Expiration Day Effects in Korean Stock Market: Wag the Dog?

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Abstracts

Despite great success of derivative market, regulators express concerns regarding the additional volatility due to expiration of derivative securities. The expiration day effect around the world varies depending on the structure of settlement procedure. This paper examines the impact of the expiration of KOSPI 200 derivatives on the underlying cash market in Korea Stock Exchange (KSE). The KOSPI 200 derivative market has a unique settlement price determination process since the closing price of stock market is determined by call auction during the last 10 minutes. We analyze typical maturity effects such as volume, volatility, and price effects on the expiration days. In addition, we explore the influence of the unique settlement procedure of KSE on the underlying cash market during the last 10 minutes.

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CHAPTER 1

Introduction

Stock index futures and options have been a great success story in Korea. After stock index futures and index options were introduced in 1997 and 1998 respectively, the trading volume and value of these financial derivatives have grown enormously and Korean derivative market has become one of the biggest derivative exchange markets in the world. Although there are other derivative markets, which have shown successful growth, the success of derivative market in Korea is rather extraordinary. As of 2002, the trading volume of index option in KSE is more than 16 times that of the second place market, EURONEXT (France).[1]

The success of index derivative market is mainly due to its convenience in managing market risk exposure and leverage effects. In general, derivative trading is more convenient and less expensive than stock trading.

Despite this success, there have been some concerns regarding the effects of the introductions of these financial derivatives. Especially, the popular program trading is considered by market participants and popular media as a possible main force to generate additional volatility in the market. Since the U.S. stock market crash of October 1987, researchers have studied the adverse effects of derivative expiration on the underlying stock market.[2]

1. Related Literature

The most widely cited work on the maturity effect is a series of researches by Stoll and Whaley (1987, 1990, 1991). Stoll and Whaley (1987) have investigated the effects of large transactions on prices, and they found significant volatility on expiration days. As the response to the criticism on the effects of derivative expiration, the Chicago Mercantile Exchange (CME) imposed a new procedure on the future expiration. Beginning with the June 1987 S&P 500 futures contract, the last trading day was moved from Friday to Thursday with final settlement based on a “special”[3] Friday opening for the underlying index. After this change in the market structure, Stoll and Whaley (1991) and others try to answer the following question. Has this change reduced expiration day effects? Stoll and Whaley and most other studies argue that this change has only moved the expiration effects to the Friday opening. That is, although the triple witching hour effects has been reduced or removed, the Friday opening preceding the expiration day is associated with greater price volatility than before this change.

After the derivative market became popular in other international markets, quiet a few studies have analyzed the expiration day effects in each market. (Chamberlain, Cheung,

1 It is an intriguing research topic to investigate sources of the extraordinary volume of the KSE option market.

2 It is called as triple witching hour effect since there are expirations of index future, index option, and individual options every three months.

3 See Table 10.

and Kwan (1989) – TSE 300 Index on the Toronto Stock Exchange, Pope and Yadav (1992) – United Kingdom case, Schlag (1996) – DAX derivatives in Germany, Karolyi (1996) – Nikkei 225 index in Japan, and Stoll and Whaley (1997) AOI futures of the Sydney Futures Exchange) Most of these studies find similar expiration day effects in each market as in the case of the United States.

A recent notable paper by Chow, Yung, and Zhang (2002) explores the expiration day effects in Hong Kong. The Hang Seng Index derivatives traded in the Hong Kong Futures Exchange use a unique procedure for determining the settlement price of both index future and index option contracts. The final settlement price is determined by taking the average every 5-minute interval of the Han Seng Index quotation on the expiration day. Their analyses show that there are almost no expiration day effects in Hong Kong derivative market. With some reservation, they argue this is due to the unique settlement price determination scheme in Hong Kong.

The concern regarding expiration day effects is no different in Korea. Popular media and financial analysts show interest on the expiration day whenever either options or futures expire. Despite these concerns, there are not many studies, which tackle these expiration day effects in the KSE directly.[4] A few exceptions are Min (2000), and Che (2001). Previous studies using daily data have not found typical expiration day effects in the KSE.

In this paper, we analyze the expiration day effects in the KSE using minute-by-minute price and trading data. As other studies on expiration day effects, we explore the following four issues; i) volatility of underlying cash market on expiration day, ii) volume changes on expiration day, iii) price effect on the underlying index components, and iv) price reversal of underlying individual stocks after the expiration. As others have shown previously, there is no strong evidence of expiration day effects in the KSE using daily data. But if we concentrate our analyses on the later part of trading time on expiration day, there are significant expiration day effects. We try to interpret our result with the market microstructure of settlement determination procedure.[5]

This paper is organized as follows. Chapter 2 describes the market structure of derivatives in the Korean Stock Exchange. Chapter 3 analyzes the maturity day effect in the KSE and Chapter 4 concludes.

4 There are some studies regarding volatility and trading volume of futures over the maturity such as Seo, Um, Kang (1999) or regarding changes of volatility in the cash market after the introduction of derivatives such as .

5 The importance of the market microstructure in derivative market has been emphasized several times by Stoll (1988), Stoll and Whaley (1997), and Chow, Yung, and Zhang (2002).

CHAPTER 2

The Market Structure of Derivatives in the KSE

The maturity day effect depends on the market structure of derivative such as trading time, and settlement price determination process. So it is essential to understand the market microstructure of both derivative and cash markets.

1. Description of Cash Market

Orders submitted by investors are executed according to price and time priority, by means of periodic call auction[6] and continuous auction. During regular trading hours (from 9:00 am to 2:50 PM), all orders are matched using continuous auction. Periodic call auction is utilized to determine a price after a period of trade suspension or in case where detailed information on securities market is lacking or unavailable. This method brings together all bids and offers submitted during a certain period of time and matches a single price. This price is determined at a level which all bids with prices higher than the price and all offers with prices lower than the prices are filled. This periodic call auction is regularly utilized to determine the opening price (from 8:00 am to 9:00 am) and the closing price (from 2:50 PM to 3:00 PM).

2. Description of Derivative Market

The underlying asset of stock index futures and options in the Korean Stock Exchange (KSE) is the KOSPI 200. It is a market capitalization weighted index composed of 200 major stocks listed on the KSE. Contract months of index futures are March, June, September, and December. As for the index option contract months are three consecutive near months plus one nearest from quarterly cycle.

The KSE also provides seven individual stock options on the blue chip stocks such as Samsung Electronics, SK Telecom, etc, since 2002. Considering the short period of existence and minute trading volume of these individual stock options, the introduction of these individual stock options would be negligible.

The unique part of derivative structure in the KSE is the settlement price determination process. On the last trading day of derivatives, the trading of matured derivative contracts ends at 2:50 PM. Then, the settlement price is set to the closing price of cash market, which is determined by the 10-minute call auction.

6 Sometimes it is called as batch auction.

3. Possible Sources of the Maturity Effect

Most studies argue that the primary source of expiration day effect is from the cash settlement feature of index derivative contracts. Index arbitrage represents a trading activity that exploits mis-pricing between a derivative asset and its underlying cash market price.

Index arbitrage links the price of future or option contract to the level of the underlying index. In the absence of transaction costs, the equilibrium requires,

$$F = S(1 + r - d)$$

where F, S, r, and d represent index futures price, index cash price, riskless (risk free)interest rate, and dividend yield of the stock index over the remaining maturity. If this equality does not hold by some reason, arbitrageurs buy and sell the component of index and exploit this mis-pricing. At maturity, the derivatives contract self-liquidate since index futures and options call for cash settlement, while stock position should be liquidated through trade in the market place. Arbitrageur's trading activity could cause abnormal volume and return in underlying cash market.7

This can be easily observed by analyzing the program trading activity in the KSE. The following table shows the proportion of program trading in the KSE between March 2002 and June 2003. The trading volume in the KSE is larger during non-expiration day than during expiration day. However, the proportion of program is much bigger during expiration day than non-expiration day. This reflects the degree of program trading on expiration day.[8]

In Chapter 3, we analyze expiration day effects in the KSE and explore effects of unique settlement procedure described in this section.

Table 1. The Proportion of Program Trading in the KSE

	Arbitrage Trading	Non Arbitrage Trading	Total Program Trading	Total Trading Volume
Non-Expiration Day	1.20%	0.70%	1.90%	804,982
Expiration Day	3.90%	2.30%	6.20%	690,854

Note: From March 2002 to June 2003.

7 For more detailed description on the mechanism of expiration day effects, see Stoll (1988).
8 The proportion of program trading in the KSE is much smaller than that in the NYSE, which is over 20%.

Table 2. Specifications of the Derivatives Traded on the KSE

	Index Futures	Index Options	Equity Options
Underlying Asset	KOSPI 200		7 listed stocks (Hyundai Motor, KEPCO, Kookmin Bank, KT, POSCO, Samsung Electronics, SK Telecom)
Contract Months	March, June, September, December	Three consecutive near months plus one nearest from quarterly cycle (March, June, September, and December)	
Exercise Style	-	European	
Multiplier	KRW 500,000	KRW 100,000	10 shares
Last Trading Day	Second Thursday of the contract month		
First Trading Day	The day following the last trading day		
Trading Hours	09:00~15:15 **(09:00~14:50 on the last trading day)**		09:00~15:15
Trading Unit	One contract		
Tick Size & Value	0.05 point	- 0.05 point for 3 point or more of premium - 0.01 point for less than 3 point of premium	KRW 10~200
Type of Order	Limit order, Market order, Limit-or-market on close order, Best order		
Price Limit	10% of the previous day's closing price	-	-
Position Limit	Net position of 5,000 contracts	-	Net position of 50,000~200,000 contracts depending on the number of listed shares and trading volume of the underlying stock.

CHAPTER 3

Empirical Analyses

1. Abnormal Return and Volatility: Daily Data Analysis

As discussed above, the expiration of derivative securities such as futures or options written on the KOSPI 200 Index is expected to accompany a high trading volume and significant fluctuation in prices of the underlying asset since program traders try to unwind their positions before the expiration of derivatives to avoid the cumbersome settlement procedure.

As the first step to investigate the price effects of derivative expiration in Korean stock market, we compare the average return of the Index for derivative-expiring Thursdays with the average return for non-expiring Thursday. We construct the sample by collecting only Thursdays' observations to control for the possible presence of calendar effect in stock market.[9]

The institutional arrangement in the Korean Stock Exchange (KSE) in which all stocks included in the KOSPI 200 Index are traded allows us to split all Thursdays in the sample into three different groups; non-expiration (NE) Thursdays when neither futures nor options expire, Option-expiration Thursdays (OE) when options expire but no futures do, and Twin-expiration (TE) Thursdays[10] when both futures and options expire. Our sample covers about five and half years' span from June 19, 1997 to December 26, 2002. The starting week was chosen simply because it was the first week just after the expiration of the last futures contracts issued before the first option contract was introduced. Except for national holidays and irregular closing days for various reasons, there are 269 Thursdays in the sample of which 42 are NE Thursdays and 21 are TE Thursdays.[11]

One can expect to observe significantly different patterns of price movements between non-expiring Thursdays and expiring Thursdays if expiration-day effects indeed exist. Efforts to unwind positions taken by program traders to avoid settlement procedure make trading more active and present themselves in the form of abnormal daily returns, whether higher or lower, or higher volatilities on expiring Thursdays than ordinary Thursdays.

We calculate two different daily log-returns and their standard deviations for each Thursday; intra-day and inter-day. Intra-day return is the log difference between opening price and closing price on each Thursday and inter-day return is the log difference of closing prices between each Thursday and the immediately preceding trading day.[12]

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9 For a comprehensive and critical review of calendar effect in U.S. stock markets, see Schwert (2002).

10 They are often called as "double-witching" days.

11 Options expired on April 12, 2000 and May 10, 2000 instead of April 13, 2000 and May 11, 2000 when they were supposed to expire, respectively. Moreover, June 2002 option and futures expired on Wednesday rather than Thursday since market was closed on Thursday. We drop the three observations from the subsequent analyses to maintain the uniformity of the sample.

12 In most cases, it was Wednesday.

Table 3. Daily Return and Volatility

		NE[1]	OE[2]	TE[3]
Intra-day[4]	Mean	-0.0764	-0.3604	0.7537
	S.D.	2.3273	2.1170	2.9694
Inter-day[5]	Mean	0.0019	-0.1461	0.8545
	S.D.	2.6619	2.6243	3.3620
No. of Obs.		206	42	21

Note: 1) Non-expiration Thursdays when neither a future nor an option contract expires.
2) Option-expiration Thursday when an option contract expires.
3) Twin-expiration Thursdays when both a future and an option contracts expire.
4) Log-return between opening and closing prices on the corresponding Thursday.
5) Log-return between Thursday's closing price and Wednesday's closing price.

Table 3 shows mean returns and standard deviations of three groups. Mean return is highest in TE followed by NE and OE. The volatilities in terms of standard deviation are ranked in the same order. A casual inspection shows that there is no material difference in average return and standard deviation across three groups of Thursdays considering the magnitudes of standard deviations. To confirm the conjecture, we perform a series of formal statistical tests in Table 4. Table 4 reports the results of tests for equality of means and variances of different groups.

Assuming that daily returns, r_i's are independently and identically distributed, one can show that the distribution of test statistic given in (1) is t-distribution with the degrees of freedom $(N_{NE} + N_j - 1)$ under the null hypothesis that there is no difference in means of the two groups under consideration.

$$t = \frac{\bar{r}^{NE} - \bar{r}^{j}}{s_p} \tag{1}$$

where $\bar{r}^{NE} = \frac{1}{N_{NE}} \sum_{i=1}^{N_{NE}} r_i^{NE}$, $\bar{r}^{j} = \frac{1}{N_j} \sum_{i=1}^{N_j} r_i^{j}$ along with $j = OE \text{ or } TE$ and s_p is the standard deviation of the pooled sample defined as

$$s_p = \sqrt{\frac{(N_{NE} - 1)s_{NE}^2 + (N_j - 1)s_j^2}{(N_{NE} + N_j - 2)}}$$

with $s_j^2 = \frac{1}{(N_j - 1)} \sum_{i=1}^{N_j} \left(r_i^j - \bar{r}^j \right)$, $j = NE, OE, TE.$

On the other hand, it is also easy to show that the distribution of test statistic given in (2) is F-distribution with the degrees of freedom $((N_{NE} - 1), (N_j - 1))$ under the null hypothesis that there is no difference in variances of the two groups.

$$F = \frac{s_{NE}^2}{s_j^2} \text{ when } s_{NE}^2 > s_j^2 \text{ or } = \frac{s_j^2}{s_{NE}^2} \text{ when } s_j^2 > s_{NE}^2 \tag{2}$$

Table 4. Tests of Differences in Means and Variances of Daily Returns

	Difference in Means		Variance Ratios	
	Intra-day	Inter-day	Intra-day	Inter-day
NE vs. OE	0.2841[1)]	0.1480	1.2086[2)]	1.0288
	(0.4652)	(0.7423)	(0.3947)	(0.8639)
NE vs. TE	-0.8301	-0.8526	1.6279	1.5953
	(0.1311)	(0.1743)	(0.2004)	(0.2199)

Note: 1) The number is the difference in means between NE and OE and the number in parenthesis is p-value of t-statistic to test the equality of means.
2) The number is variance ratio of NE and OE and the number in parenthesis is p-value of F-test to test the equality of variances.

In no case presented in Table 4 do we reject the null hypothesis of no difference in means. Moreover, we find no evidence for different patterns of volatility across three groups. The findings are in agreement with the results reported by Chen and Williams (1994) in that using observations on the inter-day returns of the NYSE Composite Index and the S&P 500 Index on triple-witching Fridays and non-triple-witching Fridays, they conclude that the differences of mean returns and standard deviations are statistically insignificant. The findings are, however, at odds with the prediction based on position unwinding on expiration days offered originally by Stoll and Whaley (1987).

2. Abnormal Return and Volatility: High Frequency Data Analysis

As discussed in Stoll and Whaley (1987) or Stoll and Whaley (1991), we expect to detect activities associated with position clearing on expiration days at the later stage of trading day since program traders, in general, have the tendency to postpone position unwinding as long as possible. Therefore, it is highly likely that we will not observe the predicted pattern of return structure, that is, unusual level of return and higher volatility simply because the unit interval is too lengthy to pick up characteristic pattern of returns for expiration days. One way to solve the identification problem is to use high frequency data. In other words, minute-by-minute price data for the KOSPI 200 Index are used to analyze each group separately. We examine means and their standard deviations of the Index's returns realized on Thursdays at 10-minute, 30-minute, and 60-minute intervals.

A slight change in notation facilitates subsequent analyses with high frequency data. First of all, define the rate of return on the KOSPI 200 Index at 10-minute[13] intervals during one Thursday as

$$r_{i,t}^j = \frac{P_{i,t+1}^j - P_{i,t}^j}{P_{i,t}^j}$$

where $P_{i,t}^j$ is the Index level at the beginning of interval t on Thursday i with j=*NE,OE,TE*.

The mean return for an expiration day and a non-expiration day is then defined as

13 Returns at 30-minute and 60-minute intervals are defined and analyzed analogously.

$$\bar{r}_i^{\,j} = \frac{1}{N_{j,i}} \sum_{t=1}^{N_{j,i}} r_{i,t}^j$$

where $N_{i,j}$ is the number of 10-minute intervals on Thursday *i* of type *j*. Finally, the mean return of type *j* Thursdays over the sample period is defined as

$$\bar{r}^{\,j} = \frac{1}{N_j} \sum_{i=1}^{N_j} \bar{r}_i^{\,j}$$

The t-statistic given in (1) along with the standard deviation of the pooled sample can be used to examine the equality of the mean returns between NE and OE or between NE and TE. In addition, we use the variance ratio test described in (2) to compare the return volatilities between non-expiration and expiration Thursdays.

The first column of Table 5 reports the difference in mean returns and variance ratio between NE and OE Thursdays at 10-minute, 30-minute, and 60-minute intervals. We cannot find any evidence of abnormal returns, higher or lower, on option-expiring Thursdays compared to non-expiring Thursdays, which is in accord with the case of daily returns. The variances of returns at 30-minute and 60-minute intervals do not show statistically different magnitudes between NE and OE Thursdays, which also coincides with the result with daily returns. However, the return fluctuations on option-expiration Thursday seem to be much more volatile than those on non-expiration Thursdays.

As for the comparison between NE and TE Thursdays illustrated in the second column of Table 5, one can find somewhat marginal evidences for difference in mean returns. The test statistics for mean differences are significantly different from zero at 10% significance level in the case of 30-minute and 60-minute returns. Although the finding can be used as an argument to support the existence of abnormally high returns[14] when options and futures expire on the same day, the evidence is not overwhelming but marginal in the sense that, if we were indeed able to identify the presence of abnormally high returns on twin-expiration Thursdays by increasing the sampling frequencies for a given time span,

Table 5. Test of Differences in Means and Variances of High Frequency Returns

		NE vs. OE	NE vs. TE
Mean Difference	10 minutes	0.0150[1)] (0.3131)	-0.0175 (0.3934)
	30 minutes	0.0175 (0.6389)	-0.0864* (0.0914)
	60 minutes	0.0291 (0.7294)	-0.1751* (0.0788)
Variance Ratio	10 minutes	1.2512***[2), 3)] (0.0000)	1.7439*** (0.0000)
	30 minutes	1.0936 (0.2403)	1.4838*** (0.0002)
	60 minutes	1.1567 (0.1814)	1.6943*** (0.0006)

Note: 1) The number is the difference in means between NE and OE and the number in parenthesis below is

14 Since the test statistic is negative with a statistical significance, it implies abnormally high mean returns on TE Thursdays.

p-value of t-statistic to test the equality of means.

2) The number is variance ratio of NE and OE and the number in parenthesis below is p-value of F-test to test the equality of variances.

3) *(***) : The null hypothesis is rejected at 10(1)% significance level.

the test statistic for mean differences at 10-minute intervals should have been statistically significant. On the other hand, we can conclude that returns on TE Thursdays are much more volatile than those on NE Thursdays. The conclusion is supported by all cases we considered in Table 5 and the evidence is overwhelmingly contrary to the cases of mean differences.

In sum, analyses up to this point reveal the fact that by employing daily instead of high frequency sample, we must have missed a different pattern of return volatility among three groups of Thursdays and may have failed to pick up abnormally high mean return on TE Thursdays compared to NE Thursdays. In addition, the choice of observational scheme concerning the sampling frequency brings no material difference into the conclusion when we make comparison of return structures on NE and OE Thursdays.

As an additional check for abnormal return and volatility on expiration days, we also investigate the last 10-minute, 30-minute, and 60-minute returns before the market closes on each Thursday. Aside from being another test for the existence of expiration-day effects, there are two more reasons we examine the behavior of returns just before the market closes. First, the literature on stock market microstructure has suggested that intra-day trading volume and return variance tend to follow a U-shaped pattern during a trading day. Second, as Stoll and Whaley (1987) argue, the efforts to unwind the positions by program traders are likely to center around closing time since they have every incentive to postpone taking the offsetting positions. Therefore, it is of interest to examine whether there is any distinguishable behavior in returns of the Index just before the market closes. Table 6 presents the results of last 10-minute, 30-minute, and 60-minute returns of NE and OE Thursdays (first column) and of NE and TE Thursdays (second column). It can be seen from the first column of the table that there is a strong evidence of price effects, abnormal return and high volatility on OE Thursdays, for all cases. Evident from the level of p-values, it is also true that the evidence of price effects become stronger as we shorten the comparison window from 60 minutes to 10 minutes. The last 60-minute mean return on OE Thursdays is lower by about 10 times in magnitude (-0.4362 versus –0.0438) and its variance is about 1.7 times larger (1.9119 versus 1.1226) than on NE Thursdays. On the other hand, the last 10-minute mean return on OE Thursdays is lower by about 37 times in magnitude (-0.4644 versus –0.0125) and its variance is about 7 times larger (1.0519 versus 0.1487) than on NE Thursdays. Turning to the comparison between NE and TE Thursdays, the differences in means and variances are much bigger. The last 60-minute mean return on TE Thursdays is higher by about 20 times in magnitude (0.8307 versus –0.0438) and its variance is about 3 times larger (3.4662 versus 1.1226) than on NE Thursdays. The last 10-minute mean return on TE Thursdays is higher by about 35 times in magnitude (0.4378 versus –0.0125) and its variance is about 10 times larger (1.5373 versus 0.1487) than on NE Thursdays. In general, the above results suggest that we do have strong evidence that the last 60 minutes, 30 minutes, and 10 minutes on expiration days are associated with considerable abnormal returns and very volatile movements of the Index. We also find that there exists a downward price pressure on the underlying stock index during Thursdays when only options expire.[15] Strangely enough, expirations of both options and futures on the same Thursday apply an upward instead of downward pressure to prices on the stock market. It is very difficult to figure out the reason why pressures on stock price movements work in opposite directions on two

15 The finding agrees with the results of Pope and Yadev (1992) in UK case and Stoll and Whaley (1991) in US case.

groups of expiration Thursdays.[16]

Table 6. Test of Differences in Means and Variances of Returns

		NE vs. OE	NE vs. TE
Mean Difference	Last 10 minutes	0.4520***1) (0.0000)	-0.4503*** (0.0002)
	Last 30 minutes	0.3119** (0.0455)	-0.7336*** (0.0009)
	Last 60 minutes	0.3924** (0.0396)	-0.8744*** (0.0011)
Variance Ratio	Last 10 minutes	7.0742***2), 3) (0.0000)	10.3374*** (0.0000)
	Last 30 minutes	2.0988*** (0.0058)	4..1766*** (0.0005)
	Last 60 minutes	1.7031** (0.0441)	3.0875*** (0.0047)

Note: 1) The number is the difference in means between NE and OE and the number in parenthesis below is p-value of t-statistic to test the equality of means.
2) The number is variance ratio of NE and OE and the number in parenthesis below is p-value of F-test to test the equality of variances.
3) **(***) : The null hypothesis is rejected at 5(1)% significance level.

The way in which the KSE determines the closing price probably is accountable for the pattern of volatility we found in Table 6. Two trading methods are used by the electronic order matching system in the KSE: a periodic auction and a continuous, discriminating auction. The periodic auction is used twice a day to generate opening and closing prices. All orders are submitted during the morning pre-trade session for the opening price and between 2:50 PM to 3:00 PM for the closing price. All orders submitted are batched for execution at a single equilibrium price. Therefore, information flow is blocked for 10 minutes before the market closes since trade through continuous, discriminating auctions are not allowed while orders are submitted and processed to determine a single price for closing price. If a program trader still possesses considerable open interests in derivative markets, whether it is in options or futures markets, on an expiring day, she may wait until 2:50 PM in unwinding the positions by taking offsetting positions in the underlying stock market. If she takes actions before 2:50 PM and cannot conceal the source of unusual order flow she initiates, that would invite strategic trading activities from other traders and be likely to bring in unintended or unfavorable outcome. The story thus far offers a partial explanation for abnormal return and high volatility during the last 10 minutes in expiring Thursdays.

Another explanation can be found in the way the KSE determines the settlement price of a derivative security when it matures. On an expiring day, all trades are halted at 2:50 PM and buy and sell orders are submitted to determine the closing price that will be also used for the settlement price of the expiring derivative. If a trader takes significant positions on

16 For a reasonable account of the puzzling discovery, we may need to scrutinize transactions and quotes (TAQ) data tapes provided by the KSE. By doing so, we can identify who placed buy or sell order in stock market during the time we are interested in and what positions they take in derivatives.

one side of the market and thinks that he has the least market power to make differences, he has an incentive to use the window of 10 minutes before closing when all information flow on trading activities are blocked so that he can effectively conceal his intention to make difference in the equilibrium price. One way to check the possible presence of the above-mentioned motive is to compare abnormal returns and volatilities of the last 10 trading minutes on each day of a week. Table 7 presents the results. The first and the third column report mean returns and standard deviations of each day in a week, respectively. For comparison's sake, we split Thursdays into two groups: non-expiring (NE) Thursdays and expiring Thursdays (OE and TE). The second column summarizes the differences in mean returns between NE Thursdays and other dates along with the p-value of the t-statistic of the null hypothesis that the two means are equal. Except for the case of Wednesdays versus NE Thursdays, we cannot find any statistically significant difference in mean returns between NE Thursdays and other dates. One unfortunate result in Table 7 is that we can find any evidence for the mean difference between NE and expiring Thursdays, which, at first glance, seems to be irreconcilable with the results in Table 6.[17] A careful inspection of Table 6 helps us understand the seemingly contradictory results. The difference in mean returns between NE and OE Thursdays is significantly positive and between NE and TE Thursdays significantly negative. Moreover, the differences are very close to each other in magnitude. If we pool the two samples of OE and TE Thursdays, it is predictable to obtain the result in Table 7. Excluding expiring days, we cannot find any evidence for abnormal returns on Thursdays compared to other dates if we focus on the return of the last 10 trading minutes. That is, we can identify nothing special in Thursdays' return were not it for expirations of derivative securities.

The last column in Table 7 reports the variance ratio between NE Thursdays and other dates along with the p-value of the F-statistic of the null hypothesis that the two variances are equal. First, all dates other than Fridays show different levels of volatility from NE

Table 7. Return and Volatility of the Last 10 Minutes[1)]

	Mean	Mean Difference	S.D.	Variance Ratio
Monday	-0.0028	-0.0097[1)] (0.7578)	0.2996	1.6572***[2), 3)] (0.0002)
Tuesday	0.0401	-0.0526 (0.1072)	0.3217	1.4370*** (0.0065)
Wednesday	0.0437	-0.0562* (0.0747)	0.2972	1.6838*** (0.0001)
Friday	0.0009	-0.0134 (0.7153)	0.4065	1.1114 (0.4149)
Thursday[4)] (OE and TE)	-0.1637	0.1512 (0.1119)	1.1728	9.2489*** (0.0000)
Thursday (NE)	-0.0125	N.A.	0.3856	N.A.

Note: 1) The number is the difference in means between Monday and NE Thursday and the number in parenthesis below is p-value of t-statistic to test the equality of means.
2) The number is variance ratio of Monday and NE Thursday and the number in parenthesis below is

17 In Table 6, we argue that there exists a significant difference in means between NE and OE as well as between NE and TE.

p-value of F-test to test the equality of variances.

3) ***(*) : The null hypothesis of equality is rejected at 1(10)% significance level.

4) The pooled sample of OE and TE Thursdays.

Thursdays. Second, it is not possible to locate a regular pattern from the distribution of standard deviations across dates in a week. Third, although all other pairs except for one display statistically significant differences in volatilities, the magnitudes of F-statistic and p-value implies that the difference is bigger between expiring and NE Thursdays than between NE Thursdays and other dates.

We can conclude from the discussion thus far that the stock returns show a much more volatile behavior for the last 10 trading minutes on expiring Thursdays and a plausible explanation can be found from possible activities of program traders during the time.

3. Price Reversals

Additional measure of the price effects is the degree of price reversal on the morning of the trading day after the expiration day suggested by Stoll and Whaley (1987, 1991). The unwinding of index arbitrage stock positions by program traders at an expiration day, especially close to the closing time, would drive the stock index temporarily out of equilibrium. If such a price pressure indeed exists on the expiration day, then stock index should on average reverse to the opposite direction after the derivative contract have expire since it is not unreasonable to expect that the price pressure will be absorbed or dissipated and the stock index will start to move back toward the previous equilibrium as time passes.

Following Stoll and Whaley (1987), we define three types of price reversal as

$$REV_{1t} = \begin{cases} r_{t+1} & \text{if } r_t < 0 \\ -r_{t+1} & \text{if } r_t \geq 0 \end{cases} \tag{3}$$

$$REV_{2t} = \begin{cases} |r_{t+1}| & \text{if } sign(r_t) \neq sign(r_{t+1}) \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

$$REV_{3t} = \begin{cases} |r_t| & \text{if } sign(r_t) \neq sign(r_{t+1}) \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

where $r_t = 100(\ln(P_{close,t}) - \ln(P_{close-10,t}))$, the return for 10 minutes just before the market closes on an expiration day and $r_{t+1} = 100(\ln(P_{open+10,t+1}) - \ln(P_{open,t+1}))$, the return for 10 minutes just after the market opens the next day.

A positive value for REV_{0t} indicates a reversal, a negative value a continuation. The second measure REV_{1t} is assigned the value zero if there is no reversal and the absolute return for the 10 minutes of the Friday following expiration if there is a reversal. REV_{1t} overstates the price effect somewhat because price reversals due to new information unrelated to the activities accompanying expiration are fully reflected, whereas the failure of price reversals due to new information is not reflected. As for the type 3 price reversal, the measure uses the first-period (Thursday) price change rather than the second-period (Friday) price change used for the type 2 reversal. It has the same kinds of drawbacks as the type 2 reversal. If the price change on the first day conveys new information, the measure tends to overstate the amount of pressure on price as distinguished from information effect. But it does convey new information about the price change on the expiration day.[18]

Table 8 reports three different measures of price reversals discussed above for three different time intervals. The last row requires some explanation. A pair of returns is

18 Further information on various measures of price reversals can be found in Stoll and Whaley (1987).

calculated to measure over-night reversals. Returns from 2:50 PM to 3:00 PM on an expiring Thursday are compared to the returns from Thursday's closing price and Friday's opening

Table 8. Price Reversals: 10-minute, 60-minute, over-night returns

		OE Thursday			TE Thursday		
		No. of Days1)	No. of Rev.2)	Ave. Rev.3)	No. of Days	No. of Rev.	Ave. Rev.
10 minutes	REV_1	42	25	0.3275	21	13	0.4402
	REV_2	42	25	0.4848	21	13	0.5886
	REV_3	42	25	0.4523	21	12	0.4579
60 minutes	REV_1	42	16	-0.0969	21	8	-0.0637
	REV_2	42	16	0.4307	21	8	0.3806
	REV_3	42	16	0.4647	21	9	0.6002
Over-night	REV_1	42	32	0.0088	21	18	0.0111
	REV_2	42	31	0.0105	21	18	0.0123
	REV_3	42	32	0.5819	21	17	0.7000

Note: 1) The number of all OE Thursdays
2) The number of OE Thursdays with price reversal
3) Average price reversals (%)

price. The reason we pay close attention to the comparison of two returns is that the returns in those intervals are determined by periodic auctions instead of continuous, discriminating auctions to determine the closing, therefore the settlement price. One may infer, as discussed above, that program traders possess considerable incentive to conceal their strategic trading patterns by amassing orders while the periodic auctions are conducted when they trade to satisfy the needs of positions taken in derivatives and spot markets. If it is indeed the case, it is highly likely that over-night price reversal can serve as an excellent indicator for price reversals. We can find stronger evidence for the existence of price reversals as window for return observations become shorter. The 10-minute window shows more frequent and bigger price reversals in almost all cases than the 60-minute one. Although the over-night window shows more frequent price reversals than 10-minute window, the degree of price reversals is lower when we use the over-night window rather than the 10-minute one. We are able to find evidence for price reversals on neither OE nor TE Thursdays, which is to be confirmed by the negative value for REV_1.

In sum, we can find some evidence for price reversals if we take shorter intervals. Especially, the finding that the price reversals between two subsequent periods of periodic auctions are significant has a great importance if we recall the result from the previous sections that price effects on the expiration day seem to be clustered around the closing time.

4. Volume Effect

An additional arena in which we can possibly detect unusual patterns in stock trading activities associated with expirations of derivative securities is the total volume of stocks traded during a given period of time surrounding expirations of derivatives. The efforts mainly by program traders to unwind the position before expiration may result in higher trading volume than usual to reflect more frequent trading activities around the expiration time.

We compare trading volumes in three different groups of Thursdays: NE, OE, and TE Thursdays. In order to detect the possibility that unusual pattern of trading volumes becomes more conspicuous as the closing time nears, we also compare the volumes of the Index traded for 60 minutes, 30 minutes, and 10 minutes before the market closes in addition to daily trading volumes on three groups of Thursdays from June 19, 1997 to December 26, 2002. As easily recognized from a casual plot of trading volumes in each category[19], it is almost certain that all series contain exponential trend. One can explain the existence of exponential trend in the series by arguing that the growth of the economy and the progress of depth in capital market are generally accompanied with increases in stock market activities. We model the feature by specifying the following equation for the growth of stock trading volume.[20]

$$\ln y_t = \alpha + \beta t + \varepsilon_t \tag{6}$$

where y_t is the volume of stock traded during period t. The log of a variable with an exponential growth pattern can be well described by a linear time trend model. Therefore, we run the regression (6) and keep the residuals for later use.

$$\hat{\varepsilon}_t = \ln y_t - \hat{\alpha} - \hat{\beta} t \tag{7}$$

The residual series[21] obtained from (7) are subjected to further analyses to find the evidence for higher trading volumes than usual due to expiration of derivatives.

Table 9 summarizes the results of the tests for mean-differences of (residual) trading volumes in three groups of Thursdays. We confront with the same pattern as in Table 4 and Table 6. Employing daily data, we find no evidence for unusually high trading volumes in OE or TE Thursdays compared to NE Thursdays. However, if we turn our attention to high frequency data set, we uncover strong evidence for bigger trading volumes both in OE and TE Thursdays. Moreover, as we shorten the interval of observations from 60 minutes to 30 minutes and finally to 10 minutes before the market closes, the evidence for volume effect becomes stronger. The effect becomes more striking on Thursdays when both futures and options expire rather than when only option contracts expire.

Table 9. Tests of Differences in Means: Trading Volumes

		NE vs. OE	NE vs. TE
Mean Difference	Daily	-0.0320 (0.7252)	0.1678 (0.1739)
	60 minutes	0.0984[1)] (0.2828)	0.3119** (0.0123)
	30 minutes	0.2350** (0.0188)	0.4736*** (0.0005)
	10 minutes	0.4549*** (0.0000)	1.2398*** (0.0000)

Note: 1) The number is the difference in means between NE and OE and the number in parenthesis below is

19 They are daily, 60-minute, 30-minute, and 10-minute trading volumes.

20 We would have specified the model with both time trend and a unit root. Augmented Dickey-Fuller test rejects the null of one unit root in all cases.

21 Actually, we analyze the residual series after taking anti-log to convert into the natural scale.

p-value of t-statistic to test the equality of means.
2) **(***) : The null hypothesis of equality is rejected at 5(1)% significance level.

CHAPTER 4

Conclusion

As we have shown in Chapter 3, empirical analysis strongly suggests that there are expiration day effects in the KSE. These effects are relatively unrevealed in the previous research using daily data set. There are, however, significant abnormal price and volatility around the last 10 minutes of trading time. We guess that these results are due to the settlement procedure of the KSE. After the trading of derivative at maturity ends at 2:50 PM, the price determination process for the settlement price begins. During these 10 minutes of call auction, program traders, who have already finalized their derivative position could optimize their cash index position by selling and buying index components.

To reduce or remove this expiration day effects, regulators around the world have made various efforts on modifications to the procedure of derivative expiration. Table 10 summarizes the main features of expiration procedure in international derivative markets. Some markets such as the CME and the Osaka Exchange use the special quotation as the settlement price is based on the total opening prices of each component issue in the index on the business day following the last trading day. Some markets use the average value of the index calculations performed during later part of the trading period on the last trading day.

Some of these changes have turned out not to be very useful in reducing the expiration day effects such as the current scheme of the CME and the Osaka Exchange. On the other hand, the recent paper by Chow, Yung, and Zhang shows that the expiration day effects does not appear in Hong Kong derivative market, which utilizes a unique procedure for determination of settlement price.

Various merits of derivative products could be well appreciated with minimal impact on the underlying cash market by derivatives. Given that there are very big expiration day effects in the KSE, further research on this issue is necessary. Although derivative market in the KSE has grown as one of the biggest exchange in the world, our understating is far behind to this quantitative growth. Only proper market microstructure based on rigorous research can guarantee sound growth for both cash market and derivative market in Korea.

Table 10. Specifications of the Derivatives Traded in other Exchanges

Country	USA	Hong Kong	Germany
Name	S&P500 Index Future (e-Mini S&P500)	Han Seng Index	DAX Index
Market	CME	Hong Kong Future Exchange	EUREX
Contract Months	March, June, September, December	March, June, September, December	March, June, September, December
Last Trading Day	The trading day preceding the second Friday of each contract month	The business day immediately preceding the last business day of the contract month	Third Friday
Settlement Price	Special Quotation (Special Quotation is based on the total opening prices of each component issue in the S&P 500 on the business day following the last trading day)	The average of quotations of the HIS taken at 5-minute intervals during the last trading day	The average value of the DAX calculations performed between 1:21 PM and 1:30 PM on the last trading day

Country	France	England	Japan
Underlying Asset	CAC40 Index	FTSE100 Index	NIKKEI225 Index
Market	MONEP	LIFFE	Osaka Exchange
Contract Months	March, June, September, December	March, June, September, December	March, June, September, December
Last Trading Day	Last trading day of each contract month	Third Friday of each contract month	The trading day preceding the second Friday of each contract month
Settlement Price	The settlement price is the average values calculated and disseminated between 3:40 and 4:00 PM on the last trading day.	The settlement price is based on the average values of the FTSE100 index every 15 seconds between 10:10 and 10:30 on the last trading day	Same as S&P 500

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