IEEE SSCI CIFEr 2016
7th Dec. 2016

Affecting Market Efficiency by Increasing Speed of Order Matching Systems on Financial Exchanges – Investigation using Agent Based Model

Takanobu Mizuta	SPARX Asset Management Co., Ltd.
Yoshito Noritake	Daiwa SB Investments Ltd.
Satoshi Hayakawa	Osaka Exchange, Inc.
Kiyoshi Izumi	The University of Tokyo

(1) Introduction

(2) Artificial Market Model

(3) Simulation Results

(4) Summary & Future Works

Speedup of Financial Exchange's System

The speed of order matching systems has been increasing due to

- Competition between Financial Exchanges
- Their investors' demand

(Example of Speedup of an order matching system)

Tokyo Stock Exchange's Arrowhead (Started from 2010)	**Latency (length of time required to transport data and match orders)**
Before Launch	3,000ms (3 seconds)
After Launch	4.5ms

Opposite Opinions in Increasing Speed

Good Point

Increasing market liquidity so that investors can trade without delay and large execution costs

conflict

Bad Point

Increasing maintenance costs of systems imposed to a Financial Exchange

What is the sufficient speed of Financial Exchange's System ?

Need Discussions

Artificial Market Simulation (Multi-Agent Simulation)

- How much speed does a Market system need?
  - No Market system implemented further high-speed: Impossible to verify by using empirical study (historical data)

- If system’s speed effect market efficiency, what are the mechanisms?
- Can investor buy or sell a stock around its fair (fundamental) price regardless of its speed?
  - Need to analyze Micro Process, but too many factors may affect stock’s price: Empirical study cannot isolate the pure contribution of speed

(1) Introduction

(2) Artificial Market Model

(3) Simulation Results

(4) Summary & Future Works

Agents (Investors) Model

Same as Mizuta et. al. 2013

* **Continuous Double Auction**: **as the real stock exchanges**
* **Simple Agent model:** **to avoid an arbitrary result**

heterogeneous 1,000 agents

each agent places an order 10,000 times

Expected Return

$$r_{e,j}^{t} = \frac{1}{\sum_i w_{i,j}} \left(w_{1,j} \log \frac{P_f}{P^t} + w_{2,j} r_{h,j}^{t} + u_j \varepsilon_j^{t} \right)$$

Fundamental | Technical | noise

$w_{i,j}$

Strategy Weight different for each agent

Order Process

$$P_{o,j}^{t} \sim N\left(P_{e,j}^{t}, P_\delta\right) \ where \ P_{e,j}^{t} = P^t \exp\left(r_{e,j}^{t}\right)$$

$$P_{e,j}^{t} > P_{o,j}^{t} \Rightarrow Buy, \ P_{e,j}^{t} < P_{o,j}^{t} \Rightarrow Sell$$

Replicate traditional Stylized Facts and Micro Structures

Latency has Micro Structure Time Scale, Millie Seconds

Model of Latency

How do we model it?

Latency: Time-lag required for data transfer and/or matching orders (The most important factor of Market's speed)

Matching System
(Inside Financial Exchange)

Match orders & Change price

New Order

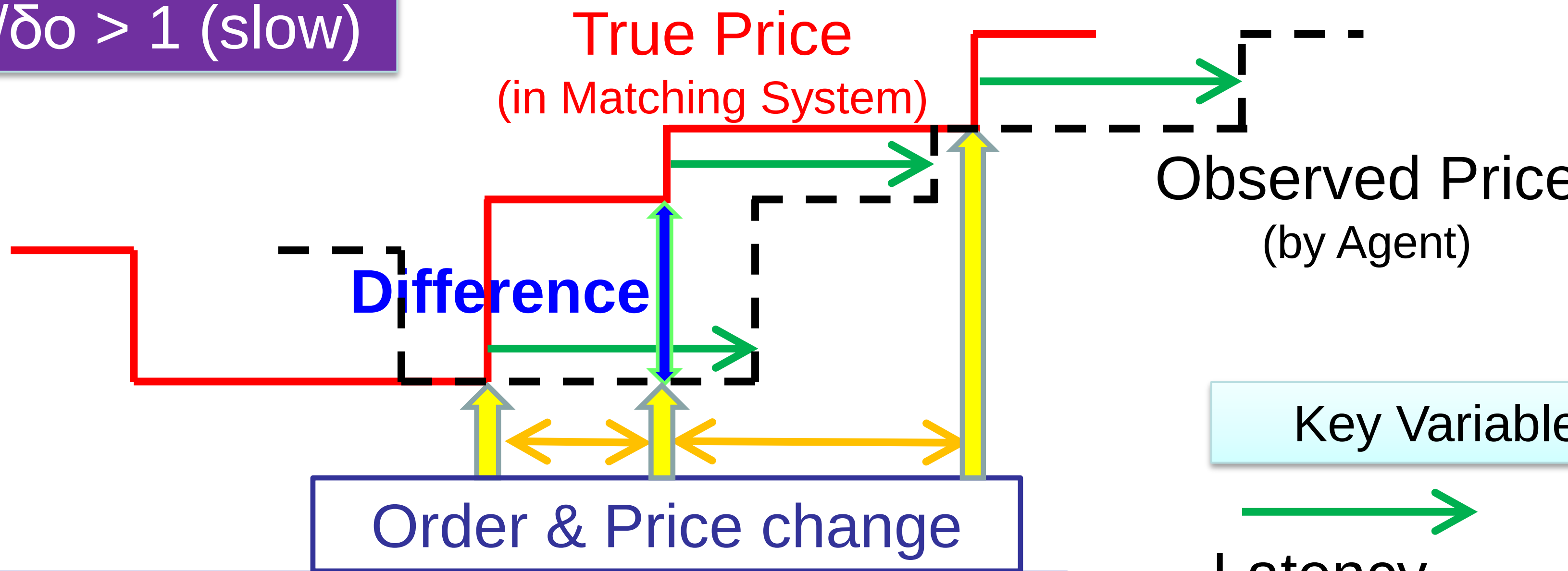
Information of the order book
(e.g. Updated Traded Price)

Agents
(Investors)

We assume finite time intervals here = **latency**

An agent recognizes the price which is delayed for a latency

δl/δo > 1 (slow)



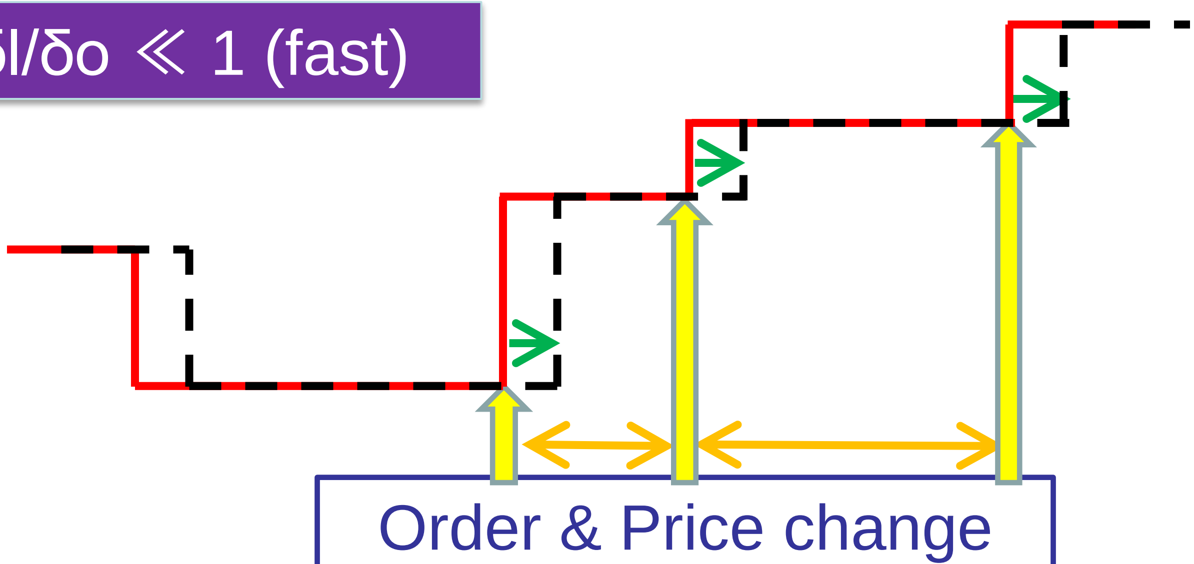
True and Observed prices are different

Key Variables

Latency
constant = δl

Order interval = δt
exponential
random numbers
Avg. = δo

δl/δo ≪ 1 (fast)



In most cases, an agent knows True Latest Price

Market Inefficiency

Market Inefficiency

$$= \frac{\text{Time Avg. of } |\text{Market Price} - \text{Fundamental Price}|}{\text{Fundamental Price}}$$

The Market Inefficiency is based on difference between market and fundamental prices.
If the price in the stock market highly deviates from its fundamental, the market was not consider to be efficient.
-> But we don't know the "true" fundamental price in real financial markets, so we can't assess correct inefficiency by empirical studies.

We can directly measure Market Inefficiency, by defining its Fundamental Price (=10,000) in Artificial Market Simulation.

Independent of time period used to calculate return

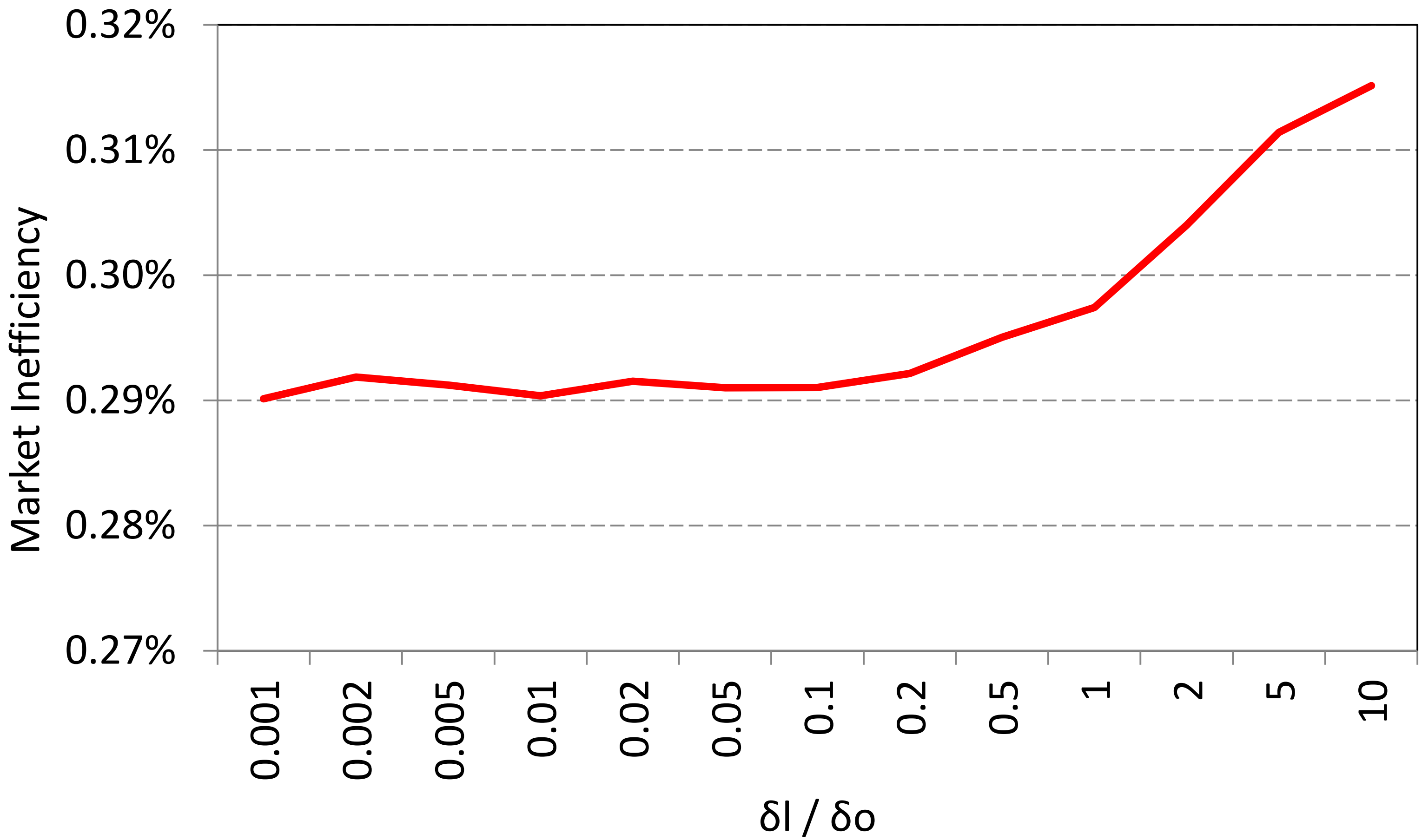
(1) Introduction

(2) Artificial Market Model

(3) Simulation Results

(4) Summary & Future Works

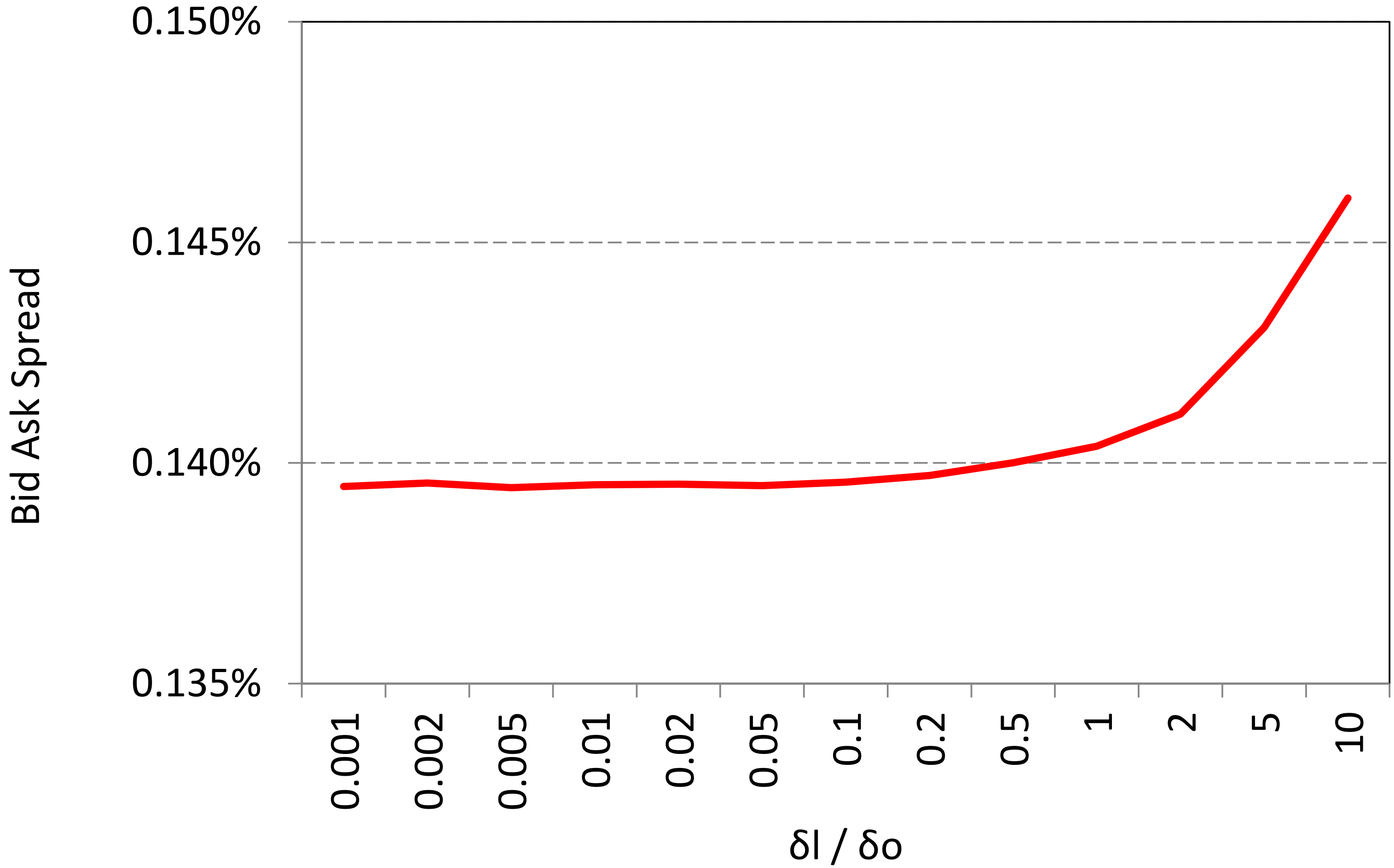
Market Inefficiencies



δI/δo > 1 : Inefficient

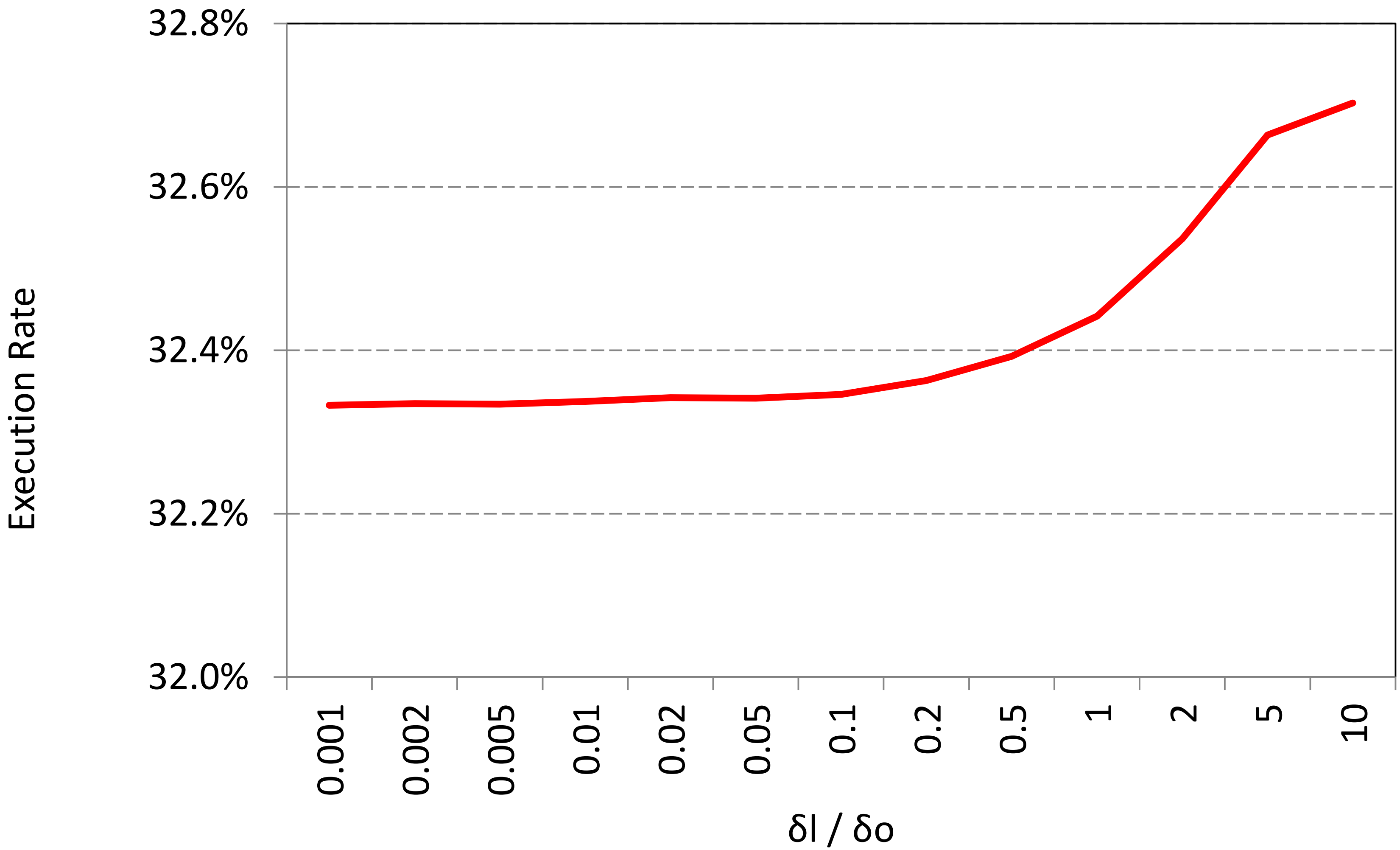
Right side δI/δo ≥ 0.5, Market becomes Inefficient

Bid Ask Spreads (per Fundamental Price)

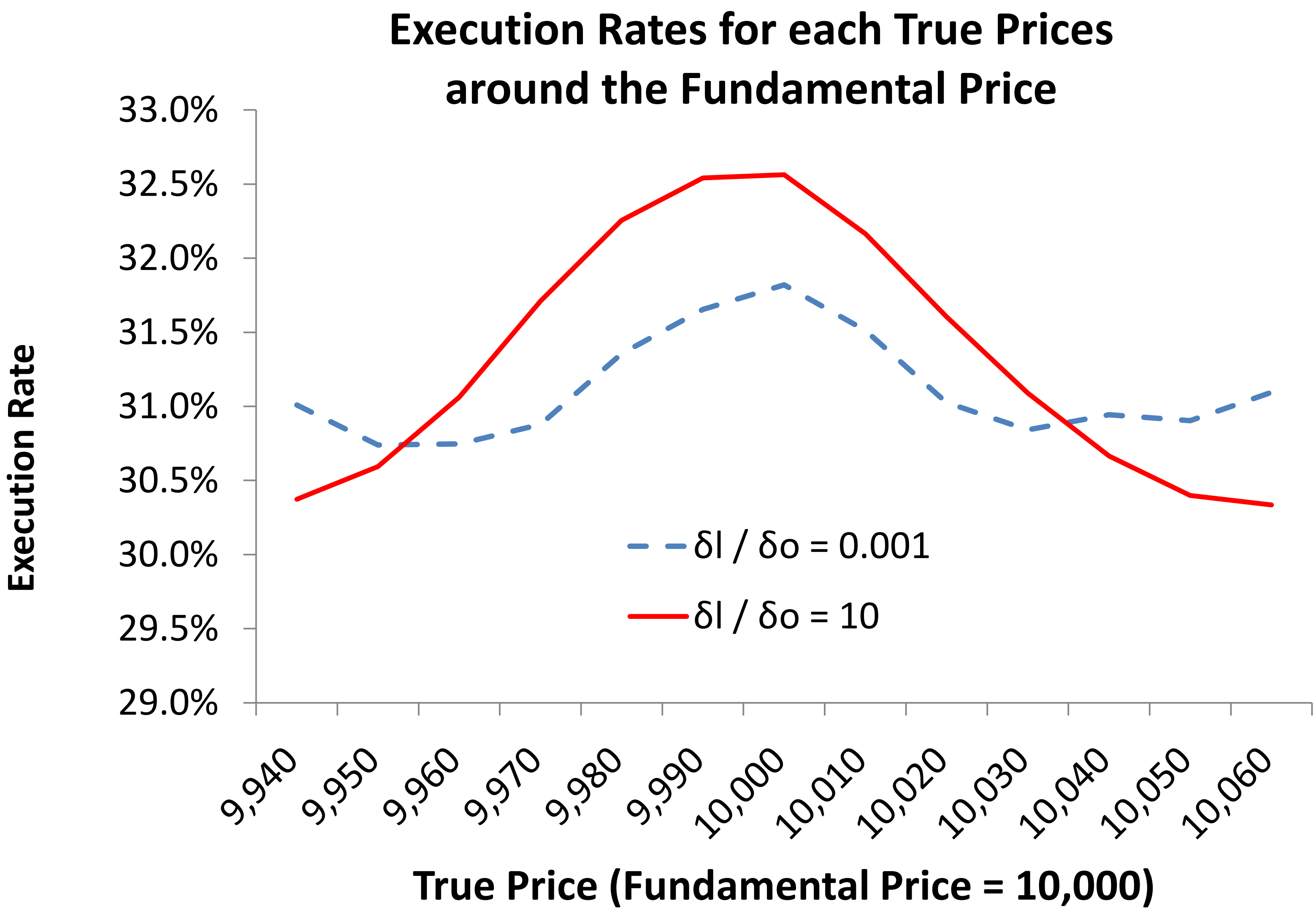


δl/δo > 1 : Wider Bid Ask Spread

Execution Rates (= Orders executed immediately / All orders)



δl/δo > 1 : Increasing Execution Rate



Increasing Execution Rate especially near the Fundamental Price$\left(P^t \sim P_f\right)$, where Technical term$(r_h^t)$ dominates an expected return of an agent

- Execution rates and Average Expected Returns of all agents* compared by δl/δo=10, 0.001 and Relationship between Observed and True prices (slow market only)

δl/δo	Relationship between Observed and True prices	Execution Rate			Avg. Expected Return of agents
		Total	Buy Market Sell Limit Orders	Sell Market Buy Limit Orders	
10 (slow)	True P. > Observed P.	32.5%	28.9%	3.5%	0.28%
	True P. < Observed P.	32.5%	3.6%	28.9%	−0.27%
0.001 (fast)	–––	31.2%	15.6%	15.6%	0.00%

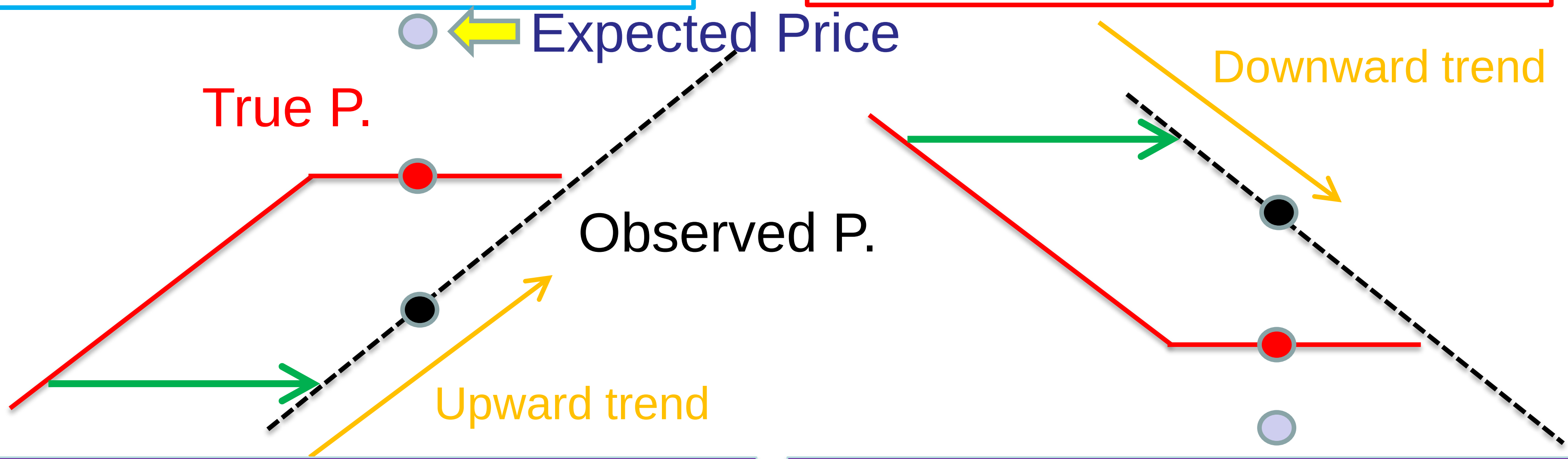
*Population of data: all executions and orders

In a slow (δl/δo) market···
True Price > Observed : Positive expected returns, Upward trend expectation
True Price < Observed : Negative expected returns, Downward trend expectation

(In a slow market)

Observed Price < True Price

Observed Price > True Price



Too High Expected Price
⇒ Market Buy order

Too Low Expected Price
⇒ Market Sell order

A trend has actually been finished around Fundamental Price.

But, agents cannot quickly modify their expected prices.

Agents then place unnecessary market orders.

Agents wouldn’t placed such orders if they knew the true price.

Mechanism of Large Latency（δl/δo>1）making Market Inefficient

Stop Upward/Downward trend

But, agents cannot quickly change their expectation ← Large Latency

Unnecessary trend following orders ← Especially near Fundamental Price

Increasing Execution Rate

Decreasing remaining orders near Market Price, relatively

Expanding Bid Ask Spread

Market becomes Inefficient

(1) Introduction

(2) Artificial Market Model

(3) Simulation Results

(4) Summary & Future Works

Summary

* The ratio（δl/δo）is key parameter,
  Latency（δl）per Average of Order interval（δo）

* the sufficient speed of Exchange's System is δl < δo（δt）.

* Trend stops in slow market (with Large Latency)
  -> agents cannot change Estimate price, quickly
  -> Unnecessary market following trades near fundamental
  -> Increasing Execution Rate -> Expanding Bid Ask Spread
  -> Market becomes Inefficient

Future Works

* We should discuss it with more kinds of agents and situations.（example: High Frequency Trading Agents, Crowded Orders immediately after great market impacting information)

Appendix

Definition of Market/Limit order | In this study

A little difference from actual market

All agents decide an order price

sell

order book

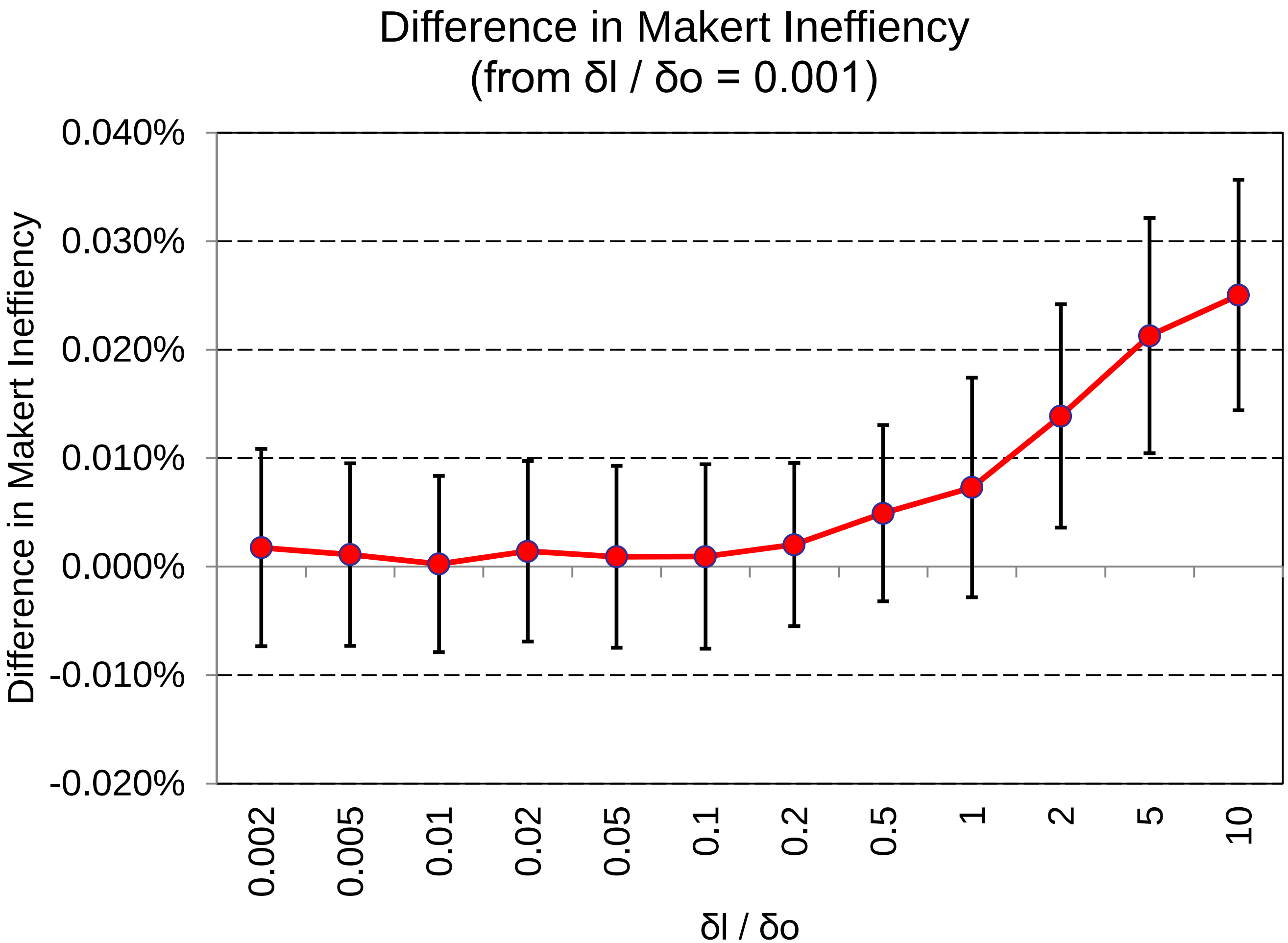
buy

	sell	price	buy	
limit	84	101		market
	176	100		
market		99	2	limit
		98	77	

Exist matching order
Order executed immediately

No matching order
Order not executed immediately

Agents decide an order price,
if exist matching order, market order else limit order



δl / δo > 2 : be Inefficient significantly