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

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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)
Latency

Most important factor of Market speed

Needed time for matching orders
and/or data transfer

Only here, it needs finite time (latency).
True & Observed prices are difference

Most cases, agents know True Price

$\delta l / \delta o > 1$

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

Order interval
exponential random numbers
Avg. = $\delta o$

Latency constant = $\delta l$

Difference

Order & Price change

True Price

Observed Price
Same Model as JPX Working Paper vol.2; Mizuta et. al. 2013

* Continuous Double Auction: to implement realistic latency
* Simple Agent model: to avoid arbitrary result

heterogeneous 1000 agents

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

Replicate traditional Stylized Facts and Replicate Micro Structures

Latency has Micro Structure Time Scale, MilliSeconds

\[ w_{i,j} \]

\[ \text{Strategy Weight} \]

\[ \text{Different for each agent} \]
(1) Introduction
(2) Artificial Market Model
(3) Simulation Results
(4) Empirical Study to Compare
(5) Summary & Future Works
\( \frac{\delta l}{\delta o} > 1: \) increasing Volatility, decreasing Kurtosis (flatter fat tail) 
\( \Rightarrow \) be inefficient?

\( \frac{\delta l}{\delta o}: \) latency / order interval 
\( \frac{\delta r}{\delta o}: \) return calculation period / order interval
Volatility & Kurtosis ($\delta r / \delta o = 10$)

- Volatility
- Kurtosis

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

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

If Market was perfect efficient, Market prices were exactly same as the fundamental price.

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

-> We can not use this definition for an empirical study.
   Experimental study for human sometimes uses this definition.

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

Independent of return calculation period
\[
\frac{\delta l}{\delta o} > 1: \text{be Inefficient}
\]

Right side \( \frac{\delta l}{\delta o} = 0.5, \) Market becomes Inefficient
\[ \frac{\delta l}{\delta o} > 1 : \text{Wider Bid Ask Spread} \]
$\delta l / \delta o > 1$ : Increasing Execution Rate
Increasing Execution Rate especially near the fundamental price

Execution Rate for True Prices
Fundamental Price = 10,000
<table>
<thead>
<tr>
<th>$\delta l / \delta o$</th>
<th>Observed P. $&lt; \text{True P.}$</th>
<th>Observed P. $&gt; \text{True P.}$</th>
<th>Execution Rate</th>
<th>Avg. Estimated Return of agents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Buy Market</strong></td>
<td><strong>Sell Market</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Sum</strong></td>
<td><strong>Sell Limit</strong></td>
</tr>
<tr>
<td>10</td>
<td>Observed P. $&lt; \text{True P.}$</td>
<td></td>
<td>32.5%</td>
<td>28.9%</td>
</tr>
<tr>
<td>0.001</td>
<td>Observed P. $&gt; \text{True P.}$</td>
<td>---</td>
<td>32.5%</td>
<td>3.6%</td>
</tr>
<tr>
<td></td>
<td>0.001</td>
<td>31.2%</td>
<td>15.6%</td>
<td>15.6%</td>
</tr>
</tbody>
</table>

Observed Price $< \text{True Price}$: More Buy Market Orders: Positive estimated returns

Observed Price $> \text{True Price}$: More Sell Market Orders: Negative estimated returns
Unnecessary market following trades

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.

But, agents cannot change Estimate price, quickly

Stop market trend

Unnecessary market following trades
Mechanism of Large Latency ($\delta l/\delta o > 1$) making Market Inefficient

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 Bid Ask Spread

Market becomes Inefficient

Large Latency

Especially near Fundamental Price

Mechanism of Large Latency ($\delta l/\delta o > 1$) making Market Inefficient
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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>
<td>0.525</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>
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<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>
</tr>
<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>
</tr>
<tr>
<td>5</td>
<td>31 October 2014 (one day)</td>
<td></td>
<td>87,109</td>
<td>385</td>
<td>265</td>
<td>4.5</td>
<td>0.017</td>
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<tr>
<td>6</td>
<td>4 November 2014 (one day)</td>
<td></td>
<td>114,027</td>
<td>385</td>
<td>203</td>
<td>4.5</td>
<td>0.022</td>
</tr>
</tbody>
</table>

1: Uno, 2012
2~6: In this study

**Before Arrowhead**

It is Possible that Market is Chronically Inefficient

**After Arrowhead**

Market is NOT Chronically Inefficient by the Mechanism we showed
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
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 minute.

Market is NOT Inefficient even for one minute
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* The ratio \( \frac{\delta l}{\delta o} \) is key parameter, Latency \( (\delta l) \) per Order Interval \( (\delta o) \)

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

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

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

* After arrowhead:
  Market is NOT Inefficient even for one minute
* We should discuss the case of very crowded orders for less than one minute, 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
Definition of Market/Limit order

In this study

A little difference from actual market

All agents decide an order price

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

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