Impacts of Speedup of Market System on Price Formations using Artificial Market Simulations

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(1) Introduction
(2) Artificial Market Model
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(4) Empirical Study to Compare
(5) Summary & Future Works
Speedup of Exchange System

Because of competition between Markets and big investors demands

Increasing liquidity by increasing providing liquidity traders

Increasing cost for systems of Markets and investors

How much speedup is best?
Does Market speed purely effect market efficiency?

- So many factors cause price formation:
  An empirical study cannot isolate the pure contribution

What are Mechanisms?

- Analysis Micro Process: Impossible by empirical study

How much enough speedup is Market system?

- No Market experienced more Speedup:
  Impossible by empirical study

Artificial Market Simulation
(Multi-Agent Simulation)
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Model of Latency

Latency: Most important factor of Market speed

Needed time for matching orders and/or data transfer

Market

Matching orders & Changing traded prices

Order

New Traded Price

Agents (Investors)

Only here, it needs finite time (latency).
True Price

Observed Price

Latency constant = $\delta_l$

Order interval exponential random numbers Avg. = $\delta_o$

$\delta l / \delta o > 1$

$\delta l / \delta o \ll 1$

True and Observed prices are divergent

Most cases, agents know True Price
Continuous Double Auction: to implement realistic latency

Simple Agent model: to avoid arbitrary result

* Same Model, Mizuta et. al. 2013


**Expected Return**

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

- **Strategic Weight**
- **Fundamental**
- **Technical**
- **Noise**

- Different for each agent

Replicate traditional Stylized Facts and Replicate Micro Structures

Latency has Micro Structure Time Scale, MilliSeconds

heterogeneous 1000 agents
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$\delta l/\delta o > 1$: increasing Volatility, decreasing Kurtosis (flatter fat tail)  
⇒ be inefficiency?
Volatility & Kurtosis ($\delta r/\delta o=10$)

- Volatility: 0.00% to 0.12%
- Kurtosis: 0.00 to 2.5

$\delta l/\delta o > 1$: Volatility is flat, Increasing Kurtosis (fatter fat tail) => be inefficiency?

We should use the way independent of return calculation period
Market Inefficiency

\[
\text{Market Inefficiency} = \frac{\text{Average of } |\text{Market Price} - \text{Fundamental Price}|}{\text{Fundamental Price}}
\]

If Market was prefect efficiency, Market prices were exactly same as the fundamental price.

This Market Inefficiency is defined actual difference between market and fundamental prices.

\[\rightarrow\] We can not use this definition for an empirical study.

Experimental study for human sometimes use this definition.

We can measure Market Inefficiency Directly, not estimation in simulation studies.

Independent of return calculation period
Market Inefficiency

δl / δo > 1 : be Inefficiency

Right side δl / δo = 0.5, Market becomes Inefficiency
\( \frac{\delta l}{\delta o} > 1 \): Expanding Bit Ask Spread
\( \delta l / \delta o > 1 \): Increasing Execution Rate
Increasing Execution Rate especially near the fundamental price

Execution Rate for True Prices
Fundamental Price = 10,000

- $\frac{\delta l}{\delta o} = 0.001$
- $\frac{\delta l}{\delta o} = 10$
<table>
<thead>
<tr>
<th>$\delta l / \delta o$</th>
<th>Execution Rate</th>
<th>Avg. Estimated Return of agents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum Buy Market</td>
<td>Sell Market Buy Limit Orders</td>
</tr>
<tr>
<td>Observed P. $&lt;$ True P.</td>
<td>32.5%</td>
<td>28.9%</td>
</tr>
<tr>
<td>Observed P. $&gt;$ True P.</td>
<td>32.5%</td>
<td>3.6%</td>
</tr>
<tr>
<td>0.001</td>
<td>31.2%</td>
<td>15.6%</td>
</tr>
</tbody>
</table>

Observed Price $<$ True Price: More Buy Market Orders: Plus estimated returns
Observed Price $>$ True Price: More Sell Market Orders: Minus estimated returns
Unnecessary market following trades

But, agents cannot change Estimate price, quickly

Observed Price < True Price
- Too High Estimated P. ⇒ Market Buy order
  ↑ If agents knew True P. they did not order.

Observed Price > True Price
- Too Low Estimated P. ⇒ Market Sell order
  ↑ If agents knew True P. they did not order.

Stop market trend

Observations:
- Observed Price > True Price
- Observed Price < True Price
- True P.
- Estimated P.
- Upward trend

Fundamental Price (near Fundamental Price)
Mechanism of Large Latency ($\delta l/\delta o > 1$) making Market Inefficiency

Stop market trend

But, agents cannot change Estimate price, quickly

Unnecessary market following trades

Increasing Execution Rate

Decreasing Limit orders near Market Price, relatively

Expanding Bit Ask Spread

Market becomes Inefficiency
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<table>
<thead>
<tr>
<th>No.</th>
<th>Analysis Period</th>
<th>arrowhead</th>
<th>Order No. Avg. for day Avg. names</th>
<th>Calculation Period (min)</th>
<th>Avg. $\delta o$ (ms) = Period (ms) / Order No.</th>
<th>Latency $\delta l$ (ms)</th>
<th>$\delta l / \delta o$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>December 2009 (one month)</td>
<td>Before</td>
<td>2,833</td>
<td>270</td>
<td>5,718</td>
<td>3,000</td>
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<tr>
<td>2</td>
<td>2 August 2010 – 18 November 2011</td>
<td></td>
<td>14,621</td>
<td>355</td>
<td>1,457</td>
<td>4.5</td>
<td>0.003</td>
</tr>
<tr>
<td>3</td>
<td>21 November 2011 – 26 November 2014</td>
<td>After</td>
<td>28,974</td>
<td>385</td>
<td>797</td>
<td>4.5</td>
<td>0.006</td>
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<tr>
<td>4</td>
<td>27 October 2014 – 26 November 2014</td>
<td></td>
<td>66,044</td>
<td>385</td>
<td>350</td>
<td>4.5</td>
<td>0.013</td>
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<tr>
<td>5</td>
<td>31 October 2014 (one day)</td>
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<td>87,109</td>
<td>385</td>
<td>265</td>
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<tr>
<td>6</td>
<td>4 November 2014 (one day)</td>
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<td>114,027</td>
<td>385</td>
<td>203</td>
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<td>0.022</td>
</tr>
</tbody>
</table>

Before arrowhead

It is Possible that Market is Chronically Inefficient

After arrowhead

Market is NOT Chronically Inefficient by the Mechanism we showed

1: Uno, 2012
2～6: In this study
Even though near 31 October 2014, Bank of Japan announced “Expansion of the Quantitative and Qualitative Monetary Easing”, Market is NOT Chronically Inefficient by the Mechanism we showed
Market is NOT Inefficient even for one minutes

31 October 2014 at 13:44 Japan time, Bank of Japan announced it. For a few minutes after the announcement, orders are crowded.

We cannot deny market inefficiency for less than one minutes.
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Summary

* The ratio \( \frac{\delta l}{\delta o} \) is key parameter,
  Latency \( \delta l \) per Order Interval \( \delta o \)

* Enough fast market system is required \( \delta l << \delta o \).

* Stop market trend -> Large Latency
  -> agents cannot change Estimate price, quickly
  -> Unnecessary market following trades
  -> Increasing Execution Rate -> Expanding Bit Ask Spread
  -> Market becomes Inefficiency

* Before arrowhead:
  It is Possible that Market is Chronically Inefficient

* After arrowhead:
  Market is NOT Inefficient even for one minutes
* We should discuss the case of very crowded orders for less than one minutes, for example, at announced great market impacting information.
  -> needed simulation and empirical studies
  <- Certainly, such very short time scale event does not effect to general investors much.
  <--> It may effect to High Frequency Trading very much.

* We should discuss it in more kinds of agents.
  (For example: High Frequency Trading such as Market Maker strategy, Arbitrage Strategy, and so on.)
Appendix
A little difference from actual market

All agents decide an order price

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

<table>
<thead>
<tr>
<th></th>
<th>sell</th>
<th>order book</th>
<th>buy</th>
</tr>
</thead>
<tbody>
<tr>
<td>sell</td>
<td>84</td>
<td>101</td>
<td>limit</td>
</tr>
<tr>
<td></td>
<td>176</td>
<td>100</td>
<td>market</td>
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<tr>
<td>market</td>
<td>99</td>
<td>2</td>
<td>limit</td>
</tr>
<tr>
<td></td>
<td>98</td>
<td>77</td>
<td></td>
</tr>
</tbody>
</table>