Chapter 4.

Identification of Price Overshooting

4.1. Price Overshooting

The empirical test of the price overshooting hypothesis is based on the idea that stock price behavior might be different if circuit breakers are triggered than if they are not. In order to capture systematic differences in price behavior which may arise due to the existence of circuit breakers, we first need to specify a stochastic process governing price movements. In the model described in Chapter 3, price fluctuations are modeled as driven by fundamental shocks which affect future dividend streams of an asset and also by supply shocks. We analyzed the effect of circuit breakers under the simplifying assumption that further shocks will not arrive until the effect of one shock is fully resolved. To accommodate the actual stock market where shocks are continuously coming to the market, we need to know a stochastic process governing the occurrence of shocks.

Instead of specifying such a process which is difficult to identify, we employ the following martingale model which is frequently used as a characterization of equilibrium in financial markets.[35]

$$p_t = (1+\rho)^{-1} E[p_{t+1} + d_{t+1} | \Phi_t] \qquad (4.1)$$

[35]For a review of martingale models in financial markets, see LeRoy (1989).

where d is dividends, ρ is the discount rate and Φ_t denotes information available at time t. Equation (4.1) states that the stock price today equals the sum of the expected future price and dividends, discounted back to the present at rate ρ. Although the above martingale model holds under certain assumptions such as risk neutrality, it has long been considered to be a reasonable approximation to actual stock price behavior and used to test capital market efficiency. If the market is efficient, any systematic discrepancies between p_t and $(1+\rho)^{-1}E[p_{t+1}+d_{t+1}|\Phi_t]$ will disappear through the intertemporal arbitrage activities of traders.

Since we are concerned with a relatively short time interval, say, a day, we can ignore dividends and discount rate terms. Then, (4.1) can be written as:

$$E[p_{t+1}|\Phi_t] = p_t \tag{4.2}$$

That is, the best forecast of p_{t+1} that can be constructed based on current information Φ_t would just equal the current price p_t. From (4.2),

$$p_{t+1} = p_t + e_{t+1}, \tag{4.3}$$

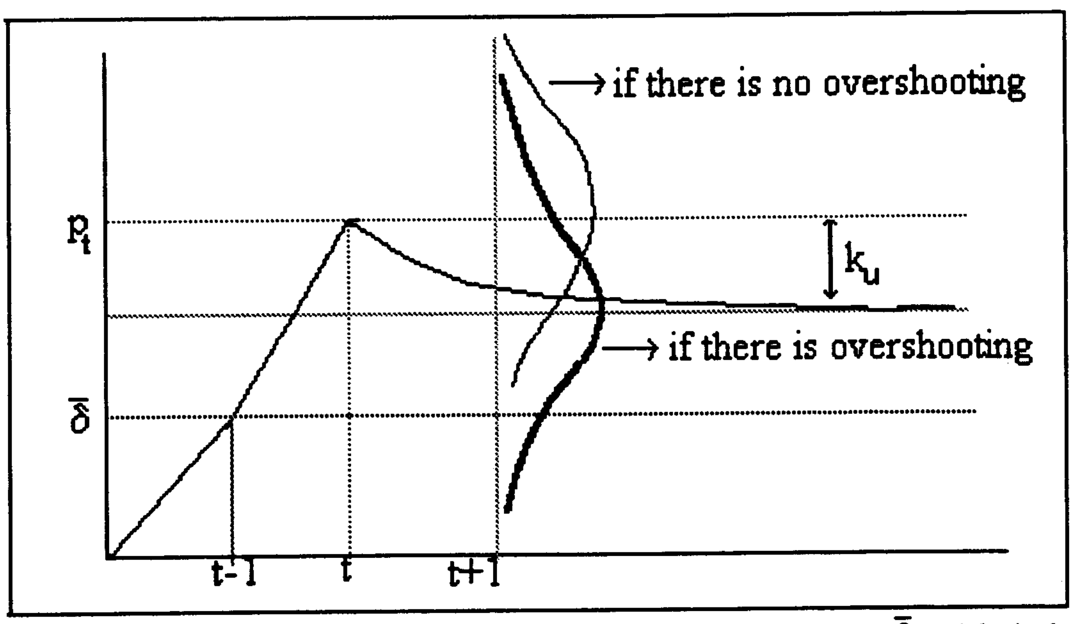
where e_{t+1} is the unexpected component of the one period return on stock. That is,

$$e_{t+1} \equiv p_{t+1} - E[p_{t+1}|\Phi_t] \tag{4.4}$$

Based on (4.2)-(4.4), we can empirically identify price overshooting, if any, as follows. Consider Figure 4.1, which describes the price behavior after triggering circuit breakers as predicted in Chapter 3. Suppose that the upper circuit breaker bound is triggered in period *t-1* and also that the market has cleared in period *t*. If the existence of circuit breakers helps facilitate a price discovery process, then the price will jump to the equilibrium level as soon as circuit breaker bound is expanded and no longer binds. Since p_t is the equilibrium price which fully resolves the effect of previous shocks, p_t should be the best forecast of p_{t+1}. Let us define $\Delta p_{t,\,t+1}$ to be the price difference between period *t* and *t+1* in growth terms. Then, we can model $\Delta p_{t,\,t+1}$ as white noise, as shown in Figure 4.1.

On the other hand, if price overshooting has occurred after the circuit breaker bound is triggered, the market clearing price at period *t* would be higher than the price which would have been determined without circuit breakers. Since the overshot price

Figure 4.1: Identification of Price Overshooting[a]



[a] It describes the case for a positive shock. The upper price limit is indicated by $\bar{\delta}$ and k_u is the magnitude by which price overshoots the equilibrium level when the upper limit is triggered. The case for a negative shock can be construed by reversing the figure upside down.

converges to the equilibrium level as time passes, price behavior after the circuit breaker is triggered will be systematically different from one with no triggering of circuit breakers. In this situation, the best forecast of p_{t+1} is no longer p_t as it has a systematic bias reflecting the magnitude of price overshooting. If we denote it by k_u (k_l) for the upper (lower) limit-triggered case, as drawn in Figure 4.1, we have $\Delta p_{t,\,t+1} = e_{t+1} + k_u(k_l)$, where k_u (k_l) is negative (positive).[36] That is, if price overshooting has occurred, $\Delta p_{t,\,t+1}$ no longer follows a fair game and (4.3) should be adjusted to the following.[37]

$$E[\Delta p_{t,t+1} | \Phi_t] = \begin{cases} k_u & \text{after the upper bound is triggered} \\ k_l & \text{after the lower bound is triggered} \\ 0 & \text{after no triggering} \end{cases} \tag{4.5}$$

As empirical counterparts of $\Delta p_{t,\,t+1}$, we use three price difference series measured at different time intervals, that is, intraday, daily and weekly returns (denoted by *IR*, *DR* and *WR*). Since p_t is the opening price on the day when the circuit breaker bound is lifted, the intraday return denotes the difference between the opening and closing price, and the daily (weekly) return denotes price differences over one day (one week), all in growth terms. That is,

[36]The magnitude of overshooting may vary depending on the particular circumstances in which the price limits were triggered. The size of a shock, the width of the circuit breaker bounds and the proportion of naive traders are among other factors which may cause bias. Since we can hardly identify these factors, we treat the magnitude of overshooting as constant by interpreting it as '*on the average*'.

[37]A stochastic process $\{y_t\}$ is a fair game if it has the property that $E[y_{t+1} | \Phi_t] = 0$. The martingale and fair game models are two names for the same characterization of equilibrium in financial markets.

$$
\begin{aligned}
IR_t &= (CLOSE_t - OPEN_t) / OPEN_t \\
DR_t &= (OPEN_{t+1} - OPEN_t) / OPEN_t \\
WR_t &= (OPEN_{t+6} - OPEN_t) / OPEN_t
\end{aligned} \tag{4.6}
$$

where $OPEN_t$ and $CLOSE_t$ denote the opening and closing price at day t.

If price overshooting has occurred, all measures would show a significant negative (positive) bias for the upper (lower) bound triggered events compared to those when circuit breakers were not triggered. The magnitude of the bias will also depend on the speed of convergence. If it converges rapidly, say, within a day, the bias will be similar for all three measures. If not, the bias will be larger for the weekly return than for the intraday or daily returns.

4.2. Volatility Effect of Circuit Breakers

Besides price overshooting, we also examine how the existence of circuit breakers affects price volatility. Proponents of circuit breakers have asserted that circuit breakers can reduce price volatility by preventing panic trading, enabling traders to condition their trading decision on better information and attracting more traders to the market (see the Brady Report (1988), Greenwald and Stein (1990)). If so, the distribution of successive price changes after circuit breakers are triggered should be less dispersed than the one without triggering. On the other hand, circuit breakers may increase price volatility by bringing additional uncertainty into the market (Gerety and Mulherin (1990), McMillan (1991)) or distorting trading decisions (Subrahmanyam (1993)).[38]

[38]For example, Gerety and Mulherin (1990) state that "to the extent that circuit breakers increase the uncertainty regarding the ability to exit the market, an environment with circuit breakers may be *less*

We employ two volatility measures: conditional standard deviation and conditional average dispersion.[39] Comparison of those measures between the circuit breaker triggered events and non-circuit breaker triggered events will show how the existence of circuit breakers affects price volatility. If the existence of circuit breakers impaired the price discovery process and brought additional uncertainty into the market, a greater volatility would be observed after circuit breakers were triggered and vice versa.

First, the conditional standard deviation of successive price changes is defined as follows:

$$\begin{aligned}\{Var(p_{t+1}-p_t\,|\Phi_t)\}^{1/2} &= \{E[(p_{t+1}-E[p_{t+1}|\Phi_t])^2\,|\Phi_t]\}^{1/2} \\ &= \{E[e_{t+1}^2|\Phi_t]\}^{1/2}\end{aligned} \tag{4.7}$$

Note that the conditional standard deviation does not include the volatility effect brought about by price overshooting. Since the magnitude of price overshooting is reflected in both p_{t+1} and $E[p_{t+1}|\Phi_t]$, comparison of the conditional standard deviation between circuit breaker triggered events and non-circuit breaker triggered events will show the pure volatility effect of circuit breakers.

The second measure of volatility employed is the average absolute error of successive price changes (abbreviated as *average dispersion* for brevity), which is defined as follows:

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stable than an environment without circuit breakers." (pp. 1765-1766)

[39]In a study of the mini-market crash in the United States on October 13, 1989, Kuhn, Kuserk and Locke (1990) examine whether circuit breakers moderated price volatility by employing several measures of volatility for price changes of one-minute intervals. The volatility measures they employed are "standard deviation of price change," "average absolute log price change" and "range." The first two measures correspond to the ones employed in this study. On the other hand, we did not use the 'range' measure since the maximum price change is determined by the price limit itself.

$$avg.\ dispersion = E[\ |e_{t+1}|\ |\Phi_t]$$ (4.8)

where the forecasting error e_{t+1} is price changes adjusted by the magnitude of price overshooting, that is, $e_{t+1} = \Delta p_{t,t+1} - k_u(k_l)$. The bias which may be introduced by price overshooting is also excluded in the average dispersion as in the conditional standard deviation. Compared to the conditional standard deviation which is sensitive to a few observations of large price changes, the average dispersion measure has the advantage that it is less affected by those observations. Consideration of the two volatility measures above will tell us whether market uncertainty has increased or decreased due to the existence of circuit breakers.

Chapter 5.

Data

5.1. The Korean Stock Market and Price Limits

Korean stock market data were used to evaluate the effect of circuit breakers on price behavior. As mentioned in the literature review (Chapter 2), the existing empirical studies of circuit breakers have been limited by data problems. In this context, use of Korean stock market data has the substantial advantage that it has relatively abundant observations of circuit breaker triggered events.

The Korean Stock Exchange (the Exchange) is the only stock exchange authorized in Korea. The Exchange market operates on an order-driven system and is best described as an auction market.[40] Its micro-structure is quite different from American or British exchanges where there are specialists who act as market makers. All bids and offers are brought to the Exchange, but it plays no role in market making. All orders are executed on the market according to a certain set of auction rules based on the principles of "price," "time" and "size" priority. The time priority principle is that the highest bid and the lowest offer have the precedence over all others. When bids and offers are made at the same price, the earliest one takes priority over those delivered later. Among simultaneous bids and offers at the same price, precedence is given to the largest order. Trading is conducted during two sessions each day (a morning session from 09:40 to 11:40, and an afternoon session from 13:20 to 15:20)

[40]For details of the Korean stock market including its price limits system, see Korea Stock Exchange (1992).

and according to two types of auction method, a call and continuous auction. Once the opening price in each session is established by the call auction, stocks are traded on a continuous basis during the remainder of the session.

The Exchange introduced a price limit system in the early 1960s. To avoid excessive price fluctuation and to foster an orderly market, the Exchange sets a maximum daily price change based on the previous day's closing price. Unlike the circuit breakers in the United States such as trading halts in the NYSE and price limits in the CME which are triggered based on the prespecified change in the *overall market index*, price limits in the Korean Stock Exchange are applied to each individual stock. Also, both upward and downward movements are subject to price limits.

The width of the price limits varies depending on the price level. Rather than specifying the maximum price change as a certain percentage of closing price, the Exchange sets a maximum amount of change for each price level.[41] Price limits become narrower in percentage terms as stock prices become greater. Also, price limits depend on whether an issue is under special supervision by the Exchange. When an issue falls under some delisting criteria, the Exchange may designate this issue as an *administrative* issue in order to warn the investing public of its exposure to risk. Among several restrictions imposed on trading administrative issues, the Exchange establishes more restrictive price limits for their price movements. Table 5.1 summarizes the current regulation on price limits. Compared to circuit breakers in other countries, the width of the price limits is very narrow.[42] For normal issues, it ranges from 2 to 7% as a percentage of the previous day's closing price and amounts

[41]Whereas Taiwan or Thailand sets price limits by a certain percentage, price limits in Japan are prespecified as a certain amount which varies depending on the price level.
[42]Among countries in which price limits apply to individual stocks, the width of the price limits is 16% (Japan, average figure), 7% (Taiwan) and 10% (Thailand). On the other hand, trading halts in NYSE are triggered when the Index (DJIA) declines by 250 points which amount to 6-7%.

to 4.6% on the average. And it ranges from 1 to 2 percent for most administrative issues.

5.2. Description of the Data and Variables

Since price limits apply to each individual stock, we selected 30 firms out of 374 firms which were in business since Dec. 15, 1986. Table 5.2 shows the name and characteristics of each firm. They represent different industries (1 mining, 11 manufacturing, 5 construction, 9 financial services and 4 other services) and different price levels, and also include 5 administrative issues.

The sample period covers Dec. 15, 1986 to Dec. 28, 1992, giving a total of 1761 daily observations. The starting point is chosen because the current structure of price limits has been maintained since Dec. 15, 1986. Each observation consists of daily price and trading volume. As a minimum requirement for the analysis, opening and closing price series were selected. The opening price is necessary since it represents the market clearing price first determined after the price limits were triggered. The closing price series is needed to identify the price limit-triggered events. When the price difference between successive closing prices is equal to the maximum daily change specified by price limits, those trading days are recorded as a limit-triggered event.

Among the limit-triggered events, there are cases in which the price limits are triggered not only in a single day but in successive days. In the latter cases, we can identify price overshooting only after the last limit-triggered day since the others dictate the next day to be a limit-triggered event whose opening price may not be a market clearing one. To differentiate one from the other, we define a dummy variable *UPLIM (LOLIM)* to indicate the single upper (lower) limit-triggered event or the last event when the upper (lower) limit is triggered in successive days. The other events among successive limit-triggered events are denoted by *UPLIM2 (LOLIM2)*. Let us temporarily denote the limit-triggered day as one and zero otherwise. Suppose, for example, data show {0, 1, 1, 1, 0, 1, 0} for a series of trading days, indicating that price limits were triggered on day 2, 3, 4 and day 6. In this case, the limit-triggered events for day 4 and 6 are recorded as *UPLIM (LOLIM)* and those for day 2 and 3 are as *UPLIM2 (LOLIM2)* if it is the upper (lower) limit that is triggered.

There are also cases where price changes are not subject to price limits. For example, when a firm pays a dividend or raises its capital by issuing new shares which typically entails a large price swing, price limits do not apply and prices can jump freely to their market clearing level. To indicate those events, we employed a dummy variable BAD which takes a value of one whenever the daily price change is greater than the maximum specified by the price limits.[43]

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[43]To be precise, we need to identify those events by investigating the past record of business activities for each individual firm. Since the BAD variable is included for the purpose of controlling outliers, we followed the above simple convention.