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Comparing effects of price limit and circuit breaker in stock exchanges by an agent-based model

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(1) Introduction

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Price Limit v.s. Circuit Breaker

The prevention of rapidly and steeply falling market prices is very very important to avoid financial crisis. So, some stock exchanges implement,,,

Price Limit

refuses orders that are priced significantly away from the current market price

Stock exchanges in Japan, South Korea, China, and other Asian countries tend to implement

Circuit Breaker

halts placing orders for a while when the market prices are largely changed

in the USA and Europe tend to implement

It is a big question which regulation best prevents rapid and large variations in price

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Difficulty of Empirical Study

Empirical studies cannot be conducted to isolate the direct effect of implementing a trading regulation due to the many diverse factors affecting price formation in actual markets.

Artificial Market Model can

agent-based model for a financial market

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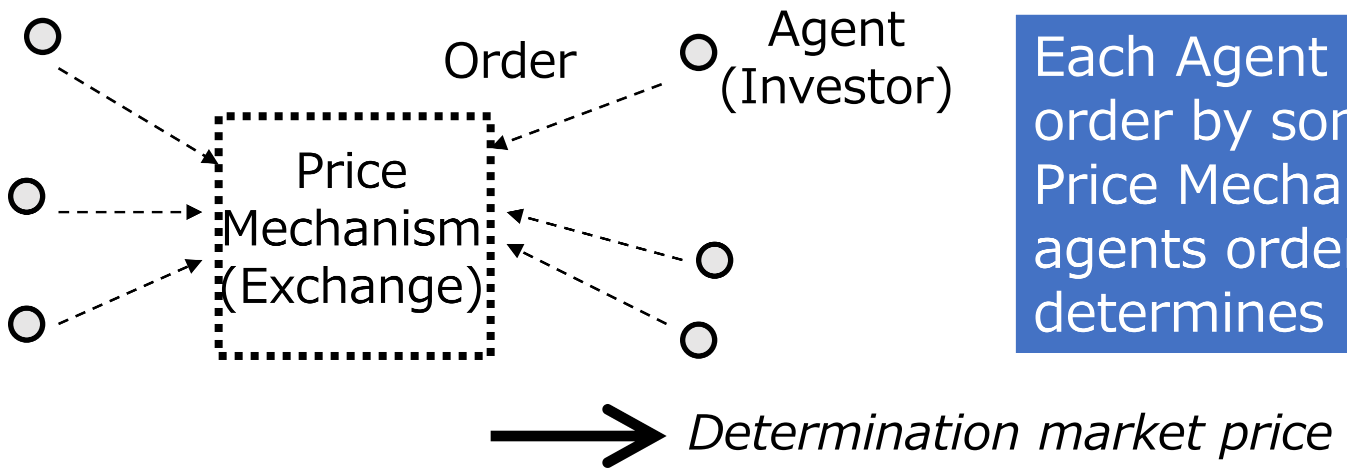
An artificial market model = an agent-based model for a financial market

Virtual and Artificial financial Market built on Computers

Models Include

Agents (Artificial Investors)
+
Price Mechanism (Artificial Exchange)



Each Agent determines an order by some rules, Price Mechanism gather agents orders and determines Market Price

Complete Computer Simulation needing NO Empirical Data

- ✓ can isolate the direct effect of implementing a trading regulation
- ✓ can be conducted to investigate situations that have never occurred in actual financial markets
- ✓ can effectively handling micro-macro feedback loops

[Mizuta 2016]

investigated the price limit and showed that the some conditions (of parameters) prevent large price variations

In [Mizuta 2016] model, the time passes only when an order is placed.

But the model cannot treat “time passing,”: when a circuit breaker is active, time simply passes without orders being placed,

the model needs to be improved before the price limit and circuit breaker can be compared under an equal condition

So, in this study

[Mizuta 2016] + Stop loss behavior

Compares the price limit and circuit breaker under an equal condition

Each agent estimates a fair price and then re-estimates it when market prices fall significantly below that price. The agents need a long time for the re-estimation, so they place stop-loss orders during the re-estimation,

which enables the model to let time pass without placing orders

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Continuous Double Auction

Shares Sell	Price	Shares Buy
10	103	
30	102	
	101	
50	100	
130	99	
	98	150
	97	
	96	70

Waiting Orders → (sell orders at 103, 102)

When buy order come here transaction immediately occurs (→ 99)

When sell order come here transaction immediately occurs (→ 98)

Multiple buyers and sellers compete to buy and sell stocks in the market, and transactions can occur at any time whenever an offer to buy and an offer to sell match.

Agents

1000 agents

j: agent number ordering in number order
t: tick time

This term is needed To replicate stylized facts

Technical

Expected Return of each agent

$$r^t_{e,j} = \frac{1}{\sum_i w_{i,j}} \left(w_{1,j} \log \frac{P_f}{P^{t-1}} + w_{2,j} \log \frac{P^{t-1}}{P^{t-\tau_j}} + w_{3,j} \varepsilon^t_j \right)$$

Fundamental

P_f Fundamental Price

10000 = constant

P^t Market Price at t

This term is needed to prevent the prices go out far away

noise

ε^t_j

Random of Normal Distribution

Average=0

σ=3%

To keep agents varied

To keep simulation runs stably

Parameters for agents

$w_{i,j}$ and τ_j

Random of Uniform Distribution

$w_{i,j}$ i=1,3: 0～1
i=2: 0～100

τ_j 0～10000

Expected Price of each agent

$$P^t{}_{e,j} = P^t \exp(r^t{}_{e,j})$$

Fundamental Strategy

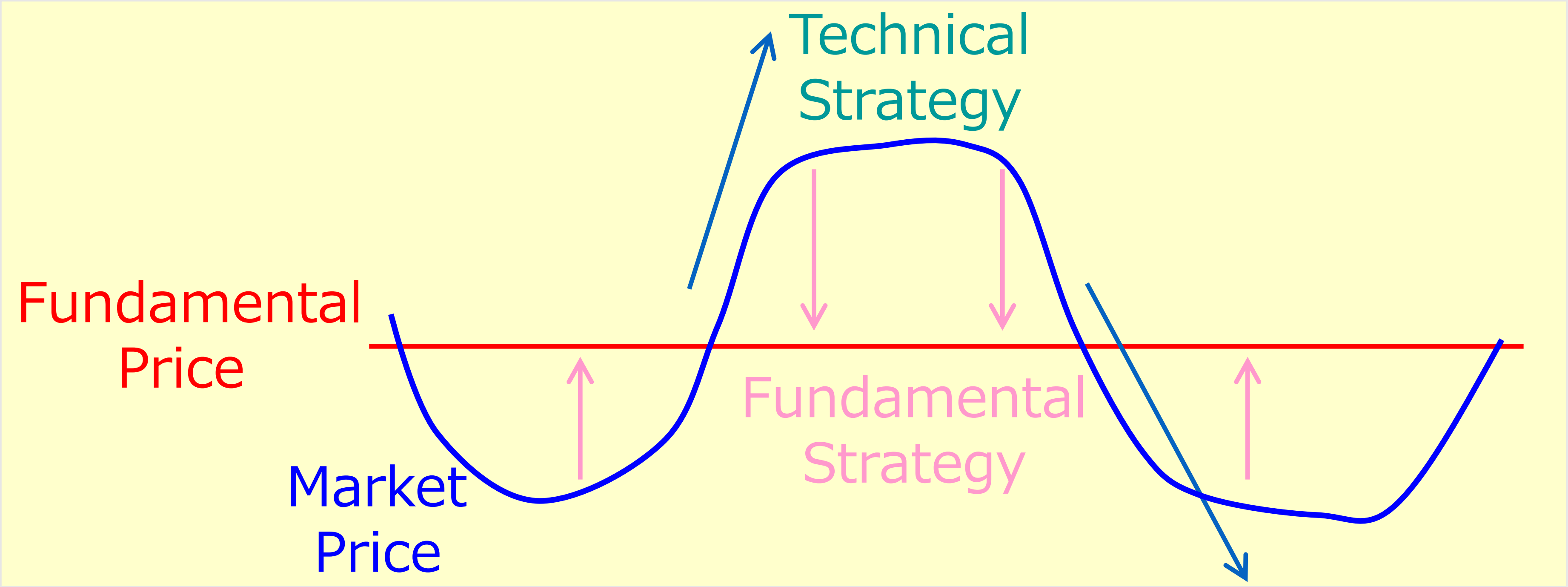
Fundamental Price > Market Price -> Expect + return

Fundamental Price < Market Price -> Expect - return

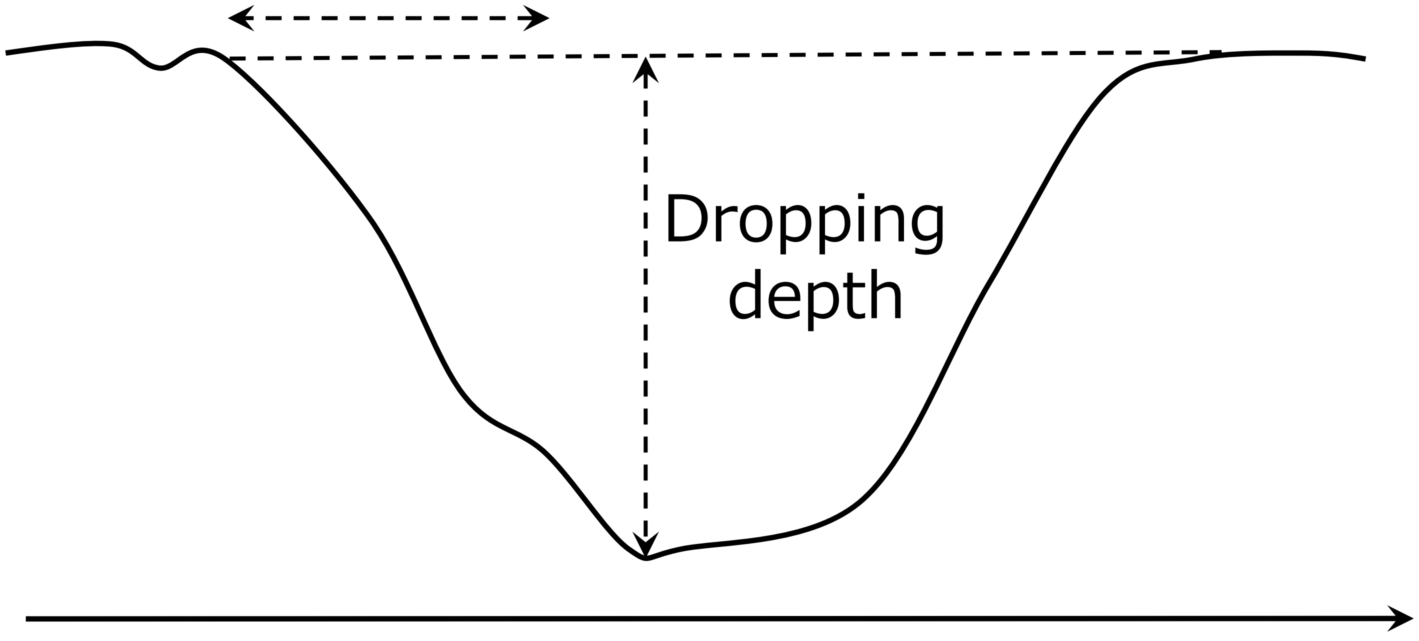
Technical Strategy (Historical Return)

Historical Return > 0 -> Expect + return

Historical Return < 0 -> Expect - return



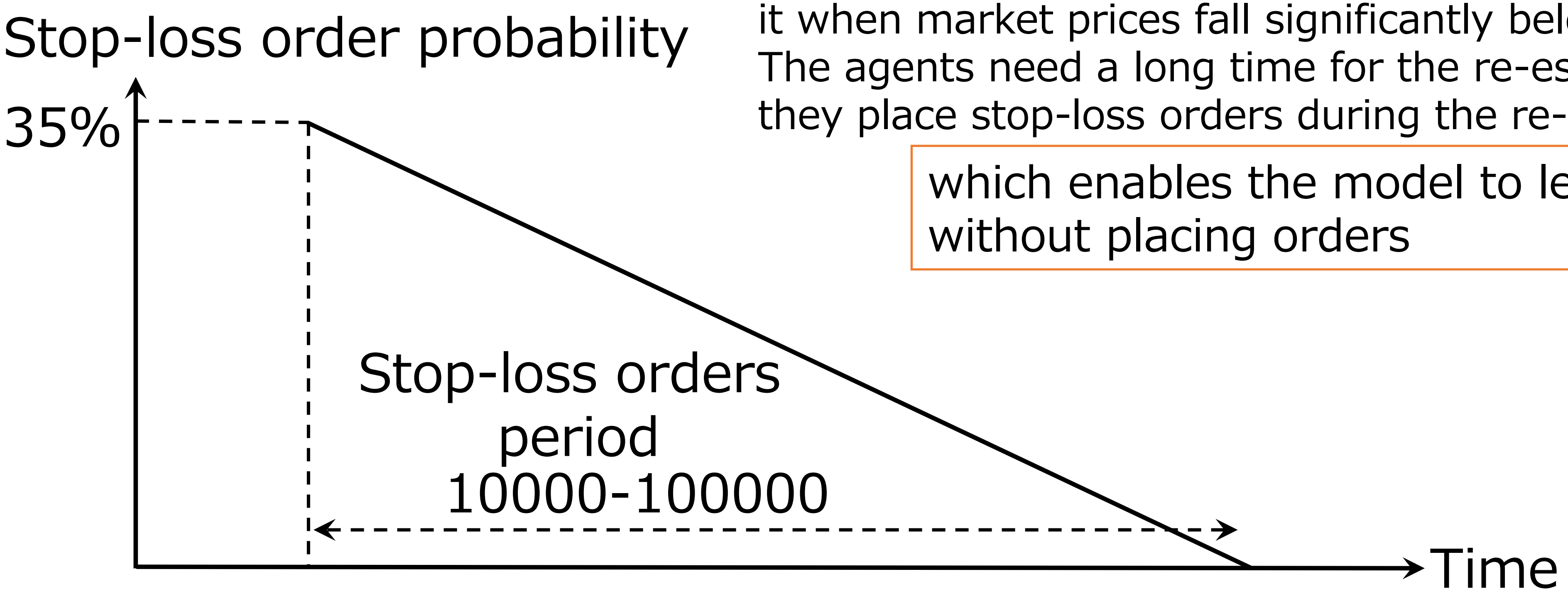
Erroneous orders



Within the period, with a constant probability 15% each order of the agents is changed to sell with very low price

Increasing such erroneous sell orders is what makes market prices fall

Stop-loss orders



Each agent estimates a fair price and then re-estimates it when market prices fall significantly below that price. The agents need a long time for the re-estimation, so they place stop-loss orders during the re-estimation,

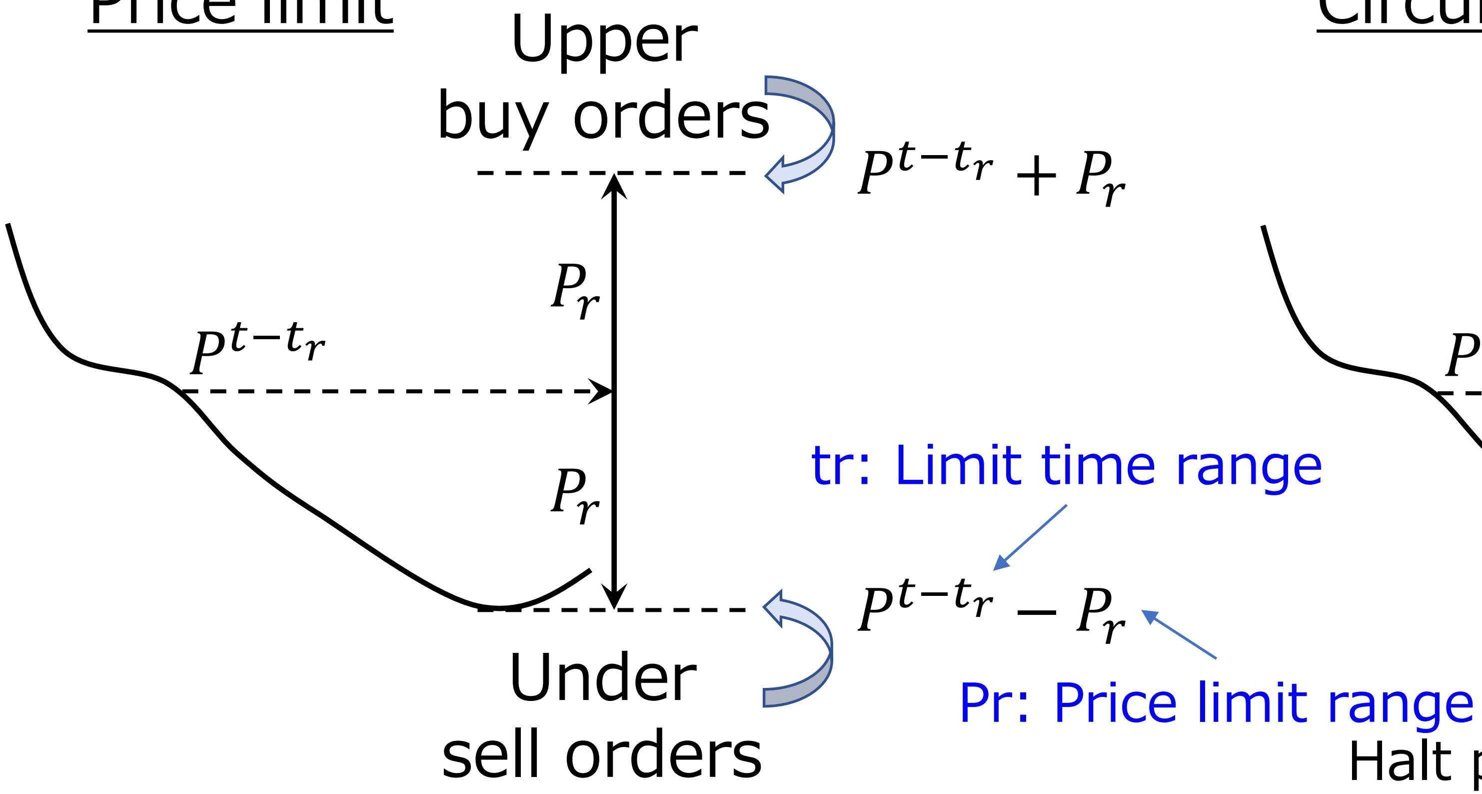
which enables the model to let time pass without placing orders

Each agent starts to place stop-loss orders when a market price dropped to about 7000-9000. Within the stop-loss period with a probability 35%(initial) to 0%, gradually reduced, each order of an agent is changed to sell

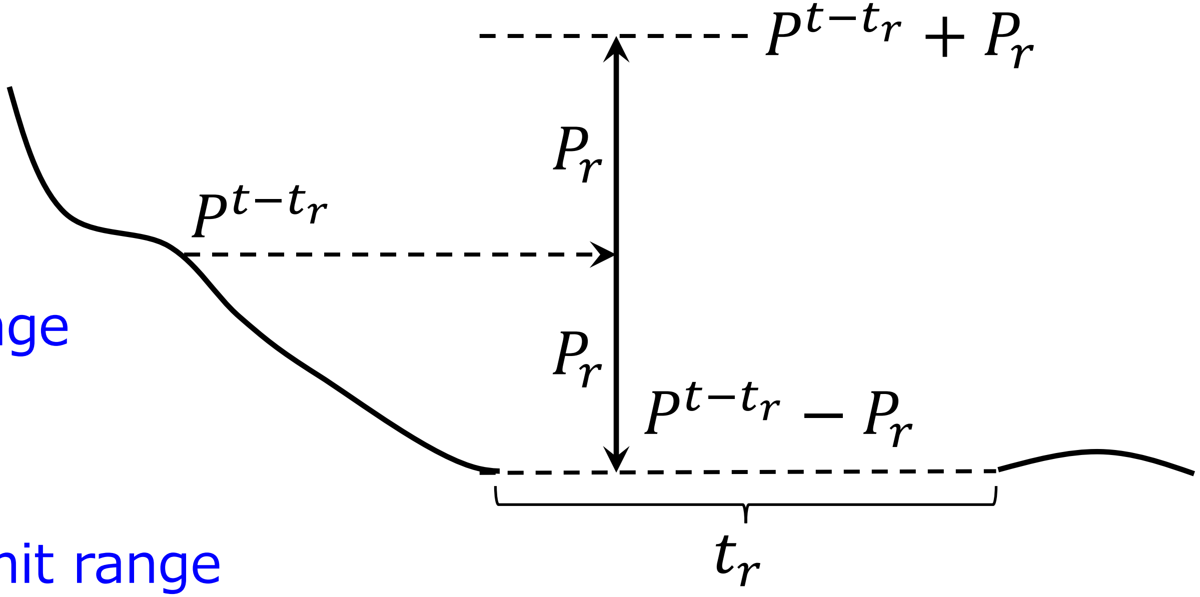
Erroneous orders cause prices to fall and Stop-loss orders make prices to continue falling after end of erroneous orders

Price limit & Circuit breaker

Price limit



Circuit breaker



Halt placing orders and cancel for a while

Price limit or Circuit braker stars when P^t reaches $P^{t-t_r} - P_r$ (lower limit).

Price limit: any order prices under the lower limit changed to the lower limit

Circuit breaker: placing or cancelling orders are stopped during tr

Price limit 2: cancel sell orders under the lower limit (unrealistic but to understand)

For various tr and Pr, we compare effects of Price limit with Circuit breaker

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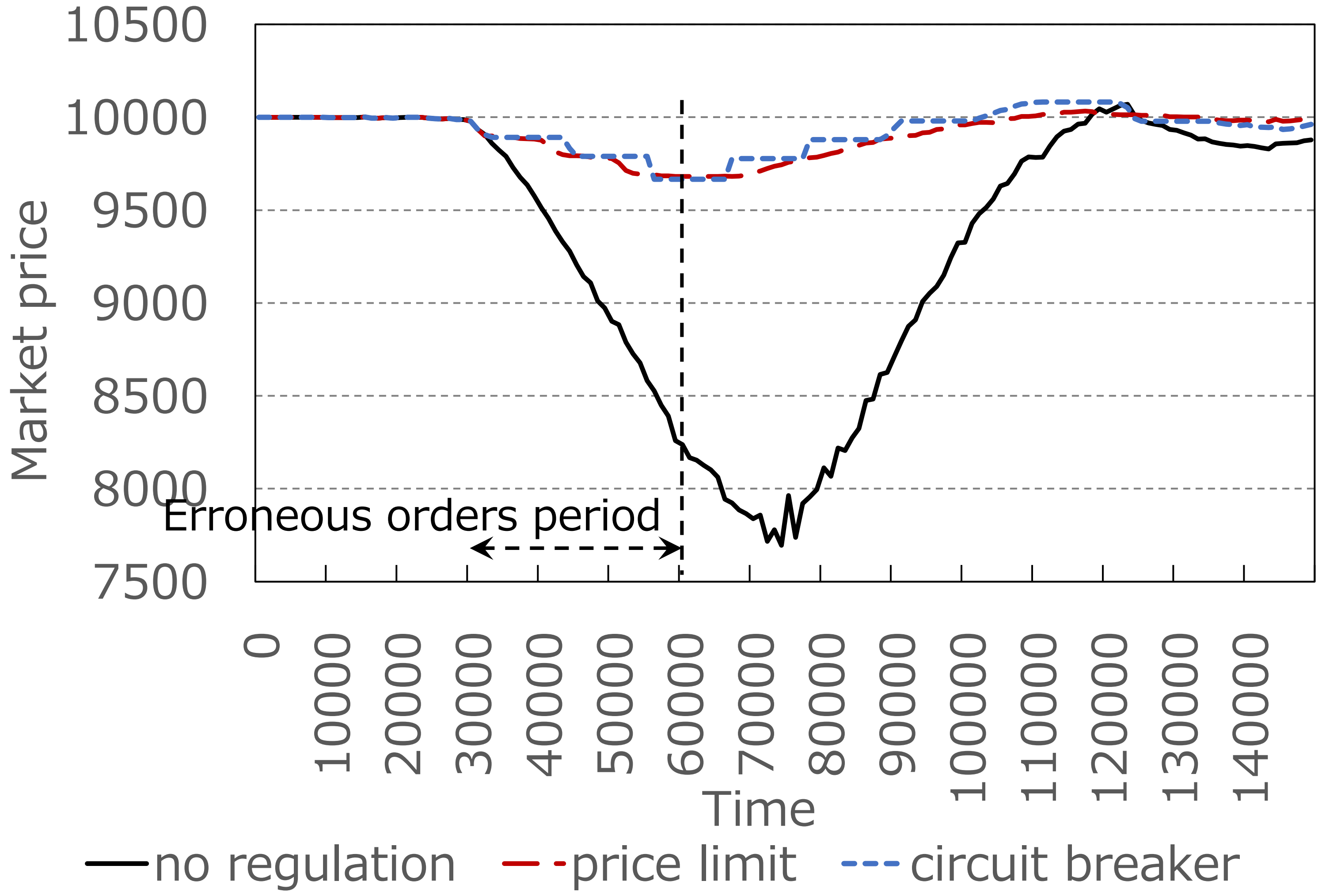
An example of the time evolution of market prices with tr=10000, Pr=100



No regulations: market prices fell sharply and continued after erroneous orders stopped
With regulations: not significantly fall, an overshoot did not occur

Averages of falling depth for various tr, Pr

Price Limit

Limit time range (tr); rows: Price limit range (Pr)

Pr \ tr	1000	2000	5000	10000	20000
10	298	157	73	45	33
20	577	302	134	79	52
50	1227	721	313	167	110
100	2000	1296	612	315	209
200	2194	2111	1140	615	408
500	2054	2054	2053	1419	906
1000	2054	2054	2054	2054	1433

Circuit breaker

Limit time range (tr); rows: Price limit range (Pr)

Pr \ tr	1000	2000	5000	10000	20000
10	152	103	57	34	22
20	297	207	107	58	43
50	702	487	266	163	105
100	1222	869	520	315	208
200	1954	1522	821	614	407
500	2054	2054	2038	1061	503
1000	2054	2054	2054	2054	1006

[Mizuta 2016] showed the condition that price limit prevent large falls
Pr / tr < falling speed of market prices
Yellow shading indicates this is not satisfied (cannot prevent falls)
So, we should see only the non-shading area

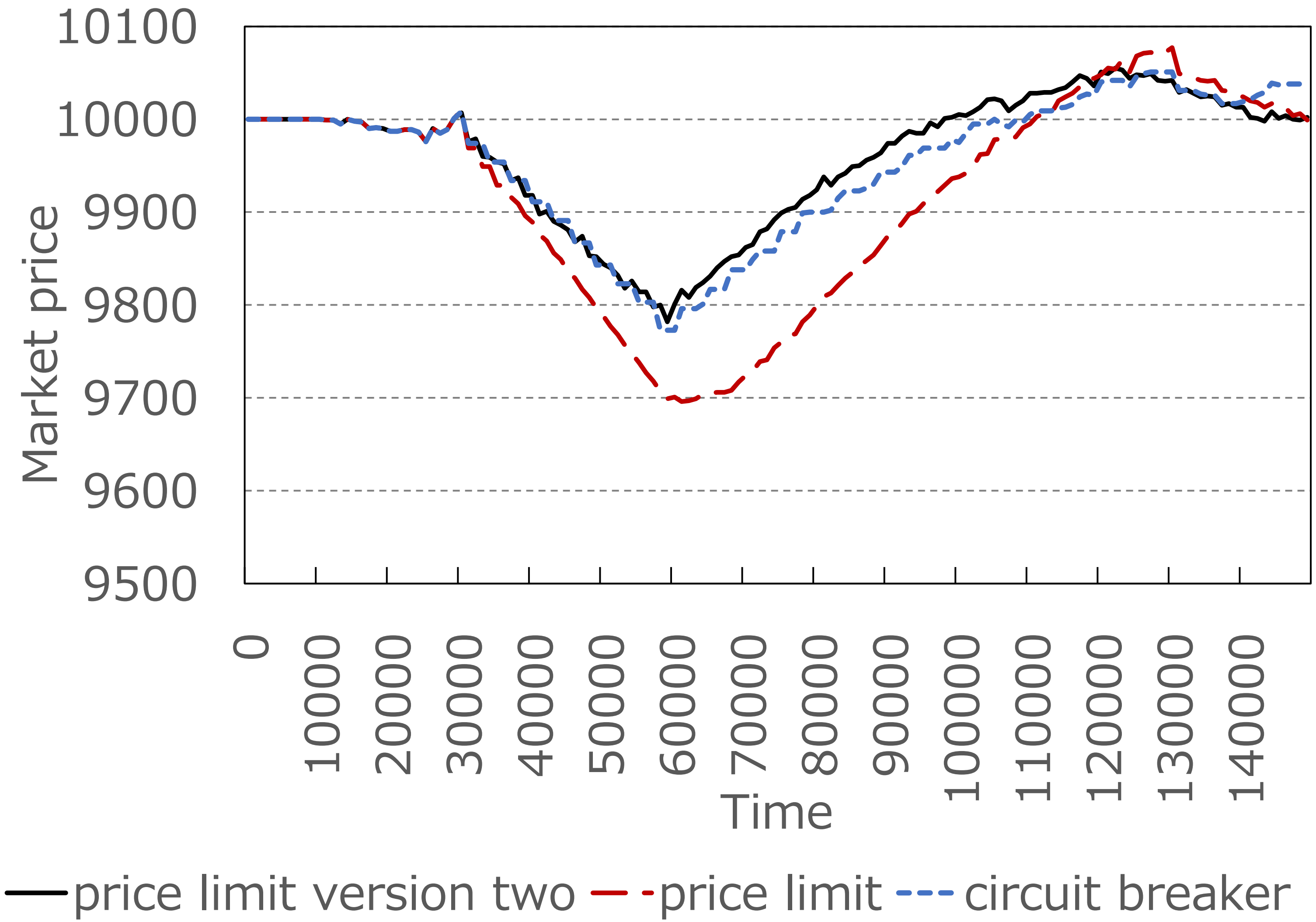
tr≧10000 : almost the same effectiveness to prevent the falling
tr<10000 : the circuit breaker was more effective

the differences between price limit - circuit breaker

Price limit range (Pr) \ Limit time range (tr)	1000	2000	5000	10000	20000
10	146	54	16	12	11
20	280	95	27	21	9
50	525	234	47	4	5
100	778	427	92	0	1
200	240	589	319	1	1
500	0	0	15	359	403
1000	0	0	0	0	427

It is clarified the circuit breaker was more effective when tr<10000

An example of the time evolution of market prices with tr=2000, Pr=20



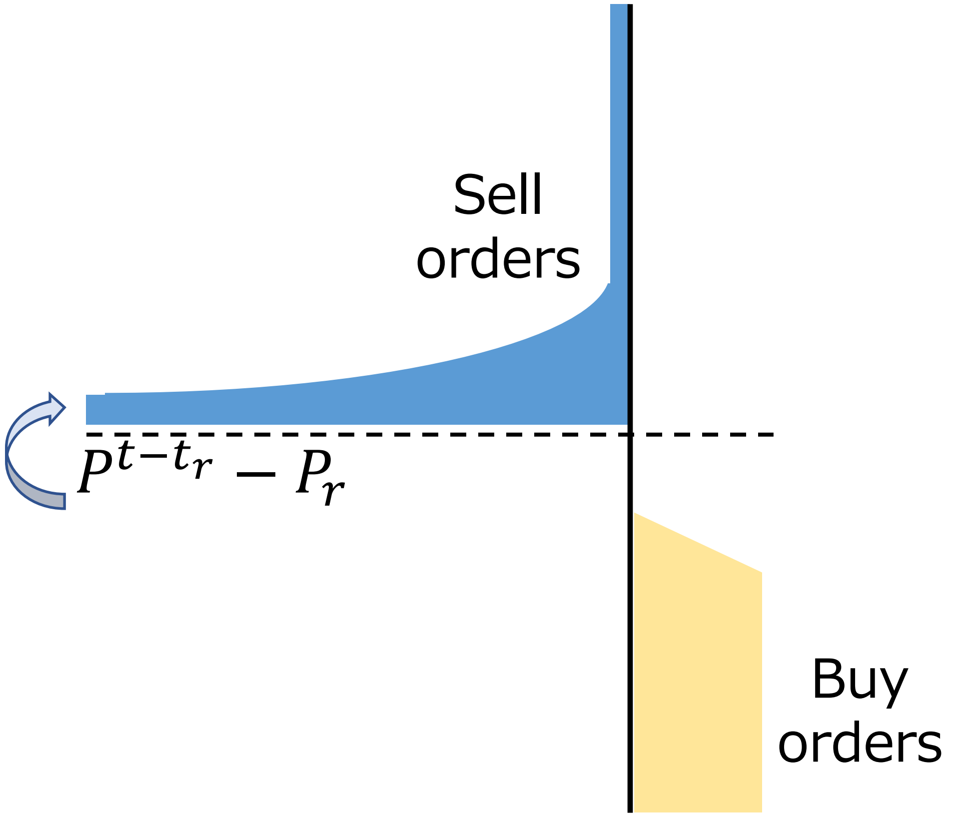
Price limit version two were almost the same as circuit breaker

the differences between price limit 2 - circuit breaker

Price limit range (Pr) \ Limit time range (tr)	1000	2000	5000	10000	20000
10	-8	-17	-13	-5	-1
20	56	3	-4	2	-3
50	212	83	16	-14	-6
100	418	247	38	-17	-10
200	69	413	231	-23	-10
500	0	0	15	318	392
1000	0	0	0	0	417

Price limit 2 were almost the same as circuit breaker

Mechanism of price limit is less effective when tr<10000



The threshold, tr=10000, is exactly the same as the cancel period, tc
$P^{t-t_r} - P_r$ is changed before the accumulated sell orders are cancelled, which leads to the accumulation of more sell orders of various prices

This accumulation then acts like a wall against buy orders, which prevents rising prices

The order books at t=600000 (tr=2000, Pr=20)

TABLE V
THE ORDER BOOKS AT $t = t_{me} = 60000$ IN THE EXAMPLE FROM FIG. 4.

Price limit			Circuit breaker			Price limit version two		
sell shares	price	buy shares	sell shares	price	buy shares	sell shares	price	buy shares
272	9780-9800		6	9860-9880		82	9880-9900	
290	9760-9780		9	9840-9860		85	9860-9880	
279	9740-9760		8	9820-9840		55	9840-9860	
278	9720-9740		1	9800-9820		25	9820-9840	
136	9700-9720		1	9780-9800		3	9800-9820	
	9680-9700	49		9760-9780	17		9700-9800	4
	9660-9680	69		9740-9660	44		9720-9780	74
	9640-9660	83		9720-9740	44		9740-9760	72
	9620-9640	80		9700-9720	64		9720-9740	86
	9600-9620	67		9680-9700	54		9700-9720	88

Only in the case with the price limit,
many sell orders were accumulated
and they prevented the prices from rising

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Summary

- ✓ In this study, we expanded on Mizuta et al.'s artificial market model [Mizuta 2016] by adding stop loss behavior of the agents and a circuit breaker and then used it to investigate whether the price limit or the circuit breaker is more effective to prevent falling market prices.

- ✓ Our findings showed that the price limit and the circuit breaker are basically equally effective when the limit price range (Pr) and limit time range (tr) parameters are the same.

- ✓ However, the price limit is less effective when tr is smaller than the cancel time range (tc). In the case with the price limit, many sell orders are accumulated around the lower limit price. When tr<tc, the lower limit price is changed before the accumulated sell orders are cancelled, which leads to the accumulation of more sell orders of various prices. This accumulation then acts like a wall against buy orders, which prevents the prices from rising.

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Future Works

- ✓ These results pertain only to a limited situation. Specifically, the fact that the circuit breaker is better than the price limit should be adapted only in the case where the reason for falling prices is erroneous orders and where individual stocks are regulated. In cases where other reasons make the market prices fall (for example, large variations in the fundamental price) or in cases where individual stocks are not regulated (for example, stock indexes are regulated), the results might be different.
- ✓ In fact, in real financial markets, market prices frequently fall for reasons other than erroneous orders, and there are many cases where a stock index is regulated by circuit breakers while individual stocks are not regulated.
- ✓ [Wang 2022] indicated that if a stock index is regulated and the index closes to the limit price of circuit breaker, some traders are in a hurry to sell and their sell orders make the index fall, which means that sometimes a circuit breaker induces a sharp fall rather than preventing it.
- ✓ In the current work, we did not examine such behavior of traders, so these mentioned above will be the focus of our future work.

Reference

- [Mizuta 2016] Mizuta, T., Kosugi, S., Kusumoto, T., Matsumoto, W., Izumi, K., Yagi, I., and Yoshimura, S., "Effects of Price Regulations and Dark Pools on Financial Market Stability: An Investigation by Multiagent Simulations", Intelligent Systems in Accounting, Finance and Management, Vol. 23, No. 1-2, pp. 97-120, 2016, https://doi.org/10.1002/isaf.1374

- [Wang 2022] X. Wang, M. H. Kim, and S. Suardi, "Herding and China's market-wide circuit breaker," Journal of Banking and Finance, vol. 141, p.106533, 2022, https://doi.org/10.1016/j.jbankfin.2022.106533

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Reference (Reviews of agent-based models for a financial market)

Review of an agent-based model for designing a financial market

Mizuta (2020) An agent-based model for designing a financial market that works well, CIFEr 2020
arXiv https://arxiv.org/abs/1906.06000
Slide: https://mizutatakanobu.com/2021kyushu.pdf
YouTube: https://youtu.be/rmlb72ykmlE

Mizuta (2022) Artificial Intelligence (AI) for Financial Markets: A Good AI for Designing Better Financial Markets and a Bad AI for Manipulating Markets https://doi.org/10.1007/978-981-19-0937-5_13

Citing many previous studies

Mizuta (2016) A Brief Review of Recent Artificial Market Simulation Studies for Financial Market Regulations And/Or Rules, SSRN Working Paper Series
https://ssrn.com/abstract=2710495

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Appendix

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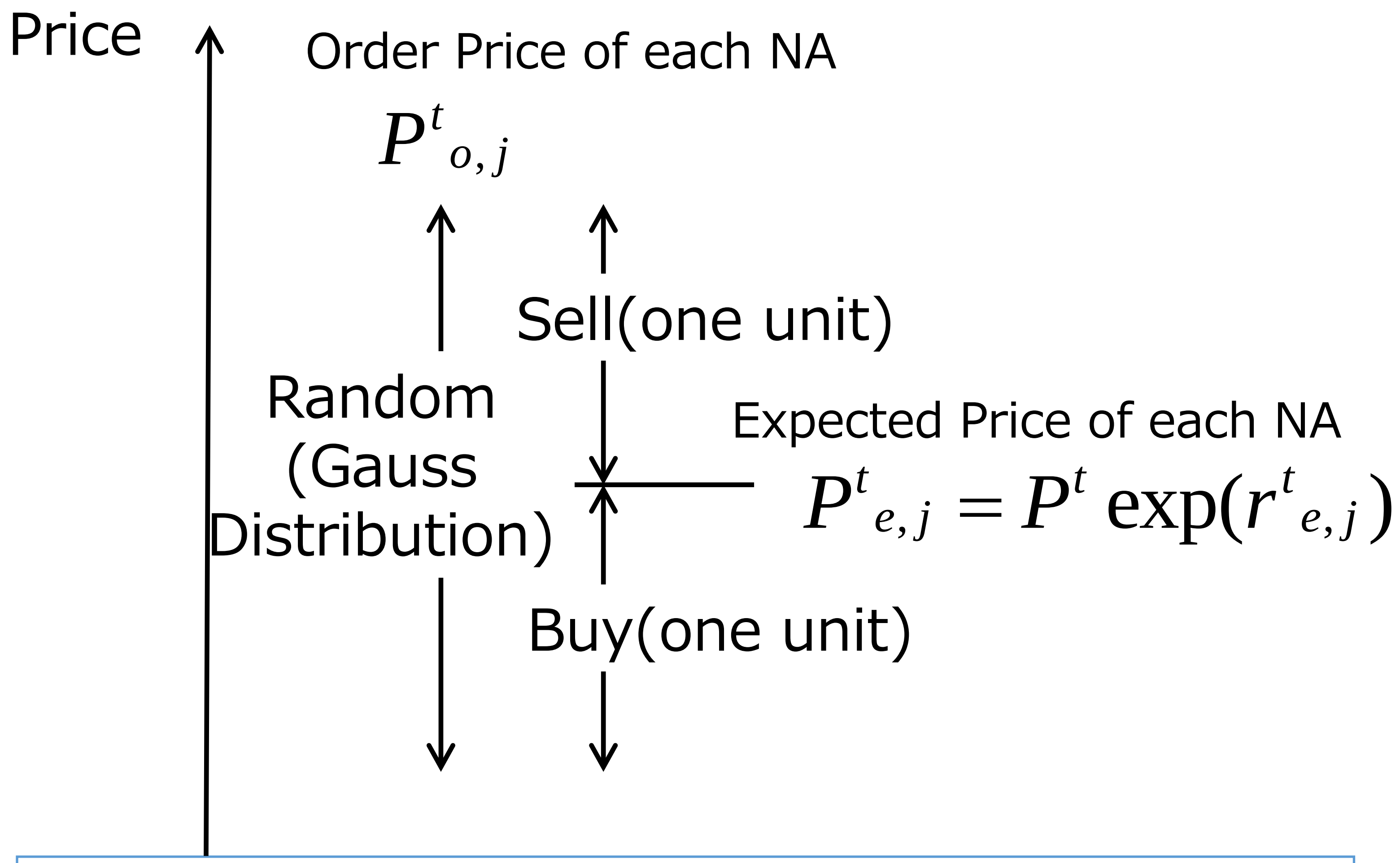
Order Price and Buy or Sell



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

NA places one **buy** order when <u>order price > expected price</u>
NA places one **sell** order when <u>order price < expected price</u>

Verification: Stylized Facts

The purpose of simulation is understanding the reasons and mechanism, not replicating ALL Stylized Facts

The simplicity of the model is very important because unnecessary replication of macro phenomena leads to models that are overfitted and too complex. Such models prevent understanding and discovery of mechanisms affecting price formation because of the increase in related factors.

Many empirical studies, e.g., Sewell 2006 have shown that both stylized facts (fat-tail and volatility-clustering) exist statistically in almost all financial markets.
Conversely, they also have shown that only the fat-tail and volatility-clustering are stable for any asset and in any period because financial markets are generally unstable.

Fat-tail 1 to 100

kurtosis of price returns is positive

Volatility-clustering 0 to 0.2

square returns have a positive auto-correlation

The magnitudes of these values are unstable and vary greatly depending on the asset and/or period.

For the above reasons, an artificial market model should replicate these values as significantly positive and within a reasonable range as I mentioned. It is not essential for the model to replicate specific values of stylized facts because the values of these facts are unstable in actual financial markets.

Stylized Facts

Table 1 Statistics without arbitrage agents

	execution rate	32.3%
trading	cancel rate	26.1%
	number of trades / 1 day	6467
standard	for 1 tick	0.0512%
deviations	for 1 day (20000 ticks)	0.562%
	kurtosis	1.42
	lag	
	1	0.225
autocorrelation	2	0.138
coefficient for	3	0.106
square return	4	0.087
	5	0.075

The model of Chiarella (2002) is very simple but replicates long-term statistical characteristics observed in actual financial markets: a fat tail and volatility clustering.

In contrast, Mizuta (2013) replicates high-frequency micro structures, such as execution rates, cancel rates, and one-tick volatility, that cannot be replicated with the model of Chiarella (2002).

The simplicity of the model is very important for this study, because unnecessary replication of macro phenomena leads to models that are overfitted and too complex. Such models prevent understanding and discovery of mechanisms affecting price formation because of the increase in related factors.