# Call Auction Design and Closing Price Manipulation: Evidence from the Hong Kong Stock Exchange*

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**ABSTRACT**

The Hong Kong Stock Exchange adopted a closing call auction in 2008 but suspended its operation 10 months later due to suspicion of widespread price manipulation. The Exchange relaunched the auction in 2016 with manipulation-deterrence enhancements. We exploit this unique setting by applying a triple-differences methodology to examine the causal effect of call auction design on closing price manipulation. Our results indicate that there is a noticeable increase in closing price manipulation under a plain-vanilla call auction mechanism. Under this mechanism overnight price reversal is more pronounced on days when derivatives expire and on days when large orders were submitted just before the market close.

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# 1. Introduction

In equity markets closing prices are the most important prices of the day. They are widely used to calculate net asset values of mutual funds, to determine settlement prices of derivatives contracts, and to compute stock returns analyzed by academic researchers (Carhart et al., 2002; Kumar and Seppi, 1992; Stoll and Whaley, 1991; Chamberlain et al., 1989). Due to their importance, closing prices are prone to manipulation and can be distorted from fundamental values (Spatt, 2014; Hillion and Suominen, 2004; Felixson and Pelli, 1999). Therefore, when and to what extent the closing price is set efficiently is a relevant theoretical and applied question. Nowadays, closing prices in equity markets are predominantly set by call auction mechanisms, where orders are consolidated and executed at a single price at which the quantity supplied equals the quantity demanded (Demsetz, 1968). In October 2018, closing call auctions were used in 9 of the world's top 10 stock exchanges by market capitalization—including the New York Stock Exchange, Nasdaq, Tokyo Stock Exchange, Euronext, and London Stock Exchange group—with a combined market capitalization of approximately US$57 trillion, or 73% of the world's total value of equities.

Closing call auctions are widely used for many reasons. First, they can facilitate trades at the market close.[1] Second, they can absorb extreme liquidity shocks without producing inefficient prices and excess volatility (Barclay et al., 2008). Third, they can improve price discovery at the market close (Chang et al., 2008; Comerton-Forde et al., 2007a; Pagano and Schwartz, 2003; Schwartz, 2001; Cao et al., 2000; Biais et al., 1999; Madhavan, 1992).[2] Last, it

[1] The ability to facilitate trades at the market close is increasingly important due to the rising popularity of passively managed mutual funds in recent decades. Appel et al. (2019) show that in the United States the percentage of total market capitalization that is held by passively managed funds increased substantially (from 1.6% to 8.1%) between 1998 and 2014.

[2] A few studies find that call auctions do not always improve market quality. For example, Comerton-Forde et al. (2007b) and Madhavan and Panchanpagesan (2000) examine the performance of call auctions at the market open and find that price discovery in call auctions does not improve for illiquid stocks and at times of extreme order

is widely believed that closing call auctions are robust to price manipulation (Chang et al., 2008; Comerton-Forde et al., 2007a).[3]

In this paper, we use the experience at the Hong Kong Stock Exchange (HKEx) to show that the benefits of call auctions are highly sensitive to market designs, particularly their ability to deter price manipulation. To facilitate institutional investors to trade at the closing price, the HKEx introduced a closing call auction mechanism on May 26, 2008. The auction was conducted in a Closing Auction Session ("CAS") from 4:00–4:10 p.m. Unlike other major equity markets, this call auction was unique in that its mechanism design was plain-vanilla or standard, i.e., devoid of manipulation-deterrence features such as binding price limit, randomization of closing times, and volatility extensions. Just five days after the introduction, excessive price movements occurred during the closing session on the MSCI index rebalancing day.[4] HKEx eventually suspended this mechanism due to extreme volatility and suspicion of widespread price manipulation:

> "Almost immediately, the system attracted criticism after closing prices in some shares began swinging wildly during the 10-minute auction." ("HKEx drops late auction," *The Wall Street Journal Asia*, March 13, 2009.)

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imbalances. In addition, Ellul et al. (2005) compare the performance of call market with dealership market, while Muscarella and Piwowar (2001) compare the performance of stocks that transferred between periodic call market and continuous trading market. They also point to the same conclusion that call auctions do not always improve price discovery.

[3] To reduce closing price manipulation is a widely stated reason for implementing closing call auctions by exchange operators because call auctions can consolidate order flows at the market close, thus increasing the cost of price manipulation. Consistent with this claim, the New York Stock Exchange (NYSE) and Nasdaq opposed a recent decision made by the U.S. Securities and Exchange Commission to allow fragmentation of order flows at the market close due to concerns about closing price manipulation. According to the decision, buy or sell orders designated to be executed at daily closing prices in the Chicago Board Options Exchange will not be used to determine closing prices at the NYSE and Nasdaq. ("SEC Decision on 4 p.m. Closing Trades Deals Blow to NYSE, Nasdaq," *The Wall Street Journal*, January 21, 2020.)

[4] One hundred sixty-seven stocks were affected (i.e., added, deleted, or re-weighted) by the MSCI rebalancing on May 30, 2008. Twenty-two stocks had more than a 5% price fluctuation during the closing auction session and also experienced large price reversals on the following open (to be discussed in Section 5.5.).

To illustrate, consider the plunge in HSBC shares on March 9, 2009. That plunge was the biggest one-day drop since Black Monday in 1987, and its impact was exceptionally large because HSBC was the largest company on the HKEx with a global market capitalization of HK$1.6 trillion (or US$200 billion). On that day, the indicative equilibrium price of HSBC fluctuated within a tight range between HK$37 and HK$38.[5] However, three seconds before the end of the closing session, a trader submitted five exceptionally large sell orders. These orders caused the HSBC shares to plunge from HK$37 to close at HK$33, i.e., a drop of over 10% in just three seconds. When the market opened the next day, HSBC shares bounced back to HK$37.25. Panel A of Figure 1 presents the indicative equilibrium price and the sell queue of HSBC shares during the closing session. The five sell orders were remarkably large, at 5.4 million shares, and represented over 50% of the then-prevailing indicative equilibrium volume at the closing auction session.[6]

[Insert Figure 1 here.]

To reduce potential manipulation and extreme price volatility, the HKEx revamped the closing call auction mechanism and re-launched it on July 25, 2016. The revamped mechanism adds several enhancements to deter manipulation, particularly binding price limit and random closing time. We use these two episodes to examine the effect of trading designs on closing price

[5] Section 2 contains a detailed explanation of indicative equilibrium price and the closing mechanism.

[6] We believe that the sniping incident on March 9, 2009 was well planned due to unusual trading activities of HSBC shares on the previous trading day (March 6). Panel B of Figure 1 shows the trading activities during the closing session on that day. First, a small but unusually aggressive limit sell order of $33 was submitted between 4:01 p.m. and 4:02 p.m., causing the indicative equilibrium price to fall immediately to $33. Coincidentally, this indicative equilibrium price at $33 was identical to the closing price of the following trading day. This limit sell order was aggressive because it was submitted at a deep discount from the last transacted price of $43.15 at 4:00 p.m. Second, this order was subsequently canceled even though that seller could have sold the shares at a price significantly higher than $33. Third, an exceptionally large sell order of over 5.8 million shares was canceled just one second prior to the cancellation deadline at 4:08 p.m. Our evidence indicates that some traders attempted to depress the HSBC share price on March 6 but were unsuccessful. An alternative interpretation is that these traders tested the market reaction should HSBC shares drop to $33. Congruent with our belief, several local newspapers reported that HSBC shares might have been manipulated during the closing auction session on March 6 ("Sell Order at $33 during CAS," *The Sun*, March 07, 2009.).

manipulation. Our findings indicate that a plain-vanilla closing call auction mechanism is vulnerable to manipulation on CBBC expiration days (days when "callable bull/bear contracts" expire) as well as sniping days (days when large orders are submitted in the last few seconds before the market close).

In this paper, we systematically evaluate the performance of the HKEx's closing call auction mechanisms. We find that a plain-vanilla call auction mechanism induces excessive volatility at the close on suspected manipulation days. For example, on CBBC expiration days the volatility of the final 10-minute return before the close is, on average, 346% larger under the plain-vanilla call auction mechanism than that under the revamped call auction mechanism (13.10% vs. 2.94%.[7]

Our paper adds to the literature in several ways. First, contrary to conventional wisdom, we find that call auction mechanisms can be prone to manipulation, especially those devoid of manipulation-deterrence features. For example, a non-binding price limit increases profit from price manipulation (Kim and Park, 2010). Under the CAS regime, orders submitted during the closing auction ranged from +800% to –89% of the last traded price, compared with approximately ±2.4% of the prevailing market price during the continuous trading session. Furthermore, sniping can be more successfully implemented under a fixed closing time because manipulators can surprise the market by submitting exceptionally large orders shortly before the end of the auction, leaving no time for other traders to react. Consistent with this claim, we find that overnight price reversal is more pronounced on sniping days under the plain-vanilla closing call auction mechanism than under other closing mechanisms. Our findings are consistent with

[7] The annualized volatility is computed by multiplying volatility in the final 10-minute return before the market close by √252. Therefore, the annualized volatility is 13.10% (= 0.825%×√252) under the plain-vanilla call auction mechanism and 2.94% (= 0.185%×√252) under the revamped call auction mechanism.

the auction design literature, which emphasizes that *institutional details matter*.[8] For example, current studies indicate that randomization of closing times, well-designed call auction matching algorithms, and an order-balancing mechanism reduce price manipulation (Cordi et al., 2015; Hauser et al., 2012; Comerton-Forde and Rydge, 2006).

Second, our paper provides a clean identification to study the causal effect of adopting a plain-vanilla call auction on closing price manipulation. The unique experience of the HKEx to adopt, and then to suspend, and eventually to relaunch the closing auction mechanism provides a quasi-experimental setting in which to apply a triple-differences methodology. Thus, our setting is less susceptible to possible biases from confounding factors that are correlated with time trends. Prior works that examine the performance of call auctions in major stock exchanges—e.g., the NYSE, Nasdaq, and Euronext—typically rely on a before-and-after comparison, which may make it difficult to disentangle the real effect from unobserved time trends (Pagano et al., 2013; Pagano and Schwartz, 2003; Stoll and Whaley, 1990; Amihud and Mendelson, 1987).

Third, we study a motive of manipulation in closing auctions by linking the performance of closing auctions to the underlying equity on the expiration day of CBBCs—a derivative product of the underlying equity. CBBCs are also known as turbo warrants, which are similar to knock-out options in that they expire if the price of the underlying stock reaches a prespecified level, i.e., strike price. Importantly, on the expiration day CBBC buyers are entitled to a residual value that can be determined by the closing price of the underlying stock. As CBBCs are actively traded among investors in Hong Kong, the incentive of manipulation is strong, particularly on the expiration day. For example, in 2009 the total turnover value of CBBCs was approximately HK$1.7 trillion (US$219 billion), constituting about 11% of total turnover value

[8] Hasbrouck (2007, p.18) states that "although auctions may appear simple, seemingly minor details of implementation can have profound effects."

on the HKEx. Consistent with our expectations, we find that overnight price reversal is more pronounced on CBBC expiration days under the plain-vanilla closing call auction mechanism than under the median pricing procedure. Our results corroborate evidence that profitable trading strategies can be devised on days when CBBCs expire (Lei, 2015; Cheung et al., 2010).

Fourth, our results are less unlikely to be confounded by extreme market conditions because our main variables of interest are measured at very fine time intervals, namely five-second and 10-minute intervals. Besides, we also include day fixed effects in our regressions to control for variation in liquidity shocks across trading days. Focusing on such fine details allows us to isolate the effects of market microstructure from those of broader market movements. Doing so is particularly relevant, as the stock market was extremely volatile and on the decline during the CAS period.

Last, many studies use prosecuted cases to examine price manipulation (Comerton-Forde and Putniņš, 2011, 2013; Comerton-Forde and Rydge, 2006; Aggarwal and Wu, 2006). They find that price manipulation typically occurs among small and illiquid stocks. Because our sample comprises the largest companies of the HKEx, our evidence suggests that manipulation can occur even for large and liquid stocks. Further, this study sheds light on the limitation of using prosecuted cases to draw inferences on the extent of price manipulation, as the number of prosecuted cases is very small.[9] Further, they are limited by the capability of regulators to accurately detect and successfully prosecute price manipulators.

## 2. Trading Mechanisms

[9] Despite our statistical evidence, which suggests systematic attempts of closing price manipulation under the plain-vanilla call auction mechanism, we find only three prosecuted cases of closing price manipulation of listed equities during the CAS period.

Trading in the HKEx is conducted in two continuous auction sessions. The morning session is from 9:30 a.m.–12:00 p.m. and the afternoon session is from 1:00–4:00 p.m. The opening price is determined by a call auction mechanism with a fixed opening time in the pre-opening session from 9:00–9:30 a.m.[10] During our sample period, the HKEx used three different mechanisms to determine the closing price.

### *2.1. Closing Auction Session: CAS regime*

For approximately 10 months from May 26, 2008 to March 22, 2009, the HKEx introduced a closing auction session to determine the closing price. This session lasted 10 minutes from 4:00–4:10 p.m. The closing price was concluded by a call auction mechanism with a fixed closing time at 4:10 p.m. During the closing session, buy and sell orders set to determine the closing price would accumulate. Traders could place, modify, and cancel market and limit orders during the first eight minutes of the session.[11] In the final two minutes of the session, new market orders were allowed to place but modification and cancellation of existing orders were disallowed. Throughout the closing session, market participants could observe the resulting indicative equilibrium price (IEP) and indicative equilibrium volume (IEV), without any trades actually taking place.[12] At 4:10 p.m., orders were matched, and transactions were executed at the

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[10] To increase the overlap of trading hours between the HKEx and the Mainland Chinese markets, the HKEx modified its trading hours twice during our sample period. Before March 6, 2011, pre-opening auctions were held from 9:30 a.m. to 10:00 a.m., morning session from 10:00 a.m. to 12:30 p.m., and afternoon session from 2:00 p.m. to 4:00 p.m. From March 7, 2011 to March 4, 2012, trading hours were revised so that pre-opening auctions were held from 9:00 a.m. to 9:30 a.m., morning session from 9:30 a.m. to noon, and afternoon session from 1:30 p.m. to 4:00 p.m. The current trading hours began from March 5, 2012. See http://www.hkex.com.hk/-/media/HKEX-Market/News/Market-Consultations/2006-to-2010/September-2010-Consultation-Paper-on-Proposed-Changes/Conclusions/cp2010093cc.pdf for more details about the trading hours changes around our sample period.

[11] The official names for market and limit orders allowed during the closing auction session are at-auction orders and at-auction limit orders, respectively.

[12] According to the call auction matching algorithm of the HKEx, the IEP must be a price between the highest limit bid and the lowest limit ask that maximizes the matched shares. If there is a tie in the IEP, three tie-breaker rules would apply. The first rule selects the price with the lowest order imbalance. If this fails to break the tie, the second

indicative equilibrium price at 4:10 p.m., which was the closing price of the day.[13] The indicative equilibrium price is the price obtained from a single-price call auction that yields the maximum number of shares transacted. In addition, short selling was prohibited during the closing session. Appendix A describes the algorithm used to compute IEP and IEV during the closing session.

During the closing auction session, the price specified by a limit order was bounded by the "9-times restriction rule": the upper price limit of submitted orders is 9 times (+800%) the nominal price at 4:00 p.m., and the lower price limit of submitted orders is 1/9 of (–89%) the nominal price at 4:00 p.m. In contrast, limit orders submitted during the continuous trading session were restricted to narrower bands. Specifically, they must be input within 24 ticks of the prevailing market price (henceforth the "24-tick rule"). For example, 24 ticks correspond to a price range of ±2.4% for a stock trading at $50.

### *2.2. Median Pricing Procedure: Non-CAS regime*

Starting in 1993, the HKEx used the median pricing procedure to compute the closing price. The closing price was determined by the median of five snapshot nominal prices in the final minute of the afternoon session. These nominal prices are taken at five specific times, which are 15 seconds apart, from 3:59–4:00 p.m. Choosing the median of these prices ensures that the closing price would not be unduly influenced by one single trade. Note that the 24-tick rule applied to orders submitted during this procedure because it is part of the continuous trading session. This mechanism was abandoned when the closing auction session was first introduced

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rule would apply and pick the price, which is closest to the nominal price at 4:00 p.m. Should these two rules also fail to break the tie, the third rule would apply and pick the highest price as the IEP.

[13] If there is no IEP available after the closing session (i.e., there is no match at all), the closing price is determined by the median of five nominal prices in the final minute of the afternoon session.

on May 26, 2008. However, it was reinstated on March 23, 2009 after the closing auction session was suspended and remained effective until the HKEx introduced the revamped closing call auction mechanism on July 24, 2016.

### *2.3. Revamped Closing Auction Session: RevampCAS regime*

On July 24, 2016, the HKEx reintroduced the closing auction session with two major enhancements in call auction design to deter manipulation. First, the closing time is randomized between 4:08–4:10 p.m. Second, the price limit is significantly reduced to only ±5% of the reference price set at 4:00 p.m. The reference price is determined by the median of five nominal prices taken in the final minute of the continuous trading session rather than a single nominal price taken at 4:00 p.m. used in the CAS period. Other minor enhancements include no modification and cancellation of existing orders during the final four minutes of the closing session. However, limit orders are allowed throughout the entire session. Other design features are identical to those used in the CAS period. Currently, the revamped mechanism is applied to mostly large and liquid stocks, including constituent stocks of Hang Seng Composite LargeCap and MidCap Indexes, H-shares that have A-shares listed on a Mainland Exchange, and all exchange–traded funds.

## 3. Data and Sample

Our sample begins with all constituent stocks in the Hang Seng Index between May 26, 2008 and January 22, 2010. Our final sample has 36 stocks after excluding those with less than 180 daily observations in each of the four subperiods (to be described later). Appendix B presents a list of stocks used in the final sample. These stocks are large and comparable in size to component stocks of the S&P500 index. Their market capitalizations ranged from US$2.9

billion (COSCO Pacific) to US$200.5 billion (HSBC) in 2009. Our sample stocks were actively traded and constituted 61% of the market capitalization of all stocks listed on the HKEx at the end of 2009. We choose these stocks because they allow us to evaluate the vulnerability of a plain-vanilla call auction to closing price manipulation even for large and liquid stocks. In addition, they allow us to study a motive of closing price manipulation because their closing prices are used to determine values of derivatives contracts.

Our study combines two sample periods covering a total of 38 months. The first sample period is from May 26, 2008 through January 22, 2010, which overlaps with the subprime mortgage crisis ("Crisis period") when the market was extremely volatile. We divide this period into two 10-month sub-periods covering two closing mechanisms. The first sub-period is 5/26/2008–3/22/2009 under the closing auction session ("CAS") regime, while the second sub-period is 3/23/2009–1/22/2010 under the median pricing procedure ("non-CAS") regime. The second sample period is from October 25, 2015 through April 24, 2017, which is after the subprime mortgage crisis ("non-Crisis period"). Similarly, it is divided into two nine-month sub-periods covering two closing mechanisms. The first sub-period is 7/25/2016–4/24/2017 under the revamped closing auction session ("revampCAS") regime, while the second sub-period is 10/25/2015–7/24/2016 under the median pricing procedure ("non-CAS") regime.

We construct our data set from six data files published by the HKEx. Data on intra-day bid and ask quotes, indicative equilibrium prices, indicative equilibrium volume, and primary buy and sell queues are collected from the Bid and Ask Record files, Historical Full Book Market – Securities Market files, and Historical Order Book and Statistics Update – Securities Market files; data on transaction prices and volume are from the Trade Record files; data on day-high and day-low events are taken from the Day-end Closing Data files; and data on expiration dates of CBBCs are taken from Stock Static Data (Daily) files, HKEx Fact Book, and the HKEx website. Transaction prices and volume are recorded to the nearest second. Data on bid-ask quotes, IEP, IEV, and queues are recorded to the nearest one-thousandth of a second.

## 4. Empirical Strategy: Triple-Differences Methodology

To estimate the effect of closing price manipulation under a call auction mechanism, relative to the median pricing procedure, we apply a standard difference-in-differences framework in either the Crisis period or the non-Crisis period as follows:

$$(1) \qquad y_{i,t} = \beta_1 manipulate_{i,t} \times CALL_t + \beta_2 manipulate_{i,t} + FE + v_{i,t},$$

where $y_{i,t}$ is an outcome of closing price manipulation; $manipulate_{i,t}$ measures the type or intensity of closing price manipulation; and $CALL_t$ is a binary variable equal to one during the period when closing price is determined by a call auction mechanism (i.e., CAS and revampCAS regimes) and zero otherwise; and $FE$ are dummy variables for fixed effects. The estimate $\beta_2$ measures the baseline effect of closing price manipulation, while the estimate $\beta_1$ is the difference-in-differences estimate, which measures the differential effect of closing price manipulation between a closing call auction mechanism and the median pricing procedure.

As the market is very volatile during the Crisis period, our estimates in equation (1) could be biased due to omitted confounding factors that increase the intensity of closing price manipulation during the Crisis period relative to the non-Crisis period. To precisely estimate the manipulation effect under the plain-vanilla closing auction mechanism, we apply a triple-differences framework as follows:

$$\begin{aligned}(2) \qquad y_{i,t} = {} & \gamma_1 manipulate_{i,t} \times CrisisPeriod_t \times CALL_t \\ & + \gamma_2 manipulate_{i,t} \times CrisisPeriod_t + \gamma_3 manipulate_{i,t} \times CALL_t \\ & + \gamma_4 manipulate_{i,t} + FE + \varepsilon_{it}\end{aligned}$$

where $CrisisPeriod_t$ is a binary variable equal to one during the Crisis period (2008–2010) and zero during the non-Crisis period (2015–2017). This variable measures the increased demand for closing price manipulation during the Crisis period. This assumption is reasonable because the stock market was more volatile and prone to manipulation during the subprime mortgage crisis period than during the non-Crisis period. The difference-in-differences estimate $\gamma_2$ measures the differential effect of the closing price manipulation between the Crisis period and the non-Crisis period; the difference-in-differences estimate $\gamma_3$ measures that between a closing call auction mechanism and the median pricing procedure; and the triple-differences estimate $\gamma_1$ measures the effect of closing price manipulation for the plain-vanilla closing auction mechanism by comparing the differential effect of the closing price manipulation between a closing call auction mechanism and the median pricing procedure in the Crisis-period, relative to that in the non-Crisis period.

## 5. Empirical Analysis

### 5.1. Sniping

We argue that manipulative sniping can be successfully implemented under a plain-vanilla call auction mechanism for two reasons. First, sniping is achievable under fixed closing time because manipulators can surprise the market by submitting exceedingly large orders shortly before the market close to create short-term order imbalances, leaving no time for the market to react (Putninš, 2012; Allen and Gale, 1992). Second, a nonbinding price limit raises the ability to profit from derivative positions because the closing price can deviate significantly from the fundamental value. Therefore, we expect sniping events to occur more frequently under the plain-vanilla call auction mechanism than under other closing procedures.

We define sniping as either a sudden change in price or a sudden surge in orders just before the market close. The former measure is defined as sniping in price and the latter as sniping in trade volume. Current studies show that these measures are relevant attributes to identify the manipulator's intent (Comerton-Forde and Putninš, 2011; Comerton-Forde and Rydge, 2006).[14] We construct the sniping variables as follows: $snipe(x)$ is a binary variable that takes the value of one if (i) the absolute change in $x$ for a stock during the "sniping measurement window" is strictly greater than the absolute change in $x$ for the stock in all "benchmark intervals," and (ii) the absolute change in price in the final five seconds is larger than the 90$^{th}$ percentile of the absolute change in price during the same five-second interval in each period, where $x$ is either $p$ (price) or $v$ (trade volume).[15]

We use the time when the closing price is set to define our sniping measurement window. The "sniping measurement window" is the five-second interval before the market close under the CAS and revampCAS regimes. The "sniping measurement window" is fixed between 4:09:55–4:10:00 p.m. under the CAS regime, but varies daily between 4:08–4:10 p.m. under the revampCAS regime. For example, under the revampCAS regime if the market closes at 4:08:35 p.m., the "sniping measurement window" will be 4:08:30–4:08:35 p.m. During the non-CAS regime, it is the five-second interval prior to the snapshot nominal price being taken as the closing price. For example, if the median snapshot price occurs at 3:59:15 p.m., the "sniping measurement window" will be 3:59:10–3:59:15 p.m.

[14] These studies also find that a large increase in bid-ask spread is an important attribute for closing price manipulation. However, we are unable to examine this attribute because data on bid-ask spreads are unavailable under the CAS and revampCAS regimes.

[15] We are grateful to an anonymous referee's suggestion to impose a threshold requirement (i.e., the second condition) on our sniping variables. The threshold requirement ensures that the intensity of sniping is meaningfully large to prevent our results from mechanically confounded by the bid-ask bounce (Roll, 1984). The average threshold of our sample is 0.17%, which is slightly larger than the minimum price variation of our sample stocks, i.e., 0.14% (= \$0.05/\$36). Our main results are robust and qualitatively similar even if we lower or remove this requirement.

To successfully influence the closing price under the median pricing procedure, manipulators have to influence the median snapshot price. To do so, they must manipulate at least three of the five snapshot nominal prices. Therefore, prices taken at these five snapshots might be manipulated and thus unsuitable as benchmark prices. Consequently, in the two non-CAS periods, we choose four benchmark intervals in the final minute before the close as follows: (i) 3:59:05–3:59:10 p.m., (ii) 3:59:20 p.m.–3:59:25 p.m., (iii) 3:59:35 p.m.–3:59:40 p.m., and (iv) 3:59:50 p.m.–3:59:55 p.m. Similarly, four comparable "benchmark intervals" are created during the closing minute under the CAS and revampCAS regimes.[16] Under the CAS and revampCAS regimes, we measure price and trade volume by the indicative equilibrium price (IEP) and the indicative equilibrium trade volume (IEV), respectively. Under the non-CAS regime, we use the actual transaction price and the actual transaction volume, respectively.

Table 1 reports a simple difference-in-differences analysis of the mean likelihood of sniping under the plain-vanilla call auction mechanism. We present the mean likelihood of sniping under a closing call auction mechanism in column (1) and that under the median pricing procedure in column (2). Column (3) presents the differences in the mean likelihood of sniping between these two mechanisms. Rows 3 and 6 of the table present the differences in mean likelihood of sniping between the Crisis period and the non-Crisis period. Rows 1–3 report the estimates for sniping in price, while those for sniping in trade volume are reported in rows 4–6.

[Insert Table 1 here]

The results in row 1 (row 4) indicate that the mean likelihood of sniping in price (trade volume) rises by 1.6% (12.6%) under the plain-vanilla closing auction mechanism compared to that under the median pricing procedure. In contrast, results in row 2 (row 4) shows that the

[16] Under the CAS regime, the four benchmark intervals are fixed as follows: (i) 4:09:05–4:09:10 p.m., (ii) 4:09:20–4:09:25 p.m., (iii) 4:09:35–4:09:40 p.m., and (iv) 4:09:50–4:09:55 p.m.

mean likelihood of sniping in price (trade volume) falls by 2.8% (28%) under the revamped closing auction mechanism compared to under the median pricing procedure. Our evidence in column (1) indicates that manipulation-deterrence features in call auctions are effective for reducing sniping. Specifically, the mean likelihood of sniping in price is only 0.7% under the revamped closing auction mechanism, compared with 7.4% under the plain-vanilla closing auction mechanism.

Using the results based on the non-Crisis period as a control, the difference-in-differences estimates indicate that the mean likelihood of sniping in price (trade volume) rises by 4.2% (40.6%) under the plain-vanilla closing auction mechanism. Overall, our results indicate that sniping is significantly more likely to occur under the plain-vanilla closing call auction mechanism.[17]

### 5.2. CBBC Expiration

We use a derivative product of the underlying stock—callable bull and bear contracts—to study a motive of closing price manipulation. We emphasize that this is not the only possible motive for manipulation, but it is the only derivative product in the HKEx that uses closing price of the underlying equity to determine the settlement price on the expiration day.[18] On the expiration day, CBBC buyers are entitled to a residual value that is determined by the settlement

[17] Our difference-in-differences results remain qualitatively identical even if we lower or remove the threshold requirement on the minimum price change during the final five-second interval before the close for our sniping variables. However, removing the threshold requirement completely increases the mean likelihood of sniping in the non-CAS period relative to that in the CAS period during the Crisis period. Conversations with the HKEx officials indicated that the increase in sniping is non-manipulative under the median pricing procedure because many institutional investors (e.g., passively-managed mutual funds) are obligated to fill their customer orders at the closing price to reduce tracking errors. Therefore, they may submit orders shortly before the five snapshot times, hoping that the average transacted price is close to the actual closing price. Our results on overnight price reversal (to be reported in Table 2) are consistent with this claim.

[18] In Hong Kong, the settlement price for an index future/option contract is the average based on a five-minute quotation and the closing index on the expiration day, while that for derivative warrants is the average closing price computed over a five-day period immediately before the expiration day.

price less the strike price if this amount is positive and zero otherwise. For an expiring bull (bear) CBBC contract, the settlement price is the minimum (maximum) price of the underlying stock from the expiration time to the next trading session of the day, typically including the market close.

As the settlement value is a zero-sum outcome, the incentive to manipulate the closing price on the expiration day should be identical between CBBC issuers and CBBC buyers. However, we argue that the incentive to manipulate should be stronger for CBBC issuers because the issuer market is concentrated but the buyer market is diffuse. In terms of the dollar amount, the top three CBBC writers issued an aggregate of 75.5% of all CBBCs in Hong Kong from June 12, 2006 to May 31, 2009. In contrast, many CBBC buyers were small retail investors. Consistent with this claim, Li et al. (2018) find that gross profits of CBBC issuers were substantial at approximately HK$12.93 billion (US$1.67 billion) for trading CBBCs on only the Hang Seng Index from 2009–2014.

To reduce the settlement expenses paid to CBBC buyers, CBBC issuers may depress the closing price of the underlying equity on the day when bull contracts expire, and inflate it on the day when bear contracts expire. Therefore, we expect that the likelihood of observing a day-low (day-high) at the close to be particularly high on the expiration day of bull (bear) contracts under the plain-vanilla closing call auction mechanism. We use a probit regression model with firm fixed-effects to estimate equations (1) and (2). Our dependent variable is a dummy variable to capture whether the closing price is the highest or the lowest price of the day: $day-low$ is a dummy variable equal to one if the closing price is the lowest transacted price of the day for the stock, and $day-high$ is defined analogously.

The incentive to inflate or deflate the closing price varies with the bullish or bearish position of the expiring derivative contracts. Thus, we create two binary variables to separate bullish contracts from bearish ones. $ExpireBull$ is a binary variable equal to one for the underlying stock on the day when a bull CBBC contract expires, and $ExpireBear$ is defined analogously. In equation (1), we include a dummy variable $CALL_t$ to capture the incremental likelihood under a closing auction mechanism, relative to under the median pricing procedure, and we include $CALL_t$, $CrisisPeriod_t$ and their interaction term in equation (2) to capture their corresponding baseline effects.

Table 2 presents the triple-differences estimates of the likelihood of day-high or day-low at the close under the plain-vanilla closing call auction mechanism. Column (1) reports the difference-in-differences estimates from equation (1) during the Crisis period, column (2) reports those during the non-Crisis period, and column (3) reports the triple-differences estimates from equation (2). The marginal effects for day-low at the close are reported in panel A, while those for day-high at the close are reported in panel B.

[Insert Table 2 here]

We find that the probability of observing a day-low or day-high at the close is significantly higher under the plain-vanilla closing call auction mechanism than under the median pricing procedure. The estimate $\beta_1$ in column (1) of panel A is 0.05 and significantly different from zero. This implies that the probability of observing a day-low at the close on the day when a bull contract expires increases by 5% under the plain-vanilla closing auction mechanism compated to that under the median pricing procedure. Similarly, the estimate $\beta_1$ in column (1) of panel B implies that the probability of observing a day-high at the close on the day when a bear contract expires also increases by 3.1% under the plain-vanilla closing auction mechanism compared to the median pricing procedure. In contrast, we find that the probability of observing a day-low or day-high at the close is similar between the revamped closing call auction mechanism and the median pricing procedure. None of the $\beta_1$estimates in column (2) of panels A and B are significantly different from zero. This implies that on CBBC expiration days the revamped closing auction mechanism is more effective at deterring closing price manipulation than the plain-vanilla closing auction mechanism.

The triple-differences estimate $\gamma_1$ in column (3) of panel A is 0.077, which is sizable and statistically significant. This implies that the probability of observing a day-low at the close on the expiration day of a bull contract is 7.7% larger under the plain-vanilla closing call auction mechanism. In contrast, the same estimate $\gamma_1$ in column (3) of panel B is 0.02, which is close to zero and not statistically significant. This implies that there is no significant difference in the likelihood of observing a day-high at the close on the expiration day of a bear contract under the plain-vanilla closing call auction mechanism. Our results indicate that under the plain-vanilla call auction mechanism the intensity of closing price manipulation is strong on days when bull contracts expire but weak on days when bear contracts expire. This asymmetry is consistent with the significant decline in stock prices during the CAS period. Consequently, many bull CBBC contracts were knocked out, providing strong incentive for CBBC issuers to depress the closing price on such expiration days.[19]

### 5.3. Overnight Price Reversal

As closing price manipulation creates short-term order imbalance at the market close and pushes the closing price away from the fundamental value, the distorted closing price shouldrevert toward the fundamental value when new orders arrive at the market open on the following day (Chordia et al., 2002). Therefore, we expect overnight price reversal to be more pronounced on days when closing price manipulation occurs. As the incentive of closing price manipulation is strong on sniping days and CBBC expiration days, we expect overnight price

[19] Consistent with this claim, we find that 61.5% of the expired CBBCs are bull contracts during the CAS period in 2008–2009, whereas that during the non-CAS period in 2009–2010 is only 47.6%.

reversal to be more pronounced on such days. On the other hand, closing price may reflect the fundamental value if sniping or CBBC expiration is motivated by private information. Therefore, overnight price reversal should not occur on such days. To disentangle these possibilities, we use the difference-in-differences framework from equations (1) and (2) to estimate the extent of overnight price reversal on suspected manipulation days under the plain-vanilla closing auction mechanism.

Specifically, our dependent variable is close-to-open return to proxy for overnight price reversal. The close-to-open return is defined as $(P_{o,t+1} - P_{c,t})/P_{c,t}$, where $P_{c,t}$ is the closing price on the day and $P_{o,t+1}$ is the opening price of the following day (Pagano and Schwartz, 2003). The extent of overnight price reversal should increase with the intensity of closing price manipulation because the closing price is more distorted from the fundamental value. Thus, we measure the intensity of closing price manipulation by interacting the type of manipulation with the stock return measured over the final seconds or final minutes before the close as follows: $snipe(p) \times r_{5s}$ and $snipe(v) \times r_{5s}$ for the intensity of sniping in price and the intensity of sniping in trade volume, respectively, and $ExpireCbbc \times r_{10m}$ for the intensity of closing price manipulation on the CBBC expiration day. $r_{5s}$ is the five-second stock return in the sniping measurement window, $ExpireCbbc$ is a binary variable equal to one for the underlying stock on the expiration day of a CBBC contract, and $r_{10m}$ is the stock return measured during the closing auction session (i.e., the CAS and revampedCAS regimes) or the final 10-minute interval before the market close during the non-CAS regime.

Our stock return proxies capture the intensity of closing price manipulation, which is in line with the literature. Extant studies indicate that a large change in price before the close is a key attribute of closing price manipulation. For example, Cushing and Madhavan (2000) find that the last five minutes of trading account for a large fraction of daily return variability and others find that an unexpectedly large price change before the close is a key indicator in prosecuted cases of closing price manipulation (Comerton-Forde and Putninš, 2011, 2013; Comerton-Forde and Rydge, 2006). As the volatility of daily stock returns is high during the Crisis period, we also include day fixed effects to capture across-day variation in overnight price reversal due to differences in the arrival of overnight information.

Table 3 presents the triple-differences estimates on the effect of sniping on overnight price reversal under the plain-vanilla closing call auction mechanism. The results for sniping in price are reported panel A, while those for sniping in trade volume are reported in panel B.

[Insert Table 3 here]

We find that overnight price reversal is more pronounced on sniping days under the plain-vanilla closing auction mechanism than under the median pricing procedure. The estimate of $\beta_1$ in column (1) of panel A is –0.772, which is negative, large, and statistically significant. The estimate, evaluated at the mean of $|r_{5s}|$ on the sniping days, implies that the stock price reverts by 0.26% on average on the following open on days when sniping in price occurs under the plain-vanilla closing call auction mechanism, compared with a stock price increase of 0.1% on average under the median pricing procedure.[20] In contrast, the estimate $\beta_1$ in column (2) of panel A is 2.336, which is positive, sizable, and statistically significant. This implies that the stock price shows momentum on the following day opening when sniping in price occurs under the revamped closing call auction mechanism, relative to that under the median pricing procedure.

The triple-differences estimate $\gamma_1$ in column (3) of panel A is –3.109, which is negative, sizable, and statistically significant. The estimate, evaluated at the mean of $|r_{5s}|$ on the sniping

[20] The sniping effect on overnight price reversal under the plain-vanilla closing auction mechanism is computed as follows: $(\beta_1 + \beta_2) \times$ mean of $|r_{5s}|$, where $|r_{5s}|$ is the absolute final five-second return before the market close on sniping days during the CAS regime. Numerically, the sniping effect is 0.26% = (–0.772 + 0.192) × 0.4511%.

days, implies that stock price reverts by 1.40% on average on the following open on days when sniping in price occurs under the plain-vanilla closing call auction mechanism. Our inference on the sniping effect on overnight price reversal is qualitatively similar but quantitatively weaker if we measure sniping based on trade volume in panel B. Overall, we find that overnight price reversal subsequent to sniping is meaningfully large under the plain-vanilla closing call auction mechanism.

Table 4 presents the triple-differences estimates on the effect of CBBC expiration on overnight price reversal under the plain-vanilla closing call auction mechanism. We find that the effect of CBBC expiration on overnight price reversal is significantly more pronounced under the plain-vanilla closing auction mechanism than under the median pricing procedure. The estimate $\beta_1$ in column (1) is −0.390, which is large and statistically significant. The estimate, evaluated at the mean of $|r_{10m}|$ on the CBBC expiration days, implies that stock price reverts by 0.32% on average following the CBBC expiration day under the plain-vanilla closing call auction mechanism relative to that under the median pricing procedure.[21] However, the estimate $\beta_1$ in column (2) is close to zero and not statistically significant. This implies that there is no overnight price reversal following CBBC expiration days under the revamped closing auction mechanism relative to the median pricing procedure.

[Insert Table 4 here]

The triple-differences estimate $\gamma_1$ in column (3) is –0.387, which is similar to the difference-in-differences estimate $\beta_1$ in column (1). However, it is not statistically significant. Overall, the effect of CBBC expiration on overnight price reversal is mixed. On one hand, the

[21] The CBBC expiration effect on overnight price reversal under the plain-vanilla closing auction mechanism is computed as follows: $(\beta_1 + \beta_2) \times$ mean of $|r_{10m}|$, where $|r_{10m}|$ is the absolute final 10-minutes return before the market close on CBBC expiration days during the CAS regime. Numerically, the CBBC expiration effect is 0.32% = (–0.390 + –0.133) × 0.617%.

triple-differences result implies that there is no overnight price reversal following CBBC expiration days under the plain-vanilla closing call auction mechanism. On the other hand, the difference-in-differences result implies that there is a meaningfully large overnight price reversal following CBBC expiration days under the plain-vanilla closing call auction mechanism, relative to that under the median pricing procedure.

### 5.4. Closing Price Informativeness

In this subsection, we examine the closing price informativeness under the plain-vanilla closing auction mechanism. Price changes are due to either the arrival of new information that induces a change in the fundamental value of the asset or trading frictions, which induce noise in the observed stock price (Stoll, 2000). Closing price manipulation is a source of friction and increases the volatility of close-to-close return. To correctly measure the incremental volatility due to closing price manipulation, we use the volatility of open-to-open return as a control to exclude price changes due to the arrival of new information. Any new information reflected in the close-to-close return should be equally reflected in the open-to-open return. The open-to-open return is a fair benchmark because the HKEx's opening procedure remains unchanged throughout the sample period and opening prices are less prone to manipulation because they are not used to price any derivative products in the HKEx.

We follow the literature to compute these returns and a variance ratio between the open-to-open return and close-to-close return (Amihud and Mendelson, 1987; French and Roll, 1986). The open-to-open return is calculated as $R_o = (P_{o,t+1} - P_{o,t})/P_{o,t}$ , where $P_{o,t}$ is the opening price on the day and $P_{o,t+1}$ is the opening price of the following day for the same stock, and the close-to-close return ($R_c$) is measured analogously. The variance ratio is computed as $\frac{\sigma^2(O)}{\sigma^2(C)}$, where $\sigma^2(O)$ is the variance of the open-to-open return for a stock during the period, and $\sigma^2(C)$ is computed analogously.

As indicated in the previous sections, our suspected manipulation days include CBBC expiration days and sniping days. To conduct a triple-differences analysis for each of these measures, we split our sample in two: a manipulation sample and a non manipulation sample. As closing price manipulation introduces trading frictions and increases the volatility of close-to-close return, the variance ratio should be small in a period when closing price manipulation is rampant. Thus, we expect the variance ratio to be significantly smaller on manipulation days than on non-manipulation days under the plain-vanilla closing call auction mechanism.

Table 5 reports the mean variance ratio on manipulation days in columns (1)–(3), non-manipulation days in columns (4)–(6), and the difference-in-differences and triple-differences estimates in column (7). We also present the mean variance ratios under a closing call auction mechanism in columns (1) and (4), those under the median pricing procedure in columns (2) and (5), and their differences by manipulation days in column (3) and by non manipulation days in column (6). In each panel, the first row reports the estimates during the Crisis period and those for the non-Crisis period are reported in the second row. The last row of each panel presents the differences in mean variance ratio between the Crisis period and the non-Crisis period. In each panel, the triple-differences estimate is reported in the last cell of the last row.

[Insert Table 5 here]

As expected, our results indicate that trading frictions are greater at the opening than at the closing. All the mean variance ratios are greater than one and comparable to those in the literature (Gerety and Mulherin, 1994; Cheung et al., 1994; Stoll and Whaley, 1990; Amihud and Mendelson, 1987). We also find that on non manipulation days, closing price is significantly more informative under the plain-vanilla closing auction mechanism and under the median pricing procedure. The estimates in column (6) of the first row of each panel convincingly show that on non-manipulation days the variance ratio is significantly larger under the plain-vanilla closing auction mechanism than under the median pricing procedure. This implies that on non manipulation days, investors who trade at the close are exposed to a smaller volatility under the plain-vanilla closing auction mechanism than under the median pricing procedure.

In contrast, closing price appears to be less informative under the plain-vanilla closing auction mechanism and under the median pricing procedure on days with suspected manipulation. The estimates in column (3) of the first row of panels A and B are negative but not statistically significant. The estimate in column (3) of the first row of panel A is –0.811 and implies that the variance ratio is reduced by 31% under the plain-vanilla closing auction mechanism compared to that under the median pricing procedure.[22] The reduction is meaningfully large but not statistically significant due to a large standard error of the estimate. Similarly, the difference-in-differences estimates in column (7) of the first row of each panel are consistently negative but not statistically significant. Again, these estimates imply a meaningfully large reduction in the variance ratio and suggest that closing prices on manipulation days are less informative under the plain-vanilla closing auction mechanism.

In contrast, we find that closing price is more informative under the revamped closing auction mechanism. The estimates in column (3) of the second row of panels A and C indicates that on manipulation days the variance ratio is larger under the revamped closing auction mechanism than under the median pricing procedure. This implies that on these suspected manipulation days investors who trade at the close are exposed to a smaller volatility under the revamped closing auction mechanism than under the median pricing procedure. However, on

[22] On CBBC expiration days, the reduction in the variance ratio between the plain-vanilla closing auction mechanism and the median pricing procedure is computed as follows: 1 – 1.529/2.221 = 31.16%.

non-manipulation days, closing price appears to be equally informative between these two mechanisms. The difference-in-differences estimate in column (7) of the second row of panels A and C indicate that closing price is significantly more informative under the revamped closing auction mechanism than under the median pricing procedure. However, the difference-in-differences estimate for the sniping in price in column (7) of the second row in panel B is not statistically significant. This may be due to a rare occurrence of sniping under the revamped closing auction mechanism, resulting in a large standard error in the difference-in-differences estimate.

Finally, the triple-differences estimates all point to the same conclusion that on manipulation days closing price is significantly less informative under the plain-vanilla closing auction mechanism. The triple-differences estimates in columns (7) of panels A and C are sizable and statistically significant. An alternative interpretation of our results is that the revamped closing auction mechanism is effective at reducing closing price manipulation on suspected manipulation days. Overall, the triple-differences results in Table 5 are fairly consistent with our findings in the previous sections that a plain-vanilla call auction mechanism is vulnerable to manipulation on days when the incentive to manipulation is strong.

### 5.5. Overnight Price Reversals on MSCI Rebalancing Days

The incentive of closing price manipulation can also be strong on days when closing prices are used to determine index prices. Comerton-Forde, Lau, and McInish (2007) find that suspected closing price manipulations occurred in the Singapore Exchange on days when MSCI rebalanced its indexes prior to the Singapore Exchange's adoptiong of a closing call auction mechanism. To examine the extent and impact of closing price manipulation on MSCI index rebalancing days under different closing mechanisms in the HKEx, we first expand our sample to include all stocks listed on the main board of the HKEx. This expansion is necessary because the expanded sample also includes small- and mid-cap stocks, which constitute nearly all the stocks that are added to or deleted from major MSCI indices.[23] Second, we report stocks that experienced large price changes in the last 10 minutes before the close on days when MSCI implemented its semi-annual index rebalancing. We define large price changes as stocks with the last-10-minute return of 5% or more (by absolute value) on MSCI rebalancing days.[24] In the closing auction mechanism, the last-10-minute return is measured by the simple percentage return between the last transacted price at 4:00 p.m. and the closing price of the day. In the median pricing procedure, it is measured by the simple percentage return between the last transacted price at 3:50 p.m. and the closing price of the day.

Table 6 present overnight price reversals for stocks experiencing large price changes in the last 10 minutes before close on MSCI rebalancing days under three different closing mechanisms: (i) the plain-vanilla closing auction mechanism on May 30, 2008 in panel A and November 25, 2008 in panel B; (ii) the median pricing procedure on May 29, 2009 in panel C and November 30, 2009 in panel D; (iii) the revamped closing auction mechanism on November 30, 2016 in panel E; and (iv) the median pricing procedure on November 30, 2015 in panel F. Overnight price reversal is the close-to-open return, which is measured by the simple percentage return between the closing price on the MSCI rebalancing day and the opening price of the following day.

[Insert Table 6 here.]

[23] We also exclude stocks with prices less than $1 from the expanded sample to ensure that our results are not driven by the bid-ask bounce effect (Roll, 1984). The bid-ask spread for penny stocks can be very large. This implies that a round-trip transaction at the bid and ask quotes can produce a large price reversal even if this reversal is not motivated by closing price manipulation.

[24] Our results are qualitatively similar even if we change the threshold of large price changes to 2% or 10% (by absolute value).

Results in panels A and B indicate that there are 34 stocks experiencing a price change of 5% or more during the last-10-minute return before the close on the MSCI rebalancing days under the plain-vanilla closing auction mechanism. In addition, the mean last-10-minute return ($R_{10m}$) by absolute value for the 34 stocks is 9.2 percent, which is large and has economic significance. Overnight price reversals occurred in 32 out of the 34 stocks, or precisely 94%. Besides, many price reversals are meaningfully large. In contrast, results in panels C and D indicate that there are only four stocks experiencing a price change of 5% during the last-10-minute return before the close on the MSCI index rebalancing days under the median pricing procedure. Only two of them experienced price reversals on the next day. Our findings strongly suggest that, under the plain-vanilla closing auction mechanism, fluctuation of closing prices was volatile and some closing prices were likely to be manipulated on the MSCI index rebalancing days.[25]

In contrast, results in panel E indicate that, under the revamped closing auction mechanism, there are only three stocks experiencing large price change in the last 10 minutes before close, compared with 14 stocks under the median pricing procedure in panel F. Furthermore, the ensuing price reversals under the revamped closing auction were also smaller than those under the plain-vanilla closing auction mechanism reported in panels A and B. Overall, our results indicate that a plain-vanilla closing auction mechanism is more prone to closing price manipulation than the revamped closing auction mechanism and also the median pricing procedure.

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[25] Barclay, Hendershott, and Jones (2008) find that the closing auction mechanism produces efficient prices because it can absorb extreme liquidity shocks, e.g., triple-witching days. In contrast, our findings imply that a closing auction mechanism that is devoid of manipulation-deterrence features can produce inefficient prices, particularly during times of high liquidity demand. On the MSCI index rebalancing day of May 30, 2008, the price fluctuation during the 10-minute closing auction session was exceptionally volatile: Eight stocks experienced a price discrepancy of over 10% and 14 stocks experienced a price discrepancy of 5%-10%, relative to their last traded prices at 4:00 p.m. All of them were affected by the MSCI index rebalancing activity (addition, deletion, or major re-weighting) on that day.

## 6. Conclusions

During the 10-month period in 2008–2009 when the HKEx introduced a plain-vanilla closing auction mechanism that is devoid of manipulation-deterrence features, we find that there are large overnight price reversals on suspected manipulation days. However, we find no overnight price reversal on such days under the revamped closing auction mechanism. Our findings highlight the importance of call auction design and have policy implications given that call auctions are widely used to determine opening and closing prices in major stock markets. The lesson we take from the HKEx experience is that seemingly minor details in call auction design can meaningfully affect the call auction's ability to deter manipulation. The HKEx experience in 2008–2009 is exceptional in that it was the only major stock exchange in the world that adopted a closing auction procedure without any precautions against price manipulation. All major stock markets around the world have specific refinements in auction design to deter manipulation.

We present some of these refinements in major stock exchanges in Appendix C. The first refinement is the daily price limit, which is a tight daily price limit to reduce the potential profit from closing price manipulation. Most Asian-Pacific stock markets adopted this feature with the exception of the Australian Securities Exchange (Comerton-Forde and Rydge, 2006). The second refinement is randomization of closing times, which is currently used by the Australian Securities Exchange, the London Stock Exchange, and the Deutsche Börse. This refinement discourages sniping because it is nearly impossible for snipers to determine the exact closing time. The third refinement is price stabilization mechanisms. One variant of this is an order-balancing mechanism that is currently used by the New York Stock Exchange and Nasdaq. Specifically, to stabilize closing price in the final minutes before the close, these markets accept only orders that are on the stabilizing side of the market. Another price-stabilizing mechanism is to trigger a volatility interruption when the closing price deviates significantly from a pre-specified price limit. Recent developments in call auction mechanisms around global stock exchanges point to the importance of call auction design. On September 26, 2011, the Singapore Exchange introduced randomization of closing times in closing auctions to prevent sniping from disrupting the market. Therefore, future research on call auction design is needed to understand the performance of call auctions under each (or different combinations) of these refinements.

## References


Aggarwal, R. K., & Wu, G. (2006). Stock market manipulations. *Journal of Business* 79(4), 1915–1953.

Allen, F., & Gale, D. (1992). Stock price manipulation, *Review of Financial Studies* 5(3), 503–529.

Amihud, Y., & Mendelson, H. (1987). Trading mechanisms and stock returns: An empirical investigation. *Journal of Finance* 42(3), 533–553.

Appel, I. R., Gormley, T. A., & Keim, D. B. (2019). Standing on the shoulders of giants: The effect of passive investors on activism. *Review of Financial Studies* 32(7), 2720–2774.

Barclay, M. J., Hendershott, T., & Jones, C. M. (2008). Order consolidation, price efficiency, and extreme liquidity shocks. *Journal of Financial and Quantitative Analysis* 43(1), 93–121.

Biais, B., Hillion, P., & Spatt, C. (1999). Price discovery and learning during the preopening period in the Paris Bourse. *Journal of Political Economy* 107(6), 1218–1248.

Cao, C., Ghysels, E., & Hatheway, F. (2000). Price discovery without trading: Evidence from the Nasdaq preopening. *Journal of Finance* 55(3), 1339–1365.

Carhart, M. M., Kaniel, R., Musto, D. K., & Reed, A. V. (2002). Leaning for the tape: Evidence of gaming behavior in equity mutual funds. *Journal of Finance* 57(2), 661–693.

Chamberlain, T. W., Cheung, C. S., & Kwan, C. C. (1989). Expiration-day effects of index futures and options: Some Canadian evidence. *Financial Analysts Journal* 45(5), 67–71.

Chang, R. P., Rhee, S. G., Stone, G. R., & Tang, N. (2008). How does the call market method affect price efficiency? Evidence from the Singapore Stock Market. *Journal of Banking & Finance* 32(10), 2205–2219.

Cheung, Y. L., Cheung, Y. W., He, A. W., & Wan, A. T. (2010). A trading strategy based on Callable Bull/Bear Contracts. *Pacific-Basin Finance Journal* 18(2), 186–198.

Cheung, Y. L., Ho, R. Y. K., Pope, P., & Draper, P. (1994). Intraday stock return volatility: The Hong Kong evidence. *Pacific-Basin Finance Journal* 2(2–3), 261–276.

Chordia, T., Roll, R., & Subrahmanyam, A. (2002). Order imbalance, liquidity, and market returns. *Journal of Financial Economics* 65(1), 111–130.

Comerton-Forde, C., Lau, S. T., & McInish, T. (2007a). Opening and closing behavior following the introduction of call auctions in Singapore. *Pacific-Basin Finance Journal* 15(1), 18–35.

Comerton-Forde, C., & Putniņš, T. J. (2011). Measuring closing price manipulation. *Journal of Financial Intermediation* 20(2), 135–158.

Comerton-Forde, C., & Putniņš, T. J. (2013). Stock price manipulation: Prevalence and determinants. *Review of Finance* 18(1), 23–66.

Comerton-Forde, C., & Rydge, J. (2006). Call auction algorithm design and market manipulation. *Journal of Multinational Financial Management* 16(2), 184–198.

Comerton-Forde, C., Rydge, J., & Burridge, H. (2007b). Not all call auctions are created equal: Evidence from Hong Kong. *Review of Quantitative Finance and Accounting* 29(4), 395–413.

Cordi, N., Foley, S., & Putniņš, T. J. (2015). Is there an optimal closing mechanism? Working Paper.

Cushing, D., & Madhavan, A. (2000). Stock returns and trading at the close. *Journal of Financial Markets* 3(1), 45–67.

Demsetz, H. (1968). The cost of transacting. *Quarterly Journal of Economics* 82(1), 33–53.

Ellul, A., Shin, H. S., & Tonks, I. (2005). Opening and closing the market: Evidence from the London Stock Exchange. *Journal of Financial and Quantitative Analysis* 40(4), 779–801.

Felixson, K., & Pelli, A. (1999). Day end returns—stock price manipulation. *Journal of Multinational Financial Management* 9(2), 95–127.

French, K. R., & Roll, R. (1986). Stock return variances: The arrival of information and the reaction of traders. *Journal of Financial Economics* 17(1), 5–26.

Gerety, M. S., & Mulherin, J. H. (1994). Price formation on stock exchanges: The evolution of trading within the day. *Review of Financial Studies* 7(3), 609–629.

Hasbrouck, J. (2007). *Empirical Market Microstructure: The Institutions, Economics, and Econometrics of Securities Trading*. New York: Oxford University Press.

Hauser, S., Kamara, A., & Shurki, I. (2012). The effects of randomizing the opening time on the performance of a stock market under stress. *Journal of Financial Markets* 15(4), 392–415.

Hillion, P., & Suominen, M. (2004). The manipulation of closing prices. *Journal of Financial Markets* 7(4), 351–375.

Kim, A., & Park, J. (2010). Why do price limits exist in stock markets? A manipulation-based explanation. *European Financial Management* 16(2), 296–318.

Kumar, P., & Seppi, D. J. (1992). Futures manipulation with “cash settlement.” *Journal of Finance* 47(4), 1485–1502.

Lei, A. C. (2015). Price and volume effects of exchange-traded barrier options: Evidence from callable bull/bear contracts. *Journal of Futures Markets* 35(11), 1042–1066.

Li, X., Subrahmanyam, A., & Yang, X. (2018). Can financial innovation succeed by catering to behavioral preferences? Evidence from a callable options market, *Journal of Financial Economics* 128(1), 38–65.

Madhavan, A. (1992). Trading mechanisms in securities markets. *Journal of Finance* 47(2), 607–641.

Madhavan, A., & Panchapagesan, V. (2000). Price discovery in auction markets: A look inside the black box. *Review of Financial Studies*, *13*(3), 627–658.

Muscarella, C. J., & Piwowar, M. S. (2001). Market microstructure and securities values:: Evidence from the Paris Bourse. *Journal of Financial Markets* 4(3), 209–229.

Pagano, M. S., Peng, L., & Schwartz, R. A. (2013). A call auction's impact on price formation and order routing: Evidence from the NASDAQ stock market. *Journal of Financial Markets* 16(2), 331–361.

Pagano, M. S., & Schwartz, R. A. (2003). A closing call’s impact on market quality at Euronext Paris. *Journal of Financial Economics* 68(3), 439–484.

Putniņš, T. J. (2012). Market manipulation: A survey. *Journal of Economic Surveys* 26(5), 952–967.

Roll, R. (1984). A simple implicit measure of the effective bid-ask spread in an efficient market. *Journal of Finance* 39(4), 1127–1139.

Schwartz, R. A. (2001). The call auction alternative. In: Schwartz, R.A. (Ed.), *The Electronic Call Auction: Market Mechanism and Trading, Building a Better Stock Market*. Boston: Kluwer Academic Publishers.

Spatt, C. (2014). Security market manipulation. *Annual Review of Financial Economics* 6, 405–418.

Stoll, H. R., (2000). Friction. *Journal of Finance* 55(4), 1479–1514.

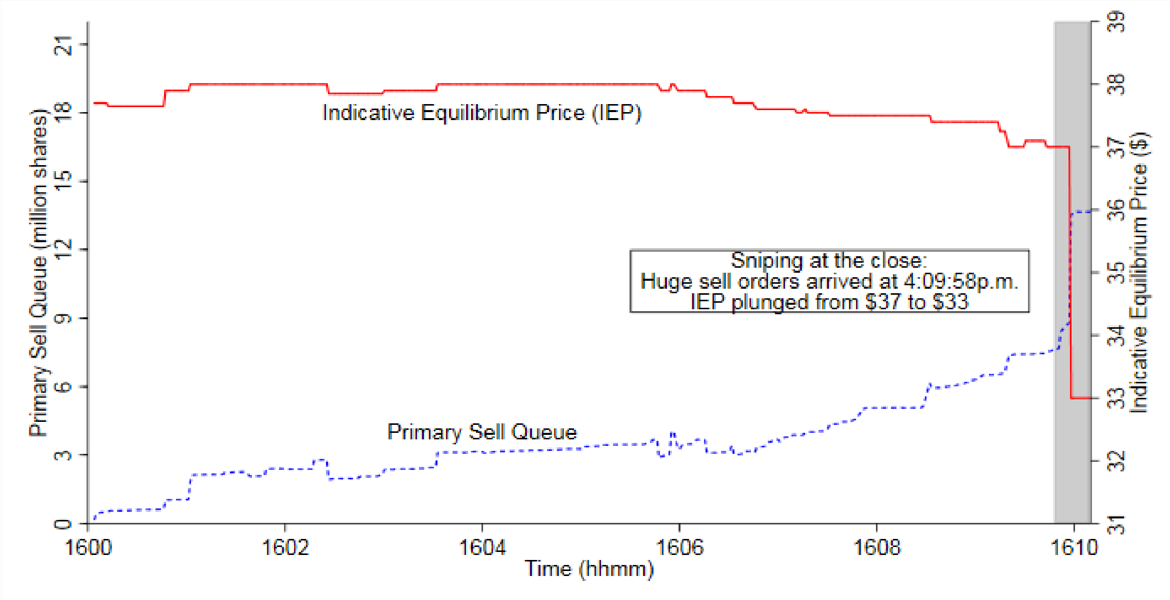
Stoll, H. R., & Whaley, R. E. (1990). Stock market structure and volatility. *Review of Financial Studies* 3(1), 37–71.

Stoll, H. R., & Whaley, R. E. (1991). Expiration-day effects: What has changed? *Financial Analyst Journal* 47(1), 58–72.

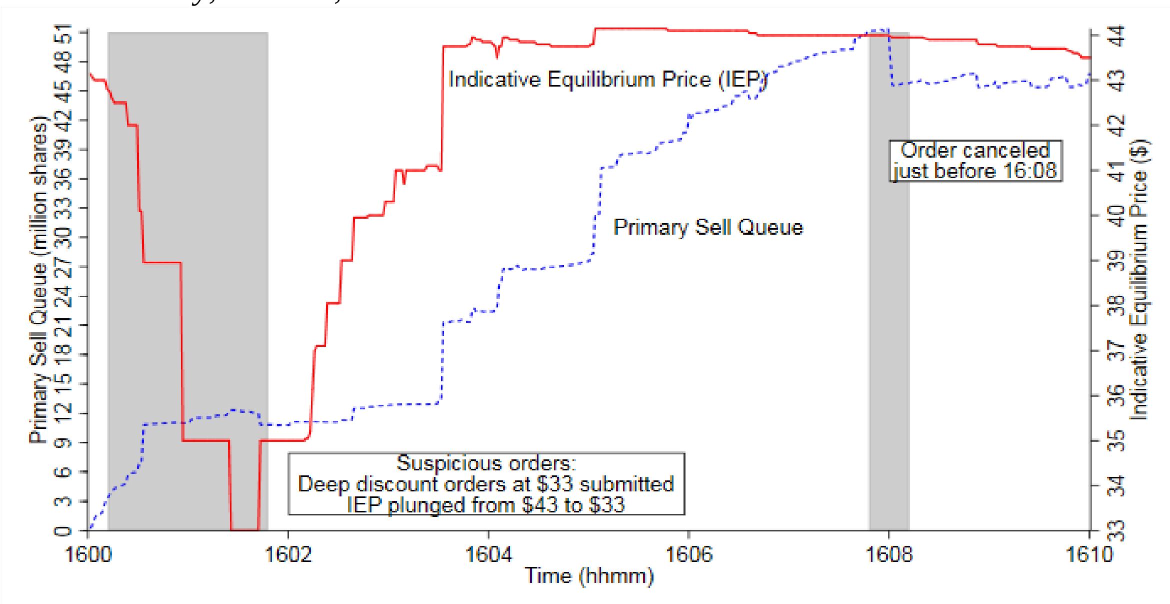
**Figure 1. Indicative Equilibrium Price and Primary Sell Queue for HSBC Shares during the Closing Auction Session**

The solid line represents the indicative equilibrium price (IEP) and the dotted line represents the primary sell queue. The left axis is the primary sell queue, which is the accumulated sell orders available to be matched with the accumulated buy orders at the indicative equilibrium price. The right axis is the indicative equilibrium price. Order cancellation and amendment were prohibited between 4:08–4:10 p.m. during the closing auction session.

*Panel A: Monday, March 9, 2009*




*Panel B: Friday, March 6, 2009*



## Table 1. Difference-in-difference : Sniping

This table presents the mean likelihood of sniping for different sample periods. The Crisis period is from May 22, 2008 through January 22, 2010, which overlaps with the subprime mortgage crisis, when the market was extremely volatile. The non-Crisis period is from May 25, 2015 through April 27, 2017, which is after the subprime mortgage crisis. $CALL$ covers the period when closing price is determined by call auction mechanisms, while non$CALL$ covers the period when closing price is determined by the median pricing procedure. The binary variable $snipe(p)$ takes the value of one if the absolute change in price for a stock during the "sniping measurement window" is strictly greater than the absolute change in price for the stock in four "benchmark intervals" in the final minute before the market close, and the absolute change in price in the final five seconds is larger than the 90$^{th}$ percentile of the absolute change in the same five-second interval in each period. The "sniping measurement window" is the five-second interval before the market close in the $CALL$ period, and the five-second interval prior to the snapshot nominal price being taken as the closing price in the non$CALL$ period. In the non$CALL$ period, the four benchmark intervals are (i) 3:59:05–3:59:10 p.m., (ii) 3:59:20 p.m.–3:59:25 p.m., (iii) 3:59:35 p.m.–3:59:40 p.m., and (iv) 3:59:50 p.m.–3:59:55 p.m. In the $CALL$ period, four comparable benchmark intervals are constructed in the final minute before the market close. We use the beginning and ending values of price to compute the five-second absolute change in price of each interval. We measure price and trade volume by the indicative equilibrium price (IEP) and the indicative equilibrium trade volume (IEV), respectively, in the $CALL$ period, but the actual transaction price and the actual transaction volume, respectively, in the non$CALL$ period. $snipe(v)$is defined analogously. The corresponding standard errors are reported in parentheses. Statistical significance is marked at the 1% (***), 5% (**), and 10% (*) levels.

**Dependent Variable: Sniping**

| | | (1) | (2) | (3) |
|---|---|---|---|---|
| | | *CALL* | non*CALL* | Difference between Mechanisms |
| $snipe(p)$ | Crisis period | 0.074*** | 0.058*** | 0.016* |
| | | (0.006) | (0.006) | (0.009) |
| | Non-Crisis period | 0.007*** | 0.033*** | -0.026*** |
| | | (0.001) | (0.005) | (0.005) |
| | Difference between periods | 0.068*** | 0.025*** | |
| | | (0.006) | (0.006) | |
| | | | | 0.042*** |
| | Difference-in-Difference | | | (0.008) |
| $snipe(v)$ | Crisis period | 0.197*** | 0.071*** | 0.126*** |
| | | (0.012) | (0.004) | (0.013) |
| | Non-Crisis period | 0.033*** | 0.313*** | -0.280*** |
| | | (0.004) | (0.013) | (0.014) |
| | Difference | 0.164*** | -0.242*** | |
| | | (0.010) | (0.012) | |
| | | | | 0.406*** |
| | Difference-in-Difference | | | (0.016) |

## Table 2. Expired CBBCs, Day-High and Day-Low at the Close

This table shows the likelihood of observing a day-low or day-high at the close on the day when a bull or bear CBBC contract expires under the plain-vanilla closing auction mechanism by employing a probit regression with firm fixed-effects. The dependent variable $day-low$ (panel A) is a dummy variable equal to one if the closing price is the lowest transacted price of the day for the stock, and $day-high$ (panel B) is analogously defined for the highest transacted price of the day. $Expirebull$ (panel A) is a binary variable equal to one for the underlying stock on the day when a bull CBBC expires and $Expirebear$ (panel B) is analogously defined for a bear CBBC contract. $CALL$ is a binary variable equal to one during the period when closing price is determined by a call auction mechanism (i.e., CAS and revampCAS regimes) and zero otherwise and $CrisisPeriod$ is a binary variable equal to one during the Crisis period (2008-2010) and zero during the non-Crisis period (2015–2017). Robust standard errors clustered at the firm-period level are reported in parentheses. Statistical significance is marked at the 1% (***), 5% (**), and 10% (*) levels. Estimates presented in the table are marginal effects.

Panel A: Expiration of bull CBBCs and day-low at the close

| | (1)<br>Crisis Period | (2)<br>Non-Crisis Period | (3)<br>Full Sample |
|---|---|---|---|
| $ExpireBull \times CrisisPeriod \times CALL$ | | | 0.077*** |
| | | | (0.028) |
| $ExpireBull \times CrisisPeriod$ | | | -0.040 |
| | | | (0.025) |
| $ExpireBull \times CALL$ | 0.050*** | -0.028 | -0.031 |
| | (0.019) | (0.019) | (0.023) |
| $ExpireBull$ | -0.019 | 0.022 | 0.024 |
| | (0.016) | (0.018) | (0.021) |
| $CrisisPeriod \times CALL$ | | | -0.020*** |
| | | | (0.006) |
| $CrisisPeriod$ | | | 0.026*** |
| | | | (0.006) |
| $CALL$ | 0.045*** | 0.051*** | 0.060*** |
| | (0.003) | (0.003) | (0.005) |
| Firm fixed-effect | Yes | Yes | Yes |
| $N$ | 14,766 | 13,243 | 28,009 |
| Pseudo $R^2$ | 0.0477 | 0.0771 | 0.0544 |
| Log Likelihood | -2776 | -2000 | -4816 |

(Table 2 cont'd)

Panel B: Expiration of bear CBBCs and day-high at the close

| | (1)<br>Crisis Period | (2)<br>Non-Crisis Period | (3)<br>Full Sample |
|---|---|---|---|
| $ExpireBear \times CrisisPeriod \times CALL$ | | | 0.020 |
| | | | (0.041) |
| $ExpireBear \times CrisisPeriod$ | | | 0.036 |
| | | | (0.041) |
| $ExpireBear \times CALL$ | 0.031** | 0.008 | 0.009 |
| | (0.014) | (0.042) | (0.039) |
| $ExpireBear$ | 0.011 | -0.013 | -0.021 |
| | (0.011) | (0.037) | (0.039) |
| $CrisisPeriod \times CALL$ | | | -0.036*** |
| | | | (0.007) |
| $CrisisPeriod$ | | | 0.027*** |
| | | | (0.007) |
| $CALL$ | 0.032*** | 0.064*** | 0.070*** |
| | (0.003) | (0.004) | (0.007) |
| Firm fixed-effect | Yes | Yes | Yes |
| $N$ | 14,766 | 13,243 | 28,009 |
| Pseudo $R^2$ | 0.0337 | 0.0840 | 0.0503 |
| Log Likelihood | -3066 | -2562 | -5670 |

## Table 3. Sniping and Overnight Price Reversal

This table presents the effect of sniping on overnight price reversal under the plain-vanilla closing auction mechanism. The dependent variable is the close-to-open return, which is the simple percentage stock return between the closing price of day $t$ and the opening price of day $t$+1. The binary variable $snipe(p)$ is sniping in price reported in panel A and the binary variable $snipe(v)$ is sniping in trade volume reported in panel B. The construction of these variables is explained in the notes to Table 1. $R_{5s}$ is the five-second stock return in the sniping measurement window for the stock. $CALL$ is a binary variable equal to one during the period when closing price is determined by a call auction mechanism (i.e., CAS and revampCAS regimes) and zero otherwise. $CrisisPeriod$ is a binary variable equal to one during the Crisis period (2008–2010) and zero during the non-Crisis period (2015–2017). The corresponding robust standard errors clustered at the firm-period level are reported in parentheses. Statistical significance is marked at the 1% (***), 5% (**), and 10% (*) levels.

Dependent Variable: Close-to-Open Return

| | Panel A: $snipe(p)$ | | |
|---|---|---|---|
| | (1)<br>Crisis Period | (2)<br>Non-Crisis Period | (3)<br>Full Sample |
| $snipe(p) \times R_{5s} \times CrisisPeriod \times CALL$ | | | -3.109*** |
| | | | (0.574) |
| $snipe(p) \times R_{5s} \times CrisisPeriod$ | | | 0.601*** |
| | | | (0.159) |
| $snipe(p) \times R_{5s} \times CALL$ | -0.772*** | 2.336*** | 2.336*** |
| | (0.254) | (0.517) | (0.515) |
| $snipe(p) \times R_{5s}$ | 0.192** | -0.410*** | -0.410*** |
| | (0.087) | (0.133) | (0.133) |
| Constant | 0.046** | 0.073*** | 0.059*** |
| | (0.020) | (0.012) | (0.012) |
| Day fixed-effects | Yes | Yes | Yes |
| $N$ | 14,766 | 13,242 | 28,008 |
| $R^2$ | 0.003 | 0.001 | 0.003 |

(Table 3 cont'd)

**D**ependent Variable: Close-to-Open Return

| | Panel B: $snipe(v)$ | | |
|---|---|---|---|
| | (1) Crisis Period | (2) Non-Crisis Period | (3) Full Sample |
| $snipe(v) \times R_{5s} \times CrisisPeriod \times CALL$ | | | -2.849*** |
| | | | (0.605) |
| $snipe(v) \times R_{5s} \times CrisisPeriod$ | | | 0.070 |
| | | | (0.220) |
| $snipe(v) \times R_{5s} \times CALL$ | -0.495* | 2.354*** | 2.354*** |
| | (0.295) | (0.531) | (0.529) |
| $snipe(v) \times R_{5s}$ | -0.168 | -0.238* | -0.238* |
| | (0.183) | (0.125) | (0.124) |
| Constant | 0.047** | 0.073*** | 0.059*** |
| | (0.020) | (0.012) | (0.012) |
| Day fixed-effects | Yes | Yes | Yes |
| $N$ | 14,766 | 13,242 | 28,008 |
| $R^2$ | 0.004 | 0.001 | 0.003 |

## Table 4. CBBC Expiration and Overnight Price Reversal

This table shows the effect of CBBC expiration on overnight price reversal under the plain-vanilla closing auction mechanism. The dependent variable is the close-to-open return, which is the simple percentage stock return between the closing price of day $t$ and the opening price of day $t$+1. $ExpireCbbc$ is a binary variable equal to one for the underlying stock on the expiration day of a CBBC contract and $r_{10m}$ is the stock return measured during the closing auction session (i.e., the CAS and revampedCAS regimes) or the final 10-minute interval before the market close during the non-CAS regime, $CALL$ is a binary variable equal to one during the period when closing price is determined by a call auction mechanism (i.e., CAS and revampCAS regimes) and zero otherwise, and $CrisisPeriod$ is a binary variable equal to one during the Crisis period (2008–2010) and zero during the non-Crisis period (2015–2017). Robust standard errors clustered at the firm-period level are reported in parentheses. Statistical significance is marked at the 1% (***), 5% (**), and 10% (*) levels.

Dependent Variable: Close-to-Open Return

| | (1)<br>Crisis Period | (2)<br>Non-Crisis Period | (3)<br>Full Sample |
|---|---|---|---|
| $ExpireCbbc \times r_{10m} \times CrisisPeriod \times CALL$ | | | -0.387 |
| | | | (0.333) |
| $ExpireCbbc \times r_{10m} \times CrisisPeriod$ | | | 0.267 |
| | | | (0.261) |
| $ExpireCbbc \times r_{10m} \times CALL$ | -0.390** | -0.003 | -0.003 |
| | (0.158) | (0.295) | (0.294) |
| $ExpireCbbc \times r_{10m}$ | -0.133 | -0.400* | -0.400* |
| | (0.111) | (0.238) | (0.237) |
| Constant | 0.047** | 0.073*** | 0.059*** |
| | (0.020) | (0.012) | (0.012) |
| Day fixed-effects | Yes | Yes | Yes |
| $N$ | 14,766 | 13,242 | 28,008 |
| $R^2$ | 0.004 | 0.001 | 0.003 |

**Table 5. Informativeness of Closing Price**

This table reports the closing price informativeness on different event days. The first two rows are the variance ratio, which is calculated by the ratio of variance of open-to-open returns to variance of close-to-close returns ($\sigma^2(O)/\sigma^2(C)$) for each of the subsamples. Panel A reports the figures on days when CBBC expires or not, panel B reports those on days when sniping in price is observed or not, and panel C reports those on days when sniping in trade volume is observed or not. $CrisisPeriod$ is a binary variable equal to one during the Crisis period (2008-2010) and zero during the non-Crisis period (2015-2017). Robust standard errors clustered at the firm-period level are reported in parentheses. Statistical significance is marked at the 1% (***), 5% (**), and 10% (*) levels.

Panel A: CBBC Expiration

| | | CBBC Expiration Days | | | CBBC non-Expiration Days | | | |
|---|---|---|---|---|---|---|---|---|
| | | (1)<br>*CALL* | (2)<br>*nonCALL* | (3)<br>*Difference*<br>*(1)-(2)* | (4)<br>*CALL* | (5)<br>*nonCALL* | (6)<br>*Difference*<br>*(4)-(5)* | (7)<br>*Diff-in-Diff*<br>*(3)-(6)* |
| Variance Ratio | $CrisisPeriod = 1$ | 1.529*** | 2.221** | -0.811 | 1.345*** | 1.105*** | 0.241*** | -1.250 |
| $\sigma^2(O)/\sigma^2(C)$ | | (0.320) | (0.854) | (1.072) | (0.033) | (0.033) | (0.051) | (1.105) |
| Variance Ratio | $CrisisPeriod = 0$ | 2.158*** | 1.236*** | 0.987** | 1.032*** | 1.083*** | -0.051 | 1.016** |
| $\sigma^2(O)/\sigma^2(C)$ | | (0.386) | (0.163) | (0.338) | (0.033) | (0.032) | (0.040) | (0.354) |
| Difference | | -0.384 | 0.163 | -1.019** | 0.314*** | 0.021 | 0.292*** | -1.483*** |
| | | (0.381) | (0.222) | (0.358) | (0.050) | (0.044) | (0.065) | (0.334) |

Panel B: Sniping in Price

| | | Sniping Days $snipe(p) = 1$ | | | Non-Sniping Days $snipe(p) = 0$ | | | |
|---|---|---|---|---|---|---|---|---|
| | | (1)<br>*CALL* | (2)<br>*nonCALL* | (3)<br>*Difference*<br>*(1)-(2)* | (4)<br>*CALL* | (5)<br>*nonCALL* | (6)<br>*Difference*<br>*(4)-(5)* | (7)<br>*Diff-in-Diff*<br>*(3)-(6)* |
| Variance Ratio | $CrisisPeriod = 1$ | 1.646*** | 1.980*** | -0.336 | 1.338*** | 1.168*** | 0.170*** | -0.503 |
| $\sigma^2(O)/\sigma^2(C)$ | | (0.270) | (0.612) | (0.154) | (0.034) | (0.036) | (0.039) | (0.615) |
| Variance Ratio | $CrisisPeriod = 0$ | 8.463* | 2.221** | 6.110 | 1.072*** | 1.103*** | -0.031 | 6.101 |
| $\sigma^2(O)/\sigma^2(C)$ | | (4.037) | (0.818) | (4.485) | (0.030) | (0.030) | (0.043) | (4.530) |
| Difference | | -6.674 | -0.120 | -6.016 | 0.265*** | 0.065 | 0.201*** | -6.174 |
| | | (4.147) | (1.155) | (4.520) | (0.048) | (0.048) | (0.064) | (4.623) |

(Table 5 cont'd)

**Panel C: Sniping in Volume**

| | | Sniping Days $snipe(v) = 1$ | | | Non- Sniping Days $snipe(v) = 0$ | | | |
|---|---|---|---|---|---|---|---|---|
| | | (1) *CALL* | (2) *nonCALL* | (3) *Difference (1)-(2)* | (4) *CALL* | (5) *nonCALL* | (6) *Difference (4)-(5)* | (7) *Diff-in-Diff (3)-(6)* |
| Variance Ratio $\sigma^2(O)/\sigma^2(C)$ | $CrisisPeriod = 1$ | 1.272*** | 1.262*** | 0.009 | 1.360*** | 1.180*** | 0.180*** | -0.171 |
| | | (0.076) | (0.138) | (0.165) | (0.035) | (0.035) | (0.047) | (0.179) |
| Variance Ratio $\sigma^2(O)/\sigma^2(C)$ | $CrisisPeriod = 0$ | 4.019** | 1.002* | 3.022* | 1.066*** | 1.188*** | -0.123** | 3.158** |
| | | (1.504) | (0.036) | (1.514) | (0.030) | (0.047) | (0.068) | (1.522) |
| Difference | | -2.761* | 0.261* | -3.080** | 0.294*** | -0.009 | 0.303*** | -3.398** |
| | | (1.488) | (0.149) | (1.478) | (0.050) | (0.060) | (0.083) | (1.495) |

## Table 6: Overnight Price Reversals on MSCI Index Rebalancing Days

This table reports overnight price reversals for HKEx-listed stocks with the last-10-minute return of 5% or more (by absolute value) on days when MSCI implemented its semi-annual index re-balancing activity. Panels A and B report overnight price reversals under a plain-vanilla closing auction mechanism on MSCI index rebalancing days of May 30, 2008 and November 25, 2008; panels C and D report those under the median pricing procedure on MSCI index rebalancing days on May 29, 2009 and November 30, 2009; panel E reports those under the revamped closing auction mechanism on MSCI index rebalancing day on November 30, 2016; and panel F reports those under the median pricing procedure on MSCI index rebalancing day on November 30, 2015. The variable $r_{10m}$ is the simple stock return in the last 10 minutes before the market close, i.e., last transacted price at 4:00 p.m. and the closing price of the day under the closing auction mechanism but last transacted price at 3:50 p.m. and the closing price of the day under the median pricing procedure; $r_{co}$ denotes the close-to-open return, which is the simple percentage return between the closing price of the MSCI index rebalancing day and the opening price of the following day. Bold faced type indicates that a stock exhibits a price reversal on the open following the MSCI index rebalancing activity.

Panel A: MSCI Index Rebalancing on May 30, 2008 : Plain-Vanilla Closing Auction Mechanism

| Stock Code | Company Name | $r_{10m}$ | $r_{co}$ | $r_{co}/r_{10m}$ |
|---|---|---|---|---|
| **1224** | **C C Land** | **24.92%** | **-16.21%** | **-0.65** |
| **0276** | **Mongolia Energy** | **18.16%** | **-8.93%** | **-0.49** |
| **1880** | **Belle Intl.** | **13.59%** | **-9.20%** | **-0.68** |
| **0069** | **Shangri-La Asia** | **13.36%** | **-15.59%** | **-1.17** |
| **1186** | **China Railway Construction** | **12.18%** | **-9.29%** | **-0.76** |
| **2626** | **Hunan Nonferrous Metals** | **-11.82%** | **7.28%** | **-0.62** |
| **1393** | **Hidili Industry Intl. Development** | **10.95%** | **-8.55%** | **-0.78** |
| **3377** | **Sino-Ocean Land** | **10.32%** | **-5.61%** | **-0.54** |
| **2689** | **Nine Dragons Paper** | **8.70%** | **-5.88%** | **-0.68** |
| **0002** | **CLP Holdings** | **7.88%** | **-6.38%** | **-0.81** |
| **2688** | **XinAo Gas Holdings** | **-7.49%** | **6.67%** | **-0.89** |
| **0754** | **Hopson Development Holdings** | **6.67%** | **-8.05%** | **-1.21** |
| **0903** | **TPV Technology** | **-6.62%** | **7.08%** | **-1.07** |
| **3368** | **Parkson Retail Group** | **6.01%** | **-4.03%** | **-0.67** |
| **3383** | **Agile Property Holdings** | **5.92%** | **-3.92%** | **-0.66** |
| **1072** | **Dongfang Electric** | **5.88%** | **-3.70%** | **-0.63** |
| **0032** | **Cross-Harbour (Holdings)** | **-5.72%** | **9.26%** | **-1.62** |
| **0606** | **China Agri-Industries Holdings** | **5.67%** | **-4.29%** | **-0.76** |
| **1114** | **Brilliance China Automotive Holdings** | **-5.47%** | **5.79%** | **-1.06** |
| **0604** | **Shenzhen Investment** | **-5.29%** | **3.11%** | **-0.59** |
| **0511** | **Television Broadcasts** | **5.29%** | **-1.54%** | **-0.29** |
| **0806** | **Value Partners Group** | **5.26%** | **-3.63%** | **-0.69** |

Panel B: MSCI Index Rebalancing on November 25, 2008: Plain-Vanilla Closing Auction Mechanism

| Stock Code | Company Name | $r_{10m}$ | $r_{co}$ | $r_{co}/r_{10m}$ |
|---|---|---|---|---|
| **0276** | **Mongolia Energy** | **-29.12%** | **13.51%** | **-0.46** |
| **1068** | **China Yurun Food Group** | **12.99%** | **-3.00%** | **-0.23** |
| **1000** | **Beijing Media** | **-7.95%** | **4.55%** | **-0.57** |
| **0258** | **Tomson Group** | **7.62%** | **-2.66%** | **-0.35** |
| **0020** | **Wheelock and Co.** | **7.44%** | **-5.39%** | **-0.72** |
| **2689** | **Nine Dragons Paper** | **-7.26%** | **2.61%** | **-0.36** |
| **0682** | **Chaoda Modern Agriculture** | **7.14%** | **-4.90%** | **-0.69** |
| **0573** | **Tao Heung Holdings** | **-6.45%** | **6.03%** | **-0.94** |
| **1193** | **China Resources Logic** | **5.91%** | **-0.47%** | **-0.08** |
| **0242** | **Shun Tak Holdings** | **-5.88%** | **5.47%** | **-0.93** |
| 0836 | China Resources Power | 5.75% | 1.12% | 0.19 |
| 2314 | Lee & Man Paper Manufacturing | -5.51% | -5.00% | 0.91 |

Panel C: MSCI Index Rebalancing on May 29, 2009: Median Pricing Procedure

| Stock Code | Company Name | $r_{10m}$ | $r_{co}$ | $r_{co}/r_{10m}$ |
|---|---|---|---|---|
| 0236 | San Miguel Brewery Hong Kong | 9.91% | 3.28% | 0.33 |
| **1109** | **China Resources Land** | **7.91%** | **-2.89%** | **-0.37** |
| 1882 | Haitian International Holdings | 5.42% | 0.00% | 0.00 |

Panel D: MSCI Index Rebalancing on November 30, 2009: Median Pricing Procedure

| Stock Code | Company Name | $r_{10m}$ | $r_{co}$ | $r_{co}/r_{10m}$ |
|---|---|---|---|---|
| **1136** | **TCC International Holdings** | **-7.14%** | **14.77%** | **-2.07** |

Panel E: MSCI Index Rebalancing on November 30, 2016: Revamped Closing Auction Mechanism

| Stock Code | Company Name | $r_{10m}$ | $r_{co}$ | $r_{co}/r_{10m}$ |
|---|---|---|---|---|
| **2768** | **Jiayuan International Group** | **5.63%** | **-4.44%** | **-0.79** |
| **1199** | **COSCO Shipping Ports** | **5.46%** | **-1.60%** | **-0.29** |
| **1269** | **China First Capital Group** | **-5.00%** | **0.33%** | **-0.07** |

Panel F: MSCI Index Rebalancing on November 30, 2015: Median Pricing Procedure

| Stock Code | Company Name | $r_{10m}$ | $r_{co}$ | $r_{co}/r_{10m}$ |
|---|---|---|---|---|
| 2686 | AAG Energy Holdings | -12.50% | -0.71% | 0.06 |
| 0727 | Crown International Corp. | -8.39% | -0.70% | 0.08 |
| 0377 | Huajun Holdings | -8.33% | -1.01% | 0.12 |
| 6896 | Golden Throat Holdings Group | -8.06% | -1.42% | 0.18 |
| 0378 | CIAM Group | -7.98% | 0.00% | 0.00 |
| 1321 | China New City Comm. Dev. | 7.93% | 1.93% | 0.24 |
| **0222** | **Min Xin Holdings** | **-7.40%** | **2.51%** | **-0.34** |
| **6826** | **Shanghai Haohai Biological Tech.** | **-6.67%** | **0.88%** | **-0.13** |
| **1456** | **Guolian Securities** | **-6.44%** | **1.08%** | **-0.17** |
| 6839 | Yunnan Water Investment | -6.39% | -0.22% | 0.03 |
| **1165** | **Shunfeng Intl. Clean Energy** | **5.65%** | **-1.24%** | **-0.22** |
| **6123** | **On Time Logistics Holdings** | **5.39%** | **-4.38%** | **-0.81** |
| 0915 | Daohe Global Group | 5.17% | 0.82% | 0.16 |
| **1682** | **Highlight China IoT Intl.** | **-5.06%** | **9.33%** | **-1.84** |

## Appendix A. Algorithm to Compute IEP and IEV during the Closing Auction Session

The indicative equilibrium price (IEP) must be a price at and between the highest limit bid and the lowest limit ask and that maximizes the matched shares, i.e., the indicative equilibrium volume (IEV). If there is a tie in the IEP, three tie-breaker rules apply. The first rule selects the price with the lowest order imbalance as the IEP. If this rule fails to break the tie, the second rule will apply and pick the price that is closest to the nominal price at 4 p.m. as the IEP. If these two rules fail, the third rule will apply and pick the highest price as the IEP.

The following example illustrates the algorithm to compute IEP, IEV, and the primary queue for buy and sell orders during the CAS. Bold- faced type indicates equilibrium. The primary queue is the queue of at-auction orders and at-auction limit orders with a specified price at or more competitive than the IEP. Let us assume that the best bid and offer at 4 p.m. are $37 and $38, respectively; the limit order book at 4:07:59 p.m. is presented in the benchmark case (I) as follows:

(I) Benchmark Case

| 4:07:59 p.m. Bid (Buy Orders) | | Ask (Sell Orders) | |
|---|---|---|---|
| Price | Quantity | Price | Quantity |
| At-auction | 1,000 | At-auction | 2,000 |
| $39 | 1,000 | $37 | 1,000 |
| $38 | 1,000 | $38 | 500 |
| $37 | 1,000 | $39 | 10,000 |

| Price | Acc. Buy | Acc. Sell | Matched Order | Order Imbalance |
|---|---|---|---|---|
| $39 | 2,000 | 13,500 | 2,000 | 11,500 |
| **$38** | **3,000** | **3,500** | **3,000** | **500** |
| $37 | 4,000 | 3,000 | 3,000 | 1,000 |

| Primary Queue | | IEP | IEV |
|---|---|---|---|
| Buy | 3,000 | $38 | 3,000 |
| Sell | 3,500 | | |

(IA) Sniping on the Sell-side: A large at-auction sell-order of 18,000 arrives at 4:09:58 p.m.

| 4:09:58 p.m. Bid (Buy Orders) | | Ask (Sell Orders) | |
|---|---|---|---|
| Price | Quantity | Price | Quantity |
| At-auction | 1,000 | At-auction | 20,000 |
| $39 | 1,000 | $37 | 1,000 |
| $38 | 1,000 | $38 | 500 |
| $37 | 1,000 | $39 | 10,000 |

| Price | Acc. Buy | Acc. Sell | Matched Order | Order Imbalance |
|---|---|---|---|---|
| $39 | 2,000 | 31,500 | 2,000 | 29,500 |
| $38 | 3,000 | 21,500 | 3,000 | 18,500 |
| **$37** | **4,000** | **21,000** | **4,000** | **17,000** |

| Primary Queue | | IEP | IEV |
|---|---|---|---|
| Buy | 4,000 | $37 | 4,000 |
| Sell | 21,000 | | |

(IB) Sniping on the Buy-Side: A large at-auction buy-order of 18,000 arrives at 4:09:58 p.m.

| 4:09:58 p.m. Bid (Buy Orders) | | Ask (Sell Orders) | |
|---|---|---|---|
| Price | Quantity | Price | Quantity |
| At-auction | 19,000 | At-auction | 2,000 |
| $39 | 1,000 | $37 | 1,000 |
| $38 | 1,000 | $38 | 500 |
| $37 | 1,000 | $39 | 10,000 |

| Price | Acc. Buy | Acc. Sell | Matched Order | Order Imbalance |
|---|---|---|---|---|
| **$39** | **20,000** | **13,500** | **13,500** | **6,500** |
| $38 | 21,000 | 3,500 | 3,500 | 17,500 |
| $37 | 22,000 | 3,000 | 3,000 | 19,000 |

| Primary Queue | | IEP | IEV |
|---|---|---|---|
| Buy | 20,000 | $39 | 13,500 |
| Sell | 13,500 | | |

(II) Benchmark Case with a small but aggressive limit sell-order at $33

4:07:59 p.m.

| Bid (Buy Orders) Price | Quantity | Ask (Sell Orders) Price | Quantity |
|---|---|---|---|
| At-auction | 1,000 | At-auction | 2,000 |
| $39 | 1,000 | $33 | 100 |
| $38 | 1,000 | $37 | 1,000 |
| $37 | 1,000 | $38 | 500 |
| | | $39 | 10,000 |

| Price | Acc. Buy | Acc. Sell | Matched Order | Order Imbalance |
|---|---|---|---|---|
| $39 | 2,000 | 13,600 | 2,000 | 11,600 |
| $38 | 3,000 | 3,600 | 3,000 | 600 |
| **$37** | **4,000** | **3,100** | **3,100** | **900** |
| $33 | 4,000 | 2,100 | 2,100 | 1,900 |

| Primary Queue | | IEP | IEV |
|---|---|---|---|
| Buy | 4,000 | $37 | 3,100 |
| Sell | 3,100 | | |

(IIA) Sniping on the Sell-Side: A large at-auction sell-order of 18,000 arrives at 4:09:58 p.m.

4:09:58 p.m.

| Bid (Buy Orders) Price | Quantity | Ask (Sell Orders) Price | Quantity |
|---|---|---|---|
| At-auction | 1,000 | At-auction | 20,000 |
| $39 | 1,000 | $33 | 100 |
| $38 | 1,000 | $37 | 1,000 |
| $37 | 1,000 | $38 | 500 |
| | | $39 | 10,000 |

| Price | Acc. Buy | Acc. Sell | Matched Order | Order Imbalance |
|---|---|---|---|---|
| $39 | 2,000 | 31,600 | 2,000 | 29,600 |
| $38 | 3,000 | 21,600 | 3,000 | 18,600 |
| $37 | 4,000 | 21,100 | 4,000 | 17,100 |
| **$33** | **4,000** | **20,100** | **4,000** | **16,100** |

| Primary Queue | | IEP | IEV |
|---|---|---|---|
| Buy | 4,000 | $33 | 4,000 |
| Sell | 20,100 | | |

(IIB) Sniping on the Buy-Side: A large at-auction buy-order of 18,000 arrives at 4:09:58 p.m.

4:09:58 p.m.

| Bid (Buy Orders) Price | Quantity | Ask (Sell Orders) Price | Quantity |
|---|---|---|---|
| At-auction | 19,000 | At-auction | 2,000 |
| $39 | 1,000 | $33 | 100 |
| $38 | 1,000 | $37 | 1,000 |
| $37 | 1,000 | $38 | 500 |
| | | $39 | 10,000 |

| Price | Acc. Buy | Acc. Sell | Matched Order | Order Imbalance |
|---|---|---|---|---|
| **$39** | **20,000** | **13,600** | **13,600** | **6,400** |
| $38 | 21,000 | 3,600 | 3,600 | 17,500 |
| $37 | 22,000 | 3,100 | 3,100 | 18,900 |
| $33 | 22,000 | 2,100 | 2,100 | 19,900 |

| Primary Queue | | IEP | IEV |
|---|---|---|---|
| Buy | 20,000 | $39 | 13,600 |
| Sell | 13,600 | | |

(IIC) Order Cancellation: The limit sell-order at $33 is canceled prior to 4:08:00 p.m.

4:08:00 p.m.

| Bid (Buy Orders) Price | Quantity | Ask (Sell Orders) Price | Quantity |
|---|---|---|---|
| At-auction | 1,000 | At-auction | 2,000 |
| $39 | 1,000 | ~~$33~~ | ~~100~~ |
| $38 | 1,000 | $37 | 1,000 |
| $37 | 1,000 | $38 | 500 |
| | | $39 | 10,000 |

| Price | Acc. Buy | Acc. Sell | Matched Order | Order Imbalance |
|---|---|---|---|---|
| $39 | 2,000 | 13,500 | 2,000 | 11,500 |
| **$38** | **3,000** | **3,500** | **3,000** | **500** |
| $37 | 4,000 | 3,000 | 3,000 | 1,000 |

| Primary Queue | | IEP | IEV |
|---|---|---|---|
| Buy | 3,000 | $38 | 3,000 |
| Sell | 3,500 | | |

## Appendix B. List of Stocks Used in the Study

This table lists the 36 stocks used in this study. Price is the closing price, market cap is the market capitalization of the stock, and market share is the percentage of the total market capitalization of the securities market of the HKEx accounted for by the stock as of December 31, 2009. All data are collected from the 2009 HKEx Fact Book.

| Code | Company Name | Price (HK$) | Market cap (HK$mil) | Market Share % |
|---|---|---|---|---|
| 00005 | HSBC Holdings | 89.40 | 1,556,218.26 | 8.76 |
| 00939 | China Construction Bank Corporation | 6.67 | 1,498,676.19 | 8.43 |
| 00941 | China Mobile | 72.85 | 1,461,412.00 | 8.22 |
| 00883 | CNOOC | 12.20 | 544,964.24 | 3.07 |
| 01398 | Industrial and Commercial Bank of China | 6.44 | 534,883.87 | 3.01 |
| 03988 | Bank of China | 4.20 | 319,285.06 | 1.80 |
| 00016 | Sun Hung Kai Properties | 116.30 | 298,231.97 | 1.68 |
| 02628 | China Life Insurance Co. | 38.35 | 285,369.06 | 1.61 |
| 00762 | China Unicom | 10.28 | 242,218.31 | 1.36 |
| 00001 | Cheung Kong | 100.30 | 232,311.28 | 1.31 |
| 00013 | Hutchison Whampoa | 53.40 | 227,664.00 | 1.28 |
| 00011 | Hang Seng Bank | 114.70 | 219,288.36 | 1.23 |
| 03328 | Bank of Communications Co. | 9.01 | 207,810.86 | 1.17 |
| 00857 | PetroChina Co. | 9.32 | 196,641.75 | 1.11 |
| 02388 | BOC Hong Kong | 17.60 | 186,080.93 | 1.05 |
| 02318 | Ping An Insurance (Group) Co. | 68.00 | 173,987.77 | 0.98 |
| 00066 | MTR Corporation | 26.80 | 153,504.43 | 0.86 |
| 00388 | Hong Kong Exchanges and Clearing | 139.40 | 150,016.33 | 0.84 |
| 00019 | Swire Pacific 'A' | 94.00 | 136,043.12 | 0.77 |
| 00688 | China Overseas Land & Investment | 16.40 | 133,971.99 | 0.75 |
| 01088 | China Shenhua Energy Co. | 38.00 | 129,146.14 | 0.73 |
| 00003 | Hong Kong and China Gas Co. | 19.50 | 127,322.98 | 0.72 |
| 00101 | Hang Lung Properties | 30.60 | 126,904.89 | 0.71 |
| 00002 | CLP Holdings | 52.45 | 126,202.22 | 0.71 |
| 00012 | Henderson Land Development Co. | 58.40 | 125,369.76 | 0.71 |
| 00004 | Wharf (Holdings) | 44.75 | 123,235.29 | 0.69 |
| 00494 | Li & Fung | 32.25 | 121,762.40 | 0.69 |
| 00386 | China Petroleum & Chemical Corporation[a] | 6.91 | 115,953.17 | 0.65 |
| 00006 | Hong Kong Electric Holdings | 42.20 | 90,065.84 | 0.51 |
| 00267 | CITIC Pacific | 20.90 | 76,257.58 | 0.43 |
| 00083 | Sino Land Co. | 15.10 | 73,825.89 | 0.42 |
| 00291 | China Resources Power Holdings | 28.35 | 67,913.79 | 0.38 |
| 00330 | Esprit Holdings | 51.75 | 64,559.52 | 0.36 |
| 02038 | Foxconn International Holdings | 9.02 | 64,040.99 | 0.36 |
| 00017 | New World Development Co. | 15.96 | 61,722.40 | 0.35 |
| 00144 | China Merchant Holdings | 25.25 | 61,426.91 | 0.35 |

[a] Currently known as China Sinopec

## Appendix C. Refinements in Call Auction Designs to Reduce Extreme Price Movement in Major Stock Exchanges[a]

This table presents refinements to the closing auction mechanism to reduce extreme price movements in major stock exchanges around the world.

| Stock Exchanges | Daily Price Limit | Deadline | Other refinements on the closing auctions |
|---|---|---|---|
| Tokyo Stock Exchange | Yes (sliding scale with respect to the previous closing price) | Fixed | No |
| Korea Exchange | Yes (±30% of the previous closing price) | Fixed | No |
| Taiwan Stock Exchange | Yes (±7% of the previous closing price) | Fixed | No |
| Shenzhen Stock Exchange | Yes (±10% of the previous closing price) | Fixed | No |
| Toronto Stock Exchange | Yes (±3% or 5 trading increments of the preceding last board-lot sale price) | Fixed | No |
| Australian Securities Exchange | No | Random | No |
| London Stock Exchange | No | Random | No |
| Deutsche Börse | No | Random | Yes (triggers a volatility interruption when the indicative closing price falls outside a pre-defined price range) |
| New York Stock Exchange[b] | No | Fixed | Yes (accepts on-close orders on the stabilizing side of the market in the final 15 minutes) |
| Nasdaq[b] | No | Fixed | Yes (accepts imbalance-only orders on the stabilizing side of the market in the final 20 minutes) |
| Euronext | No | Fixed | Yes (triggers a volatility interruption when the indicative closing price falls outside a pre-defined price range) |

[a] Information on the refinements on the closing auction mechanisms among worldwide stock exchanges are obtained from the two HKEx consultation papers: (i) "Introduction of a price control mechanism during the closing auction session in the securities market" and (ii) "The introduction of a closing auction session," available from http://www.hkex.com.hk/eng/newsconsul/mktconsul/marketconsultation.htm.

[b] Information on other refinements on the closing auction mechanism for the NYSE and Nasdaq is obtained from their corporate websites.