model and Dimson (1979) beta regression to measure the speed of price adjustment to market-wide information of shortable and non-shortable stocks. They document empirical evidence for Hong Kong that short sales contribute to market efficiency by increasing the speed of price adjustment to not only private/public firm-specific information but also market-wide information. While Chen and Rhee (2010) also disentangle the speed of adjustment issue under short sale constraints, they focus more on the firm level evidence.

Specifically, we employ TECM to explore the speed of price adjustment to new equilibrium with transaction cost and different short sale constraints regimes. How much do investors cost response to tax, fee, and other obstacles? Threshold Error Correction Model (TECM) provides the possible estimates for explicit and implicit transaction cost. Dwyer et al. (1996) analyze nonlinear dynamic relationship between the S&P 500 futures and cash indexes due to nonzero transaction costs and show the estimated threshold value is similar with real transaction cost. We rely on TECM and estimate threshold value to capture market frictions such as market liquidity, transaction cost, tax burden, market microstructure, etc. 3-regime TECM provides us to specify how large deviation from theoretical price will trigger trade.

If short sales restrictions impede the incorporation of negative information into prices, the speed of downward price adjustment should increase more when short sales are allowed. In another word, when short sales are restricted, stock returns respond immediately to undervaluation, but price incorporate only partly if the price deviation is positive. Therefore, we expect market efficiency improve while relaxing constraints, that is, the speed of adjustment back to equilibrium arise while lifting constraints. We have two hypotheses.

Hypothesis 2a: The speed of upward adjustment is faster than that of downward adjustment with control market liquidity, and market condition, etc.

Hypothesis 2b: The speed for downward adjustment improved after relaxing short sale constraints.

2.4 Faster Convergence for Transactions with High Short Demand

If there are some transactions with high short demand in stock market, the adjustment speed of that should be quicker during the period with relaxing constraints. We follow Fung and Jiang (1999) and Jiang et al. (2001) in measuring market directions by the Relative Strength Index (RSI), illustrate the direction of price movements.

$$RSI_t = \frac{N_t^-}{N_t^+ + N_t^-},$$

where N_t^+ and N_t^- are the number of 1-minute intervals in which the TWSE spot index advances and declines during the day, respectively. They define the lowest 10% percentile of RSI as transactions with high short demand. It is interesting to examine whether lifting constraints improve transaction activity with great demand of short sale. Therefore, we test the following hypothesis.

Hypothesis 3: Relaxing short sale constraints accelerate the rate of price adjustment for high propensity to short.

2.5 Price Stabilization and Short Sale Constraints

Lending market has well-developed. Utilization of loan supply by value is from 7% for US stocks (D'Avolio, 2002) in early 21 century to 22% around the world in 2008 (Saffi and Sigurdsson, 2011). Short sale activity is important for discussing the issue about market efficiency. D'Avolio (2002) Saffi and Sigurdsson (2011) find the stocks with higher lending supply lead to greater degree of negative skewness. These results differ from those of Bris et al. (2007) and Charoenrook and Daouk (2009). They provide possible explanation for the contradict results is due to decreasing the frequency and magnitude of extreme positive returns rather than increased frequency of extreme negative returns. Since relaxing short-sale constraints make price adjust quickly as downward adjustment, the frequency and magnitude of extreme positive returns decrease. Another possible explanation is that different skewness measures may results in different results. Rather than formal calculations, Bris et al. (2007) calculate the skewness of raw returns as $\log(1+r)$ where r are stock returns. Saffi and Sigurdsson (2011) also document the stocks with lower short sale constraints possess lower kurtosis, lower levels of downside risk and total volatility. These results do not support the view expressed by regulators that short-sale constraints can stabilize prices. We also examine the hypothesis:

Hypothesis 4: Can short sale constraints or ban stabilize prices?

3. Data and Short Sale Policy

3.1 Data

The data analyzed are intraday TAIFEX Index Options and the underlying asset, Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX), available from Taiwan Economic Journal Database (TEJ). We drop missing data on 1st March, 2003, 8th March, 2003, and 14th March, 2003, and also drop wrong data during 12th July, 2005 to 14th July, 2005. The sample period is during from 2002 to 2009, yielding 539109 intraday observations in 1989 days. These 7 series contracts were shifted on previous two days of last trading day. The shifted days are chosen as they have the most active options market with significantly larger trading volumes than other contracts on the TAIFEX Exchange, that ensure prices do not become stale. We collect 7 series near-month option contracts. For example, if close price in previous day is 5678, we rounded the value as 5700. We collect the contracts of strike price from 5400 to 6000 to derive theoretical index price. Match each series with the same strike price and the same maturity to calculate implied index price. Average 7 series implied index price to obtain theoretical index price (S_t^o). We rule out the effects of moneyness on theoretical price.

<<Insert Figure 1 here>>

We perform the behavior of price adjustment for different policy changes using high frequency data during from 2002 to 2009. Why policy change may have important for high frequency data as compare to daily frequency data? There are two reasons it is more sensitive that we resolve the pattern with high frequency data than with lower frequency data.

First, Diether et al. (2009a) employ daily short interest to measure short sale activity rather than common monthly data, since the monthly short interest does not allow studying short-term trading strategy. Diether et al. (2009a) find short sellers cover their positions more quickly, that is, they cover the positions in 5.4 days for NYSE and 4.4 days for NASDAQ. Jones (2004) also notes such day trade volume is about 5% of daily volume in early 1930s. Diether et al. (2009a) document short sale activity represents on average 23.9% of trading volume in NYSE and 31.3% in NASDAQ. We find the evidence in Taiwan during 2002 to 2009 that the time spent converge to equilibrium is in 25 minutes on average. These results suggest there is more information content in high frequency data to investigate the pattern for short-run strategy and mean reversion. In addition, it is important for the implications of price efficiency that whether mean reversion is affected by exogenous policy changes.

Second, there is a high proportion of day trade in Taiwan security market. Barber et al. (2004) analyze the performance of day traders in Taiwan during 1995 to 1999. They denoted day trading by individual investors is over 20 percent of total volume in Taiwan. Heavy day traders earn gross profits, but more than eight out of ten day traders lose money when account for transaction cost. Barber et al. (2009) also denoted the most individual trading losses with aggressive orders. The individuals suffer an annual aggregate loss of 3.8 percentage points, that is, losses are equivalent to 2.2% of Taiwan's gross domestic product or 2.8% of the total personal income. The rank of annual dollar turnover in Taiwan security market is top three in the world's major security markets during 2001 to 2008. The averaged proportion of trading volume for individual investors is 72% during 2002 to 2009 while that for domestic and foreign institutional investors is only 12% and 14%, respectively. It is very important to analyze the specific phenomena, high turnover and high proportion of individual investors, in Taiwan security market with high frequency data.

3.2 Theoretical Index Price

The theoretical index price is obtained by put-call parity. Put-call parity is a simple no arbitrage relationship which does not need to impose the assumption of agents' preference and return distribution. The put-call parity states that the implied index price is given by:

$$S_t^O = C_t - P_t + Ke^{-r(T-t)}, \tag{1}$$

where C_t and P_t denote by call price and put price at time t, for an option contract which matures at T, and S_t^O is the current spot price. r is the risk-free rate denoted by one-year deposit rate of First Bank in Taiwan. K represents strike price.

Chiou et al. (2007) illustrate that substituting put-call parity for Black and Scholes model to derive the implied price can avoid concern of model misspecification and biased volatility estimates. In addition, there are three advantages for theoretical index price from put call parity. First, Since TAIFEX options belong to European options; we avoid the possible effects of early exercise risk on mispricing errors. The synchronous matching data per minutes could rule out nonsynchronous problem in this paper. Second, there is little transaction limitation in options market than stock market. Miller (1977) show investors prefer to trade in less limited market since asset price reflect new information immediately. Finally, transactions in derivatives market are forward-looking; therefore we serve the derived price with put-call parity as theoretical price or real price in spot market.

<<Insert Table 1 here>>

The logarithm index value and theoretical value are found to be cointegrated. The common trend is also shown in panel A of Figure 1. The formal tests are provided in Table 1. The results indicate that for two logarithm prices have a unit root, and two price of the first difference is stationary.

3.3 The Policy Changes for Short Sale Constraints

A main short sale constraint in Taiwan is that requires short sales to take place at no lower than the previous day's closing price, we denoted by short sale rule. Short sale is banned as the stock prices are not greater than close price of previous trading day before 2003. Lift short sale constraints is a global trend as the security market is matured. To promote Taiwan security market to a developed one, Taiwan Top50 Tracker Fund (TTT) is listed in Taiwan Stock Exchange (TWSE) and is exempted from the short sale rule on 30th June, 2003. TWSE allow 50 constituents of TTT (ID：0050) to short sale exempted from the short sale rule on 16th May, 2005, and additionally allow 100 constituents of the Taiwan mid-cap 100 (ID：0051) and the Taiwan Technology Index (ID：0052) exempted from the short sale rule on 12th November, 2007. These indices cover about 80% of the Taiwan Stock Exchange’s market capitalization. These policy changes provide us treat them as the natural proxy for short sale constraints. We conjecture that more stocks free to short lead to promote price efficiency as price is overvalued.

Another good chance provides us to compare the different response of stock market if short sale constraints reverse severe like before. To protect the stocks from further contagion of the global financial crisis, the Financial Supervisory Commission (FSC) impose a ban of short selling of all stocks from 22nd September to the end of 2008 if they trade below the previous day's closing price. The FSC further imposes a ban on short-selling of all stocks from 1st October to 27th November in 2008 which it is prohibit to short sale overall. A wave of international markets followed after United State, including Australia, Belgium, Canada, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Russia, Singapore, Switzerland, Taiwan, and the United Kingdom. The sample period from 2002 to 2009 allow to explore the effect of different short sale constraints regimes changes on price adjustment.

We divide into 6 periods according to policy changes for short sale rule, denoted as P_1, P_2, P_3, P_4, P_5, P_6. P_1 represents all listed stocks are bind by short sale rule during January 2nd, 2002 to June 29th, 2003; P_2 denotes Taiwan Top50 Tracker Fund (TTT) is exempted from the short sale rule on 30th June, 2003. To promote Taiwan security market to a developed one, Taiwan Stock Exchange Corporation (TWSE) launched a centralized SBL system[1] in June 2003 to meet the needs of qualified institutional investors while TWSE serves as an intermediary. In addition, Taiwan Top50 Tracker Fund (TTT) is listed in TWSE and is exempted from the short sale rule on 30th June, 2003. Investors should check with his/her broker to see if there is any quota available before executing short-selling. TTT is first Exchange Traded Fund

[1] This system provides three kinds of transactions: Fixed-rate transaction, competitive auction transaction and negotiated transaction. In terms of SBL trading volume for 2007, competitive auction transactions accounted for 41% and negotiated transactions accounted for 59%. Starting July 2007, qualified securities firms and securities finance companies are allowed to conduct SBL business acting as principal. Investors thus have additional options, not only borrowing from the existing TWSE SBL system but also from securities firms and securities finance companies that are qualified. Other information of SBL system refer to http://www.twse.com.tw/en/products/SBL/SBL_edu.php.

(ETF) in Taiwan and the underlying index is Taiwan 50 Index[2]. Investment objective of TTT is to closely track the performance of Taiwan 50 Index (before fees and expenses). P_2 is during from 30th June, 2003 to 15th May, 2005.

<<Insert Table 2 here>>

Additional 50 constituents of TTT are exempted from the short sale rule from 16th May, 2005. Therefore, we denote P_3 from 16th May, 2005 to 11th November, 2007. TWSE launched additional 100 constituents of the Taiwan mid-cap 100 and the Taiwan Technology Index is exempted from the short sale rule on 12th November, 2007. P_4 denotes from 12th November, 2007 to 21st September, 2008.

P_5 denotes from 22nd September, 2008 to the end of 2008 which all listed stocks are constrained by short sale rule. And the regulators further imposes a ban on short-selling of all stocks from 1st October to 27th November in 2008 which it is prohibit to short sale overall. P_6 denotes relaxing all constraints during 2009, that is, it is the same with P_4. The highest intensity to lowest intensity for short sale constraints are P_5, P_1, P_2, P_3, P_6 and P_4, respectively. These policy changes provide us treat them as the natural proxy for examining the effects of short sale constraints on market efficiency. It is interesting to explore that why positive deviations become larger and more frequency during short sale ban period as we see in Panel C of Figure 1 and Panel A of Figure 2, and whether regulators execute short sale constraints to stable price while we witness the more fluctuated return in Panel B of Figure 1.

[2] The Taiwan 50 Index was launched on October 29, 2002. The first tradable index for the Taiwan market was created under the collaboration of Taiwan Stock Exchange Corporation (TWSE) and FTSE International Limited (FTSE). This Index covers the top 50 companies by total market capitalization. FTSE's free float methodology applied throughout the index to ensure the weights within the index reflect the market capitalization available for investment. The base date value as of April 30, 2002 was set at 5,000 and the index is reviewed quarterly in January, April, July and October every year, and constituent changes are implemented on the next trading day following the third Friday of the same month.

3.4 Control Variables

Results have reported non-linear behavior of price movement due to the presence of transaction costs (Brooks and Garrett, 2002, Ofek et al, 2004, Ackert and Tian, 2001) or non-synchronous trading (Easton, 1994). Other explanations for price deviations have market illiquidity (Ofek et al., 2004, Roll et al., 2007, Kamara and Miller, 1995), idiosyncratic risk (Duan et al., 2010), microstructure effect (Bakshi et al., 2000), analyst disagreement (Saka and Scherbina, 2007), and short sale constraints or short sale cost (Ofek et al., 2004, Ackert and Tian, 2001). High frequency data in this study avoid non-synchronous trading problem mislead our results. Index level analysis could avoid idiosyncratic risk and analyst disagreement for firm-level analysis. Given the potential link between short-selling constraints and other variables, such as liquidity, transaction costs, market condition, and microstructure effect, it is essential to prevent spurious findings by adding proper controls to our models.

Saffi and Sigurdsson (2011) study how stock price efficiency and return distributions are affected by short-sale constraints. They control firm capitalization, liquidity and transaction cost which avoid spurious findings. The variables for liquidity and transaction cost include total share turnover, the incidence of zero weekly returns, annual average of the weekly quoted bid-ask spread, and Datastream's measure of free float. We employ 5 measures of market liquidity to control the effects of market liquidity on price movement in this paper. No. of trade is number of trade previous minute for index. No. of shares denotes number of trading shares previous minute for index. $TDOLLAR_{t-1}$ (thousand) denotes the amount of trading dollars previous minute for index. Daily turnover is calculated as previous daily trading volume divided by previous daily number of outstanding shares for index. Daily turn/MV denotes daily trading dollars divided by daily market value for index by Saffi and Sigurdsson (2011). In Table 2, market is obviously liquid during relaxing short sale constraints period.

Five measures are applied to describe market condition. Daily realized variance is calculated by 1-min index return per day. $\overline{R}_{-3m}^{spot}$, $skew_{-3m}^{spot}$, $kurt_{-3m}^{spot}$, and $stdr_{-3m}^{spot}$ are averaged return, skewness, kurtosis, and standard deviations calculated by previous 3-month 1-min index return, respectively. Daily realized variance and $stdr_{-3m}^{spot}$ capture variations of index price. Price volatility is highest during restrict restrictions period in Table 2. The averaged market returns by previous 3-month capture how bear market or bull market affects price movements. $skew_{-3m}^{spot}$ and $kurt_{-3m}^{spot}$ capture the phenomena of heavy tail for index return. Authorities claim lifting short sale constraints increase the likelihood of extreme price fluctuations, but there is more negative skewness near ban period.

Jiang et al. (1996) delete the first ten-minute data segments from the sample since investors might be over-reacting to news released overnight. Our focus is on intraday return behavior. We add overnight dummy variable in our model, if transactions occur in 9:00 to control overnight effect on price movement. We also include open noise dummy and close noise dummy. Diether et al. (2009b) analyze the effects of the Pilot plan of short-sale price tests on market quality in America exclude data from 9:30-10:00 due to avoid the influence of open noise on the results. We define $open$ equals 1 if transactions occur during 9:01-9:30 and $close$ equals 1 if transactions occur during 13:01-13:30.

3.5 Variables and Descriptive Statistics

Table 2 illustrates the distribution of index price, return, violations, and control variables. Intraday index price (S_t) and theoretical index price (S_t^O) almost have the common trend in Panel A of Figure 1. Theoretical index price is derived from put call parity in equation (1). The distributions of index price ($\Delta \ln S_t$) and theoretical index price ($\Delta \ln S_t^O$) are approximately mean zero. Averaged price deviations (Z_t) are greater than zero and the pattern of price deviations are asymmetric for each period especially in strict restriction regime as we witness in Figure 2. The price deviations are dramatically over three times greater during period of heaviest short sale constraints than others. It is interesting to discuss the relation between asymmetric price deviations and short sale constraints.

According to policy changes, we divided the sample into six subsamples as mentioned above. The highest intensity to lowest intensity for short sale constraints are P_5, P_1, P_2, P_3, P_6, and P_4, respectively. Market liquidity decreases with several measures such as the frequency of trade, the trading volume and trading dollars per minutes under the heaviest constraints condition. The daily turnover is also decreasing in P_5. How efficient is the market under the superimposed short sale constraint has long been debated in the recent literature. We disentangle the related efficient adjustment issues by examining the defined equilibrium deviations from the put-call parity.

4. Econometric Models and Testable Implications

There are some trading mechanisms, such as short sale constraints or price limit, impede price back to equilibrium, especially the spot price is overpriced. Fewer transaction limit, volatility modeling free, and forward-looking perspectives in options markets convince us of that the derived price with put-call parity rather than Black and Scholes model as real price in spot market.

Taking natural logarithms one can define error-correction term as such:

$$Z_t = \ln S_t - \ln S_t^O . \quad (2)$$

We serve S_t^O as theoretical index price. The deviation, or error-correction term, therefore represents the presence of possible arbitrage opportunities. That is, if the index price is too high relative to the real value ($Z_t > 0$) then arbitrageurs will short sale or sell the spot commodity; if the index price is undervalued ($Z_t < 0$), the opposite trading strategy will arise. Both actions will ensure adjustment towards equilibrium ($Z_t = 0$). We conjecture downward adjustment spent more time as index price is higher than real price due to short sale constraint impede the arbitrageurs trade while market price is overvalued. We calculate the time spent of adjustment to test our first hypothesis.

$$\begin{cases} H_0: adjusting\ period^{+} - adjusting\ period^{-} \leq 0 \\ H_1: adjusting\ period^{+} - adjusting\ period^{-} > 0 \end{cases}$$

For example, if a four-minute Z_t is positive, we simply define the deviation spent 4 minutes converging towards equilibrium while Z_t reverse in the fifth minute. In addition, we also examine whether it spent more time to converge in severe short sale constraints.

4.1 Asymmetric Convergence Rate of Equilibrium Deviations

Arbitragers will only enter into the market when the violation is sufficiently large to offset transaction costs, including price limitations, market frictions, market illiquidity, short sale constraints, etc. Rational investors will buy a stock when price is underpriced ($Z_t < 0$), and short sale when price is overvalued ($Z_t > 0$) in perfect market which pricing error deviates from zero. We rely on estimated threshold value of TECM to account for explicit and implicit transaction cost and exploit whether the directions of converge speed exist asymmetric pattern.

We employ the error-correction model with constant rate of adjustment in this paper:

$$
\begin{cases}
\Delta \ln S_t = c_S + \alpha_S Z_{t-1} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\
\Delta \ln S_t^O = c_{S^O} + \alpha_{S^O} Z_{t-1} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O}
\end{cases} \quad (3)
$$

,

where α_S and α_{S^o} denotes convergence rate for $\Delta \ln S_t$ and $\Delta \ln S_t^o$. ε_t^S and $\varepsilon_t^{S^o}$ are zero mean, serially uncorrelated error terms that can be contemporaneously correlated. C denotes control variables such as market liquidity, market condition and market microstructure. This error correction model specifies how the returns respond to deviations from the equilibrium. Positive error correction term imply spot price is overpriced, we expect price will downward adjust, and vice versus. Therefore the coefficient of error correction term, α_S, should be negative. α_S specifies the adjustment speed toward equilibrium regardless of bad news or good news.

To illustrate the different effects on downward and upward price adjustment, we develop the model with varying rate of upward and downward adjustment with threshold ($c = 0$):

$$
\begin{cases}
\Delta \ln S_t = c_S + \alpha_S^+ Z_{t-1} I_{\{Z_{t-1} \geq 0\}} + \alpha_S^- Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\
\Delta \ln S_t^O = c_{S^O} + \alpha_{S^O}^+ Z_{t-1} I_{\{Z_{t-1} \geq 0\}} + \alpha_{S^O}^- Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O}
\end{cases} \quad (4)
$$

The threshold is given as 0 due to no arbitrage condition assumption. α_j^+ and α_j^- denote the speed of downward and upward adjustment under the assumption of perfect market, such as $j = S \ or \ S^o$. We conjecture adjustment speed is quicker while market price is lower than theoretical price due to short sale constraint delay downward adjustment towards equilibrium. Therefore, the null is that

$$
\begin{cases}
H_0 : \alpha_S^- - \alpha_S^+ \geq 0 \\
H_1 : \alpha_S^d - \alpha_S^u < 0
\end{cases}
$$

In fact, the transaction cost for buying a stock is at least 0.1425%, and the transaction cost for selling a stock is at least 0.4425% when investors ignore other implicit transaction cost. How many do investors cost response to tax, fee, and other obstacles? Threshold error correction model provide the possible estimates for explicit and implicit transaction cost which may prevent investors from adjusting immediately. In this paper, we use 3-regime threshold error correction model to specify how large deviation from theoretical price will trigger trade.

TECM have been used to describe many economic phenomena, for example, government intervene exchange rate only as the market price diverge too far from fair price. Exchange rate is almost random walk in inside band. Similarly, in financial issue, we discuss how the deviations are large enough to cover the cost even risk. In this paper, we attempt to characterize market frictions and price adjustment in terms of threshold cointegration.

The estimates in 3-regime threshold error correction model are the following 3 steps. First, in different policy regimes, determine the lag order of autoregression for Z_t with minimum Schwarz information criterion (SIC). Second, we utilize Chan (1993) methodology to sort the mispricing error (Z_t) in ascending order. We drop the largest and smallest 10% of Z_t and the remaining value as possible thresholds c_i. Third, we locate lag error correction term as the threshold candidates (c_1 *and* c_2) and threshold lag (d) using a grid search procedure by Enders and Siklos (2001). Balke and Fomby (1997) document threshold lag (d) reflects the possibility that investors only know the deviations from the equilibrium with a lag.

To obtain estimated threshold, minimizing sum of square error for all threshold candidates in threshold autocorrelation (TAR) is provided as:

$$\Delta Z_t = \phi_1^{(1)} Z_{t-1} I^- + \phi_1^{(3)} Z_{t-1} I^+ + \phi_1^{(2)} Z_{t-1}\left(1 - I^- - I^+\right) + \sum_{i=1}^{p} \phi_i \Delta Z_{t-i} + \varepsilon_t, \qquad (5)$$

where

$$\begin{cases} I^- = 1,\ if\ Z_{t-d} < c_1 \\ I^+ = 1,\ if\ Z_{t-d} > c_2 \end{cases},$$

and Z_t denotes pricing error or error correction term. While Z_t may have a unit root when $c_1 \le Z_{t-1} \le c_2$, this series is stationary globally. And we also expect $\phi_1^{(1)} < 0$ and $\phi_1^{(3)} < 0$ which present price adjust when deviation is large enough. $\phi_1^{(1)} \ne \phi_1^{(3)}$ represent upward price adjustment is asymmetric with downward price adjustment.

Finally, 3-regime threshold error correction model is estimated with the thresholds c_1, c_2 and d:

$$\begin{cases} \Delta \ln S_t = c_S + \alpha_S^- Z_{t-1} I_{\{Z_{t-1} \le c_1\}} + \alpha_S^{btwn} Z_{t-1} I_{\{c_1 < Z_{t-1} < c_2\}} + \alpha_S^+ Z_{t-1} I_{\{Z_{t-1} \ge c_2\}} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \alpha_{S^O}^- Z_{t-1} I_{\{Z_{t-1} \le c_1\}} + \alpha_{S^O}^{btwn} Z_{t-1} I_{\{c_1 < Z_{t-1} < c_2\}} + \alpha_{S^O}^+ Z_{t-1} I_{\{Z_{t-1} \ge c_2\}} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases}, \quad (6)$$

where S_t is index price and S_t^o is theoretical index price. $\Delta \ln S_t$ and $\Delta \ln S_t^o$ are returns. Z_{t-1} denotes error correction term, and C denotes the control variables for returns. α_j^+ and α_j^- denote the speed of downward and upward adjustment accounting for all transaction cost as possible, such as $j = S \text{ or } S^o$. And α_j^{btw} means the speed of adjustment in the inter band. In this model, we examine the second hypothesis that the speed of upward adjustment is faster than that of downward adjustment with control market liquidity, and market condition, etc. therefore the null hypothesis and alternative hypothesis are:

$$\begin{cases} H_0: \alpha_S^- - \alpha_S^+ > 0 \\ H_1: \alpha_S^- - \alpha_S^+ \le 0 \end{cases}$$

4.2 Price Adjustments under Different Policy Regimes

It is interesting to investigate whether price efficiency improve during relaxing constraints period. We serve the short sale policy changes from 2002 to 2009 in Taiwan as different level of short sale constraints. We divide into six to investigate whether policy changes affect price adjustment and employ the model with varying rate of adjustment for different short sale constraint policy changes:

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{pi} Z_{t-1} I_{\{t \in pi\}} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{pi} Z_{t-1} I_{\{t \in pi\}} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} ,(7)$$

where $\alpha_j^{p_i}$ denoted the speed of adjustment for different policy regardless of the direction for price movement, such as $i = 1,2,...,6$ and $j = S \text{ or } S^o$. Testing whether the speed differ from different policy changes, the comparisons between lowest (α_S^{p4}) and highest intensity (α_S^{p5}) restrictions is significantly different.

We also exploit the effects of different policy changes on price adjustment using the model with varying rate of upward and downward adjustment for different short sale constraint policy change with threshold ($c = 0$):

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{+pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \geq 0\}} + \sum_{i=1}^{6} \alpha_S^{-pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} < 0\}} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{+pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \geq 0\}} + \sum_{i=1}^{6} \alpha_{S^O}^{-pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} < 0\}} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} ,(8)$$

where $\alpha_j^{+,pi}$ and $\alpha_j^{-,pi}$ denote the speed of downward and upward adjustment under different constraints pressures and the assumption of perfect market, such as $i = 1,2,...,6$ and $j = S \text{ or } S^o$. The null and alternative hypotheses in Hypothesis 2b are

$$\begin{cases} H_0: \alpha_S^{+,p4} - \alpha_S^{+,p5} \geq 0 \\ H_1: \alpha_S^{+,p4} - \alpha_S^{+,p5} < 0 \end{cases} ,$$

that is, the speed of downward adjustment does not differ from the different level of short sale constraints while we disregard of transaction cost.

Similarly, we construct a 3-regime model to rule out the effects of market frictions on price movement. 3-regime threshold error correction model with different policy changes is estimated with the estimated thresholds c_1 and c_2:

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{-,pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \leq c_1\}} + \sum_{i=1}^{6} \alpha_{S^O}^{btwn,pi} Z_{t-1} I_{\{t \in pi, c_1 < Z_{t-1} < c_2\}} + \sum_{i=1}^{6} \alpha_S^{+,pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \geq c_2\}} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{-,pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \leq c_1\}} + \sum_{i=1}^{6} \alpha_{S^O}^{btwn,pi} Z_{t-1} I_{\{t \in pi, c_1 < Z_{t-1} < c_2\}} + \sum_{i=1}^{6} \alpha_{S^O}^{+,pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \geq c_2\}} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} , (9)$$

where $\alpha_j^{+,pi}$ and $\alpha_j^{-,pi}$ denote the speed of downward and upward adjustment accounting for all transaction cost under different restrictions pressure changes, such as $i = 1,2,...,6$ and $j = S \; or \; S^{O}$. We examine the hypothesis 2b that the speed for downward adjustment improved after relaxing short sale constraints. In other word, the null hypothesis is that $\alpha_{S}^{+,p4} - \alpha_{S}^{-,p5} \geq 0$. The speed of downward adjustment does not change if short sale constraints do not play a key role on price adjustment.

4.3 Arbitrageur Behavior and Short Sale Policy Changes

If short sale constraints affect price adjustment, some transactions with high short demand should be more active during relaxing restrictions period. We follow Fung and Jiang (1999) and Jiang et al. (2001) in measuring market directions by the Relative Strength Index (RSI). We sort our observations into ten deciles based on the daily relative strength index. The highest deciles represents the mostly downward price movements, which indicates that short selling is more likely in. We define the lowest 10% percentile of Relative Strength Index (RSI) as more likely to short and denote as high propensity to short (HPTS). The model with varying rate in case of high propensity to short (HPTS) is constructed as:

$$\begin{cases} \Delta \ln S_t = c_S + \alpha_S^{HPTS} Z_{t-1} I_{\{RSI_{t-1} \geq 90\% \; percentile\}} + \alpha_S^{ow} Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \alpha_{S^O}^{HPTS} Z_{t-1} I_{\{RSI_{t-1} \geq 90\% \; percentile\}} + \alpha_{S^O}^{ow} Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases}, \quad (10)$$

where α_j^{HPTS} denote the speed of adjustment in case of high propensity to short (HPTS) for $j = S \; or \; S^{O}$.

In addition, it is interesting to explore the model with varying rate of upward and downward adjustment in case of high propensity to short (HPTS):

$$\begin{cases} \Delta \ln S_t = c_S + \alpha_S^{+HPTS} Z_{t-1} I^+ + \alpha_S^{-HPTS} Z_{t-1} I^- + \alpha_S^{ow} Z_{t-1}(1-I^+-I^-) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \alpha_{S^O}^{+HPTS} Z_{t-1} I^+ + \alpha_{S^O}^{-HPTS} Z_{t-1} I^- + \alpha_{S^O}^{ow} Z_{t-1}(1-I^+-I^-) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases}. \quad (11)$$

We examine the asymmetric pattern with the null and alternative hypotheses are:

$$\begin{cases} H_0: \alpha_S^{-HPTS} - \alpha_S^{+HPTS} \geq 0 \\ H_1: \alpha_S^{-HPTS} - \alpha_S^{+HPTS} < 0 \end{cases}.$$

The upward and downward adjustment would be also significant asymmetric in case of transaction with high short demand.

We also concentrate on varying rate with different short sale constraints pressures in case of high short demand:

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{HPTS,pi} Z_{t-1} I_{\{t\in pi, RSI\geq 90\%\ percentile\}} + \sum_{i=1}^{6} \alpha_S^{ow} Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{HPTS,pi} Z_{t-1} I_{\{t\in pi, RSI\geq 90\%\ percentile\}} + \sum_{i=1}^{6} \alpha_{S^O}^{ow} Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} . \quad (12)$$

We could test our third hypothesis that relaxing short sale constraints accelerate the rate of price adjustment for high propensity to short, that is, the absolute value of $\alpha_S^{HPTS,p4}$ is greater than that of $\alpha_S^{HPTS,p5}$. Next, the model with varying rate of upward and downward adjustment in case of high propensity to short (HPTS) with different constraints pressures:

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{+HPTS,pi} Z_{t-1} I^{+,pi} + \sum_{i=1}^{6} \alpha_S^{+HPTS,pi} Z_{t-1} I^{-,pi} + \sum_{i=1}^{6} \alpha_S^{ow,pi} Z_{t-1}(1-I^{+,pi}-I^{-,pi}) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{+HPTS,pi} Z_{t-1} I^{+,pi} + \sum_{i=1}^{6} \alpha_{S^O}^{-HPTS,pi} Z_{t-1} I^{-,pi} + \sum_{i=1}^{6} \alpha_{S^O}^{ow,pi} Z_{t-1}(1-I^{+,pi}-I^{-,pi}) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} . \quad (13)$$

The model above provides us to further investigate whether relaxing short sale constraints promote the speed of downward adjustment for transactions with high short demand. In other words, the null and alternative hypotheses are

$$\begin{cases} H_0: \alpha_S^{+HPTS,p4} - \alpha_S^{+HPTS,p5} \geq 0 \\ H_1: \alpha_S^{+HPTS,p4} - \alpha_S^{+HPTS,p5} < 0 \end{cases} .$$

4.4 Can Short Sale Constraints Stabilize Price Fluctuation?

Regulators claim short sale play an evil role in price stabilization. The high frequency data allow us to calculate the characteristics of index return distribution day by day. Testing the difference of characteristics of index return distribution during different policy changes could test the fourth hypothesis:

$$\begin{cases} H_0: downrisk^{p4} - downrisk^{p5} \geq 0 \\ H_1: downrisk^{p4} - downrisk^{p5} < 0 \end{cases}$$

and provide some suggestions about short sale for regulators.

5. Empirical results

5.1 Asymmetric Duration between Price Overvaluation or Undervaluation

Under no arbitrage pricing, the prices adjust immediately as departure from fundamental value. Therefore, the time spent of upward adjustment is almost the same with the time spent of downward adjustment theoretically. The unconditional adjusting period accounting in Table 3, there is asymmetric pattern in upward and downward adjustment. In frictionless market, the price deviations should converge to zero under no arbitrage relationship. Therefore, we calculate the time spent converge to equilibrium with threshold, 0, first. It spent more than 40 minutes to converge as overvaluation, and only spent 11 minutes as undervaluation. We also keep an eye on how long price converge to new equilibrium accounting for transaction costs or other implicit cost.

<<Insert Table 3 here>>

As mentioned above, the visible transaction cost in stock market is 0.4425% while investors sell a stock and 0.1425% while investors buy a stock. Second, we employ -0.001425 and 0.004425 as lower bound and upper bound of transaction cost due to the definition of violations. In other words, investors buy a stock as stock is underpriced, that is, $Z_t < \ln\left(S_t / S_t^O \right) = \ln\left(1.001425^{-1}\right) \approx -0.001425$ or violations less than -0.001425. Investors sell a stock as violations greater than 0.004425. The similar results are obtained with exogenous transaction cost in Table 3. It spent more than 26 minutes to converge as overvaluation, and only spent 11 minutes as undervaluation.

We have strong evidence to support our first hypothesis that the time spent converge to equilibrium is longer as overvaluation than as undervaluation even considering exogenous transaction cost. Another interesting results is that the differences between least and heaviest short sale constraints is significant as overvaluation, but insignificant as undervaluation. The results are similar with the findings of Martens et al. (1998). They show the impacts of mispricing error is significant larger when S&P 500 index is overpriced with respect to derived price by the cost-of-carry relation. What cause diverges for long time only as spot market is overvalued? Miller (1977) and Shleifer and Vishny (1997) illustrate some constraints impede arbitrageurs enter the spot market and trade. It might be caused by illiquidity risk or short sale constraints. It motivate us to examine whether short sale constraint improve the speed of adjustment when the constraints are lifting gradually from 2002 to 2009 in Taiwan.

5.2 Faster upward v.s. Sluggish downward Adjustment

The preliminary results do not report but are available upon request. We find market liquidity decrease enormously while spot market is extremely overvalued relative to extremely undervalued. We denote $Z_t \leq -2\sigma$ and $Z_t \geq 2\sigma$ as index is extreme undervalued and overvalued, that is, price deviations are greater than two standard deviation of Z_t, and vice versa. Intraday number of trade, number of shares and the amount of trading dollars decrease more than 50% as extreme overvaluation versus undervaluation. The relations between price deviations with trading volume and trading frequency are not significant as undervaluation, but it is significant as overvaluation. It motives us to explore whether short sale constraint is related to the asymmetric patterns after transaction cost and market illiquidity or not.

<<Insert Table 4 here>>

There is evidence that the cointegrating vector is not strictly (1, -0.99). We simplify and use the (1, -1) vector, that is, the mispricing error or error correction term as defined in equation (2). In Table 4, that implies that if index price depart long-run relationship, index price decrease as overvaluation and increase as undervaluation.

<<Insert Figure 2 here>>

The relative high frequency for price deviations during the period of tight short sale constraints is obvious in Panel C of Figure 1 and Panel A of Figure 2. There are some interesting results in Figure 2. First, the occurrences of positive deviation is greater than that of negative deviation, especially during $p5$ of tight short sale constraints. Second, it is consistent with overvaluation effect by Miller (1977) which short sale constraints lamed information incorporation and result in overvaluation and low sequent returns.

We are curious about the different effects on downward and upward price adjustment, and develop the model with varying rate of upward and downward adjustment with threshold ($c=0$) in equation (4). In the model, p is lag operator determined by minimum SIC to compromise white noise for ε_t^j. And p is 21. C represents control variables and we include three categories control variables expressed in the third section, such as market liquidity, market condition, and microstructure effect. In addition, Connolly (1989) illustrate conventional *t* value criteria is not appropriate if sample size is large sample, therefore we use size-adjusted critical *t* value, 3.65, to determine significance.

<<Insert Table 5 here>>

In 2-regime exogenous threshold error correction model, the threshold is given as 0 due to perfect market condition assumption. The results report in the first fourth columns of Table 5. The speed of upward adjustment is more than seven times faster than that of downward adjustment with control market liquidity, market condition, and market microstructure. The results support our hypothesis 2a.

<<Insert Table 6 here>>

Next, to specify how large deviation from theoretical price will trigger trade, we construct the 3-regime threshold error correction model with all market friction concern in Equation (6). In other words, the outside band of estimated thresholds represent the profit of the trade could cover the transaction cost. Follow by Enders and Siklos (2001), the threshold values and threshold lag (d) are obtained as minimum mean of squared error of TAR model in equation (5) and the estimation procedures show in previous section. The thresholds are different with the policy changes, -0.0003 and 0.0051 for $p1$; -0.0015 and 0 for $p2$; -0.0001 and 0.0001 for $p3$; -0.0002 and 0.0139 for $p4$; 0.0030 and 0.0270 for $p5$; -0.0001 and 0.0006 for $p6$, respectively. The threshold lag (d) is 1 in $p1, p4, p5, and\ p6$; the threshold lag (d) is 3 in $p2$ and 2 in $p3$. It is intuitive that the range of the inter band is largest in $p5$ and imply investors should pay more cost and face more obstacles as they trade. α_j^+ and α_j^- denote the speed of downward and upward adjustment with transaction cost and market friction concern, such as $j = S\ or\ S^o$. And α_j^{btwn} means the speed of adjustment in the inter band. The differences between upward and downward adjustment speed are significant in Table 6 and therefore we conclude the speed of upward adjustment to new equilibrium is quicker than that of downward adjustment even control all market frictions as possible.

The similar results with different models highlight that short sale constraint seems hinder the bad news incorporate on price. If the conjecture holds, downward adjustment speed should improve as lifting constraints versus heaviest constraints. Next, we pay close attention on the market response for bad news arrival under different level of short sale constraints.

5.3 Enhanced Adjustment Rate under Relaxed Short sale constraints

We rule out the possible effects on price movement and further examine our hypothesis which short sale constraints do affect price adjustment. The model with varying rate of adjustment for different short sale constraint policy changes is shown as equation (7). Testing whether the speed differ from different policy changes, the comparisons between lowest (P_4) and highest (P_5) intensity restrictions is significantly different in last four columns of Table 4. Relaxing short sale constraints do improve negative information reflect on price. Ignoring the different effects on upward and downward adjustment, the speed is more than two times quicker during lowest intensity restrictions (P_4) than lowest (P_4) and highest intensity restrictions (P_5).

Diamond and Verrecchia (1987) and Hong et al. (2000) specify short sale constraints delay negative news reflect on price. Short sale constraints impede to disclose bad news, and the cumulative negative momentums are too heavy to hind some day. Lim (2011) and Hong and Stein (2003) point that leads to collapse or bubble. In the other hand, relaxing restrictions improve bad news to release (Phillips, 2011, Charoenrook and Daouk, 2005, Bris et al, 2007). We employ the model with varying rate of upward and downward adjustment for different short sale constraint policy change with threshold ($c = 0$) to examine whether lifting short sale constraints improve negative information disclosure in Table 5. The model represents as equation (8). The speed response for negative information is almost two times quicker during P_4 than P_5.

As for controlling the effects of transaction cost on return, we employ 3-regime TECM which imply how large deviation from theoretical price will trigger trade. The arbitrageurs may do nothing while price deviations fall in the area between the upper and lower bounds. That's the reason we believe 3-regime TECM had accounted for transaction cost. We use 3-regime TECM with varying rate of upward and downward adjustment for different short sale constraint policy changes in Equation (9) to capture the effects of transaction cost on price movements in Table 6. The estimated thresholds are obtained separately for each individual period by minimum sum of square error in Equation (5). The estimated thresholds are shown in section 5.2. There are asymmetric patterns with different policy in Table 5 and Table 6. The comparisons between lowest (P_4) and highest (P_5) intensity restrictions is significantly different in upper regime in Table 6. We conclude the results support our hypothesis 2b, that is, the speed for downward adjustment improved after relaxing short sale constraints.

5.4 Further Evidence on Transactions with High Short Demand

In this section, we further do robustness check for our conjecture. If short sale could improve price adjustment, the transaction labeled as high short demand or high propensity to short (HPTS) should speedier for information incorporate during P_4 than P_5. We denoted the lowest Relative Strength Index (RSI), by Fung and Jiang (1999) and Jiang et al. (2001), as HPTS or high short demand.

<<Insert Table 7 here>>

The model with varying rate in case of HPTS is shown in equation (10) and the results represent in Table 7. To investigate asymmetric adjustment pattern, we engage in the different rate of upward and downward adjustment in case of HPTS is shown in equation (11) and the results represent in Table 7. There is strong evidence that asymmetric adjusting speed exists and upward adjusting speed is quicker more than downward one even in the case of HPTS. We divide transactions of high short demand into 6 groups according to policy changes to double check whether lifting constraints is speed up the convergence toward equilibrium or not. The model is shown as in equation (12). The results are similar as above. Next, based on the estimated threshold value, we explore whether the convergent rate of downward adjustment is more efficiency for transactions with HPTS while short sale is easier. The model is shown as in equation (13). The results support our third hypothesis. It is good for price efficiency improvement since the stocks with HPTS liberated to trade. We suggest the authorities should not close the trendy trade and short sale constraints really impede price adjustment.

5.5 Tighter SSC, Higher Risk and Price Fluctuation

The evidences above are shown that short sale constraints do affect the adjustment speed towards equilibrium. Relaxing short sale constraints significantly improve the speed as market price is overvalued, the results still hold even though control other lurking variables. The speeds during least short sale constraints are quickest.

As for the perspectives for regulators, short selling plays a devil's role in price stabilization. Bris et al. (2007), Charoenrook and Daouk (2005), and Saffi and Sigurdsson (2011) do not agree the claim. Saffi and Sigurdsson (2011) find the total risk and down risk of the stocks with higher loan fee or low loan supply increase significantly. Bris et al. (2007) analyze 46 security markets and find the distributions of market return with short sale constraints present less negative skewness. There is no evidence to support short sale allowance will lead to crisis.

<<Insert Table 8 here>>

In this paper, to give regulators some recommendations, we reexamine how the characteristics of index return distribution and risk of spot market affect by short sale policy changes. The characteristics of index return distribution is measured by the variables of skewness (skew) and kurtosis (kurt) in Table 8. skew and kurt represent skewness and excess kurtosis of index return per day. For the TAIEX intraday data, the average daily excess kurtosis is 120 in P_5 and 96 in P_4. The daily skewness is −3.01 in P_5 and 1.06 in P_4; the negative skewness indicates that the left tail is heavier than the right tail. Consistent with the evidence by Bris et al. (2007), skewness decrease with higher short-sale constraints. We find that higher short sale constraints are associated with higher kurtosis that is in accordance with Saffi and Sigurdsson (2011). We conclude that short-sale constraints are associated with lower skewness and higher kurtosis.

$Extre.Freq^-$ and $Extre.Freq^+$ denoted as the proportion of the occurrence for extreme negative and positive return per day. We define extreme negative and positive return as index return is less or greater than two times standard deviation for each period of policy changes. There is no evidence that short sale would increase the frequency of extreme return or the possibility of crash.

realized variance is sum of squared 1-minute index return per day. down risk represent realized semi-variance, that is, sum of squared negative return. In last two columns in Panel A of Table 8, we find higher short sale constraints are positively related to both downside and total risks. This result is similar to Charoenrook and Daouk (2005).

Someone may debate that increasing downside and total risks in 2008 financial crisis, p5, are result from fear of investors rather than short sale constraints. In Panel B of Table 8, we rule out the possibility effect of market expectations, VIX, on risk increment and compare realized variance and down risk with different level of short sale constraints. VIX, the TAIEX index options volatility, represents market expectations prepared by CBOE VIX index method. Compare with the old VIX, the new VIX is calculated by weighted average index options of different strike prices, but not from the Black-Scholes model. In general, higher VIX index, more severe future volatility of stock price index which investors expect. Conversely, the lower VIX index shows traders expect share price indices will tend to moderate. As the index has described the situation changes in investor psychology, it is also known as the fear index of investors. We conclude higher short sale constraints are positively related to both downside and total risks with controlling the fear of investors.

Overall, by using policy changes as proxies for short selling constraints, there is no evidence that an increase in short-sale constraints is associated with higher price stability. Furthermore, the imposition of constraints is associated with decreasing price efficiency and increasing downside risk.

5.6 What if No Short Sale Constraints -- A Counterfactual Analysis

The evidence seems to support our hypothesis that short-selling constraints cannot stabilize the financial markets, instead increasing total risk and downside risk. It is consistent with the evidences from Franklin and Gale (1991), Bris et al. (2007) and Charoenrook and Daouk (2009), Saffi and Sigurdsson (2011). We almost could conclude short sale constraints fail to meet the requirement of regulators and the tight constraints are harmful for market efficiency.

Of course, one could argue that in the absence of the short sale ban market would have dropped even further. The results shown in section 5.3 provide the evidences of other perspectives that the source of market inefficiency is tightened short sale constraints. The speed of downward adjustment is indeed slower during short sale ban. If we interpret the evidence with view from opposite side, slower speed response to bad news seems provide another view to advocate the purpose of stabilizing market fluctuation. The reason is that the slower downward adjustment may pacify market confidence for investors.

The argument seems are verified indirectly by Veronesi and Zingales (2010), Hoshi and Kashyap (2010), and Diamond and Rajan (2009). They document financial bailouts do rescue the credit crunch problem but related cost is huge.

This paper exploits whether the market price have dropped even further without short sale ban by counterfactual test with stationary bootstrap method based on Politis and Romano (2004) and Hsu et al. (2010). We simulate market price without short sale ban and compare whether the price with short sale ban really pacify the price fluctuations. The simulation with stationary bootstrap algorithm is computed as follows.

(1) Start by the residuals in equation (13) during short sale ban period $\{\varepsilon_1^j,...,\varepsilon_T^j\}$ where and $T = 19241$ and $j = S \ or \ S^O$.

(2) Let $\{u_{b,t}\}_{t=1}^T$ be randomly drawn i.i.d. with uniform distribution on the set $\{1,2,...,T\}$; there are the starting points of new blocks.

(3) Let $\{v_{b,t}\}_{t=1}^T$ be randomly drawn i.i.d. from continuous uniform distribution with domain value $(0,1]$; there are probability of resample.

(4) Start by $\tau_{b,1} = u_{b,1}$. For any $t > 1$, the b-th resample of $\varepsilon_t^b = \varepsilon_{\tau_{b,t}}$ where $\tau_{b,t}$ is

$$\tau_{b,t} = \begin{cases} u_{b,t} & , \ if \ v_{b,t} < 0.5 \\ \tau_{b,t} \bullet 1_{\{\tau_{b,t-1} < T\}} + 1, & if \ v_{b,t} \geq 0.5 \end{cases}$$

. A resample ε_t^b is done when T observations are drawn.

(5) Using speed of adjustment and the estimated threshold during P_4 to calculate $\Delta \ln S_{b,t}$, $\Delta \ln S_{b,t}^O$, $S_{b,t}$, $S_{b,t}^O$ and $Z_{b,t}$ to obtain $S_{b,t+1}$, $S_{b,t+1}^O$ until T observations are included. A simulation the price series without short sale ban is completed. We assume speed of adjustment and the estimated threshold in equation (13) is the same with those during P_4 if short sale ban did not execute during P_5.

Repeat this procedure $b = 5000$ times yield a price series, $\overline{S}_t$ (averaged simulated index price), without short sale ban shown in Figure 3.

<<Insert Figure 3 here>>

Comparing index price with and without short sale ban, it seems to witness price did not stop dropping just like regulators claimed. Recall the theoretical price is free for short sale constraints, therefore the theoretical price should not be affect by short sale ban or not. Next, we only resample ε_t^b and S_b rather than resample both two price series and obtain the time series plot for index price with/without short sale ban in Figure 4. The price differences of with/without short sale ban shown in Figure 5.

<<Insert Figure 4 and Figure 5 here>>

The first and second pair dash lines denote as the first day and the end day for short sale ban of all stocks overall. The positive price difference with/without short sale ban represents that short sale ban is valid to alleviate dropping price. As we see in Figure 4, price difference almost positive and large during overall short sale ban period, but less positive price difference emerge while only forbid short sale price lower than previous day's close price. We conclude that short sale constraint rescues the investors' confidence from executing more fire sales and save the market from further liquidity dry-ups via our counterfactual analysis though it helps little in stabilizing the market from fluctuations. By contrast, we find that heavier short sale restrictions are associated with greater downside risk and higher volatility even we control for investors' fear gauge that is proxy by VIX.

6. Conclusion

Several policy changes of short-sale constraints in Taiwan stock market during 2002 to 2009 provide us a natural experiment of short-sale constraints to examine how the stock market response these policy changes. There are three findings in this paper. First, short sale constraints lead to a less efficient market by creating the asymmetric patterns in both the magnitude as well as the speed of price adjustment in the presence of mispricing. We find that short sale constraints in general hinder negative information into price, therefore the convergence rate of upward adjustment is faster than that of downward adjustment within our entertained threshold error correction model (TECM), even controlled for market conditions and liquidity. Second, we document that short sale constraints influences adjusting period and the speed of adjustment—markets with short sale ban are associated with lower efficiency. The speed for downward adjustment improved after relaxing short sale constraints. Finally, the realized equilibrium adjustments via our counterfactual analysis also indicate that the short sale constraint rescues the investors' confidence from executing more fire sales and save the market from further liquidity dry-ups though it helps little in stabilizing the market from fluctuations. By contrast, we find that heavier short sale restrictions are associated with greater downside risk and higher volatility. The results hold true even we control for investors' fear gauge that is proxy by VIX. Interestingly, although these findings do not support the view expressed by regulators that restraining short sales can stabilize prices, they do patronize academic findings that short-sale restrictions generally lead to less efficient markets.

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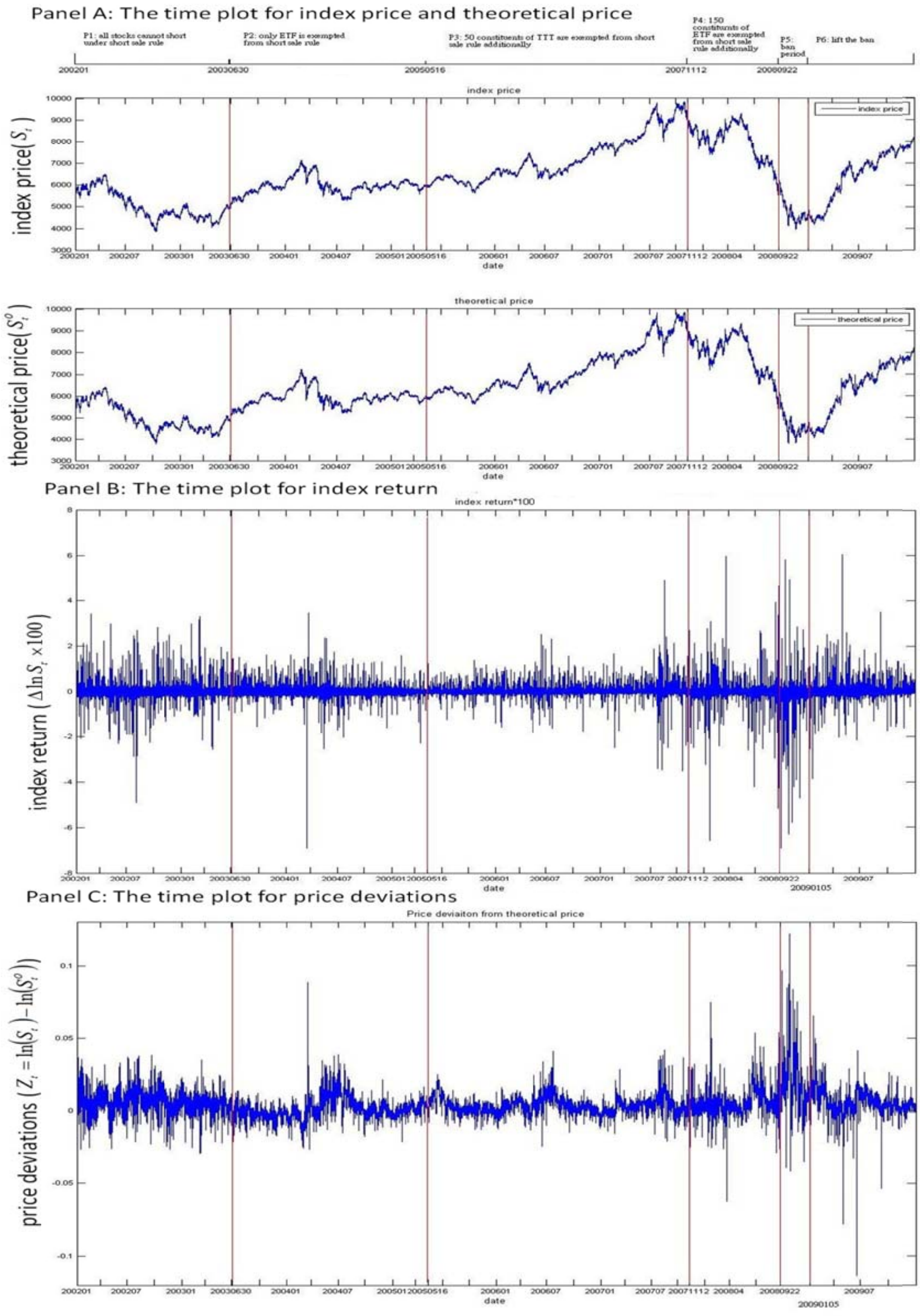

Figure 1 The Time Plot for Index Price, Index Return and Price Deviation

Figure 1 shows the time plot for index price, index return and price deviation during 2002 to 2009. There are six short sale constraints policy changes divided by the vertical red lines. Panel A presents the time plot for index price and equilibrium price. Panel B presents the time plot for index return. Panel C presents the time plot for price deviations.

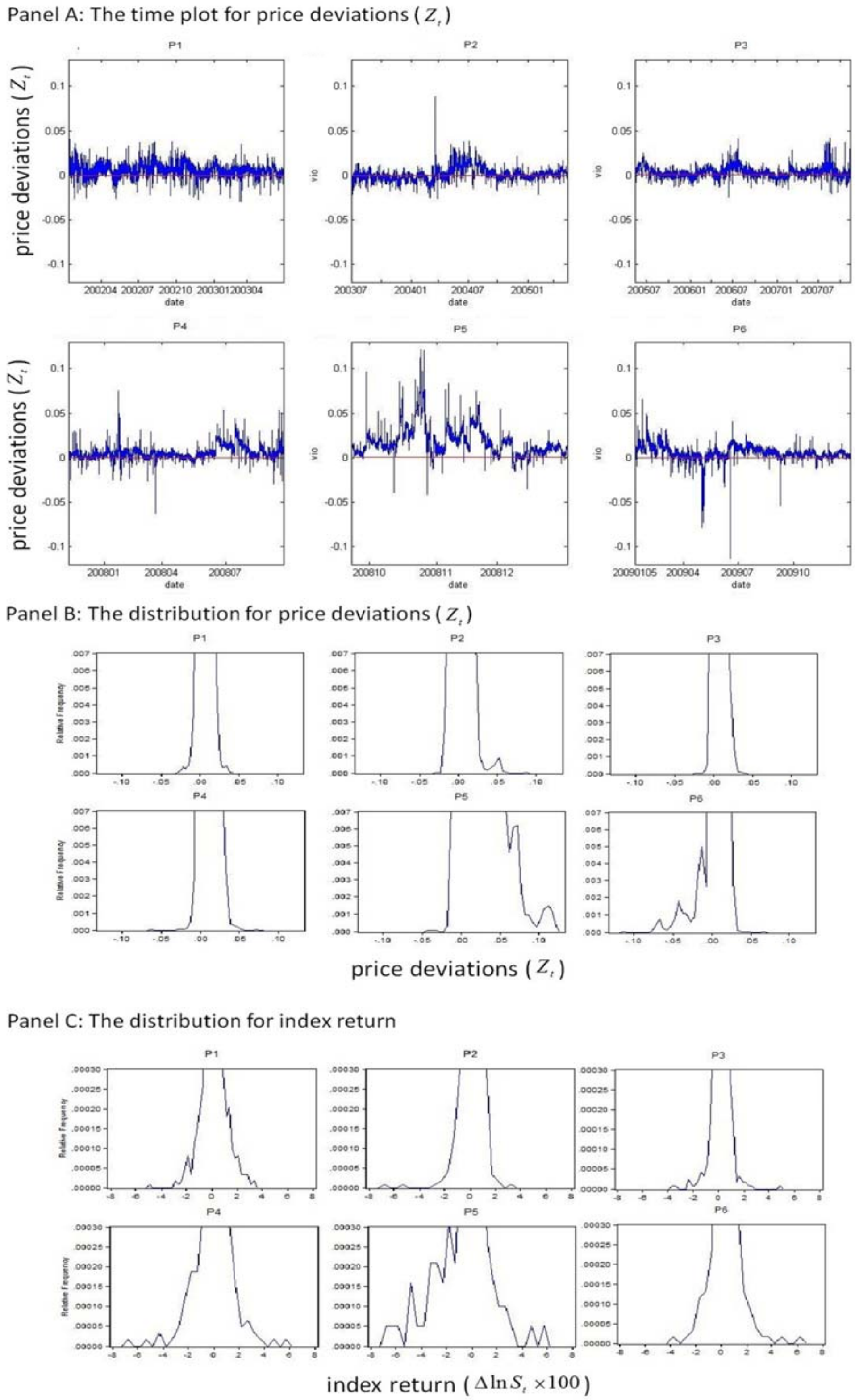

Figure 2 The Distributions for Index Return and Price Deviations

Figure 2 shows the distributions for index return and price deviations. Panel A presents the time plot for price deviations with different short sale constraints pressures. Panel B concentrates on the tail behavior of price deviations. Panel C concentrate on the tail behavior of index return.

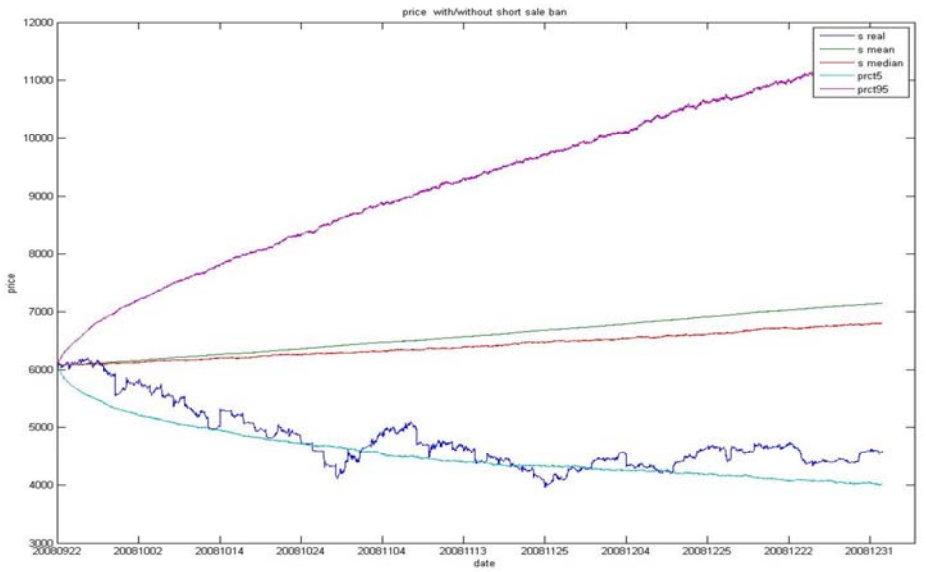

Figure 3 Price with/without Short Sale Ban from Counterfactual Analysis

Figure 3 shows comparison of index price with and without short sale ban from Counterfactual Analysis. We assume both index price and theoretical price change in case of no short sale ban. Blue line represents market index price. Green and red line represent the mean and median of simulate market price without short sale ban. Cyan and purple line present the 5% and 95% percentile of simulate market price without short sale ban.

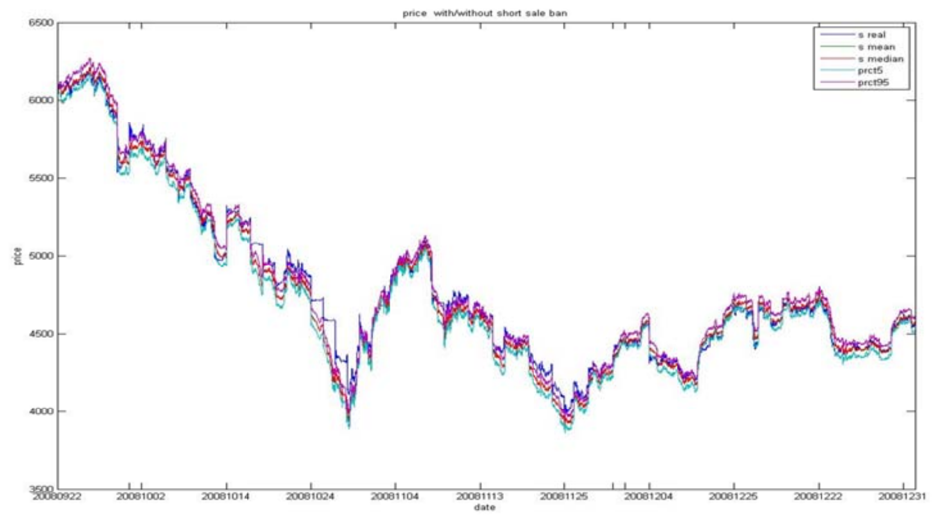

Figure 4 Price from Counterfactual Analysis (Fixed Equilibrium Price)

Figure 4 shows comparison of index price with and without short sale ban from Counterfactual Analysis that we assume only index price changes in case of no short sale ban. Blue line represents market index price. Green and red line represent the mean and median of simulate market price without short sale ban. Cyan and purple line present the 5% and 95% percentile of simulate market price without short sale ban.

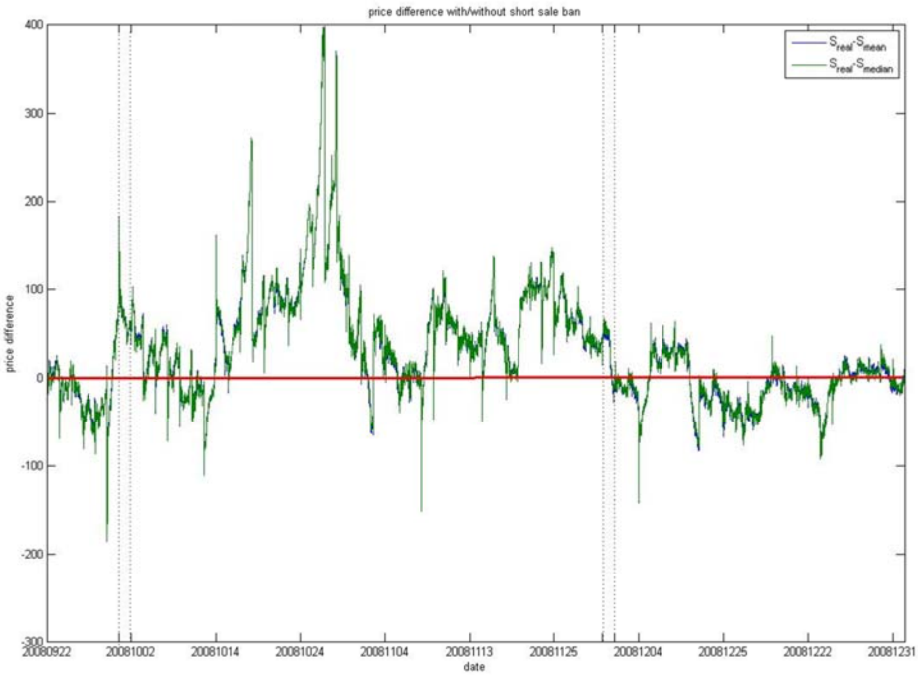

Figure5 Price Difference with/without Short Sale Ban from Counterfactual Analysis

Figure 5 shows the difference between index price with and without short sale ban from Counterfactual Analysis that we assume only index price changes in case of no short sale ban. Blue (green) line represents the price difference of market index price with short sale ban and mean (median) of simulate market price without short sale ban. The first and second pair dash lines denote as the first day and the end day for short sale ban of all stocks overall.

Table 1: Unit-root test and Cointegration Test

Panel A: Augmented Dickey-Fuller test statistic

	level		first difference	
	t-Statistic	critical values	t-Statistic	critical values
$\ln S_t$	-1.38	-3.43019	-212.365	-2.86136
$\ln S_t^O$	-1.60	-2.86136	-287.005	-2.86136

Panel B: Cointegration Test

	Statistic	Critical Value
Trace test	1180.213	25.87211
Max-eigenvalue test	1176.022	19.38704

Note: $\ln S_t^O$ denotes 1-mininute logarithm theoretical price derived from put call parity, and $\ln S_t$ denotes logarithm TAIEX Index price, which are available from Taiwan Economic Journal Database (TEJ). The sample period is from 2002-2009, yielding 1989 trading days and 539109 pairs of intraday observations.

Table 2 Summary statistics

Period	All						P1	P2	P3	P4	P5	P6
Variable	Obs.	Mean	Median	Std	Min	Max	Mean	Mean	Mean	Mean	Mean	Mean
Obs.	539019						99186	126557	168020	57994	19241	68021
S_t	539019	6421	6212	1307	3846	9860	5024	5931	7239	8006	4790	6463
S_t^O	539019	6393	6174	1308	3774	9848	4995	5922	7211	7963	4705	6428
$\Delta \ln S_t \times 10^5$	539018	0.0721	0.0000	82	-6905	6047	-0.1304	0.1612	0.2412	-0.7021	-1.3651	0.8505
$\Delta \ln S_t^O \times 10^5$	539018	0.0731	0.0000	107	-12810	12744	-0.1310	0.1673	0.2400	-0.7111	-1.4137	0.8723
Z_t	539019	0.0047	0.0036	0.0074	-0.1132	0.1218	0.0058	0.0016	0.0039	0.0056	0.0183	0.0058
Market liquidity												
No. of trade	539019	2862	2289	2807	0	152241	2434	2467	2745	3507	2690	4011
No. of shares	539019	14877	11477	17737	0	1063416	12965	14971	14411	16936	12759	17485
$TDOLLAR_{t-1}$	539019	368	281	434	0	35933	301	332	394	450	223	438
Obs.							366	467	620	214	71	251
Daily turnover	1989	0.0069	0.0061	0.0030	0.0020	0.0223	0.0082	0.0078	0.0059	0.0057	0.0048	0.0075
Daily turn/MV	1989	0.0068	0.0062	0.0025	0.0021	0.0193	0.0083	0.0070	0.0061	0.0061	0.0050	0.0074
Market condition												
realized variance*100	1989.0000	0.0186	0.0101	0.0358	0.0009	0.4814	0.0240	0.0158	0.0080	0.0272	0.0757	0.0188
$\overline{R}_{-3m}^{spot}$	1989.0000	0.0003	0.0005	0.0021	-0.0070	0.0060	0.0001	0.0006	0.0008	-0.0012	-0.0053	0.0014
$stdr_{-3m}^{spot}$	1989.0000	0.0148	0.0148	0.0053	0.0068	0.0270	0.0181	0.0127	0.0100	0.0200	0.0242	0.0187
$skew_{-3m}^{spot}$	1989.0000	-0.1706	-0.1374	0.6337	-1.9077	2.2563	0.1864	-0.1878	-0.4167	0.1668	0.3709	-0.4920
$kurt_{-3m}^{spot}$	1989.0000	1.7216	0.8466	2.4404	-0.3963	16.2872	0.3252	1.4754	2.4858	2.4188	0.2950	2.1374

Note: S_t is index price, and S_t^O is theoretical index price. $\Delta \ln S_t$ and $\Delta \ln S_t^O$ represent returns for index and theoretical index. $Z_t = \ln S_t - \ln S_t^O$ denotes the violations for logarithm index price. We include three categories control variables, such as market liquidity, market condition, and microstructure effect. No. of trade is number of trade per minute for index. No. of shares (thousand) denotes number of trading shares per minute for index. $TDOLLAR_{t-1}$ (thousand) denotes the amount of trading dollars per minute for index. Daily turnover is calculated as daily trading volume divided by daily number of outstanding shares for index. Daily turn/MV denotes daily trading dollars divided by daily market value for index. Realized variance is calculated by 1-min index return per day. $\overline{R}_{-3m}^{spot}$, $skew_{-3m}^{spot}$, $kurt_{-3m}^{spot}$, and $stdr_{-3m}^{spot}$ are averaged return, skewness, kurtosis, and standard deviations calculated by previous 90 days 1-min index return, respectively. NR_t denotes the number of extreme negative index return per day. We denotes extreme negative index return as less than two standard deviation of index return mean. We follow Fung and Jiang (1999) and Jiang et al. (2001) in measuring market directions by the Relative Strength Index (RSI), $RSI_t = \frac{N_t^-}{N_t^+ + N_t^-}$, where N_t^+ and N_t^- are the number of 1-minute intervals in which the TWSE spot index advances and declines during the day, respectively. We sort our observations into ten deciles based on the daily relative strength index. The highest deciles represents the mostly downward price movements, which indicates that short selling is more likely in.

Table 3: How many minutes do price overvaluation or undervaluation sustain?

period		Perfect market assumption			Exogenous transaction cost		
		sustained overvaluation (mins)	sustained undervaluation (mins)		sustained overvaluation (mins)	sustained undervaluation (mins)	
	statistic	mean	mean	DIFF	mean	mean	DIFF
	threshold	0	0		0.004425	-0.001425	
p1	20020102~20030629	69.21	12.30	56.91a	32.76	11.07	21.69a
p2	20030630~20050515	41.20	34.55	6.65	39.66	26.26	13.40c
p3	20030516~20071111	82.22	22.36	59.86a	38.49	19.24	19.25b
p4	20071112~20080921	72.02	10.91	61.11a	26.56	10.44	16.12a
p5	20080922~20081231	212.30	12.20	200.10a	85.82	15.83	69.98a
p6	20090105~20091231	96.44	13.01	83.42a	45.61	10.80	34.81a
Test: Does adjusting period differ from different policy change?							
The null is $H_0^1: adjusting\ period^{p4} - adjusting\ period^{p5} \geq 0$							
	p4-p5	-140.28a	-1.29		-59.26a	-5.40	

Note: We examine how many minutes price overvaluation or undervaluation sustain. The price overvaluation defined as the violations are greater than threshold and price undervaluation defined as the violations are lower than threshold. The violations are deviation between logarithm index price ($\ln S_t$) and logarithm theoretical price ($\ln S_t^o$), denoted by $Z_t = \ln S_t - \ln S_t^o$. We simply employ zero as the threshold value in the first case under the assumption of perfect market. In second case, the threshold is exogenously given by -0.001425 and 0.004425, denoted the transaction cost directly as investors buy or sell stocks in security market. We assume investor will short as price ratio is larger than 1.004425, that is, Z_t is about 0.004425. Investor will buy as price ratio is less than 1/1.001425, that is, Z_t is about -0.001425. DIFF in last column is to test whether downward adjustment spent more time as index price is overpriced. And the null is $H_0: adjusting\ period^+ - adjusting\ period^- \leq 0$. a denotes significant level at 1%. b denotes significant level at 5%. c denotes significant level at 10%.

Table 4 The estimates of VECM model with different policy change.

MODEL	[1a]		[1b]		[2a]		[2b]	
Dep. Var.	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$
Intercept	**0.0000***	**-0.0000***	-0.0000	0.0000	**0.0000***	**0.0000***	-0.0000	0.0000
α_j	**-0.0023***	**0.0021***	**-0.0030***	**0.0027***				
α_j^{p1}					**0.0012***	**0.0085***	0.0010	**0.0100***
α_j^{p2}					**-0.0038***	**0.0019***	**-0.0050***	**0.0023***
α_j^{p3}					**-0.0032***	**0.0017***	**-0.0038***	0.0003
α_j^{p4}					**-0.0068***	0.0005	**-0.0073***	0.0014
α_j^{p5}					**-0.0022***	-0.0006	**-0.0029***	0.0002
α_j^{p6}					-0.0009	**0.0044***	**-0.0015***	**0.0056***
$TDOLLAR_{t-1}$			**-0.0000***	0.0000			**0.0000***	0.0000
$\overline{R}_{-3m}^{spot}$			-0.0006	0.0029			**-0.0028***	-0.0014
$stdr_{-3m}^{spot}$			**0.0017***	-0.0009			**0.0010***	**-0.0027***
$skew_{-3m}^{spot}$			**-0.0000***	-0.0000			**0.0000***	-0.0000
$kurt_{-3m}^{spot}$			-0.0000	0.0000			0.0000	**0.0000***
overnight			0.0001	0.0006			0.0001	0.0006
open			**0.0001***	**0.0000***			**0.0001***	**0.0000***
close			-0.0000	0.0000			-0.0000	0.0000
AIC	-22.6113		-22.6143		-22.6125		-22.6156	
Test: Does the speed of adjustment differ from policy changes?								
$H_0: \alpha_S^{p4} - \alpha_S^{p5} \geq 0$					-0.0046a		-0.0044a	

Note: The estimates in Table 4 are specified with the two models as following.
Constant rate of adjustment:

$$\begin{cases} \Delta \ln S_t = c_S + \alpha_S Z_{t-1} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \alpha_{S^O} Z_{t-1} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} . \quad (1)$$

Varying rate of adjustment for different short sale constraint policy change:

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{pi} Z_{t-1} I_{\{t\in pi\}} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{pi} Z_{t-1} I_{\{t\in pi\}} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} . \quad (2)$$

$\Delta\ln S_t$ and $\Delta\ln S_t^O$ represent returns for index and theoretical index. Z_{t-1} denotes lag error correction term. α_j^{Pi} denote the speed of adjustment for different policy, such as $i = 1,2,\ldots,6$ and $j = S \text{ or } S^o$. p is lag operator determined by minimum SIC to compromise white noise for ε_t^j. And p is 21. C represents control variables. We include three categories control variables, such as market liquidity, market condition, and microstructure effect. $TDOLLAR_{t-1}$ (thousand) denotes the amount of trading dollars per minute for index. $\overline{R}_{-3m}^{spot}$, $skew_{-3m}^{spot}$, $kurt_{-3m}^{spot}$, and $stdr_{-3m}^{spot}$ are averaged return, skewness, kurtosis, and standard deviations calculated by previous 90 days index return per minute, respectively. overnight equals 1 if transactions occur in 9:00. open equals 1 if transactions occur during 9:01-9:30, and close equals 1 if transactions occur during 13:01-13:30. a denotes significant level at 1%. b denotes significant level at 5%. c denotes significant level at 10%. * is significantly different from zero if its conventional *t* value is greater than the sample size-adjusted critical *t* value, 3.65. The value is calculated by Connolly (1989) who illustrate conventional *t* value criteria is not appropriate if sample size is large.

Table 5 The estimates of 2-regime TECM with different policy change.

MODEL	[3a]		[3b]		[4a]		[4b]	
Dep. Var.	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$
Intercept	-0.0000	0.0000	**-0.0000***	0.0000	**-0.0000***	**-0.0000***	**-0.0000***	-0.0000
α_j^+	**-0.0010***	0.0008	**-0.0016***	**0.0014***				
α_j^-	**-0.0099***	**0.0093***	**-0.0105***	**0.0097***				
α_j^{+p1}					**0.0038***	**0.0067***	**0.0035***	**0.0073***
α_j^{-p1}					**-0.0051***	**0.0505***	-0.0043	**0.0495***
α_j^{+p2}					-0.0004	**0.0023***	**-0.0016***	**0.0024***
α_j^{-p2}					**-0.0139***	-0.0008	**-0.0156***	-0.0004
α_j^{+p3}					0.0006	**0.0013***	0.0000	0.0008
α_j^{-p3}					**-0.0394***	-0.0050	**-0.0438***	-0.0038
α_j^{+p4}					**-0.0026***	0.0003	**-0.0026***	0.0008
α_j^{-p4}					**-0.2007***	-0.0162	**-0.2005***	-0.0164
α_j^{+p5}					**-0.0011***	-0.0007	**-0.0015***	-0.0003
α_j^{-p5}					**-0.0804***	-0.0026	**-0.0793***	-0.0039
α_j^{+p6}					0.0007	**0.0021***	-0.0002	**0.0023***
α_j^{-p6}					0.0009	**0.0121***	0.0010	**0.0122***
$TDOLLAR_{t-1}$			**-0.0000***	0.0000			**-0.0000***	0.0000
$\overline{R}_{-3m}^{spot}$			-0.0005	0.0028			-0.0002	0.0010
$stdr_{-3m}^{spot}$			**0.0014***	-0.0007			**0.0014***	-0.0005
$skew_{-3m}^{spot}$			**-0.0000***	0.0000			**-0.0000***	-0.0000
$kurt_{-3m}^{spot}$			0.0000	-0.0000			0.0000	0.0000
overnight			**0.0002***	**0.0006***			**0.0002***	**0.0006***
open			**0.0001***	**-0.0000***			**0.0001***	**-0.0000***
close			-0.0000	0.0000			-0.0000	0.0000
	-22.6104		-22.613		-22.6194		-22.6221	
Test: Does the speed of upward versus downward adjustment represent asymmetric pattern?								
$H_0^{2a}: \alpha_S^- - \alpha_S^+ \ge 0$	**-0.0089a**		**-0.0089a**					
Test: Does the speed of downward adjustment differ from policy changes?								
$H_0^{2b}: \alpha_S^{+p4} - \alpha_S^{+p5} \ge 0$					**-0.0015a**		**-0.0012a**	

Note: The estimates in Table 5 are specified with the 2-regime TECM as following.

Varying rate of upward and downward adjustment with threshold ($c = 0$):

$$\begin{cases} \Delta \ln S_t = c_S + \alpha_S^+ Z_{t-1} I_{\{Z_{t-1}\ge 0\}} + \alpha_S^- Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \alpha_{S^O}^+ Z_{t-1} I_{\{Z_{t-1}\ge 0\}} + \alpha_{S^O}^- Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} \quad (3)$$

Varying rate of upward and downward adjustment for different short sale constraint policy change with threshold ($c = 0$):

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{+pi} Z_{t-1} I_{\{t\in pi, Z_{t-1}\ge 0\}} + \sum_{i=1}^{6} \alpha_S^{-pi} Z_{t-1} I_{\{t\in pi, Z_{t-1}< 0\}} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{+pi} Z_{t-1} I_{\{t\in pi, Z_{t-1}\ge 0\}} + \sum_{i=1}^{6} \alpha_{S^O}^{-pi} Z_{t-1} I_{\{t\in pi, Z_{t-1}< 0\}} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} \quad (4)$$

$\Delta \ln S_t$ and $\Delta \ln S_t^o$ represent returns for index and theoretical index. Z_{t-1} denotes lag error correction term. α_j^+ and α_j^- denote the speed of downward and upward adjustment under the assumption of perfect market, such as $j = S \; or \; S^o$. p is lag operator determined by minimum SIC to compromise white noise for ε_t^j. And p is 21. C represents control variables. We include three categories control variables, such as market liquidity, market condition, and microstructure effect. $TDOLLAR_{t-1}$ (thousand) denotes the amount of trading dollars per minute for index. $\overline{R}_{-3m}^{spot}$, $skew_{-3m}^{spot}$, $kurt_{-3m}^{spot}$, and $stdr_{-3m}^{spot}$ are averaged return, skewness, kurtosis, and standard deviations calculated by previous 90 days index return per minute, respectively. overnight equals 1 if transactions occur in 9:00. open equals 1 if transactions occur during 9:01-9:30, and close equals 1 if transactions occur during 13:01-13:30. $\alpha_j^{+,pi}$ and $\alpha_j^{-,pi}$ denote the speed of downward and upward adjustment under different constraint condition and the assumption of perfect market, such as $i = 1,2,...,6$ and $j = S \; or \; S^o$. a denotes significant level at 1%. b denotes significant level at 5%. c denotes significant level at 10%. * is significantly different from zero if its conventional *t* value is greater than the sample size-adjusted critical *t* value, 3.65. The value is calculated by Connolly (1989) who illustrate conventional *t* value criteria is not appropriate if sample size is large.

Table 6 The estimates of 3-regime TECM model with different policy change.

MODEL	[5a]		[5b]		[6a]		[6b]	
Dep. Var.	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$	$\Delta\ln S_t$	$\Delta\ln S_t^O$
Intercept	-0.0000	0.0000	**-0.0000***	0.0000	**-0.0000***	-0.0000	**-0.0000***	-0.0000
α_j^{+}	**-0.0011***	**0.0012***	**-0.0016***	**0.0014***				
α_j^{btw}	-0.0007	**-0.0021***	**-0.0017***	-0.0014				
α_j^{-}	**-0.0100***	**0.0094***	**-0.0105***	**0.0097***				
$\alpha_j^{+,p1}$					**0.0041***	**0.0070***	**0.0041***	**0.0073***
$\alpha_j^{-,p1}$					-0.0055	**0.0511***	-0.0049	**0.0505***
$\alpha_j^{+,p2}$					-0.0002	**0.0020***	-0.0012	**0.0021***
$\alpha_j^{-,p2}$					**-0.0143***	-0.0001	**-0.0157***	0.0001
$\alpha_j^{+,p3}$					0.0008	0.0009	0.0001	0.0007
$\alpha_j^{d,p3}$					**-0.0401***	-0.0038	**-0.0437***	-0.0033
$\alpha_j^{+,p4}$					**-0.0051***	0.0008	**-0.0050***	0.0009
$\alpha_j^{-,p4}$					**-0.2013***	-0.0152	**-0.2020***	-0.0151
$\alpha_j^{+,p5}$					**-0.0018***	-0.0008	**-0.0018***	-0.0006
$\alpha_j^{-,p5}$					**-0.0743***	-0.0022	**-0.0742***	-0.0025
$\alpha_j^{+,p6}$					0.0009	0.0017	0.0002	0.0019
$\alpha_j^{-,p6}$					0.0009	**0.0123***	0.0009	**0.0124***
$\alpha_j^{btw,p1}$					0.0009	-0.0052	0.0011	-0.0043
$\alpha_j^{btw,p2}$					-0.0136	-0.0045	-0.0148	-0.0051
$\alpha_j^{btw,p3}$					0.0014	0.0748	-0.0001	0.0732
$\alpha_j^{btw,p4}$					0.0017	-0.0013	0.0023	-0.0005
$\alpha_j^{btw,p5}$					0.0009	-0.0009	0.0008	-0.0002
$\alpha_j^{btw,p6}$					-0.0007	0.0971	-0.0335	0.0811
$TDOLLAR_{t-1}$			**-0.0000***	0.0000			-0.0000	0.0000
$\overline{R}_{-3m}^{spot}$			-0.0006	0.0015			0.0008	0.0010
$stdr_{-3m}^{spot}$			**-0.0000***	0.0000			**-0.0000***	-0.0000
$skew_{-3m}^{spot}$			**0.0014***	-0.0004			0.0009	-0.0002
$kurt_{-3m}^{spot}$			0.0000	-0.0000			0.0000	0.0000
overnight			**0.0002***	**0.0006***			**0.0002***	**0.0006***
open			**0.0001***	**0.0000***			**0.0001***	**-0.0000***
close			-0.0000	0.0000			-0.0000	0.0000
AIC	-22.6123		-22.6152		-22.6218		-22.6249	
Test: Does the speed of upward versus downward adjustment represent asymmetric pattern?								
$H_0^{2a}: \alpha_S^{-} - \alpha_S^{+} \geq 0$	**-0.0089a**		**-0.0089a**					
Test: Does the speed of downward adjustment differ from policy changes?								
$H_0^{2b}: \alpha_S^{+,p4} - \alpha_S^{+,p5} \geq 0$					**-0.0033a**		**-0.0032a**	

Note: The estimates in Table 6 are specified with the two 3-regime TECM as following.
Varying rate of upward and downward adjustment for 3-regime TECM:

$$\begin{cases} \Delta \ln S_t = c_S + \alpha_S^- Z_{t-1} I_{\{Z_{t-1} \le c_1\}} + \alpha_S^{btwn} Z_{t-1} I_{\{c_1 < Z_{t-1} < c_2\}} + \alpha_S^+ Z_{t-1} I_{\{Z_{t-1} \ge c_2\}} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \alpha_{S^O}^- Z_{t-1} I_{\{Z_{t-1} \le c_1\}} + \alpha_{S^O}^{btwn} Z_{t-1} I_{\{c_1 < Z_{t-1} < c_2\}} + \alpha_{S^O}^+ Z_{t-1} I_{\{Z_{t-1} \ge c_2\}} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} \quad (5)$$

Varying rate of upward and downward adjustment for different short sale constraint policy change with 3-regime TECM:

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{-,pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \le c_1\}} + \sum_{i=1}^{6} \alpha_{S^O}^{btwn,pi} Z_{t-1} I_{\{t \in pi, c_1 < Z_{t-1} < c_2\}} + \sum_{i=1}^{6} \alpha_S^{+,pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \ge c_2\}} + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{-,pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \le c_1\}} + \sum_{i=1}^{6} \alpha_{S^O}^{btwn,pi} Z_{t-1} I_{\{t \in pi, c_1 < Z_{t-1} < c_2\}} + \sum_{i=1}^{6} \alpha_{S^O}^{+,pi} Z_{t-1} I_{\{t \in pi, Z_{t-1} \ge c_2\}} + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} \quad (6)$$

The thresholds and threshold lag (d) in equation (5) and (6) are estimated by Enders and Siklos (2001). The thresholds are different with the policy changes, -0.0003 and 0.0051 for subsample period from 20020102 to 20030629; -0.0015 and 0 for subsample period from 20030630 to 20050515; -0.0001 and 0.0001 for subsample period from 20050516 to 20071111; -0.0002 and 0.0139 for subsample period from 20071112 to 20080921; 0.0030 and 0.0270 for subsample period from 20080922 to 20081231; -0.0001 and 0.0006 for subsample period from 20090105 to 20091231, respectively. The threshold lag (d) is 1 in $p1, p4, p5, and\ p6$; the threshold lag (d) is 3 in $p2$ and 2 in $p3$. $\Delta \ln S_t$ and $\Delta \ln S_t^O$ represent returns for index and theoretical index. Z_{t-1} denotes lag error correction term. α_j^+ and α_j^- denote the speed of downward and upward adjustment with transaction cost and market friction concern, such as $j = S\ or\ S^O$. And α_j^{btwn} means the speed of adjustment in the inter band. p is lag operator determined by minimum SIC to compromise white noise for ε_t^j. And p is 21. C represents control variables. We include three categories control variables, such as market liquidity, market condition, and microstructure effect. $TDOLLAR_{t-1}$ (thousand) denotes the amount of trading dollars per minute for index. $\overline{R}_{-3m}^{spot}$, $skew_{-3m}^{spot}$, $kurt_{-3m}^{spot}$, and $stdr_{-3m}^{spot}$ are averaged return, skewness, kurtosis, and standard deviations calculated by previous 3-month index return per minute, respectively. overnight equals 1 if transactions occur in 9:00. open equals 1 if transactions occur during 9:01-9:30, and close equals 1 if transactions occur during 13:01-13:30. $\alpha_j^{+,pi}$ and $\alpha_j^{-,pi}$ denote the speed of downward and upward adjustment under different constraint condition and the assumption of perfect market, such as $i = 1,2,...,6$ and $j = S\ or\ S^O$. a denotes significant level at 1%. b denotes significant level at 5%. c denotes significant level at 10%. * is significantly different from zero if its conventional *t* value is greater than the sample size-adjusted critical *t* value, 3.65. The value is calculated by Connolly (1989) who illustrate conventional *t* value criteria is not appropriate if sample size is large.

Table 7 The estimates of VECM model with high propensity to short (HPTS).

MODEL	(7)			(8)			(9)			(10)	
Dep. Var.	$\Delta \ln S_t$	$\Delta \ln S_t^O$		$\Delta \ln S_t$	$\Delta \ln S_t^O$		$\Delta \ln S_t$	$\Delta \ln S_t^O$		$\Delta \ln S_t$	$\Delta \ln S_t^O$
Intercept	-0.0000	0.0000	Intercept	-0.0000	0.0000	Intercept	-0.0000	0.0000	Intercept	-0.0000	-0.0000
α_j^{HPTS}	**-0.0055***	0.0011	α_j^{+HPTS}	**-0.0035***	-0.0004	$\alpha_j^{HPTS,p1}$	-0.0026	**0.0055***	$\alpha_j^{+HPTS,p1}$	**-0.0032***	0.0026
			α_j^{-HPTS}	**-0.0262***	**0.0174***	$\alpha_j^{HPTS,p2}$	-0.0023	-0.0009	$\alpha_j^{-HPTS,p1}$	**0.0129***	**0.0495***
						$\alpha_j^{HPTS,p3}$	**-0.0051***	-0.0025	$\alpha_j^{+HPTS,p2}$	-0.0028	-0.0025
						$\alpha_j^{HPTS,p4}$	**-0.0083***	-0.0002	$\alpha_j^{-HPTS,p2}$	0.0007	0.0042
						$\alpha_j^{HPTS,p5}$	**-0.0038***	0.0028	$\alpha_j^{+HPTS,p3}$	**-0.0035***	-0.0029
						$\alpha_j^{HPTS,p6}$	**-0.0148***	0.0059	$\alpha_j^{-HPTS,p3}$	**-0.0573***	0.0060
									$\alpha_j^{+HPTS,p4}$	**-0.0050***	-0.0007
									$\alpha_j^{-HPTS,p4}$	**-0.3309***	0.0228
									$\alpha_j^{+HPTS,p5}$	-0.0010	0.0025
									$\alpha_j^{-HPTS,p5}$	**-0.2231***	0.0016
									$\alpha_j^{+HPTS,p6}$	-0.0051	-0.0042
									$\alpha_j^{-HPTS,p6}$	**-0.0326***	**0.0241***
α_j^{ow}	**-0.0028***	**0.0028***		**-0.0025***	**0.0026***		**-0.0027***	**0.0029***		**-0.0024***	**0.0026***
$TDOLLAR_{t-1}$	**-0.0000***	0.0000		**-0.0000***	0.0000		**-0.0000***	0.0000		**-0.0000***	0.0000
$\overline{R}_{-3m}^{spot}$	-0.0007	0.0028		-0.0005	0.0027		-0.0007	0.0028		0.0003	0.0029
$stdr_{-3m}^{spot}$	**0.0017***	-0.0009		**0.0015***	-0.0008		**0.0016***	-0.0011		**0.0012***	-0.0007
$skew_{-3m}^{spot}$	**-0.0000***	-0.0000		**-0.0000***	-0.0000		**-0.0000***	-0.0000		**-0.0000***	-0.0000
$kurt_{-3m}^{spot}$	-0.0000	0.0000		-0.0000	0.0000		-0.0000	0.0000		-0.0000	0.0000
overnight	**0.0001***	**0.0006***		**0.0002***	**0.0006***		**0.0001***	**0.0006***		**0.0002***	**0.0006***
open	**0.0001***	**-0.0000***		**0.0001***	**-0.0000***		**0.0001***	**-0.0000***		**0.0001***	**-0.0000***
close	-0.0000	0.0000		-0.0000	0.0000		-0.0000	0.0000		-0.0000	0.0000
AIC	-22.6144			-22.6151			-22.6146			-22.6202	
Test: asymmetry											
$H_0^3: \alpha_S^{-HPTS} - \alpha_S^{+HPTS} \geq 0$				-0.0226a							
Test: different policy											
$H_0^3: \alpha_S^{HPTS,p4} - \alpha_S^{HPTS,p5} \geq 0$							-0.0045a				
Test: downward adjustment with different policy											
$H_0^3: \alpha_S^{+HPTS,p4} - \alpha_S^{+HPTS,p5} \geq 0$										-0.0039a	

Note: Varying rate in case of high propensity to short (HPTS):

$$\begin{cases} \Delta \ln S_t = c_S + \alpha_S^{HPTS} Z_{t-1} I_{\{RSI_{t-1} \geq 90\%\ percentile\}} + \alpha_S^{ow} Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \alpha_{S^O}^{HPTS} Z_{t-1} I_{\{RSI_{t-1} \geq 90\%\ percentile\}} + \alpha_{S^O}^{ow} Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} \quad (7)$$

Varying rate of upward and downward adjustment in case of high propensity to short (HPTS):

$$\begin{cases} \Delta \ln S_t = c_S + \alpha_S^{+HPTS} Z_{t-1} I^+ + \alpha_S^{-HPTS} Z_{t-1} I^- + \alpha_S^{ow} Z_{t-1}(1-I^+-I^-) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \alpha_{S^O}^{+HPTS} Z_{t-1} I^+ + \alpha_{S^O}^{-HPTS} Z_{t-1} I^- + \alpha_{S^O}^{ow} Z_{t-1}(1-I^+-I^-) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} \quad (8)$$

Varying rate with different level of short sale constraints in case of high propensity to short (HPTS):

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{HPTS,pi} Z_{t-1} I_{\{t \in pi, RSI \geq 90\%\ percentile\}} + \sum_{i=1}^{6} \alpha_S^{ow} Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{HPTS,pi} Z_{t-1} I_{\{t \in pi, RSI \geq 90\%\ percentile\}} + \sum_{i=1}^{6} \alpha_{S^O}^{ow} Z_{t-1}(1-I) + \sum_{i=1}^{p} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{p} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} \quad (9)$$

Varying rate of upward and downward adjustment in case of high propensity to short (HPTS) with different level of short sale constraints:

$$\begin{cases} \Delta \ln S_t = c_S + \sum_{i=1}^{6} \alpha_S^{+HPTS,pi} Z_{t-1} I^{+,pi} + \sum_{i=1}^{6} \alpha_S^{+HPTS,pi} Z_{t-1} I^{-,pi} + \sum_{i=1}^{6} \alpha_S^{ow,pi} Z_{t-1}(1-I^{+,pi}-I^{-,pi}) + \sum_{i=1}^{5} \beta_i^S \Delta \ln S_{t-i} + \sum_{i=1}^{5} \gamma_i^S \Delta \ln S_{t-i}^O + \xi^S C + \varepsilon_t^S \\ \Delta \ln S_t^O = c_{S^O} + \sum_{i=1}^{6} \alpha_{S^O}^{+HPTS,pi} Z_{t-1} I^{+,pi} + \sum_{i=1}^{6} \alpha_{S^O}^{-HPTS,pi} Z_{t-1} I^{-,pi} + \sum_{i=1}^{6} \alpha_{S^O}^{ow,pi} Z_{t-1}(1-I^{+,pi}-I^{-,pi}) + \sum_{i=1}^{5} \beta_i^{S^O} \Delta \ln S_{t-i} + \sum_{i=1}^{5} \gamma_i^{S^O} \Delta \ln S_{t-i}^O + \xi^{S^O} C + \varepsilon_t^{S^O} \end{cases} \quad (10)$$

We follow Fung and Jiang (1999) and Jiang et al. (2001) in measuring market directions by the Relative Strength Index (RSI), $RSI_t = \frac{N_t^-}{N_t^+ + N_t^-}$, where N_t^+ and N_t^- are the number of 1-minute intervals in which the TWSE spot index advances and declines during the day, respectively. We sort our observations into ten deciles based on the daily relative strength index. The highest deciles represents the mostly downward price movements, which indicates that short selling is more likely in. We denote the lowest deciles of RSI as high propensity to short (HPTS) or the transaction with high short demand. $\Delta \ln S_t$ and $\Delta \ln S_t^O$ represent returns for index and theoretical index. Z_{t-1} denotes lag error correction term. α_j^k denote the speed of adjustment in case of high propensity to short (HPTS) under different condition k, such as $j = S\ or\ S^O$. For example, $\alpha_S^{+HPTS,pi}$ represents the speed of downward adjustment for the transaction with HPTS under different constraint condition, such as $i = 1,2,...,6$. We include three categories control variables, such as market liquidity, market condition, and microstructure effect. $TDOLLAR_{t-1}$ (thousand) denotes the amount of trading dollars per minute for index. $\overline{R}_{-3m}^{spot}$, $skew_{-3m}^{spot}$, $kurt_{-3m}^{spot}$, and $stdr_{-3m}^{spot}$ are averaged return, skewness, kurtosis, and standard deviations calculated by previous 3-month 1-min index return, respectively. overnight equals 1 if transactions occur in 9:00. open equals 1 if transactions occur during 9:01-9:30, and close equals 1 if transactions occur during 13:01-13:30. a denotes significant level at 1%. b denotes significant level at 5%. c denotes significant level at 10%. * is significantly different from zero if its conventional *t* value is greater than the sample size-adjusted critical *t* value, 3.65.

Table 8 Short sale constraint policies versus characteristics of return distribution

Panel A: Short sale constraint policy and characteristics of stock return distribution

	Obs.	skew	kurt	$Extre.Freq^{-}$	$Extre.Freq^{+}$	realized variance *100	down risk*100
p1	99186	0.9126	56.04	0.0054	0.0063	0.0240	0.0106
p2	126557	0.8683	32.62	0.0092	0.0111	0.0158	0.0079
p3	168020	2.6429	75.12	0.0049	0.0058	0.0080	0.0034
p4	57994	1.0573	96.01	0.0031	0.0037	0.0272	0.0141
p5	19241	-3.0075	120.54	0.0032	0.0034	0.0757	0.0530
p6	68021	2.8151	75.75	0.0073	0.0071	0.0188	0.0064
Test: Do characteristics of stock return distribution change with different policy?							
p4-p5		4.0648a	-24.54a	-0.00003	0.0003	-0.0484a	-0.0389a

Panel B: Short sale constraint policy and risk with the market's fear expectation of investors concern

Dep. var	Obs.	intercept	p3	p5	p6	VIX
realized variance *100	768	-0.0343a	0.0011	0.0162b	-0.0111a	0.0020a
down risk*100	768	-0.0182a	0.0000	0.0220a	-0.0091a	0.0011a

Note: The measures in Panel A are calculated day by day with 1-minute index return. skew and kurt represent skewness and excess kurtosis of index return per day. $Extre.Freq^{-}$ and $Extre.Freq^{+}$ denoted as the proportion of the occurrence for extreme negative and positive return per day. We define extreme negative and positive return as index return is less or greater than two times standard deviation for each period of policy changes. realized variance is sum of squared 1-minute index return per day. down risk represent realized semi-variance, that is, sum of squared negative return. We rule out the possibility effect of market expectations on risk increment and compare realized variance and down risk with different level of short sale constraints in Panel B. VIX, new VIX, the TAIEX index options volatility, represents market expectations prepared by CBOE VIX index method. Compare with the old VIX, the new VIX is calculated by weighted average index options of different strike prices, but not from the Black-Scholes model. In general, VIX index higher, the show traders expect future volatility of stock price index the more severe; Conversely, the lower the time when the VIX index, shows traders expect share price indices will tend to moderate. As the index has described the situation changes in investor psychology, it is also known as the fear index of investors. a denote significant level at 1%. b denotes significant level at 5%. c denotes significant level at 10%.