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Idiosyncratic Volatility and Interruption Mechanisms in South Korean Stock Markets

Seungho Shin
University of New Orleans, sshin2@uno.edu

Idiosyncratic Volatility and Interruption Mechanisms in South Korean Stock Markets

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By

Seungho Shin

B.S. University of Central Florida, 2013
M.B.A. Rollins College, 2015
M.S. University of New Orleans, 2018
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DEDICATION

This dissertation is dedicated to my wife, Kelly, who has been a constant source of love, support, and encouragement during the challenges of graduate school and life. I am truly thankful for having you in my life. This dissertation is also dedicated to my parents and parents-in-law, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

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TABLE OF CONTENTS

LIST OF TABLES

C h a p t e r 1

IDIOSYNCRATIC VOLATILITY AND INTERRUPTION MECHANISMS IN SOUTH KOREAN STOCK MARKETS

Abstract

The purpose of this study is to examine how the volatility interruption mechanisms affect idiosyncratic volatilities in Korean stock markets. Collecting the South Korea Stock Market (KOSPI) data from June 15, 2015 to March 31, 2019, we collect each residual,, from three different estimated models: CAPM, FF3, and FF5. To estimate the conditional idiosyncratic volatility, we employ two conditional time-varying measurements: GARCH and TGARCH. Our results show that the conditional idiosyncratic volatility increases when stock prices reach the upper and lower static limits, indicating the implementation of adopting static VI mechanism neither stabilize market conditions nor reduce excess volatility along with the existence of price limits. Although market regulators and policymakers improve market conditions with the advanced volatility interruption mechanism, our empirical results show the adverse effect of the mechanism. Not allowing investors to earn above average returns without accepting above average risks makes Korean stock markets inefficient along with advanced volatility interruption mechanisms.

JEL classification: G12, G14, G18, G28

Keywords: Market Regulation, Trading Halt Mechanism, Idiosyncratic Volatility, Korean Stock Markets

1.1 Introduction

In advanced technology and mechanisms, financial regulations and policies have evolved over time since market regulators and policymakers add in response to failures or breakdowns in financial markets, and they trim back during financial market booms. The main goal of market regulators and policymakers is to stabilize financial markets with increased market efficiency. After the market crash of October 19, 1987, as known as Black Monday, circuit breakers were proposed by Nicholas Brady, the former United Stated Treasury Secretary, to temporarily limit trading during periods of exceptional volatility. Market Mechanisms (1988) suggests setting up wide ranges of bounds to trigger, so that the mechanisms do not disturb very often, but protect investors from unpredictable market turmoil. Despite of the initial intention, conflicting interests have discussed in finance literature. Proponents of price limits claim that the necessity of sophisticated versions of circuit breakers, such as price limits and trading halts. They believe that sophisticated mechanisms decrease stock price volatility and counter overreaction without trading activity. On the other hand, critics claim that price limits provide ambiguous conceptual impact and implication for price movements and trading interference.

Abad and Pascual (2013) distinguish between two types of price limits, daily price limits and intraday price limits. Compared daily price limits, intraday price limits, as known as volatility interruption (VI hereafter), provide much sophisticated mechanisms to financial markets. VI consists of dynamic volatility interruption (dynamic VI hereafter) and static volatility interruption (static VI hereafter). These sophisticated mechanisms have been adopted in European and Asian exchanges, mainly to stabilize their financial markets[1].

In this paper, we investigate impact of static VI on the idiosyncratic volatility in Korean stock markets. They sequentially adopt price limits, dynamic VI and static VI, indicating that Korean stock markets allow us to investigate separate effects of those mechanisms respectively. Kwon et al. (2018) examine the effect of introducing the dynamic VI and static VI to the pre-existing price limits in Korean stock markets. They find that dynamic VI significantly contributes to stabilizing stock prices while static VI does not. Also, they point out that limited effects of static VI are similar to those of the existing price limits. Early study of Berkman and J. B. T. Lee (2002) only investigates the effectiveness of price limits and Seddighi and Yoon (2018) study the recent relaxation of price limits, not dynamic VI and static VI. Compared with other countries such as Japan, Taiwan and China, only few related studies of price limits in Korean stock markets have been conducted. Also, conditions that Korean stock markets adopt dynamic VI and static VI sequentially allow us to

[1] For further details, see Appendix A

investigate asymmetric impacts of price limits.

The study by Tassinari et al. (2019) illustrates Korean industrial development with peculiar economic and historical circumstances over the period 1963 through 2012, and mainly focuses on the relationship between government, markets, and civil society. We update literature review in Korean stock markets and show the effect of new mechanisms as well. To distinguish our study with others, we focus on the impact of adopting static VI associated with the long-run conditional idiosyncratic volatility. Since dynamic VI triggered when a short-term supply and demand imbalance is very strong, we do not consider the impact of adopting dynamic VI[2]. We also investigate how often this phenomenon detected during a continuous trading session. We focus on Korea composite stock price index (KOSPI hereafter), which is the largest and integrated exchange in South Korea.

The rest of the paper is organized as follows. Section 1.2 describes literature review. Section 1.3 provides motivation and hypotheses of this study. Section 1.4 presents the data and methodology. Section 1.5 reports empirical results and interpretations. Lastly, Section 1.6 offers concluding remarks of this study.

1.2 Literature Review

1.2.1 Background of Price Limits

Since the first circuit breakers in place following the market crash of October 19, 1987, market regulators and researchers have debated impacts on market intervention mechanisms and consequences of possible results from those mechanisms. According to the Brady Commission Report (1988), more precise market mechanisms are necessary during market downturns and circuit breaker mechanisms such as price limits and coordinated trading halts should be formulated and implemented to protect the market system. Subrahmanyam (1994) interprets a circuit breaker as a mandated trading halt triggered on extreme market movements. Examining the impact of the circuit breaker, he finds that the circuit breaker generally increases price variability and the probability of the price crossing the circuit breaker bounds if the price is very close to the limit. Also, it is not consistent with the objective of maximizing market liquidity. Lehmann (1989) defines circuit breakers as devices for halting or limiting trading when prices have moved too much. He describes that some see circuit breakers as self-evident that devices as price limits curb "excess volatility," while others suggest that circuit breakers interfere with the price discovery process and the impounding of information in market prices. Setting up their own regulations with certain

[2]Abad and Pascual (2010) describe that a dynamic volatility auction may be triggered either by a single, large-sized market order or by an ordinary market order submitted in times of low liquidity.

thresholds, for example +/- 10% or +/- 20%, many different countries are followed by the rules of the United States in imposing circuit breakers in their financial markets.

The 2010 Flash Crash, one of momentous events in the stock market, reminds regulators and policymakers of the necessity of intervention mechanisms to protect market participants in market volatility. Subrahmanyam (2013) describes that if impediments to trade are necessary to combat clearly anomalous price moves, the question is what type of breakers are the best way to go about the design. He suggests adopting wide enough trigger bounds based on percentage, avoiding sweep orders, and using different point systems to compute indices in different markets. Based on different financial market conditions, many different countries have developed and implemented updated versions of circuit breakers in their financial markets. Abad and Pascual (2013) describe more detailed and sophisticated versions of circuit breakers, such as price limits and trading halts. According to their study, price limits are either daily based or intraday based. Daily based price limits, as known as static VI, set a daily percentage range of trading that is based on previous day's closing price, thus stabilizing and curbing day-to-day volatility. Compared with daily based price limits, intraday based prices limits, as known as dynamic VI, are more advanced mechanisms because it is triggered when the difference between a stock's most recent execution price and potential execution price exceeds a specified price range. C. M. Lee, Ready, and Seguin (1994) investigate the efficacy of trading halts by examining the effect of firm-specific NYSE trading halts on volume and price volatility. Focusing on the levels of trading volume and price volatility, they conclude that trading halts do not reduce either trading volume or price volatility.

1.2.2 Proponents of Price Limits

Price limits have two main attributes to control volatility. First, they establish price constraints. Secondly, they provide time for rational reassessment during times of panic trading. As advocates of price limits, Ma, Rao, and Sears (1989) investigate the price limits and the empirical behavior of futures prices for a selected group of commodities around price limits. They find that prices tend to either stabilize or reverse directions, indicating that price limits provide a cooling-off effect during the period for the market. By employing China's experience with price limits, K. A. Kim, Liu, and Yang (2013) test the performance of price limits by examining stock price behaviors during periods with and without price limits from the same market. They conclude that price limits can facilitate price discovery, moderate transitory volatility, mitigate abnormal trading activity, and help market recovery following crashes. Recently, Wan et al. (2018) investigate the cooling-off effect by using the intraday-level high frequency data in Chinese stock markets. They find that price limits provide a positive effect on maintaining the stability of the Chinese stock markets because the price limits restrict the investors' irrational behavior. Abad and Pascual (2007) investigate the magnet effect[3] of price limits in the Spanish Stock Exchange (SSE), where limit hits trigger five-minute trading halts, followed by continuous trading with revised price limits. Analyzing both the price patterns and the trading behavior, they conclude that there is no magnet effect of price limits.

Overall, proponents of price limits claim that price limits decrease stock price volatility, counter-overreaction, and do not interfere with trading activity. They also advocate that price limits provide important considerations to market regulators and policymakers who continue to weigh the benefits and costs of price limits.

1.2.3 Critics of Price Limits

or more than a decade, however, other academic researchers and practitioners have found evidence of costs to imposing price limits. After the market crash of October 19, 1987, there has been increased interest in the usefulness of price limits as well as other forms of market intervention mechanisms. Lehmann (1989) states that price limits not only have an ambiguous conceptual impact on liquidity around limit price moves, thus increasing volatility, but also have no clear implications for the behavior of prices on the day after a limit price move. Kuhn, Kuserk, and Locke (1991) find that price limits are ineffective in decreasing volatility during the 1989 U.S. mini-crash. E. Fama (1989) proposes the delayed price discovery hypothesis. As price limits represent upper and lower bounds on stock prices, some trading usually decreases or stop until the limits are revised creating an interference with the price discovery process.

Examining the Tokyo Stock Exchange (TYO), K. A. Kim and Rhee (1997) support three main hypotheses such as volatility spillover, delayed price discovery, and trading interference, indicating that price limits may be ineffective. For stocks that experience limit-hits, they document that volatility does not return to normal levels as quickly as the stocks that do not reach price limits (volatility spillover hypothesis), price continuations occur more frequently than for stocks that do not reach limits (delayed price discovery hypothesis), and trading activity increases on the day after the limit day, while all other stock subgroups experience drastic trading activity declines (trading interference hypothesis). Supporting the study of K. A. Kim and Rhee (1997), Deb, Kalev, and Marisetty (2017) provide new evidence on efficacy of daily price limits, employing propensity score matching techniques to reduce the possible sample selection bias[4]. Results of their study are consistent with the findings

[3]The magnet effect causes to push prices further towards the price upper or lower limits.

[4]They also provide conflicting evidence that supports proponents of price limits to reduce transitory

of K. A. Kim and Rhee (1997). They also show that price limits affect volatility spillover for upper limit hits, but lower limit hits. Bacha and Vila (1994) investigate price volatility of the Nikkei 255 stock index and its futures contracts traded on Singapore International Monetary Exchange (SIMEX), Osaka Securities Exchange (OSE) and Chicago Mercantile Exchange (CME). They find that completing the markets by creating derivative securities seems to be more effective in stabilizing prices than imposing restrictions on trading and on price movements.

To investigate whether illiquid stocks are especially vulnerable to price limits,G.-M. Chen, K. A. Kim, and Rui (2005) use data from the Chinese stock exchanges, where stocks have different ownership structures[5]. They find that illiquid stocks hit price limits more often than liquid stocks and hence stocks with wide bid-ask spreads are constrained by narrow price limits. Using transactions data from Shanghai Stock Exchange (SHSE), Bo, Yong, et al. (2009) explore the magnet effect of price limits. According to their study, when limit hits are imminent, stock prices approach the price limits at faster rates, with higher trading intensity and larger price variation. When stock price approach the floor limits, they observe lower than normal market conditions' trading volume and size, but a wider spread. Employing account-level data from Shenzhen Stock Exchange (SZSE), T. Chen et al. (2019) analyze how daily price limits affect market dynamics and whether the daily price limits may induce destructive trading behavior by a group of speculators against other investors. They find a set of results indicating that the daily price limits may have an unintended effect of inducing large investors to pursue a destructive strategy of pushing up stock prices to the upper price limits and then selling on the next day. This unintended effect highlights the challenge in designing the trading system for emerging markets.

Employing intraday data from Taiwan Stock Exchange (TSE), Cho et al. (2003) investigate the magnet effect of price limits. They find a significant tendency for stock prices to accelerate toward the upper bound and weak evidence of acceleration toward the lower bound as the price approaches the price limits. Using transaction data from the Taiwan Stock Exchange (TSE), Hsieh, Y. H. Kim, and Yang (2009) find evidence of the magnet effect of price limits, a finding with important regulatory implications. They show that the conditional probability of a price increase (decrease) increases significantly when the price approaches the upper (lower) price limits. They state that the magnet effect receives support from not only the greater conditional probability, but also the increasing price limits moves when the price approaches the limits. Tooma (2011) investigates the magnet effect of price

volatility on lit hit days and do not spillover the post limit hit days.

[5] In the Chinese stock markets, there are A-shares and B-shares. A-shares are owned by local Chinese citizens and B-shares are owned primarily by foreigners or overseas Chinese citizens.

limits in the Egyptian Stock Exchange (EGX) and his findings are consistent with the early study of Cho et al. (2003).

Overall, critics of price limits claim that price limits provide ambiguous conceptual impact and implications for price movements. In addition, academic researchers and practitioners support three main hypotheses such as volatility spillover, delayed price discovery and trading interference with many empirical evidence and studies.

1.2.4 Korea Stock Exchange (KRX)

Based on the fixed amounts, price limits first initiated on March 3, 1956 in the Korean Stock Exchange (KRX). On April 1, 1995, the KRX made a modification on its price limits to be based on fixed rates instead of fixed amounts and the rates have gradually increased to 30% from 6%. In addition, market regulators have adopted two volatility interruption mechanisms to keep maintaining stable market conditions.

Berkman and J. B. T. Lee (2002) investigate the effectiveness of price limits by examining market characteristics around a revision in the price limit system on the Korean Stock Exchange (KRX). They find the evidence of a positive relationship between price limits and long-term volatility and a negative relationship between price limits and trading volumes. Based on their empirical results, stricter price limits have benefits, especially in emerging markets, despite the cost of preventing trading on limit-hit days. In addition, adverse effects of the widening of price limits are greater for small stocks, providing possible explanation why strict price limits frequently adopt for emerging markets. Seddighi and Yoon (2018) examine the efficacy of the Korean stock markets with reference to the recent relaxation, from 15% to 30%, of price limits. Using the daily returns of the market index and 60 stocks selected from different industrial sectors, they find that compared with 15% price limits, the number of stocks following the random walk process increases under the 30% price limits, indicating that Korean stock markets become more efficient as daily price limits are expanded. Kwon et al. (2018) investigate the effect of sequential introducing the dynamic VI and static VI to the pre-existing price limits in the Korean Stock Markets. According to their study, dynamic VI contributes significantly to stabilizing stock prices, but static VI. Also, they find that the limited effects of static VI come from its similar functionality to the existing price limit system in Korean stock markets.

1.2.5 Dynamic and Static Volatility Interruptions

In extreme market conditions, market participants can be over-reacting rather than be rational. Due to such market distortions, they need cooling-off time to make rational decisions. In the relatively short history of security trading, to protect market participants and improve market conditions, the Korean stock markets have adopted circuit breaker system to provide cooling-off period for market participants in times of sudden market downturns[6]. It also adopted a sophisticate microstructure mechanism, called volatility interruption (VI). This mechanism consists of two components: dynamic and static. In other words, Korean stock markets operate a daily price limit system, a circuit breaker, and an arrangement to ease volatility of individual issue system to prevent sharp fluctuations in stock prices[7].

The Korean stock markets adopted the dynamic VI first on September 1, 2014, and then static VI on June 15, 2015. The sequential adaptations of dynamic VI and static VI to the Korean stock markets provide market participants with a cooling-off period to alleviate emotional stress or deliver time to analysis new information of market downturns. Because there is no limit to the numbers of times VI can be triggered in a day these two different VI mechanisms can be differentiated by their purposes and reference prices. Dynamic VI is a mechanism to relieve a short-term volatility caused by supply-demand imbalances or fat-finger errors. This mechanism is invoked when the newly executed price is 2 to 6% than the last execution price. The specific thresholds for dynamic VI for KOSPI 200 constituent stocks are 2% for closing auction, 3% for continuous auction and 3% for off-hours single price auction. The thresholds for KOSPI and KOSDAQ markets are 4% for closing auction, 6% for continuous auction and 6% for off-hours single price auction. This mechanism is effective during the continuous trading, closing trading and off-hour periodic trading sessions. Static VI is a tool to relieve a long-term cumulative price change caused by a specific or various quotation. This tool is invoked when the price changes by 10% or more from the previous single price execution for all stocks on the KOSPI and KOSDAQ markets. This mechanism is effective during the continuous trading and opening/closing trading sessions.

When a dynamic VI or static VI is triggered, the orders are received for 2 minutes for periodic call action and then executed. If it occurs during a continuous trading session, the session would be converted to periodic call auction, and for periodic call auction, the time would be extended.

1.3 Motivation and Hypothesis Development

Since the 1987 Black Monday and the 2010 Flash Crash, many countries and exchanges have developed and adopted a new trading mechanism to improve stable market conditions and decrease market volatility. Major European exchanges such as Euronext, Bolsa de Madrid (BME), Deutche Borse, London stock exchange (LSE) do not have price

[6] In Korean stock markets, circuit breaker system has only applied to market indices, we do not discuss it in this study.

[7] Appendix C provides the Korean stock market timelines.

limits but employ elaborate volatility mechanisms such as dynamic VI and static VI that protect investors and listed firms from uncertainty to crisis. Two major exchanges in United States, New York stock exchange (NYSE) and national association of securities dealers automated quotations (NASDAQ), only adopt dynamic VI, indicating that market regulators and policymakers allow investors and listed firms to interact more freely. Compared with European and US exchanges, Asian exchanges are complicated because they have price limits, but fully or partially adopt dynamic VI or static VI. This comes from different levels of market and political conditions. In Japan, Japan exchange group (JPX) adopts not only price limits, but also dynamic VI and static VI. It operates multiple exchanges such as Tokyo stock exchange (TYO) and Osaka securities exchange (OSE). Another major exchange in Asia, Taiwan stock exchange (TWSE) adopts price limits and dynamic VI, but static VI. Shanghai stock exchange (SSE) only adopts price limits. In the relatively short history of security trading, the Korean stock exchange (KRX) adopts dynamic VI and static VI sequentially along with price limits, which have increased over time.

We focus on one specific type of circuit breaker, the VI mechanism, static VI and examine how static VI affects the idiosyncratic volatility of common stocks traded under a group of Korea Composite Stock Price Index (KOSPI). According to Abad and Pascual (2010), dynamic VI is triggered by either by a single, large-sized market order or by an ordinary market order submitted in times of low liquidity, indicating that it usually captures when a short-term supply and demand imbalance is very strong. Eom et al. (2015) analyze all dynamic VI events in the three months following the adoption and find that dynamic VI does not contribute meaningfully to market stabilization in the two major Korean stock markets, KOSPI and KOSDAQ. Following this notion, we do not consider an impact of adopting dynamic VI[8] and investigate an impact of adopting static VI on the conditional idiosyncratic volatility in the KOSPI market. The main reason we initiate this study in the KOSPI market is that sequential introduction of volatility interruption mechanisms allows us to investigate whether the mechanism mitigates day to day volatility and protect investors and listed firms. Also, conducting this study allows us to update outdated market microstructure literature in Korean stock exchange.

The main implementation of adopting static VI mechanism is to stabilize market conditions and reduce excess volatility along with price limits. Nevertheless, investors and listed firms are sensitive to the stock price movements either upward or downward, indicating that volatility has an impact on price movements. Investors overreact or underreact based on their information, and it compounds volatility. The study of Diacogiannis et al. (2005)

[8] Another reason to not consider dynamic VI is a lack of intraday data accessibility.

examines the overreaction hypothesis and its association with the existence of price limits, indicating that investors overreaction is present when price limits hit the upper bound. E. Fama (1989) also points out that investors tend to overreact or underreact, when they get good or bad news in the market. As a result of their reactions, stock prices move up or down toward their equilibrium levels. Following this notion, we expect idiosyncratic volatility increases when stock prices move either upward or downward. We test the following two hypotheses:

H1: Idiosyncratic volatility increases when a stock price hits the upper static limit.

H2: Idiosyncratic volatility increases when a stock price hits the lower static limit.

If these two testable hypotheses are true, the results allow us to conclude that Korean stock markets are inefficient financial markets along with the advanced volatility interruption mechanism, static VI, indicating that market regulators and policymakers are failure to maintain stable market conditions due to its adverse effect.

1.4 Data and Methodology

We obtain daily stock prices and other related financial data from Thomson Reuters Datastream. All data for this research span from June 15, 2015 to March 31, 2019. We chose June 15, 2015 to be the starting date for our sample because the static VI first introduced the date we chose as the starting date. To avoid survivorship bias, we include delisted firms and new IPOs during our sample period. The final sample consists of 790 firms listed on KOSPI market. We focus on the KOSPI stocks to test static VI in the continuous trading session between 9:00 am and 3:20 pm. To begin with, we count the number of static upper and lower hit occurrences.

To estimate the idiosyncratic volatility, we employ the capital asset pricing model, Eugene F Fama and French (1993) three-factor model, Eugene F Fama and French (2015) five-factor model. The main reason to employ three different asset pricing models is for the robustness check and to show that our empirical results are consistent with model selections. To begin with, based on the notion of Sharpe (1964), the estimated CAPM model as follows:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{i,t}(R_{m,t} - R_{f,t}) + \varepsilon_{i,t} \tag{1.1}$$

where $R_{i,t}$ is the return on asset i in period t, $R_{f,t}$ is the risk-free rate in period t, $\beta_{i,t}$ is the beta on asset i in period t, $R_{m,t}$ is the market portfolio in period t, and $\varepsilon_{i,t}$ is the zero-mean residual in period t. We estimate Eugene F Fama and French (1993) three-factor model as follows:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{i,t}(R_{m,t} - R_{f,t}) + s_i SMB + h_i HML + \varepsilon_{i,t} \tag{1.2}$$

Eugene F Fama and French (1993) three-factor model is an extension version of CAPM model along with two additional factors, SMB and HML. SMB is the return on a diversified portfolio of small stocks minus the return on a diversified portfolio of big stocks. HML is the difference between the returns on diversified portfolios of high and low M/B stocks[9]. We estimate Eugene F Fama and French (2015) five-factor model as follows:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{i,t}(R_{m,t} - R_{f,t}) + s_i SMB + h_i HML + r_i RMW + c_i CMA + +\varepsilon_{i,t} \tag{1.3}$$

Eugene F Fama and French (2015) five-factor model is an extension version of Eugene F Fama and French (1993) three-factor model along with two additional factors, RMW and CMA. RMW is the difference between the returns on diversified portfolios of stocks with robust and weak profitability, and CMA is the difference between the returns on diversified portfolios of low (conservative) and high (aggressive) investment stocks. We construct Fama and French three and five factors following the notion of Eugene F Fama and French (1993) and Eugene F Fama and French (2015)[10].

From three different estimated models above, we obtain the conditional idiosyncratic volatility measures by utilizing time-varying variances. Bali and Cakici (2008) employ GARCH (1, 1) model of Bollerslev (1986) to estimate the conditional idiosyncratic volatility. They state that GARCH (1, 1) model is relatively simple and easy to follow properties for time aggregation and stationarity. One main drawback of GARCH model is that the model cannot capture the leverage effect. There are many asymmetric GARCH models that estimate the leverage effect. EGARCH introduced by Nelson (1991) and TGARCH introduced by Zakoian (1994) are employed by measuring asymmetric impact of positive and negative information. Fu (2009) and Glosten, Jagannathan, and Runkle (1993) employ EGARCH

[9]Bagchi (2012) employs Fama and French 3 factor model to investigate the direct and cross-sectional relationship of India volatility index (VIX).

[10]We follow the description of Fama and French 5 factors from Ken French's website and compare our constructed factors to Fama and French emerging factors. See Appendix E.

and TGARCH respectively to estimate the conditional idiosyncratic volatility. According to Bollerslev (1986), GARCH (1, 1) model is specified as follows:

$$h_i = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{1.4}$$

TGARCH (1, 1) introduced by Zakoian (1994) is given as follows:

$$h_i = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \lambda_1 d_{t-1} \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{1.5}$$

where d_{t-1} is a dummy variable that is equal to one if $e_{t-1} < 0$ (bad news) and is equal to zero if $e_{t-1} \geq 0$ (good news). From the results of these models, we could collect residuals as our conditional idiosyncratic volatility.

1.5 Empirical Results

1.5.1 Summary Statistics

Table 1 reports the summary statistics for entire 790 stocks listed on KOSPI market. Based on different VI mechanisms and size of firms, KOSPI stocks consist of two subgroups: KOSPI 200 constituent stocks and general issues. Although the static VI is subject to +/- 10% for them, we generate summary statistics for these subgroups because it allows us to investigate some characteristics of Korean firms[11]. On Table 1, we separately report each KOSPI group on Panel A, Panel B, and Panel C.

We report three generated summary statistics during our sample period between June 15, 2015 and March 31, 2019. The maximum and minimum stock returns are between -30% and 30% due to the price limits. Annualized average return of KOSPI stocks is close to 4.60% and we do not observe high and low spikes in stock return because the VI mechanism constrains upper and lower boundaries. The huge variations of maximum and minimum prices of open, close, intra-high and intra-low come from different price levels of stocks listed on the KOSPI market. The annualized average return of KOSPI general issues is 4.69%, while annualized average return of KOSPI 200 constituent stocks is 4.28%.

Table 2 reports the upper and lower static volatility interruption hits in the KOSPI market during the continuous trading session. Compared with the dynamic VI[12], static VI is invoked when the price changes by +/- 10%. Sorted by year, 235,157 times the static VI

[11]South Korea's Chaebol is a large conglomerate that is run and controlled by an owner or family member.

[12]Based on different thresholds, the dynamic VI consists of KOSPI 200 constituent stocks and KOSPI General issues. KOSPI 200 constituent stocks are subject to narrow upper and lower thresholds, +/- 3% and KOSPI General issues are subject to wide ranges of upper and lower thresholds, +/- 6%.

Table 1.1: Summary Statistics

Table 1 reports summary statistics for 790 stocks listed on KOSPI. Based on different thresholds of dynamic VI, its sample consist of two subgroups: KOSPI 200 constituent stocks and general issues. KOSPI 200 constituent stocks have represented 200 stocks and general issues have 590 stocks. For static VI, we combine all 790 stocks and generate summary statistics during our sample period between June 15, 2015 and March 31, 2019.

Stats	Open Price	Close Price	Intraday High Price	Intraday Low Price	Daily Return
Panel A. Summary Statistics for entire stocks listed on KOSPI					
Mean	43,884.31	43,864.83	44,576.18	43,167.18	0.000126
Median	11,450	11,400	11,650	11,200	0
Std. Dev.	105,594.30	105,587.70	107,232.40	103,976.10	0.028
# of Year	5	5	5	5	5
# of Firms	790	790	790	790	790
# of Observations	697,789	697,789	697,789	697,789	696,880
Panel B. Summary Statistics for KOSPI 200 Constituent Stocks					
Mean	113,346.30	113,328.90	115,075.00	111,614.50	0.000117
Median	51,700.00	51,700	52,500	50,900	0
Std. Dev.	177,725.30	177,794.50	180,406.90	175,145.60	0.023463
# of Year	5	5	5	5	5
# of Firms	200	200	200	200	200
# of Observations	180,277	180,277	180,277	180,277	180,071
Panel C. Summary Statistics for KOSPI General Issues					
Mean	19,686.99	19,666.78	20,017.68	19,323.32	0.000128
Median	6,990	6,980	7,100	6,860	0
Std. Dev.	42,010.72	41,884.43	42,805.05	41,115.42	0.028995
# of Year	5	5	5	5	5
# of Firms	590	590	590	590	590
# of Observations	517,512	517,512	517,512	517,512	516,809

were triggered from June 15, 2015 to March 31, 2019. The number of hits consists of 89,144 static upper hits and 146,013 static lower hits. The years following the implementation of the VI rules, 2018, witnessed the highest static VI occurrences with a total of 65,604 limit reaches. Out of the 65,604 hits, 25,311 static upper hits and 40,293 static lower hits are observed. Sorted by industry, finance, chemical, and electrical and electronic equipment industries are observed the highest static VI occurrence with 32,332, 28,083, and 17,498 limit hits, respectively. Conversely, fishing, mining, medical and precision machines industries are witnessed the lowest static VI occurrences with 160, 541, and 817 limit hits, respectively.

1.5.2 Volatility Interruptions and Idiosyncratic Volatility

To figure out the positive or negative relationship between idiosyncratic volatility and static VI hits, we first need to create two dummy variables - static upper and lower hits - in this study. These first steps allow us to test our two hypotheses that there is a positive or negative relationship between idiosyncratic volatility and upper or lower static VI hits. Following the notion of Ferreira and Laux (2007) and Lins, Servaes, and Tamayo (2017) we set up the fixed effect panel regression model as follows:

$$\psi_{i,t} = \gamma_0 + \gamma_1 LimitDummy_{i,t} + \gamma_2 ROE_{i,t-1} + \gamma_3 Leverage_{i,t} + \gamma_4 MTB_{i,t} \gamma_5 MktCap_{i,t} + \varepsilon_{i,t} \quad (1.6)$$

where $\psi_{i,t}$ measures the idiosyncratic volatility for each firm taking log of the conditional variance based on GARCH (1, 1) and TGARCH (1, 1) for three asset pricing models. $LimitDummy_{i,t}$ is the VI dummy associated with the number of static upper or lower limit hits. $ROE_{i,t-1}$ is the firm return on equity ratio, $Leverage_{i,t}$ is the firm debt to asset ratio, $MTB_{i,t}$ is the firm market-to-book ratio, and $MktCap_{i,t}$ is the firm's market capitalization. To distinguish the impact of the different market conditions on the idiosyncratic volatility, $SentimentDummy_i$, is included in the equation. We collect the consumer sentiment index (CSI) data from Bank of Korea and constructed a dummy variable. Korean consumer sentiment dummy is associated with the high- and low- consumer expectations in South Korea[13]. Also, we include time dummy and firm fixed effect as Lins, Servaes, and Tamayo (2017) to control issues associated with a changing economic and political environment over time.

The main independent variable is Static Upper and Static Lower, which are a limit dummy that takes the value of 1 if the triggered condition is met, or the value of 0 otherwise. With the model above, a positive relationship between the idiosyncratic volatility and

[13] We follow the studies of Chung, Hung, and Yeh (2012), Wang (2018a) and Wang (2018b) to investigate investors' trading behaviors in different market conditions.

Table 1.2: Static Upper and Lower Hits for KOSPI Markets

Panel A and B on Table 2 report the upper and lower static volatility interruption hits of entire stocks listed on KOSPI market during the continuous trading session (09:00 - 15:20). The sample period is from June 15, 2015 to March 31, 2019.

Panel A. Upper and Lower Static VI Hit stocks listed on KOSPI by Year

Year	Static Upper	Static Lower	Occurrences of Static VI
2015	12,024	21,004	33,028
2016	22,290	36,974	59,264
2017	23,242	37,657	60,899
2018	25,311	40,293	65,604
2019	6,277	10,085	16,362
Total	89,144	146,013	235,157

Panel B. Upper and Lower Static VI Hit stocks listed on KOSPI by Industry

Industry	Static Upper	Static Lower	Occurrences of Static VI
Chemicals	10,575	17,508	28,083
Communications	931	932	1,863
Construction	2,947	5,455	8,402
Distribution	5,734	10,557	16,291
Electrical and Electronic Equipment	6,274	11,224	17,498
Electricity and Gas	2,953	3,997	6,950
Finance	11,309	21,023	32,332
Fishing	19	141	160
Food and Beverages	4,425	5,817	10,242
Iron and Metal Products	5,076	8,290	13,366
Machinery	2,434	5,169	7,603
Medical Supplies	6,178	9,513	15,691
Medical and Precision Machines	268	549	817
Mining	110	431	541
Non-metallic Mineral Products	1,748	3,487	5,235
Other Manufacture	2,877	4,353	7,230
Paper and Wood	3,315	5,038	8,353
Services	7,652	11,860	19,512
Textile and Wearing Apparel	4,787	6,292	11,079
Transport Equipment	4,652	7,923	12,575
Transport and Storage	4,880	6,454	11,334

static upper and lower hits is expected. ROE and Leverage show the capital structure of the listed firms, which can directly impact the idiosyncratic volatility, because a higher level of leverage leads to a higher level of ROE. With Market-to-book (M/B) and market capitalization (Size) variables, we investigate how large and small firms impact to the idiosyncratic volatility notion of rational market conditions and expect a negative relationship between the idiosyncratic volatility these variables. We anticipate a positive relationship between the idiosyncratic volatility and consumer expectations. Wang (2018a) describes that investors are likely to trade in stock market when investors are relatively optimistic, so their participation in stock market distorts the risk-return tradeoff. To correct for heteroscedasticity, serial correlation, or contemporaneous cross-sectional correlations of error terms by adjusting standard errors for clustering at the firm level, we employ the method of Rogers (1994).

Table 3 reports the estimation results of the panel regression based on Model (6) for a total of KOSPI 790 firms. The dependent variable in column (1) is the conditional idiosyncratic volatility estimated from GARCH (1, 1) in equation (4) on the CAPM model in equation (1). The dependent variable in column (2) is the conditional idiosyncratic volatility estimated from TGARCH (1, 1) in equation (5) on the CAPM model. The dependent variable in column (3) is the conditional idiosyncratic volatility estimated from GARCH (1, 1) in equation (4) on the Eugene F Fama and French (1993) three-factor model in equation (2). The dependent variable in column (4) is the conditional idiosyncratic volatility estimated from TGARCH (1, 1) in equation (5) on the Eugene F Fama and French (1993) three-factor model. The dependent variable in column (5) is the conditional idiosyncratic volatility estimated from GARCH (1, 1) in equation (4) on the Eugene F Fama and French (2015) five-factor model in equation (3). The dependent variable in column (6) is the conditional idiosyncratic volatility estimated from TGARCH (1, 1) in equation (5) on the Eugene F Fama and French (2015) five-factor model[14].

The coefficients of static upper are positive and statistically significant at the one percent confidence level for our all six model specifications, which are 0.5474, 0.5495, 0.5378, 0.5402, 0.5380, and 0.5405 respectively. These results indicate that when stocks listed on KOSPI market reach the upper static limit, + 10%, the idiosyncratic volatility increases by approximately 0.54%. The coefficients of static lower are also positive and statistically significant at the one percent confidence level through our all six models 0.5880, 0.5905, 0.5798, 0.5826, 0.5801, and 0.5831 respectively, indicating that when such stocks reach the lower static limit, - 10%, idiosyncratic volatility increases by approximately 0.58%. This empirical evidence provides support to our testable hypotheses that idiosyncratic volatility

[14] We also use EGARCH model to estimate the idiosyncratic volatility and confirm that EGARCH model provides consistent results.

Table 1.3: Conditional Idiosyncratic Volatility

Table 3 reports the results of estimating the panel regression fixed effect models for a total of KOSPI 790 firms. The dependent variable is the firm's conditional idiosyncratic volatility measured using GARCH (1, 1) and TGARCH (1, 1) from estimating the capital asset pricing model (CAPM),Eugene F Fama and French (1993) three-factor model, and Eugene F Fama and French (2015) five-factor model. Along with control variables, the main independent variables are static uppers and lowers which are dummy variables that equal to 1 if they hit their thresholds and 0 otherwise. Following the notion of Rogers (1994), we collect t-statistics. We report the results of entire stocks listed on KOSPI market for static upper and lower limits. The sample period is from June 15, 2015 to March 31, 2019.

	CAPM		FF 3-Factor		FF 5-Factor	
	GARCH (1)	TGARCH (2)	GARCH (3)	TGARCH (4)	GARCH (5)	TGARCH (6)
Static Upper	0.5474	0.5495	0.5378	0.5402	0.5380	0.5405
	(51.22)	(51.39)	(50.02)	(50.23)	(50.06)	(50.29)
ROE	0.1164	0.1032	0.0753	0.0666	0.0766	0.0674
	(8.41)	(7.46)	(5.59)	(4.94)	(5.66)	(4.98)
Leverage	5.30E-10	5.15E-10	4.44E-10	4.38E-10	4.26E-10	4.21E-10
	(7.59)	(7.41)	(6.46)	(6.38)	(5.80)	(5.71)
M/B	-0.2554	-0.2484	-0.2017	-0.1994	-0.1834	-0.1811
	(-9.14)	(-8.92)	(-7.70)	(-7.64)	(-7.03)	(-6.96)
Size	-4.54E-17	-4.00E-17	-3.08E-17	-2.77E-17	-3.39E-17	-3.07E-17
	(-4.82)	(-4.48)	(-3.93)	(-3.75)	(-3.99)	(-3.81)
Sentiment	0.0114	0.0112	0.0120	0.0117	0.0123	0.0121
	(4.38)	(4.30)	(4.58)	(4.49)	(4.72)	(4.63)
Obs.	696,701	696,701	696,701	696,701	696,701	696,701
R^2	0.0518	0.0513	0.0499	0.0496	0.0495	0.0492
Static Lower	0.5880	0.5905	0.5798	0.5826	0.5801	0.5831
	(49.49)	(49.68)	(48.62)	(48.85)	(48.68)	(48.92)
ROE	0.1410	0.1278	0.0992	0.0906	0.1004	0.0914
	(10.10)	(9.18)	(7.36)	(6.72)	(7.43)	(6.76)
Leverage	5.42E-10	5.28E-10	4.56E-10	4.51E-10	4.38E-10	4.33E-10
	(7.60)	(7.42)	(6.50)	(6.42)	(5.85)	(5.77)
M/B	-0.2618	-0.2550	-0.2081	-0.2060	-0.1898	-0.1877
	(-9.18)	(-8.97)	(-7.78)	(-7.72)	(-7.12)	(-7.06)
Size	-5.31E-17	-4.78E-17	-3.83E-17	-3.51E-17	-4.13E-17	-3.81E-17
	(-5.05)	(-4.70)	(-4.14)	(-3.95)	(-4.20)	(-4.01)
Sentiment	0.0106	0.0103	0.0112	0.0108	0.0115	0.0112
	(4.02)	(3.92)	(4.22)	(4.09)	(4.35)	(4.23)
Obs.	696,742	696,742	696,742	696,742	696,742	696,742
R^2	0.0484	0.0480	0.0468	0.0465	0.0464	0.0462
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

increases when stock prices reach the static upper limit and static lower limit as well. Our empirical results are agreeable with K. A. Kim and Rhee (1997) who show that volatility does not return to normal levels as quickly as the stocks that do not reach price limits in Tokyo Stock Exchange markets. These findings also support a recent paper by T. Chen et al. (2019), who analyze the effect of daily price limits on market dynamics and detect destructive trading behavior by a group of speculators against other investors resulting in an unintended effect on the markets.

ROE and Leverage show positive effect on the conditional idiosyncratic volatility since the capital structure of the listed firms can directly impact the idiosyncratic volatility, where a higher level of leverage leads to a higher level of ROE. We find negative effect of Market-to-book (M/B) and market capitalization (Size) on the conditional idiosyncratic volatility. These results are consistent with the findings by Ferreira and Laux (2007). The coefficients of the sentiment value are positive and statistically significant for all asset pricing models with both GARCH and TGARCH specifications. Our empirical results are consistent with Wang (2018a) and Wan et al. (2018), where their results indicate that high consumer expectations distort the risk and return tradeoff, which may contribute to increases to the idiosyncratic volatility. Further we find that time and firm fixed effects are supported as Lins, Servaes, and Tamayo (2017) All results agree with both static upper and lower limits.

Table 4 and 5 presents the results of estimation of Model (6) for subgroups of KOSPI firms, where the results of KOSPI 200 constituent stocks are shown in table 4 and KOSPI general issues in table 5. All results are qualitatively the same as those found in Table 3. Compared with KOSPI general issues, KOSPI 200 constituent stocks indicate relatively stable when stocks reach the static upper and lower bounds. Our results indicate the implementation of adopting static VI mechanism neither stabilize market conditions nor reduce excess volatility along with the existence of price limits. As discussed by E. Fama (1989) and Diacogiannis et al. (2005), these results support overreaction hypothesis that investors tend to overreact when price hits limits. Although main purpose of adopting advanced volatility interruption mechanism is to help stable and improve market conditions, we find the adverse effect of the mechanism, indicating that market participants are exposed to the additional risks when stock prices hit the upper and lower limits. As such, investors must not react quickly to the price changes that may hit the limits in order to avoid the unintended excess risk. We added the above discussion in the Conclusion section.

Table 1.4: Conditional Idiosyncratic Volatility - KOSPI 200 Constituent Stocks

Table 4 reports the results of estimating the panel regression fixed effect models for KOSPI 200. The dependent variable is the firm's conditional idiosyncratic volatility measured using GARCH (1, 1) and TGARCH (1, 1) from estimating the capital asset pricing model (CAPM), Fama and French (1993) three-factor model, and Fama and French (2015) five-factor model. Along with control variables, the main independent variables are static uppers and lowers which are dummy variables that equal to 1 if they hit their thresholds and 0 otherwise. Following the notion of Rogers (1993), we collect t-statistics. Panel A reports the results of KOSPI 200 constituent stocks for static upper and lower limits. The sample period is from June 15, 2015 to March 31, 2019.

	CAPM		FF 3-Factor		FF 5-Factor	
	GARCH (1)	TGARCH (2)	GARCH (3)	TGARCH (4)	GARCH (5)	TGARCH (6)
Static Upper	0.3149	0.3144	0.3128	0.3125	0.3139	0.3137
	(12.63)	(12.64)	(12.57)	(12.59)	(12.56)	(12.57)
ROE	0.2098	0.2138	0.2084	0.2107	0.2075	0.2092
	(12.65)	(12.86)	(12.99)	(13.11)	(12.98)	(13.07)
Leverage	-3.30E-11	-3.13E-11	-2.05E-11	-2.09E-11	-5.44E-11	-5.50E-11
	(-0.42)	(-0.39)	(-0.56)	(-0.56)	(-1.28)	(-1.29)
M/B	-0.0324	-0.0334	-0.0293	-0.0293	-0.0069	-0.0067
	(-1.09)	(-1.12)	(-1.01)	(-1.01)	(-0.24)	(-0.23)
Size	-2.40E-17	-2.59E-17	-2.64E-17	-2.73E-17	-3.32E-17	-3.40E-7
	(-1.95)	(-2.09)	(-2.31)	(-2.40)	(-2.53)	(-2.60)
Sentiment	0.0039	0.0040	0.0040	0.0042	0.0039	0.0040
	(1.31)	(1.37)	(1.37)	(1.44)	(1.32)	(1.37)
Obs.	180,077	180,077	180,077	180,077	180,077	180,077
R^2	0.0313	0.0318	0.0321	0.0324	0.0321	0.0323
Static Lower	0.3562	0.3556	0.3544	0.3541	0.3560	0.3558
	(10.99)	(11.01)	(10.97)	(11.00)	(10.98)	(11.00)
ROE	0.2167	0.2206	0.2152	0.2175	0.2143	0.2160
	(12.89)	(13.10)	(13.24)	(13.37)	(13.23)	(13.32)
Leverage	-3.20E-11	-3.04E-11	-1.95E-11	-1.99E-11	-5.34E-11	-5.40E-11
	(-0.39)	(-0.37)	(-0.53)	(-0.53)	(-1.25)	(-1.26)
M/B	-0.0331	-0.0341	-0.0300	-0.0299	-0.0075	-0.0074
	(-1.09)	(-1.12)	(-1.02)	(-1.02)	(-0.26)	(-0.25)
Size	-2.55E-17	-2.75E-17	-2.79E-17	-2.88E-17	-3.48E-17	-3.55E-17
	(-2.05)	(-2.20)	(-2.41)	(-2.50)	(-2.63)	(-2.70)
Sentiment	0.0040	0.0042	0.0042	0.0044	0.0041	0.0042
	(1.37)	(1.44)	(1.43)	(1.51)	(1.39)	(1.44)
Obs.	180,274	180,274	180,274	180,274	180,274	180,274
R^2	0.0299	0.0304	0.0307	0.0311	0.0308	0.0310
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Table 1.5: Conditional Idiosyncratic Volatility - KOSPI 200 Constituent Stocks

Table 5 reports the results of estimating the panel regression fixed effect models for KOSPI 200. The dependent variable is the firm's conditional idiosyncratic volatility measured using GARCH (1, 1) and TGARCH (1, 1) from estimating the capital asset pricing model (CAPM), Fama and French (1993) three-factor model, and Fama and French (2015) five-factor model. Along with control variables, the main independent variables are static uppers and lowers which are dummy variables that equal to 1 if they hit their thresholds and 0 otherwise. Following the notion of Rogers (1993), we collect t-statistics. The sample period is from June 15, 2015 to March 31, 2019.

	CAPM		FF 3-Factor		FF 5-Factor	
	GARCH (1)	TGARCH (2)	GARCH (3)	TGARCH (4)	GARCH (5)	TGARCH (6)
Static Upper	0.5797	0.5816	0.5721	0.5742	0.5721	0.5742
	(50.73)	(50.92)	(49.59)	(49.82)	(49.64)	(49.88)
ROE	0.0697	0.0523	-0.0028	-0.0128	-0.0003	-0.0105
	(3.96)	(2.98)	(-0.17)	(-0.75)	(-0.02)	(-0.62)
Leverage	7.65E-10	7.44E-10	5.84E-10	5.76E-10	5.78E-10	5.70E-10
	(8.58)	(8.37)	(6.82)	(6.73)	(6.44)	(6.34)
M/B	-0.3450	-0.3348	-0.2489	-0.2494	-0.2351	-0.2318
	(-9.60)	(-9.36)	(-7.39)	(-7.32)	(-7.02)	(-6.94)
Size	-4.77E-17	-4.08E-17	-1.56E-17	-1.24E-17	-1.75E-17	-1.44E-17
	(-4.14)	(-3.81)	(-2.63)	(-2.48)	(-2.56)	(-2.42)
Sentiment	0.0135	0.0133	0.0146	0.0143	0.0148	0.0146
	(4.04)	(3.98)	(4.31)	(4.25)	(4.39)	(4.34)
Obs.	516,624	516,624	516,624	516,624	516,624	516,624
R^2	0.0563	0.0557	0.0534	0.0531	0.0530	0.0527
Static Lower	0.6183	0.6206	0.6129	0.6153	0.6128	0.6154
	(48.95)	(49.16)	(48.22)	(48.45)	(48.26)	(48.51)
ROE	0.0997	0.0825	0.0265	0.0167	0.0290	0.0189
	(5.62)	(4.66)	(1.55)	(0.98)	(1.69)	(1.11)
Leverage	7.83E-10	7.62E-10	6.02E-10	5.94E-10	5.95E-10	5.87E-10
	(8.57)	(8.37)	(6.87)	(6.79)	(6.50)	(6.41)
M/B	-0.3539	-0.3437	-0.2579	-0.2548	-0.2442	-0.2409
	(-9.64)	(-9.40)	(-7.50)	(-7.43)	(-7.13)	(-7.06)
Size	-5.79E-17	-5.10E-17	-2.53E-17	-2.20E-17	-2.71E-17	-2.41E-17
	(-4.36)	(-4.02)	(-2.84)	(-2.68)	(-2.77)	(-2.62)
Sentiment	0.0124	0.0121	0.0134	0.0131	0.0137	0.0134
	(3.66)	(3.57)	(3.91)	(3.82)	(3.99)	(3.91)
Obs.	517,468	517,468	517,468	517,468	517,468	517,468
R^2	0.0524	0.0519	0.0498	0.0496	0.0495	0.0492
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

1.6 Concluding Remarks

Since major market events such as the 1987 Black Monday and the 2010 Flash Crash, many countries and exchanges have developed and adopted a new trading mechanism to improve stable market conditions and decrease market volatility. Due to sequential adoptions of price limits, dynamic VI, and static VI, the study of Korean markets allows us to see separate effects of those mechanisms respectively. In Korean stocks markets, the VI system was built on top of a pre-existing price limits, indicating that stabilized market mechanisms are required by investors, market regulators and policymakers. In this paper, we examine impact of static VI in KOSPI market. We find that the conditional idiosyncratic volatility increases when stock prices reach the upper or lower static limits. Moreover, the conditional idiosyncratic volatility increases more when stock prices reach the lower static limit than when stock prices reach the upper static limit. Although market regulators and policymakers improve market conditions with the advanced volatility interruption mechanism, our empirical results show the adverse effect of the mechanism, indicating that market participants are exposed to the additional risks with price movements. Investors overreact or underreact based on their information, and it compounds volatility. As such, the investors must not react quickly to the price changes that may hit the limits in order to avoid the unintended excess risk.

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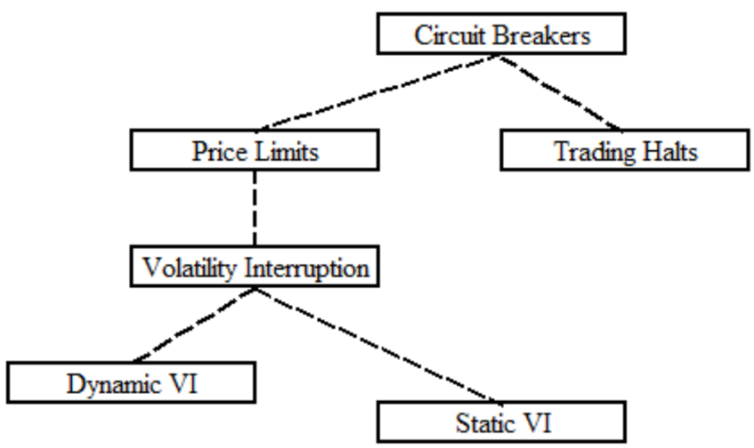
Appendix A

GLOBAL MARKET STRUCTURES

Table A.1: Global Market Structures

Appendix A reports the global market structures of circuit breakers. According to Abad and Pascual (2013) there are two main types of circuit breakers: price limits and trading halts. volatility interruptions. During trading halts, any trades cannot be executed. Price limits allow trades to occur in certain thresholds thereby protecting investors from market fluctuations. To improve price limits along with their own market regulations and polices, global financial markets have adopted different combinations of mechanisms. All European markets do not have price limits but adopt volatility interruption mechanisms. US markets only partially adopt volatility interruption mechanisms. Compared with European and US markets, Asian markets have price limits, but fully or partially adopt volatility interruption mechanisms except Shanghai stock exchange (SSE).



Market Classification		Price Limits	Volatility Interruption	
			Dynamic VI	Static VI
Europe	Euronext	x	o	o
	BME	x	o	o
	Deutsche Borsa	x	o	o
	LSE	x	o	o
USA	NYSE	x	o	x
	NASDAQ	x	o	x
Asia	JPX	Average 22%	o	o
	TWSE	±10%	o	x
	SSE	±10%	x	x

Appendix B

HISTORY OF PRICE LIMITS OF KOREA STOCK EXCHANGE (KRX)

Table B.1: Global Market Structures

Appendix B reports the changes in price limits in South Korean markets.

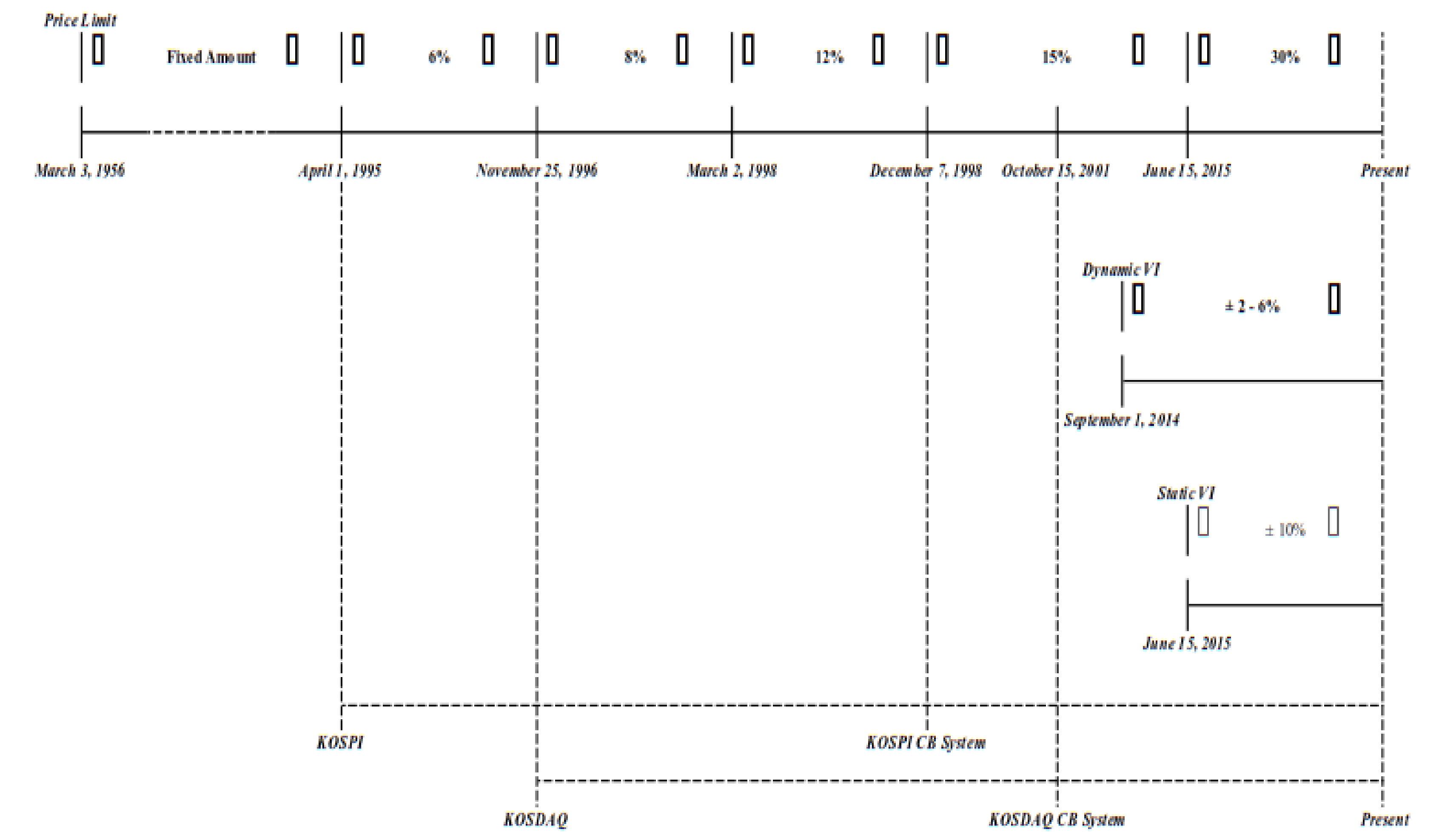
Period			Price Limits	Remarks
March 3, 1956	-	March 31, 1995	2.2% - 6.7%	Fixed Amount
April 1, 1995	-	November 24, 1996	6%	Fixed Fixed
November 25, 1996	-	March 1, 1998	8%	Fixed Fixed
March 2, 1998	-	December 6, 1998	12%	Fixed Fixed
December 7, 1998	-	June 14, 2015	15%	Fixed Fixed
June 15, 2015	-	Present	30%	Fixed Fixed

Appendix C

TIME LIMITS FOR SOUTH KOREAN MARKETS

Table C.1: Time Limits for South Korean Markets

Appendix C shows the initiation of Circuit Breakers (CB) system in South Korean markets. CB systems were first introduced on December 7, 1998 for the KRX KOSPI market, and on October 15, 2001 for the KRX KOSDAQ market. It also visualizes the changes in price limits and the introduction of dynamic and static volatility interruptions in South Korean Markets. Price limits initiated on March 3, 1956, and maintained the price limit based on the fixed amount. Since 1995, the price limits have increased to 30% from 6%. The KOSPI market initiated on April 1, 1995, and then KOSDAQ on November 25, 1996. Later South Korean market regulators added two volatility interruption mechanisms to stabilize their market conditions. On September 1, 2014, they adopted the dynamic VI first, and then static VI on June 15, 2015.



Appendix D

THRESHOLDS OF DYNAMIC AND STATIC VOLATILITY INTERRUPTIONS IN SOUTH KOREAN MARKETS

Table D.1: Thresholds of Dynamic and Static Volatility Interruptions in South Korean Markets

Appendix D reports the dynamic and static volatility interruption thresholds for Korean stock markets. South Korean markets - KOSPI and KOSDAQ - offer different rates of thresholds based on markets Dynamic VI is based on last execution price.

	Dynamic VI			Static VI
Classification	Continuous Trading Session (09:00:15:20)	Closing Trading Session (15:20-15:30)	Off-Hours Single Price Trading Session (16:00-18:00)	Regular Session
KOSPI 200 Constituents	3%	2%	3%	10%
General Issues	6%	4%	6%	10%

Appendix E

SUMMARY STATISTICS FOR FACTOR RETURNS

Table E.1: Summary Statistics for Factor Returns

Appendix E presents factor returns for South Korea and emerging countries listed on Fama and French website. Panel A reports Mean, Std Dev, and t-Mean for factor returns for two different groups. Panel B reports the correlations of each factor and its shapes. The sample period of factor returns is between April 1, 1995 and March 31, 2019.

Panel A. Mean, Standard Deviations, and t-Mean of Factor Returns

	Mkt	SMB	HML	RMW	CMA
	South Korea				
Mean	0.1706	0.0981	-0.0914	-0.4541	0.1016
Std Dev	7.9868	5.3270	5.0293	4.0585	3.5346
t-Mean	0.4706	0.3139	0.2964	0.2391	0.2083
	Emerging Countries				
Mean	0.5795	0.0027	0.6618	0.2291	0.3053
Std Dev	6.1357	2.0171	2.1613	1.3948	1.6695
t-Mean	0.3615	0.1189	0.1274	0.0822	0.0984

Panel B. Correlation Matrices for Factors in Two Different Groups

Mkt	South Korea	Emerging Countries
South Korea	1.0000	
Emerging Countries	0.6215	1
SMB	**South Korea**	**Emerging Countries**
South Korea	1.0000	
Emerging Countries	0.4298	1
HML	**South Korea**	**Emerging Countries**
South Korea	1.0000	
Emerging Countries	0.2192	1
RMW	**South Korea**	**Emerging Countries**
South Korea	1.0000	
Emerging Countries	-0.1285	1
CMA	**South Korea**	**Emerging Countries**
South Korea	1.0000	
Emerging Countries	0.2006	1

VITA

Seungho Shin was born and raised in Seoul, South Korea. He obtained his bachelor's degree in Finance from University of Central Florida in 2013 and his MBA in Finance and Operations Management from Crummer Graduate School of Business at Rollins College in 2015. He joined the College of Business Administration at the University of New Orleans in 2016 and earned his MS in Financial Economics in 2018 and PhD in Financial Economics in 2021. While he was pursuing his PhD, he worked as a graduate assistant and a teaching associate, teaching undergraduate classes in Engineering Economics, Finance Capstone, Bank Administration, Financial Management, Principles of Microeconomics, and Intermediate Business Statistics. His research interests are in the fields of empirical asset pricing, market microstructure, corporate governance, machine learning, and fintech.