

Analysis of Differences in Trading Behavior at Day and Night Sessions for Nikkei 225 Futures

【Summary】



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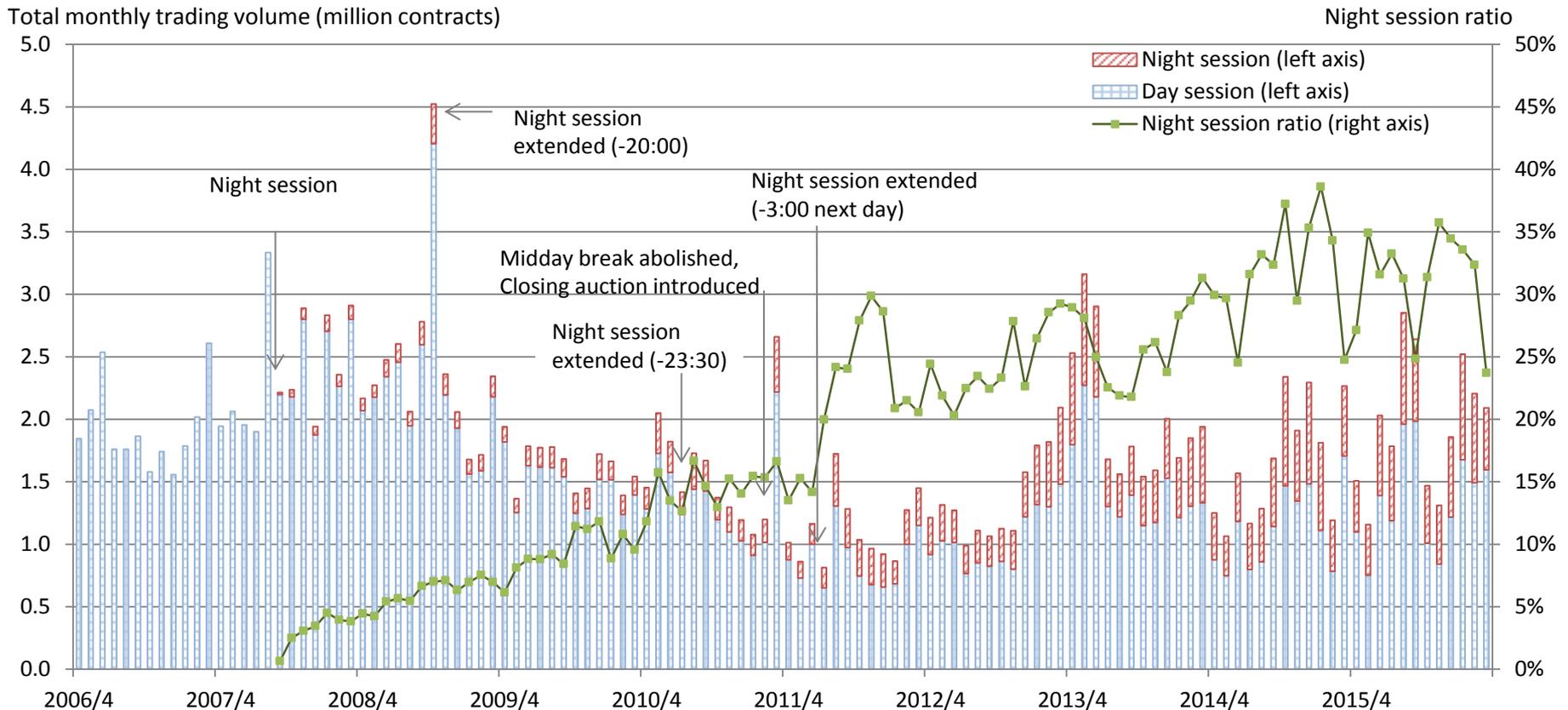
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1. Introduction

- OSE trading hours have been gradually extended since night trading began in 2007
 - ⇒ In recent years, night trading has constituted more than 30% of daily trading
- There is probably a skewing of investor types in night trading compared with day trading, with a potential effect on depth and best bid-offer (BBO) spread
 - ⇒ Analysis of market conditions based on orders





2-1. Prior research—Order aggressiveness ①

- Order aggressiveness is a method proposed by Biais, Hillion, and Spatt (1995) to classify the degree of investor aggressiveness in order execution

⇒ This method facilitates analysis based on orders

Order categories as defined by Biais et al. (1995) (for buy orders)

- Grouped into seven categories (A–G) according to order price and order volume
- In descending order of aggressiveness from A through G

Category	Description
A	Buy orders for which the order price is higher than the sell BBO when placed
B	Buy orders for which the order price is equal to the sell BBO when placed and the order size is greater than the BBO sell depth
C	Buy orders for which the order price is equal to the sell BBO when placed and the order size is not more than the BBO sell depth
D	Buy orders for which the order price is lower than the sell BBO but higher than the buy BBO when placed
E	Buy orders for which the order price is equal to the buy BBO when placed
F	Buy orders for which the order price is less than the buy BBO when placed
G	Canceled orders

2-2. Prior research—Order aggressiveness ②

Depiction of order aggressiveness as defined by Biais et al. (1995) (for buy orders)

Sell orders	Price	Buy orders	
	...		
200	17,040		
200	17,030		
150	17,020		A
100	17,010		B (more than 100 lots) C (less than or equal to 100 lots)
	17,000		D
	16,990	200	E
	16,980	200	F
	16,970	200	
	16,960	200	
	...		

*Category G is canceled orders



2-3. Previous research—Model analysis using order aggressiveness

- Many studies have analyzed the correlation between order aggressiveness and market conditions
- Furthermore, many analyses have created models with modified definition of order aggressiveness

⇒ This study tests whether trading trends for day and night sessions differ depending on the relation between order aggressiveness and order book information

Griffiths, Smith, Turnbull and White (2000)

Tested autocorrelation, a phenomenon observed in the market
⇒ Argued that if the immediately preceding order was aggressive, the next order would also tend to be aggressive

Ranaldo (2004)

Analyzed the effect of volatility as a factor in trading behavior
⇒ Argued that trading becomes less aggressive as volatility increases

Sasaki (2004)

Considered the example of derivatives (Nikkei 225 Futures) for analysis
⇒ Argued that as remaining time to maturity gets shorter, orders become more aggressive and sell orders move differently than buy orders

Xu (2009)

Argued that orders become more aggressive as the order volume increases

Develop a model to estimate order aggressiveness



Analyze factors in trading behavior



3-1. Data

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Sample contract

■ Used historical order data from OSE (replicable with data on total orders from a fee-based service)

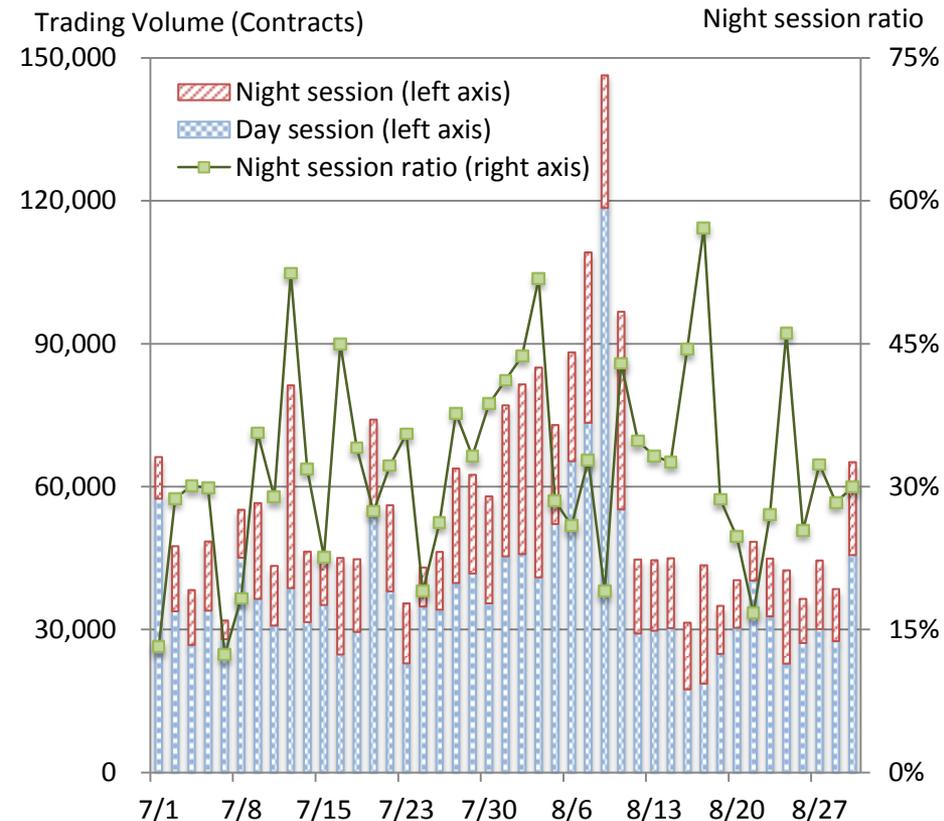
■ Sample: Nikkei 225 Futures September 2014 contract from July 1 through August 29, 2014 (trading days) (trading sessions only)

* Single price auction trades for the 5 min after session opens and 5 min before session closes, for a total of 20 min of trading. Excludes strategy trades.

OHLC prices for the sample contract



Sample contract trading volume by session





3-2. Market analysis—Investigating skewing of investor types

We aggregated trading volume (buys + sells) by the main trading participants during our sample period, as published by OSE

In the day session, the top five companies constituted approximately 56.5% of the total trading volume

In the night session, the top five companies constituted approximately 70.9% of the total trading volume

⇒ Although the trading movements of investors are not known, this shows that investor types may be skewed overall

	Trading volume (contracts)	Share
Top five companies at the day session	1,826,938	56.5%
Top five companies at the night session	1,555,562	70.9%



3-3. Market analysis—Evaluation of the bid-offer spread and depth levels

The time-weighted averages of the bid-offer spread and BBO depth during the sample period are

Trading session	BBO depth for a sell	BBO depth for a buy	Bid-offer spread
Day	231	232	1.000
Night	156	146	1.003

*BBO depth is rounded down to the nearest unit; bid-offer spread is rounded to the fourth decimal place.

- The bid-offer spread is approximately one tick for both day and night sessions
⇒The bid-offer spread does not have much of an effect on market liquidity

- BBO depth during night sessions is only approximately 60% of that during day sessions

To determine if depth is adequate, we define the ratio of unfilled orders

Ratio of unfilled orders = the proportion of partially executed “take” orders remaining unfilled in the order book

*Excludes fill & kill and other orders that expire when filled

*“Take” orders are orders on the order book awaiting execution

	Day session	Night session
Ratio of unfilled orders	4.7%	6.1%

- ⇒This study estimates that the difference in the ratio of unfilled orders is less than the difference in depth at the day and night sessions. It indicates that depth does not have much of an effect on market liquidity.



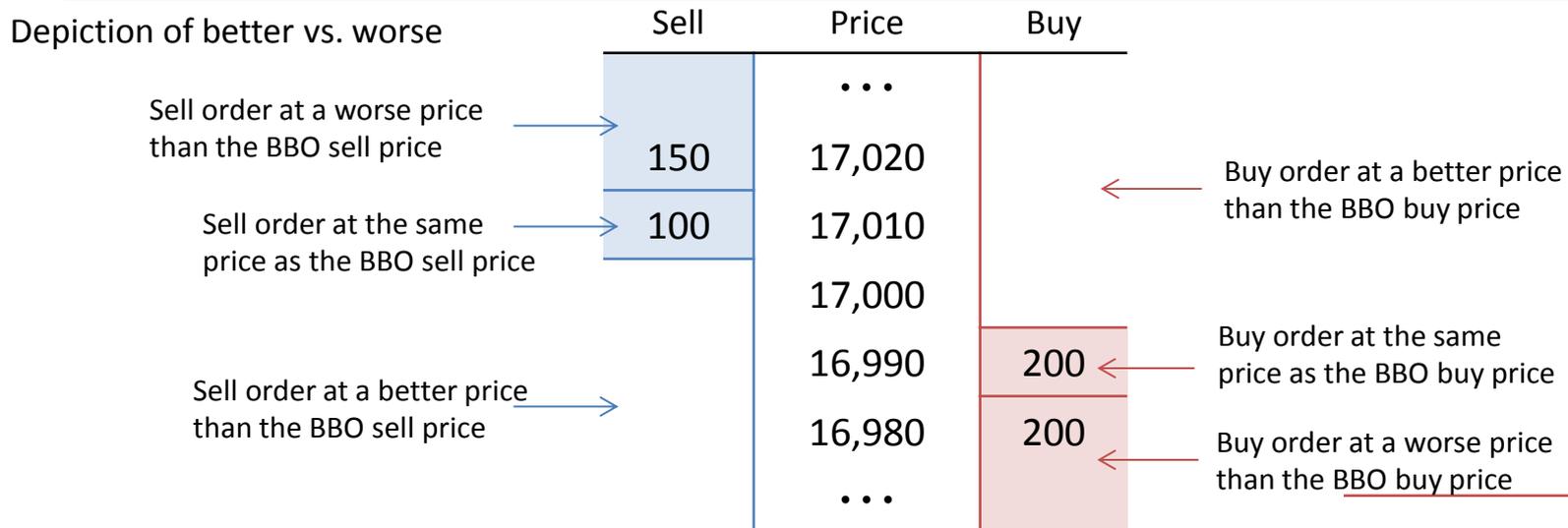
3-4. Market analysis—Distribution of orders by order price range

Analysis of the correlation between order prices and market prices (comparison with BBO price that conforms with the order book)

- The ratio of orders at the BBO price rises in the night session
- Simultaneously, the ratio of orders worse than the BBO by 4 or more ticks declines

⇒ In the day session, more orders are placed for avoiding losses that exceed expectations

Order price	Sell (Day)	Buy (Day)	Sell (Night)	Buy (Night)
Market order or Better than the BBO price	3.0%	3.1%	2.0%	2.1%
Same as the BBO price	52.9%	53.1%	58.2%	58.1%
1 tick worse than the BBO price	26.5%	26.1%	29.2%	29.6%
2 ticks worse than the BBO price	3.1%	3.1%	2.7%	2.8%
3 ticks worse than the BBO price	1.6%	1.7%	2.9%	2.7%
4 ticks worse than the BBO price	12.9%	12.9%	5.0%	4.8%





3-5. Market analysis—Sample order categories

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Sample orders

- Classification of orders by aggressiveness
- We analyzed orders and grouped them into the following four categories as defined by Biais et al. (1995) (buy orders shown here)

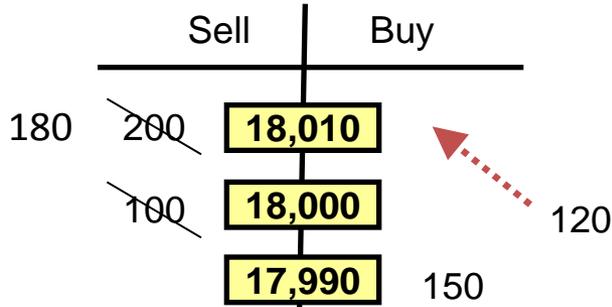
Order aggressiveness	Description
1	Buy orders that are filled when placed and that reset the sell BBO price
2	Buy orders that are filled when placed but that do not reset the sell BBO price
3	Buy orders at prices better than the buy BBO price but are not filled immediately
4	Buy orders canceled at the buy BBO price or for which the prices were modified to worse than the buy BBO price

Number of sample orders

Order aggressiveness	Sell (day)	Buy (day)	Sell (night)	Buy (night)
1	13,707	13,367	14,891	14,617
2	91,578	91,959	61,487	60,271
3	1,683	1,611	12,048	12,783
4	960,479	962,162	1,235,243	1,262,984
Total	1,067,447	1,069,099	1,323,669	1,350,655

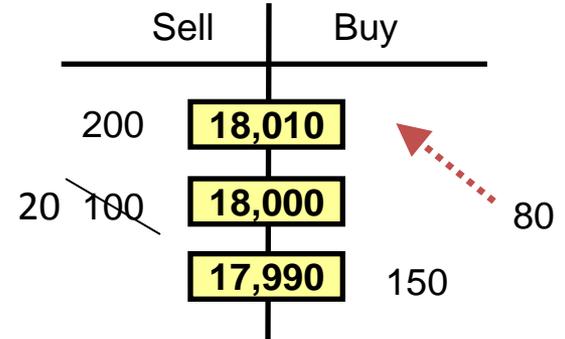
3-6. Order classification method used in the analysis

Aggressiveness 1



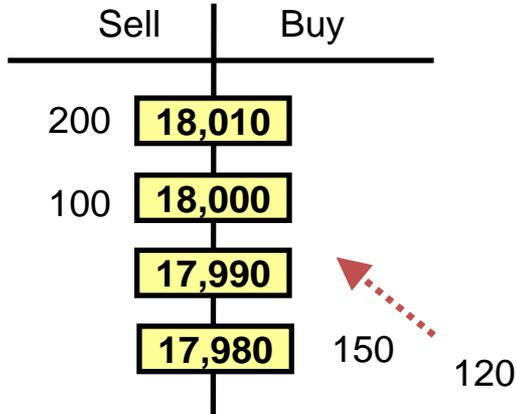
- Step 1. BBO sell price is ¥18,000; BBO buy price is ¥17,990
 - Step 2. Order 1 placed to buy 120 lots at ¥18,010
 - Step 3. 100-lot sell order filled at ¥18,000, and 20-lot sell order filled at ¥18,100
 - Step 4. BBO sell price changes to ¥18,010
- ⇒ Order 1 corresponds to **Aggressiveness 1**

Aggressiveness 2



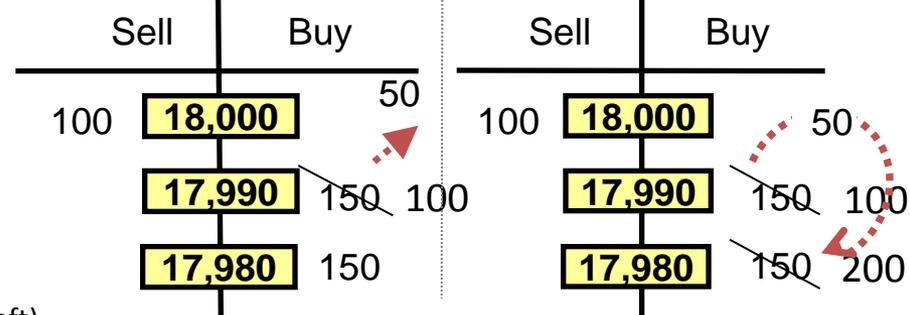
- Step 1. BBO sell price is ¥18,000; BBO buy price is ¥17,990
 - Step 2. Order 2 placed to buy 80 lots at ¥18,010
 - Step 3. 80-lot sell order filled at ¥18,000
 - Step 4. BBO sell price unchanged at ¥18,000
- ⇒ Order 2 corresponds to **Aggressiveness 2**

Aggressiveness 3



- Step 1. BBO sell price is ¥18,000; BBO buy price is ¥17,980
 - Step 2. Order 3 placed to buy 120 lots at ¥17,990
 - Step 3. BBO buy price changes to ¥17,990
- ⇒ Order 3 corresponds to **Aggressiveness 3**

Aggressiveness 4



(Left)

- Step 1. BBO sell price is ¥18,000; BBO buy price is ¥17,990
- Step 2. Order 4 to buy 50 lots at ¥17,990 is canceled

(Right)

- Step 1. BBO sell price is ¥18,000; BBO buy price is ¥17,990
 - Step 2. Order 5 to buy 50 lots at ¥17,990 is modified to ¥17,980
- ⇒ Orders 4 & 5 correspond to **Aggressiveness 4**



4-1. Details of analysis

Overview

Estimate the model to determine order aggressiveness according to the four combinations of trading session (day and night) and order book (buy and sell)

⇒ Identify characteristics by comparing the relation between order aggressiveness and the determinants of investor behavior

Hypothesized factors determining trading behavior

- Most recent BBO sell depth
- Most recent BBO buy depth
- Orders filled during the preceding 1 min

Selection criteria

1. Order data should be easily obtainable
(The presence or absence of events such as economic policy and economic data announcements is not treated as an independent variable)
2. Should be fluctuating during trading hours
(The bid-offer spread is excluded because it is 1 tick in almost all time periods)
3. No consideration is given to the impact of other contracts
(The sample does not include Nikkei 225 Futures further-out contracts, the Nikkei 225 Futures listed on overseas exchanges, or Nikkei 225 mini)



4-2. Analysis using an ordered probit model

We estimate the parameters $\beta_1 \sim \beta_3$ and $\gamma_1 \sim \gamma_3$ using the following ordered probit model

$$y_t^* = \beta_1 Vol_{t-1}^{Ask} + \beta_2 Vol_{t-1}^{Bid} + \beta_3 Vol_t^{Execution} + \varepsilon_t \equiv Z_t + \varepsilon_t$$

$$y_t = \begin{cases} 1 & (\text{if } -\infty < y_t^* \leq \gamma_1) \\ m & (\text{if } \gamma_{m-1} < y_t^* \leq \gamma_m) \text{ (for } m = 2, 3) \\ 4 & (\text{if } \gamma_3 < y_t^* < \infty) \end{cases}$$

Variable	Description
t	Time (changes whenever an order is placed)
y_t^*	Non-observed true order aggressiveness
y_t	Indicator of categorized observed order aggressiveness
$\beta_1 \sim \beta_3$	Independent variable parameters
ε_t	Error term (assumed to follow a normal distribution)
$\gamma_1 \sim \gamma_3$	Threshold for estimating y_t to y_t^* ($\gamma_1 < \gamma_2 < \gamma_3$)

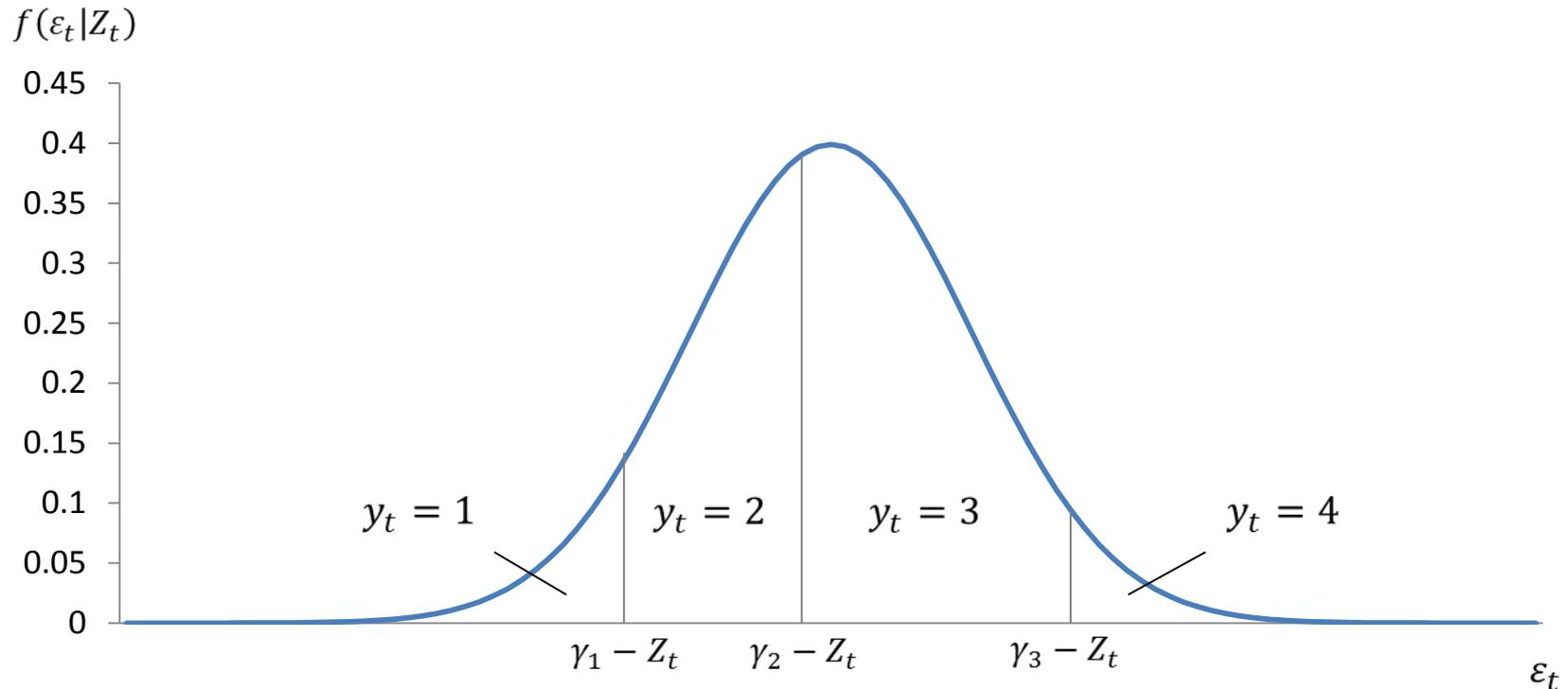
Independent Variable	Description
Vol_t^{Ask}	BBO depth for a sell at time t / 100
Vol_t^{Bid}	BBO depth for a buy at time t / 100
$Vol_t^{Execution}$	Execution volume from 1 min before time t until time $t - 1$



4-3. Logic for determining order aggressiveness

Order aggressiveness is affected by the error term ε_t

The correlation between ε_t and the probability density function $f(\varepsilon_t|Z_t)$ is as follows



The probability that an order placed at time t will belong to the respective categories is as follows (for an ordered probit model) $\Phi(\cdot)$: Cumulative distribution function of a standard normal distribution

$$P(y_t = 1|Z_t) = \Phi(\gamma_1 - Z_t)$$

$$P(y_t = m|Z_t) = \Phi(\gamma_m - Z_t) - \Phi(\gamma_{m-1} - Z_t) \text{ (for } m = 2, 3)$$

$$P(y_t = 4|Z_t) = 1 - \Phi(\gamma_3 - Z_t)$$



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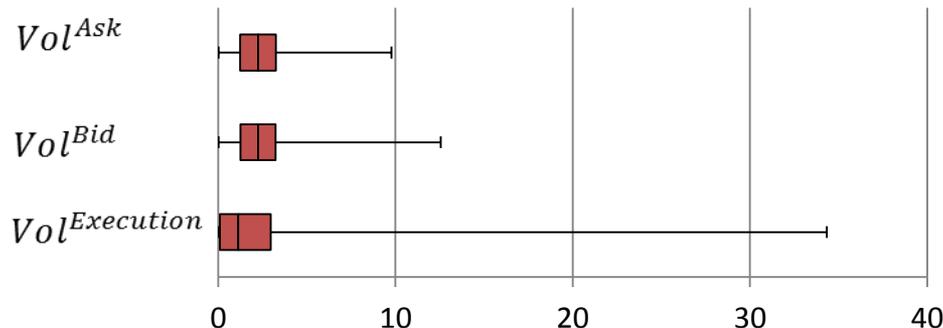
4-4. Basic statistics for the independent variables

- In terms of quartiles, little difference exists between day and night sessions, except for the highest price
- Looking at the symmetry between BBO depth for buys and sells, there is less symmetry in the night session than the day session with regard to dispersion, skewness, and kurtosis

Day session trading

Indep. variable	Mean	Variance	Skewness	Kurtosis
Vol^{Ask}	2.344	1.446	0.561	0.176
Vol^{Bid}	2.353	1.443	0.578	0.255
$Vol^{Execution}$	2.223	3.283	3.237	15.667

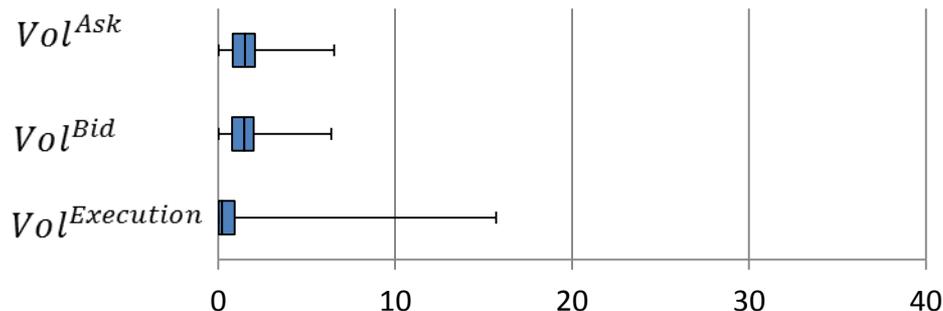
Independent variable quartiles
(day session)



Night session trading

Indep. variable	Mean	Variance	Skewness	Kurtosis
Vol^{Ask}	1.521	0.865	0.581	0.626
Vol^{Bid}	1.454	0.927	0.406	0.163
$Vol^{Execution}$	0.659	1.054	3.479	21.417

Independent variable quartiles
(night session)





5-1. Analytical findings—Independent variable and order aggressiveness correlation

Aspects common to day and night sessions

Impact factor	Impact on order aggressiveness
BBO depth on same side of the order book	The larger the independent variable, the more aggressive the order
BBO depth on opposite side of the order book	The larger the independent variable, the less aggressive the order
Latest executed volume	The larger the independent variable, the more aggressive the order

⇒ The results of this study are consistent with the findings of previous research

Estimated parameter values

	Estimated parameter	Sell (Day)	Buy (Day)	Sell (Night)	Buy (Night)	
BBO depth for sells	β_1	-0.17	0.37	-0.31	0.37	Positive parameter The larger the indep. variable, the less aggressive the order
BBO depth for buys	β_2	0.37	-0.17	0.42	-0.41	
Latest executed volume	β_3	-0.04	-0.04	-0.19	-0.18	Negative parameter The larger the indep. variable, the more aggressive the order
Aggressive 1 & 2 boundary	γ_1	-2.40	-2.39	-2.72	-2.93	
Aggressive 2 & 3 boundary	γ_2	-1.25	-1.24	-1.86	-2.07	
Aggressive 3 & 4 boundary	γ_3	-1.23	-1.23	-1.77	-1.97	

*Using the Wald test, all estimation values are significant at 0.1%

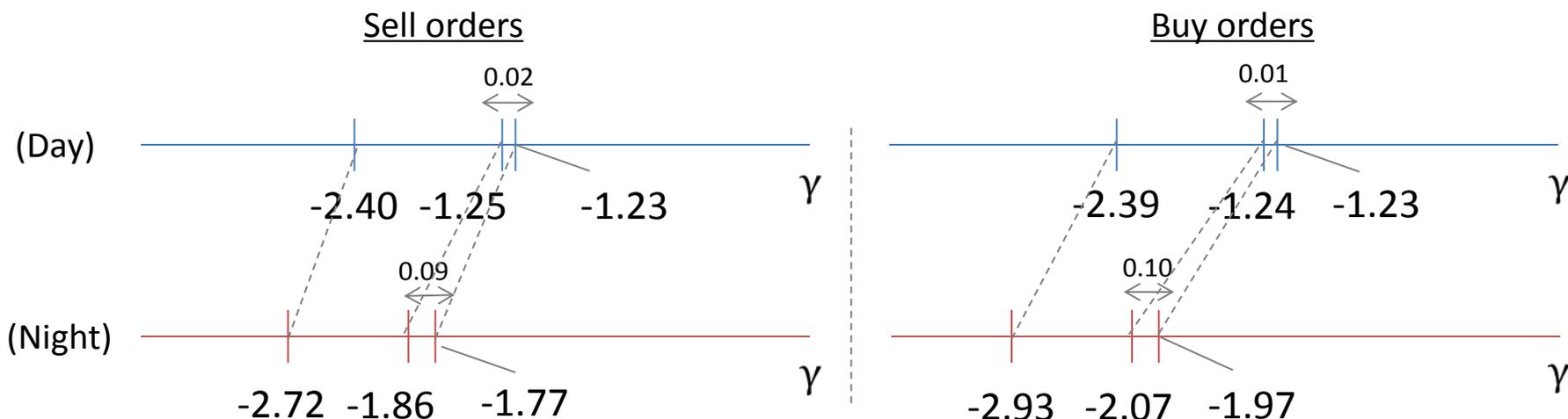
5-2. Analytical findings—Effect of the error term



Differences between day and night sessions I

The threshold interval tends to be wider during night sessions

- The day session intervals of γ_2 and γ_3 are narrow, so evaluation of order aggressiveness levels 2 – 4 is somewhat dependent on the error term
- The error term has less of an effect during the night session, so the independent variables have more of an impact on order aggressiveness



⇒ This indicates that at night sessions, the order book information contributes more to price discovery by order. However, to make a judgment, we need to consider cases when more order categories are included in the sample.

*Contribution to price discovery denotes the degree of influence on prices and differs from the concept of the market's price discovery mechanism



Differences between day and night sessions II

The absolute values of each independent variable's parameters is higher in night sessions

- Independent variables have a greater influence in determining order aggressiveness

【Parameter changes】

Depth of BBO sell price for sell orders

(Day) -0.17 → (Night) -0.31

Depth of BBO buy prices for buy orders

(Day) -0.17 → (Night) -0.41

Latest executed volume

(Day) -0.04 → (Night) -0.19, -0.18

⇒ More trades are based on factors such as BBO depth and latest executed volume, and the relevance between order book information and order aggressiveness is higher

- • • This may be because the night session has fewer economic events and less arbitrage opportunities.



5-4. Analytical findings—Impact of order book side and depth

Differences between day and night sessions III

The difference in the absolute values of the parameters of BBO depth for buys and sells is less in night sessions

- BBO depth on the opposite side of the order book has a greater impact on order aggressiveness in day sessions
- Depth on the same side of the order book increases, and the impact of depth is about the same on both sides in night sessions

【Parameter changes】

BBO depth for sells

(Day) Sell order -0.17, buy order 0.37 ••• Difference in absolute value: 0.20

(Night) Sell order -0.31, buy order 0.37 ••• Difference in absolute value: **0.06**

Decrease

BBO depth for buys

(Day) Sell order 0.37, buy order -0.17 ••• Difference in absolute value: 0.20

(Night) Sell order 0.42, buy order -0.41 ••• Difference in absolute value: **0.01**

Decrease

⇒ More orders consider depth on both the buy and sell sides

••• Investors trade more cautiously than in day sessions because of less depth at night

From the order aggressiveness perspective, this could be because of insufficient BBO depth at night



5-5. Analytical findings—Symmetry between buy and sell orders

Differences between day and night sessions IV

Less symmetry between the parameters for buy and sell orders in night sessions

- Trading behavior for buy and sell orders has less symmetry in night sessions than in day sessions
- In particular, the impact of BBO depth on the buy side is relatively higher
- We are unable to identify the reason for the higher impact of BBO depth for buys
- We assume that it is because of differences in number of orders placed, but we are conducting a separate study to investigate whether differences in buying and selling activity are due to market movements alone

【Parameter changes】

Impact of BBO depth on the same side of the order book

(Day) Sell order, sell BBO -0.17, buy order, buy BBO -0.17 ∴ Difference: 0.00

(Night) Sell order, sell BBO -0.31, buy order, buy BBO -0.41 ∴ Difference: **0.10** Increase

Impact of BBO depth on the opposite side of the order book

(Day) Buy order, sell BBO 0.37, sell order, buy BBO 0.37 ∴ Difference: 0.00

(Night) Buy order, sell BBO 0.37, sell order, buy BBO 0.42 ∴ Difference: **0.05** Increase

⇒ Analysis shows that order behavior is different for buy and sell orders

6. Conclusions

Characteristics of night trading in Nikkei 225 Futures

- More contribution to each order's price discovery
- More relevance between order book data and order aggressiveness
- More tendency to focus on BBO depth on the same side of the order book
- Trading behavior for buy and sell orders may differ

Posited causes

- Fewer factors to move the market during night sessions (economic events, arbitrage opportunities, etc.) than during day sessions
- Investors may be more cautious
- Possible bias in types of investors

⇒ The proportion of cautious investors in the overall market may be high because of less factors for trading in night sessions

- Policy proposals for increasing night trading activity are needed, in addition to further assessment of the impact on the market of changes during the night session



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