- JPX Working Paper -
Analysis of High-Frequency Trading at Tokyo Stock Exchange

March 2014, Go Hosaka, Tokyo Stock Exchange, Inc

1. Background

2. Earlier Studies

3. Data Sources and Estimates

4. Empirical Analysis

5. Conclusion

1. Background

2. Earlier Studies

3. Data Sources and Estimates
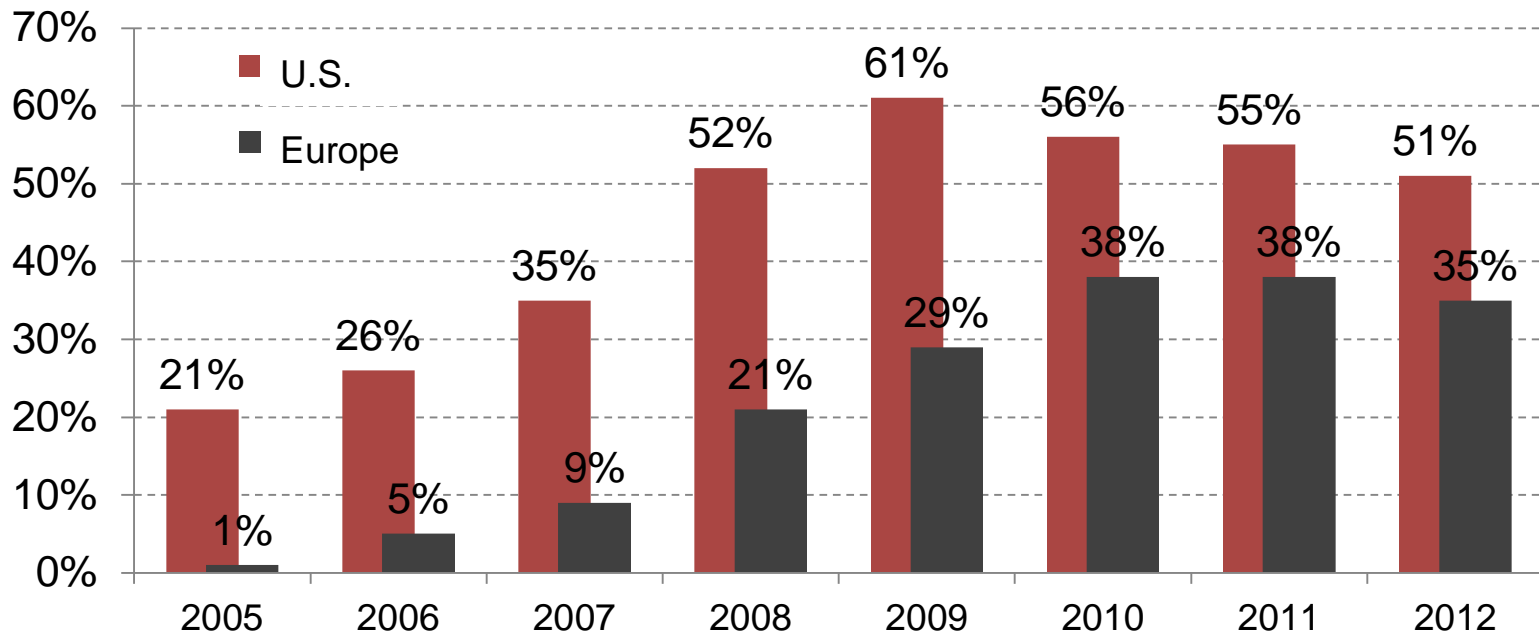
4. Empirical Analysis

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1.1 Changes in the Securities Market

A type of investment strategy whereby profits are attempted to be made by rapidly buying and selling stocks

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HFT
High Frequency Trading

Estimated Share of HFT in Europe and U.S.

Legend:
- U.S.
- Europe

Year	U.S.	Europe
2005	21%	1%
2006	26%	5%
2007	35%	9%
2008	52%	21%
2009	61%	29%
2010	56%	38%
2011	55%	38%
2012	51%	35%

Source: WFE [2013]

1.2 Purpose and Expected Outcome of this Study

Perception of HFT	• Some view HFT as the villain and a factor behind recent stock price plunges. • These concerns stem from the fact that the workings of HFT remain obscure and people know very little about it.
Earlier studies	• Mostly on HFT in the US and Europe markets. • Almost no previous research on HFT in Japanese markets.
Purpose of this study	• To conduct empirical research to reveal the effect of HFT on the Japanese stock market in terms of price formation and liquidity.

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2.1 Definitions of HFT and Features of Earlier Studies

One point that is often highlighted as a feature of HFT firms is that they place and cancel a large number of orders.

Definition by Ferber, M. [2012]

A HFT firm is defined as one that meets at least four of the following six criteria.

- Uses co-location service
- Daily trading value is at least 50% of portfolio
- **Order execution rate is less than 25%**
- **Order cancellation rate is more than 20%**
- More than half of positions are offset by intraday transactions
- Receive rebates on more than 50% or of transactions or orders

Definition by Gomber et al. [2011]

HFT has the following characteristics.

- **Very high number of orders**
- **Rapid order cancellation**
- Proprietary trading
- Profit from buying and selling (as middleman)
- No significant position at end of day (flat position)
- Very short holding periods
- Extracting very low margins per trade
- Low latency requirement
- Use of co-location/proximity services and individual data feeds
- Focus on high liquid instruments

ASIC [2010] categorizes HFT activity into the following three trading techniques

1

Electronic Liquidity Provision

Quote on both sell and buy sides, taking positions similar to market makers

2

Statistical Arbitrage

Attempt to profit from discrepancies between market prices and theoretical prices calculated based on fundamentals, assuming that market prices will converge to the latter.

3

Liquidity Detection

Estimate hidden liquidity such as iceberg orders by placing small-lot orders and execute orders based on such estimates.

2.3 Empirical Analysis of HFT Impact on Stock Markets (US/Europe)

HFT firms tend to act as market makers by providing liquidity through placing orders.

Brogaard, Hendershott, and Riordan[2013]

- They pointed out that HFT contributes to improved price discovery and market efficiency by providing liquidity to markets through placing orders that addressed temporary misspricings in the stock market.

Hasbrouck [2012]

- This study suggested that HFT contributes to narrower spreads and increased depth, and that HFT could alleviate short-term volatility.

Hendershoot and Riordan [2011]

- In times of abundant liquidity, HFT firms meet demand for immediate execution of orders by placing small-lot market orders. When liquidity is scarce, they provide liquidity to the market by placing market-to-limit orders.

2.4 Empirical Analysis on Stock Markets (Japan)

Past studies on Japanese markets are limited to comparisons between the market conditions before and after the launch of arrowhead or the analysis of daily data.

Uno, Shibata [2012]

- Since the introduction of arrowhead, executions have become more frequent and trade sizes have decreased, leading to increased adverse selection costs, which in turn increased liquidity provision risk.

Arai [2012]

- The launch of arrowhead boosted liquidity provision in volatile stocks, contributing to reduced transaction costs.

➡ This study attempts to use TSE intraday data to conduct empirical analysis of the impact of HFT on the TSE market in terms of price formation and liquidity.

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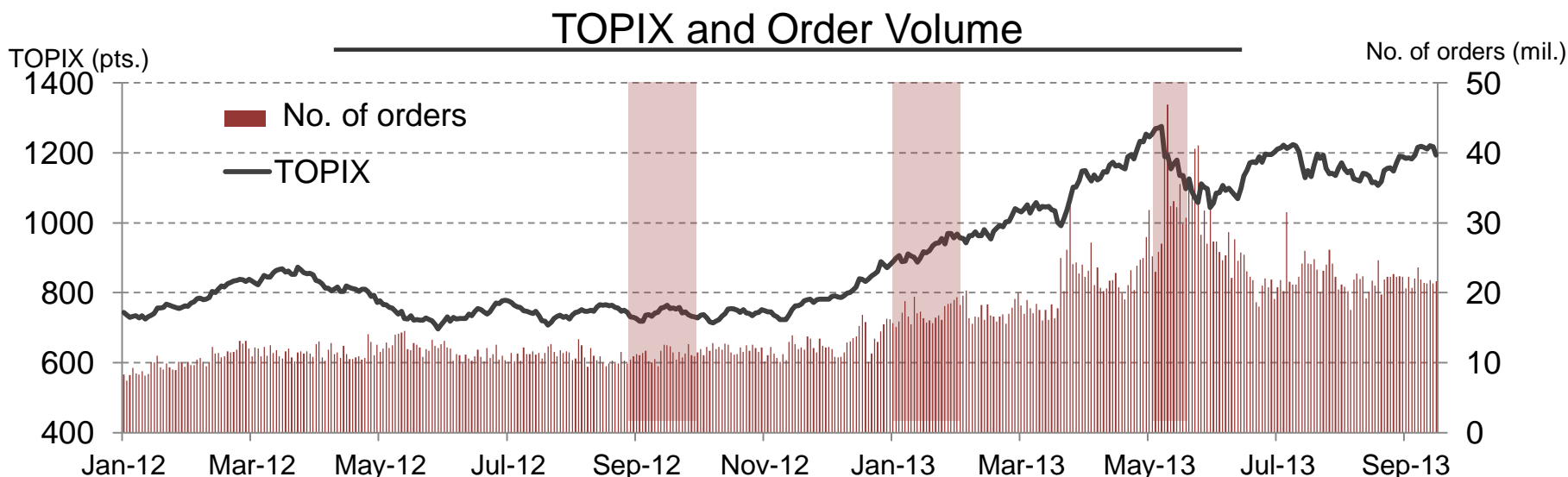5. Conclusion

3.1 Data used in Analysis

This study is based on historical order book data with permission of TSE.

Data used in analysis

Data used in analysis

| Originator (Investor) | → | Trading Participant (Broker/Dealer) | → | TSE |

Data from Sep 1-30, 2012, Jan 4-31, 2013, and May 23-24, 2013 was used in analysis.

TOPIX and Order Volume

3.2 Stocks Selected for Analysis

> ## 373 stocks were selected for analysis

- Domestic common stocks listed on the TSE 1st Section were considered.
- 373 stocks were selected for analysis and the stocks below were excluded to avoid light HFT activity and the impact of corporate actions on trading activity.
  - Stocks which were newly listed, delisted, or transferred to other market sections between Sep 1, 2012 -May 24, 2013.
  - Stocks which recorded HFT trading value of less than JPY 50 mil. on any single day during the periods for analysis.
  - Stock whose QUICK Principal Market is not TSE (OSE-listed stocks, etc.)

Coverage of Selected Stocks

	Sep. 2012	Jan. 2013	May. 2013
Trading Value*1	88.7%	82.1%	79.4%
Market Capitalization*2	80.6%	81.1%	81.3%

*1: Sum of auction and off-auction trading at TSE for the period
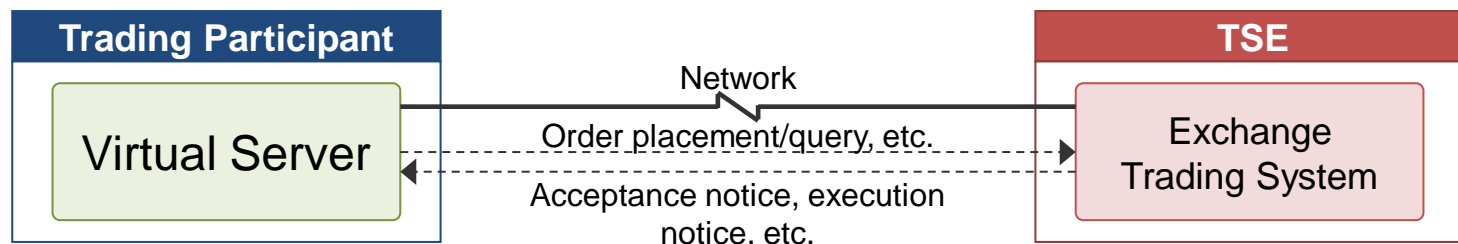*2: As of the last business day of each period.

3.3 Estimate of HFT Orders

we specified conditions to estimate the number of HFT orders

- Since we were unable to identify order originators (= investors), we specified conditions to estimate the number of HFT orders.
- For estimation, partly based on the definition presented in Ferber, M. [2012] we deemed orders to be HFT when they meet all of the following conditions:

  1) orders placed via virtual servers

  2) order cancellation rate exceeds 20%,

  3) order execution rate is less than 25%.

## Supplementary explanation about virtual servers

- A virtual server is a logical device that needs to be set up in a trading participant's system for the trading participant to send/receive data to/from a trading system.
- A single TCP connection is established between a virtual server and a trading system.
- Market participants can set up multiple virtual servers in a single physical server.

Trading Participant	TSE
Virtual Server	Exchange Trading System

Network

Order placement/query, etc.

Acceptance notice, execution notice, etc.

3.4 Share of HFT Orders/Trading

The share of HFT in terms of trading value was about 20%,

Distribution of Virtual Servers (Sep.2012)

Execution Rate vs Cancellation Rate

Estimated to be HFT orders
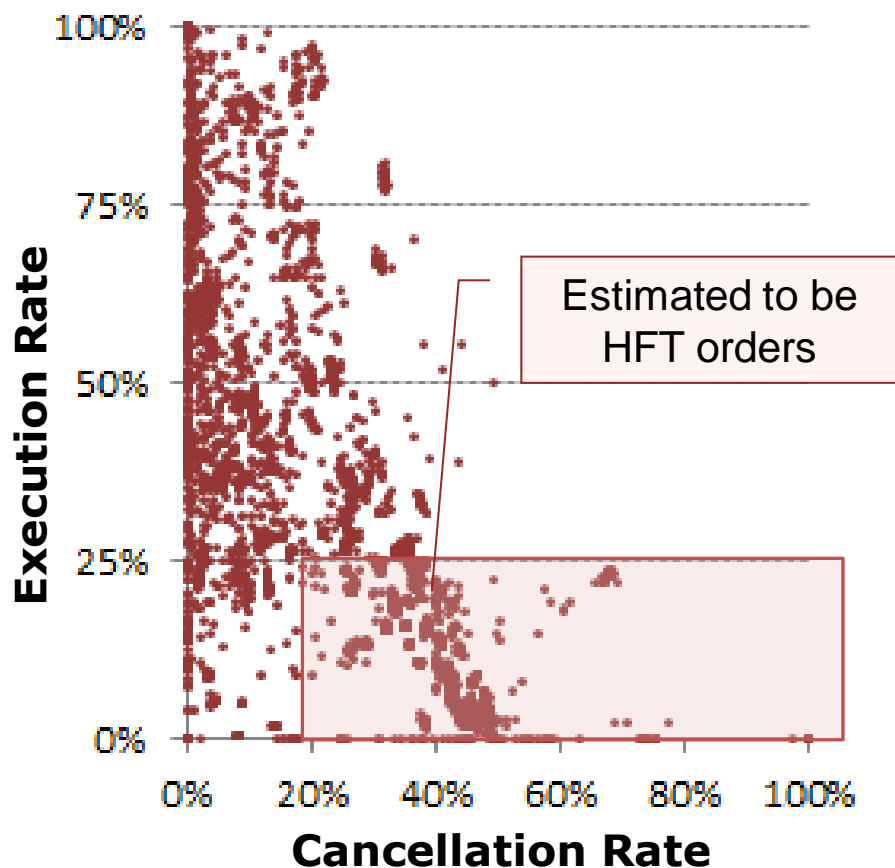
HFT Share per Period

Order Value	
Sep. 2012	27.3%
Jan. 2013	44.3%
May. 2013	51.6%

Trading Value	
Sep. 2012	17.1%
Jan. 2013	24.8%
May. 2013	25.9%

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4.1 Hypotheses and Analysis regarding HFT Impact on Market

> Set hypotheses based on earlier studies
> and validate hypotheses through analysis

Hypothesis 1

HFT provides liquidity to the market.

Hypothesis 2

HFT contributes toward smoother stock price movement.

Validate hypotheses through analysis

| 4.2.(1) | Order time periods and prices |

| 4.2.(2) | Limit orders (PRICE > ASK) |

| 4.3 | Resting time of market-to-limit orders (BID < PRICE < ASK or PRICE = ASK) |

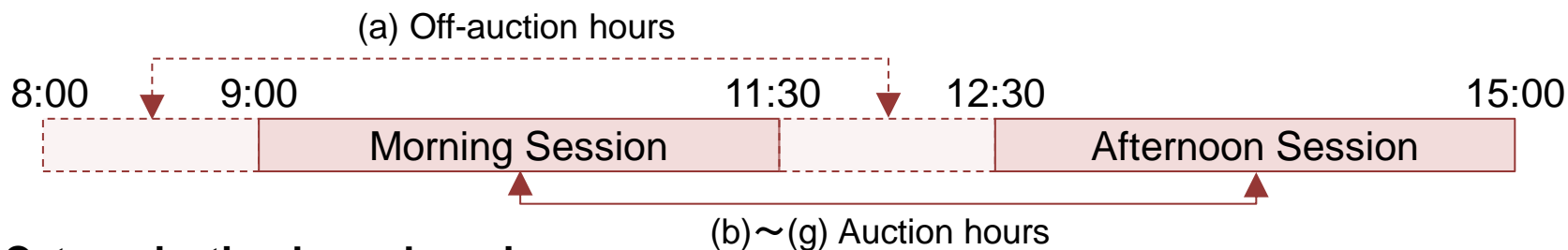| 4.4 | Trading value by order type |

| 4.5 | Price movement and distribution of "take" orders |

4.2.(1) Order Time Periods and Prices

Orders were categorized into the following 7 order types based on order time period and order price

Methodology

Categorization by order time period

(a) Off-auction hours

| 8:00 | 9:00 | 11:30 | 12:30 | 15:00 |

Morning Session   Afternoon Session

(b)〜(g) Auction hours

Categorization by order price

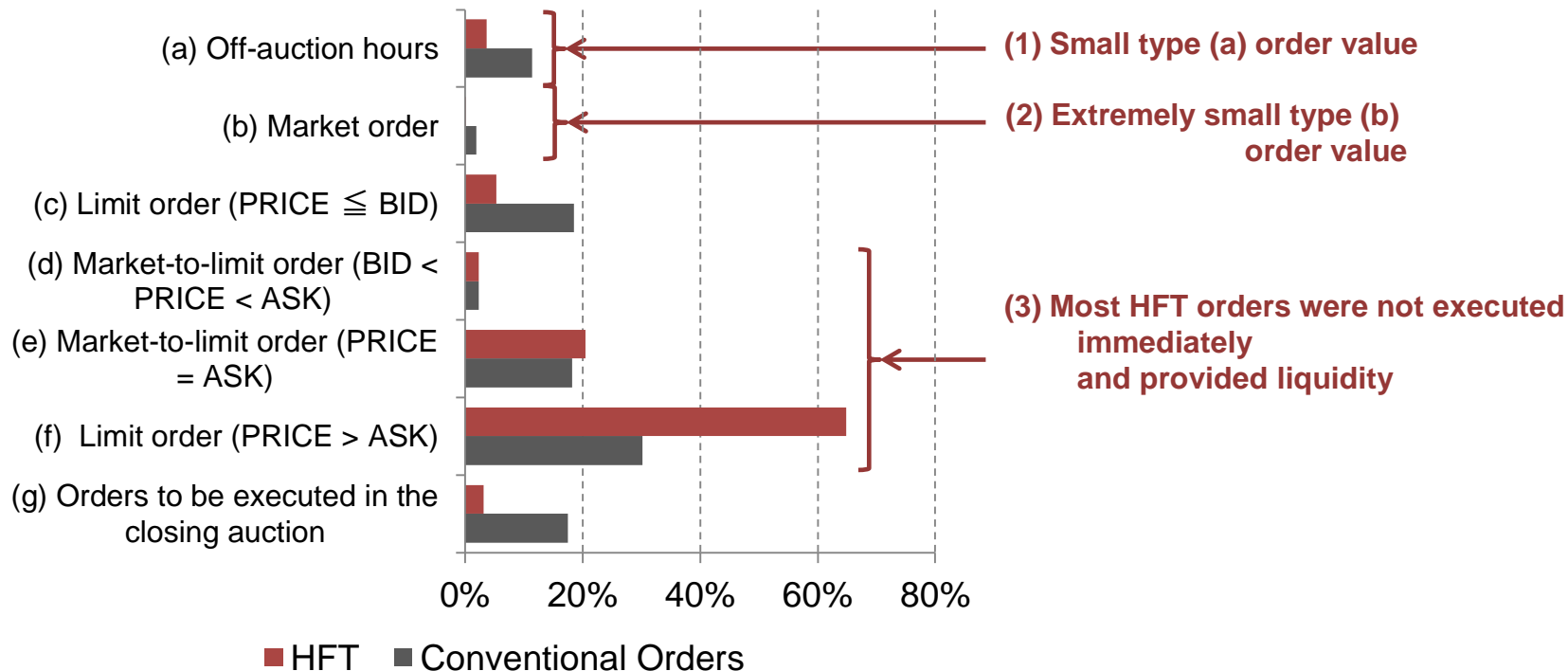|	Sell volume	Price	Buy volume	
(b)->		Market Order		<-(b) Market order
(f)->	1,000	502		
(e)->	900	501		<-(c) Limit order (PRICE ≦ BID)
(d)->		500		<-(d) Market-to-limit order (BID < PRICE < ASK)
(c)->		499	200	<-(e) Market-to-limit order (PRICE = ASK)
		498	500	<-(f) Limit order (PRICE > ASK)

"Take" order

"Make" order

(g) Orders to be executed in the closing auction

4.2.(1) Order Time Periods and Prices

Most HFT orders were placed during auction hours and provided liquidity to the market.

Result

Shares of HFT and conventional orders by price (Jan. 2013)

Chart categories (vertical axis):
- (a) Off-auction hours
- (b) Market order
- (c) Limit order (PRICE ≦ BID)
- (d) Market-to-limit order (BID < PRICE < ASK)
- (e) Market-to-limit order (PRICE = ASK)
- (f) Limit order (PRICE > ASK)
- (g) Orders to be executed in the closing auction

Horizontal axis: 0%, 20%, 40%, 60%, 80%

Legend: ■ HFT   ■ Conventional Orders

Annotations:
- (1) Small type (a) order value
- (2) Extremely small type (b) order value
- (3) Most HFT orders were not executed immediately and provided liquidity

As a result of the chi-square test, the null hypothesis that the ratio of HFT and conventional orders over all periods are the same is rejected at the 0.1% significance level. Therefore, we concluded that HFT and conventional orders exhibit different tendencies.
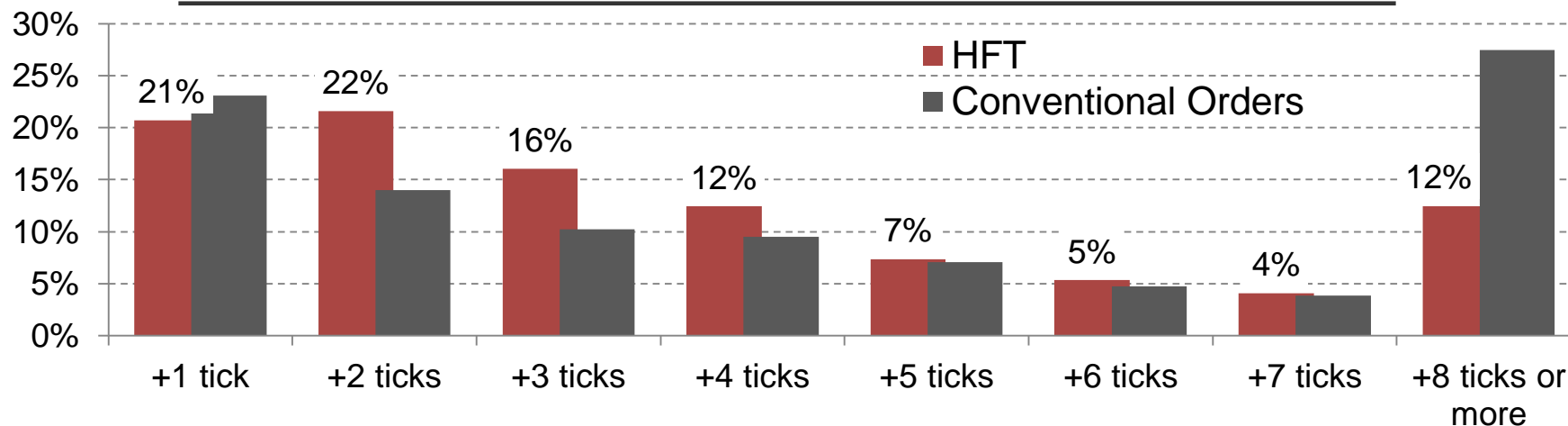
A higher proportion of HFT orders than conventional orders were placed within 4 ticks of the BBO

Perspective/Methodology

- At least 60% of HFT orders fell under this category.
- We measured the variance of such orders from the BBO.

Result

### Distribution of limit orders (PRICE > ASK) by variance from best price (Jan. 2013)

As a result of the chi-square test, the null hypothesis that the ratio of HFT and conventional orders are the same over all periods was rejected at the 0.1% significance level. Therefore, we concluded that HFT and conventional orders exhibit different tendencies.

4.3 Resting Time of Market-to-Limit Orders

> we analyzed the degree to which HFT orders contributed to liquidity by measuring their resting times in the order book

Perspective/Methodology

- Two types of orders, (d) Market-to-limit order (BID < PRICE < ASK）and (e) Market-to-limit order (PRICE=ASK and PRICE=BID), contribute most to the liquidity of the stock market.

- Since trading participants may cancel orders placed on the TSE market at any time, we analyzed the degree to which HFT orders contributed to liquidity by measuring their resting times in the order book.
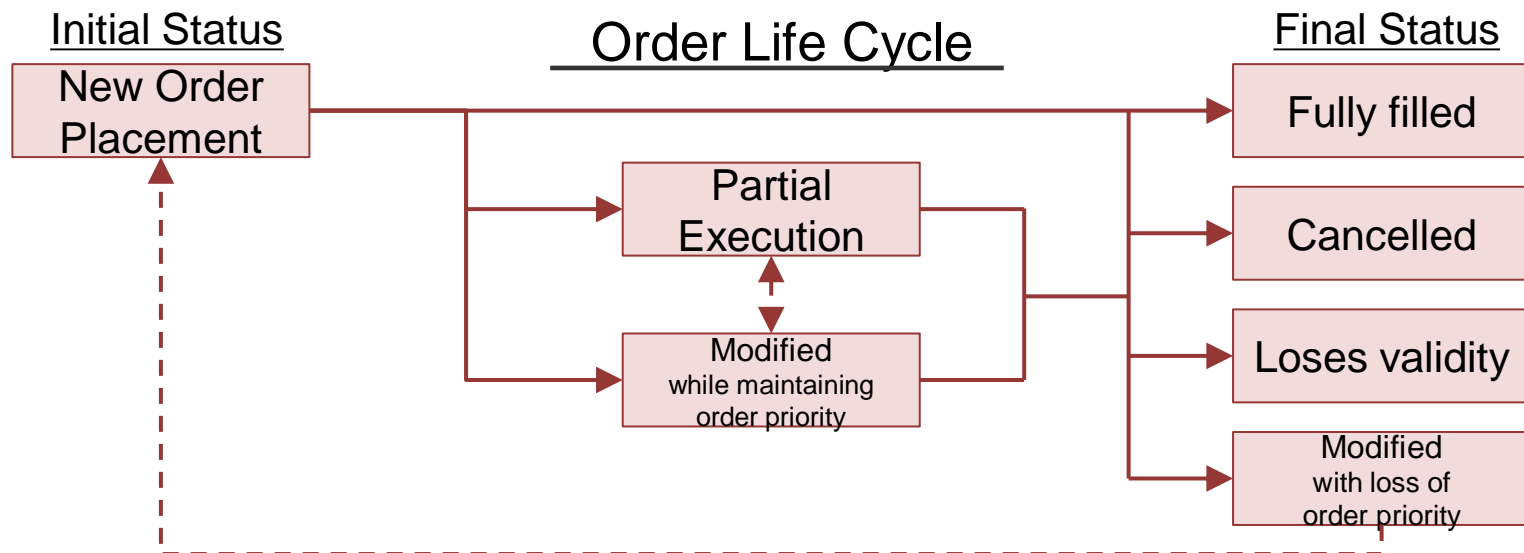
- "Partial execution" and "modified while maintaining order priority" may occur multiple times.
- Orders may go directly from initial to final status.
- Orders that were "modified with loss of order priority" were considered new orders.

4.3 Resting Time of Market-to-Limit Orders

> ## market-to-limit orders tended to be cancelled soon after placement

Result

- Both (d) and (e) type market-to-limit orders tended to be cancelled soon after placement. This tendency was common among both HFT and conventional orders.

Order Resting Time (Jan. 2013)

|	(d) Market-to-limit order (BID < PRICE < ASK)		(e) Market-to-limit order (PRICE=ASK and PRICE=BID)	
	HFT	Conventional	HFT	Conventional
Minimum value	0	0	0	0
First quartile	95	206	1,408	4,497
Median value	1,820	1,406	15,253	30,206
Third quartile	8,090	13,044	77,349	120,450
Maximum value	8,998,875	8,996,836	8,999,569	8,999,417
Average	30,701	74,828	139,972	175,734

(Note):Msec

> Generally, the ratio of "make" order value was around 60% for HFT, making up the majority of total order value

Perspective/Methodology

- We conducted analysis to determine whether HFT provided or took liquidity in terms of execution.

- For orders that were executed during auction hours, market orders and limit orders (PRICE ≦ BID) were classified as "take" orders, while orders that were matched with such "take" orders were classified as "make" orders.

- We calculated the ratio of "make" order value to total order value for HFT and conventional trading.

Result

Ratio of "make" order value in HFT and conventional trading
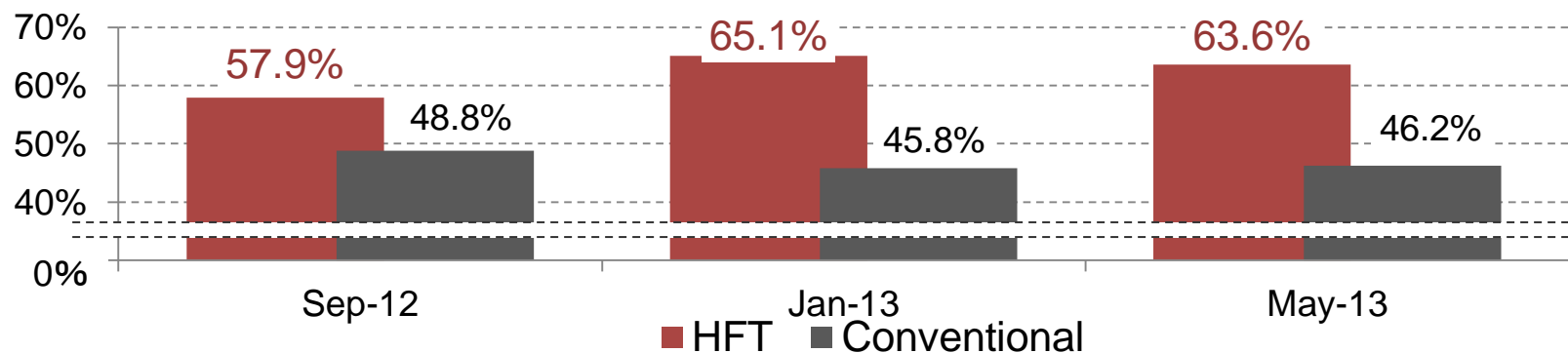
As a result of the test of proportional differences, the null hypothesis that the ratio of the value of "make orders" in HFT and conventional trading over all periods are the same was rejected at the 0.1% significance level. Therefore, we concluded that HFT and conventional trading exhibit different tendencies.
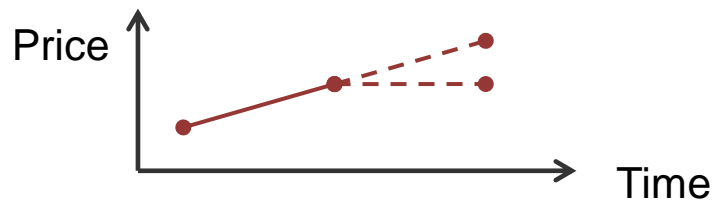
> I categorized "take" orders into the following two categories in order to analyze trading value ratio in terms of price movement
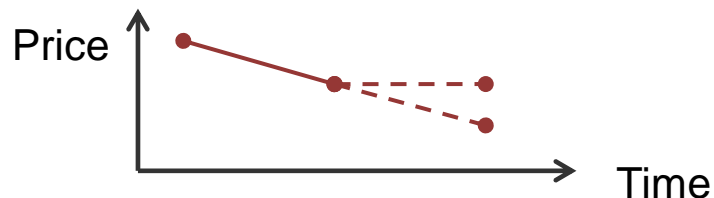
Perspective/Methodology

- Prime formation is affected by market orders and limit orders (PRICE > ASK) which take away liquidity ("take" orders).

- I categorized "take" orders into the following two categories in order to analyze trading value ratio in terms of price movement (rising or falling market).
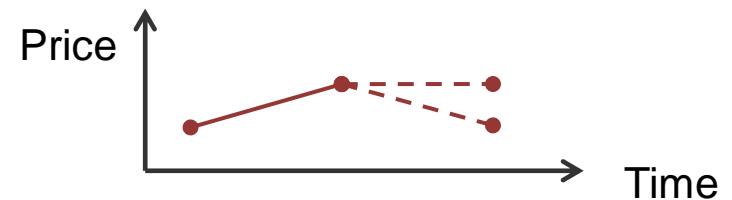
Follow price trend	Oppose price trend
Buy "take" orders in rising market	Sell "take" order in rising market
Sell "take" orders in falling market	Buy "take" order in falling market

(Each quadrant shows a Price vs. Time graph)

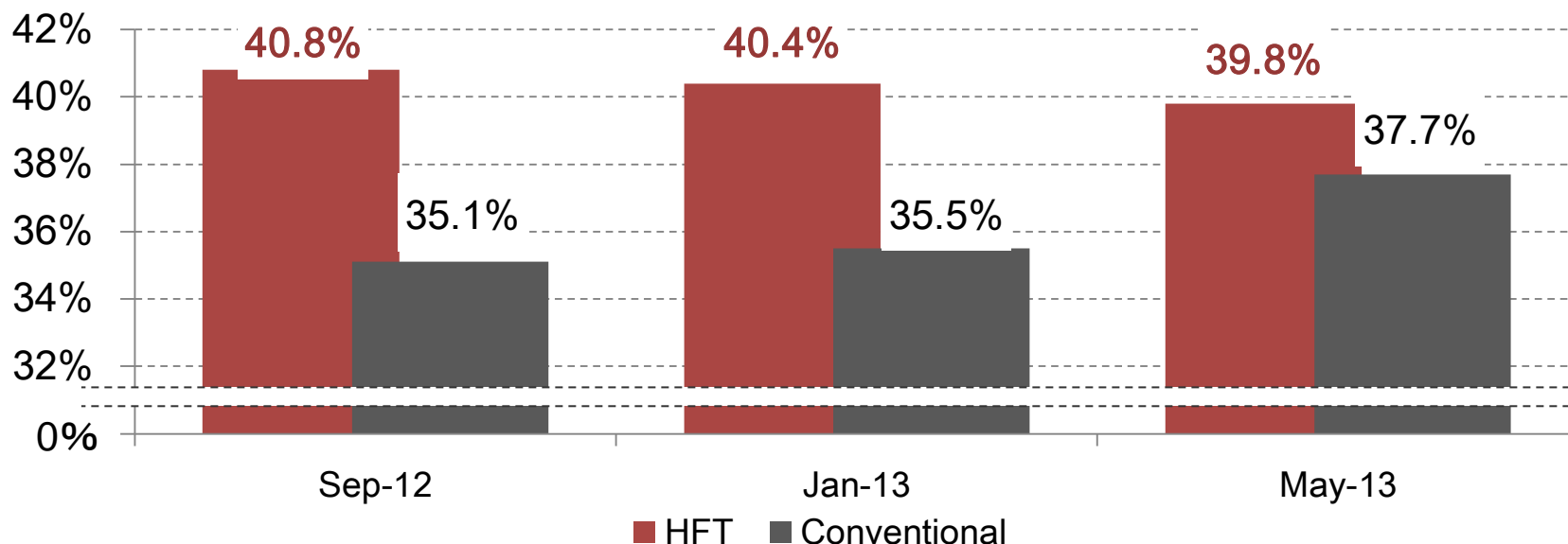●——● : Price movement before "take" order is placed
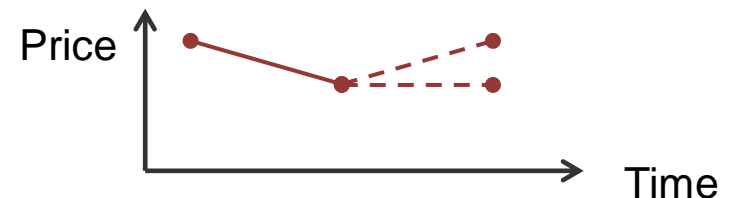
●- - -● : Price movement due to "take" order

4.5 Price Movement and Distribution of "Take" Orders

The share of "take" order opposing market moves is higher for HFT than for conventional trading, meaning HFT is more neutral than conventional trading.

Result

Share oppose price trends in value of HFT and conventional orders

As a result of the test on proportional differences, the null hypothesis that the ratio of the trading value of trend following orders in HFT and conventional trading are the same was rejected at the 0.1% significance level. Therefore, we concluded that HFT and conventional trading exhibited different order placement tendencies.

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Conclusion

> The results are consistent with the hypothesis that HFT provides liquidity to the market

| Hypothesis 1 | "HFT provides liquidity to the market" |

4.2.(1) Order Time Period and Prices

- Most HFT orders were placed during auction hours.
- There were very few market orders.
- Orders were not executed immediately and provided liquidity.

4.2.(2) Limit Orders (PRICE > ASK)

- HFT orders tended to be within 4 ticks of the BBO when compared with conventional orders.

4.3 Resting Time of Market-to-Limit Orders

- Market-to-limit orders tended to be cancelled soon after placement and HFT and conventional trading exhibited the same trend.

4.4 Trading Value by Order Type

- Generally, the ratio of "make" trading value in total HFT trading value is approximately 60%, making up the majority of overall trading value.

Conclusion

> The result is consistent with the hypothesis that HFT contributes toward smoother stock price movement.

Hypothesis 2	"HFT contributes toward smoother stock price movement"

4.5	Price Movement and Distribution of "Take" Orders

- The share of orders opposing price trends is higher for HFT than for conventional trading.

➡ The result is consistent with the hypothesis that HFT contributes toward smoother stock price movement.

Further Research

- While this study analyzed the general tendencies observed in HFT orders, it did not cover the differences in the order trends in individual stocks or analyze execution costs which directly affect investor convenience.

- Execution cost analysis or longer analysis periods were recognized as areas to be addressed in future research.

References

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