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Effectiveness of the conditional random-end trading mechanism on the Korea Exchange: Normal trade and Option Shock

ABSTRACT

Option Shock was a notable 2010 manipulation in Korean stock and derivatives markets. Motivated by Option Shock, we examine the effectiveness of the conditional random-end (RE) trading mechanism during the opening or closing call auction on the KRX. We find the RE trading mechanism promotes price stabilization, but with some reservations, and improves price discovery and efficiency at the open, but causes overshooting at the close. We also find it somewhat effective in filtering out spoofing orders, but failed to stabilize the market in the extreme case of Option Shock, which motivated a change to an unconditional RE trading mechanism.

Keywords: Random-end trading mechanism; Call auction; Price discovery; Price stabilization; Option-linked manipulation
JEL Classification: G10, G18, G20

1. INTRODUCTION

On November 11, 2010, a KOSPI 200 index options expiration date, the Korea Exchange (KRX) experienced the so-called "Option Shock."[1] During the 10 minutes of the closing call auction, the KOSPI composite index dropped 2.46%, while the price of the deep out-of-the-money (OTM) put option skyrocketed almost 500 times. This shock turned out to be price manipulation by a foreign securities firm (Deutsche Bank) which sold massively in the spot market connected to the derivatives market on the KOSPI 200 index, and garnered a whopping 40.5 million USD (44.9 billion KRW) profit (see Section 2.3 for details). Option Shock was the largest manipulation connected with stock and derivatives in the history of the Korean financial markets (see Section 6.2), and so has drawn great attention from investors and regulators looking to revamp rules and regulations.[2] More specifically, the KRX had in place a random-end (RE) trading mechanism that was particularly designed to improve market quality[3] and restrict price manipulation during the opening or closing call auction, and thus an event such as Option Shock calls for scrutiny of the effectiveness of this specific market microstructure.

An RE trading mechanism, a key feature in the call auction mechanism, randomizes the opening and closing times within a brief randomly-chosen span of time, usually 30 seconds to 5 minutes. The major world exchanges[4] have adopted RE trading mechanisms for the same

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[1] KOSPI stands for the Korea Composite Stock Price Index. However, it is popularly used for the KOSPI market as well. In this paper, to avoid the confusion, we use KOSPI for the KOSPI market. When we mention indices, then we use either the KOSPI 200 index or the KOSPI composite index. The KRX is comprised of two equity markets, KOSPI and KOSDAQ. KOSPI is the main board, while KOSDAQ is the new (or growth) market which provides funding mainly to IT-related, newly incorporated, and/or innovative small- and medium-sized enterprises (SMEs).

[2] There was a great deal of news coverage of this event. For examples, Jin-Seo Cho, "Deutsche Bank faces probe over KOSPI shock," The Korea Times (November 28, 2010); Simon Mundy & Jung-A Song, "Deutsche Bank S Korea employee jailed for role in market plunge," The Financial Times (January 25, 2016).

[3] http://global.krx.co.kr/board/GLB0205020100/bbs#view=19813.

[4] European exchanges, especially Deutsche Börse (DB), Euronext, and the London Stock Exchange (LSE) have been praised for providing some of the most sophisticated RE trading mechanisms in the world. For details, see Section 2.2 for the KRX motivation and page 25 of Deutsche Börse Group (2014) for DB.

purpose as the KRX (see e.g., Abad & Pascual, 2010; Brugler, Linton, Noss, & Pedace, 2018).[5] The randomization is primarily designed to enhance the market integrity by forcing traders to withdraw orders that were not intended to be executed, but instead intended solely to manipulate the price. In addition, on the expiration days of derivative contracts whose prices are closely connected to the prices of underlying stocks, the threshold for invoking the RE trading mechanism is drastically reduced to prevent a possible surge of manipulation. The randomization is intended to enhance price discovery, efficiency, and stabilization during the opening and closing call auctions.

But are RE trading mechanisms effective in achieving these goals? The KRX provides an ideal opportunity to address these questions. First, it experienced a large manipulation, Option Shock, during the period when the conditional RE trading mechanism was in effect. Second, it altered the parameters of the conditional RE mechanism in the aftermath of Option Shock and then removed the conditionality of RE invocation four years later, allowing us to examine each marginal effect of the whole life-cycle of the conditional RE mechanism (see Section 2.2 for details). More specifically, we address the following concrete questions in this paper: Is the conditional RE trading mechanism effective for price discovery and stabilization? Does it make a contribution to price efficiency? Is it effective against price manipulation connected to the expiration of derivative contracts such as index options and futures? How effective is the conditionality of RE invocation compared to the automatic RE invocation (i.e., the unconditional RE trading mechanism) with the RE session shortened during the opening and closing call auctions?

[5] Abad & Pascual (2010) report that the volatility interruptions of Spanish Stock Exchange (SSE) have a 30-second RE session and "The goal of this random end is to avoid price manipulation." Brugler et al. (2018) state that the LSE introduced a RE mechanism "to remove the incentive to enter erroneous orders that would unduly affect price formation towards the end of the auction." We believe they meant "manipulative" or "spoofing" orders, rather than "erroneous" orders; it is hard to see how an RE could correct errors, but easy to see how it discourages manipulative orders.

The extensive literature on the call auction mechanism in general has documented that it improves price discovery and the market's ability to absorb liquidity shocks, and reduces information asymmetry problems and price manipulation (Madhavan, 1992; Pagano & Schwartz, 2003; Hagströmer & Nordén, 2014; Hillion & Souminen, 2004; Comerton-Forde & Rydge, 2006; Lei, Ma, & Yick, 2020). However, most of this literature does not investigate either the built-in RE component or its effectiveness against price manipulation operating between spot and derivatives markets. For RE mechanisms, there is one theory paper (Medrano & Vives, 2001) and a few empirical papers (Hauser, Kamara, & Shurki, 2012; Zimmermann, 2013; Guillaumie, Loiacono, Winkler, & Kern, 2020). They generally come to the conclusion that RE mechanisms improve price discovery and stabilization, and reduce price manipulation or distortion during the call auction. However, the empirical papers analyze RE as part of a "*volatility interruption*" system, rather than on its own, and they do not address the effectiveness of RE against price manipulation connected to the expiration of derivative contracts. To our knowledge, no paper addressed the effectiveness of RE mechanisms on manipulative attempts connected to derivatives trading. Lei et al. (2020) examine the effectiveness of the closing call auction in the Hong Kong Stock Exchange (HKEx), focusing on the underlying stocks of exchange-traded derivatives (callable bull/bear contracts). However, they cannot separately examine the roles and functions of RE mechanisms because they use daily data. We further discuss how our study can be distinguished from the existing literature in Section 3.

Our main analyses examine trade and quote (TAQ) data of the opening and closing call auctions from 1,567 stocks listed on the KRX stock markets from 2009 to 2010, including the day of Option Shock. We also use two other complementary datasets: One-minute intraday data of the KOSPI 200 index from January 2006 to December 2015 and TAQ data of all stocks listed on the KRX

from May 30, 2011 to May 30, 2012, and from June 15, 2015 to December 31, 2015. We find the following empirical results and implications.

First, for the price-discovery effect of the conditional RE trading mechanism, we perform an unbiased regression analysis as in Biais, Hillion, & Spatt (1999). We find that the conditional RE trading mechanism makes a meaningful contribution to price discovery for the opening price, but price discovery for the closing price is delayed from the beginning of the closing call auction at 14:50 to RE invocation at 15:00 and that prices overshoot during the RE session. This indicates that it might be desirable for the KRX to employ multiple RE sessions at the close, as is the practice in Europe.

Second, for the effect of the conditional RE trading mechanism on price efficiency, we use a volatility analysis on the 15-minute (or 30-minute or 1-hour) returns calculated from the potential opening price at 9:00 and from the opening price (i.e., immediately after the RE session ends), respectively. We find a significant decrease in volatility when RE occurs, implying that the RE trading mechanism improves the efficiency of the opening price. Naturally, however, this improvement is not big enough to exceed price efficiency on the days when RE did not occur.

Third, for the price-stabilization effect of an RE occurrence, we employ a binomial distribution analysis on the price reversals. We find that the conditional RE trading mechanism stabilizes prices in most of the cases, but with some reservations since the potential price at the normally scheduled opening (or closing) price and the actual opening (or closing) price are equal in 43.3% of the 24,641 total RE occurrences in our sample.

Fourth, using Kuk, Liu, & Pham's (2016) definition of spoofing order, we find that there exists a substantial rate of spoofing orders in the opening and closing call auctions, especially at the close, and that spoofing orders fell sharply after RE invocation, at both the open and close, suggesting

that the RE mechanism helps to discourage spoofing. For the effect of RE trading mechanism against manipulative attempts connected to derivatives trading during the closing call auction, we further perform a comparative analysis and a simple time-series analysis using the numbers of RE occurrences in KOSPI 200 index constituent stocks and non-constituent stocks. We find that RE occurs significantly more in non-constituent stocks than in constituent stocks, suggesting that the KRX RE trading mechanism is invoked for additional reasons other than events related to index options and futures. In nutshell, the conditional RE mechanism is effective in filtering spoofing orders out to some extent, but it failed to stabilize the market in an extreme case such as Option Shock.

Fifth, following the same methodology as used in the analyses for the conditional RE trading mechanism, we find that the limited efficacy of the RE trading mechanism has been largely addressed by two subsequent rule changes: the KRX reduced the threshold at the close on option expiration days from 5% to 3% in May 2011, and lowered the threshold to 0% and shortened the length of the RE session to 30 seconds on all days in June 2015. The first change improved the price-stabilization effect moderately, while the second change addressed the overshooting problem at the close and helped the prices at the normally scheduled open and close to reflect the true prices.

This paper makes contributions to the literature in three important ways. First, while the KRX was one of the leading stock and derivatives markets in the world during our sample period, its RE trading mechanism was less sophisticated than those of major European exchanges. Our study allows us to obtain insight on how to set the parameters of the RE trading mechanism for a specific market with a given level of maturity. Second, the closing call auction is especially important in derivatives markets because the closing price is generally used to compute the settlement of derivative positions (Chang, Chou, & Yang, 2019). However, as Option Shock demonstrates,

price manipulation can be done in the stock and derivatives markets together to create arbitrages, so the details of the closing call auction, including the RE feature, need careful scrutiny of the type we carry out. Third, because the increased prevalence of algorithmic and high-frequency trading has drastically changed global markets, practitioners, market operators, and policymakers have become increasingly interested in the RE trading mechanism for its roles in ensuring price discovery, market stability and integrity, and investor protection. Hence, our research provides meaningful insight on the economic functions and roles of RE trading mechanisms to both academics and practitioners.

The remainder of the paper is organized as follows. Section 2 briefly describes the trading mechanism at the open and close on the KRX, including its RE trading mechanism, and Option Shock. Section 3 reviews the related literature and Section 4 discusses the data and the characteristics of the stocks for which RE occurred. Section 5 investigates the effectiveness of the KRX RE trading mechanism in terms of price discovery, efficiency, and stabilization. Section 6 analyzes the effectiveness of the RE trading mechanism in relation with spoofing orders and provides policy implications. Section 7 provides further discussion regarding the marginal effects of the ensuing rule changes on the price stabilization and discovery of RE trading mechanism. We conclude the paper in Section 8.

2. THE KRX CALL AUCTION MECHANISM AT THE OPEN AND CLOSE, AND OPTION SHOCK

2.1. The normally scheduled open and close

Here, we describe the KRX opening and closing call auction mechanisms in place through our

sample period; for convenience, we use present tense.[6] The KRX starts accepting orders for the opening (closing) call auction at 8:00 (14:50). For each stock, it announces the projected price (or indicative price), which is the real-time auction price, from 8:10 (14:50) for the open (close). During this pre-opening (closing) time, the KRX publicly discloses the three best bid and ask prices and the number of shares desired or offered at those prices. The KRX also starts disclosing publicly the projected level of the KOSPI 200 index, calculated from the projected prices of the constituent stocks, from 8:30 (14:50).

The projected price of any given stock fluctuates as orders are placed or withdrawn. During our sample period, if the extreme distance exceeds the threshold of 5%, then the RE trading mechanism extends the call auction for the given stock for a brief randomly-chosen span of time, RE session, with a five-minute maximum duration. Otherwise, the market for the given stock opens (closes) at the normally scheduled time at 9:00 (15:00).

2.2. The RE trading mechanism

An RE trading mechanism is an integral part of a call auction mechanism. Opening and closing prices of individual stocks in a traditional limit-order book stock exchange are typically determined by call auctions, in which the exchange accumulates orders that are held but not executed until the open or close. These call auctions for individual stocks have generally evolved to include an RE trading mechanism, namely a randomization of the opening or closing time. The ending time of the call auction is not fixed, but extended automatically (hereafter "*unconditional*") or under certain

[6] Since our sample period, the KRX has changed its opening and closing call auction times. On April 29, 2019, for the opening call auction, the KRX changed the starting time to accept orders from 8:00 to 8:30 and to publicly disclose the projected (or indicative) prices from 8:10 to 8:40. On August 1, 2016, the KRX changed the closing time of the stock markets from 15:00 to 15:30 and that of the derivatives markets from 15:15 to 15:45. Accordingly, the closing call auction time was changed from 14:50 to 15:20.

circumstances (hereafter "*conditional*") for a brief randomly-chosen span of time less than or equal to a "*maximum duration.*" The random-ending time is not announced until it is reached. In practice, the maximum duration of an RE session is usually set at 30 seconds to five minutes on most global exchanges.

[Insert Figure 1 about here]

In a conditional RE trading mechanism, the orders are used to project an opening or closing price on a real-time basis over a certain time interval (e.g., five or ten minutes) before the normal opening or closing time.[7] The *projected price* may fluctuate, as orders are placed or withdrawn; see Figure 1 for a detailed illustration. The projected price at the normally scheduled opening or closing time is called the *potential price*. The *extreme projected price* is the projected price with the largest absolute difference from the potential price; the absolute difference between the extreme projected price and the potential price is called the *extreme distance*. If the extreme distance exceeds a threshold (expressed as a percentage of the potential price), the RE trading mechanism is invoked and the call auction extends for a brief randomly-chosen span of time (hereafter the "RE session"); otherwise, the market opens or closes at the normally scheduled time. For example, during our sample period, the KRX calculated the extreme distance over the five minutes before the open or close. This is the sense in which the KRX RE mechanism was conditional. If the threshold is zero, then the RE trading mechanism is invoked for all listed stocks at the normal opening or closing time, i.e., the RE trading mechanism is unconditional. The random length of the extension is not announced until the extension ends.

[7] Here, the "normal" opening or closing time means the scheduled opening or closing time that is fixed on each trading day (e.g., at 9:00 or 15:00 at the KRX), unless the [conditional] RE trading mechanism is invoked. The same projected price rules apply both on days on which the RE mechanism is invoked and those on which it is not invoked, up until the normal opening or closing time. On days on which the RE mechanism is invoked, the projected price continues to fluctuate through the RE session.

A variety of RE trading mechanisms have been developed especially in Europe and in the U.S., and now RE trading mechanisms are very broadly used globally. The major European exchanges adopted RE trading mechanisms with a goal of protecting investors, reducing potential price manipulation, and promoting market stabilization when the stock price moves dramatically due to market overshooting. Hence, in Europe, the RE trading mechanism is widely utilized as a built-in conditional tool by which stock exchanges try to maximize positive effects from their volatility interruption[8] during the continuous trading session as well as at the open and close. The European exchanges allow for two or three consecutive RE sessions to achieve the objectives of the volatility interruption (see London Stock Exchange, 2020). For example, in the London Stock Exchange (LSE), the 30-second unconditional RE is embedded in the opening volatility interruption for all listed stocks on the Main Market between 7:50 and 8:00. However, if a potential price exceeds a pre-determined price range,[9] then the call period is extended by 5 minutes and the 30-second RE session is held at 8:05. If the potential price still exceeds the pre-determined price range, then the call period is extended by another 5 minutes, and the 30-second RE session is held at 8:10. This is called the Price Monitoring Extension (PME).

In contrast, U.S. versions of volatility interruption in stock or derivatives markets do not include RE trading components mainly due to the existence of a market maker.[10] For the U.S., both stock and derivatives markets introduced volatility interruptions intended to prevent the recurrence of the

[8] A volatility interruption is a sophisticated microstructure mechanism providing cooling-off periods and effective price discovery in brief periods of abnormal volatility. Even though academics have broadly defined the volatility interruption as a kind of circuit breakers, it applies only to an individual stock, not to the market as a whole (see Brugler, et al., 2018). In this sense, volatility interruptions are implicit dynamic price-limit systems, compared to the explicit price-limit systems which most Asian exchanges have adopted (see Sifat & Mohamad, 2019). For an example of a volatility interruption, see Deutsche Börse Group (2014) and London Stock Exchange (2020).

[9] The pre-determined price range is public information in the LSE but Euronext does not announce it, to increase the uncertainty among potential price manipulators.

[10] Instead of a conditional RE trading mechanism, for example, the orders placed in the New York Stock Exchange (NYSE) between 9:28 and 9:35 cannot be canceled. This is a typical call auction mechanism at the open or close when an exchange has a market maker.

Flash Crash of May 6, 2010, which was arguably caused by a price manipulator, Navinder Singh Sarao. Since February 2014, all U.S. stock markets have adopted Limit Up/Limit Down (LULD), which is a system of single-stock circuit breakers (see Hautsch & Horvath, 2019). For derivatives markets, for example, the Chicago Mercantile Exchange (CME) introduced "*Velocity Logic* (VL)," a sophisticated version of LULD, to its Globex products in September 2015. A generic VL of a futures product is invoked when an incoming order is beyond upper- and lower-price limits of the reference price. Both price limits and the reference price are set based on those in the "Lookback Window," one-second period immediately prior to the incoming order. Once VL is invoked, then the trading is paused for 5 to 10 seconds and resumed depending on products, regardless of trading sessions, including the opening.[11] If the trading in a futures product is paused, so is the trading in its related options products.

The intended purpose of the conditional RE trading mechanism in the KRX was narrower and more specific than in the European exchanges. The KRX introduced the RE trading mechanism on January 26, 2004 (March 7, 2005) on KOSPI (KOSDAQ) to "prevent price manipulation utilizing spoofing orders and protect investors during the call auction at the open and close" (see Eom, Kang, & Lee, 2008). The KRX RE trading mechanism throughout our data period is as follows.

The threshold for invoking an RE session is an extreme distance of 5% within a five-minute period immediately prior to the normally scheduled opening (i.e., 9:00) or closing time (i.e., 15:00). The maximum duration of an RE session on the KRX is five minutes. Thus, the market opens or closes at a random time within this five-minute interval as shown in Figure 1.

[11] Most recently on December 6, 2018, there were more than 40 occurrences in VL to the Standard and Poor's 500 (S&P 500) index futures during the first six minutes after the open as the futures price plunged by 1.8%. 37,000 contracts were traded during the first 10 minutes at the open, which was extremely high compared to about 5,000 contracts on a regular day. This happened due to the liquidation of positions by large hedge funds following the news of Huawei CFO's arrest. In addition, the market had been closed the previous day for the funeral of former President George H. W. Bush. For details of the CME Globex's VL, see https://www.cmegroup.com/education/demos-and-tutorials/understanding-velocity-logic.html.

The period 2004-2015, during which the KRX adopted and revised its conditional RE trading mechanism, corresponds roughly to the period of the Korean stock markets' transition to an advanced emerging market.[12] During this period, the Korean stock markets also frequently experienced temporary increases in volatility; spoofers were suspected as the cause. Hence, the efficacy of the conditional RE trading mechanism adopted by the KRX can provide insightful lessons to many emerging (or advanced emerging) markets. Since June 15, 2015, when the transition to a sophisticated version of volatility interruption was completed, the RE trading mechanism has no longer been an independent trading mechanism, but rather an ancillary trading mechanism for volatility interruption in the KRX.[13] In the remainder of this paper, "RE trading mechanism" means a conditional RE trading mechanism, unless otherwise specified; we will return to explicitly use the term, conditional, in Section 7.2 where we compare the conditional RE trading mechanism with the unconditional RE trading mechanism on the KRX.

The effect of RE trading mechanisms during opening and closing call auctions, which we analyze in this paper, are quite different from those during the continuous trading session. Volatility interruptions during the continuous trading session are triggered by price movements of actual trades, greatly diminishing the possibility of manipulative orders. By contrast, the opening and closing RE trading mechanisms are triggered by movements of the projected price in a call auction, in which actual trade is not occurring; in the absence of an RE mechanism, manipulative orders can be placed and then withdrawn without risk of execution. We focus on the dynamic evolution of prices, in a way that cannot be done in cross-section.

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[12] Korea was included in "Developed indices" within the FTSE Global Equity Index Series starting in September 2009. According to the World Federation of Exchanges (WFE, 2015), the KRX ranked 18th in 2010, 16th in 2014 in terms of market capitalization in the world.

[13] As part of this major change in stabilization schemes for individual stock prices, the KRX changed its [conditional] RE trading mechanism to unconditional, with a maximum duration of thirty seconds rather than five minutes. For details and economic functions on the KRX volatility interruptions, see Eom, Kwon, La, & Park (2018).

2.3. Option Shock

On November 11, 2010, immediately before the closing call auction began at 14:50, the KOSPI composite index stood at 1,963.03. The KOSPI order book contained about 280 billion KRW (253 million USD)[14] of net buy orders by program traders using index arbitrage (i.e., net buying of individual stocks and shorting the index). At 14:57, Deutsche Bank branches in Hong Kong and Seoul submitted a block programmed sell order for about 2.44 trillion KRW (2.2 billion USD) worth of individual stocks. Shortly before placing the order, Deutsche Bank purchased 1.6 billion KRW (1.4 million USD) of put options and synthetic short futures on the KOSPI 200 index. The KOSPI composite index dropped by 48.30 from 1963.03 at 14:50 to 1,914.73 at the close, a 2.46% decline. The price of the deep OTM put option skyrocketed almost 500 times from little less than 1,000 KRW (0.92 USD), then the minimum price, to 499,000 KRW (450.4 USD) during the ten-minute closing call auction. Deutsche Bank roughly broke even on the block program sale combined with the synthetic futures contract; it earned a huge 44.9 billion KRW (40.5 million USD) from the OTM puts at the closing call auction, which was about 40 times the amount it paid for the options.

In terms of the monetary magnitude, the connection of stock and derivatives markets, and the briefness of strategic trading execution, this event remains the worst manipulation connected with stock and derivatives in Korean financial market history. The Financial Times (2016) quotes an expert as saying that "Stemming unfair trading and market manipulation has become one of the government's top priorities. Local authorities have taken this case particularly seriously because it [imposed] huge losses on many investors." However, the KRX already had an RE trading

[14] Here and throughout the paper, we convert KRW to USD at the exchange rate prevailing on the day in question.

mechanism that is particularly designed to improve market quality and restrict price manipulation during the opening or closing call auction, and thus an event such as Option Shock casts doubt on the effectiveness of this specific market microstructure.

3. RELATED LITERATURE

This paper is related to two lines of research. One is on RE trading mechanisms, while the other is on the effectiveness of RE trading mechanisms against manipulative attempts connected to derivatives trading at the close.

First, let us look into the papers on RE trading mechanisms. As far as we know, there are only a handful of papers—Medrano & Vives (2001), Hauser et al. (2012), Zimmermann (2013), and Guillaumie et al. (2020).[15] Medrano & Vives (2001) theoretically analyze the price discovery process during the opening call auction with an RE trading mechanism. They show that the RE trading mechanism can limit, but not eliminate, stock price manipulation, and that the market price does not converge to the fundamental value of the stock, no matter how many rounds of *tâtonnement* are carried out.

Empirically, Hauser et al. (2012) conduct an event study of the introduction of an unconditional RE trading mechanism at the market opening of the Tel Aviv Stock Exchange (TASE), to examine the effects of opening time randomization and options expiration on pre-opening and opening stock prices. They find that, after the adoption of an RE trading mechanism, the informativeness of pre-opening prices on the TASE improved significantly and pre-opening prices on expiration dates

[15] Even though Kuk et al. (2016) do not analyze an RE trading mechanism, we do make use of their definition of spoofing order; see Section 6.1. Abad & Pascual (2010) and Brugler et al. (2018) examine the effectiveness of European volatility interruptions which have built-in RE trading mechanisms; they do not investigate RE trading mechanisms themselves. In a paper in Korean, Eom & Park (2015) mainly focus on the relationship between RE occurrences and spoofing orders using graphical and cross-sectional analyses; the present paper has a broader research range, and greater analytic and methodological rigor.

became as accurate as on non-expiration dates, so that the distortions of opening prices on expiration dates became significantly smaller. Meanwhile, Zimmermann (2013) directly analyzes the efficacy of price stabilization and discovery of volatility interruptions, which contain built-in RE trading mechanisms, adopted by the DB Xetra platform. He reports that "volatility interruptions dissolve on average 36 percent of the pre-interruption price uncertainty," and that "this level of price discovery is a major determinant in shaping post-interruption market quality as subsequent continuous trading benefits conditionally on the price discovery condition of the interruption." In a recent paper, Guillaumie et al. (2020) analyzes VI occurrences on 40 EU trading venues from April 2016 to December 2016. They generally confirm those of Zimmermann (2013) on price-stabilization and price-discovery effects, and also report that, for the cross-listed stocks, "trading activity on the satellite market decreases drastically and liquidity dries up as investors refrain from trading waiting for the reference market to set the [VI] auction price."

Hauser et al. (2012) analyze RE trading mechanisms through an event study, just before and just after the adoption of the RE trading mechanism rule, including the price path but not the detailed placement and cancellation of orders. Our focus is on the detailed functioning of the RE trading mechanism, the path followed by the projected price, the changes in opening or closing price resulting from the RE mechanism, its effectiveness against spoofing orders at the open and close, especially on expiration days of derivatives. Zimmermann (2013) is closest to this paper. He directly examines the RE trading mechanism itself, but only during volatility interruptions (which incorporate call auctions with a [conditional] RE trading mechanism) occurring during continuous trading sessions, using cross-sectional methods. In addition, he does not discuss the potential manipulative trading in stock markets associated with derivatives markets while Option Shock and the literature (Lei et al., 2020) imply that it is likely to happen. Guillaumie et al. (2020)

make the first attempt for the efficacy of volatility interruptions in cross-listed stocks. In similar analyses as Zimmermann (2013), however, they cannot help but treat all data equally for the analyses since the data from those 40 trading venues are too different in parameters and characteristics.

Now, we discuss the research on the effectiveness of RE trading mechanisms against manipulative attempts connected to derivatives trading at the close. In a paper with similar research objectives to ours, Lei et al. (2020) report that an RE feature in the closing call auction in the HKEx reduces price manipulation connected to a derivative product.[16] In the HKEx, the closing call auction was first implemented in May 2008 but removed in March 2009. Then, it was reintroduced in an enhanced version in July 2016. Lei et al. (2020) note that the enhanced version has many refinements including a conditional RE (random closing), appearing to be more effective in the reduction of price manipulation. The extreme distances of RE trading mechanisms in the HKEx and KRX are both set to 5%, but the extreme event such as Option Shock suggests that RE trading mechanisms may be vulnerable to such events despite Lei et al.'s (2020) findings. In spite of sharing a conditional RE trading mechanism, the KRX closing call auction has substantial differences from that of the HKEx. In the HKEx, the closing call auction consists of four phases and the last phase, i.e., the RE session, does not allow any cancellation (see further details from Section 2.2 of Lei et al., 2020). In contrast, the KRX allows an order to be submitted, revised, or cancelled during the call auction without distinguishing phases or states, making it more vulnerable to manipulation attempts.

Our study is in the same line as Lei et al. (2020) in motivation, but our unique intraday data allow us to focus directly on the RE mechanism itself that is a critical feature of the call auction mechanism.

[16] Hagströmer & Nordén (2014) investigate the effects of the introduction of a closing call auction at the index futures market in Nasdaq OMX. Even though the closing call auction has an RE feature, it is on the futures market, not on the underlying stock market. They do not examine an RE feature independently.

It allows us to directly examine whether and how the RE mechanism affects price discovery and stabilization, and discuss its effectiveness in controlling potential price manipulation. In contrast, Lei et al. (2020) used daily data, which cannot separate an RE feature from the call auction mechanism.

4. DATA AND THE CHARACTERISTICS OF STOCKS WITH AN RE OCCURRENCE

In this paper, the main sample period is 504 trading days from January 2009 to December 2010. The objectives of this paper are to examine the economic roles and significance of the independent RE trading mechanism, including those related to the intermarket manipulations. Our sample period is appropriate for this analysis for the following reasons. First, we need a period when the [conditional] RE trading mechanism is only in place for the opening or closing call auction. The [conditional] RE mechanism adopted in the KRX from 2004 to 2015 was a very rare and unique experiment for our analyses. Second, our sample period should include Option Shock, which is central to our interest, but exclude any change in the mechanism. On May 30, 2011, six months after Option Shock, the KRX changed the threshold at the close to 3%, only on KOSPI index option and/or futures expiration days (see Section 7.1). Third, as documented in Section 2.3, there has been a continuing debate and revisions of the mechanism, so a thorough examination of the KRX RE mechanism is highly desirable, even based on a comparatively old data set. Fourth, the KRX RE mechanism was revised to unconditional RE in June 2015 and thus became an ancillary feature of volatility interruptions (see Section 7.2). By contrast, in our sample period, the [conditional] RE trading mechanism was the key feature of the closing session and thus it allows us to investigate the economic roles and significance of the [conditional] RE trading mechanism independent of other features, such as volatility interruptions.

For the sample stocks, we include all common stocks listed on KOSPI and KOSDAQ, except

Special Purpose Acquisition Companies (SPACs), investment companies (including Real Estate Investment Trusts, REITs), newly-listed or delisted stocks, and stocks that switched their listings from KOSDAQ to KOSPI within the data period. Altogether, our sample consists of 1,567 stocks, of which 671 stocks were listed on KOSPI and 896 stocks were listed on KOSDAQ.

For data, we use the KRX TAQ data for our sample stocks. We also reconstruct the real-time order book from the KRX TAQ data and use the complete set of actual RE occurrences provided by the KRX.

[Insert Table 1 about here]

Table 1 shows descriptive statistics on RE occurrences at the opening and closing call auctions in KOSPI and KOSDAQ. The total sample consists of 1,567 stocks over 504 trading days, so that the opening and closing call auctions were each held 789,768 times. In our sample, there were 24,641 RE events (3.1%) in total: 17,548 (4.4%) RE events at the open and 7,093 (1.8%) at the close. During our sample period, RE occurred in 1,497 stocks (95.5%) of our 1,567 sample stocks. Specifically, RE occurred in 606 stocks (90.3%) of 671 stocks listed on KOSPI and 891 stocks (99.4%) of 896 stocks listed on KOSDAQ. While RE occurred more in KOSDAQ than in KOSPI, almost all stocks listed on KOSPI and KOSDAQ experienced at least one RE event.

Meanwhile, more than half of the orders during the RE session were submitted in the first minute and few orders were submitted after three minutes, both at the open and close. This phenomenon was much stronger at the close than at the open.[17] In the KRX during our sample period, the random-ending time was selected as a computer-generated random number in the

[17] The median intervals are 81.5 and 91 seconds on the open/close on KOSPI (116 and 124 seconds on KOSDAQ), while the means are 82.5 and 90 seconds on KOSPI (115.7 and 122 seconds on KOSDAQ). There were 24 (8 on KOSPI, 16 on KOSDAQ, all at the opening) times when the interval exceeded five minutes. The KRX confirmed the validity of our results, but replied that it could not provide the details for investor protection reasons. Figure A1 of the Appendix shows the distribution of orders by ordinary, cancellation, and correction categories during the opening and closing RE sessions.

interval between zero and the maximum duration specified by the exchange (i.e., five minutes). However, the random number evidently does not come from a uniform distribution. There is a theoretical advantage to use an exponential distribution rather than a uniform distribution, because the exponential distribution has a constant hazard rate, while the uniform distribution has a low hazard rate at the beginning of the interval, increasing over time.

[Insert Table 2 about here]

Table 2 shows Spearman correlation among major characteristics of stocks and RE occurrences. Firm size (measured by market capitalization) and the number of RE occurrences in the opening (*nt_open*) or closing price (*nt_close*) are strongly negatively correlated (-0.62, -0.56). Hence, the smaller the firm size, the more RE occurrences in the opening or closing price. Additionally, RE events occur more frequently on stocks with low price (*prc*) or high volatility (*std_dev*), and this relation is stronger in the opening price than in the closing price. The results from Pearson correlation are qualitatively similar, and available from the authors on request.

We also use two other complementary datasets to further discuss our main results in Sections 6 and 7. One consists of one-minute intraday data of the KOSPI 200 index from January 2006 to December 2015. The other consists of TAQ data of all stocks listed on the KRX from May 30, 2011 to May 30, 2012, and from June 15, 2015 to December 31, 2015.

5. PRICE DISCOVERY, EFFICIENCY, AND STABILIZATION

In this section, we investigate the effectiveness of the KRX RE trading mechanism, especially in terms of price discovery, efficiency, and stabilization. Then, we further discuss its role in relation to Option Shock in Section 6 and the changes resulting from later revisions in Section 7.

5.1. Price-discovery effect

To identify the price-discovery effect of the RE trading mechanism, we compare the price-discovery effect of the stocks for which RE did not occur (hereafter "non-RE stocks") to that of the stocks for which RE occurred (hereafter "RE stocks"). We estimate the price-discovery effect utilizing an unbiased regression proposed by Biais et al. (1999), who analyze all the sample stocks using seemingly unrelated regressions (SUR). Compared to Biais et al. (1999), however, we have too many sample stocks and too few days to run SUR. Therefore, instead, we first estimate the coefficients from simple OLS regressions of equation (1) for each stock and then average the coefficients of all stocks.[18]

$$\frac{V_i - E(V_i|I_0)}{E(V_i|I_0)} = \alpha_{i,t} + \beta_{i,t} \left[\frac{P_{i,t} - E(V_i|I_0)}{E(V_i|I_0)}\right] + z_{i,t} \tag{1}$$

where V_i is the opening price of stock *i*, $E(V_i|I_0)$ is the previous day closing price of stock *i*, $P_{i,t}$ is the projected price of stock *i* at pre-opening time *t*, and $z_{i,t}$ is an error term. For testing, we first estimate the coefficient $\beta_{i,t}$ of equation (1) for each stock *i* listed on the KRX. Next, we categorize all the sample stock-day pairs into two groups, RE stocks and non-RE stocks, and then average the coefficients at each minute from 8:10 to the opening time for each group of RE stocks and non-RE stocks. Finally, we perform a paired *t*-test for the difference in mean of the two groups for each minute.

[18] SUR is not applicable to our setting because it requires that the number of days be large relative to the number of stocks, which is not the case. OLS is consistent, but less efficient than SUR in settings in which SUR is applicable. We also considered using paired sample to control for firm characteristics. However, the number of firms that experienced RE during our sample period exceeds 90% of the listed firms, hence there are not nearly enough candidate matching firms.

[Insert Figure 2 about here]

Panel A in Figure 2 displays the mean of coefficients (or slopes) $\beta_{i,t}$ of equation (1) for each group of RE stocks and non-RE stocks at each minute at the open. The price discovery of RE stocks is a little faster than that of non-RE stocks until 8:25, but, after that time, it slows down. Thus, before the regularly scheduled opening time, the group of RE stocks generally shows delayed price discovery. During the RE session after 9:00, however, $\beta_{i,t}$ of RE stocks becomes close to 1 and is larger than that of non-RE stocks at 9:00, indicating that the KRX RE trading mechanism makes a meaningful contribution to the price discovery at the open. Our result supports the "no-manipulation-hypothesis" proposed by Medrano & Vives (2001);[19] by contrast, Hauser et al. (2012) find that $\beta_{i,t}$ did not necessarily converge to 1. Put differently, the KRX RE trading mechanism makes a meaningful contribution to price discovery for the opening price, sufficient to support the no-manipulation-hypothesis proposed by Medrano & Vives (2001).

Panel B in Figure 2 depicts the price-discovery effect for each group of RE stocks and non-RE stocks at the close, which is quite different from the price-discovery effect at the open. The price discovery of RE stocks is delayed from the beginning of the closing auction at 14:50 to the RE occurrence at 15:00. Moreover, $\beta_{i,t}$ goes down briefly immediately after 15:00 and then moves above 1 during the rest of the RE session, indicating that the prices overshoot during the RE session.[20] This seems to be closely related to the fact that trading on the KRX is not active after the closing auction. With the lack of trading opportunity for the rest of the day, some traders, possibly high frequency or day traders, want to make their positions as flat as possible, i.e., close

[19] According to them, the pre-opening price, in a competitive market with no manipulation, converges to the full-information price, so that their "no-manipulation-hypothesis postulates that $\beta_{i,t} = 1$ in the last minute before the opening of trade" (see Hauser et al., 2012).

[20] Unlike at the open, prices overshoot at the close. Even so, this does not support the result of Hauser et al. (2012), but rather supports the no-manipulation-hypothesis by Medrano & Vives (2001) since $\beta_{i,t}$ moves below and over 1.

out their positions to the extent possible. This indicates that it might be desirable for the KRX to adopt multiple RE sessions[21] at the close, as is the practice in Europe. Especially when an extreme price manipulation is feasible, for example on witching days, the adoption of multiple RE sessions at the close might be essential for the effectiveness of the mechanism.

5.2. Price-efficiency effect

To see the effect of the RE trading mechanism on price efficiency, we utilize a conventional method in the finance literature (Hagströmer & Nordén, 2014; Hauser et al., 2012) and compare the volatility of 15-minute returns calculated from the potential opening price at 9:00 and to that of 15-minute returns calculated from the opening price (i.e., immediately after the RE session ends) for RE stocks, separately for the days when RE occurred (hereafter "RE days") and for the days when RE did not occur (hereafter "non-RE days").[22] So, we assume that an equilibrium price is reached 15 minutes after the open. Volatility is measured by standard deviation. To obtain meaningful standard deviations of the returns, we have limited our sample to 722 stocks for which RE occurred more than ten times.

We use a paired *t*-test twice. The first paired *t*-test compares the standard deviations of 15-minute returns calculated from the potential opening price at 9:00 to those of 15-minute returns calculated from the opening price for each stock on RE days. Table 3 shows that the volatility of 15-minute returns calculated from the opening price is lower than that of 15-minute returns calculated from the potential opening price, and is statistically significant at the 1% level. Assuming that the price about 15 minutes after the normal opening time is a true equilibrium price,

[21] This means that if the opening or closing price is still out of the threshold even at the end of the first RE session, then additional one or two RE sessions are allowed consecutively.
[22] Non-RE days mean all the trading days except RE days over our two-year sample period.

this implies that the RE trading mechanism improves the efficiency of the opening price.

[Insert Table 3 about here]

The second paired *t*-test compares the standard deviations of 15-minute returns calculated from the opening price on RE days to those on non-RE days, for each stock. Table 3 shows that the volatility of 15-minute returns calculated from the opening price on RE days is higher than that on non-RE days, and is statistically significant at the 1% level. This implies that the opening price on RE days is inefficient relative to that on non-RE days, which seems a natural result since the RE event itself is invoked when the opening (or closing) price discovery exhibits extreme volatility. In untabulated results, we also use 30 minutes and 1 hour instead of 15 minutes and confirm that the results are qualitatively similar.

5.3. Price-stabilization effect

When the gap between the projected price and the potential opening (or closing) price exceeds 5%, the KRX RE mechanism is invoked. We examine the changes between the extreme projected price and the potential price, and between the potential price and the actual opening (or closing) price. The reversal in these two changes is an indication of stabilization: the potential price had moved substantially as a result of orders, and this movement is reversed in whole or in part during the RE session.[23] As discussed in Section 2.2, these increases or declines of the potential price might result from information as well as manipulation. However, extremely short-lived volatility during the minutes of the opening or closing call auction is unlikely to reflect material information,

[23] Taking price reversal as an indication of stabilization during the RE session is analogous to the practice of taking price reversal as an indication of stabilization in daily data. According to theoretical (e.g., Foucault, Kadan, & Kandel, 2005; Roşu, 2009) and empirical studies (e.g., Lei et al., 2020), if the introduction of the closing call auction improves price accuracy, then the returns of close-to-open and open-to-close have a negative correlation since the closing call auction reduces much noise. Here, noise is caused by liquidity shocks or price manipulation, and the closing call auction corrects the noise. The RE trading mechanism has the same effect in intraday data.

as firms typically withhold material announcements until after the market has closed.

[Insert Table 4 about here]

To test the price-stabilization effect, we take three steps. At the first step, we examine how many times the potential opening (or closing) price moves up or down from the extreme projected opening (or closing) price when the RE event is invoked. As shown in Table 4, for the opening price, the number of times that the potential price moves up is 8,519, which is slightly less than the number of times (8,998) that the potential price moves down. However, they look balanced in general. In contrast, for the closing price, the number of upward movements is 4,708, which is almost twice the number of downward movements (2,372).

[Insert Table 5 about here]

At the second step, we examine the change between the potential price and the opening (or closing) price terminating the RE session. The third column A in Table 5 (and also the fifth column in Table 4) reports the number of RE events in which the potential price and the opening (or closing) price are equal, which implies that the RE mechanism did not affect the opening (closing) price; the total number is 10,674, or 43.3% of the 24,641 RE occurrences (KRX total in column A/KRX total in column D). This indicates either that the relatively large price movement was appropriate, or that it was inappropriate but the RE occurrence failed to correct it. Nonetheless, 56.7% of all RE occurrences had an effect on price. This effect is higher in KOSDAQ (57.3%) than in KOSPI (54.5%), but the difference is not statistically significant.

As the third step, we directly address whether the RE occurrences stabilized prices by examining price reversals. Specifically, we compare the number of reversals of price changes (column B in Table 5), which indicates price stabilization, with the number of continuations of price changes (column C in Table 5). If the potential price accurately reflected the information

available to the market and any change between the projected price and the opening (closing) price reflected the arrival of new information, the probability of a reversal should be exactly one-half and the observed distribution of the number of reversals would be binomial. If the number of reversals significantly exceeds half, it indicates that the RE mechanism is counteracting mispricing in the potential price, and hence stabilizing the price.[24] Table 5 shows that in seven out of eight cases (two exchanges, two years, open and close), the number of reversals was statistically significantly greater than one-half. The exception, the 2010 closing call auctions on KOSPI, the period containing Option Shock.

We considered performing a trinomial analysis. For this, however, we would need to make at least one additional assumption, that no new information that might affect the price arrived during the RE session. Without that assumption, we cannot separate the effects from the RE session and the informational arrival, and in particular cannot assign probabilities to the three possibilities (continuation, reversal, no change). However, there is a natural distribution, 50/50, over two possibilities (continuation and reversal), allowing us to use the binomial distribution for the price-stabilization effect of RE trading mechanism.

Next, we address the size of the price-stabilization effect. The results in Table 5 show that the reversals offset 24.3% and 25.8% of the extreme distances at the open and close, respectively. When the two changes go in the same direction, the second change averages 17.1% and 13.2% of the extreme distance. Thus, there are more price reversals than continuations, and the reversals

[24] Hence, our methodology is an event study, where each RE occurrence is an event. One might argue that we should use, as a control group, trades that occurred before the KRX implemented the RE mechanism. However, it is not possible to study RE occurrences in the period before the RE mechanism was implemented. Since our interest is the effect of RE occurrences on price stabilization, an event study focused on the RE occurrences is the most natural way to address the problem. Regarding our reversal test, one might object that, in intraday data, reversals are more common than continuations because of Bid-Ask Bounce. Bid-Ask Bounce is important in continuous trading, but not in call auctions. It is hard to see how Bid-Ask Bounce could be relevant in call auctions triggered by unusually large price moves that are many times larger than the typical Bid-Ask spread.

are larger than the continuations. Along with its price-stabilization effect, however, we should also note the result that the KRX RE trading mechanism failed to change the price in 43.3% of all RE occurrences. Altogether, the above three-step analysis shows that the RE trading mechanism stabilizes prices, but with some reservations.

6. MANIPULATIVE ATTEMPTS AND RE MECHANISM

6.1. Spoofing orders

It is well documented that, on the options and/or futures expiration days, attempts at price manipulation on the underlying index constituent stocks are often made at the closing call auction to generate a profit in the corresponding index options and/or futures positions (for example, see Hsieh, 2009). Option Shock in the Korean stock markets on November 11, 2010 proved that the Korean stock markets was not an exception.

There is much literature documenting that the closing call auction system on stock markets is important for reducing manipulation of closing stock prices on the settlement day of options and/or futures (see e.g., Kandel, Rindi, & Bosetti, 2012). Here, we focus on the impact of an RE mechanism, within the call auction, in reducing manipulation.

First, we investigate whether manipulative trading activities are substantially higher on the days when RE mechanism was invoked. Kyle & Viswanathan (2008) define illegal manipulation as "The violator's intent is to pursue a scheme that undermines economic efficiency both by making prices less accurate as signals for efficient resource allocation and by making markets less liquid for risk transfer." The placement of spoofing orders is one important example of a manipulative strategy. For empirical designs, it is generally very difficult to identify the violator's intent. Kuk et al.'s (2016) definition of spoofing order ("submit-cancel strategy" in

their terminology) supports a strong inference of manipulative intent: "A limit order is classified as strategic based on three criteria. First, the order should be executable upon submission[25] to convey a strong price signal to the rest of the market. Second, before the end of the pre-opening [or pre-closing] period, the order is withdrawn, revised out of the executable region, or in the case that the order has become non-executable since its submission, it is revised to become less executable. … Third, if the order is not canceled but only revised to non-executable prior to the open, it must continue to be non-executable right until the end of the first trading day or eventually canceled, indicating that the submitter has no intention to trade at any price prevailing during the day."

[Insert Figure 3 about here]

Figure 3 presents the ratio of spoofing buy (sell) orders to the number of ordinary orders on non-RE stocks, RE stocks on days RE was invoked (RE days), and RE stocks on days RE was not invoked (non-RE days), respectively at the open and close during our main sample period (January 2009 to December 2010). First, the common feature is that all stocks show much higher manipulative orders at the close than at the open, which is indeed consistent with the literature (Hagströmer & Nordén, 2014; Lei et al., 2020). Second, there are small differences between non-RE stocks (0.39%/6.26% for buy and 0.17%/4.06% for sell orders at the open/close) and RE stocks on non-RE days (0.63%/7.45% for buy and 0.28%/5.07% for sell orders at the open/close). Compared to non-RE stocks and RE stocks on non-RE days, however, RE stocks on RE days show much larger manipulative attempts for both buy and sell orders and both at the open and the close. Specifically, the ratio of spoofing orders on RE stocks on RE days is 1.30%/12.97% for buy and 0.92%/9.68% for sell orders at the open/close.

[25] They define a buy (sell) order to be "executable on submission" if it is at or above (at or below) the projected price at the time of submission.

Our results suggest that there are manipulative attempts (spoofing orders) at the open and close. Combining this result with the price-stabilization effect documented in Section 5.3, our results also imply that the KRX RE mechanism is somewhat effective in limiting the impact of spoofing orders.

6.2. RE trading mechanism against intermarket manipulative attempts

To evaluate the effectiveness of the KRX RE trading mechanism against potential manipulative attempts in connection with derivatives trading during the closing call auction, we compare the number of RE occurrences between KOSPI 200 index constituent stocks and non-constituent stocks. The manipulation attempts can be observed from the derivatives and their underlying assets at the same time to create temporary arbitrages, and thus manipulative trading activities on the prices of KOSPI 200 index constituent stocks would occur at the closing call auction.

[Insert Table 6 about here]

Panel A in Table 6 shows that RE occurred 1,327 times (828 times in 2009 and 499 times in 2010) in 1,267 non-constituent stocks during our main sample period, which is significantly more than 207 times (158 times in 2009 and 49 times in 2010) in 230 constituent stocks. This suggests that the KRX RE trading mechanism is invoked for additional reasons other than events related to index options and futures.

In addition, the KRX RE trading mechanism at the closing call auction is not particularly effective, as can be seen from Panel B in Table 6, which reports the price-stabilization effect of RE trading mechanism at the close in KOSPI 200 index constituent stocks. Table 6 shows that the stabilization rate and the size of the price-stabilization effect at the close in KOSPI 200 index constituent stocks are 51.9% (statistically insignificant) and 21.0%, respectively, which are lower

than those in the whole sample period in Table 5.

6.3. Option Shock and policy implications

As mentioned earlier, Option Shock is a notable event in KOSPI history and this calls for research on the effectiveness of market rules including RE to restrict potential manipulations. To start with, we compare Option Shock to other days with high volatility near the close. Using one-minute intraday data from January 2006 to December 2015, we calculate the volatility of the KOSPI 200 index during 15 minutes (14:45~15:00) prior to the closing call auction on all the option expiration days, and obtain the ten highest. Our result shows that the volatility on the day of Option Shock was the highest (1.14%). Specifically, it is more than 60% higher than the second highest day (0.70%; November 11, 2010) and about six times higher than the average volatility during this specific ten-year period (0.18%).[26]

Now, to understand the effectiveness of the KRX RE trading mechanism in the extreme condition (during Option Shock), we perform a simple time-series analysis using the numbers of RE occurrences at the close in KOSPI 200 index constituent stocks during the main sample period.

[Insert Figure 4 about here]

Figure 4 shows that RE did not occur to most of KOSPI 200 index constituent stocks. In particular, on the day of Option Shock, November 11, 2010, the RE event was invoked in only three KOSPI 200 index constituent stocks: SK Telecom, KT and LG Household and Health Care (see the small circle in Figure 4). On that day, the projected closing price of SK Telecom at 15:00

[26] The date, volatility, and number of RE occurrence of the ten highest 15-minutes volatility prior to the closing call auction on the option expiration days are as follows. The volatility is measured by standard deviation and the average volatility from 2006 to 2015 is 0.1810%. (1st) [2010/11/11, 1.1428%, 3], (2nd) [2008/11/13, 0.7034%, 0], (3rd) [2011/11/10, 0.4181, 0], (4th) [2009/08/13, 0.3944, 2], (5th) [2009/12/10, 0.3507, 12], (6th) [2007/05/10, 0.3459, 7], (7th) [2009/11/12, 0.3329, 0] (8th) [2015/03/12, 0.3183, 0], (9th) [2012/07/12, 0.3088, 0], (10th) [2014/09/11, 0.2708, 5].

was 168,000 KRW (151.64 USD) and its closing price was 168,500 KRW (152.08 USD). The projected closing prices of KT and LG Household and Health Care were 45,500 KRW (41.07 USD) and 379,000 KRW (342.09 USD), respectively, and their closing prices were the same as their projected prices. Hence, on the day of Option Shock, the RE invoked on individual constituent stocks had little effect on the closing price of the KOSPI 200 index. Moreover, on the second and third highest volatility days just prior to the close from January 2006 to December 2015, RE was not invoked at all (see footnote 26).

These results suggest that the KRX RE trading mechanism was not effective against large manipulations of the stock market connected to the expiration of the KOSPI 200 index options and/or futures. According to our simple simulation results, if the threshold had been 4% (3%, 2%, and 1%), RE would have been invoked on 16 (36, 79, and 125) KOSPI 200 index constituent stocks on the day of Option Shock.

Our results provide some policy implications. First, policymakers should consider tightening the RE trading mechanism on the expiration days of index options and/or futures to restrain extreme manipulative attempts connected to derivatives trading on the stock market. For example, policymakers could lower the threshold for invoking an RE session, and use repeated RE sessions, on days on which they expect highly volatile price movements. The European exchanges, which allow for two or three consecutive RE sessions or a much-reduced price threshold on options expiration days, are a good example. In fact, the KRX has twice lowered the threshold on the expiration days of index options and/or futures, and since then, no notable event comparable to Option Shock has occurred. Next, to maximize the positive effects from the RE trading mechanism, we recommend using an exponential distribution for randomization during the RE session, rather than a uniform distribution. Third, the securities markets in the process of

transitioning from emerging to more advanced markets should consider employing a more sophisticated RE trading mechanism than the one that KRX used during our sample period, to prevent manipulation by sophisticated investors.

7. DISCUSSION

7.1. Change in threshold after Option Shock

Prior to May 30, 2011, the threshold to invoke an RE on option expiration days was the same as that on other days. Starting May 30, 2011, the threshold at the close was lowered to 3% on KOSPI index option and/or futures expiration days, 5% at the close on all other days, and 5% at the opening of all days.[27] To shed further light on the effectiveness of the RE against potential spoofing orders on option expiration days, in this section, we compare the effectiveness of the RE at the close using the actual 3% threshold and the 5% threshold that would have been in place without this rule change in threshold after Option Shock on the option expiration days from May 30, 2011 to May 30, 2012. Specifically, for stocks that experienced more than 3% (5%) change in the potential price from the extreme projected price on these option expiration days, we test the price-stabilization effect following the analysis in Section 5.3. We examine the reversals of two price changes—the changes between the extreme projected price and the potential price, and between the potential price and the actual price—at the close in this specific period. To do this, we use all stocks listed on KOSPI during the period.

[Insert Table 7 about here]

[27] The Korean policymakers continued to suspect that spoofing stock orders connected to derivatives trading remained. Hence, on June 15, 2015, the KRX further reduced the threshold to 1% at the close on KOSPI index option and/or futures expiration days when an RE is invoked by dynamic volatility interruption. These reductions indicate that Korean regulators concluded the prior thresholds had been too loose.

Panel A of Table 7 reports the results for the 3% and 5% thresholds. The results show that, not surprisingly, the number of RE occurrences became larger after the threshold was reduced from 5% to 3%. The results also show that during the closing call auction, the size of the price-stabilization effect strongly improves (20.7% to 38.0%) with the reduction in the threshold, but the size of price-continuation (i.e., price-destabilization) effect increases (i.e., deteriorates) (6.2% to 11.5%). Taking into account the relatively small number of RE occurrences at the close, the reduction of threshold at the close from 5% to 3% on the option expiration days due to Option Shock moderately improves the price-stabilization effect.

7.2. Unconditional RE trading mechanism

On June 15, 2015, the KRX adopted static volatility interruption and simultaneously changed its long-standing RE trading mechanism to an unconditional RE trading mechanism. To obtain more insights on the role of the conditional RE trading mechanism, in this section, we analyze the effects of price discovery and stabilization in the unconditional RE trading mechanism and compare them with those in the conditional RE trading mechanism reported in Figure 2 and Table 5. We use the TAQ data for the firms listed on the KRX from June 15, 2015 to December 31, 2015.

[Insert Figure 5 about here]

For the price-discovery effect, we follow the same empirical methodology as we used for the conditional RE trading mechanism in Section 5.1. Specifically, we estimate the mean of coefficients (or slopes) $\beta_{i,t}$ of equation (1) for all of our sample stocks at each minute at the open and the close, respectively. The results are shown in Figure 5. The mean of coefficients (or slopes) $\beta_{i,t}$ of equation (1) in Panel A becomes close to, but not exactly 1, at 9:00. However, it converges to 1 at the opening after the unconditional RE was invoked. This result is essentially

the same as that from the conditional RE trading mechanism in Panel A of Figure 2. Thus, the conditional RE trading mechanism was as effective as the current unconditional RE trading mechanism in terms of the price discovery at the open.

$\beta_{i,t}$ in Panel B converges almost to 1 at 15:00 and price discovery continues, with $\beta_{i,t}$ reaching 1 after the RE session. No overshooting occurs. This suggests that the current unconditional RE corrects the overshooting problem at the close in the previous KRX conditional RE, which we reported in Panel B of Figure 2.

For the price-stabilization effect, we cannot apply the same methodology as we did in the conditional RE trading mechanism in Section 5.3, because an unconditional RE is invoked without any condition. Instead, we analyze the stock-day pairs on which a conditional RE would have been invoked, i.e., prices moved beyond ± 5% during five minutes before the open or close. The unconditional RE session lasts 30 seconds. For convenience, we refer to these stock-day pairs as "unconditional RE with a restriction." Now, we can utilize the same methodology employed in Section 5.3. Though restricted, this will provide some insights for the price-stabilization effect in the current KRX unconditional RE trading mechanism.

Panel B of Table 7 reports the price-stabilization effect for the unconditional RE trading mechanism, where the RE session lasts 30 seconds. The results of the unconditional RE with a restriction show two interesting features compared to those of the conditional RE. First, in terms of the directional movement of the potential price when the unconditional RE with a restriction is invoked, we find that the proportion of "no. of unchanged prices" in subsequent price changes[28] notably increases at both the open and close: 60.27% at the open and 76.58% at the close (see

[28] The subsequent price changes means the changes between the extreme projected price and the potential price, and between the potential price and the actual opening (or closing) price. This result is equivalent to that of Table 4 for the conditional RE trading mechanism. For brevity, we do not report the detailed results in tabular form, but the numbers (%) in parenthesis in Panel B of Table 7 are sufficient to grasp the implications.

column (A) of Table 7). The results suggest that the accuracy of the on-time opening (9:00) or closing (15:00) price has significantly improved. This positive effect might have arisen due to the shortening of the RE session to 30 seconds.

Second, in the unconditional RE with a restriction, the size of price-stabilization (price-continuation) is 15.4% (7.6%) at the open and 7.3% (5.2%) at the close. Compared to the conditional RE trading mechanism in Table 5, the price-stabilization effect has deteriorated, but the price-continuation effect decreased, indicating an improvement; the two effects offset each other to some extent. However, the result on "stabilization rate" is mixed, showing that the price-stabilization effect is statistically significantly stronger than the price-continuation effect at the close, but the reverse holds at the open. The dominance of "no. of unchanged prices" in column (A) seems related to these results. This should not be surprising, since the very brief 30-second RE session allows little time for price change.

Putting together these two features of the unconditional RE with a restriction, it seems that the result of the first feature, i.e., the directional movement of the potential price, should have a greater weight in the interpretation. Thus, in the current unconditional RE trading mechanism, the price-stabilization effect is weaker than under the conditional RE trading mechanism. Instead, the accuracy of the on-time opening (9:00) or closing (15:00) price has significantly improved.[29]

8. CONCLUSION

A variety of RE trading mechanisms have been adopted by major world exchanges to reduce rapid

[29] To exclude the potential impact of the static volatility interruption on our results, we also conduct the analysis only with stocks for which the static volatility interruption was not invoked on the same day. In untabulated results, we find that the results are qualitatively similar, confirming that our findings on the unconditional RE mechanism are not driven by the volatility interruption. To obtain both on-time price accuracy and stronger price-stabilization effect during the RE session, one should consider lengthening the current 30-second RE session.

price fluctuation, including that resulting from price manipulation, during periodic call auctions. The intended purpose of the [conditional] RE trading mechanism in the KRX was to "prevent price manipulation utilizing spoofing orders and protect investors during the call auction at the open and close" (see Eom et al., 2008), which was narrower and more specific than in other advanced exchanges. Nevertheless, the Korean stock and derivatives markets experienced Option Shock, the largest manipulation connected with stock and derivatives in the history of the Korean financial markets. Motivated by Option Shock, we examine the effectiveness of the particular RE trading mechanism, especially in terms of price discovery, efficiency, and stabilization, during the opening and closing call auctions on the KRX. We also investigate how the RE trading mechanism is related to spoofing orders and analyze the effectiveness of the KRX RE trading mechanism during Option Shock. Furthermore, we analyze the effectiveness of the current KRX unconditional RE trading mechanism and compare it with that of the KRX RE trading mechanism.

Using the real-time order book, we find that the [conditional] RE trading mechanism promotes price stabilization, but with some reservations, and improves price discovery and efficiency at the open, but causes overshooting at the close. We also find that it is somewhat effective in filtering out spoofing orders, but failed to stabilize the market in an extreme case such as Option Shock. Our results suggest that there are manipulative attempts (spoofing orders) at the open and close. Combined with the price-stabilization effect, our results also imply that the KRX RE mechanism is somewhat effective in limiting the impact of spoofing orders. This limited efficacy of the [conditional] RE trading mechanism was addressed to some extent by two subsequent rule changes, particularly the adoption of the unconditional RE trading mechanism on May 30, 2015.

Our findings suggest some policy implications. First, the RE threshold should be tightened on the expiration days of index options and/or futures to restrain extreme manipulative attempts

connected to derivatives trading on the underlying stock market. Second, an exponential distribution is recommended for randomization during the RE session, rather than a uniform distribution. Third a more sophisticated RE trading mechanism should be employed by countries transitioning to more advanced markets, to prevent manipulation by sophisticated investors.

REFERENCES

Abad, D., & Pascual, R. (2010). Switching to a temporary call auction in times of high uncertainty. *Journal of Financial Research*, *33*(1), 44–75.

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.

Brugler, J., Linton, O., Noss, J., & Pedace, L. (2018). *The cross-sectional spillovers of single stock circuit breakers* (Working paper). Bank of England.

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

Deutsche Börse Group. (2014). *Xetra® release 15.0 market model equities*.

Eom, K. S., Kang, H. C., & Lee, Y. J. (2008). *An alternative to the price-limit system on the Korea Exchange* (Research report). Korea Capital Market Institute. (in Korean)

Eom, K. S., Kwon, K. Y., La, S. C., & Park, J.-H. (2018). *The role of dynamic and static volatility interruption: Evidence from the Korean stock markets* (Working paper). University of California at Berkeley.

Eom, K. S., & Park, J.-H. (2015). The random-end trading mechanism on the KRX: Characteristics, price stabilization, and the relation to spoofing orders. *Asian Review of Financial Research*, *28*(4), 561–598. (in Korean)

Foucault, T., Kadan, O., & Kandel, E. (2005). Limit order book as a market for liquidity. *Review of Financial Studies*, *18*(4), 1171–1217.

Guillaumie, C., Loiacono, G., Winkler, C., & Kern, S. (2020). *Market impacts of circuit breakers: Evidence from EU trading venues* (Working paper). European Securities Markets Authority.

Hagströmer, B., & Nordén, L. (2014). Closing call auctions at the index futures market. *Journal of Futures Markets*, *34*(4), 299–319.

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.

Hautsch, N., & Horvath, A. (2019). How effective are trading pauses? *Journal of Financial Economics*, 131(2), 378–403.

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

Hsieh, W.-L. G. (2009). Expiration-day effects on individual stocks and the overall market: Evidence from Taiwan. *Journal of Futures Markets*, 29(10), 920–945.

Kandel, E., Rindi, B., & Bosetti, L. (2012). The effect of a closing call auction on market quality and trading strategies. *Journal of Financial Intermediation*, *21*(1), 23–49.

Kuk, J., Liu, W.-M., & Pham, P. K. (2016). *Strategic order submission and cancellation in pre-opening periods: The case of IPO firms* (Working paper). Australian National University.

Kyle, A. S., & Viswanathan, S. (2008). How to define illegal price manipulation. *American Economic Review: Papers & Proceedings*, *98*(2), 274–79.

Lei, A. C., Ma, X., & Yick, M. H. (2020). Callable bull/bear contracts, call auction sessions, and price manipulations: Evidence from Hong Kong. *Journal of Futures Markets*, *forthcoming*.

London Stock Exchange. (2020). *MIT201—Guide to the trading system*.

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

Medrano, L. A., & Vives, X. (2001). Strategic behavior and price discovery. *RAND Journal of Economics*, *32*(2), 221–248.

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.

Roşu, I. (2009). A dynamic model of the limit order book. *Review of Financial Studies*, *22*(11), 4601–4641.

Sifat, I. M., & Mohamad, A. (2019). Circuit breakers as market stability levers: A survey of research, praxis, and challenges. *International Journal of Finance and Economics*, *24*(3), 1130–1169.

World Federation of Exchanges. (2015). <http://www.world-exchanges.org/statistics/annual>

Zimmermann, K. (2013). *Price discovery in European volatility interruptions* (Working paper). Goethe University Frankfurt.

TABLE 1 Descriptive statistics on RE occurrences

	Total	Opening	Closing	KOSPI	Opening	Closing	KOSDAQ	Opening	Closing
Panel A: Number of sample stocks, number of RE stocks, and fraction of RE stocks									
Number of sample stocks (A)	1,567			671			896		
Number of RE stocks (B)	1,497	1,440	1,318	606	554	480	891	886	838
Fraction of RE stocks (B/A)	95.5%	91.9%	84.1%	90.3%	82.6%	71.5%	99.4%	98.9%	93.5%
Panel B: Number of RE occurrences per RE stock									
Max.	117	78	60	54	43	24	117	78	60
Min.	1	1	1	1	1	1	1	1	1
Average	16.46	12.19	5.38	8.91	6.98	3.20	21.59	15.44	6.63
Median	13	10	4	7	5	2	18	13	5
Panel C: Number of RE occurrences and RE occurrence ratio to the total number of call auctions									
Number of RE occurrences	24,641	17,548	7,093	5,402	3,868	1,534	19,239	13,680	5,559
RE occurrence ratio	3.1%	4.4%	1.8%	1.6%	2.3%	0.9%	4.3%	6.1%	2.5%

Notes: This table presents descriptive statistics on RE occurrences at the opening and closing call auctions by markets – KOSPI and KOSDAQ. Panel A shows the number of sample stocks, the number of RE stocks, and the ratio of RE stocks to the total number of stocks (fraction of RE stocks) in each market and aggregated market (Total). Panel B provides statistics on the number of RE occurrences, that are the maximum (Max.), minimum (Min.), average, and median of number of RE occurrences per RE stock. Panel C shows the number of RE occurrences and the RE occurrence ratio, which is the ratio of the number of RE occurrences to the total number of the opening and/or closing call auctions (789,768 for Total and 394,884 for Opening or Closing).

TABLE 2 Spearman correlations among major characteristics of stocks and RE occurrences

	nt_open	*nt_close*	*prc*	*ret*	*turnover*	*std_dev*	*volume_value*	*volume_share*	*mrk_cap*
nt_open	1.000	0.657	-0.594	0.036	0.406	0.744	-0.202	0.190	-0.620
nt_close		1.000	-0.414	-0.014	0.097	0.446	-0.364	-0.066	-0.562
prc			1.000	0.101	-0.415	-0.553	0.224	-0.444	0.672
ret				1.000	0.201	0.185	0.228	0.105	0.055
turnover					1.000	0.764	0.603	0.811	-0.186
std_dev						1.000	0.241	0.586	-0.425
volume_value							1.000	0.723	0.600
volume_share								1.000	0.093
mrk_cap									1.000

Notes: The variables in this table are as follows. *nt_open:* number of RE occurrences in the opening price, *nt_close:* number of RE occurrences in the closing price, *prc:* average closing price, *ret:* average daily return, *turnover:* average daily turnover ratio, *std_dev:* standard deviation of daily returns, *volume_value:* trading volume (in Korean won, KRW), *volume_share:* trading volume in shares, and *mkt_cap:* market capitalization.

TABLE 3 Price efficiency of the opening call auction on the days when RE occurred

	RE days			Non-RE days	
	Returns from the potential opening price at 9:00 (A)	Returns from the opening price (B)	A−B	Returns from the opening price (C)	B−C
Std. dev.	3.4227	2.9061	0.5166***	2.0293	0.8768***
Number of stocks that the standard deviation of column A (or B) is greater [smaller] than that of column B (or C) at the 5% level			61[0]		391[13]

Notes: This table presents the empirical results on price efficiency of the opening call auction on the days when RE occurred. In this table, RE days indicates the days when RE occurred and non-RE days indicate the days when RE did not occur. This table reports the results from two paired *t*-tests. The first paired *t*-test compares the standard deviations of 15-minute returns calculated from the potential opening price at 9:00 (A) to those of 15-minute returns calculated from the opening price (i.e., immediately after the RE session ends) (B) for each stock on RE days. The second paired *t*-test compares the standard deviations (std. dev.) of 15-minute returns calculated from the opening price on RE days (B) to those on non-RE days (C) for each stock. To obtain meaningful standard deviations of the returns, we have limited our sample to 722 stocks for which RE occurred more than ten times. *** denotes statistical significance at the 1% level.

TABLE 4 The directional movement of the potential price when the RE trading mechanism was invoked

	Direction of the changes in the potential price	No. of occurrences	Subsequent price changes		
			Price continuation	No change	Price reversal
Opening	Up	8,519	2,437 (28.6%)	2,989 (35.1%)	3,093 (36.3%)
	Equal up and down†	31	-	-	-
	Down	8,998	2,460 (27.3%)	3,194 (35.5%)	3,344 (37.2%)
Closing	Up	4,708	805 (17.1%)	3,026 (64.3%)	877 (18.6%)
	Equal up and down†	13	-	-	-
	Down	2,372	237 (10.0%)	1,421 (59.9%)	714 (30.1%)

Notes: This table shows the number of times that the potential opening (or closing) price moved up or down from the projected opening (or closing) price when the RE trading mechanism was invoked. The first column indicates whether it is a result for the opening or closing session, and the second column presents the direction of the changes from the projected opening or closing price to the potential price. † denotes that the potential price moved up or down more than 5% during the five minutes before the normal opening (9:00) or the normal closing (15:00) time and, by coincidence, the maximum up and down are of equal magnitude. The third column shows the number of occurrences for each category described in the second column. The last three columns further categorize the observations (into three cases, price continuation, no change, and price reversal) based on the subsequent price changes after the potential price to the opening or closing price, which terminates the RE session. The numbers in parenthesis indicate the fraction of the observations.

TABLE 5 Price-stabilization effect of the RE trading mechanism

Market	Year	No. of unchanged prices (A)	No. of reversals of price changes (B)	No. of continuations of price changes (C)	Total no. of RE occurrences (D)	Stabilization rate (%) (B/(B+C))	Price stabilization effect (%)[a]	Price continuation effect (%)[b]
				Panel A: Opening price				
KOSPI	2009	856	712	663	2,231	51.8**	20.1	15.3
	2010	544	596	497	1,637	54.5***	23.8	15.0
Sub-total		1,400	1,308	1,160	3,868	53.0***	21.8	15.2
KOSDAQ	2009	2,960	2,876	2,125	7,961	57.5***	25.0	17.0
	2010	1,854	2,253	1,612	5,719	58.3***	24.9	18.7
Sub-total		4,814	5,129	3,737	13,680	57.9***	25.0	17.7
Opening total		6,214	6,437	4,897	17,548	56.8***	24.3	17.1
				Panel B: Closing price				
KOSPI	2009	698	170	118	986	59.0***	22.5	11.2
	2010	358	98	92	548	51.6	23.3	12.1
Sub-total		1,056	268	210	1,534	56.1***	22.8	11.6
KOSDAQ	2009	2,377	836	508	3,721	62.2***	26.8	13.5
	2010	1,027	487	324	1,838	60.0***	25.8	13.8
Sub-total		3,404	1,323	832	5,559	61.4***	26.4	13.6
Closing total		4,460	1,591	1,042	7,093	60.4***	25.8	13.2
KRX total		10,674 (43.3%)	8,028 (32.6%)	5,939 (24.1%)	24,641 (100%)	57.5***	24.6	16.4

Notes: This table reports the test results of the price-stabilization effect. "No. of unchanged prices" in column A includes 44 of "equal up and down" in "open" (31) and "close" (13) in Table 3. [a] denotes a percentage measure of reversals of price changes (B), which is calculated as follows: |potential price – opening (or closing) price|×100/(change of projected price). [b] denotes a percentage measure of continuations of price changes (C), which is calculated as follows: {potential price – opening (or closing) price}×100/(change of projected price). *** and ** denote statistical significance using the binomial distribution at the 1% and 5% levels, respectively.

TABLE 6 Potential manipulative attempts connected to derivatives trading at the close

Panel A: The numbers of RE occurrences			
	Year		Total
	2009	2010	
KOSPI 200 index constituent stocks	158	49	207
KOSPI 200 index non-constituent stocks	828	499	1,327

Panel B: Price-stabilization effect in KOSPI 200 index constituent stocks							
Year	No. of unchanged prices (A)	No. of reversals of price changes (B)	No. of continuations of price changes (C)	Total no. of RE occurrences (D)	Stabilization rate (%) (B/(B+C))‡	Price stabilization effect (%)[a]	Price continuation effect (%)[b]
2009	94	33	31	158	51.6	20.1	5.1
2010	34	8	7	49	53.3	24.6	6.2
Total	128 (61.83%)	41 (19.81%)	38 (18.36)	1,534	51.9	21.0	5.3

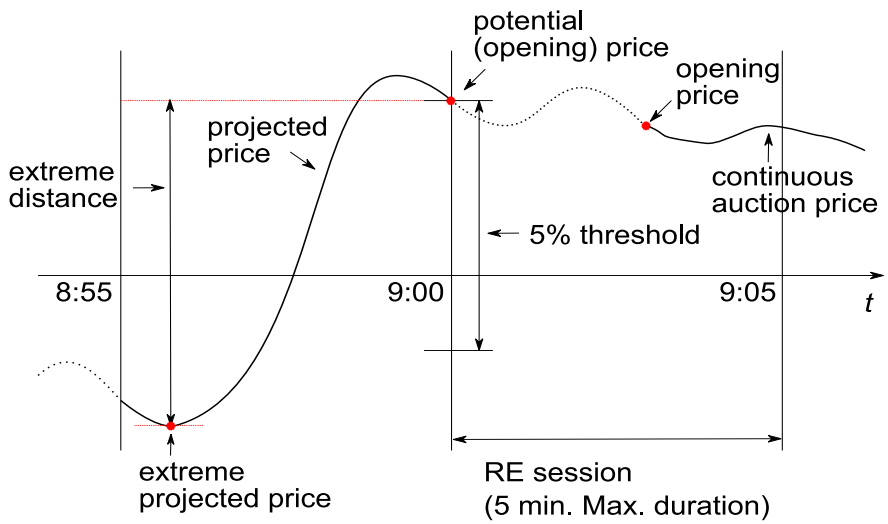
Note: This table presents the results from analyses on potential manipulative attempts connected to derivatives trading in the closing session. Panel A presents the numbers of RE occurrences in KOSPI 200 index constituent stocks and non-constituent stocks, respectively. Panel B reports the price-stabilization effect of the RE trading mechanism at the close in KOSPI 200 index constituent stocks. [a] denotes a percentage measure of reversals of price changes (B), which is calculated as follows: |potential price – opening (or closing) price|×100/(change of projected price). [b] denotes a percentage measure of continuations of price changes (C), which is calculated as follows: {potential price – opening (or closing) price}×100/(change of projected price). ‡ denotes statistical *insignificance* using the binomial distribution even at the 10% level. The numbers in parenthesis indicate the fraction of the observations.

TABLE 7 Price-stabilization effects of the RE trading mechanism following two rule changes

Market	No. of unchanged prices (A)	No. of reversals of price changes (B)	No. of continuations of price changes (C)	Total no. of RE occurrences (D)	Stabilization rate (%) (B/(B+C))	Price-stabilization effect (%)[a]	Price-continuation effect (%)[b]
Panel A: Evidence from the rule change following Option Shock							
Closing—3% Threshold	144 (74.23%)	30 (15.46%)	20 (10.31%)	194 (100.00%)	60.0**	38.0	11.5
Closing—5% Threshold	45 (64.28%)	15 (21.43%)	10 (14.29%)	70 (100.00%)	60.0*	20.7	6.2
Panel B: Evidence from the rule change to the unconditional RE trading mechanism—A case of "unconditional RE with a restriction"							
Opening	4,018 (60.27%)	1,220 (18.30%)	1,429 (21.43%)	6,667 (100.00%)	46.1***	15.4	7.6
Closing	1,439 (76.58%)	259 (13.79%)	181 (9.63%)	1,879 (100.00%)	58.9***	7.3	5.2

Notes: This table reports the test results of the price-stabilization effects following two rules changes: on May 30, 2011 and June 15, 2015. The sample firms are all the stocks listed on KOSPI during each sample period. Panel A shows the results for the actual threshold, 3%, and for the 5% threshold that would have been in place without the rule change after Option Shock. We test the effects only at the close on option expiration days from May 30, 2011 to May 30, 2012. Panel B reports the results for the unconditional RE trading mechanism from June 15, 2015 to December 30, 2015. To test the price-stabilization effect in the unconditional RE trading mechanism, we only analyze the stock-day pairs on which a conditional RE would have been invoked, i.e., prices moved beyond ± 5% during five minutes before the open or close. The unconditional RE session lasts 30 seconds. For convenience, we refer to these stock-day pairs as "unconditional RE with a restriction." [a] denotes a percentage measure of reversals of price changes (B), which is calculated as follows: |potential price – opening (or closing) price|×100/(change of projected price). [b] denotes a percentage measure of continuations of price changes (C), which is calculated as follows: {potential price – opening (or closing) price}×100/(change of projected price). The numbers in parenthesis indicate the fraction of the observations. ***, **, and * denote statistical significance using the binomial distribution at the 1%, 5%, and 10% levels, respectively.

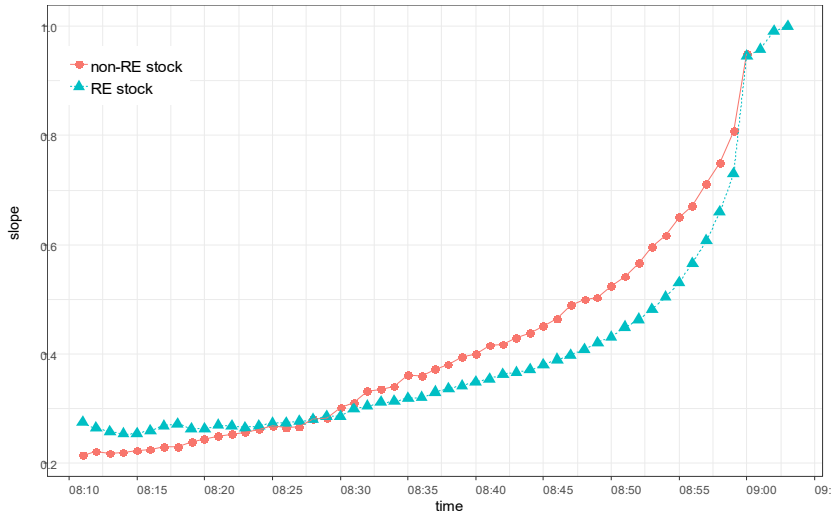
FIGURE 1 KRX RE trading mechanism



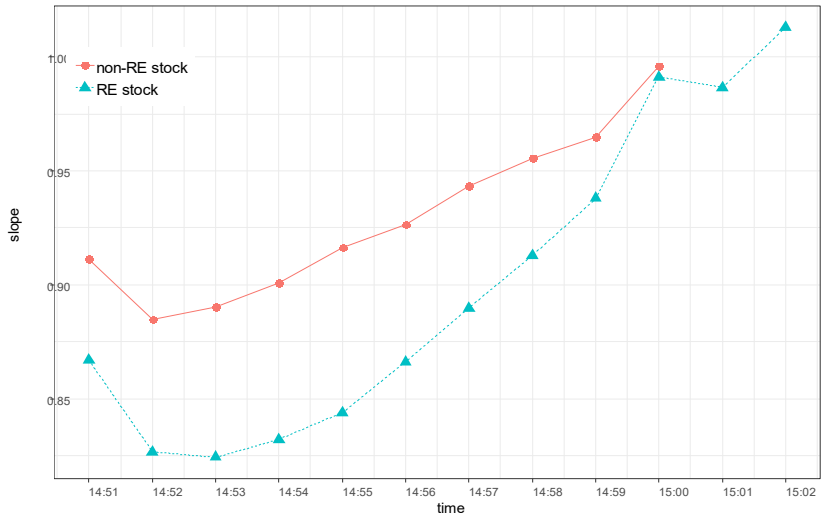
Notes: This figure provides an illustration of a conditional RE trading mechanism at the open on the KRX during our sample period. The KRX starts accepting orders for the opening (closing) call auction at 8:00 (14:50). It announces the *projected price* (or *indicative price*) which is the real-time auction price from 8:10 (14:50) for the open (close). The projected price of any given stock fluctuates as orders are placed or withdrawn. The projected price at the scheduled time of opening is called the *potential* (*opening*) *price*. The *extreme projected price* is the projected price with the largest absolute difference from the potential price; the absolute difference between the extreme projected price and the potential price is called the *extreme distance*. If the extreme distance over the five minutes before the open or close exceeded the threshold of 5% (expressed as a percentage of the potential price), then the RE trading mechanism extended the call auction for the given stock for a brief randomly-chosen span of time, RE session, with five-minute maximum duration.

FIGURE 2 Price-discovery effect during the opening and closing call auctions with RE invoked

Panel A: Opening call auction

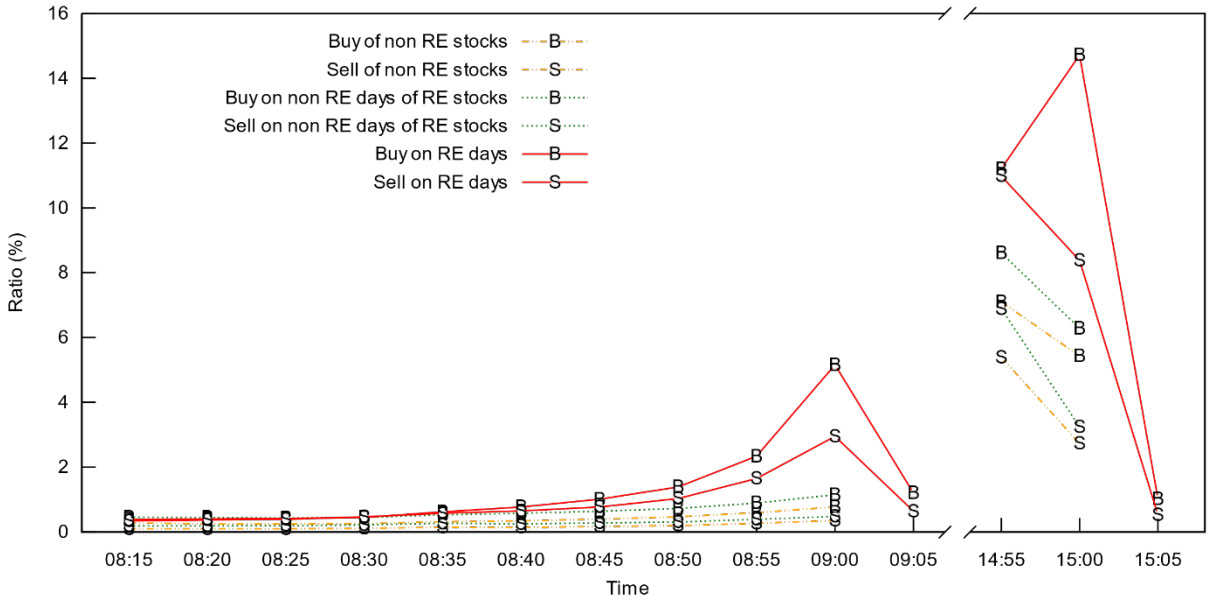


Panel B: Closing call auction



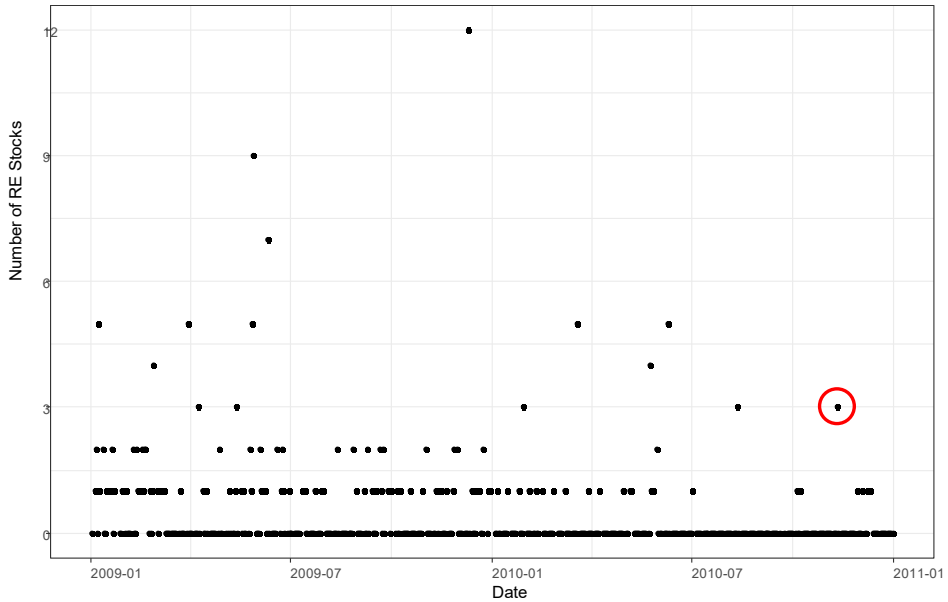
Notes: This figure displays the mean of coefficients (or slopes) $\beta_{i,t}$ of equation (1) for each group of RE stocks and non-RE stocks at each minute at the open (Panel A) and close (Panel B). "Non-RE stocks" denote the stocks for which RE did not occur, whereas "RE stocks" denote the stocks for which RE occurred.

FIGURE 3 Spoofing orders during the opening and closing call auctions



Notes: This figure presents the ratio of spoofing buy (sell) orders to the number of ordinary orders on non-RE stocks (yellow dashed line), RE stocks on days RE was not invoked (non-RE days) (green dotted line), and those on days RE was invoked (RE days) (red solid line), respectively, during the opening and closing call auctions. Specifically, for the opening (8:15 to 9:00) and the closing (14:55 to 15:00) excluding the RE session, we compute the ratio of spoofing orders every five-minute period. The ratio of spoofing orders at the open and close for each group are as follows. For buy (sell) of non-RE stocks, the average ratios at the open and close are 0.39% and 6.26% (0.17% and 4.06%). For buy (sell) of RE stocks on non-RE days, the average ratios at the open and close are 0.63% and 7.45% (0.28% and 5.07%). For buy (sell) of RE stocks on RE days, the average ratios at the open and close are 1.30% and 12.97% (0.92% and 9.68%).

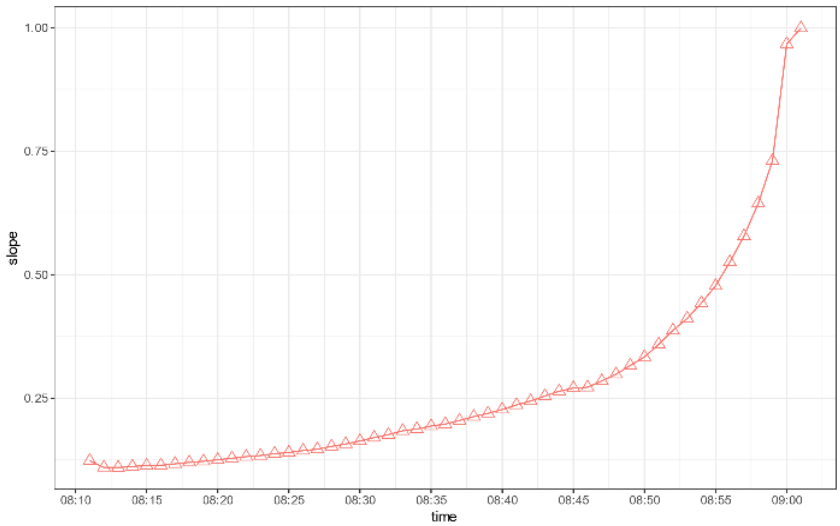
FIGURE 4 The number of RE stocks at the close in KOSPI 200 index constituent stocks.



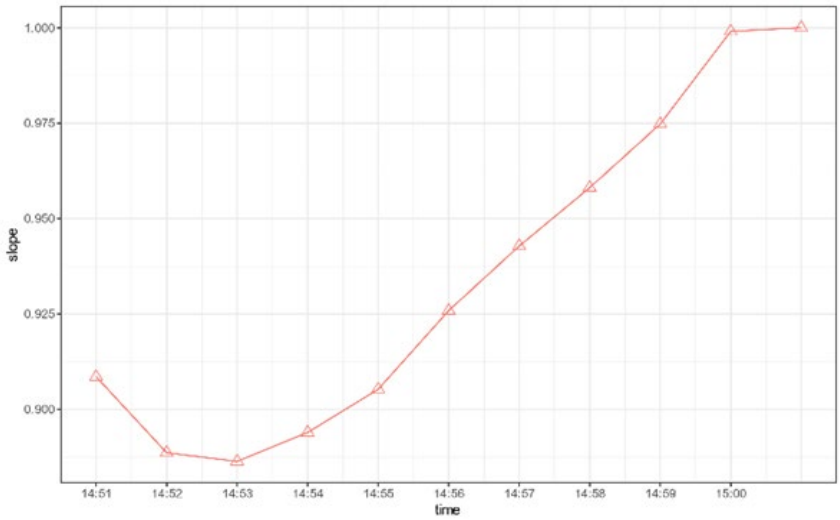
Notes: This Figure shows the number of RE occurrences at the close in KOSPI 200 index constituent stocks during the main sample period. The maximum number of RE occurrences at the close in KOSPI 200 index constituent stocks was 12, on December 10, 2009. "Option Shock" occurred on November 11, 2010, when the RE event was invoked in only three KOSPI 200 index constituent stocks: SK Telecom, KT and LG Household and Health Care (marked in the small circle).

FIGURE 5 Price-discovery effect during the opening and closing call auctions with *unconditional* RE invoked

Panel A: Opening call auction



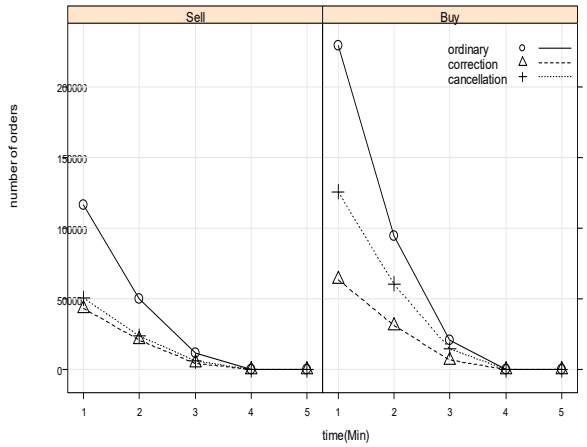
Panel B: Closing call auction



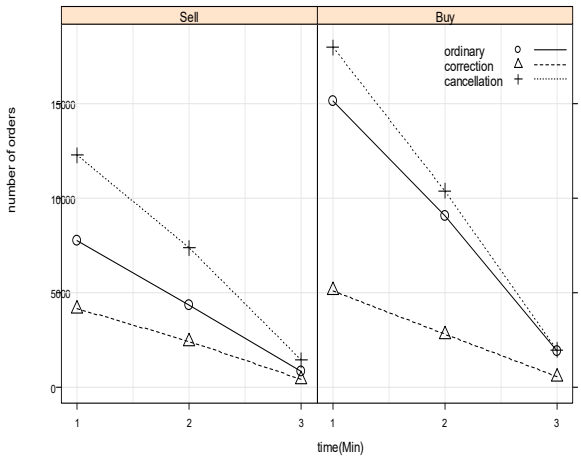
Notes: This figure displays the mean of coefficients (or slopes) $\beta_{i,t}$ of equation (1) for all stocks listed on KRX at each minute at the open (Panel A) and close (Panel B) when the unconditional RE trading mechanism was invoked from June 15, 2015 to December 30, 2015. Under the unconditional RE trading mechanism, the RE session is 30 seconds after the opening (closing) time at 9:00 (15:00).

Appendix

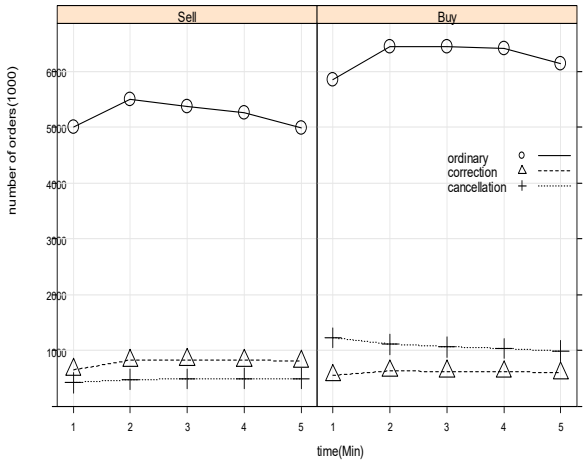
Figure A1 The number of orders by category during the opening and closing RE sessions, and the first five minutes of the continuous trading session.



Panel A. Number of orders by category during the opening RE session



Panel B. Number of orders by category during the closing RE session



Panel C. Number of orders by category during the first five minutes in the continuous trading session

Notes: The orders in all trading sessions of the above panels are categorized as ordinary buy or sell, cancellation buy or sell, and correction buy or sell orders. We count the number of orders by summing up all the number of orders of the stocks for which RE occurred. Panel A shows the number of orders by category during the opening RE session. Panel B shows the number of orders by category during the closing RE session. Instead of five minutes used for Panel A and Panel C, we report the number of orders by category for Panel B in the first three minutes of the closing RE session, since there were few orders submitted after three minutes. Panel C shows the order proportion by category during the first five minutes of the continuous trading session right after the establishment of the opening price.