Sniping to Manipulate Closing Prices in Call Auctions: Evidence from the Hong Kong Stock Exchange[*]

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Abstract. The Hong Kong Stock Exchange briefly adopted call auctions as its closing mechanism. We find evidence of abnormally large orders and price changes during the last five seconds of the auction sessions. These sniping attacks were associated with the expiration of derivative products, which provided an incentive for price manipulation. Prices had a tendency to revert the day following a sniping attack. Although prices were on average more informative in a closing auction procedure than in a random closing procedure, they were more prone to manipulation attempts.

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I. Introduction

The closing call auction mechanism is the procedure most used worldwide to determine the closing prices of listed equities. The top five stock exchange operators in the world currently use this mechanism. The closing call auction mechanism is popular because extant studies (e.g., Pagano and Schwartz, 2003; Schwartz, 2001; Cao, Ghysels, and Hatheway, 2000; Biais, Hillion, and Spatt, 1999; Madhavan, 1992) find that it improves price discovery at the market close. Moreover, Chang, Rhee, Stone and Tang (2008), Comerton-Forde, Lau, and McInish (2007), and Hillion and Souminen (2004) show that this mechanism reduces price manipulation because orders are consolidated at the close.

The Hong Kong Stock Exchange (HKEx) adopted a closing call auction mechanism for a brief period from May 26, 2008 to March 22, 2009. The auction procedure was eventually abandoned because of widespread suspicion of price manipulation and extreme price volatility:

> "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.)

We use this episode to examine the effects of closing auctions on price discovery and price manipulation. Consistent with conventional wisdom, we find that the closing auction mechanism does—*on average*—improve price discovery. However, we also find that this mechanism can be vulnerable to price manipulation, particularly in the form of unexpectedly large orders submitted in the last few seconds before closing (henceforth "sniping").

A case in point was the plunge in HSBC shares on March 9, 2009. The 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, having at that time a global market capitalization of approximately US$200 billion. On that day, the stock quote of HSBC fluctuated within a tight range of $37–$38 during the closing auction session (henceforth "CAS").[3] Two seconds before the deadline of the closing auction, a trader sniped with an exceptionally large sell order. HSBC shares immediately plunged from $37 to close at $33, representing a drop of over ten percent in merely two seconds. When the market opened the next day, HSBC shares bounced back to the pre-sniping level of $37.25. Panel (a) of Figure 1 presents the indicative equilibrium price and the primary buy and sell queue of HSBC shares during that CAS. The sniping order was remarkably large, at over 4.7 million shares. That order alone represented fifty percent of the then-prevailing indicative equilibrium volume at the closing session.

[Insert Figure 1 here.]

We believe that the sniping incident on March 9, 2009 was well planned because the trading of HSBC shares was also unusual on the previous trading day (March 6). Panel (b) of Figure 1 shows the trading activities during the CAS 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. It appears that some traders attempted to manipulate the stock

[3] Stock prices are quoted in Hong Kong dollars. The Hong Kong dollar is pegged to the U.S. dollar at an exchange rate ofUS$1:HK$7.8.

price of HSBC on March 6, 2009 but were not successful. Alternatively, they might have been testing the market reaction should HSBC shares drop to $33.

In this paper, we go beyond anecdotal evidence to systematically evaluate the performance of the closing call auction mechanism adopted by the HKEx. Our paper adds to the literature in several ways. First, in sharp contrast to conventional wisdom, we find that a poor auction design can inhibit the ability of the auction to reduce manipulation. Specifically, we argue that a plain vanilla call auction with a non-binding price limit and a fixed deadline facilitates price manipulation. A large allowable price movement increases profit from price manipulation. Orders submitted during the closing auction can range from +800% to −89% of the prevailing market price. In contrast, the price limit during the continuous trading session is only 24 ticks, which represents approximately ±2.4% of the prevailing market price. Furthermore, price manipulation via sniping can be more successfully implemented under a fixed (rather than a random) deadline 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. The HKEx experience is exceptional in that it is the only major stock exchange in the world that adopted a closing auction procedure without any precaution against price manipulation. Our findings are consistent with the auction design literature, which emphasizes that *minor institutional details matter*. For example, Hasbrouck (2007, p.18) states that "although auctions may appear simple, seemingly minor details of implementation can have profound effects."

Second, many studies (Comerton-Forde and Putniņš, 2011; Comerton-Forde and Rydge, 2006; Aggarwal and Wu, 2006) use prosecuted cases to examine price manipulation. 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 limited by the capability of regulators to accurately detect and successfully prosecute price manipulators.[4]

Third, our findings are less susceptible to possible biases from confounding factors that are correlated with time trends. Existing studies of other markets typically rely on a before-and-after comparison, which may be difficult to disentangle from unobserved time trends. The unique experience of the HKEx to adopt and then abandon closing auctions allows us to use both pre-CAS and post-CAS periods as two separate benchmarks to examine their effects. Unless one posits an unobserved time trend that coincidentally reverts itself after the CAS period, we are more confident that the effects identified during the CAS period are attributable to the trading mechanism rather than to other unobserved factors.

Fourth, we use market micro data at very fine time intervals (5-second and 10-minute intervals) to measure price movements. Focusing on such fine details allows us to isolate the effects of market structure from the effects of broader market movements. Doing so is particularly relevant, as the stock market was extremely volatile and on the decline during the period when the HKEx implemented the closing auction procedure. However, the extreme market condition should have no material effect on our results, as the relevant variables are measured at very fine intervals. For example, the absolute value of stock return in the final 5-second interval before the close was on average 4.6 basis points in the CAS period and 8.3 basis points in the non-CAS periods, even though the market was more volatile in the CAS period.

[4] Despite our statistical evidence, which suggests systematic attempts at price manipulation under the closing auction mechanism, there were only seven prosecuted cases of price manipulation during our entire sample period.

Importantly, in addition to measuring the effects of closing auctions, we also study a motive to manipulate closing prices at the auctions. In particular, we link the performance of the closing auctions in the equities market to the market of a derivative product—*callable bull and bear contracts* (CBBCs). These contracts are similar to knock-out (barrier) options in that they expire if the price of the underlying stock reaches a pre-specified level. However, unlike traditional knock-out options, CBBCs are typically not worthless on the expiration date. The residual value of an expired CBBC can be determined by the closing price of the underlying stock. Consistent with our expectations, we find that sniping attacks during the CAS period was motivated by manipulation motives. Sniping attacks were more likely to occur on days when CBBCs expired during the CAS period and were more likely to be followed by price reversals at the next open. When we compare price informativeness between the closing auction mechanism and the random closing mechanism, we find that in closing auctions, closing prices were on average more informative but were less informative on days when the incentive to manipulate prices was high.

II. Closing Call Auctions vs. Random Closing at the HKEx

The HKEx was the seventh largest worldwide stock exchange in 2009. During our sample period, its regular trading was conducted in two continuous trading sessions: a morning session from 10:00 a.m. to 12:30 p.m. and an afternoon session from 2:30 p.m. to 4:00 p.m. The following describes the closing procedures of the HKEx during the CAS and non-CAS periods.

A. Closing Auction Session

For approximately ten months starting on May 26, 2008, the HKEx adopted a closing call auction mechanism. The algorithm of the closing auction mechanism is a copy of its opening call auctions adopted more than six years earlier. The CAS begins immediately after the end of the continuous trading session at 4:00 p.m. and lasts till 4:10 p.m. During the session, buy and sell orders set to determine the closing price will accumulate. Traders can place, modify and cancel market and limit orders during the first eight minutes of the session.[5] In the last two minutes of the session, traders can place only market orders, but the modification and cancellation of orders are disallowed. Throughout the CAS, market participants can observe the resulting indicative price (IEP) and trade volume (IEV), without any trades actually taking place.[6] After 4:10 p.m., orders are matched, and transactions are executed at the indicative price at 4:10 p.m., which is the closing price of the day.[7] The indicative price is the price obtained from a single-price call auction that yields the maximum number of shares transacted. In addition, short selling is prohibited during the CAS. Appendix A describes the algorithm used to compute IEP and IEV during the closing auction session.

The HKEx implemented the closing auction mechanism to improve the quality of the price discovery process, lessen price volatility and manipulation, and facilitate institutional investors to execute clients' orders at the closing price. However, this mechanism was eventually suspended due to widespread suspicion of manipulation and extreme price volatility. Extreme price volatility is feasible because the allowable price movement is immensely wider

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

[6] 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 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.

[7] If there is no IEP available after the CAS (i.e., there is no match at all), the closing price is determined by the random closing procedure as is used in the non-CAS period.

during the CAS than during the continuous trading session. During the CAS, the price specified by a limit order is 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 times (−89%) the nominal price at 4:00 p.m. In contrast, limit orders submitted during the continuous trading session are restricted to much narrower bands. Specifically, they must be input within 24 ticks of the prevailing market price (henceforth the "24-tick rule").[8] For example, 24 ticks correspond to a price range of ±2.4% for a stock trading at $50.

In retrospect, it is puzzling why the "9-times restriction rule" is permitted if the HKEx aims to use closing auctions to reduce price volatility and manipulation. This algorithm is adopted because it had operated smoothly to determine opening prices for more than six years. In particular, incidents of price manipulation and extreme price volatility in the opening call auctions were rare. Therefore, the HKEx formed a false impression that this algorithm should be equally robust to price manipulation and extreme price volatility when it is applied to determine closing prices. It is unfortunate that the HKEx fails to recognize that the motive to manipulate is weak for opening prices but strong for closing prices, as closing prices are used to price derivative products in Hong Kong.

B. The Random Closing Procedure

The random closing procedure is used to determine the closing price during the pre- and post-CAS periods. The closing price of a stock is determined by taking the median of five snapshots of nominal prices in the last minute before the end of the continuous trading session at 4 p.m. These prices are taken at five specific times, which are 15 seconds apart, starting from 3:59 p.m.

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[8] In Hong Kong, the official term for the 24-tick rule is the 24-spread rule. We change the official name to the current one to conform to the terminology in the literature.

Choosing the median of these prices ensures that the closing price will not be unduly influenced by one single trade. Note that the 24-tick rule applies to orders submitted during the random closing procedure because it is part of the continuous trading session.

III. Data and Sample

Our sample spans a period of 34 months and can be divided into three periods. It covers a ten-month period when the closing call auction mechanism was adopted (CAS period: 5/26/2008−3/22/2009), a one-year period before CAS (pre-CAS period: 5/26/2007−5/25/2008) and a one-year period after CAS (post-CAS period: 3/23/2009−3/22/2010). Our sample is drawn from the constituent stocks of the Hang Seng Index. These companies are comparable in size to S&P500 companies, with market capitalizations ranging from US$2.9 billion (COSCO Pacific) to US$200.5 billion (HSBC) in 2009. Our sample stocks constituted 61 percent of the market capitalization of all stocks listed on the HKEx at the end of 2009. Because their closing prices are used to price many derivative products, investigating these stocks allows us to study the incentive of price manipulation.

Our final sample has 39 stocks. We include companies only if they have at least 60 daily observations in each period. We construct our dataset from four 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; 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 the expiration dates of CBBCs are taken from various years of *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 since January 1, 2008 but only at 30-second intervals prior to that date.

IV. Manipulative Sniping

In financial markets, sniping in closing auctions has been occasionally documented. Cushing and Madhavan (2000) find that the last five minutes of trading account for a large fraction of daily return variability. Comerton-Forde and Rydge (2006) and Comerton-Forde and Putniņš (2011) use prosecuted cases and find that unexpectedly large changes in price and volume before the close are key characteristics of closing price manipulation. In this paper, we provide more systematic evidence of sniping attacks in the HKEx. Importantly, we propose a motive for sniping: manipulative sniping—manipulators use sniping to influence closing prices. We argue that manipulative sniping is a rational strategy to influence the closing price under the call auction mechanism. This practice is particularly effective for a plain vanilla call auction with a fixed deadline and without price limits. The fixed deadline empowers manipulators to surprise the market by submitting exceptionally large orders in the final seconds, giving no time for other traders to react. The absence of binding price limits allows manipulators to produce large and sudden changes in prices within a short interval that are otherwise unachievable in a continuous trading session. Manipulators can profit from sniping when closing prices of equities are used as settlement prices for derivatives, e.g., CBBCs, stock warrants, stock index futures, and stock options (see Kumar and Seppi, 1992; Stoll and Whaley, 1991; Chamberlain, Cheung, and Kwan, 1989).

A. Measures of Sniping

We measure sniping by a sudden change in price just before the closing price is determined because the sniping strategy is profitable only when it can successfully influence the closing price. We also examine sniping in trade volume (sudden surge in orders right before the auction ends) and sniping in both price and trade volume for completeness.[9]

We measure sniping as follows: `snipe(x)` is a binary variable and takes the value of one if 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", where `x` is either `p` (price), `v` (trade volume), or `pv` (both price and trade volume). We use the time when the closing price is set to define our sniping measurement window. The "sniping measurement window" is the 5-second interval before the market close in the CAS period, i.e., 4:09:55–4:10:00 p.m. In the non-CAS period, it is the 5-second interval *prior to the snapshot nominal price being taken as the closing price*. This procedure is necessary because to achieve a successful closing price manipulation under the random closing procedure, manipulators would have to influence the median price of the five snapshot nominal prices. For example, if the median price taken at the five snapshots occurs at 3:59:15 p.m., the "sniping measurement window" would be 3:59:10–3:59:15 p.m.

The "benchmark intervals" in the closing minute for comparison are chosen to avoid covering any one of the five snapshot times—3:59:00, 3:59:15, 3:59:30, 3:59:45, and 4:00:00 p.m. In the non-CAS period, prices can be distorted if manipulators submit orders shortly before each of the five designated snapshots of the closing minute, hoping to influence the median

[9] In addition, Comerton-Forde and Rydge (2006) and Comerton-Forde and Putniņš (2011) find that closing price manipulations are also strongly correlated with large increases in return reversals and bid-ask spreads. Consistent with their findings, we find that sniping is positively and significantly correlated with return reversals (to be described in Section V). However, we are unable to examine the relationship between large increases in bid-ask spreads and closing price manipulation. Meaningful bid-ask spreads are unavailable during the CAS period, as only a single indicative price is generated during the call auction procedure.

price.[10] If this is the case, prices taken at these five snapshots might be manipulated and thus unsuitable as benchmark prices. Therefore, in the non-CAS period, 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 in the CAS period. We measure price by IEP and trade volume by IEV in the CAS period. In the pre-CAS and post-CAS periods, we measure price and trade volume by the actual transaction price and the actual transaction volume, respectively. The variable `snipe(pv)` is equal to one if both `snipe(p)` and `snipe(v)` are equal to one.

Table 1 presents descriptive statistics on the sniping variables we have constructed. Our results indicate that sniping in trade volume and sniping in both price and trade volume are significantly more prevalent during the CAS period than during the non-CAS periods. Specifically, the likelihood of sniping in trade volume is 12.5%, 22.2%, and 15.0% in the pre-CAS, CAS, and post-CAS periods, respectively. This means that, in over one fifth of our firm-day observations in the CAS period, the most intense trading activities of the closing minute occur during the last 5-second interval. Similarly, the likelihood of sniping in both price and trade volume is 3.3%, 7.1%, and 3.1% in the pre-CAS, CAS, and post-CAS periods, respectively. In contrast, sniping in price is less prevalent in the CAS period than in the non-CAS period. The likelihood of sniping in price is 17.2%, 10.4%, and 14.3% in the pre-CAS, CAS, and post-CAS periods, respectively.

[Insert Table 1 here.]

[10] To successfully influence the closing price, manipulators must influence at least three of the five snapshot nominal prices because the median of the five prices is chosen as the closing price. Theoretically, the most cost-effective way to manipulate is to snipe at only three of the five snapshot times.

B. Motives for Sniping

We use a particular derivative product—callable bull and bear contracts—to explore a financial motive for closing price manipulation. We emphasize that this is not the only possible motive for price manipulation, but it is the only derivative product in the HKEx that uses the closing price of the underlying equity to determine the settlement price on the expiration day.[11] In addition, CBBCs are a derivative product that we can have sufficient information to study.

The residual value of an expired bull CBBC is determined by the settlement price less the strike price (a pre-specified price) if this amount is positive and zero otherwise. The settlement price is the minimum price of the underlying stock from the expiration time to the next trading session of the day (typically including the market close).[12] The residual value of an expired bear CBBC is analogously calculated, except that the settlement price is the maximum price of the underlying stock. To reduce settlement expenses to buyers of CBBCs, issuers of CBBC have an incentive to depress the closing price of the underlying equity on the expiration day of a bull CBBC while inflating it on the expiration day of a bear CBBC.[13]

[11] In Hong Kong, the settlement price for index futures/options is the average based on five-minute quotation and the closing index on the expiration day, whereas that for derivative warrants is the average closing price computed over a five-day period immediately before the expiration day.

[12] A typical bull contract is issued with an expiration day, allowing investors to hold a bullish position on the underlying stock. Further, it pre-specifies a call price and a strike price. The call price sets a threshold to determine whether the contract will expire prematurely, while the strike price is used to determine the residual value of the contract on the expiration day. Imagine that a bull contract is issued with an expiration period of one year and the stock price of the underlying asset is $100 on the issuing date. The contract also specifies a call price at $90 and a strike price at $80. In the next day, if the stock price drops to $90 at 11 a.m. during the morning session, the bull contract will expire immediately. The settlement price will be determined by the minimum of all transacted prices of the underlying equity from 11 a.m. until the market close (inclusive of the closing price). If the minimum price of the underlying equity during that period is $82, the residual value of the bull contract will be $2 [= settlement price – strike price = $82 – $80 = $2].

[13] Theoretically, both issuers and buyers of CBBCs have an incentive to manipulate the closing price of the underlying equity on the expiration day. However, the incentive to manipulate should be stronger for issuers than for buyers of CBBCs, as the issuer market is very concentrated. 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 buyers of these products are small retail investors.

The number of expired CBBCs is very small in the pre-CAS period because they were introduced by the HKEx only in 2006. Trading of CBBCs has increased rapidly since 2008. The turnover value of CBBCs was US$9.2 billion in 2007, reaching US$133.96 in 2008 and US$215.99 billion in 2009. For our sample stocks, the number of expired CBBCs is 55 in the pre-CAS period, 830 in the CAS period, and 2,719 in the post-CAS period. To have a meaningful comparison between periods, we combine observations in the pre-CAS and post-CAS periods into a single period and call it the non-CAS period. Doing so is necessary, as the number of expired CBBCs is very small in the pre-CAS period, particularly for expired bear contracts (only five contracts).

We use a probit regression model with firm fixed-effects to examine the impact of the number of expired CBBCs on the likelihood of sniping. Table 2 presents marginal effects for the three measures of sniping. The variable `ncbbc` measures the number of expired CBBCs for a stock on a given day. Consistent with our expectation, the estimates for `ncbbc` in columns (1)–(3) are positive and statistically significant at the 5% level. The estimate in column (1) suggests that during the CAS period, the probability of observing a sniping attack is 3.1 percentage points higher on a day when a CBBC expires. As the average probability of a sniping attack during our sample CAS period is merely 11.8 percent, the positive effect of CBBC expiry on the likelihood of sniping is quantitatively significant. In contrast, the expiration of CBBC only has a negligible effect on sniping ($-0.0354 + 0.0313 = -0.004$ percentage point) during the non-CAS period.

[Insert Table 2 here.]

We recognize that sniping is only one of many possible means of manipulating closing prices. To directly investigate the relation between the motive for price manipulation and the behavior of closing prices, we split CBBCs by their type (bull or bear) to examine how they affect the likelihood of observing day-high and day-low at the close and the direction of price movements in the "sniping measurement window." A day-high event (`day-high`) is said to occur if the closing price is the highest price of the trading day, and a day-low event (`day-high`) is analogously defined. The direction of price movement in the sniping measurement window can be positive ($\Delta P_{5s}>0$) or negative ($\Delta P_{5s}<0$).

When a bull CBBC expires, its residual value is determined by the minimum price of the underlying stock from the expiration time to the next trading session of the day, which typically includes the closing price. Therefore, closing prices could be used to determine the residual value of bull contracts if they are the minimum price of the underlying stocks. We hypothesize that if issuers of bull contracts manipulate closing prices, the probability of a day-low event at the close should be particularly high on days when the number of expired bull CBBCs is large. Similarly, the probability of day-high events should be higher when the number of expired bear contracts is large. More importantly, this relationship should be stronger in the CAS period than in the non-CAS period if the closing call auction mechanism is indeed vulnerable to price manipulation.

We use a probit regression model with firm fixed-effects to examine the impact of the number of expired CBBC by type (`nbull` and `nbear`) on the behavior of closing prices. Table 3 presents marginal effects of observing a day-low at the close (column 1), a day-high at the close (column 2), a negative price change in the sniping measurement window (column 3), and a positive price change in the sniping measurement window (column 4). The CAS period of our sample happened to be a period of high volatility. We include the dummy variable `nonCAS` in our probit regressions to capture this effect and find that its effect on the dependent variables is negative and significant.

[Insert Table 3 here.]

The main variables of interest are `nbull`, `nbear`, and their interaction with `nonCAS`. In column (1), the estimate of `nbull` is positive and statistically significant, indicating that during the CAS period, a day-low at the close is more likely to occur when the number of expired bull CBBCs on that day is larger. In contrast, this relationship is very weak during the non-CAS period: the marginal effect of the interaction term `nbull×nonCAS` is negative and of roughly the same magnitude as the marginal effect of `nbull`. Similarly, the results in column (2) show that, during the CAS period, a day-high at the close is 1.9 percentage points more likely on a day when a bear CBBC expires. However, during the non-CAS period, the effect drops to only 0.3 percentage points (= 0.019 − 0.0158) and is not economically significant.

Similarly, our results in columns (3)–(4) show that price movements on the CBBC expiration days are consistent with the use of sniping to manipulate closing prices. For example, the results in column (3) indicate that during the CAS period, the probability of observing a negative price change in the "sniping measurement window" is 6 percentage points higher on a day when a bull CBBC expires. This means that the orders submitted shortly before the close are predominantly sell orders, consistent with an attempt to depress the residual value of the expired bull CBBC. Also note that such an effect cannot be interpreted simply as an artifact of a down market. During the non-CAS period, orders submitted during the "sniping measurement window" are not predominantly sell orders when a bull CBBC expires. Similarly, our results in column (4) indicate that the probability of observing a positive price change in the "sniping measurement window" is significantly higher on a day when a bear CBBC expires during the CAS period than during the non-CAS period.

In sum, we find that expiration of CBBCs is more likely on days when sniping occurs and also on days when the closing price is either the highest or lowest price of the day. Furthermore, we find that price movement in the final seconds before the close on the CBBC expiration days is in the right direction to support closing price manipulation. These findings lend support to our hypothesis that manipulative sniping is used to influence closing prices under the closing call auction mechanism.

V. Price Informativeness

This section investigates the impact of the introduction of closing call auctions on price informativeness. One measure of price informativeness is the goodness-of-fit (i.e., adjusted R-square) of the standard market model, as proposed by Roll (1988). If closing prices fully reflect all publicly available information under the call auction mechanism, we expect that the co-movement between an individual stock return and the market return to be greater in the period when closing call auctions are used than that in the period when such auctions are not used. We follow extant studies (e.g., Comerton-Forde, Lau, and McInish, 2007; Pagano and Schwartz, 2003) and use the co-movement in close-to-close returns to measure price informativeness. Specifically, for each stock and each period, we regress the daily close-to-close return of the stock against the market return to obtain the R-squared of the regression. We then use the R-squared so obtained as the dependent variable and estimate a regression on the dummy variables for the pre-CAS and post-CAS periods:

$$\mathtt{R}^2\mathtt{(close\text{-}to\text{-}close)} = 0.6426 - 0.0724\,\mathtt{preCAS} - 0.1499\,\mathtt{postCAS},$$

where the standard errors associated with the `preCAS` and `postCAS` variables are 0.022 and 0.017, respectively. Consistent with the findings of Pagano and Schwartz (2003), we find that prices are significantly more informative when they are determined by the closing call auction mechanism than by the random closing procedure.

Although closing prices are *on average* more informative under the auction procedure than under the random closing procedure, our evidence from the previous section indicates that the closing auction mechanism can be vulnerable to occasional price manipulation. We thus further investigate whether closing prices are less informative *on days when price manipulation is likely to occur*. To measure price informativeness on a daily basis, we use the extent of overnight price reversal. We reason that if the closing price reflects all publicly available information, price reversal is unlikely. In contrast, price reversal is likely if the closing price is manipulated by snipers whose motive is, say, to profit from the derivative market. Therefore, the market tends to correct such temporary distortions, leading prices to revert to their underlying values on the following day.

We expect that price reversal is more pronounced on days when price manipulation is likely to occur. This relation should be much stronger during the CAS period than during the non-CAS period. We follow Pagano and Schwartz (2003) in using close-to-open returns to measure the extent of price reversal. We use four methods to identify days on which price manipulation is likely to occur: (1) days when large price changes during the final 10-minute interval occur; (2) days when CBBCs expire; (3) days when sniping attacks occur; and (4) days when the 24-tick rule is violated. We discuss these four methods in turn.

Method 1. Price manipulation should be used infrequently (may be several days in a year) to ensure that the market will not develop counter-strategies to nullify its effect. To measure such infrequent attempts, it is useful to focus on "outliers," as successful price manipulation tends to produce large and sudden changes in stock prices. For each stock on each trading day, we calculate the percentage price change during the final ten-minute interval before the close. In the least-squares regression reported in column (1) of Table 4, we select ten observations with the largest absolute percentage price changes during the last ten-minute interval in each period (i.e., pre-CAS, CAS, and post-CAS). The total sample size is thus 30.[14] Column (2) selects the observations with the largest 100 absolute percentage price changes in each period. In columns (3) to (5), the sample is progressively expanded to include observations with the largest 200, 500, and 1,500 absolute percentage price changes. The full sample of observations is used in column (6).

[Insert Table 4 here.]

To measure the degree of price manipulation in the closing session of the CAS period, we include returns measured over the final ten-minute interval before the close (R_{10m}). A negative coefficient on R_{10m} indicates a price reversal at the next open. We also interact this variable with a binary variable for the pre-CAS period and a binary variable for the post-CAS period. The coefficients of $R_{10m}\times preCAS$ and $R_{10m}\times postCAS$ can be interpreted as difference-in-differences estimates: a negative coefficient means that a price reversal is less likely to occur in the relevant sub-period. Our regressions also include the control variable R_m, which measures the overnight return for the overall market. This variable captures market-wide shocks/information during the overnight period that may impact the close-to-open return.

[14] The absolute percentage price change in the final ten-minute interval before the close can be substantial for these "outlier" observations. For the observations in column (1) of Table 4, the average values are 5.8%, 8.4%, and 4.2% in the pre-CAS, CAS and post-CAS periods, respectively.

In Table 4, we find that during the CAS period, price reversal is particularly strong and noticeable on days when very large price changes occur during the final ten-minute interval. For instance, the estimate for R_{10m} in column (1) is −0.8726, which suggests that when the price changes by one percent during the CAS period, approximately 87 percent of this change will revert on the following open. In contrast, the estimate for $R_{10m}\times\texttt{postCAS}$ in column (1) is positive and significant. These findings imply that only 12 percent (= 0.7526 − 0.8726) of this change in the post-CAS period will revert on the following open. The coefficient for $R_{10m}\times\texttt{preCAS}$ is also positive but is statistically insignificant.

The price reversal during the CAS period is progressively weaker when we increase our sample size by including observations with smaller absolute price changes. The results in columns (2)–(6) show that although the price reversal estimates (i.e., coefficients on R_{10m}) during the CAS period remain negative across all regressions, their absolute magnitudes are negatively correlated with the sample size. The fact that larger price changes are associated with greater price reversals during the CAS period indicates the possibility that such large price changes may be the result of manipulation. More importantly, Table 4 also shows that price reversals are consistently weaker in the pre-CAS and post-CAS periods (the estimates on $R_{10m}\times\texttt{preCAS}$ and $R_{10m}\times\texttt{postCAS}$ remain consistently positive across all regressions), indicating that the reversal of large price changes near the close is a much more common problem under the closing auction mechanism than under the random closing mechanism.

Method 2. We also consider the extent of price reversal on days of CBBC expiration. Table 5 shows the firm fixed-effects regression results. The coefficient on $\texttt{ncbbc}\times R_{10m}$ indicates that if a CBBC expires on a certain day and the underlying stock price drops by one percentage point in the final ten-minute interval, the stock price will bounce back by 0.08 percent of this change on the following open. However, if the same event happens in the non-CAS period, we observe a very small price momentum instead.

[Insert Table 5 here.]

Method 3. In Table 6, we present firm fixed-effects regression results for the impact of sniping on price reversal on the following day. To measure the severity of a sniping attack, we include the stock return R_{5s} measured over the "sniping measurement window" and interact this variable with our measure of sniping and with a binary variable for the non-CAS period. As shown by the estimates in column (1), if a sniping attack occurs on the day for a stock and depresses the stock price by one percentage point in the sniping measurement window, the stock price will bounce back by 1.2 percentage points on the following open in the CAS period. However, the coefficient for $\texttt{snipe(p)}\times\texttt{nonCAS}\times R_{10s}$ is positive and of similar magnitude as that for $\texttt{snipe(p)}\times R_{10s}$. This finding implies that in the non-CAS period, there is no price reversal on the following open in response to such a sniping attack. Our results using sniping in trade volume and sniping in both price and volume are qualitatively the same.

[Insert Table 6 here.]

Method 4. We argue that the relaxation of the 24-tick rule during the CAS is a key factor driving closing price manipulation. Because larger price changes are feasible under the CAS, the relaxation of the 24-tick rule will make price manipulation more profitable. We thus expect to observe more price manipulation during the CAS period than during the non-CAS period. We test this hypothesis by examining the informativeness of closing prices on days when the 24-tick rule is likely to be a binding constraint. Because data on order arrivals and limit order books are unavailable to us, we cannot precisely identify stocks that have standing limit orders that are 24 ticks away from their nominal prices at 4:00 p.m. Therefore, we use IEP as a proxy to identify such a violation. Because limit orders cannot be canceled and modified during the final two-minute interval before the close in the CAS period, we use IEP during this 2-minute interval to infer whether limit orders beyond 24-ticks have been submitted during the CAS. We define a violation of the 24-tick rule on the buy side (i.e., `buy24tick`) if the maximum IEP during the last two minutes is greater than 24 ticks from the nominal price at 4:00 p.m., and a violation of the 24-tick rule at the sell-side (i.e., `sell24tick`) is similarly defined if the minimum IEP during the last two minutes is less than 24 ticks from the nominal price at 4:00 p.m. Note that our measures fail to capture all instances when the 24-tick rule is violated, as the IEP may not reach limit orders that are very high or very low. We follow similar procedures to measure deviations from 24 ticks in the non-CAS period: `buy24tick` is equal to one if the maximum price in 3:58–4:00 p.m. is more than 24 ticks higher than the price at 3:50 p.m., and `sell24tick` is similarly defined. Finally, we create a binary variable, `24tick`, which takes a value of 1 if `buy24tick` is one, –1 if `sell24tick` is one, and 0 otherwise.

Table 7 presents firm fixed-effects regression results on the impact of the 24-tick rule on price reversal during the CAS period. Consistent with our expectation, the estimate for `24tick` in column (1) is negative, whereas that for `24tick×nonCAS` is positive. Both estimates are large and have economic and statistical significance. During the CAS period, if there is a violation of the 24-tick rule on the, say, buy side in the closing session, the closing price will be 2.04 percentage points lower on the following open. In other words, the overnight price exhibits strong reversal. Meanwhile, during the non-CAS period, the price reversal effect is significantly weaker: the close-to-open return is merely 0.32 percentage points (= –2.04 + 1.72) for a violation of the 24-tick rule during the closing session. The same results hold if we separate violations by buyer- or seller-initiated orders. The estimate for `sell24tick` in column (2) is positive, whereas that for `sell24tick×nonCAS` is negative for the CAS period. However, when these two variables are interacted with `nonCAS`, there is no evidence of price reversal in the non-CAS period even when the 24-tick rule is violated.

[Insert Table 7 here.]

To summarize, all the four methods indicate that during the CAS period, price reversal occurs on the following open on days when price manipulation is likely to occur. However, the price reversal effect is significantly weaker (if not non-existent) during the non-CAS period. The evidence is consistent with the hypothesis that the closing prices on these days are manipulated.

VII. Robustness Checks

One limitation of this study is that we impose no threshold on our measures of sniping. In our current measures of sniping, if the change in price in the sniping measurement window is only 1 basis point higher than those in the benchmark intervals, then sniping in price is said to occur. To ensure that sniping is manipulative in nature, we modify our measures of sniping by imposing an additional threshold requirement, i.e., a meaningfully large change in price (or trade volume). For example, to qualify for sniping in price, we require that the simple stock return in the sniping measurement window exceeds 50, 75, or 100 basis points in absolute value. Similarly, to qualify for sniping in trade volume, we require that the change in trade volume in the sniping measurement window exceeds either two, third, or four standard deviations of the mean trade volume in the sniping measurement window. These modified measures of sniping are consistent with our empirical findings that price manipulation should be large in magnitude and infrequent in occurrence. Again, our results (available upon request) remain qualitatively similar.

Another issue is that the degree of overall market volatility differs between periods. Although we have already used a difference-in-difference methodology in our specifications to control for sub-period effects, it may be still argued that the extreme volatility of stock returns during a brief duration of the CAS period (given the financial tsunami of 2008) may bias the standard errors or our estimates. To examine this possibility, instead of clustering standard errors at the firm-period level, we also try clustering standard errors at finer firm-time intervals, i.e., firm-year, firm-month, and firm-week levels. Although we do not show these alternative standard errors in this paper, the statistical significance of our results is not materially affected by finer clustering.

IX. Conclusions

Our empirical findings indicate that a plain vanilla call auction mechanism can be susceptible to price manipulation, particularly in the form of sniping. According to the ten-month experience at the HKEx, we find that *on average,* stocks are more accurately priced under the closing auction mechanism. However, closing prices can be distorted on days when price manipulation is likely to occur, e.g., on days when large changes in price or trade volume in the final ten-minute interval occur, when CBBCs expire, and when sniping attacks occur.

This study has important policy implications, given that call auctions are widely used to determine opening and closing prices for equities around the world. In the wake of the extreme price volatility for some stocks when MSCI re-balanced the major indices on May 30, 2008, the HKEx decided to introduce a price control mechanism during the CAS to reduce price manipulation. This enhancement has never been implemented because the CAS was indefinitely suspended on March 23, 2009. The proposed price control mechanism would allow the closing price to deviate from the nominal price at 4:00 p.m. by only two percent. This enhancement should reduce closing price manipulation, as it makes such manipulation less profitable because the maximum price deviation from the prevailing nominal price at 4:00 p.m. would be drastically reduced from +800% or −89% to ±2% during the CAS. However, this enhancement cannot eradicate the incentive to manipulate prices because the deadline remains fixed. The price control mechanism would change the focal point for price manipulation from 4:10 p.m. to 4:00 p.m. Because the allowable movement of closing prices is directly determined by the nominal price at 4:00 p.m., this nominal price would become the target for price manipulation.

We believe that a fixed deadline and an extremely large price limit facilitate price manipulation in closing auctions. With the sole exception of the HKEx during the CAS period, all major stock markets around the world have enhancements to lessen closing price manipulation, particularly under the closing auction mechanism. These refinements include: (i) a daily price limit, (ii) a random (rather than fixed) deadline to determine the closing price, and (iii) a special price stabilizing mechanism to reduce extreme volatility of the closing price. Appendix B presents refinements to the closing auction mechanism to reduce extreme price movement in ten major stock exchanges around the world. The first refinement is to impose a tight daily price limit. This refinement is very common among major stock exchanges in Asia. Comerton-Forde and Rydge (2006) find that except for the Australian Securities Exchange, all Asia-Pacific stock markets have daily price limits. The second refinement adopts a random deadline in the closing auction mechanism. This refinement increases the costs to manipulate closing prices, as the closing time is non-deterministic. Examples of this refinement include the Australian Securities Exchange, the London Stock Exchange, and the Deutsche Börse. The third refinement includes a mechanism to stabilize the closing price. For example, the New York

Stock Exchange and Nasdaq have an order-balancing mechanism and widely disseminate the net order imbalance to market participants for orders designated to determine the closing price. In addition, in the final 15 minutes (20 minutes for Nasdaq) before the close, the NYSE accepts only orders that are on the stabilizing side of the market. Another form of the price-stabilizing mechanism is to trigger a volatility interruption when the closing price deviates significantly from the last transacted price or a pre-specified price limit. This mechanism is adopted by Euronext and the Deutsche Börse.

From Appendix B, we observe that the HKEx was unique among the top exchanges in adopting a plain-vanilla closing call auction system with no safeguard against price manipulation. Although many studies have shown that call auctions are efficient and effective in aggregating information and liquidity, it was the combination of a fixed deadline plus the lack of effective price limits that made the CAS in Hong Kong vulnerable to manipulation attacks. The lesson we take from the Hong Kong experience is that seemingly minor details can be very important with regard to the design and implementation of trading mechanisms.

Recent developments proposed by stock market operators in Asia are consistent with our claim. On September 26, 2011, the Singapore Exchange introduced a random closing time in its closing auction mechanism to prevent sniping from disrupting the market. Currently, the HKEx is considering re-launching the closing auction mechanism. It was proposed that the reinstated auction procedure should include a price variation control to discourage price manipulation. We believe that these measures, if adopted, can significantly improve the functioning of closing call auction procedures.

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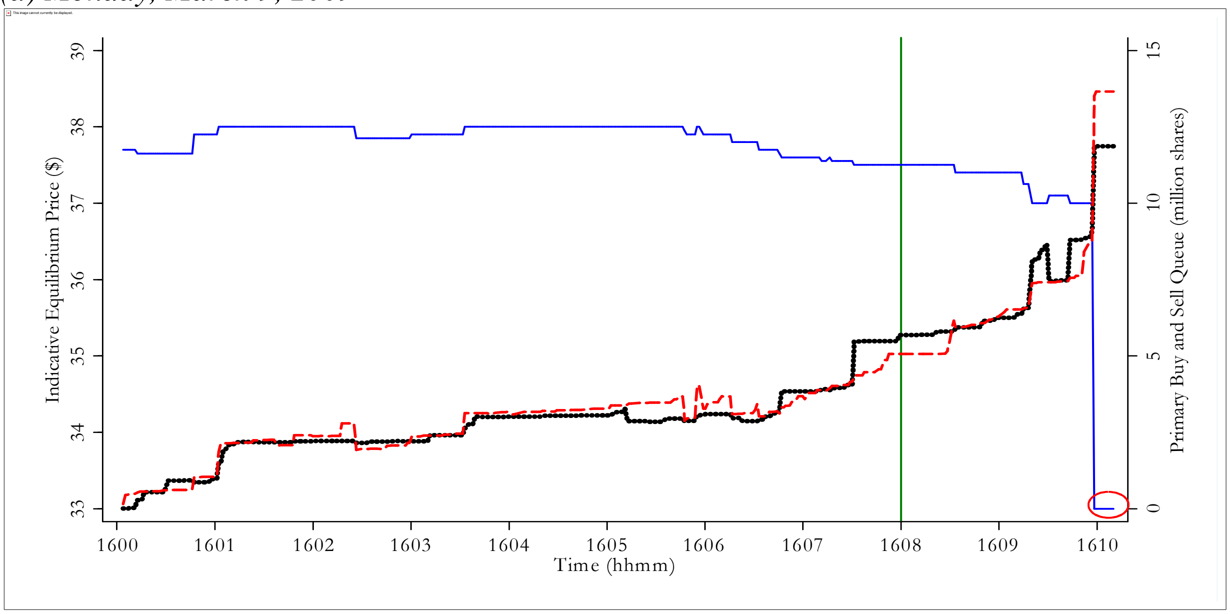
Figure 1. Indicative Equilibrium Price and Primary Buy and Sell Queue for HSBC Shares during the Closing Auction Sessions

The solid line represents the indicative equilibrium price (IEP); the dashed line represents the primary sell queue; and the dotted line represents the primary buy queue. The vertical line marks the beginning of the pre-order matching period, when order cancellation and amendment are prohibited. The circle represents the IEP at $33. According to the closing auction algorithm adopted by the HKEx, the IEP must be a price at and between the highest limit bid and the lowest limit ask and maximizes the matched shares, i.e., the indicative equilibrium volume (IEV). The primary sell (buy) queue is the queue of at-auction sell (buy) orders and at-auction limit sell (buy) orders with a specified price at or more competitive than the IEP.

(a) Monday, March 9, 2009



(b) Friday, March 6, 2009

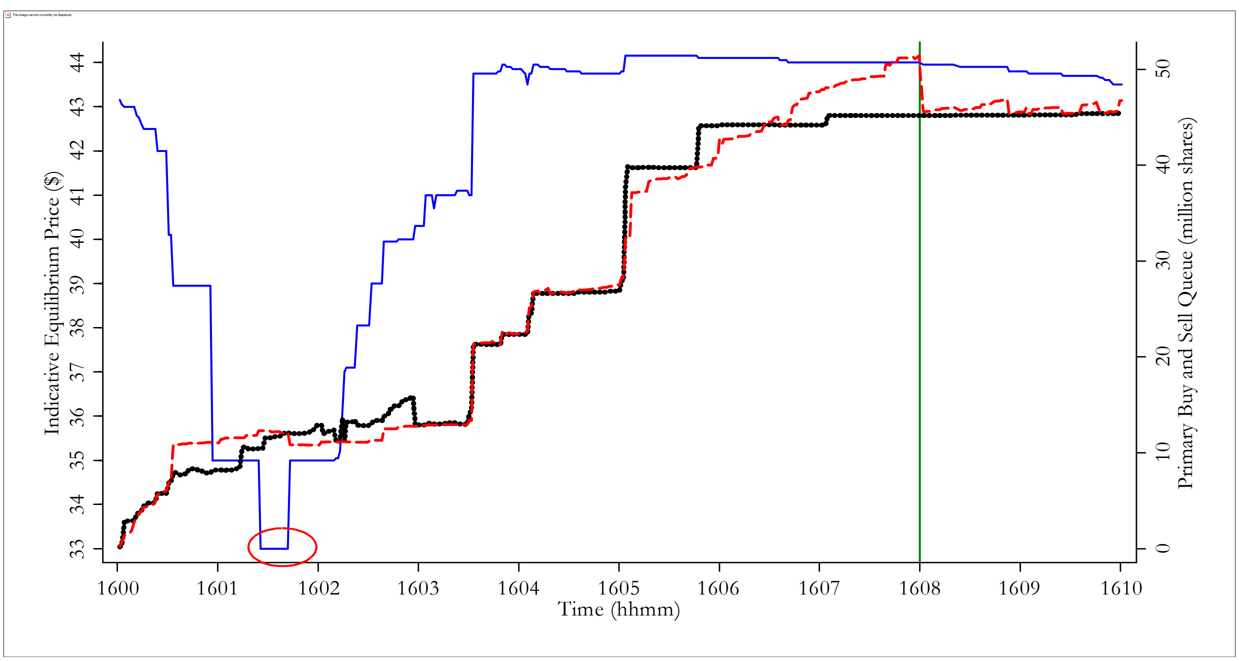


Table 1. Descriptive Statistics – Sniping

The binary variable `snipe(x)` takes the value of one if 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 four "benchmark intervals" in the final minute before the market close, where `x` is either `p` (price), `v` (trade volume), or `pv` (both price and trade volume). The "sniping measurement window" is the 5-second interval before the market close in the CAS period, i.e., 4:09:55–4:10:00 p.m. In the non-CAS period, it is the 5-second interval *prior to the snapshot nominal price being taken as the closing price*. The four benchmark intervals in the non-CAS period 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. Similarly, the comparable benchmark intervals in the CAS period are (i) 4:09:05–4:09:10 p.m., (ii) 4:09:20 p.m.–4:09:25 p.m., (iii) 4:09:35 p.m.–4:09:40 p.m., and (iv) 4:09:50 p.m.–4:09:55 p.m. We use the beginning and ending values of `x` to compute the 5-second absolute change in x of each interval. We measure price by IEP and trade volume by IEV in the CAS period. We measure the price by the actual transaction price and the trade volume by the actual transaction volume in the pre- and post-CAS periods. The corresponding standard errors are reported in parentheses.

	Pre-CAS	CAS	Post-CAS
`snipe(p)`	0.172	0.104	0.143
	(0.378)	(0.305)	(0.350)
`snipe(v)`	0.125	0.222	0.150
	(0.330)	(0.416)	(0.357)
`snipe(pv)`	0.0329	0.0707	0.0312
	(0.178)	(0.256)	(0.174)
N	9,543	7,816	9,695

Table 2. Sniping and Expired CBBCs

We use a probit regression model to examine the relationship between sniping and the number of expired CBBCs after controlling for firm fixed-effects. The dependent variable is our measure of sniping in price (`snipe(p)`), trade volume (`snipe(v)`) or both price and trade volume (`snipe(pv)`). The construction of these variables is explained in the notes to Table 1. The variable `ncbbc` shows the number of expired CBBCs for a stock on a given day. The variable `nonCAS` takes the value of one if the observation is taken in the pre-CAS and post-CAS periods, and zero if otherwise. 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. Estimates presented in the table are marginal effects.

	(1) `snipe(p)`	(2) `snipe(v)`	(3) `snipe(pv)`
`ncbbc×nonCAS`	-0.0354***	-0.0235***	-0.0160***
	(0.0111)	(0.0091)	(0.0061)
`ncbbc`	0.0313***	0.0220**	0.0071**
	(0.0108)	(0.0089)	(0.0036)
`nonCAS`	0.0604***	-0.0758***	-0.0310***
	(0.0080)	(0.0074)	(0.0033)
Firm fixed-effect	Yes	Yes	Yes
N	27,055	27,055	27,055
Pseudo R^2	0.0115	0.0172	0.0262

Table 3. Expired CBBCs, Day-high and Day-low at the Close, and Price Direction

We use a firm fixed-effects probit regression model to examine the effect of the number of expired CBBCs on the occurrence of day-low and day-high at the close and the direction of price movement in the sniping measurement window. The dependent variable `day-low` takes the value of one if the closing price of a stock is the lowest transacted price of the day for the stock, and zero otherwise, and `day-high` is analogously defined. $\Delta P_{5s}<0$ takes the value of one if the change in stock price in the 5-second sniping measurement window is negative and zero if otherwise and $\Delta P_{5s}>0$ is analogously defined. The independent variable `nbull` is the number of expired bull CBBC for a firm in the day, and `nbear` is the number of expired bear CBBC. The binary variable `nonCAS` takes the value of one if the observation is taken in the pre- or post-CAS periods. 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.

	(1) day-low	(2) day-high	(3) $\Delta P_{5s}<0$	(4) $\Delta P_{5s}>0$
nbull×nonCAS	-0.0086***		-0.0597***	
	(0.0029)		(0.0101)	
nbull	0.0090***		0.0599***	
	(0.0023)		(0.0099)	
nbear×nonCAS		-0.0158***		-0.0465***
		(0.0043)		(0.0106)
nbear		0.0190***		0.0419***
		(0.0041)		(0.0105)
nonCAS	-0.0363***	-0.0296***	0.2256***	0.2430***
	(0.0023)	(0.0022)	(0.0054)	(0.0091)
Firm fixed-effect	Yes	Yes	Yes	Yes
N	27,055	27,055	27,055	27,055
Pseudo R^2	0.0466	0.0327	0.0562	0.0597

Table 4. Large Price Change and Informativeness of Closing Price

We use a firm fixed-effects model to examine the effect of large price changes during the final 10-minute interval before the close on informativeness of closing price. For each period, we rank observations according to their absolute percentage price changes during the final 10-minute interval. Next, for each period a fixed number of observations with the largest absolute price changes (e.g., top 10, top 100, and top 200) are chosen and pooled together in each regression. We use the close-to-open return to proxy for informativeness of the closing price. The close-to-open return is the simple percentage stock return between the closing price of day t and the opening price of day t+1. The variable R_{10m} is the simple stock return in the final 10-minute interval before the close, i.e., 4:00–4:10 p.m. in the CAS period and 3:50–4:00 p.m. in the non-CAS periods. The variable R_m is the close-to-open return for the Hang Seng Index of the day. Robust standard errors clustered at the period level are reported in parentheses. Statistical significance is marked at the 1% (***), 5% (**) and 10% (*) levels.

Dependent Variable: Close-to-open Return

	(1) Top 10	(2) Top 100	(3) Top 200	(4) Top 500	(5) Top 1500	(6) Full Sample
R_{10m}×preCAS	0.4292	0.3978**	0.2503**	0.1059**	0.0843**	0.0673***
	(0.5942)	(0.0473)	(0.0373)	(0.0173)	(0.0102)	(0.0067)
R_{10m}×postCAS	0.7526***	0.3607***	0.2831***	0.1657***	0.1349***	0.1214***
	(0.0340)	(0.0226)	(0.0206)	(0.0066)	(0.0121)	(0.0063)
R_{10m}	-0.8726***	-0.4754***	-0.3629***	-0.2800***	-0.2542***	-0.2381***
	(0.0525)	(0.0345)	(0.0319)	(0.0087)	(0.0076)	(0.0046)
preCAS	8.5498	-0.4962*	-0.3938**	-0.1219	-0.0728*	0.0433**
	(5.5668)	(0.1441)	(0.0649)	(0.0595)	(0.0232)	(0.0062)
postCAS	6.4602*	-0.3134*	-0.1555	-0.0767	-0.0844**	0.0011
	(1.6716)	(0.0980)	(0.1140)	(0.0349)	(0.0140)	(0.0066)
R_m	0.0488	0.9101***	1.0153***	1.0010***	1.0016***	0.9620***
	(1.4723)	(0.0511)	(0.0114)	(0.0310)	(0.0172)	(0.0195)
constant	-3.6344*	0.6051**	0.2600*	0.1929**	0.1322***	0.0383***
	(0.9783)	(0.1308)	(0.0710)	(0.0236)	(0.0100)	(0.0029)
Firm Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
N	30	300	600	1,500	4,500	27,055
Pseudo R^2	0.5258	0.4295	0.5262	0.5526	0.5898	0.5805

Table 5. Expired CBBCs and Informativeness of Closing Price

We use a firm fixed-effects model to examine the effect of the number of expired CBBC on the informativeness of closing price. 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 variable `ncbbc` is the number of expired CBBC for a firm on a given day. Other variables are defined in the notes to Table 4. Robust standard errors clustered at the firm-period level are reported in parentheses. Statistical significance is marked at the 1% (***), 5% (**) and 10% (*) levels.

	(1) close-to-open return
$\mathtt{ncbbc}\times\mathtt{nonCAS}\times\mathtt{R}_{\mathtt{10m}}$	0.0868***
	(0.0247)
$\mathtt{ncbbc}\times\mathtt{R}_{\mathtt{10m}}$	-0.0815***
	(0.0239)
$\mathtt{ncbbc}\times\mathtt{nonCAS}$	0.0331
	(0.0489)
Ncbbc	-0.0332
	(0.0489)
$\mathtt{nonCAS}\times\mathtt{R}_{\mathtt{10m}}$	0.0679
	(0.0549)
$\mathtt{R}_{\mathtt{10m}}$	-0.2197***
	(0.0526)
nonCAS	0.0202
	(0.0219)
$\mathtt{R}_{\mathtt{m}}$	0.9620***
	(0.0300)
Constant	0.0405**
	(0.0193)
Firm fixed-effect	Yes
N	27,055
adj. R^2	0.5807

Table 6. Sniping and Informativeness of Closing Price

We use the firm fixed-effects model to examine the effect of sniping on price informativeness. 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(x)` refers to our measure of sniping in price (`snipe(p)`), trade volume (`snipe(v)`) or both price and trade volume (`snipe(pv)`). The construction of these variables is explained in the notes to Table 1. The variable R_{5s} is the 5-second stock return in the sniping measurement window for the stock. The variable `nonCAS` takes the value of one if the observation is taken in the non-CAS, and zero otherwise, and R_m is the close-to-open return for the Hang Seng Index of the day. 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

	(1) snipe(p)	(2) snipe(v)	(3) snipe(pv)
snipe(x)×nonCAS×R_{5s}	1.4128*** (0.5042)	0.9847*** (0.3123)	1.1904*** (0.3322)
snipe(x)×R_{5s}	-1.2383** (0.4938)	-1.1249*** (0.2854)	-1.2134*** (0.2853)
snipe(x)×nonCAS	-0.1011 (0.0822)	-0.0408 (0.0563)	-0.0371 (0.1101)
snipe(x)	0.1043 (0.0780)	0.0418 (0.0480)	0.0950 (0.0968)
NONCAS×R_{5s}	-0.9449** (0.4224)	-0.6526*** (0.2280)	-0.7256*** (0.1979)
R_{5s}	0.7769* (0.4162)	0.6072*** (0.2205)	0.6588*** (0.1906)
nonCAS	0.0385* (0.0228)	0.0387 (0.0250)	0.0345 (0.0223)
R_m	0.9589*** (0.0301)	0.9589*** (0.0301)	0.9588*** (0.0301)
constant	0.0131 (0.0196)	0.0135 (0.0218)	0.0161 (0.0194)
Firm fixed-effects	Yes	Yes	Yes
N	27,054	27,054	27,054
adj. R^2	0.5771	0.5772	0.5773

Table 7. Restriction on 24-tick on Informativeness of Closing Price

We use a firm fixed-effects model to examine the effect of violation of the 24-tick rule on the informativeness of closing price. 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 variable `buy24tick` (`sell24tick`) is a binary variable and takes the value of one if the largest (smallest) indicative equilibrium price taken within the final two-minute interval before the close deviates more than 24 ticks from the transacted price taken at the final ten-minute interval before the close, i.e., 4:00 p.m. in the CAS period and 3:50 p.m. in the non-CAS periods. The variable `24tick` takes the value of 1 if `buy24tick` is one, −1 if `sell24tick` is one, and 0 otherwise. The other variables are defined in the notes to Table 4. Robust standard errors clustered at the firm-period level are reported in parentheses. Statistical significance is marked at the 1% (***), 5% (**) and 10% (*) levels.

	(1) close-to-open return	(2) close-to-open return
buy24tick×nonCAS		1.4141
		(0.9068)
buy24tick		-1.9782***
		(0.7160)
sell24tick×nonCAS		-2.2284**
		(0.8725)
sell24tick		2.1868***
		(0.5652)
24tick×nonCAS	1.7183**	
	(0.7245)	
24tick	-2.0422***	
	(0.5904)	
nonCAS×R_{10m}	0.0556	0.0552
	(0.0535)	(0.0535)
R_{10m}	-0.2049***	-0.2050***
	(0.0511)	(0.0512)
nonCAS	0.0223	0.0228
	(0.0221)	(0.0220)
R_m	0.9615***	0.9616***
	(0.0300)	(0.0301)
Constant	0.0384*	0.0382*
	(0.0196)	(0.0195)
Firm fixed-effect	Yes	Yes
N	27,055	27,055
adj. R^2	0.5811	0.5811

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 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. 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)		Ask (Sell Orders)						
Price	Quantity	Price	Quantity	Price	Acc. Buy	Acc. Sell	Matched Order	Order Imbalance
At-auction	1,000	At-auction	2,000	$39	2,000	13,600	2,000	11,600
$39	1,000	$33	100	$38	3,000	3,600	3,000	600
$38	1,000	$37	1,000	**$37**	**4,000**	**3,100**	**3,100**	**900**
$37	1,000	$38	500	$33	4,000	2,100	2,100	1,900
		$39	10,000					

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)		Ask (Sell Orders)						
Price	Quantity	Price	Quantity	Price	Acc. Buy	Acc. Sell	Matched Order	Order Imbalance
At-auction	1,000	At-auction	20,000	$39	2,000	31,600	2,000	29,600
$39	1,000	$33	100	$38	3,000	21,600	3,000	18,600
$38	1,000	$37	1,000	$37	4,000	21,100	4,000	17,100
$37	1,000	$38	500	**$33**	**4,000**	**20,100**	**4,000**	**16,100**
		$39	10,000					

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)		Ask (Sell Orders)						
Price	Quantity	Price	Quantity	Price	Acc. Buy	Acc. Sell	Matched Order	Order Imbalance
At-auction	19,000	At-auction	2,000	**$39**	**20,000**	**13,600**	**13,600**	**6,400**
$39	1,000	$33	100	$38	21,000	3,600	3,600	17,500
$38	1,000	$37	1,000	$37	22,000	3,100	3,100	18,900
$37	1,000	$38	500	$33	22,000	2,100	2,100	19,900
		$39	10,000					

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)		Ask (Sell Orders)						
Price	Quantity	Price	Quantity	Price	Acc. Buy	Acc. Sell	Matched Order	Order Imbalance
At-auction	1,000	At-auction	2,000	$39	2,000	13,500	2,000	11,500
$39	1,000	~~$33~~	~~100~~	**$38**	**3,000**	**3,500**	**3,000**	**500**
$38	1,000	$37	1,000	$37	4,000	3,000	3,000	1000
$37	1,000	$38	500					
		$39	10,000					

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

Appendix B. Using Auction Mechanism to Reduce Extreme Price Movement in Ten Major Worldwide Stock Exchanges[a]

This table presents refinements to the closing auction mechanism to reduce extreme price movements in ten 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 of the previous closing price)	Fixed	No
Korea Exchange	Yes (±15% 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
Australian Securities Exchange	No	Random	No
London Stock Exchange	No	Random	No
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)
Deutsche Börse	No	Random	Yes (triggers a volatility interruption when the indicative closing price falls outside a pre-defined price range)
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.