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# Investigation of Frequent Batch Auctions using Agent Based Model

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(1) Introduction

(2) Artificial Market Model

(3) Simulation Result

(4) Summary and Future Works

(1) Introduction

(2) Artificial Market Model

(3) Simulation Result

(4) Summary and Future Works

# Increasing Speed of Order Matching Systems on Financial Exchanges and Frequent Batch Auction (FBA)

**FBA: GOOD**

Increasing Speed: causes socially wasteful arms race for speed and these costs are passed to other investors as execution costs.

Budish et al.(2015)

Proposed FBA which reduces the value of speed advantages

**Conflict**

**FBA: BAD**

Increasing Speed: causes increasing liquidity by increasing orders of Market Maker Strategies who earn profits by providing liquidity.

Otsuka(2014)

On FBA, profit risks of Market Maker Strategies increase, then the strategies can NOT continue to trade, in the result execution costs increase.

# Difficulty of Empirical Study

- ✓ Empirical studies cannot be conducted to investigate situations that have never occurred in actual financial markets, changing from Continuance Double Auction (CDA) to Frequent Batch Auction (FBA).
- ✓ So many factors cause price formation and liquidity in actual markets, an empirical study cannot be conducted to isolate the direct effect of latency to price formation.

**Artificial Market Simulation**

- ✓ can isolate the pure contribution of the changes to the price formation
- ✓ can treat the changes that have never been employed

# Features and contributions of Artificial Market Model

(Agent Based Model)

- ✓ can isolate the pure contribution of the changes to the price formation
- ✓ can treat the changes that have never been employed
  - ✓ The artificial market simulation needs to show "possible" mechanisms affecting the price formation by many simulation runs.
  - ✓ The possible mechanisms shown by these simulation runs will give us new intelligence and insight about effects of the changes to price formation in actual financial markets.
  - ✓ It is not a primary purpose for the artificial market to replicate specific macro phenomena only for a specific asset or a specific period.

- ✓ Recently, some artificial market studies contributed to discussion what financial regulations and rules should be (Mizuta 2016)
- ✓ Not only academies but also financial regulators and stock exchanges are recently interested in multi-agent simulations such artificial market models to investigate regulations and rules of financial markets

Battiston et al. (2016) SCIENCE (most authoritative academic journal same as NATURE)

- ✓ 'since the 2008 crisis, there has been increasing interest in using ideas from complexity theory (using network models, multi-agent models, and so on) to make sense of economic and financial markets'
- ✓ There is strong empirical evidence of monetary and fiscal policies and financial regulation designed to weaken positive feedback are successful in stabilizing experimental macroeconomic systems when properly calibrated. Complexity theory provides mathematical understanding of these effects.

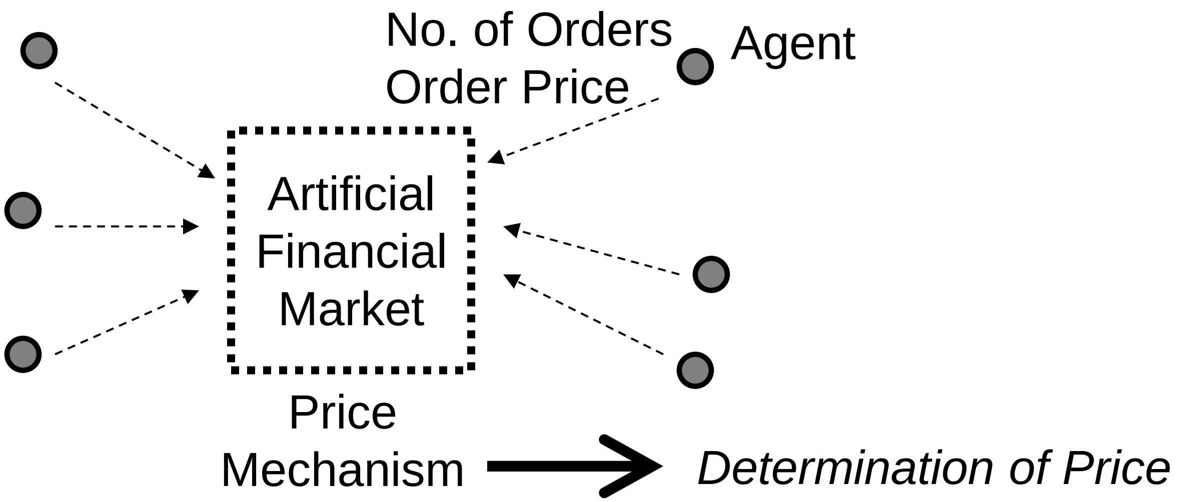
# Composition of Artificial Market Model

(Agent Based Model)

Artificial Market built in a Computer
Multi Agents ＋ Price Mechanism

- Multi Agents (Artificial Traders)
  Artificial Traders molded by computer program
  They determine Buy/Sell, Order Price and No. of Orders obeying the rules of orders

- Price Mechanism (Artificial Financial Market)
  It determines the trade price aggregating agents orders



(1) Introduction

(2) Artificial Market Model

(3) Simulation Result

(4) Summary and Future Works

# 2.1 Price Mechanism

## Introduce: Batch Auction Interval (δt)

To be comparable Continuance Double Auction (CDA,δt=1) with Frequent Batch Auction (FBA,δt>1)

| | | | | | |
|---|---|---|---|---|---|
| New Order -> | | Sell 99 | Buy 100 | Buy 101 | Sell 98 |
| time | t=0 | t=1 | t=2 | t=3 | t=4 |

**CDA δt=1**

t=0

| Sell | Price | Buy |
|---|---|---|
| 1 | 101 | |
| 1 | 100 | |
| | 99 | 1 |
| | 98 | 1 |

t=1

| Sell | Price | Buy |
|---|---|---|
| 1 | 101 | |
| 1 | 100 | |
| ~~1~~ | 99 | ~~1~~ |
| | 98 | 1 |

Immediately Executed

t=2

| Sell | Price | Buy |
|---|---|---|
| 1 | 101 | |
| ~~1~~ | 100 | ~~1~~ |
| | 99 | |
| | 98 | 1 |

Immediately Executed

t=3

| Sell | Price | Buy |
|---|---|---|
| ~~1~~ | 101 | ~~1~~ |
| | 100 | |
| | 99 | |
| | 98 | 1 |

Immediately Executed

t=4

| Sell | Price | Buy |
|---|---|---|
| | 101 | |
| | 100 | |
| | 99 | |
| ~~1~~ | 98 | ~~1~~ |

Immediately Executed

**FBA δt=4**

t=0

| Sell | Price | Buy |
|---|---|---|
| 1 | 101 | |
| 1 | 100 | |
| | 99 | 1 |
| | 98 | 1 |

t=1

| Sell | Price | Buy |
|---|---|---|
| 1 | 101 | |
| 1 | 100 | |
| 1 | 99 | 1 |
| | 98 | 1 |

Not Executed

t=2

| Sell | Price | Buy |
|---|---|---|
| 1 | 101 | |
| 1 | 100 | 1 |
| 1 | 99 | 1 |
| | 98 | 1 |

Not Executed

t=3

| Sell | Price | Buy |
|---|---|---|
| 1 | 101 | 1 |
| 1 | 100 | 1 |
| 1 | 99 | 1 |
| | 98 | 1 |

Not Executed

t=4

| Sell | Price | Buy |
|---|---|---|
| 1 | 101 | ~~1~~ |
| 1 | 100 | ~~1~~ |
| ~~1~~ | 99 | 1 |
| ~~1~~ | 98 | 1 |

Executed at specific time

Different results: Executed Volume, Remained Orders and Pt

Pt: (Tentative)Market Price:
Executed price if orders were executed at the time

# 2.2.1 Normal Agent（NA）

j: agent number (1,000 agents)
ordering in number order

t: tick time

**Historical Return**

$$r_{h,j}^{t} = \log(P^{t} / P^{t-\tau_j})$$

**Technical**

**Expected Return of each NA**

$$r_{e,j}^{t} = \frac{1}{\sum_i w_{i,j}} \left( w_{1,j} \log \frac{P_f}{P^t} + w_{2,j} r_{h,j}^{t} + w_{3,j} \varepsilon_j^t \right)$$

**Parameters for agents**

$w_{i,j}$ and $\tau_j$

Random of Uniform Distribution

| | |
|---|---|
| $w_{i,j}$ | i=1,3: 0〜1 |
| | i=2: 0〜10 |
| $\tau_j$ | 0〜10000 |

**Fundamental**

$P_f$ Fundamental Price
10000 = constant

$P^t$ Market Price at t

**noise**

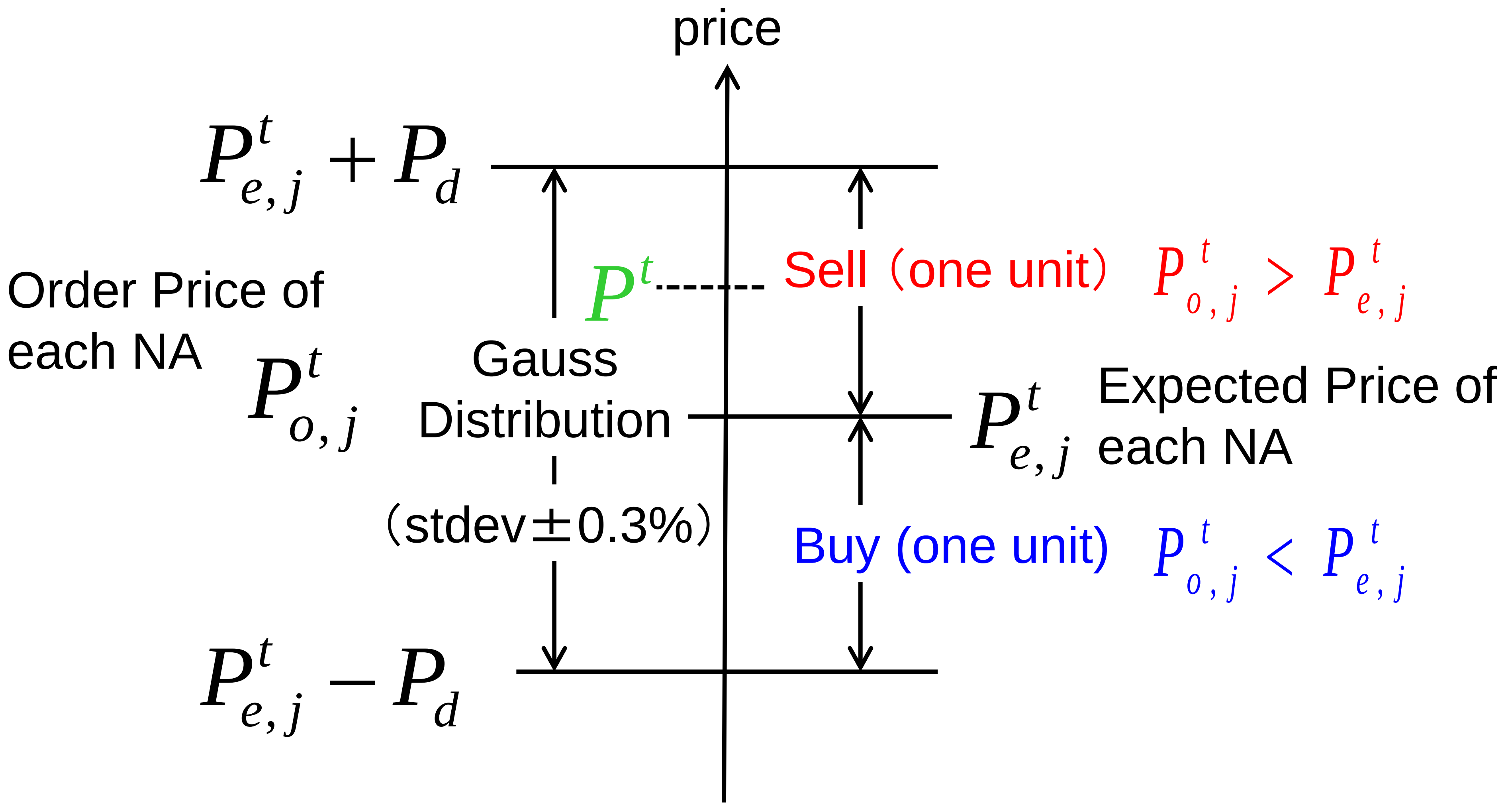
$\varepsilon_j^t$
Random of Normal Distribution
Average=0
σ=3%

**Expected Price of each NA**

$$P_{e,j}^{t} = P^{t} \exp(r_{e,j}^{t})$$

# Order Price and Buy or Sell

Order Prices are covered widely in Order Book




To replicate many waiting limit orders,
order price is scattered around expected price

# 2.2.2 Market Maker Agent（MM）

Order both Sell and Buy at once

| Sell | Price | Buy | |
|---|---|---|---|
| | 10011 | | |
| 1 | 10010 | | |
| | 10009 | | |
| | 10008 | | |
| | 10007 | | |
| | 10006 | | ← $P_{fair}$ |
| | 10005 | | |
| | 10004 | | ← $P_{spread}$ |
| | 10003 | | |
| | 10002 | 1 | |
| | 10001 | | |
| | 10000 | | |

$P_{spread}$ → (10010 to 10006)

Order every time by a batch auction

| Sell | Price | Buy | |
|---|---|---|---|
| 1 | 10011 | | |
| 1 | 10010 | | |
| | 10009 | | |
| | 10008 | | |
| | 10007 | | |
| | 10006 | | ← $P_{fair}$ |
| | 10005 | | |
| | 10004 | | |
| | 10003 | 1 | |
| | 10002 | 1 | |
| | 10001 | | |
| | 10000 | | |

- ✓ Order both Sell and Buy at once
  - Buy: $P_{fair} + P_{spread}$
  - Sell: $P_{fair} - P_{spread}$
- ✓ Order every time
  - → Cancel all its orders immediately after a batch auction

A whole number of orders Do not depend on δt
(amount of liquidity supply is constant)

# 4 kinds of MM

- ✓ Simple MM

  $P_{fair} = P^t$

  Holding position risk is very high: impracticable

- ✓ Position MM［Kusada 2014］

  $P_{fair} = (1 - kS^3)P^t$    S: Holding Position of MM, k: constant

  Remain over night risk: impracticable

- ✓ Position MM3, Position MM4［Our Original］

  It trade making position Zero Within Last 2,000 time steps in One day(20,000 time steps)

  To eliminate over night risk

<u>Position MM3</u>

<u>Do not order increasing position</u>

In the case of negative position,
within last 2,000 time steps

| | Sell | Price | Buy | |
|---|---|---|---|---|
| | ✗↑ | 10011 | | |
| Do not order | ↑ | 10010 | | |
| | | 10009 | | ← Pfair |
| | | 10008 | | |
| | | 10007 | 1 | |

<u>Position MM4</u>

<u>Change order price that of opposite side (buy/sell)</u>

In the case of negative position,
within last 2,000 time steps

| Sell | Price | Buy | |
|---|---|---|---|
| | 10011 | 1 | ←change order price here |
| | 10010 | | |
| | 10009 | | ← Pfair |
| | 10008 | | |
| | 10007 | | |

(1) Introduction

(2) Artificial Market Model

(3) Simulation Result

(4) Summary and Future Works

# 3.1 Order Spread (Pspread) and Execution Rate of MM

| Execution Rate of MM | | Pspread/Pf 0.03% | 0.10% | 0.30% | 1.00% |
|---|---|---|---|---|---|
| δt | 1(CDA) | 8.06% | 1.53% | 0.00% | 0.00% |
| | 2 | 6.30% | 0.88% | 0.00% | 0.00% |
| | 5 | 3.93% | 0.37% | 0.00% | 0.00% |
| | 10 | 2.47% | 0.14% | 0.00% | 0.00% |
| | 20 | 1.49% | 0.02% | 0.00% | 0.00% |
| | 50 | 0.77% | 0.00% | 0.00% | 0.00% |
| | 100 | 0.48% | 0.00% | 0.00% | 0.00% |
| | 200 | 0.32% | 0.00% | 0.00% | 0.00% |
| | 500 | 0.21% | 0.00% | 0.00% | 0.00% |
| | 1000 | 0.22% | 0.00% | 0.00% | 0.00% |

In the case of Position MM4

δt is Larger (FBA), Execution Rate of MM is Smaller

Decrease Liquidity Supply

# 3.2 Holding Position of several kinds of MM

| Average of ‖S‖ | | Simple MM | | Position MM | | Position MM3 | | Position MM4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Whole Period | End Period on a day | Whole Period | End Period on a day | Whole Period | End Period on a day | Whole Period | End Period on a day |
| δt | 1(CDA) | 12,357 | 12,371 | 3.18 | 3.08 | 2.90 | 0.00 | 2.89 | 0.00 |
| | 2 | 17,422 | 17,441 | 3.10 | 3.25 | 2.79 | 0.00 | 2.79 | 0.00 |
| | 5 | 4,409 | 4,414 | 3.87 | 3.95 | 3.48 | 0.00 | 3.48 | 0.00 |
| | 10 | 1,744 | 1,744 | 4.44 | 4.34 | 4.01 | 0.02 | 3.96 | 0.00 |
| | 20 | 548 | 548 | 4.84 | 4.71 | 4.52 | 0.78 | 4.35 | 0.00 |
| | 50 | 384 | 385 | 5.27 | 5.14 | 5.02 | 2.63 | 4.63 | 0.00 |
| | 100 | 369 | 370 | 5.57 | 5.51 | 5.56 | 4.26 | 4.80 | 0.00 |
| | 200 | 174 | 174 | 5.91 | 6.11 | 5.92 | 5.69 | 4.38 | 0.00 |
| | 500 | 72 | 71 | 5.75 | 6.06 | 5.70 | 5.81 | 2.32 | 0.03 |
| | 1000 | 290 | 290 | 5.94 | 6.11 | 5.61 | 5.80 | 1.76 | 0.06 |

Pspread/Pf = 0.03%

δt is Larger (FBA), only Position MM4 can make its positon Zero

# 3.3 Final Profit

| | | Final Profit of MM /Pf | Average of $\|\|S\|\|$ Whole Period | Average of $\|\|S\|\|$ End Period on a day | Execution Rate of MM | Execution Rate of NA |
|---|---|---|---|---|---|---|
| δt | 1(CDA) | 51.98 | 2.89 | 0.00 | 8.1% | 39.1% |
| | 2 | −29.42 | 2.79 | 0.00 | 6.3% | 39.1% |
| | 5 | −14.90 | 3.48 | 0.00 | 3.9% | 37.6% |
| | 10 | −4.08 | 3.96 | 0.00 | 2.5% | 36.3% |
| | 20 | 1.51 | 4.35 | 0.00 | 1.5% | 34.9% |
| | 50 | 3.68 | 4.63 | 0.00 | 0.8% | 33.4% |
| | 100 | 2.53 | 4.80 | 0.00 | 0.5% | 32.5% |
| | 200 | 0.93 | 4.38 | 0.00 | 0.3% | 31.8% |
| | 500 | −0.06 | 2.32 | 0.03 | 0.2% | 31.0% |
| | 1000 | −0.10 | 1.76 | 0.06 | 0.2% | 30.5% |

In the case of Position MM4, Pspread/Pf = 0.03%

δt is Larger (FBA), MM take few profits or lose money

Market Maker Strategies can NOT continue to trade

(1) Introduction

(2) Artificial Market Model

(3) Simulation Result

(4) Summary and Future Works

## Summary

- We investigate whether Market Maker Strategies (MM) can continue to provide liquidities even on Frequent Batch Auctions (FBA) using Artificial Market Model (Agent Based Model).
- Our simulation results showed the possibility that FBA makes more difficult for MM to earn profits for risks.
- This implies that in the result the strategies can NOT continue to trade, and then execution costs increase on FBA.

## Future Works

- Are there MM adapted with FBA?
- How about the case of very low liquidity and/or the case of no MM?

# Reference

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