The Magnet Effect of Price Limits: Evidence from High Frequency Data on Taiwan Stock Exchange

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Abstract

Some financial markets impose limits on the amount asset prices can change within a trading day to prevent the market from overreacting and, hence, to dampen the volatility. Using intraday data from Taiwan Stock Exchange(TSE), we document a statistically and economically significant tendency for stock prices to accelerate toward the upper bound and weak evidence of acceleration toward the lower bound as the price nears the bounds. Previous research has referred to this phenomenon as the magnet effect of daily price limits but, to the best of our knowledge, the result presented here is the first empirical verification of such an effect. The magnet effect continues to hold even after controlling for possible momentum effects. In addition, the effect is further confirmed by an out-of-sample study. Similar evidence cannot be found in the U.S. stocks which do not have price limits restriction.

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1 Introduction

Many stock markets, especially the emerging markets, implement price limits on daily price movements; see, for example, the markets in Austria, Belgium, France, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Spain, Switzerland, Taiwan, and Thailand. Some financial markets other than stock markets also impose daily price limits. For example, price limits exist in the U.S. futures markets. Brennan(1986) provides a convincing argument for the rationale for price limits in the U.S. futures market. He argues that the limits serve as a substitute to margin requirements to reduce the total cost of trading for market participants. However, the margin requirements and credibility issues of the futures market do not exist in the stock markets. Then a natural question arises: why do emerging stock markets impose price limits?

Advocates of stock price limits claim that the limits have two attributes to decrease the price volatility. First, the limits literally set a ceiling and a floor for the price to move within a trading day. Second, price limits provide a cooling off period. Other proponents claim that the limits counter overreaction, but do not interfere with trading activity. Critics argue that the limits have several adverse effects on the stock market. First, the volatility spillover hypothesis says price limits will increase the volatility on the subsequent trading days because the limits prevent large one day price changes and immediate corrections in order imbalance. Fama(1989) argues that inciting trading in anticipation of circuit breakers will increase the volatility. Price limits do not halt the trading but they prevent immediate corrections in order imbalance so that it will have the same volatility spillover effect as the circuit breakers. The volatility spillover hypothesis is empirically supported by Kuhn, Kurserk, and Locke(1991) who find that stock volatility was not moderated by circuit breakers during the 1989 U.S. mini-crash. Kim and Rhee(1997) use Tokyo Stock Exchange data to conclude that volatility does not return to the normal level after reaching the price limits.

Second, delayed price discovery is another problem for price limits. The delayed price discovery hypothesis says that, by putting constraints on price movements, prices are refrained from reaching the equilibrium level. If it happens, the stocks have to wait until the following trading day to reach the equilibrium level. Fama(1989) suggests that trading halts

delay the adjustment of prices to changes in fundamental values. The delayed price discovery hypothesis is supported by Lehmann(1989) and Lee, Ready, and Seguin(1994).

Third, the trading interference hypothesis says price limits interfere with trading. If the price of a stock hits the limits, then the stock becomes less liquid and the trading will be heavier on the following days. See Fama(1989), Telser(1989), and Lehmann(1989). Lee, Ready, and Seguin(1994) find that trading halts increase both the volume and volatility for the New York Stock Exchange. They find that the volume and volatility after a trading halt are higher than the normal days.

Fourth, the magnet effect says the price accelerates toward the limits as it gets closer to the limits. There are two reasons for the magnet effect: illiquidity risk and behavioral investors. First, the traders, for fear of illiquidity, would involve in active trading that pulls the price closer to the limit. Subrahmanyam(1994) shows in an intertemporal one-market model that if the price is close to the limits, the limits can increase ex ante price variability and the probability of the price crossing the limits. Lehmann(1989) contends that order imbalances, and the consequent lack of trading, induce prices to reach the limits. Arak and Cook(1997) argue that the behavioral investors who believe in the price trends can act in a way that produces a magnet effect. Avoiding being shut out of the trend, traders who think that the ceiling will be reached might buy sooner. This behavior will accelerate price changes as price gets closer to the ceiling.

The cool off effect is the opposite of magnet effect, and it is claimed to be one of the major benefits of price limits by the advocates. Price limits cause a trading halt, once the price reaches its limits. The market will then have time to reassess the fundamental value to counter the overreaction, if there is any overreaction in the market. The empirical literature on the price limits concentrated on the first three hypotheses: volatility spillover, delayed price discovery, and trading interference hypotheses. They typically used daily prices such as the close and open prices to test the hypotheses. Yet to test the magnet effect, we cannot use the daily prices. We need intraday price changes to see how the price reacts as it gets closer to the limits. Arak and Cook(1997) argue that they used the intraday price change but they only used the first 5-minute return of the day and ignored the rest 5-minute return series. In this paper, we use the entire 5-minute return series to test the magnet effect.

The paper is organized as follows. Section 2 provides a brief description of the Taiwan Stock Exchange and the main data used in the study. In Section 3, we specify an econometric model for the 5-minute return series and use the model to analyze the magnet effect. We find significant evidence for the magnet effect for the upper price limit (ceiling magnet effect). We also use 90 randomly chosen S&P 500 stocks from the TAQ database to show that the magnet effect does not exist in a market without price limits. Furthermore, the detected magnet effect in the Taiwan Stock Exchange continues to hold when the data are extended one year to April 29, 2000. In Section 4, we analyze the economic significance of the magnet effect using several trading strategies. The ceiling magnet effect is found to be of economic significance even after adjusting for transaction costs. Finally, we conclude the paper in Section 5.

2 Data Description

Daily price limits are currently used in many stock exchanges. Yet in most stock exchanges the daily price limits are set so high that the stock price rarely reaches the limits. For example, the Tokyo Stock Exchange implements daily price limits. But the limits are set, on average, at 20% so that the limits are rarely reached. An ideal stock exchange to study magnet effect is a market with low daily price limits and high volatility. The Taiwan Stock Exchange implements a daily price limit of 7% and the volatility is relatively high, making it suitable for studying magnet effect.

We begin with a brief description of the Taiwan Stock Exchange (TSE). It is an order-driven call market that does not utilize designated market makers. Investors issue orders, and the market uses a periodical batch process mode to match the orders and to determine the market clearing price so as to maximize the trading volume. Specifically, the batch process takes place every minute for inactive stocks. For an active stock, there is a call back design. Normally an active stock is executed in every 50 seconds. However, immediately following the execution, there will be an automatic call back after six seconds so that the entered orders during the six seconds can be executed again. So the minimum possible duration for an active stock is 6 seconds.

The trading hours are from 9:00 am to 12:00 noon on weekdays. Trading occurs only on the first and third Saturdays of each month and the trading hours are from 9:00 to 11:00 am until March 1998. Starting from April 1998, the trading hours for these two Saturdays are extended to 3 hours from 9:00 am to 12:00 noon.

The TSE imposes a 7% price limit for all traded stocks. Within a trading day, the price for a single stock cannot move more than 7% from the previous closing price. Therefore, the maximum 1-day return is 7% and the minimum 1-day return is -7% . But one can find some extraordinary price movements outside the limits on certain days. For example, the stock of Taiwan Semiconductor Manufacturing Company (TSCM) closed at New Taiwan Dollar (NTD) 130.5 on June 11, 1997, but opened at NTD 91 on June 12, 1997. This is impossible under the 7% limits. But once adjusting for dividend payment or stock split, the price was still within the 7% limits. All the returns in our analysis are adjusted for dividends and splits.

The main dataset used in the paper consists of 5-minute return series on all the listed companies in the TSE from January 3, 1998 to March 20, 1999. The total market capitalization of TSE at the end of 1998 was NTD 8,392,697 million, which is USD 258,234 million. The 1998 year trading volume was 612,009 million shares, or NTD 29,518,969 million (USD 911,353 million). 59.65% of the market capitalization is held by individual investors, 37.59% by institutional investors and only 2.76% by investment funds, implying individual investors are the major contributors of the capital.

There were 473 companies listed on TSE as of March 1999, but 345 companies had at least one transaction for every 5 minute bin except at the price limits to generate a reliable 5-minute return series. Considering that the batch process takes place every 50 seconds or less for a frequently traded stock, the 5-minute interval is sufficiently long to generate reliable time series for the 345 stocks. In summary, we dropped 128 infrequently traded companies from the data set and used the remaining 345 companies in the empirical analysis.

The TSE categorizes the companies into 19 industrial sectors. These sectors and the number of firms used in our study are as follows: cement(7), food(24), plastics(16), textiles(48), electrical machinery(19), electrical appliances(12), chemicals(16), glass(6), paper and pulp(6), iron and steel(25), rubber(8), automobile(4), electronics(66), construction(31),

shipping(14), tourist(5), bank(34), department stores(0) and other(4). Finally, the sample period was extended one year to April 29, 2000 in Subsection 3.6 to validate the findings of the paper.

Table 1 gives some summary statistics for how often the price limits are reached classified by the industrial sectors. For the sample period from January 3, 1998 to March 20, 1999, the price reached the ceiling, on average, 15.3 days out of the 324 trading days, which is about 4.7% of the sample period. And it reached the floor 12.3 days. The average number of days when the stocks closed at the ceiling is 12.1 days and it is 7.8 days for the floor. This implies that once the limits are reached in a trading day, it is more likely to close at the limits. Table 1 also summarizes how long the price stays at the limits. On average, the price stays at the ceiling for 52 minutes once it reaches the ceiling and it stays at the floor for 42 minutes. This implies that the stock stays at the limits roughly one third of the trading hours once it reaches the limits. Thus within a trading day, the stocks tend to stay at the limits for quite a long time. It is also interesting to see whether TSE stocks reach the limits for consecutive trading days. Among the 324 trading days, there are, on average, 4 cases when the stock reached the ceiling for two consecutive days. In other words, this is roughly a quarter of the 15.3 days when the price hits the ceiling. A similar phenomenon appears in the floor case. The Table clearly shows that the daily price limits are a binding factor during the sample period in the TSE. Therefore, the Taiwan Stock Exchange data are a natural candidate to study the intraday effect of the daily price limits.

3 Analysis Based on Econometric Models

3.1 Model

In this section, we develop an econometric model to analyze the magnet effect of daily price limits. The trading at TSE takes place from 9:00 am to 12:00 noon. For U.S. stocks, it is well known that the volatility is higher when the market opens than during the middle of trading hours. Figure 1 plots the intraday volatility pattern for the 345 TSE stocks. The volatility is defined as the standard deviation of the 5-minute returns. Figure 1 shows a clear U-shape pattern of intraday volatility. Volatility is at the peak when the market opens and

declines rapidly till 9:30 am. Volatility remains low most of the day but it jumps at the end of the trading hour. This figure clearly shows a deterministic pattern in the standard deviation of the 5-minute returns. There are two ways to handle the deterministic volatility pattern. First, one can use a multiplicative variable in the conditional variance equation as in Andersen and Bollerslev(1997). Second, one can standardize the 5-minute returns by its standard deviations. For simplicity we use the second approach. For each stock, we first compute the standard deviation of the returns for each 5-minute bin. Since there are 324 trading days, there are 324 observations to compute the standard deviation for each 5-minute bin. We then divide the 5-minute return by the corresponding standard deviation. For example, we calculate the standard deviation of the 324 returns of a stock between 11:00-11:05 am to obtain the standard deviation for the 11:00-11:05 am bin. Then all the 5-minute return of the stock between 11:00 am and 11:05 am is divided by this standard deviation. After standardizing the return series, the U-shape intraday volatility pattern is removed.

Specifically, for a given stock, let $r_{t,k}$ be the 5-minute return at day t and k th bin and

$$\delta_k = \sqrt{\frac{\sum_{i=1}^{324} (r_{i,k} - \bar{r}_k)^2}{323}}$$

be the sample standard deviation of the return, where $\bar{r}_k = \sum_{i=1}^{324} r_{i,k} / 324$. The standardized 5-minute return of the stock is defined as

$$RET_{t,k} = \frac{r_{t,k}}{\delta_k}. \quad (1)$$

For simplicity, we drop the subscript k from RET and use RET_t as the dependent variable in our study.

We exclude the overnight returns and the returns at the price limits for the following reasons. The market opens at 9:00 am with the closing price of the previous trading day as its beginning price. As such, the return from 9:00 am to 9:05 am is the overnight return, not the actual 5-minute return.¹ These overnight returns are excluded from the econometric

¹The average number of observations excluded from the estimation is less than 3% of the total number of observations. A simulation study not reported in the paper shows the data truncation does not induce any spurious effects.

analysis because they behave differently from the intraday 5-minute returns. Typically, these overnight returns are very volatile as shown in Figure 1. We also exclude the stock returns at the price limits because once the price reaches the limits, it can stay at the limits or move only in one direction hence exhibiting unusual dynamics. Once the price departs from the limits, the next return is included in the analysis.²

High frequency stock returns normally exhibit negative serial correlations. The TSE 5-minute returns typically exhibit strong negative serial correlations up to the third lag. So we use an AR(3) process as the baseline model for the stock return process.³

To investigate the magnet effect, we define the dummy variables $D(ceiling)$ and $D(floor)$ as

$$\begin{aligned} D(ceiling)_t &= \begin{cases} 1, & \text{if the price } P_t \text{ is within 3\% of the ceiling} \\ 0, & \text{otherwise} \end{cases} \\ D(floor)_t &= \begin{cases} 1, & \text{if the price } P_t \text{ is within 3\% of the floor} \\ 0, & \text{otherwise.} \end{cases} \end{aligned} \quad (2)$$

These two magnet variables⁴ are included in the conditional mean equation of the return, and the model becomes

$$RET_t = \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \varepsilon_t. \quad (3)$$

In the finance literature, it has been repeatedly shown that high frequency stock returns have heavy tails and their volatility is dynamically correlated (e.g., volatility clustering); see Andersen and Bollerslev(1998) for more details. The generalized autoregressive conditional heteroskedasticity (GARCH) model is often used to capture heavy tails and volatility

²Excluding the overnight returns and returns at the limits may cause a problem in time series analysis because the intervals between the observations may not be equally spaced. So the estimation should reinitialize whenever a new return series starts. We also have done the analysis based on reinitializing and found the results do not change significantly.

³We also implemented an MA(3) process instead of AR(3) and found similar results. AR(3) estimation is used throughout this paper for computational simplicity.

⁴We set the threshold at 3% in the definition of $D(ceiling)$ and $D(floor)$. However, we tried other specifications and found the results are not sensitive to the threshold. We also tried some monotonic function to measure the closeness to the price limits and the results are consistent. Using dummy variables has a nice interpretation of the coefficients because it measures the magnitude of the level shifts in the return series.

clustering. In this paper, we use a GARCH(2,2) process as the baseline model for the conditional variance of the returns. Furthermore, we also include some factors in the conditional variance, leading to the following conditional variance equation for the TSE stocks:

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \beta_3 \varepsilon_{t-1}^2 + \beta_4 \varepsilon_{t-2}^2 + \gamma_3 \{D(ceiling)_{t-1} + D(floor)_{t-1}\} + \gamma_4 DLIM_t. \quad (4)$$

In Equation (4), $DLIM$ is the duration of the price stayed at the limits on the previous trading day, if the price closed at the limits. This variable is used to capture the volatility spillover effect.

In the proposed AR(3)-GARCH(2,2) model, there are 4 coefficients $(\gamma_1, \gamma_2, \gamma_3, \gamma_4)$ related to the price limits with different interpretations. First, γ_1 captures the magnet effect toward the ceiling. A positive γ_1 implies that the returns become larger as the price gets closer to the ceiling after controlling for deterministic volatility pattern, serial correlations and conditional heteroskedasticity. In other words, the price accelerates to the limit as it gets closer to the ceiling. Similarly, γ_2 captures the magnet effect of the floor. A negative γ_2 implies that the price accelerates to the floor as it gets closer to the floor. These two coefficients are of the most interest in this paper.

The coefficient γ_3 allows the volatility to change as the boundary is approached. A positive γ_3 implies that the volatility increases as the price gets closer to the limits. An increased volatility will increase the chance to draw a large absolute return so that it increases the probability that the price will reach the limits. The coefficient γ_4 captures the volatility spillover effect. Suppose the price closed at the ceiling on the previous trading day. The volatility spillover effect implies that the price limits prohibit the price to reach the equilibrium level yesterday and the effect will carry on to the volatility today. A positive γ_4 says that the volatility is larger after the price closed at the limits and supports the volatility spillover hypothesis.

3.2 Estimation Results

We applied Equations (3) and (4) to the 345 TSE stocks using the E-views program. Table 2 summarizes the estimation results. It reports the average estimated coefficients and the

median of t ratios in the parenthesis for each industry. As mentioned before, the return series have significant serial correlations up to the third lag and the fitted GARCH(2,2) process is persistent.

Of particular interest among the results are $\gamma_1, \gamma_2, \gamma_3, \gamma_4$, which are the coefficients of $D(ceiling)$, $D(floor)$, $\{D(ceiling) + D(floor)\}$, and $DLIM$, respectively. First, the median t ratios for γ_1 , the coefficient of $D(ceiling)$, in the conditional mean equation are all positive except for two sectors, the paper pulp (19) and automobile industry (22). Since we look at the median t ratios, we cannot conclude the significance directly by comparing it with the critical values. We introduce a formal joint test for all 345 estimations in the next subsection. The median value for the t ratios heuristically gives an idea how many coefficients are significant. For example, bank industry (28) has a median value of 2.411. This implies that more than half of the bank stocks have significant γ_1 's. Plastics industry (13) also has similar results with a median t ratio 2.209.

The magnet effect towards the floor limit can be captured by γ_2 , the coefficient of $D(floor)$. Industrial average γ_2 does not reveal any consistent sign. In addition, none of the median t ratios are significant at the 5% level.

Instead of looking at the industrial averages, scatter plots of the estimates and the t ratios may give a better understanding on individual stock behavior. Figure 2 shows scatterplots of the estimates and t ratios of the coefficients of $D(ceiling)$ and $D(floor)$ for the 345 estimations. The x-axis (horizontal) corresponds to the ceiling magnet effect and the y-axis (vertical) corresponds to the floor magnet effect. If there are magnet effects in both limits, the points should lie in the 4th (South-East) quadrant. Most points in the scatterplots are indeed in the right-hand side of the y-axis, implying that the magnet effect toward the ceiling is strong. Regarding the floor magnet effect, there are 191 negative γ_2 out of 345. Even though there are more negative γ_2 , Figure 2 shows that the floor magnet effect is relatively weak. In summary, we conclude that the magnet effect is present in the TSE. The effect is strong toward the ceiling but weak toward the floor.

Figure 3 plots the industry average estimates from Table 2. Again, all the industries except 22(automobile) and 27(tour) exhibit the correct direction of the magnet effect towards the ceiling. Note that industry 23(electronics), 13(plastics), and 28(banking) have the

strongest magnet effects. The strong magnet effect of these three industries and the erroneous direction of the automobile and tourist industries are confirmed in Section 4, which uses a different approach.

We now turn to the results of the conditional variance equation in Table 2. The coefficients of interest are γ_3 and γ_4 . The median t ratios for γ_3 show that the volatility increases as the price gets closer to the limits. As stated before, this increases the probability of reaching the price limits. The median t ratios of γ_3 for all industrial sectors are greater than 2.

To detect the volatility spillover effect, we test the null hypothesis that $\gamma_4 = 0$. A positive γ_4 implies that the conditional variance increases as the duration staying at the limits increases. The median t ratios for γ_4 is 1.547, which is not significant. However, many industries have median t ratios greater than 2. Figure 4 gives a better description on these two coefficients. Figure 4 shows the scatterplot of t ratios for γ_3 and γ_4 . It shows that most points lie in the first quadrant. The plot clearly shows that most γ_3 's are positive and significant. Regarding γ_4 , most points lie above 0. Even though less than half points lie above 2, it is clear that most γ_4 's are positive. In short, we find an evidence for the volatility spillover hypothesis in TSE.

3.3 Test of Magnet Effect in TSE Using GMM

The analysis in the previous subsection is exploratory in nature. In this subsection, we aggregate the cross-sectional results to provide a formal test. If the returns are not correlated from one stock to another, we can simply derive a joint test statistic for the magnet coefficients. Unfortunately, it is well known that the returns are correlated across stocks so we cannot treat them as being uncorrelated. One way to allow cross and serial correlations is to adopt the GMM method. We stack all 345 returns together in GMM estimation to derive the joint distribution of the estimates. To get closed-form moments, we drop the conditional variance equation and concentrate on the conditional mean equation. Thus the model becomes

$$\mathbf{RET}_t = \boldsymbol{\alpha} + \mathbf{X}_t\boldsymbol{\beta} + \mathbf{Z}_t\boldsymbol{\gamma} + \boldsymbol{\varepsilon}_t, \quad \boldsymbol{\varepsilon}_t \sim (\mathbf{0}, \boldsymbol{\Sigma}) \quad (5)$$

where, $\mathbf{RET}_t$: stacked standardized 5-minute returns. (345 by 1)

$\mathbf{X}_t$: AR(3) or 3 lagged variables (345 by 1035)

$\mathbf{Z}_t$: stacked $D(ceiling)_{t-1}$ and $D(floor)_{t-1}$ (345 by 690)

β : AR coefficients (1035 by 1)

γ : Magnet coefficients (690 by 1)

Since each equation of the stacked returns in Equation (5) is identical to Equation (3), we can use the usual OLS moments for the GMM estimation. Advantages of using OLS moments include that it is consistent and the estimation process can be done stock by stock. Nevertheless, to calculate the proper standard errors for the estimates, we must pool all 345 stocks. The disadvantage of using OLS moments is that the estimates may not be efficient. The moments for the GMM estimation are

$$g_T(\mathbf{b}) = E_T(f_t) = \begin{bmatrix} E_T(\mathbf{RET}_t - \alpha - \mathbf{X}_t\beta - \mathbf{Z}_t\gamma) \\ E_T[\mathbf{X}'_t(\mathbf{RET}_t - \alpha - \mathbf{X}_t\beta - \mathbf{Z}_t\gamma)] \\ E_T[\mathbf{Z}'_t(\mathbf{RET}_t - \alpha - \mathbf{X}_t\beta - \mathbf{Z}_t\gamma)] \end{bmatrix} = E_T \begin{bmatrix} \varepsilon_t \\ \mathbf{X}'_t\varepsilon_t \\ \mathbf{Z}'_t\varepsilon_t \end{bmatrix} = 0$$

The solution to the above moments is simply the OLS estimators for each individual regression. Figure 5.1 scatterplots the magnet coefficients from the OLS estimations. The plots look strikingly similar to Figure 2.1 where we used GARCH(2,2) as well as the conditional mean equation. γ_1 is positive for most stocks but γ_2 does not have a consistent sign. GMM provides a sampling distribution of the estimates,

$$cov(\mathbf{b}) = cov \left(\begin{bmatrix} \hat{\alpha} \\ \hat{\beta} \\ \hat{\gamma} \end{bmatrix} \right) = \frac{1}{T} d^{-1} S d^{-1'} \quad (6)$$

$$\text{where, } d \equiv \frac{\partial g_T(\mathbf{b})}{\partial \mathbf{b}'}$$

$$S \equiv \sum_{j=-\infty}^{\infty} E(f_t f'_{t-j}).$$

In our setup, the d and S matrices can be estimated by

$$\begin{aligned}
d &\equiv \frac{\partial g_T(\mathbf{b})}{\partial \mathbf{b}'} = - \begin{bmatrix} I_N & E(\mathbf{X}_t) & E(\mathbf{Z}_t) \\ E(\mathbf{X}'_t) & E(\mathbf{X}'_t \mathbf{X}_t) & E(\mathbf{X}'_t \mathbf{Z}_t) \\ E(\mathbf{Z}'_t) & E(\mathbf{Z}'_t \mathbf{X}_t) & E(\mathbf{Z}'_t \mathbf{Z}_t) \end{bmatrix} \\
\hat{d} &= - \begin{bmatrix} I_N & \frac{1}{T} \sum (\mathbf{X}_t) & \frac{1}{T} \sum (\mathbf{Z}_t) \\ \frac{1}{T} \sum (\mathbf{X}'_t) & \frac{1}{T} \sum (\mathbf{X}'_t \mathbf{X}_t) & \frac{1}{T} \sum (\mathbf{X}'_t \mathbf{Z}_t) \\ \frac{1}{T} \sum (\mathbf{Z}'_t) & \frac{1}{T} \sum (\mathbf{Z}'_t \mathbf{X}_t) & \frac{1}{T} \sum (\mathbf{Z}'_t \mathbf{Z}_t) \end{bmatrix}, \text{ and}
\end{aligned} \tag{7}$$

$$\begin{aligned}
S &\equiv \sum_{j=-\infty}^{\infty} E(f_t f'_{t-j}) \\
&= \sum_{j=-\infty}^{\infty} \begin{bmatrix} E(\epsilon_t \epsilon'_{t-j}) & E(\epsilon_t \epsilon'_{t-j} \mathbf{X}_{t-j}) & E(\epsilon_t \epsilon'_{t-j} \mathbf{Z}_{t-j}) \\ E(\mathbf{X}'_t \epsilon_t \epsilon'_{t-j}) & E(\mathbf{X}'_t \epsilon_t \epsilon'_{t-j} \mathbf{X}_{t-j}) & E(\mathbf{X}'_t \epsilon_t \epsilon'_{t-j} \mathbf{Z}_{t-j}) \\ E(\mathbf{Z}'_t \epsilon_t \epsilon'_{t-j}) & E(\mathbf{Z}'_t \epsilon_t \epsilon'_{t-j} \mathbf{X}_{t-j}) & E(\mathbf{Z}'_t \epsilon_t \epsilon'_{t-j} \mathbf{Z}_{t-j}) \end{bmatrix} \\
\hat{S} &= \sum_{j=-\infty}^{\infty} \begin{bmatrix} \frac{1}{T} \sum (\hat{\epsilon}_t \hat{\epsilon}'_{t-j}) & \frac{1}{T} \sum (\hat{\epsilon}_t \hat{\epsilon}'_{t-j} \mathbf{X}_{t-j}) & \frac{1}{T} \sum (\hat{\epsilon}_t \hat{\epsilon}'_{t-j} \mathbf{Z}_{t-j}) \\ \frac{1}{T} \sum (\mathbf{X}'_t \hat{\epsilon}_t \hat{\epsilon}'_{t-j}) & \frac{1}{T} \sum (\mathbf{X}'_t \hat{\epsilon}_t \hat{\epsilon}'_{t-j} \mathbf{X}_{t-j}) & \frac{1}{T} \sum (\mathbf{X}'_t \hat{\epsilon}_t \hat{\epsilon}'_{t-j} \mathbf{Z}_{t-j}) \\ \frac{1}{T} \sum (\mathbf{Z}'_t \hat{\epsilon}_t \hat{\epsilon}'_{t-j}) & \frac{1}{T} \sum (\mathbf{Z}'_t \hat{\epsilon}_t \hat{\epsilon}'_{t-j} \mathbf{X}_{t-j}) & \frac{1}{T} \sum (\mathbf{Z}'_t \hat{\epsilon}_t \hat{\epsilon}'_{t-j} \mathbf{Z}_{t-j}) \end{bmatrix}
\end{aligned} \tag{8}$$

There are two potential problems in estimating the d and S matrices. First, we need to invert the 2070 by 2070 d matrix. Since each block in the d matrix is a diagonal matrix, there is no problem obtaining the inverse matrix of d . Second, to estimate the S matrix one must truncate the lag at some point because j runs from negative infinity to positive infinity. To choose an appropriate truncation point, we checked the cross correlations of the residuals of the 345 estimations. Figure 6.1 shows the boxplots of the serial correlations of these residuals. The plots show virtually no serial correlations in the residuals. This implies that the AR(3) model can adequately capture the serial correlation in the returns. Figure 6.2 shows the boxplots of residual cross correlations. There are not only significant contemporaneous cross correlations among the residuals but also serious cross correlations at lags 1 and 2. Thus we must compute the contemporaneous cross correlations and lagged cross correlations. In this analysis, we truncate the lag at ± 6 and check the sensitivity of the results to the truncation lag. The results are stable when the truncation lag is around 6.

Once the d and S matrices are estimated, we can calculate the covariance matrix for the 2070 estimates. This covariance matrix accounts for not only the serial correlations but also

the cross correlations of the stock returns. We form a joint test of the ceiling magnet effect by testing if the cross section mean of γ_1 is equal to 0. One can also test whether the 345 γ_1 's are jointly equal to zero. But the problem of the second joint test is that testing zero is misleading. The test may be rejected because some γ_1 are negative. We want to test whether the γ_1 is positive. So testing whether the mean of γ_1 is zero or positive is the correct test for the magnet effect. The standard error for the mean of γ_1 can be computed by

$$SE(\frac{1}{345} \sum_{i=1}^{345} \hat{\gamma}_{1i}) = \sqrt{a \text{ cov}(\mathbf{b}) a'}, \quad (9)$$

$$\text{where } a = [0 \ 0 \ \dots \ 0 \ \frac{1}{345} \ \frac{1}{345} \ \dots \ \frac{1}{345} \ 0 \ 0 \ \dots \ 0] \quad (1 \text{ by } 2070).$$

To test the floor magnet effect, one can use the same procedure on γ_2 to obtain the appropriate standard errors. Table 3 reports the test results for the ceiling and floor magnet effects. The average $\hat{\gamma}_1$ is 0.124 and the standard error of the mean is 0.011, which gives a t ratio of 11.134. Therefore, the ceiling magnet effect clearly exists in the TSE. However for the floor magnet effect, we cannot reject that the mean of γ_2 is zero. The results of GMM estimation are consistent with those obtained earlier by checking the magnet effect heuristically with the scatterplots and median t ratios. The industrial analysis also shows a consistent result with the previous study. Industry 23, 13, and 28, which claimed to have big ceiling magnet effect in the previous section, have t ratios greater than 6. On the other hand, industry 22 and 27 where we could not find any ceiling magnet effect have t ratios less than 1.65, which is the critical value for the one sided test.

3.4 Magnet vs. Momentum Effects

From the estimation results of Equations (3) and (4), we argue that the conditional mean return is higher as the price gets closer to the ceiling after controlling for deterministic volatility pattern, serial correlations and conditional heteroskedasticity. In other words, the expected price continues to move upward or move downward after exceeding the threshold. These results provide evidence that TSE stocks have a strong ceiling magnet effect. Another possible explanation for this finding is momentum as first documented in Jagadeesh and Titman (1993). Momentum is the name given to the observation that stocks that have done

unusually well in the recent past are more likely to do unusually well in the near future and vice-versa. While the presence of this characteristic in U.S. stocks is still being debated, it is clear that the results of subsection 3.2 could also be due to a high frequency version of momentum in the TSE stocks. That is, stocks that have risen over the first part of the day and crossed the threshold are more likely to continue rising over the remaining portion of the day.

In this section, we seek to differentiate between a pure price continuation (or momentum effect) and a magnet effect. Toward this end we construct variables which are designed to capture purely short term trends in the price movements which are not perfectly correlated with the asset price's proximity to the price limits as the magnet variables of the previous section were. We are not aware of any studies that attempt to quantify momentum effect in high frequency data so we propose two measures here both of which are designed to capture short run trends in the price. However, given no precise definition of momentum effect in high frequency data, we acknowledge that the proposed methods may not be effective to distinguish the two effects because the two effects are highly correlated. The first measure is constructed using dummy variables based upon the price changes from the opening price:

$$\begin{aligned} Day(up)_t &= \begin{cases} 1, & \text{if } \frac{P_t - P_{open}}{P_{open}} > 4\% \\ 0, & \text{otherwise} \end{cases} \\ Day(down)_t &= \begin{cases} 1, & \text{if } \frac{P_t - P_{open}}{P_{open}} < -4\% \\ 0, & \text{otherwise,} \end{cases} \end{aligned} \quad (10)$$

where P_{open} is the price at 9:05 am. Notice that the key difference between this measure and the magnet variable is that the latter is defined relative to the previous closing price. Hence while both variables are indicative of the general movement in price level over the course of the day, only the magnet variable is a direct indicator of how close the price is to the limit.

The second measure is designed to capture very high frequency trends in the price. It is defined as

$$5 \min(up)_t = \begin{cases} 1, & \text{if the previous four 5-minute returns are positive} \\ 0, & \text{otherwise} \end{cases}$$

$$5 \min(down)_t = \begin{cases} 1, & \text{if the previous four 5-minute returns are negative} \\ 0, & \text{otherwise} \end{cases} \quad (11)$$

Both of these momentum variables characterize intraday price continuations that are not perfectly correlated with the magnet variable. We proceed to include each set of momentum variables separately in the conditional mean equation (3). The remainder of the specification (the volatility structure) is left unchanged. That is,

$$RET_t = \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \gamma_5 M(up)_{t-1} + \gamma_6 M(down)_{t-1} + \varepsilon_t, \quad (12)$$

and

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \beta_3 \varepsilon_{t-1}^2 + \beta_4 \varepsilon_{t-2}^2 + \gamma_3 \{D(ceiling)_{t-1} + D(floor)_{t-1}\} + \gamma_4 DLIM_t. \quad (13)$$

where $M(up)_{t-1}$ and $M(down)_{t-1}$ are the momentum dummy variables given in (10) or (11).

If the magnet effect were purely a manifestation of a momentum effect, then we should expect that including either of these local trend variables should dilute or eliminate the significance of the magnet variables. On the other hand, if the inclusion of these momentum variables has little or no impact on the magnet coefficients, then this strengthens the conclusion of a magnet effect.

Figure 7.1 shows the scatterplot of t ratios of γ_1 and γ_2 after re-estimating the model for all 345 stocks with the momentum variables given in (10). The plot is very close to Figure 2.2, suggesting that t-ratios associated with the magnet variable coefficients are virtually unchanged. The ceiling magnet effect continues to be strong but the floor magnet effect is weak. Calculating the correlation coefficient of t ratios for γ_1 between the two econometric models is 0.93406 and that for γ_2 is 0.9383. These correlations show that the two momentum variables do not affect the estimation results. Figure 7.2 shows the scatterplot of the t ratios of γ_6 and γ_7 . It shows that the momentum effect is not strong in TSE stocks.

Figure 7.3 contains the scatterplot for the 345 t-statistics for γ_1 and γ_2 using the momentum variables defined in (11). The difference between Equation (10) and Equation (11)

is that Equation (11) uses shorter horizon by considering the most recent 4 price movements only. The plot of the t ratios associated with the magnet variables is again virtually unchanged with most t ratio points lying in the right hand side implying a strong ceiling magnet effect. But the floor magnet effect is not conclusive. Though there are more negative γ_2 's than positive, it is still hard to find any strong floor magnet effect. Figure 7.4 plots the t ratios for the new momentum variables defined in Equation (11). Unlike Figure 7.2, Figure 7.4 shows a tendency for positive γ_5 with many positive and significant. Thus for some stocks, if the price moved upward for four consecutive times, then the expected price will move upward.

We find the t-ratio plots associated with the magnet variables are virtually unchanged after adding two sets of variables specifically designed to capture short run trends or momentum effects indicating that the magnet coefficients are robust. The results in this section point in the direction of magnet effects and not to spurious effects due to unaccounted for momentum.

3.5 Stock Markets without Daily Price Limits

To further confirm the detected magnet effect of price limits, we apply the employed econometric model to a dataset without daily price limits. We randomly choose 90 stocks from the S&P 500 firms of the U.S. market and use the Trades and Quotes (TAQ) dataset, which provides the tic by tic data of the U.S. stock market, from January 1, 1997 to June 30, 1997. We interpolate the 5-minute returns from the data to match the time interval used for TSE. Although the sample period of the U.S. market is only 6 months, the number of observations for the 5-minute return series is similar to that of TSE because the daily trading hour is longer in the U.S. stock market.

Because there are no daily price limits for the U.S. data we cannot define the magnet variables as those in Equations (3) and (4). We modify the definitions of the magnet variables for both the TSE and U.S. datasets as follows:

$$D(ceiling)_t = \begin{cases} \left(\frac{P_t - P_{close}}{P_{close}} \right)^2, & \text{if } P_t > P_{close} \\ 0, & \text{otherwise,} \end{cases}$$

$$D(floor)_t = \begin{cases} \left(\frac{P_t - P_{close}}{P_{close}}\right)^2, & \text{if } P_t < P_{close} \\ 0, & \text{otherwise,} \end{cases} \quad (14)$$

where P_{close} is the closing price of the previous trading day. To capture the characteristic that the magnet effects become stronger as the price gets closer to the limits, we use a squared function in the definition of Equation (14). These new magnet variables differ from those of Equation (2) by the fact that they are continuous function of stock prices, whereas those in Equation (2) are step functions. However, as in Equation (2), large $D(ceiling)$ and $D(floor)$ imply that the price is far away from the previous close price. We apply these two new magnet variables to both TSE and U.S. stock returns.

The econometric model used in comparison becomes

$$\begin{aligned} RET_t &= \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \varepsilon_t \\ h_t &= \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \beta_3 \varepsilon_{t-1}^2 + \beta_4 \varepsilon_{t-2}^2 \\ &\quad + \gamma_3 \{D(ceiling)_{t-1} + D(floor)_{t-1}\} + \gamma_4 DLIM_t. \end{aligned} \quad (15)$$

Notice that the $DLIM$ variable is not used for the U.S. return series because there are no daily price limits.

We fit the prior AR(3)-GARCH(2,2) model with the magnet variables defined in Equation (14) to the return series of 345 TSE stocks and 90 randomly chosen S&P 500 firms. U.S. stock returns are also standardized because they also show a deterministic intraday volatility pattern. Since U.S. firms should not have magnet effect due to the price limits, we predict the magnet coefficients for U.S. data to be insignificant.

Figure 8 plots the t ratios of the magnet coefficients. In Figure 8.1, the TSE firms typically have positive ceiling magnet coefficients as in Figure 2. Even using the new magnet variables in Equation (14), we conclude that TSE stocks have a strong ceiling magnet effect. Figure 8.2 shows that most, if not all, t ratios for the U.S. firms are inside the insignificant range, implying that, as expected, there is no magnet effect for U.S. firms. It is surprising to see that there are many positively significant γ_2 's for the U.S. 500 firms, which implies a reverse magnet effect. Since U.S. stocks do not have any price limits, this effect cannot be due to the price limits but due to some other factors not accounted for.

3.6 Additional Data

The sample period of the data analyzed so far is from January 3, 1998 to March 20, 1999. A natural question is whether the results obtained are sample period specific. We recently obtained new tic by tic data for the TSE. The sample period extends to April 29, 2000. Using the new data from March 21, 1999 to April 29, we fit Equations (3) and (4) for the standardized 5-minute return series. Figure 9.1 shows the scatterplots of the estimates of the magnet coefficients, whereas Figure 9.2 shows the scatterplot of the t ratios for the new sample. The two plots are strikingly similar to Figures 2.1 and 2.2, respectively, with most points being on the right-hand side of the Y-axis and more than half of the points being in the 4th quadrant, supporting the magnet effect. Consequently, the detected magnet effect is not sample period specific. In summary, the detected magnet effect of the price limits in the TSE is statistically significant and persistent over time.

4 Analysis Based on Investment Strategies

In Section 3, we found the presence of magnet effect using econometric analysis. In this section, we use a different approach to find the same result and see whether the detected magnet effect is economically significant. Specifically, we introduce daily trading strategies to take advantage of the magnet effect and find that the effect is economically significant. Indeed, some strategies that take advantage of the magnet effect are economically meaningful even after adjusting for the transaction cost and taxes.

We introduce three simple strategies. Strategy A exploits the ceiling magnet effect. Here the investor buys the stock if the price reaches 4% and sells it at the following opening. The reason that the investor sells the stock at the following opening is due to the illiquidity problem. If the price reaches the limits, the stock remains illiquid so that the investor cannot trade it any more. Sometimes there are transactions taken place at the price limits but the trading volume is very low. To make it economically sensible, the investor closes her position at the opening on the following trading day. Because the price can move freely up or down 7% from the previous closed price, the stocks are typically liquid at the opening and easy to trade. If the stock opens at the ceiling on the second day so the stock becomes illiquid, then

the investor waits until the stock becomes liquid to close her position. For the same reason, the investor cannot invest in the stock, if its price is at the limits. For example, suppose the price of a stock increased 6% so that strategy A tells the investor to buy the stock. But if the next price reaches the ceiling, then the investor cannot buy the stock. The following analysis is done carefully so that no transaction takes place at the price limits when the stock is illiquid.

When the price of a stock reaches the threshold 4%, we assume that the investor can buy the stock at the next 5-minute price by submitting an aggressive order (i.e., the equivalence of a market order). If the next 5-minute price reaches the ceiling, then the investor waits until the stock becomes liquid to invest.

The investor must decide how to allocate her available fund (or capital). Since the investor has no knowledge about which stocks will reach 4% ex ante, she cannot allocate the fund to invest only in the stocks reaching 4% ex ante. We assume that the investor simply uses an equal weighted portfolio. First the investor allocates her available fund equally to all the stocks in the portfolio. The investor buys Stock X, if its price increases 4% over the previous close price. If the stock does not reach 4% during the trading hours, then the investor does not invest in the stock. For example, suppose there are 100 stocks in the portfolio and the investor starts out with \$100. The investor allocates \$1 to each stock and if a stock increases 4%, then she buys it at the next transaction price and sells it at the open of the following trading day. If all 100 stocks reached the 4% threshold in a trading day, then the investor invest \$100 fully. If none of the 100 stocks reached 4%, then she invests nothing and keeps the cash. In practice, the investor can invest in a riskfree asset when she holds cash. In our analysis, we take a conservative approach by assuming that the investor simply keeps the cash. This conservative approach allows the investor to invest in a stock immediately if its price reaches the threshold.

Strategy B exploits the floor magnet effect. The investor shorts the stock if the price reaches -4% and closes the position at the open of the next trading day in the same manner described for strategy A. Strategy C combines Strategies A and B. It is rare but sometimes a stock can reach both 4% and -4% during a trading day. In such cases, strategy C tells the investor to use strategy A or strategy B depending on whichever comes first.

4.1 Industry Portfolio Comparison

Provided that there is ceiling magnet effect, strategy A will work because the conditional mean return is higher if the price is above 4%. If there are both ceiling and floor magnet effects, then strategy C will work best. Performance of the three strategies is given in Table 4, which reports performance of the equally weighted industry portfolio without the transaction cost.

We use 3 benchmarks to evaluate the strategies. The first benchmark is buy and hold strategy for the Taiwan Stock Exchange Index TAIEX for the same sample period (Jan, 1998 - Mar. 1999). The average daily return of TAIEX during the sample period is -0.036% and the standard deviation of the daily returns is 1.564. To compute the Sharpe ratios, we used the annual risk-free rate equal to 3.5%. The resulting Sharpe ratio is -0.030. If an investor invests \$100 in TAIEX on Jan. 3rd, 1998, then on Mar. 20th, 1999, the portfolio will have a value of \$85.47. Even though Taiwan was not among the countries hit with the Asian crisis, the Taiwan stock market had negative return during the sample period. The second benchmark is the buy and hold strategy for the TAIEX from 1989 to 1999. The average daily return from 1989 to 1999 is 0.034% and the standard deviation is 1.949, which gives a Sharpe ratio of 0.012.

The last benchmark is a cash-TAIEX mix that matches the equity allocation of the suggested trading strategy. For example, if the investor uses strategy A and if a stock reaches 4%, the investor will invest in TAIEX instead of the individual stock. Since the proposed strategies involve market timing, the last benchmark which takes into account market timing will have similar exposure to risk factors. The performance of the last benchmark depends on the investment strategy portfolios. For example, the strategy portfolio is an equally weighted market portfolio of 345 firms, then the cash-TAIEX benchmark will have average daily return of 0.058 and standard deviation of 0.275.

Table 4 reports the strategy performance of the 18 industry portfolios and the equally weighted TSE portfolio. Note that all the strategies performed better than the buy and hold TAIEX benchmark. Even though the overall Taiwan stock market went down during the same period, all the strategies performed better than the TAIEX. One can conservatively evaluate the strategy against the risk-free return. Positive Sharpe ratios imply that all the

strategies beat the risk-free return. Using cash-TAIEX mix as a benchmark may give a better challenge. Strategy A for the TSE of 345 firms had an average daily return of 0.080%, which is higher than the cash-TAIEX mix benchmark. Though the standard deviation is higher, the Sharpe ratio of 0.235 is higher than that of the cash-TAIEX mix. Strategy A for 345 firms performed better than all the benchmarks. This is a surprising result because on average the investor only invests 11.13% of the fund in the stocks and leaves the rest in cash. There are several ways to increase the proportion to be invested in stocks, which will be introduced later. This impressive performance of strategy A is consistent with the empirical results in previous sections. We found the magnet effect toward the ceiling in TSE was statistically significant and the same results in Table 4. Strategy A which exploits the ceiling magnet effect has an outstanding performance compared with the benchmarks.

Panel B reports the performances of strategy B, which tries to capitalize the magnet effect toward the floor. The equally weighted market portfolio had a positive average daily return but the performance is not as good as strategy A. It performed better than the buy and hold TAIEX benchmark for the same sample period and cash-TAIEX mix but the average daily return of 0.019% was lower than 10 year buy and hold TAIEX benchmark. Due to small standard deviation, the Sharpe ratio of 0.027 was higher than all the benchmarks. Strategy B was not as impressive as strategy A, but had a moderate success. Even though, we could not document any statistically significant floor magnet effect, the investment strategy still worked to some extent. Panel C reports strategy C which combines both strategy A and B. Since both strategies had success, strategy C has an outstanding performance results. The average daily return is 0.099% with a Sharpe ratio of 0.226. The daily average return for cash-TAIEX mix benchmark is 0.046%, which is higher than the other benchmarks. This implies that the market timing may be important for the strategy's success. We cannot deny that market timing played an important role but we argue that the magnet effect was the major reason behind the success of strategy C. Strategy C that involves not only market timing but also magnet effect had much better performance than the cash-TAIEX mix benchmark involving market timing only. Both the average daily return and the Sharpe ratio of strategy C are much higher than those of the cash-TAIEX mix benchmark.

Figure 10 plots the cumulative returns of strategy C, buy and hold TAIEX and cash-

TAIEX mix benchmarks starting with \$100 on January 3rd, 1998. One interesting characteristic of the figure is the low volatility of the strategy returns. The low volatility magnifies the Sharpe ratios shown in Table 5. Figure 10 also shows that strategy C worked even if the market (TAIEX) went down. Strategy C also uses strategy B, which short sales the stocks, so that it can hedge against the downside.

Individual industry portfolio analysis gives a convincing support to the regression results in Section 3. The average daily returns for equally weighted portfolio of industry 22(automobile) and 27(tourist) are the lowest in Panel A of Table 4. In addition, these two industries are the only industries with average daily return lower than the cash-TAIEX benchmark. Investment strategy analysis implies that industry 22 and 27 fail to capitalize the ceiling magnet effect. We found identical results in the previous analysis. Table 2 and Figure 3 report the industry analysis using the econometric approach and they show that industry 22 and 27 are the only industries with a wrong sign for the ceiling magnet effect. Note that industry 22 and 27 are the only points in the left hand side in Figure 3. It is reassuring because two approaches are fundamentally different but they both indicate the same results. We can also find consistent results in industries with strong magnet effect. Panel C of Table 4 reports that industry 23(electronics) and 13(plastics) have the highest daily mean return for strategy C. Figure 3 shows that these two industries have strong magnet effects, which are consistent with the results in Table 4. Even though the two approaches came from different perspectives, the regression result and the investment result support each other.

4.2 Strategies with Different Thresholds

An investor may choose different thresholds other than 4% to implement the strategies. Table 5 reports the performance of the ALL portfolio using 5 different thresholds, specifically 2%, 3%, 4%, 5%, and 6%. Strategies A, B and C are identical as defined earlier except for the changes in the thresholds. The 6% strategy needs some explanation. TSE imposes tic size restrictions in price movement. With the tic size restrictions, the price typically reaches the ceiling at slightly less than 7%. Suppose the price closed at 70 yesterday. The price can move between 65.1 and 74.9 today, which is the 7% window. However, the relevant tic size for this price range is 0.5 so that the price will reach the ceiling at 74.5, or 6.43% return.

If the price is 74 (one tic smaller than 74.5), the return is 5.71%. So the 6% threshold will be reached only when the price is 74.5. We assumed that the investor cannot transact at the price limits because of the illiquidity problem. If an investor uses 6% threshold, she may not be able to buy the stock because the price that exceeds the threshold is the limit price. On the other hand, we do not use any threshold values less than 2% because the strategy becomes similar to the buy and hold strategy.

Consider Table 5. Panel A shows the performance of strategy A. The mean return, Sharpe ratios, and the \$100 investment decrease as the threshold increases. Among the 5 thresholds, 2% seems to work best. The reason why 2% works best can be found in the average \$ invested column in Panel A. The average amount invested out of \$100 is \$31.86 for the 2% threshold but just \$3.40 for 6%. If the investor uses a lower threshold, she will invest more in stocks and leave less money as cash. So using the 2% threshold, the investor will be able to invest the most and receive a better return than leaving the money in cash. Recall that the investor cannot optimally allocate her fund to the stocks ex ante because she does not know which stocks to invest ex ante. Mean returns and the \$100 investment for 2% and 3% thresholds in Panel A are greater than the cash-TAIEX mix benchmark. Sharpe ratios are all higher than the corresponding benchmarks. Strategy B performs worse than strategy A. However, combining Strategies A and B in Panel C performs the best among all the strategies. Sharpe ratios are also the highest. Note that since strategy C combines two strategies, the average amount invested increases. For example, if an investor uses strategy C with 2% threshold, then on average she will invest 58.42% in stocks and 41.58% in cash. According to Table 5, it seems that using lower threshold will be the optimal choice. However, this is not true as we will see in the following section, where we introduce the transaction costs. Intuitively, 2% threshold performed better than other thresholds because the investor invests the most using the lower threshold.

4.3 Transaction Costs

The transaction cost in TSE is 0.1425% for buying and selling, which is a fixed commission fee. Selling a stock involves additional transaction tax at 0.3%. Since the strategies involve buying and selling, the investor must pay 0.585% of the amount invested, for every stock

invested in the portfolio. Since the above investor uses day trading strategies, the transaction cost could change the results of the previous comparison. Table 6 reports the same portfolio performance as in Table 5 when the transaction cost and tax are taken into consideration.

All the portfolios performed better than the cash-TAIEX mix benchmark, as in Table 5. This is not surprising because the transaction affects the same way to the cash-TAIEX mix benchmark as the strategy portfolios. Since cash-TAIEX mix benchmark uses the same market timing as the strategies, the amount to be paid for transaction cost will be identical to that for the strategies. Therefore, the cash-TAIEX mix benchmark will not be affected by the transaction cost and we will not make any comparison.

Several portfolios now performed worse than the buy and hold TAIEX benchmark. Since buy and hold benchmark does not involve any transaction cost but the strategies incur heavy transaction costs, the strategies' performances are not as good as in Table 5. Especially, most portfolios using strategy B have lower daily average return than the buy and hold TAIEX benchmark. We argue that the reason for this is because the magnet effect toward the floor is not so strong, the strategies to capitalize this weak effect will be wiped out by the transaction costs.

Strategy A in Panel A does fairly well for thresholds greater than 2%. The investment strategy that exploits the strong magnet effect survives even after the transaction cost. Strategy C does not outperform strategy A because of the poor performance of strategy B. All the strategies in Panel C give negative returns and the 2% strategy underperforms the TAIEX benchmark. So considering the transaction cost, if the investor tries to exploit the magnet effect, she should use strategy A, which capitalize only the strong ceiling magnet effect. Once adjusted for the transaction cost, we now have the identical result as in Section 3 where we used econometric approach. Both approaches conclude that the magnet effect toward the ceiling is statistically and economically significant.

Comparing the performance of strategy A for different thresholds gives some insights on optimal trading strategy. The optimal threshold was 2% without the transaction cost but once we include the transaction cost, 2% is not optimal any more and indeed perform the worst. Because the 2% threshold strategy invests more than the other strategies, it has a higher transaction cost. The threshold with the highest mean return is 4%. Using

a threshold higher than 4% can capitalize the magnet effect more but it also encounters illiquidity problem, which causes less investment. Using the 6% threshold, even if the magnet effect may be the strongest, since there are not many rooms to invest, the investor cannot invest much to make enough profits. The average amount invested for the 6% strategy is \$3.40, leaving \$96.60 as cash. Due to the trade off between transaction cost and advantage of exploiting the magnet effect, the optimal threshold is 4%. Nevertheless, even the strategy A using 4% threshold has lower daily average return than the 10 year TAIEX. This is due to the fact that the investor does not invest enough to capitalize the magnet effect.

To summarize, taking the transaction cost into account, the investment strategies generally do not work. An interesting fact is the tradeoff associated with different threshold values. The advantage of a lower threshold is that it invests more. The advantages of a higher threshold are that it utilizes effectively the strong magnet effect and that it involves less transaction cost. One drawback of the high threshold is that it invests too little. If the investor can increase the amount to invest, then she may be able to make more profits. One possible way to increase the amount to invest is to restrict the maximum number of firms to invest. For example, suppose instead of all the firms, the investor decides to invest up to 100 firms. The investor's strategy will be that she invests \$1 each to the first 100 stocks that reach the threshold. If only 50 stocks reach the threshold, then the investor invest \$50 to the 50 stocks and leave \$50 as cash. If 200 stocks reach the threshold, then the investor invest \$100 in the first 100 stocks that reach the threshold. Now the investor has two choice variables when she adopts this new strategy. The investor can choose the threshold value and also the maximum number of firms to invest.

Table 7 shows the performance result of strategy A for different thresholds and different maximum number of firms in the portfolio. We used the same thresholds as before, 2% to 6%. The maximum number of stocks considered are 10, 20, 30, 40, 50, 60, 70, 100, 300 and 345. Panel E reports the average amount invested in a day. Half of the portfolios considered invest more than half of the available fund on average. Using lower maximum number will make the investor to invest more, but on the other hand, she may increase the risk by lack of portfolio diversification. So there is a trade off between the maximum number of firms and the amount of stock holding. As mentioned before, there is also a trade off between using

different thresholds. These two trade offs induce an optimal choice of investing strategy.

Panel A reports the mean return. The maximum return is achieved by using 5% threshold and 40 firms in the portfolio. The cumulative returns decrease as it moves away from 5% threshold and 40 firms. If we evaluate the strategies against the 10 year buy and hold TAIEX, many strategies have higher mean returns than 10 year TAIEX benchmark. We could not achieve a higher mean return than 10 year TAIEX before because of limited amount invested in stocks.

Since the TAIEX during the sample period have a negative mean return, it may be more meaningful to evaluate against the risk-free return. More than half of the considered strategies outperform the risk-free return. Taking into account for the high transaction costs involved in these strategies, the results are outstanding.

Panel C reports the Sharpe ratios. Most Sharpe ratios are positive implying that most combinations outperform the risk-free return. A more challenging task would be to evaluate the performance against the S&P 500. The optimal choice between the threshold and the number to invest is 5% and 60 firms. This combination gives a Sharpe ratio of 0.069. This strategy is economically sensible because it capitalizes the magnet effect efficiently by trying to invest more. To summarize, we found an interior optimal pairs of choice variables for the Sharpe ratio. The ceiling magnet effect can be capitalized by the optimal strategy and it can be economically significant.

5 Conclusion

We used high frequency data on Taiwan Stock Exchange (TSE) stocks to conduct an empirical study on the effects of daily price limits. High frequency data enable us to investigate the effects of price limits better than using the daily prices which are used by most empirical studies on price limits. There are four main effects on the price limits: volatility spillover effect, delayed price discovery effect, trading interference effect, and the magnet effect. The price limits literature concentrated on the first three effects using the daily prices. Because magnet effect involves intraday price movements, daily prices are not useful. With the help of high frequency data on TSE, we can analyze the intraday price movements. In this paper,

we analyze the magnet effect in TSE. The TSE imposes lower daily price limits than other markets, and the price hits the limits more frequently. Thus, the TSE is an ideal candidate for testing the magnet effect.

The magnet effect says the price accelerates toward the limits as it gets closer to the limits. We used two different approaches to analyze the magnet effect. First, we fitted a AR(3)-GARCH(2,2) model for the 5-minute returns of each individual stock. From the regression results, we found that the conditional mean return increases as the price gets closer to the ceiling. We conducted a formal test of overall magnet effect in TSE to find that the ceiling magnet effect is significant but the floor magnet effect is not. To distinguish the magnet effect from the momentum effect, we included two momentum variables in the regression and concluded that the strong ceiling magnet effects are persistent. Momentum is not strong enough to offset the magnet effect. For S&P 500 stocks which have no price limits, we could not find any evidence of the magnet effect. The coefficients for S&P 500 stocks are mostly insignificant with no conclusive directions. For the TSE data, the magnet effect is stable for different sample periods. Using the 1999/2000 data, we found similar results as the 1998/1999 data.

Second, we used the performance of investment strategies to investigate the magnet effect. We developed strategies that take advantage of the magnet effect. Implementing the investment strategies for the same period as the regression analysis supports the regression results. Strategy for ceiling magnet effect works better than the strategy for floor magnet effect, which is in good agreement with the regression results that the ceiling magnet effect is stronger than the floor magnet effect. The consistent results between the two approaches can also be found in the industry analysis. The best performing industry portfolios generally had the highest t ratios for the magnet coefficients. The worst performing industry had the wrong sign of magnet coefficients. The two approaches gave the same conclusions on the magnet effects.

Taking the transaction cost and tax into account, the strategies did not outperform the 10 year TAIEX benchmark. Because of the heavy trading, the strategies suffered from heavy transaction costs. Using different thresholds and different number of firms to invest can improve the investment strategies. Strategy with a higher threshold will enable the investor

to capture the magnet effect better because the magnet effect gets stronger as the price gets closer to the limits. However, the higher threshold will suffer from the illiquidity problem. Reducing the maximum number of firms to invest will make the investor to allocate the fund better but the portfolio becomes less diversified. We found an interior optimal pair for the threshold and number to invest.

Advocates of daily price limits claim that the price limits avoid the overreaction in the stock market by giving the market time to reassess the value of the stock (cool off effect). However we find empirical evidence for the magnet effect, which is an opposite effect to the cool off effect. Rather than preventing the overreaction in the stock market, the daily price limits cause the stock price to accelerate toward the boundaries. We conclude that the daily price limits in TSE are ineffective in preventing overreaction.

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Table 1. Summary Statistics for the Frequency of Hitting the Price Limits.

A: Number of days reaching the ceiling, industry average, out of possible 324 days. B: Number of days closing at the ceiling, industry average. C: Average number of consecutive days closing at the ceiling, industry average. D: Duration of staying at the ceiling, industry average (units in minutes). E: Number of days reaching the floor, industry average. F: Number of days closing at the floor, industry average. G: Average number of consecutive days closing at the floor, industry average. H: Duration of staying at the floor, industry average (units in minutes).

Industry			Ceiling				Floor			
code	name	# of firms	A	B	C	D	E	F	G	H
11	cement	7	9.0	7.0	1.9	37.0	6.0	2.4	1.1	43.9
12	food	24	14.5	12.0	4.6	48.5	14.9	9.6	6.7	46.6
13	plastics	16	17.9	14.9	4.6	51.0	11.5	7.8	2.8	46.1
14	textiles	48	15.0	11.7	3.5	55.3	12.0	7.1	4.3	41.7
15	elect. machinery	19	14.0	10.9	3.6	52.0	12.6	8.4	4.9	54.6
16	elect. appliance	12	10.3	8.1	2.1	45.1	11.3	7.3	4.4	50.5
17	chemicals	16	12.8	10.0	3.2	48.0	11.4	7.1	3.7	38.8
18	glass	6	10.3	9.0	2.5	59.9	8.5	4.0	2.5	41.6
19	paper pulp	6	13.0	10.5	3.7	57.6	8.2	5.0	1.8	38.3
20	iron steel	25	16.4	12.6	5.4	53.6	16.6	11.4	8.9	49.7
21	rubber	8	17.4	14.4	5.4	60.0	9.9	6.1	2.0	46.0
22	automobile	4	2.8	2.5	0	57.6	4.0	1.8	1.0	47.0
23	electronics	66	21.1	16.5	5.0	49.4	15.7	10.6	3.4	49.1
25	construction	31	15.4	12.3	4.6	45.7	15.7	10.5	6.6	51.1
26	shipping	14	10.5	8.6	2.2	49.6	8.1	4.6	1.9	28.0
27	tourist	5	13.3	10.0	3.3	49.7	7.0	3.5	1.8	29.6
28	bank	34	12.9	10.4	4.0	52.1	5.6	3.2	1.1	30.2
99	other	4	10.8	8.3	2.5	52.0	10.0	5.5	3.3	29.5
all		345	15.3	12.1	4.0	50.9	12.3	7.8	4.1	44.1

Table 2. Summary of the AR(3), GARCH(2,2) Estimation Results.

$$RET_t = \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \varepsilon_t.$$

$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \beta_3 \varepsilon_{t-1}^2 + \beta_4 \varepsilon_{t-2}^2 + \gamma_3 \{D(ceiling)_{t-1} + D(floor)_{t-1}\} + \gamma_4 DLIM_t$. The parameter estimates are averaged within each industry. The median of the t ratios are reported in the parenthesis.

industry		conditional mean					
code	firms	$\widehat{\alpha}_0$	$\widehat{\alpha}_1$	$\widehat{\alpha}_2$	$\widehat{\alpha}_3$	$\widehat{\gamma}_1$	$\widehat{\gamma}_2$
11	7	-0.032 (-5.610)	-0.281 (-25.397)	-0.144 (-13.979)	-0.078 (-7.395)	0.052 (0.558)	-0.027 (-0.698)
12	24	-0.021 (-4.455)	-0.297 (-26.011)	-0.153 (-13.337)	-0.076 (-7.385)	0.036 (0.641)	0.046 (0.957)
13	16	-0.033 (-5.774)	-0.262 (-24.715)	-0.138 (-13.942)	-0.079 (-7.827)	0.113 (2.209)	-0.024 (-0.430)
14	48	-0.031 (-5.814)	-0.272 (-24.427)	-0.132 (-11.724)	-0.070 (-7.010)	0.053 (0.858)	0.038 (0.246)
15	19	-0.023 (-4.011)	-0.280 (-25.338)	-0.125 (-11.836)	-0.060 (-6.100)	0.055 (1.249)	0.039 (0.971)
16	12	-0.028 (-5.369)	-0.312 (-28.385)	-0.152 (-14.667)	-0.077 (-7.359)	0.042 (0.840)	0.024 (-0.974)
17	16	-0.027 (-4.983)	-0.265 (-23.692)	-0.132 (-11.572)	-0.071 (-7.011)	0.050 (0.553)	0.008 (-0.212)
18	6	-0.027 (-4.979)	-0.273 (-25.747)	-0.131 (-13.851)	-0.076 (-7.075)	0.047 (1.372)	0.099 (1.409)
19	6	-0.032 (-5.649)	-0.324 (-30.036)	-0.150 (-13.623)	-0.073 (-7.441)	0.004 (-0.323)	-0.010 (-0.668)
20	25	-0.029 (-6.216)	-0.316 (-27.715)	-0.150 (-13.588)	-0.073 (-7.205)	0.054 (0.934)	0.028 (0.427)
21	8	-0.027 (-4.899)	-0.255 (-21.995)	-0.124 (-11.105)	-0.071 (-7.030)	0.025 (0.262)	0.025 (0.940)
22	4	-0.021 (-4.260)	-0.304 (-27.823)	-0.150 (-13.722)	-0.078 (-7.295)	-0.062 (-0.505)	0.102 (0.583)
23	66	-0.014 (-2.299)	-0.234 (-20.429)	-0.154 (-15.417)	-0.085 (-8.679)	0.058 (1.367)	-0.034 (-1.072)
25	31	-0.033 (-5.859)	-0.288 (-24.820)	-0.136 (-12.012)	-0.069 (-6.754)	0.049 (1.004)	0.026 (0.035)
26	14	-0.025 (-4.335)	-0.276 (-25.055)	-0.144 (-13.075)	-0.074 (-7.606)	0.005 (0.372)	-0.013 (-0.662)
27	5	-0.026 (-4.221)	-0.256 (-22.754)	-0.131 (-13.171)	-0.067 (-6.062)	-0.003 (0.210)	0.062 (1.403)
28	34	-0.035 (-6.942)	-0.329 (-28.558)	-0.175 (-15.780)	-0.090 (-9.044)	0.126 (2.411)	-0.019 (-0.554)
99	4	-0.029 (-5.422)	-0.295 (-27.015)	-0.147 (-13.795)	-0.077 (-7.624)	0.038 (0.782)	0.036 (0.266)
all	345	-0.026 (-5.030)	-0.279 (-24.946)	-0.145 (-13.767)	-0.076 (-7.672)	0.056 (1.115)	0.010 (-0.263)

Table 2(continued). Summary of the AR(3), GARCH(2,2) Estimation Results.

$$RET_t = \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \varepsilon_t.$$

$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \beta_3 \varepsilon_{t-1}^2 + \beta_4 \varepsilon_{t-2}^2 + \gamma_3 \{D(ceiling)_{t-1} + D(floor)_{t-1}\} + \gamma_4 DLIM_t$. The parameter estimates are averaged within each industry. The median of the t ratios are reported in the parenthesis.

industry		conditional variance						
code	firms	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\gamma}_3$	$\hat{\gamma}_4$
11	7	0.031 (7.797)	0.125 (19.246)	-0.090 (-16.782)	1.210 (29.949)	-0.279 (-9.258)	0.074 (5.981)	0.001 (0.879)
12	24	0.028 (8.498)	0.151 (20.623)	-0.117 (-18.831)	1.236 (42.056)	-0.302 (-13.097)	0.047 (5.171)	0.002 (2.427)
13	16	0.005 (6.928)	0.137 (16.330)	-0.123 (-14.879)	1.365 (31.701)	-0.385 (-8.992)	0.014 (4.351)	0.000 (0.331)
14	48	0.023 (7.599)	0.142 (19.081)	-0.111 (-16.520)	1.235 (43.393)	-0.294 (-14.580)	0.041 (4.758)	0.002 (1.540)
15	19	0.028 (7.067)	0.153 (18.751)	-0.111 (-17.823)	1.168 (29.502)	-0.242 (-7.392)	0.027 (3.122)	0.002 (1.329)
16	12	0.066 (7.508)	0.142 (17.811)	-0.067 (-13.770)	0.843 (22.409)	0.007 (-3.798)	0.162 (3.919)	0.004 (1.458)
17	16	0.037 (7.221)	0.137 (19.980)	-0.098 (-17.320)	1.137 (34.269)	-0.217 (-9.416)	0.106 (3.553)	0.003 (2.198)
18	6	0.014 (9.716)	0.162 (24.455)	-0.140 (-20.713)	1.217 (39.244)	-0.255 (-11.187)	0.047 (5.577)	0.004 (1.126)
19	6	0.003 (6.460)	0.141 (18.812)	-0.134 (-18.556)	1.464 (40.887)	-0.475 (-13.499)	0.009 (4.228)	0.000 (0.667)
20	25	0.015 (7.823)	0.171 (21.578)	-0.144 (-18.543)	1.279 (48.158)	-0.323 (-15.116)	0.026 (4.142)	0.002 (2.697)
21	8	0.038 (7.373)	0.157 (22.273)	-0.098 (-19.544)	0.982 (29.510)	-0.082 (-6.780)	0.056 (2.099)	0.001 (1.202)
22	4	0.033 (6.195)	0.101 (17.272)	-0.052 (-11.370)	1.135 (33.407)	-0.220 (-13.339)	0.436 (2.703)	0.003 (0.314)
23	66	0.013 (5.725)	0.124 (13.560)	-0.097 (-11.161)	1.152 (17.275)	-0.193 (-2.679)	0.012 (2.872)	0.001 (1.976)
25	31	0.013 (7.069)	0.159 (19.586)	-0.136 (-18.089)	1.327 (54.277)	-0.366 (-14.362)	0.040 (4.707)	0.001 (0.962)
26	14	0.033 (8.582)	0.157 (21.572)	-0.119 (-17.890)	1.220 (45.241)	-0.295 (-14.937)	0.116 (4.031)	0.003 (1.080)
27	5	0.003 (7.032)	0.120 (20.140)	-0.115 (-20.041)	1.518 (58.993)	-0.526 (-19.498)	0.009 (5.986)	0.000 (0.368)
28	34	0.005 (6.898)	0.141 (18.817)	-0.125 (-17.549)	1.343 (37.861)	-0.364 (-12.596)	0.011 (2.577)	0.001 (2.151)
99	4	0.006 (6.527)	0.159 (20.431)	-0.146 (-20.142)	1.332 (44.098)	-0.352 (-10.303)	0.016 (4.565)	0.000 (1.763)
all	345	0.020 (7.032)	0.143 (18.370)	-0.113 (-16.725)	1.226 (34.411)	-0.278 (-10.161)	0.044 (3.800)	0.001 (1.547)

Table 3. GMM estimation results.

$$RET_t = \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \varepsilon_t.$$

industry		Ceiling			Floor		
Code	firms	ave. $\widehat{\gamma}_1$	SE(ave. $\widehat{\gamma}_1$)	$t(\text{ave. } \widehat{\gamma}_1)$	ave. $\widehat{\gamma}_2$	SE(ave. $\widehat{\gamma}_2$)	$t(\text{ave. } \widehat{\gamma}_2)$
11	7	0.102	0.061	1.656	-0.098	0.052	-1.871
12	24	0.120	0.026	4.580	0.028	0.027	1.034
13	16	0.162	0.026	6.148	-0.039	0.036	-1.099
14	48	0.100	0.019	5.197	0.025	0.024	1.023
15	19	0.143	0.022	6.443	-0.002	0.022	-0.096
16	12	0.143	0.038	3.770	-0.044	0.055	-0.809
17	16	0.141	0.028	5.123	-0.023	0.029	-0.789
18	6	0.144	0.081	1.771	0.060	0.049	1.235
19	6	0.057	0.041	1.391	0.010	0.046	0.214
20	25	0.133	0.026	5.167	-0.014	0.030	-0.471
21	8	0.091	0.028	3.275	-0.008	0.032	-0.255
22	4	0.198	0.130	1.522	0.020	0.116	0.174
23	66	0.083	0.012	7.082	-0.041	0.017	-2.356
25	31	0.145	0.027	5.365	0.006	0.025	0.245
26	14	0.088	0.035	2.555	-0.021	0.041	-0.517
27	5	0.045	0.039	1.147	0.059	0.038	1.571
28	34	0.215	0.030	7.240	-0.052	0.030	-1.750
99	4	0.125	0.044	2.836	-0.031	0.039	-0.794
all	345	0.124	0.011	11.134	-0.014	0.017	-0.783

Table 4. Equally Weighted Industry Portfolio Performance (No transaction costs).

Strategy A: investor invests $\$ \frac{\text{available fund}}{\# \text{ of firms in the portfolio}}$ in the long position of a stock which reaches 4% during the day and closes the position when the trade opens on the following day. Strategy B invests $\$ \frac{\text{available fund}}{\# \text{ of firms in the portfolio}}$ in the short position of a stock which reaches -4% and closes the position on the following day. Strategy C combines Strategy A and Strategy B. The annual risk free rate is 3.5% for Taiwan. The benchmark portfolios are TAIEX and cash-TAIEX combination. $\bar{r}(\text{daily, \%})$ is average daily return in percentage for the sample period. std is the standard deviation of the daily returns (%). Sharpe is Sharpe ratios and \$100 is the cumulative returns starting from \$100 initially. Units in $\bar{r}(\text{daily, \%})$, std, Sharpe are in percentages and all the returns except for cumulative returns are daily returns.

Benchmarks (buy and hold)							$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100
TAIEX (Jan. 1998 - Mar. 1999)							-0.036	1.564	-0.030	85.47
TAIEX (1989 - 1999)							0.034	1.949	0.012	

Panel A. Strategy A										
industry		Strategy A					Benchmark(cash-TAIEX)			
Code	Firms	$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100	\$ inv'd	$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100
11	7	0.055	0.397	0.115	119.33	6.63	0.049	0.299	0.129	116.87
12	24	0.081	0.302	0.234	129.53	9.00	0.039	0.214	0.137	113.48
13	16	0.128	0.621	0.190	150.25	12.93	0.086	0.423	0.180	131.73
14	48	0.084	0.395	0.187	130.79	10.67	0.057	0.303	0.156	120.16
15	19	0.082	0.387	0.185	129.88	10.38	0.056	0.315	0.147	119.75
16	12	0.047	0.296	0.126	116.30	7.15	0.036	0.245	0.104	112.05
17	16	0.062	0.411	0.126	121.74	10.35	0.058	0.323	0.148	120.30
18	6	0.051	0.375	0.109	117.53	8.20	0.030	0.233	0.085	110.04
19	6	0.079	0.623	0.111	128.29	10.73	0.068	0.407	0.143	124.24
20	25	0.060	0.362	0.138	121.03	9.21	0.041	0.256	0.119	113.87
21	8	0.093	0.516	0.160	134.24	13.43	0.057	0.343	0.137	119.91
22	4	0.008	0.250	-0.010	102.37	4.57	0.010	0.214	0.000	103.21
23	66	0.112	0.536	0.191	143.05	16.60	0.077	0.395	0.169	127.73
25	31	0.077	0.478	0.141	127.83	10.31	0.057	0.355	0.133	120.09
26	14	0.054	0.318	0.138	118.82	9.16	0.042	0.264	0.123	114.55
27	5	0.037	0.620	0.043	111.85	11.70	0.058	0.410	0.118	120.42
28	34	0.061	0.463	0.111	121.47	8.71	0.059	0.365	0.135	120.90
99	4	0.091	0.505	0.161	133.70	10.76	0.056	0.323	0.143	119.73
ALL	345	0.080	0.300	0.235	129.46	11.13	0.058	0.275	0.173	120.32

Table 4(continued). Equally Weighted Industry Portfolio Performance.

Strategy A: investor invests $\$ \frac{\text{available fund}}{\# \text{ of firms in the portfolio}}$ in the long position of a stock which reaches 4% during the day and closes the position when the trade opens on the following day. Strategy B invests $\$ \frac{\text{available fund}}{\# \text{ of firms in the portfolio}}$ in the short position of a stock which reaches -4% and closes the position on the following day. Strategy C combines Strategy A and Strategy B. The annual risk free rate is 3.5% for Taiwan. The benchmark portfolios are TAIEX and cash-TAIEX combination. $\bar{r}(\text{daily, \%})$ is average daily return in percentage for the sample period. std is the standard deviation of the daily returns (%). Sharpe is Sharpe ratios and \$100 is the cumulative returns starting from \$100 initially. Units in $\bar{r}(\text{daily, \%})$, std, Sharpe are in percentages and all the returns except for cumulative returns are daily returns.

Benchmarks (buy and hold)	$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100
TAIEX (Jan. 1998 - Mar. 1999)	-0.036	1.564	-0.030	85.47
TAIEX (1989 - 1999)	0.034	1.949	0.012	

Panel B. Strategy B										
industry		Strategy B					Benchmark(cash-TAIEX)			
Code	Firms	$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100	\$ inv'd	$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100
11	7	-0.016	0.462	-0.057	94.49	5.84	-0.019	0.318	-0.091	93.97
12	24	0.017	0.392	0.017	105.32	9.88	-0.012	0.274	-0.080	96.11
13	16	0.038	0.620	0.045	112.37	9.25	-0.019	0.369	-0.077	93.99
14	48	0.022	0.431	0.028	107.04	9.84	-0.005	0.330	-0.046	98.14
15	19	0.010	0.354	0.001	103.19	9.27	-0.013	0.239	-0.097	95.77
16	12	0.029	0.459	0.041	109.43	6.86	-0.009	0.278	-0.066	97.17
17	16	0.045	0.483	0.072	115.10	9.04	-0.007	0.322	-0.053	97.62
18	6	0.036	0.437	0.059	111.87	7.02	-0.009	0.280	-0.066	97.17
19	6	0.046	0.398	0.092	115.91	7.53	0.005	0.292	-0.017	101.52
20	25	0.019	0.330	0.026	105.97	8.54	-0.012	0.233	-0.093	96.21
21	8	0.016	0.482	0.013	105.03	9.02	-0.008	0.312	-0.057	97.34
22	4	0.008	0.348	-0.007	102.33	4.95	-0.001	0.216	-0.049	99.72
23	66	0.017	0.564	0.012	105.09	13.70	-0.017	0.336	-0.081	94.37
25	31	0.022	0.495	0.023	106.79	10.24	-0.010	0.324	-0.063	96.57
26	14	0.009	0.369	-0.002	102.81	7.39	-0.012	0.261	-0.085	96.08
27	5	-0.016	0.603	-0.043	94.39	9.10	-0.023	0.377	-0.086	92.77
28	34	0.010	0.355	-0.000	103.05	5.56	-0.012	0.249	-0.090	95.95
99	4	0.023	0.555	0.023	107.05	8.20	-0.003	0.309	-0.043	98.78
ALL	345	0.019	0.340	0.027	106.17	9.53	-0.012	0.264	-0.082	96.23

Table 4(continued). Equally Weighted Industry Portfolio Performance.

Strategy A: investor invests $\$ \frac{\text{available fund}}{\# \text{ of firms in the portfolio}}$ in the long position of a stock which reaches 4% during the day and closes the position when the trade opens on the following day. Strategy B invests $\$ \frac{\text{available fund}}{\# \text{ of firms in the portfolio}}$ in the short position of a stock which reaches -4% and closes the position on the following day. Strategy C combines Strategy A and Strategy B. The annual risk free rate is 3.5% for Taiwan. The benchmark portfolios are TAIEX and cash-TAIEX combination. $\bar{r}(\text{daily, \%})$ is average daily return in percentage for the sample period. std is the standard deviation of the daily returns (%). Sharpe is Sharpe ratios and \$100 is the cumulative returns starting from \$100 initially. Units in $\bar{r}(\text{daily, \%})$, std, Sharpe are in percentages and all the returns except for cumulative returns are daily returns.

Benchmarks (buy and hold)	$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100
TAIEX (Jan. 1998 - Mar. 1999)	-0.036	1.564	-0.030	85.47
TAIEX (1989 - 1999)	0.034	1.949	0.012	

Panel C. Strategy C

industry		Strategy C					Benchmark (cash-TAIEX)			
Code	Firms	$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100	\$ inv'd	$\bar{r}(\text{daily, \%})$	std	Sharpe	\$100
11	7	0.039	0.600	0.048	112.78	12.47	0.030	0.409	0.049	109.86
12	24	0.096	0.430	0.201	136.12	18.52	0.026	0.292	0.055	108.59
13	16	0.161	0.815	0.186	166.58	22.00	0.066	0.538	0.105	123.31
14	48	0.108	0.538	0.182	140.95	20.27	0.052	0.413	0.101	117.84
15	19	0.089	0.459	0.173	132.98	19.39	0.042	0.344	0.094	114.38
16	12	0.076	0.530	0.124	127.09	13.91	0.028	0.350	0.050	109.09
17	16	0.107	0.605	0.160	140.21	19.29	0.050	0.439	0.092	117.28
18	6	0.087	0.552	0.139	131.66	15.02	0.024	0.335	0.041	107.77
19	6	0.126	0.731	0.158	148.71	18.27	0.073	0.495	0.128	126.14
20	25	0.075	0.457	0.143	127.08	17.39	0.027	0.305	0.054	108.80
21	8	0.107	0.674	0.143	140.07	22.17	0.048	0.432	0.088	116.40
22	4	0.015	0.424	0.012	104.76	9.52	0.009	0.301	-0.002	102.92
23	66	0.130	0.722	0.165	150.66	29.97	0.059	0.490	0.100	120.50
25	31	0.099	0.608	0.146	136.70	20.28	0.046	0.435	0.083	115.71
26	14	0.063	0.466	0.113	121.96	16.43	0.030	0.352	0.057	109.95
27	5	0.021	0.836	0.013	105.81	20.68	0.035	0.529	0.047	111.48
28	34	0.072	0.563	0.111	125.61	14.21	0.047	0.431	0.086	116.01
99	4	0.114	0.731	0.142	143.18	18.96	0.053	0.433	0.099	118.29
ALL	345	0.099	0.394	0.226	137.40	20.43	0.046	0.339	0.105	115.62

Table 5. Strategy Performances Using Different Thresholds. (No Transaction Costs)

The benchmarks and the risk free rates are the same as Table 4. The strategies are evaluated using 5 different thresholds from 2% to 6%. Strategy A: Long $\frac{\$ \text{fund}}{345}$ in the stock which reaches the threshold, and don't invest, otherwise. Strategy B: Short $\frac{\$ \text{fund}}{345}$ in the stock which reaches the -threshold, and don't invest, otherwise. Strategy C combines A and B.

Benchmarks (buy and hold)	$\bar{r}$ (daily, %)	std	Sharpe	\$100
TAIEX (Jan. 1998 - Mar. 1999)	-0.036	1.564	-0.030	85.47
TAIEX (1989-1999)	0.034	1.949	0.012	

Panel A. Strategy A

Strategy A						Benchmark (cash-TAIEX)			
thresholds	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100	\$ inv'd	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100
2%	0.158	0.632	0.234	165.41	31.86	0.106	0.602	0.160	140.09
3%	0.119	0.435	0.250	146.32	18.79	0.082	0.403	0.178	129.85
4%	0.080	0.300	0.235	129.46	11.13	0.058	0.275	0.173	120.32
5%	0.052	0.206	0.206	118.36	6.59	0.036	0.182	0.142	112.19
6%	0.029	0.128	0.149	109.80	3.40	0.019	0.100	0.088	106.26

Panel B. Strategy B

Strategy B						Benchmark (cash-TAIEX)			
thresholds	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100	\$ inv'd	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100
2%	0.064	0.681	0.079	122.05	29.08	-0.002	0.575	-0.021	98.79
3%	0.042	0.466	0.068	113.98	16.03	-0.005	0.371	-0.042	98.06
4%	0.019	0.340	0.027	106.17	9.53	-0.012	0.264	-0.082	96.23
5%	0.006	0.255	-0.014	102.01	5.97	-0.014	0.198	-0.120	95.58
6%	0.005	0.182	-0.026	101.65	3.53	-0.011	0.135	-0.153	96.57

Panel C. Strategy C

Strategy C						Benchmark (cash-TAIEX)			
thresholds	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100	\$ inv'd	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100
2%	0.214	0.684	0.298	197.79	58.42	0.098	0.611	0.143	136.23
3%	0.160	0.520	0.288	166.65	34.20	0.075	0.456	0.142	126.94
4%	0.099	0.394	0.226	137.40	20.43	0.046	0.339	0.105	115.62
5%	0.058	0.297	0.162	120.44	12.48	0.022	0.249	0.047	107.14
6%	0.034	0.203	0.119	111.59	6.90	0.008	0.158	-0.012	102.60

Table 6. Strategy Performances Using Different Thresholds with Transaction Costs.

The benchmarks and the risk free rates are the same as Table 4. The strategies are evaluated using 5 different thresholds from 2% to 6%. Strategy A: Long $\frac{\$ \text{fund}}{345}$ in the stock which reaches the threshold, and don't invest, otherwise. Strategy B: Short $\frac{\$ \text{fund}}{345}$ in the stock which reaches the -threshold, and don't invest, otherwise. Strategy C combines A and B. Transaction cost is 0.1425% for buying and 0.4425% for selling.

Benchmarks (buy and hold)	$\bar{r}$ (daily, %)	std	Sharpe	\$100
TAIEX (Jan. 1998 - Mar. 1999)	-0.036	1.564	-0.030	85.47
TAIEX (1989-1999)	0.034	1.949	0.012	

Panel A. Strategy A

Strategy A						Benchmark (cash-TAIEX)			
thresholds	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100	\$ inv'd	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100
2%	-0.028	0.577	-0.067	90.72	31.86	-0.080	0.552	-0.163	76.80
3%	0.009	0.387	0.003	102.67	18.79	-0.028	0.357	-0.107	91.10
4%	0.015	0.261	0.020	104.95	11.13	-0.007	0.235	-0.074	97.53
5%	0.014	0.179	0.022	104.52	6.59	-0.003	0.153	-0.084	99.07
6%	0.009	0.110	-0.008	102.97	3.40	-0.001	0.083	-0.133	99.64

Panel B. Strategy B

Strategy B						Benchmark (cash-TAIEX)			
thresholds	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100	\$ inv'd	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100
2%	-0.106	0.650	-0.179	70.49	29.08	-0.172	0.563	-0.324	57.01
3%	-0.052	0.448	-0.139	84.22	16.03	-0.099	0.373	-0.293	72.42
4%	-0.037	0.340	-0.137	88.68	9.53	-0.067	0.281	-0.276	80.36
5%	-0.028	0.264	-0.146	91.11	5.97	-0.049	0.220	-0.267	85.36
6%	-0.015	0.187	-0.136	95.09	3.53	-0.031	0.152	-0.272	90.33

Panel C. Strategy C

Strategy C						Benchmark (cash-TAIEX)			
thresholds	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100	\$ inv'd	$\bar{r}$ (daily, %)	std ret	Sharpe	\$100
2%	-0.128	0.661	-0.209	65.64	58.42	-0.244	0.596	-0.426	45.14
3%	-0.040	0.498	-0.101	87.39	34.20	-0.125	0.443	-0.305	66.52
4%	-0.020	0.384	-0.079	93.42	20.43	-0.074	0.335	-0.251	78.59
5%	-0.015	0.296	-0.085	95.15	12.48	-0.051	0.254	-0.241	84.63
6%	-0.006	0.202	-0.080	97.94	6.90	-0.032	0.166	-0.255	90.05

Table 7. Performance of Strategy A Using Different Thresholds with Different Maximum Number of Firms to Invest.

Example: Strategy (threshold = 4%, number to invest = 50 firms): invest $\frac{\$ \text{fund}}{50}$ in the first 50 stocks which reach 4% threshold.

Panel A. Mean Return (daily, %)										
threshold	Maximum Number of Firms to Invest									
	10	20	30	40	50	60	70	100	200	345
2%	-0.128	-0.158	-0.144	-0.166	-0.160	-0.137	-0.123	-0.088	-0.052	-0.028
3%	-0.033	-0.070	-0.067	-0.051	-0.054	-0.032	0.001	0.017	0.016	0.009
4%	-0.064	-0.014	0.006	0.017	0.037	0.044	0.048	0.034	0.026	0.015
5%	0.031	0.047	0.065	0.071	0.069	0.059	0.045	0.031	0.024	0.014
6%	0.024	0.059	0.055	0.048	0.048	0.040	0.030	0.021	0.016	0.009

Panel B. Standard Deviation of the Returns (daily, %)										
threshold	Maximum Number of Firms to Invest									
	10	20	30	40	50	60	70	100	200	345
2%	2.098	1.906	1.848	1.759	1.693	1.565	1.402	1.154	0.952	0.576
3%	2.061	1.814	1.654	1.550	1.460	1.291	1.064	0.808	0.646	0.386
4%	1.917	1.594	1.451	1.305	1.181	0.962	0.758	0.558	0.439	0.260
5%	1.756	1.393	1.186	1.010	0.873	0.707	0.539	0.389	0.308	0.178
6%	1.440	1.046	0.828	0.689	0.598	0.470	0.357	0.253	0.190	0.110

Panel C. Sharpe Ratios (daily)										
threshold	Maximum Number of Firms to Invest									
	10	20	30	40	50	60	70	100	200	345
2%	-0.066	-0.088	-0.083	-0.100	-0.100	-0.094	-0.095	-0.085	-0.065	-0.067
3%	-0.021	-0.044	-0.047	-0.040	-0.044	-0.033	-0.008	0.009	0.010	-0.003
4%	-0.039	-0.015	-0.003	0.005	0.023	0.035	0.050	0.044	0.036	0.020
5%	0.012	0.026	0.047	0.060	0.068	0.069	0.066	0.055	0.045	0.022
6%	0.010	0.047	0.054	0.055	0.064	0.065	0.055	0.044	0.031	-0.008

Panel D. Cumulative Returns from \$100										
threshold	Maximum Number of Firms to Invest									
	10	20	30	40	50	60	70	100	200	345
2%	61.50	56.66	59.36	55.64	56.96	61.71	65.04	73.77	83.38	90.75
3%	83.94	75.64	76.96	81.48	81.20	87.66	98.67	104.58	104.71	102.70
4%	76.69	91.75	98.41	102.81	110.09	113.54	115.59	111.23	108.35	104.93
5%	105.00	112.67	120.75	123.74	123.47	120.04	115.27	110.38	107.86	104.52
6%	104.46	119.05	117.95	115.87	116.22	113.56	109.87	106.94	105.18	102.98

Panel E. Average \$ invested										
threshold	10	20	30	40	50	60	70	100	200	345
2%	99.60	98.45	97.14	94.78	91.77	85.83	77.20	63.52	52.23	31.81
3%	97.83	93.00	86.05	79.95	74.34	65.37	53.89	40.41	31.65	18.76
4%	90.56	77.93	68.88	61.76	55.51	45.25	34.56	24.60	19.03	11.12
5%	77.71	62.85	52.36	44.09	37.53	28.90	21.36	14.89	11.38	6.58
6%	60.22	42.72	32.19	25.70	21.19	15.91	11.62	7.85	5.89	3.40

Figure 1. Intraday volatility pattern.

Figure 1 plots the average intraday volatility pattern. Volatility is defined as the standard deviation of the 5 minute returns. TSE market opens at 9:00 and closes at 12:00 to make 36 5-minute time bins. For every stock, the standard deviation of the returns are calculated for 36 time bins. Then the standard deviations for each bin are averaged over 345 stocks to create average intraday volatility pattern.

Figure 2. Scatter Plots of the Magnet Coefficients (98/1/3 - 99/3/20).

Figure 2.1. scatter plots $(\hat{\gamma}_1, \hat{\gamma}_2)$ from the following AR(3), GARCH(2,2) regression and Figure 2.2. scatter plots the t ratios associated with $(\hat{\gamma}_1, \hat{\gamma}_2)$. The same model is applied for 345 TSE firms to make 345 pairwise plots.

$$\begin{aligned}
 RET_t &= \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \varepsilon_t. \\
 h_t &= \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \beta_3 \varepsilon_{t-1}^2 + \beta_4 \varepsilon_{t-2}^2 \\
 &\quad + \gamma_3 \{D(ceiling)_{t-1} + D(floor)_{t-1}\} + \gamma_4 DLIM_t.
 \end{aligned}$$

Figure 3. Industry Average Magnet Coefficients.

Figure 3 scatter plots 18 industry average coefficients. The industry code is associated with the plots. Industry codes: 11=cement, 12=food, 13=plastics, 14=textiles, 15=electrical machinery, 16=electrical appliances, 17=chemicals, 18=glass, 19=paper and pult, 20=iron and steel, 21=rubber, 22=automobile, 23=electronics, 25=construction, 26=shipping, 27=tourist, 28=bank and 99=other.

Figure 4. Scatter Plots of T ratios in the Conditional Variance Equation.

The plots are the t ratio pairs of $(\hat{\gamma}_3, \hat{\gamma}_4)$ from the following AR(3), GARCH(2,2) regression.

$$\begin{aligned}
 RET_t &= \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \varepsilon_t. \\
 h_t &= \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \beta_3 \varepsilon_{t-1}^2 + \beta_4 \varepsilon_{t-2}^2 \\
 &\quad + \gamma_3 \{D(ceiling)_{t-1} + D(floor)_{t-1}\} + \gamma_4 DLIM_t.
 \end{aligned}$$

Figure 5.1 . Magnet Coefficients (GMM estimat

Figure 5.2. T ratios of the magnet coefficients (

Figure 5. Magnet Coefficients from GMM estimation (98/1/3 - 99/3/20).

Figure 5 scatter plots the magnet coefficients from GMM estimation. Standard errors are adjusted for the serial correlation and the cross correlation using the GMM method.

$$RET_t = \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \varepsilon_t.$$

Figure 6. Serial and Cross Correlation of the residuals from GMM estimation

Figure 6.1. plots the boxplot of the serial correlations for the individual residuals from the GMM estimation. Figure 6.2 boxplots the cross correlations of the 345 residuals.

Figure 7. T ratios of Magnet Coefficients and Momentum Coefficients.

The conditional mean equation includes two sets of additional variables $M(up)$ and $M(down)$ to control possible momentum effects. Definitions for $M(up)$ and $M(down)$ in Figure 7.1 and 7.2 are described in equation (10). $M(up)$ and $M(down)$ in Figure 7.3 and 7.4 are defined in equation (11). Figure 7.1 and 7.2 plot 308 converged results and Figure 7.3 and 7.4 plot 297 converged results.

$$RET_t = \alpha_0 + \alpha_1 RET_{t-1} + \alpha_2 RET_{t-2} + \alpha_3 RET_{t-3} \\ + \gamma_1 D(ceiling)_{t-1} + \gamma_2 D(floor)_{t-1} + \gamma_5 M(up)_{t-1} + \gamma_6 M(down)_{t-1} + \varepsilon_t$$

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \beta_3 \varepsilon_{t-1}^2 + \beta_4 \varepsilon_{t-2}^2 \\ + \gamma_3 \{D(ceiling)_{t-1} + D(floor)_{t-1}\} + \gamma_4 DLIM_t.$$

Figure 8. T ratios of Magnet Coefficients for TSE and U.S. firms

The plots are t ratio pairs for the magnet coefficients from the AR(3) GARCH(2,2) estimation

using the following magnet variables. $D(ceiling)_t = \begin{cases} sign \times \left(\frac{P_t - P_{close}}{P_{close}} \right)^2, & \text{if } P_t > P_{close} \\ 0, & \text{otherwise} \end{cases}$

and $D(floor)_t = \begin{cases} sign \times \left(\frac{P_t - P_{close}}{P_{close}} \right)^2, & \text{if } P_t < P_{close} \\ 0, & \text{otherwise} \end{cases}$. Figure 8.1 plots 300 converged re-

sults for TSE stocks and Figure 8.2. plots 81 converged results from randomly chosen 90 S&P500 firms.

Figure 9. Scatter Plots of the Magnet Coefficients (99/3/21 to 2000/4/29).

Figure 9.1. scatter plots $(\hat{\gamma}_1, \hat{\gamma}_2)$ from the AR(3), GARCH(2,2) estimation and Figure 9.2. scatter plots the t ratios associated with $(\hat{\gamma}_1, \hat{\gamma}_2)$ using the data from March 21st, 1999 to April 29th, 2000.

Figure 10. Strategy C Cumulative Returns without Transaction Costs.

Figure 10 plots the cumulative returns of Strategy C and the benchmarks. The initial wealth is \$100. Strategy C combines the following Strategy A and Strategy B. Strategy A: investor allocates equal amount of available fund to all 345 stocks. If a stock reaches 4% during the day, he/she invests allocated fund in the long position and close the position when the trade opens on the following day. Strategy B invests allocated fund in the short position if a stock reaches -4% and close the position on the following day.