# The Influence of Daily Price Limits on Trading in Nikkei Futures

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## INTRODUCTION

Following the crashes of 1987 and 1989, there has been much discussion in policy circles about the use of price limits on financial markets. Proponents argue that price limits reduce overreactions, while others suggest that price limits make trading impossible and therefore harm the price discovery process. Most empirical studies concentrate on the influence of price limits on the price formation process *after* they have been triggered.[1] This paper is an empirical study of the influence of price limits on the price formation process *before* they come into effect. This issue clearly deserves attention since prices are often close to a price limit without actually hitting it.

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[1]Ma, Rao, and Sears (1989) study the influence of price limits on the price formation process after the market has resumed trading. They conclude that price limits serve a useful function in giving the market "time to breathe." Kim and Rhee (1997) study daily price limits on the Tokyo Stock Exchange and conclude that price limits are ineffective.

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Several authors have suggested that price limits are likely to generate a "gravitation" or "magnet" effect. For example, Miller (1991) argues that price limits might become self-fulfilling "as traders rush to avoid being locked into their positions when prices come in the range of the trigger point." This important issue is addressed here by analyzing the price formation of the Nikkei 225 stock index futures contract which is traded on both the Osaka Securities Exchange (OSE), a market with strict price limits, and the more lenient Singapore International Monetary Exchange (SIMEX). Thus, a comparison is made of the price formation process of the same contract traded in markets with different price limits.

Previous studies of the gravitation effect suffer from the problem that close to the price limit the distribution of price changes is censored. This study circumvents this problem. It is shown that price differences between the OSE and SIMEX are very small, which suggests that if a gravitation effect exists due to the strict price limits on the OSE, it influences prices on the OSE and SIMEX in the same way. Uncensored data from SIMEX are used to study whether price limits on the OSE result in systematic price movements in the direction of the price limit as predicted by the gravitation effect.

The data set allows the study of other effects as well. Besides the influence of price limits on transaction prices, changes in trading volume and volatility when the price approaches the limit are analyzed. Volume and volatility are expected to change according to Subrahmanyam (1994), who examines the "ex ante" effects of circuit breakers.[2] In his model, discretionary liquidity traders have the flexibility to choose the time periods and/or markets in which to execute their trades. He shows that if the price is close to the limit, price variability and market liquidity might increase because discretionary traders have an incentive to trade earlier, rather than split their trades across time and run the risk of being unable to trade. This outcome changes if the discretionary trader has the possibility to switch to a "satellite" market where his or her trading will not trigger a circuit breaker. The trader will switch if the cost of not being able to trade is sufficiently high. As a result, trading volume and volatility might decrease on the dominant market and increase on the satellite market.

The empirical results do not confirm the existence of a gravitation effect. Using the Nikkei futures contract on SIMEX as a benchmark, it

[2]There is a difference between circuit breakers and price limits. If a circuit breaker is hit, trading is halted for a certain fixed period of time. If a price limit is hit, trading is still allowed between the upper and lower limit. In this study's sample there was no trading during the rest of the trading day after the daily limit was hit. Traders indicated that this is a common occurrence.

**TABLE I**

Nikkei Futures: Differences between SIMEX and OSE

| | *SIMEX* | *OSE* |
|---|---|---|
| Contract unit | 500 times index | 1000 times index |
| Minimum fluctuation | ¥5 | ¥10 |
| Daily price limit | 5% and 10% for 15 minutes | About 3% |
| Customers' margin | 10% | 30% (13% cash) |
| Members' margin | 10% | 25% (10% cash) |
| Commission costs | 0.030 (trading value ¥1 billion) | 0.080 (trading value ¥1 billion) |
| Trading system | Open outcry | Auction |

Source: OSE (1993); SIMEX (1993).

is found that Nikkei futures on the OSE do not trade at a relatively low (high) price near the lower (upper) price limit. Furthermore, using uncensored data from SIMEX, there is no evidence of systematic price movements in the direction of the price limit. Consistent with the "satellite market" model presented in Subrahmanyam (1994), a relative decrease in trading volume and price volatility is observed on the OSE compared to SIMEX when the actual price moves closer to the price limit.

The structure of this paper is as follows. The first section describes the institutional background and the data set. The second section starts with a discussion of the gravitation effect and presents the empirical results. The third section concentrates on trading volume and volatility. The final section presents a summary and conclusions.

## MARKET STRUCTURE AND DATA

This section describes some of the rules governing trading in Nikkei futures on the OSE and SIMEX and gives a description of the data set.

### Markets for Nikkei Futures

Derivative products based on the Nikkei index were not available until September 1986, when SIMEX introduced trading in Nikkei 225 stock-index futures and options. The OSE followed in September 1988. As shown in Table I, there are significant differences in institutional arrangements on both markets.

While the Tokyo Stock Exchange (TSE) is by far the most important cash market in Japan, the OSE is the leading market for stock-index futures. For the period from 1990 to 1992, Table II gives an overview of

**TABLE II**

Daily Average Trading Value (Billions ¥)

| *Year* | *TSE Cash Market* | *OSE Nikkei Futures* | *TSE TOPIX Futures* | *SIMEX Nikkei Futures* | *OSE Nikkei Options* |
|---|---|---|---|---|---|
| 1990 | 145.5 | 1604.1 | 291.8 | 53.9 | 14.4 |
| 1991 | 76.1 | 2181.8 | 128.3 | 36.8 | 22.4 |
| 1992 | 63.0 | 890.1 | 75.2 | 122.9 | 16.5 |

Source: OSE (1993); SIMEX (1993).

**TABLE III**

Daily Price Limits on the OSE Nikkei Futures

| *Base Price* | *Daily Price Limit* |
|---|---|
| <¥20,000 | ¥600 |
| ¥20,000–¥30,000 | ¥900 |
| ¥30,000–¥40,000 | ¥1200 |
| >¥40,000 | ¥1500 |

Source: OSE (1993).

trading volume on the spot market and the markets for options and futures on the Nikkei.

It is important to note that a futures contract that is bought on the OSE cannot be sold on SIMEX. Therefore, if trading on the OSE stops, traders can neutralize their price risk by taking the opposite position on SIMEX. They will, however, face two margin requirements.

## Price Limits

Derivative products were not welcomed wholeheartedly in Japan. The Japanese Ministry of Finance (MOF) authorized index futures trading only after intense pressure from the United States. According to Miller (1993, p. 7), "MOF saw index futures as a threat to its policies for discouraging selling—not just short-selling but any selling." Futures trading was regulated strictly from the beginning. All rules seemed to be aimed at reducing the spillover effects of futures trading to the market for the underlying stocks, including a comprehensive system of price limits.

### *Price Limits on OSE*

The Nikkei 225 futures contract is not allowed to trade at a price outside the range of the previous day's settlement price (the base price) plus or minus the daily price limit. This daily limit depends on the base price, and is listed in Table III.[3] During the sample period, the index was always below ¥20,000. Therefore, the daily price limit was equal to ¥600.[4]

Besides the system of daily price limits, there is an intraday price limit rule on the OSE. This rule allows futures prices to go up or down by not more than ¥30 within 6 minutes [see, e.g., Lehmann and Modest (1994) and Hamao and Hasbrouck (1995)].

### *Price Limits on SIMEX*

On SIMEX there are two circuit breakers which last for only 15 minutes after the price limit is hit. The first circuit breaker takes effect when the price is 5% above or below the previous trading day's settlement price. Another 5% change in the same direction, or a total of 10%, will trigger the second circuit breaker. Limits do not apply to the last 30 minutes of the trading day, unless the 15-minute cooling period spills into that time frame. There are no limits for the last day of trading for the contract nearest to expiry. During the 1991–1993 period, the first 5% price limit was hit only seven times, while the second limit was never hit.

## Data Set

Transaction data from both the OSE and SIMEX are for August, September, and October 1992. As shown in Figure 1, this period was characterized by a strong upsurge in the Nikkei index. On 16 August 1992, an economic stimulus plan was announced which restored confidence after a period of low volume and falling prices. As a result, the upper limit was reached several times in Osaka's futures market in the first two months of the sample period. In October 1992, the Nikkei index fell and lost some of its initial gains.

Two prices are used for the Nikkei futures contract to study the influence of price limits on the price formation process. For both the OSE and SIMEX, the average futures price in minute ($t$) on day ($d$) is calculated. For the OSE, this average price is denoted as $F^{O}_{t,d}$. For SIMEX, it is denoted as $F^{S}_{t,d}$.

[3]The OSE can adjust the base price of the Nikkei futures at its own discretion, taking into account market conditions and the trend of the cash index. The OSE used its discretion only once during the sample period. On August 27 and 28, 1992, the Nikkei stock price average rose rapidly and the Nikkei futures closed at the upper price limit. The OSE adjusted the base price of the Nikkei futures on August 31 from the previous day's futures closing price to that of the cash index.

[4]In September 1992, the yen was trading at $0.82/¥ 100.

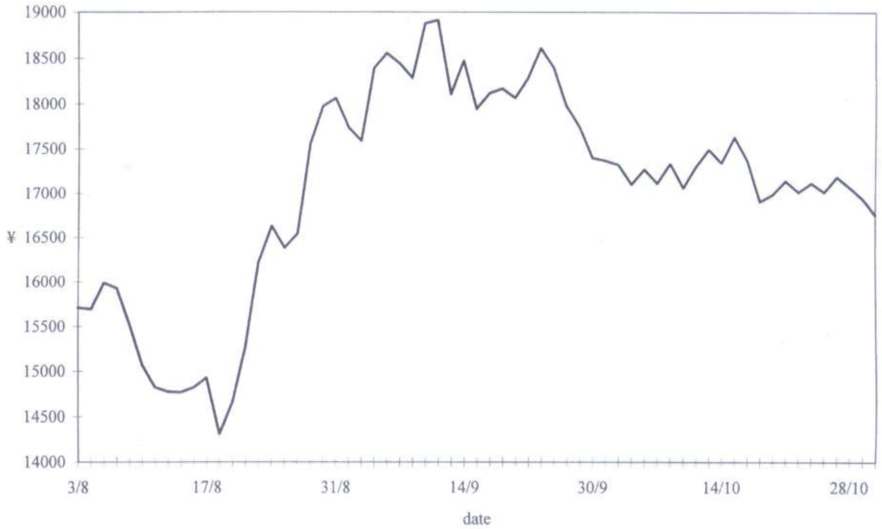


**FIGURE 1**
Nikkei index during August, September, and October 1992.

Transaction price data are used for the Nikkei futures contract traded on the OSE and SIMEX. The number of trades per minute is the proxy for trading activity on both markets (denoted as $N_{t,d}^{O}$ for the OSE and $N_{t,d}^{S}$ for SIMEX). Finally, the difference between the highest and the lowest price in a minute is used as a proxy for price volatility and this is denoted as $V_{t,d}^{O}$ for the OSE and $V_{t,d}^{S}$ for SIMEX.

All minutes in which there was no trading on the OSE and/or on SIMEX are excluded. Also all minutes during which there was a trading halt on the OSE triggered by intraday price limit rules are excluded. Finally, to facilitate comparison with SIMEX, all minutes for which trading on the OSE might have been impeded by the daily price limit are deleted. Therefore, all minutes in which at least one trade on the OSE took place at the price limit (i.e., the base price plus or minus ¥600) are deleted.[5]

## GRAVITATION EFFECT

One explanation for the gravitation effect is that if the actual price comes closer to the price limit, traders will rush because of fears of illiquidity after the limit has been hit. As a consequence, volume would be very heavy close to the limit and the price limit could serve as a magnet drawing the price closer to it [see, e.g., CFTC (1989); Miller (1991)].

[5]A referee pointed out that for a fair comparison of prices, trading volume, and volatility between the OSE and SIMEX requires unimpeded trading on the OSE.

Another explanation for the magnet effect comes from Margulis (1990). He states that several market participants, who in normal circumstances help to provide liquidity, are forced to withdraw from the market if the futures price approaches a price limit. These market participants (e.g., market makers, short-term speculators, and day traders) will avoid holding a risky position overnight and consequently change their trading strategy if the futures price is close to the price limit.

To illustrate, assume that the market has fallen dramatically. In such a situation arbitragers are typically long futures and short stock. Now imagine a liquidity provider who, given the price of the underlying index, would normally buy from the public at $p$ in anticipation of the fact that if the price moves against him, he can close his position by selling the futures contract a few ticks lower.[6] The situation is different if there is a price limit at $p - 1$ tick. In that case, the provider of liquidity knows that if the price moves against him, he might not have the opportunity to sell for an uncertain period of time. Consequently, he will require a higher compensation for inventory risk and might decide not to enter a bid at price $p$, but at a lower price. The same argument applies to traders who would normally be willing to buy at a price of $p + 1$ tick, etc. Therefore, it is expected that near the lower limit, bid quotes are drawn toward the lower limit.

Because of the relatively high bid premium near the lower limit, a provider of liquidity would be eager to sell to the public (trade at his ask) in order to buy from the public (trade at his bid) and earn the high bid premium. Thus, in a competitive market, one would expect both the bid and the ask to be drawn toward the lower price limit. It can be argued that quotes are drawn toward the upper price limit because of a similar gravitation effect.

The gravitation effect is investigated by comparing the actual market price of the futures contract on the OSE with the price of the same contract on SIMEX. As discussed in the previous section, the price limit is much more restrictive on the OSE than on SIMEX. Therefore, if a gravitation effect exists, it is expected to be stronger on the OSE. Or, more specifically, near the upper limit the futures price on the OSE is expected to be higher than the price on SIMEX, and near the lower limit the futures price on the OSE is expected to be lower than the price on SIMEX.[7]

[6]Harris (1990) discusses the behavior of "quote matchers" who also base their quotes and limit orders on quotes displayed by other liquidity providers.

[7]The calculated theoretical price of the futures contract is also used as a benchmark. The problem with this measure is that futures prices tend to lead spot prices [see MacKinlay and Ramaswamy

If there are strong arbitrage links between the OSE and SIMEX, it is possible that a gravitation effect would affect prices on SIMEX and the OSE in exactly the same way. To address this issue, the sign and size of price changes in the Nikkei futures contract on SIMEX are analyzed as a function of the distance of the actual price from the base price. The benefit of working with SIMEX data is that price changes on SIMEX are not restricted by daily price limits. Using OSE data to study *actual* price changes close to the price limit would be biased against finding a magnet effect as price changes are only observed if they do not go beyond the limit. Closer to the price limit, the bias is expected to be larger since the distribution of price changes on the OSE will be more severely censored.

## Empirical Results

Define the price difference ($PD_{t,d}$) between a futures contract on the OSE and SIMEX as

$$PD_{t,d} = (F^{O}_{t,d} - F^{S}_{t,d})/F^{S}_{t,d} \tag{1}$$

To investigate the influence of price limits, the price difference is related to the distance of the futures price from the base price of that futures contract on a certain trading day, $B_d$ (see "Price Limits"). Distance is defined as[8]

$$D_{t,d} = (F^{O}_{t,d} + F^{S}_{t,d})/2 - B_d \tag{2}$$

The observations are split into 11 groups based on $D_{t,d}$. As discussed before, the minimum distance from the base price is minus ¥600 and the maximum distance is ¥600. Table IV gives descriptive statistics of the price difference for the different groups.

The results in Table IV show no evidence of the hypothesized positive relationship between the price difference and distance. For the observa-

(1988) for U.S. evidence and Chung, Kang, and Rhee (1993) for evidence on the Japanese markets]. Near the lower limit, i.e., after a sharp drop in the futures price, the calculated futures price, which is based on the lagging spot price, is likely to overestimate the "true" price. Near the upper limit, the calculated price is likely to underestimate the "true" price. The results of an analysis using calculated futures prices are not reported since the problem of stale prices for the underlying index can not be ruled out as an explanation for the magnet effect.

[8]The average of the prices on SIMEX and the OSE are used as the actual prices in the distance measure, since the use of the price on either SIMEX or the OSE could introduce a undesired correlation between the price difference and distance. For example, if only the price on the OSE is used in the definition of distance, the relationship between the distance and mispricing is positive. This result is to be expected, since the price on the OSE enters into the definition of the dependent and the independent variable in the regression. If the distance measure is used on the SIMEX price, the relationship between distance and mispricing is negative.

**TABLE IV**

Price Difference between OSE and SIMEX

| *Distance Group* | *Number of Observations* | *Price Difference between OSE and SIMEX* | | | | |
|---|---|---|---|---|---|---|
| | | *Mean* | *Median* | *Minimum* | *Maximum* | *SD* |
| −¥600 < D < −¥550 | 108 | −0.0114 | −0.0101 | −0.1399 | 0.1344 | 0.0541 |
| −¥550 < D < −¥500 | 107 | −0.0010 | −0.0031 | −0.1100 | 0.1597 | 0.0569 |
| −¥500 < D < −¥400 | 186 | −0.0145 | −0.0220 | −0.1167 | 0.2502 | 0.0548 |
| −¥400 < D < −¥250 | 517 | −0.0001 | 0.0000 | −0.3123 | 0.1787 | 0.0514 |
| −¥250 < D < −¥100 | 1481 | −0.0070 | −0.0079 | −0.2244 | 0.2167 | 0.0484 |
| −¥100 < D < −¥100 | 4466 | 0.0015 | 0.0017 | −0.3122 | 0.3272 | 0.0557 |
| ¥100 < D < ¥250 | 2004 | 0.0028 | 0.0045 | −0.5839 | 0.2667 | 0.0620 |
| ¥250 < D < ¥400 | 617 | 0.0133 | 0.0133 | −0.2518 | 0.2432 | 0.0615 |
| ¥400 < D < ¥500 | 39 | −0.0198 | −0.0213 | −0.1791 | 0.1223 | 0.0749 |
| ¥500 < D < ¥550 | 54 | −0.0146 | −0.0105 | −0.1396 | 0.1091 | 0.0669 |
| ¥550 < D < ¥600 | 81 | −0.0277 | −0.0251 | −0.1898 | 0.1037 | 0.0619 |

Notes: Price difference is defined as $PD_{t,d} = (F^O_{t,d} - F^S_{t,d})/F^O_{t,d}$, where $F^O_{t,d}$ is the average futures price in minute $t$ on day $d$ on the OSE and $F^S_{t,d}$ is the average futures price on SIMEX in minute $t$ on day $d$. Distance ($D$) is defined as $(F^O_{t,d} + F^S_{t,d})/2 - B_d$, where $B_d$ is the base price (the closing price on the previous trading day). The numbers in the table are percentages.

tions closest to the lower limit, the median price difference between SIMEX and the OSE is −0.01%. For the observations closest to the upper limit, the median price difference is −0.025%. Note that the price difference between the OSE and SIMEX is very small in every distance group. One tick on the OSE corresponds to a price difference of 0.06%.

The results in Table IV are not necessarily inconsistent with the existence of a gravitation effect. If there are strong arbitrage links between the OSE and SIMEX, prices on both markets could simultaneously be drawn to the limit. Therefore, the sign and the size of price changes in the Nikkei futures contract traded on SIMEX are analyzed as a function of the distance. The gravitation effect predicts that close to the limit prices are drawn toward the limit. To test this prediction, the following quadratic model is estimated:

$$F^S_{t+1,d} - F^S_{t,d} = \text{constant} + \beta_1 D_{t,d} + \beta_2 D^2_{t,d} + \varepsilon_{t,d} \tag{3}$$

Equation (3) relates the change in the price on SIMEX to the distance of the futures price from the base price. A quadratic term is included to allow for an increasing effect closer to the limit. Table VA reports the results for futures prices larger than the base price. Table VB reports the results for futures prices lower than the base price.[9] The $t$-statistics in

[9]Because SIMEX data are not censored and because intraday price limit rules do not apply, no observations are deleted. All observations for which SIMEX data are available and for which the absolute difference between the price on SIMEX and the base price is less than ¥600 are included.

**TABLE V**

Price Changes on SIMEX as a Function of Distance

| | *A. Futures Price Larger Than Base Price* | | *B. Futures Price Smaller Than Base Price* | |
|---|---|---|---|---|
| | *Estimate* | *t-statistic* | *Estimate* | *t-statistic* |
| Intercept | −0.391 | −0.594 | 0.016 | 0.022 |
| $D_{t,d}$ | 0.009 | 1.347 | 0.003 | 0.401 |
| $D^2_{t,d}$ | −1.50E-05 | −1.177 | −7.44E-06 | −0.517 |
| Rsq | 0.0002 | | 0.0012 | |
| N | 9089 | | 7976 | |

Notes: This table relates price changes on SIMEX to the distance of the actual price from the base price. The regression model is $F^S_{t+1,d} - F^S_{t,d} = \text{constant} + \beta_1 D_{t,d} + \beta_2 D^2_{t,d} + \varepsilon_{t,d}$, where $F^S_{t,d}$ denotes the average futures price on SIMEX in minute $t$ on day $d$ and $D_{t,d}$ is defined as $F^S_{t,d} - B_d$, where $B_d$ is the base price (the closing price on the previous trading day). The $t$-statistics are calculated using the Newey-West (1987) asymptotic covariance matrix.

Table V are calculated using the Newey-West (1987) asymptotic covariance matrix (with one lag) to account for heteroskedastic and serially correlated errors. The results do not support the gravitation effect. There is no significant relationship between price changes on SIMEX and the distance of the actual price from the base price.

A possible reason for the absence of a magnet effect is that some traders on the OSE can easily switch to SIMEX. Therefore, if the likelihood of hitting a price limit on the OSE increases and the price formation on the OSE is influenced, some trading migrates to SIMEX. This actual and potential migration of order flow to the unrestricted trading environment of SIMEX could help to ensure efficient price formation on the OSE. According to this explanation, the price on the OSE will never deviate substantially from the price on SIMEX, which is set in a market that is not influenced by price limits.[10]

## VOLUME AND VOLATILITY

In this section trading volume and volatility on the OSE and SIMEX are analyzed as a function of price limits. Subrahmanyam (1994) discusses two forces which might influence trading decisions if the actual price is close to the price limit. First, traders have an incentive to increase their trading while the exchange is still open, resulting in an increase in trading

[10]The absence of a magnet effect cannot be generalized to markets where traders do not have the possibility to switch to an unrestricted trading environment. A referee pointed out the link between the gravitation effect and the satellite market effect.

volume and volatility. Second, if there is a satellite market, traders might switch to the satellite market to avoid hitting the price limit and possibly being unable to unwind their position for some time. This would result in a decrease in trading volume and volatility on the dominant market and an increase on the satellite market.

Subrahmanyam (1994) conjectures that the "intertemporal" effect will dominate the "satellite market" effect. He argues that in times of crisis, institutions will be forced to concentrate on the price movements on the dominant market and will not have time to shop around. Note, however, that many traders in the Nikkei 225 futures contract have both OSE and SIMEX quotes on their screens and can easily switch from one market to the other.

To test the hypotheses above, the volume and volatility on SIMEX are compared to the volume and volatility on the OSE. For each minute, the ratio of the number of trades on the OSE to the number of trades on SIMEX is measured:

$$NTR_{t,d} = N^{O}_{t,d}/N^{S}_{t,d} \tag{4}$$

where $N^{O}_{t,d}$ is the number of transactions on the OSE in minute $t$ on day $d$, and $N^{S}_{t,d}$ is the number of transactions on SIMEX in that minute.

The variable measuring the relative volatility on the OSE is defined as

$$VR_{t,d} = V^{O}_{t,d} - V^{S}_{t,d} \tag{5}$$

where $V^{O}_{t,d}$ is the difference between the highest and the lowest observed price on the OSE in minute $t$ on day $d$, and $V^{S}_{t,d}$ is the difference between the highest and the lowest price on SIMEX in that minute.

## Empirical Results

Table VIA reports the descriptive statistics for the relative number of transactions for the different price ranges. Table VIB gives the descriptive statistics for the relative volatility for the different groups.

The results in Table VI show a marked shift in relative trading activity from the OSE to SIMEX if the price comes closer to the price limit. Close to the base price the median relative number of transactions is 1.80. This number drops to 1.25 close to the lower limit and to 1.50 close to the upper limit. The relative price variability is also low close to the lower and upper limits.

**TABLE VI**

Relative Volume and Volatility on OSE and SIMEX

| *Distance Group* | *Number of Observations* | *Mean* | *Median* | *Minimum* | *Maximum* | *SD* |
|---|---|---|---|---|---|---|
| | *A. Relative Number of Transactions (NTR)* | | | | | |
| −¥600 < *D* < −¥550 | 108 | 1.539 | 1.250 | 0.167 | 6.5 | 1.138 |
| −¥550 < *D* < −¥500 | 107 | 1.892 | 1.500 | 0.167 | 7.7 | 1.470 |
| −¥500 < *D* < −¥400 | 186 | 2.570 | 2.000 | 0.143 | 15.0 | 2.027 |
| −¥400 < *D* < −¥250 | 517 | 2.367 | 2.000 | 0.083 | 14.0 | 1.918 |
| −¥250 < *D* < −¥100 | 1481 | 2.400 | 2.000 | 0.100 | 21.0 | 1.916 |
| −¥100 < *D* < ¥100 | 4466 | 2.272 | 1.800 | 0.100 | 24.0 | 1.935 |
| ¥100 < *D* < ¥250 | 2004 | 2.472 | 2.000 | 0.091 | 22.0 | 2.223 |
| ¥250 < *D* < ¥400 | 617 | 2.413 | 2.000 | 0.125 | 24.0 | 2.050 |
| ¥400 < *D* < ¥500 | 39 | 2.022 | 1.400 | 0.111 | 9.0 | 1.984 |
| ¥500 < *D* < ¥550 | 54 | 1.829 | 1.500 | 0.333 | 9.0 | 1.511 |
| ¥550 < *D* < ¥600 | 81 | 1.987 | 1.500 | 0.250 | 12.0 | 1.870 |
| | *B. Relative Volatility (VR)* | | | | | |
| −¥600 < *D* < −¥550 | 108 | −3.565 | 0.0 | −30.0 | 20.0 | 10.57 |
| −¥550 < *D* < −¥500 | 107 | −4.439 | 0.0 | −40.0 | 30.0 | 12.84 |
| −¥500 < *D* < −¥400 | 186 | −1.237 | 0.0 | −40.0 | 25.0 | 11.11 |
| −¥400 < *D* < −¥250 | 517 | 0.590 | 0.0 | −90.0 | 30.0 | 11.39 |
| −¥250 < *D* < −¥100 | 1481 | 1.158 | 0.0 | −50.0 | 40.0 | 10.42 |
| −¥100 < *D* < ¥100 | 4466 | 0.063 | 0.0 | −280.0 | 40.0 | 11.59 |
| ¥100 < *D* < ¥250 | 2004 | −0.127 | 0.0 | −60.0 | 40.0 | 11.69 |
| ¥250 < *D* < ¥400 | 617 | 0.405 | 0.0 | −40.0 | 35.0 | 11.10 |
| ¥400 < *D* < ¥500 | 39 | −5.000 | −10.0 | −30.0 | 40.0 | 16.02 |
| ¥500 < *D* < ¥550 | 54 | −7.130 | −10.0 | −50.0 | 20.0 | 14.62 |
| ¥550 < *D* < ¥600 | 81 | −2.407 | −5.0 | −35.0 | 30.0 | 12.30 |

Notes: Relative volume ($NTR_{t,d}$) is defined as the number of transactions per minute on the OSE divided by the number of transactions per minute on SIMEX. Relative volatility ($VR_{t,d}$) is defined as the difference between the highest and the lowest price per minute on the OSE minus the difference between the highest and the lowest price per minute on SIMEX. Distance ($D$) is defined as $(F^O_{t,d} + F^S_{t,d})/2 - B_d$, where $B_d$ is the base price (the closing price on the previous trading day).

To gain more insight into the relationship between relative trading volume and volatility and the absolute value of the distance from the base price, the following regressions are run[11]:

$$NTR_{t,d} = \text{constant} + \gamma_1|D_{t,d}| + \gamma_2|D^2{}_{t,d|} + \varepsilon_{t,d} \tag{6}$$

$$VR_{t,d} = \text{constant} + \delta_1|D_{t,d}| + \delta_2|D^2{}_{t,d|} + \varepsilon_{t,d} \tag{7}$$

where all variables are defined above. The results of the regressions are reported in Table VII. The $t$-statistics are calculated using the Newey-

[11]Separate estimation of the model for cases where the actual price is below and above the base price does not change any of the conclusions. Dummy variables for each half hour of the trading day are included, but none of the dummies is significant at conventional levels.

**TABLE VII**

Relative Trading Volume and Volatility as Function of Distance

| | A. *Relative Trading Volume* | | B. *Relative Volatility* | |
|---|---|---|---|---|
| | *Estimate* | *t-statistic* | *Estimate* | *t-statistic* |
| Intercept | 2.110 | 17.310 | −0.741 | −1.180 |
| $\lvert D_{t,d} \rvert$ | 0.003 | 3.517 | 0.010 | 2.868 |
| $\lvert D^2_{t,d} \rvert$ | −5.4E-06 | −4.300 | −3.1E-05 | −4.385 |
| Rsq | 0.006 | | 0.007 | |
| Observations | 9660 | | 9660 | |

Notes: This table compares the relative trading volume and volatility to the distance of the actual price from the base price. The estimated regressions are

$$NTR_{t,d} = \text{constant} + \gamma_1 \lvert D_{t,d} \rvert + \gamma_2 \lvert D^2_{t,d} \rvert + \varepsilon_{t,d}$$

$$VR_{t,d} = \text{constant} + \delta_1 \lvert D_{t,d} \rvert + \delta_2 \lvert D^2_{t,d} \rvert + \varepsilon_{t,d}$$

where $NTR_{t,d}$ is defined as the number of transactions per minute on the OSE divided by the number of transactions per minute on SIMEX. $VR_{t,d}$ is defined as the difference between the highest and the lowest price in a minute on the OSE minus the difference between the highest and lowest price on SIMEX per minute. $\lvert D_{t,d} \rvert$ is defined as the absolute value of $(F^O_{t,d} + F^S_{t,d})/2 - B_d$, where $B_d$ is the base price (the closing price on the previous trading day). The *t*-statistics are calculated using the Newey-West (1987) asymptotic covariance matrix.

West (1987) asymptotic covariance matrix (with 15 lags) to account for heteroskedastic and serially correlated errors.

Consistent with Table VI, the results in Table VIIA imply that close to the base price there is a moderately positive relationship between the absolute value of distance from the base price and the relative trading volume on the OSE. The relationship changes in sign when the actual price is about halfway between the base price and the price limit.[12] A similar result is found for the relative volatility on the OSE. Close to the base price relative volatility on the OSE increases with the distance from the base price, but when the actual price is about halfway between the base price and the price limit, relative volatility on the OSE decreases with the distance from the base price. Both results are consistent with the satellite market effect in Subrahmanyam (1994), where traders switch from the dominant market to the satellite market when the price gets closer to the limit price. As discussed in the previous section, this result can also explain the absence of a gravitation effect.

[12]At the base price (distance is ¥0) the estimated NTR equals 2.11. The estimated NTR reaches its maximum of 2.40 at a distance of ¥250. At the maximum distance of ¥600, the estimated NTR equals 1.67.

## CONCLUSIONS

This paper studies the influence of daily price limits on the price formation process of financial futures. The Nikkei 225 futures contract traded on the OSE, a market with strict price limits, is analyzed. The same contract is traded on the more lenient SIMEX. The relative price, trading volume, and volatility on these two markets are analyzed and these variables are compared to the distance of the actual price from the price limit.

The "gravitation effect," which states that the price of a security is drawn toward the price limit is investigated. The empirical results do not support this hypothesis. No evidence is found that Nikkei futures on the OSE have a relatively low (high) price compared to Nikkei futures on SIMEX when the price approaches the lower (upper) limit. This result could be due to the strong arbitrage links between the OSE and SIMEX and is not necessarily inconsistent with the existence of a gravitation effect. Using (uncensored) data from SIMEX, the study tests whether size and sign of price changes are related to the distance from the price limit. However, no evidence of such a relationship is found.

The results provide support for the "satellite market" in Subrahmanyam (1994). It is found that if the transaction price gets closer to the price limits, price variability and market liquidity decrease on the dominant market relative to the satellite market. This result is also consistent with the absence of a gravitation effect. If the likelihood of hitting the price limit on the OSE increases, more trading migrates to SIMEX. Both the actual and potential order flow migration to this unrestricted trading environment help ensure efficient price formation on the OSE.

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