Regulations' Effectiveness for Market Turbulence by Large Erroneous Orders using Multi Agent Simulation

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[Thank you very much. I'm] Takanobu MIZUTA [from] SPARX Asset Management.

[I'm also belonging to] The University of Tokyo.

[Today, I'm going to talk about] Regulations' Effectiveness for Market Turbulence by Large Erroneous Orders using Multi Agent Simulation

Today's Talk

○ Motivation
○ Our Artificial Market Model (Multi-Agent Simulation)

Experiment 1 ○ Characteristics of Erroneous-Order Turbulence

☆ Market prices declined not only during but also for a while after the period of erroneous orders.
☆ The amount of erroneous orders decided ranges of price falls.

Experiment 2 ○ Effects of Price Variation Limits to the Turbulence

Condition to Prevent the Large Turbulence	$t_{pl} < t_g$

t_{pl}: limit time span
t_g: time of erroneous orders existing

Summary & Implication to market regulations

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[This is] Today's Talk, [table of contents].

[At first, I will describe] Motivation and our artificial market model (Multi-Agent Simulation)

[In] Experiment 1, [we will investigate about] Characteristics of Erroneous-Order Turbulence [and will show that]

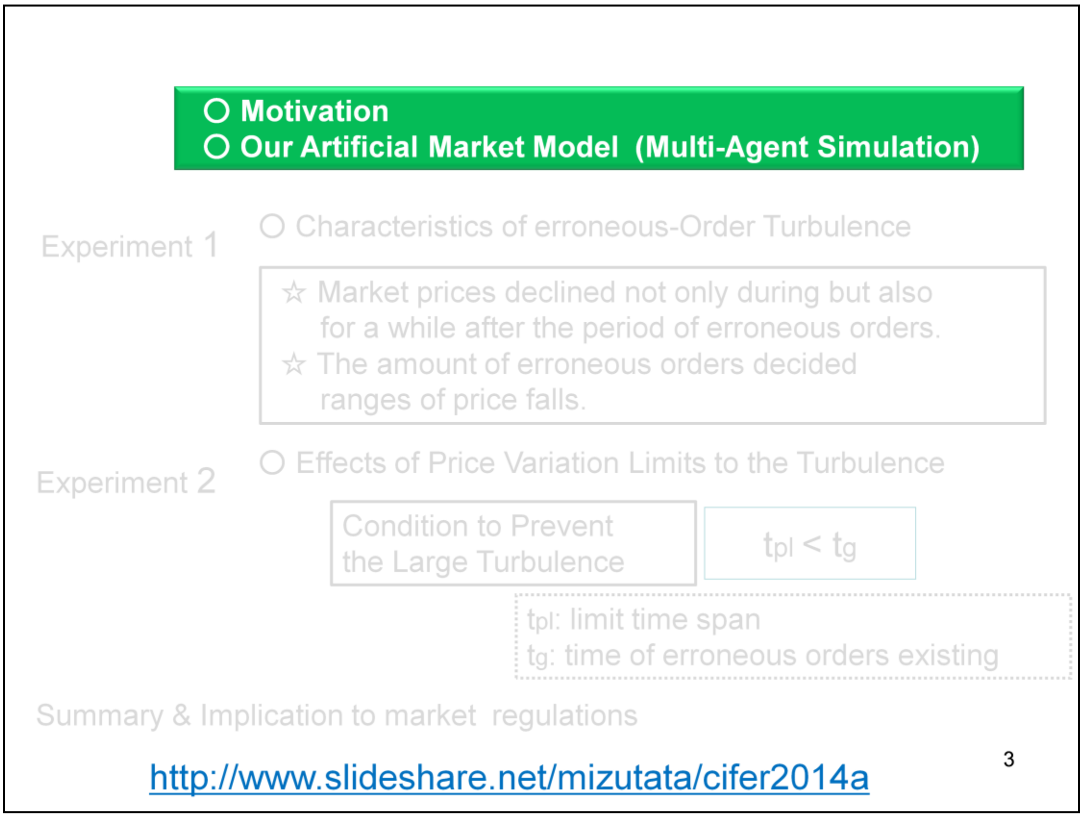
Market prices declined not only during but also for a while after the period of erroneous orders.

[And,] The amount of erroneous orders decided ranges of price falls.

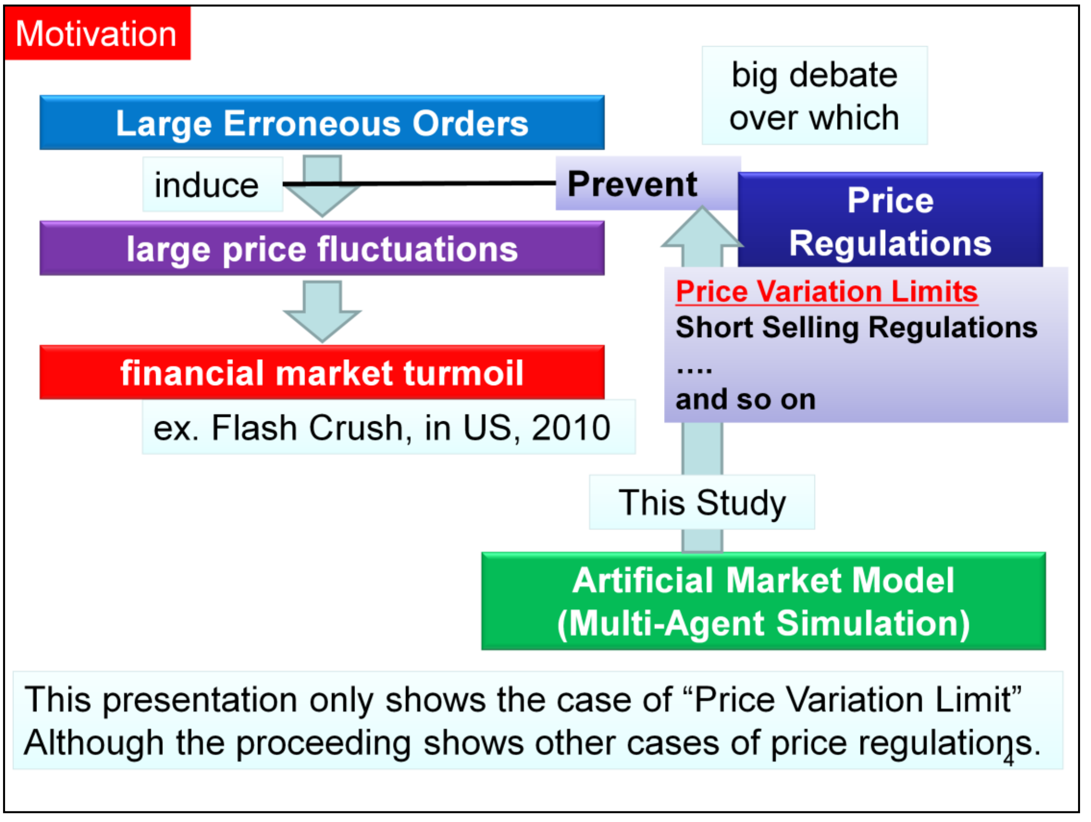
[In] Experiment 2, [we will investigate about] Effects of Price Variation Limits to the Turbulence [and will show that]

[The] Condition to Prevent the Large Turbulence [is], the limit time span should be shorter than the time of erroneous orders existing.

[Lastly, I will mention] Summary & Implication to market regulations.



[First, I will describe] Motivation and our artificial market model.



Motivation.

[In financial markets], large erroneous orders [sometimes] induce large price fluctuations.

[Such] fluctuations [often cause] financial market turmoil.

For example, Flash Crush, in US, 2010.

[Therefore, there is] a big debate over which price regulations prevent [this inducing].

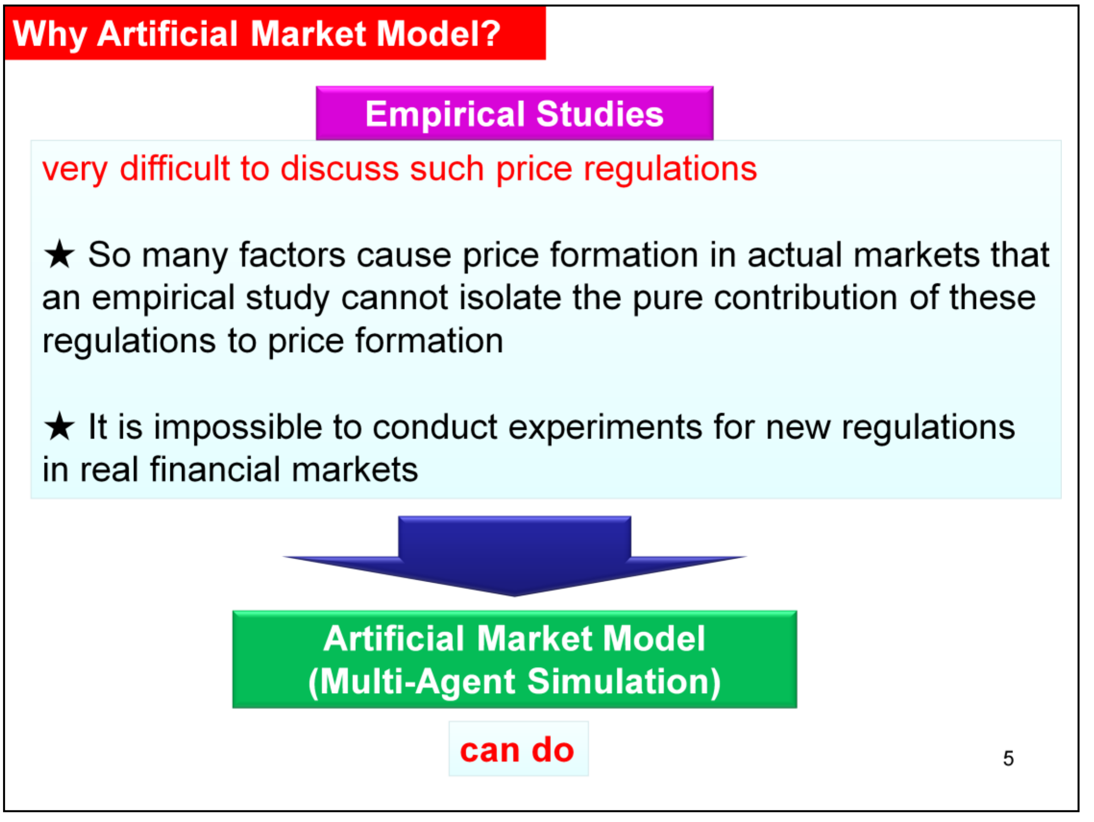
[In] this study, [we build] Artificial Market Model (Multi-Agent Simulation) [to investigate]

[Characteristics of Erroneous-Order Turbulence]

[And, Effects of] Price Regulations

This presentation only shows the case of "Price Variation Limit"

Although the proceeding shows other cases of price regulations.



Why Artificial Market Model?

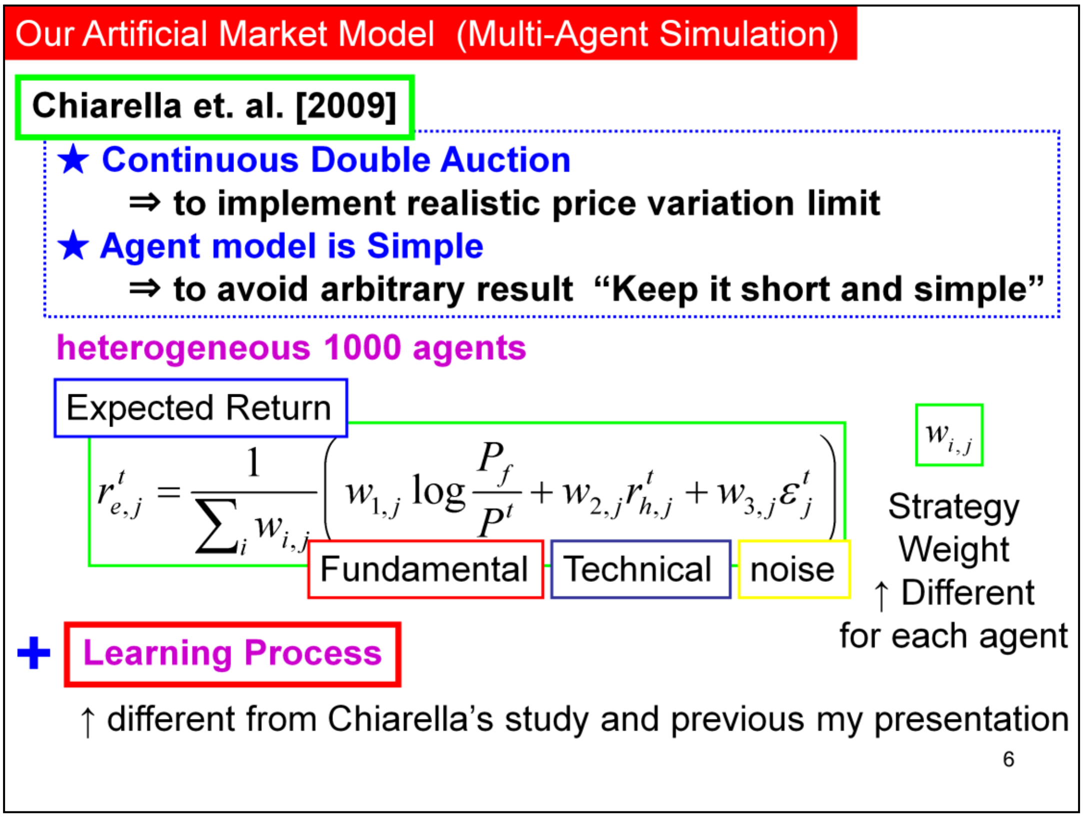
Empirical Studies are very difficult to discuss such price regulations [because],

So many factors cause price formation in actual markets that an empirical study cannot isolate the pure contribution of these regulations to price formation

[and because],

It is impossible to conduct experiments for new regulations in real financial markets

[On the other hand], Artificial Market Model (Multi-Agent Simulation) can do [them].



[This study's model is Similar to previous my presentation, previous technical session.
I think, some people did not attend it. So, I will give similar talk here, again.]

[We built an artificial market model] on basis of Chiarella et. al. 2009.

●[Pricing mechanism is] Continuous Double Auction. [It is not simple, but, we need] to implement realistic price variation limit

●Agent Model is Simple. [This is] to avoid arbitrary result, “Keep it short and simple” [principle].

[We think Artificial Market Models should explain Stylized Facts as Simply as possible].

[There are] heterogeneous 1000 agents. [All agents calculate] Expected Return [using this equation],

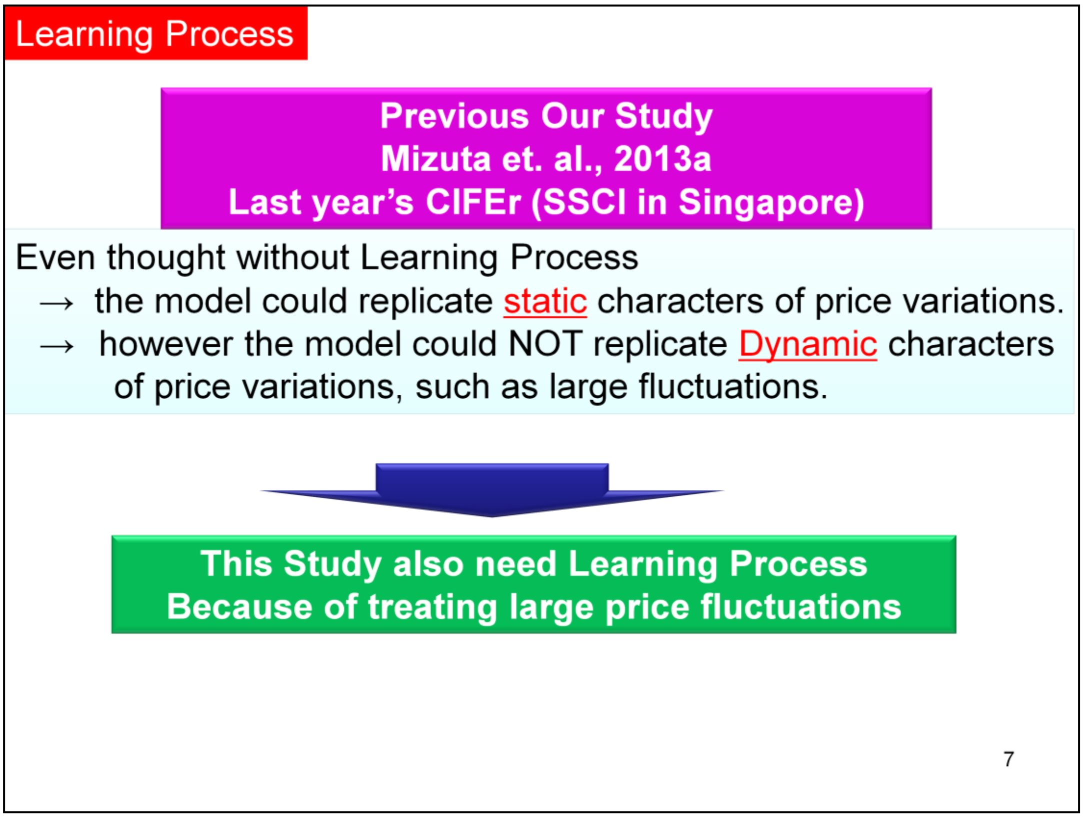
[And, the] strategy weights are different for each agent

・[First term is a] Fundamental [Strategy: When the market price is smaller than the fundamental price, an agent expects a positive return , and vice verse].

・[Second term is a] technical [strategy: When historical return is positive, an agent expects a positive return, and vice verse].

・[Third term is] noise.

[Plus, We implemented] Learning Process. [This is] different from Chiarella’s study and previous my presentation



[About] Learning Process,

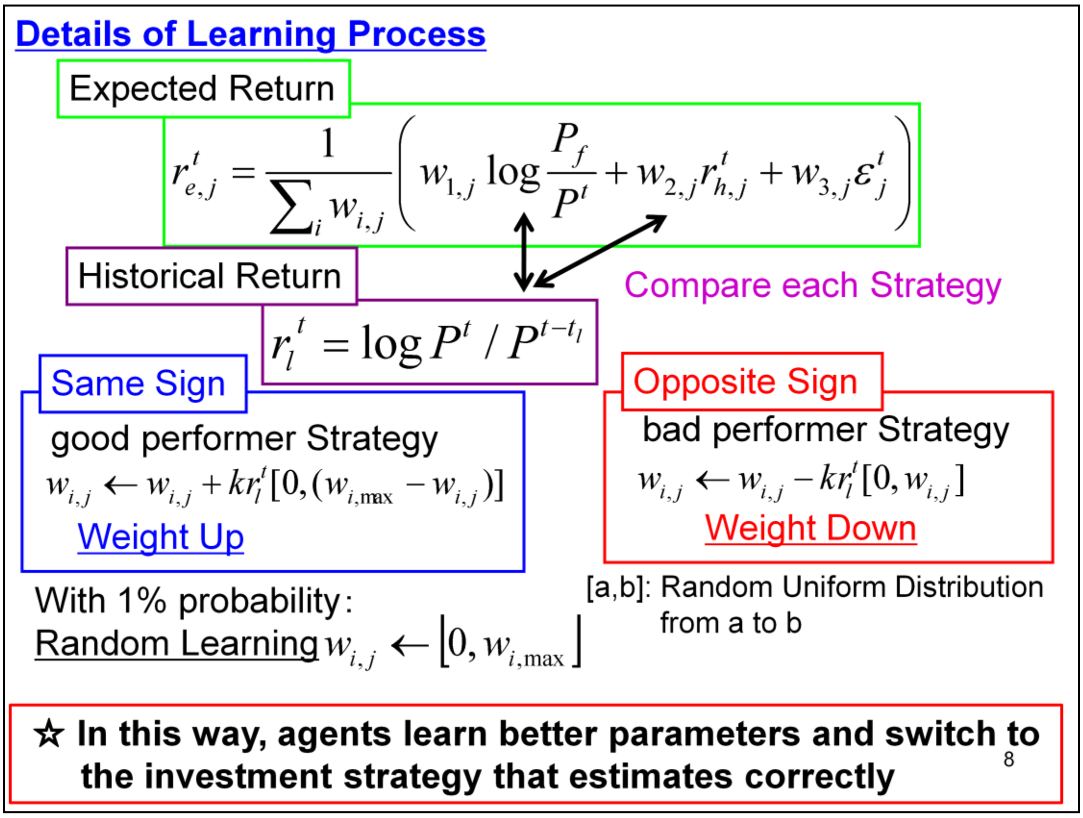
Previous Our Study Mizuta et. al., 2013a Last year's CIFEr (SSCI in Singapore) [showed that]

Even thought without Learning Process

→ the model could replicate static characters of price variations.

→ however the model could NOT replicate Dynamic characters of price variations, such as large fluctuations.

[therefore,] This Study also need Learning Process Because of treating large price fluctuations



Details of Learning Process

[Agents are] comparing Historical Return [and] each Strategy[' term, Fundamental strategy term, and Technical strategy term].

[When the strategy's expected return and Historical Return are] Same Sign,
[This means] good performer Strategy.
[The strategy's] Weight is Up.

[When the strategy's expected return and Historical Return are] Opposite Sign,
[This means] bad performer Strategy.
[The strategy's] Weight is Down.

[We also added] random learning.

In this way, agents learn better parameters and switch to the investment strategy that estimates correctly.

○ Motivation
○ Our Artificial Market Model (Multi-Agent Simulation)

Experiment 1 ○ **Characteristics of Erroneous-Order Turbulence**

☆ **Market prices declined not only during but also for a while after the period of erroneous orders.**
☆ **The amount of erroneous orders decided ranges of price falls.**

Experiment 2 ○ Effects of Price Variation Limits to the Turbulence

Condition to Prevent the Large Turbulence: $t_{pl} < t_g$

t_{pl}: limit time span
t_g: time of erroneous orders existing

Summary & Implication to market regulations

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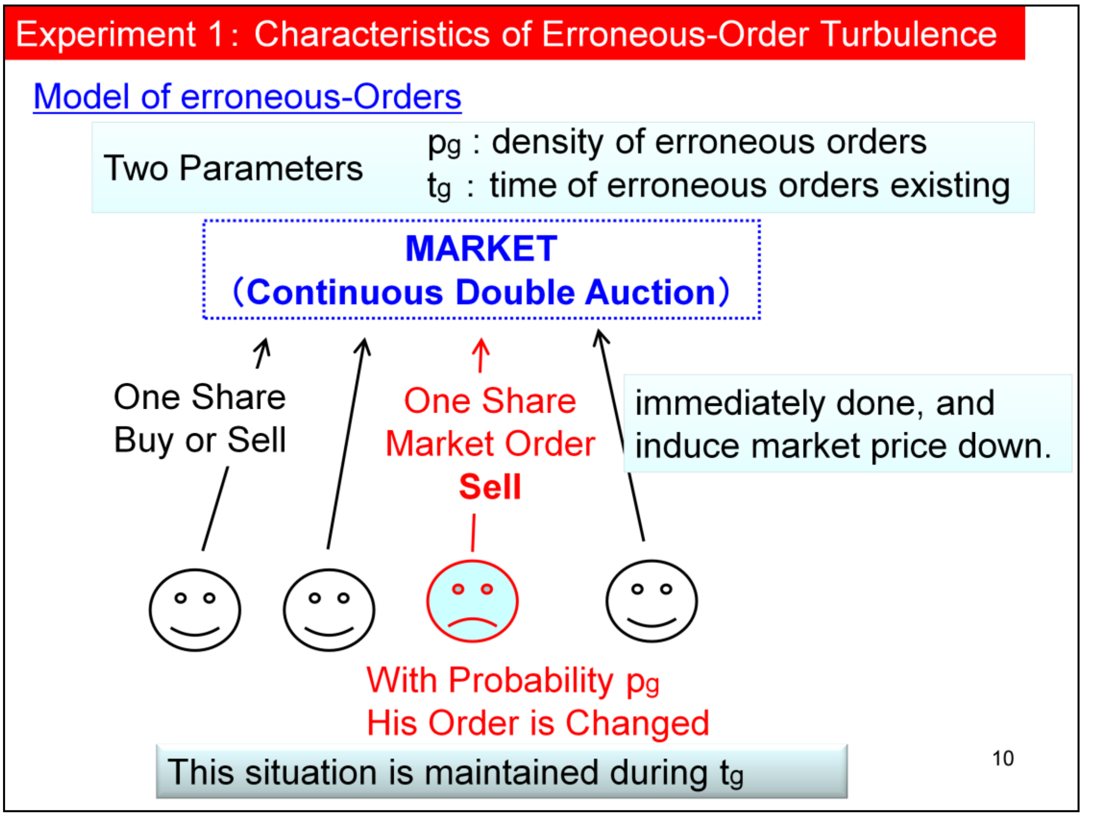
[Next, I show simulation results of] Experiment 1 [about] Characteristics of Erroneous-Order Turbulence



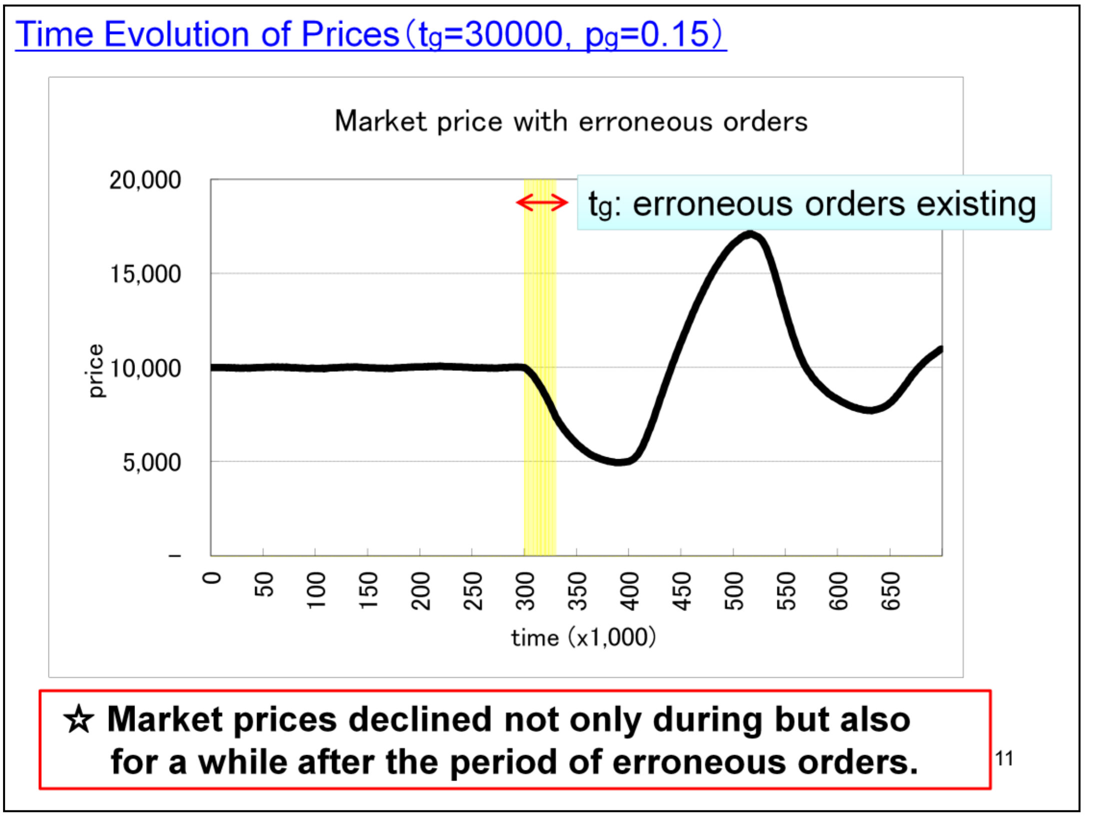
Model of Erroneous Orders

[There are] two parameters for the model: pg, density of erroneous orders, tg, time of erroneous orders existing.

With a probability pg, His order is changed to Market Order Sell.

[Such market sell orders are] immediately done, and induce market price down.

This situation is maintained during tg.

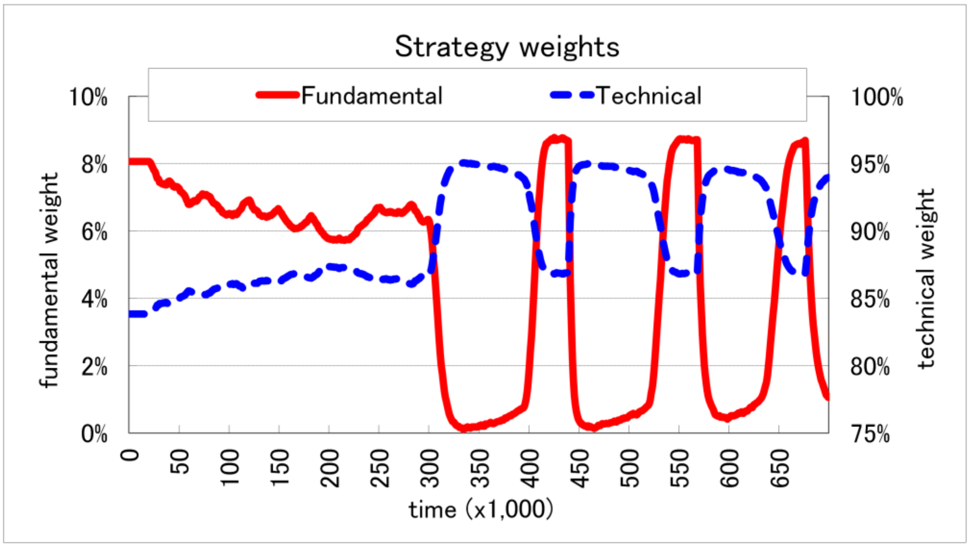


[This figure shows] a time evolution of market prices with erroneous orders.

[We shade the time rage in which] erroneous orders exist.

Market prices declined not only during but also for a while after the period of erroneous orders.

Time Evolution of Strategies Weight



☆ During erroneous-Order Existing,switching Fundamental strategy to Technical Strategy.

☆ Because of increased technical strategy weight, market prices continued to decline, even after erroneous orders were gone.

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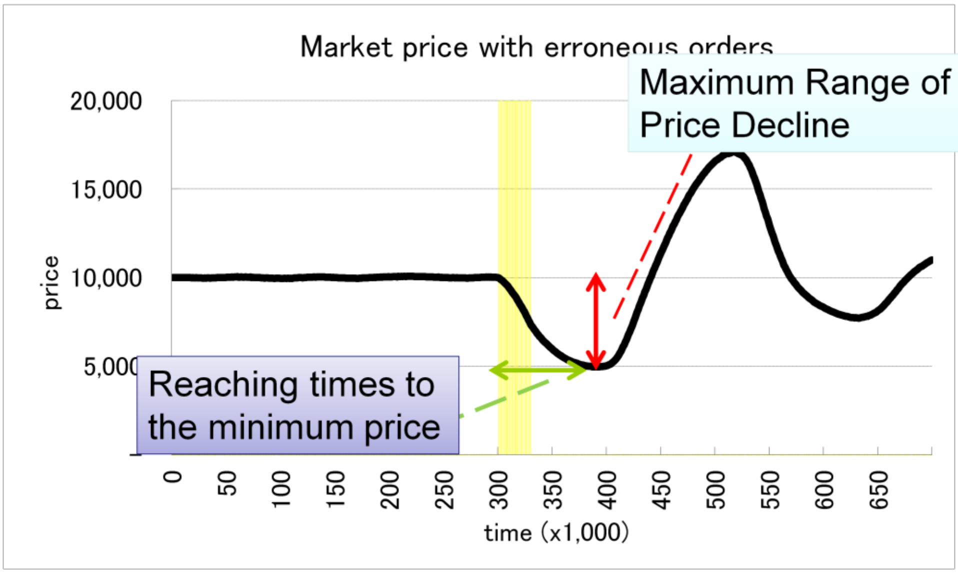
[This figure shows] a time evolutions of strategies weights.

During erroneous-Order Existing switching Fundamental strategy to Technical Strategy.

Because of increased technical strategy weight, market prices continued to decline, even after the erroneous orders were gone,

Maximum Range of Price Decline



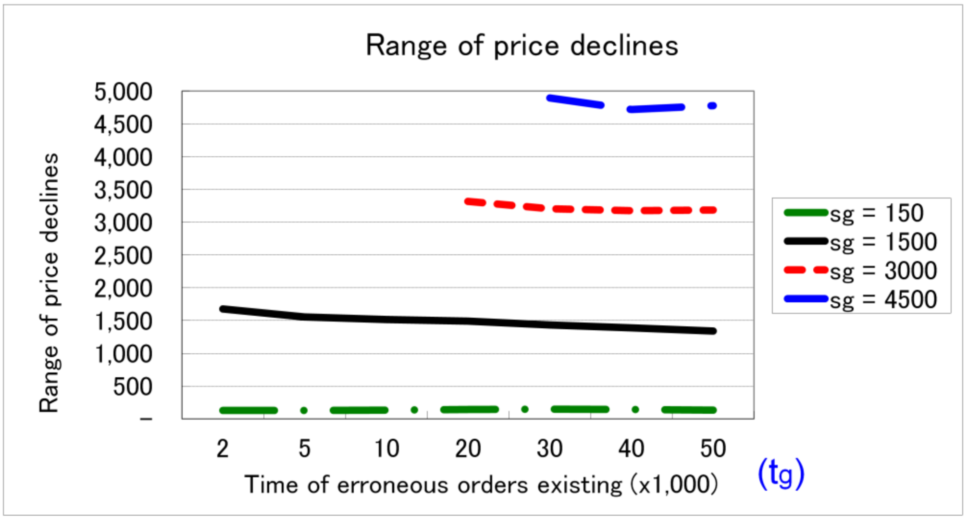
Measure Maximum Range of Price Declines and Reaching times to the minimum price for various tg, pg under $s_g = t_g \times p_g$ = const.

[Next, we Measure] maximum Range of Price Declines and Reaching times to the minimum price for various tg, pg under sg = tg times pg = const.

Maximum Range of Price Decline [is defined like this, from minimum market price to initial market price].

Reaching times to the minimum price [is defined like this, from starting erroneous orders to reaching time at minimum market price].

Maximum Range of Price Declines under $s_g = t_g \times p_g$ = const.



☆ **Ranges of price declines were almost the same when sg was constant.**

☆ **sg was increasing more, the rages were increasing more.**

☆ **The amount of erroneous orders (Sg) decided ranges of price falls. sg is a key parameter !!**

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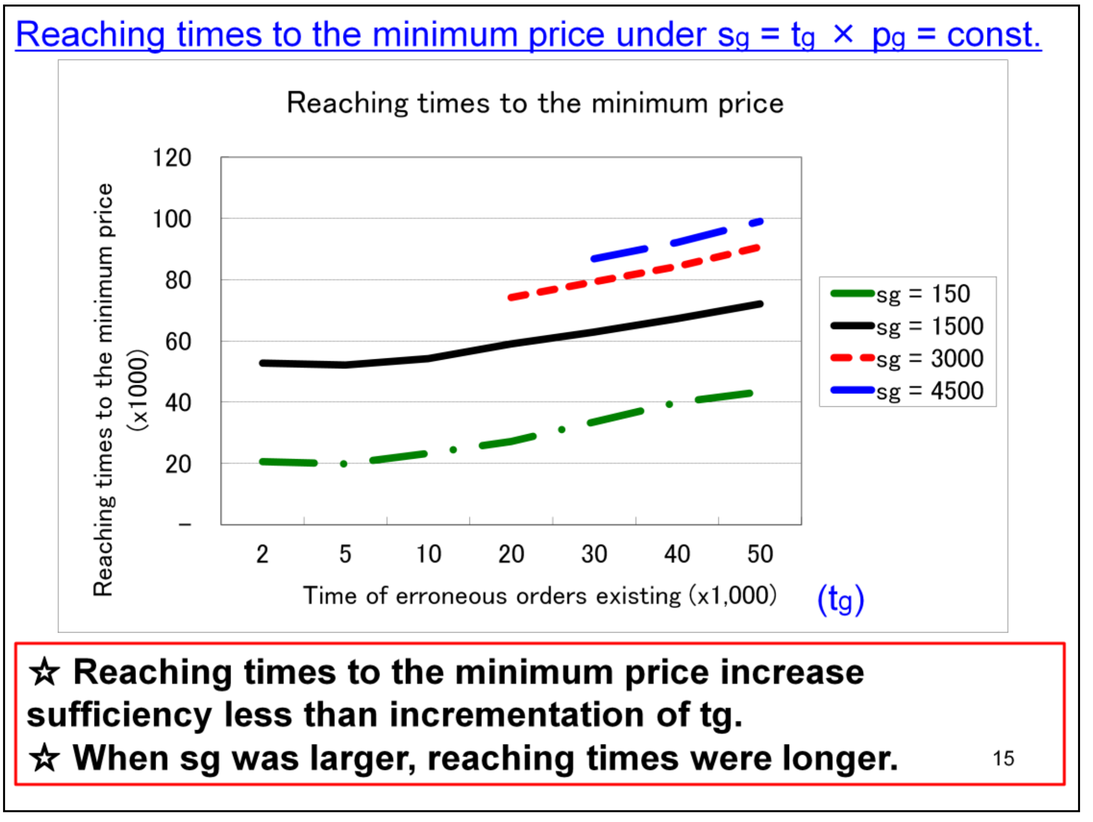
[This figure shows] maximum ranges of price declines for various tg, pg under sg = tg times pg = const.

[Horizontal axe is] times of erroneous orders existing tg.

[The amount of erroneous orders, s_g on each line is constant.]

Ranges of price declines were almost the same when sg was constant, and when, sg, was increasing more, the rages were increasing more.

[Therefore], The amount of erroneous orders, Sg, decided ranges of price falls, [and] sg is a key parameter.



[This figure shows] reaching times to the minimum under sg = tg times pg = const.

☆ Reaching times to the minimum price increase sufficiency less than incrementation of tg.

☆ When sg was larger, reaching times were longer

○ Motivation
○ Our Artificial Market Model (Multi-Agent Simulation)

Experiment 1

○ Characteristics of erroneous-Order Turbulence

☆ Market prices declined not only during but also for a while after the period of erroneous orders.
☆ The amount of erroneous orders decided ranges of price falls.

Experiment 2

○ Effects of Price Variation Limits to the Turbulence

Condition to Prevent the Large Turbulence | $t_{pl} < t_g$

t_{pl}: **limit time span**
t_g: **time of erroneous orders existing**

Summary & Implication to market regulations

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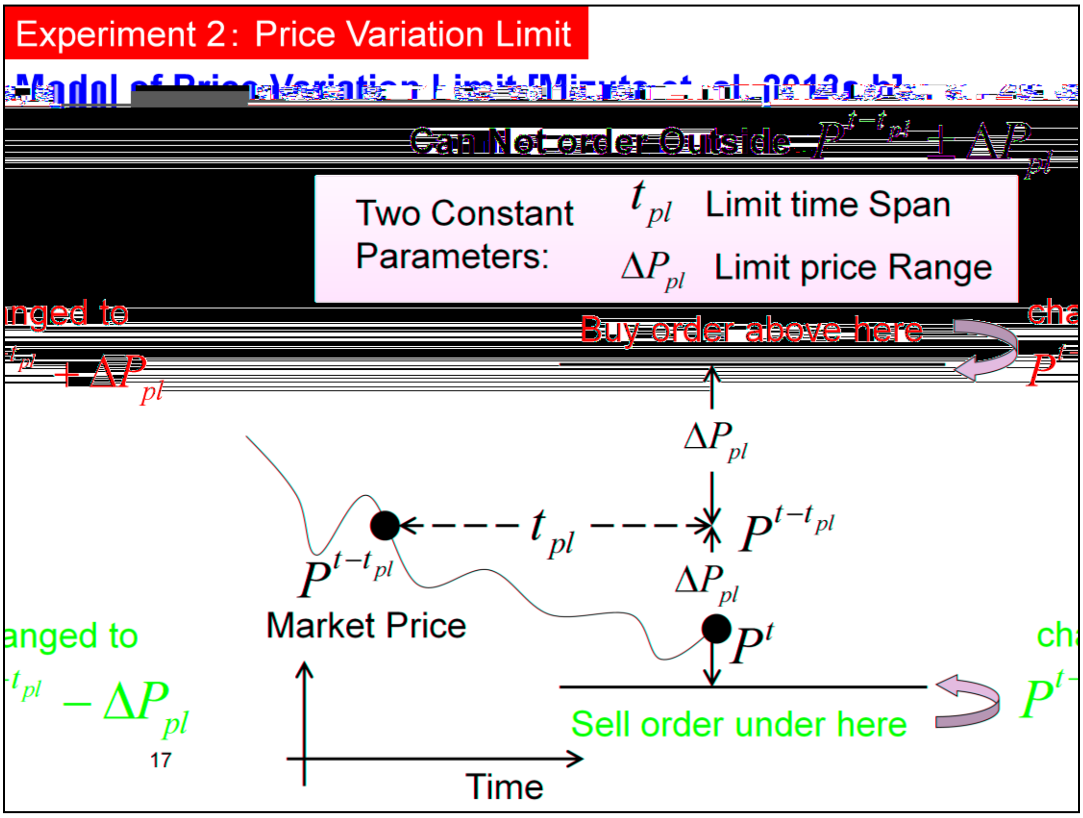
[Next, I show simulation results of] Experiment 2 [about] Effects of Price Variation Limits to the Turbulence



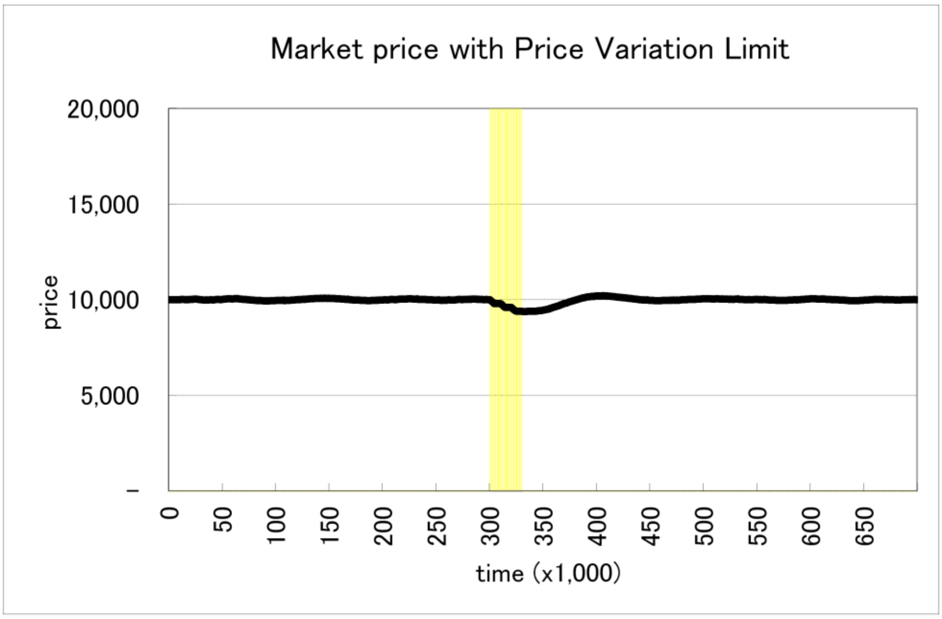
[We modeled] the price variation limit [like this].

[There are] two constant parameters.
Tpl is a limit time span, and ⊿Ppl is limit price range.

[We referred] market price [Before tpl],
[and any agents] can Not order OutSide Pt-tpl ± ⊿Ppl

[I mean, Any] buy order prices above here, [they are] changed to this price.
[and any] sell order prices under here [they are] changed to this price.

With Price Variation Limit (t_{pl}=10000, ΔP_{pl}=200)



The price variation limit succeeded to Prevent the Large Turbulence

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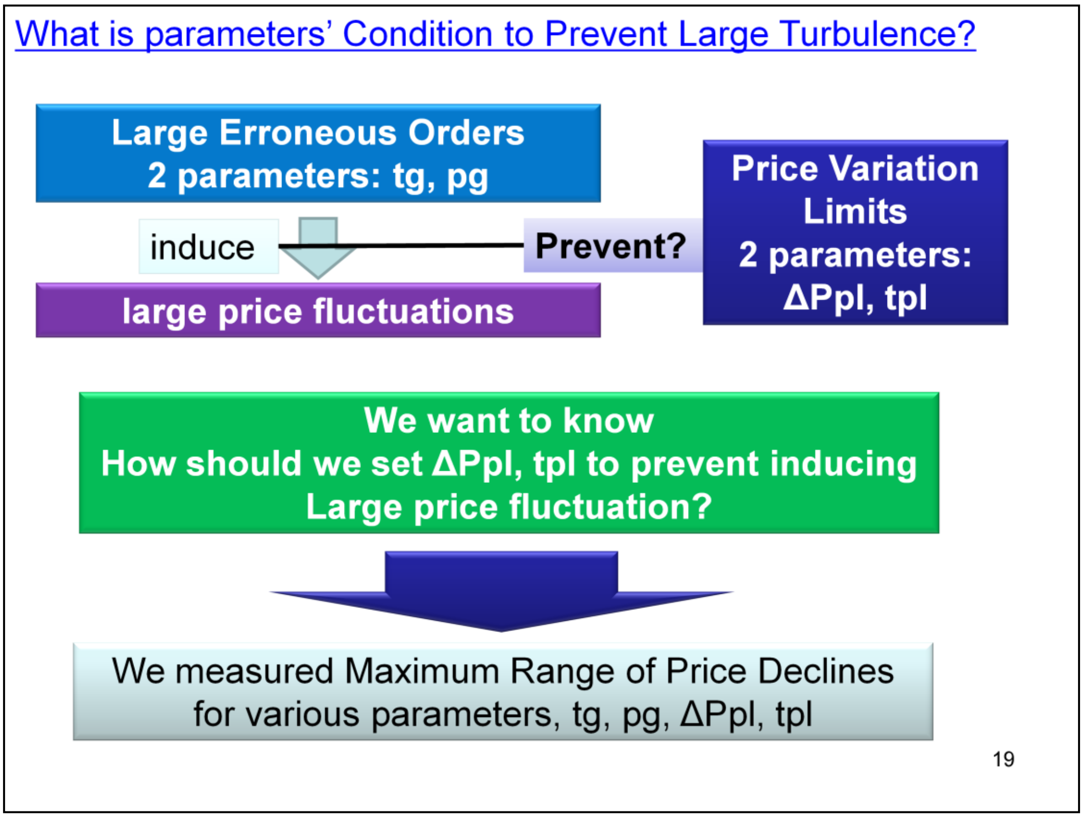
[This figure shows a time evolution of market prices] with the price variation limit.

[In these parameters], The price variation limit succeeded to prevent the large turbulences.



What is parameters' Condition to Prevent Large Turbulence?

Large Erroneous Orders [have] 2 parameters: tg, pg

Price Variation Limits [have] 2 parameters:ΔPpl, tpl

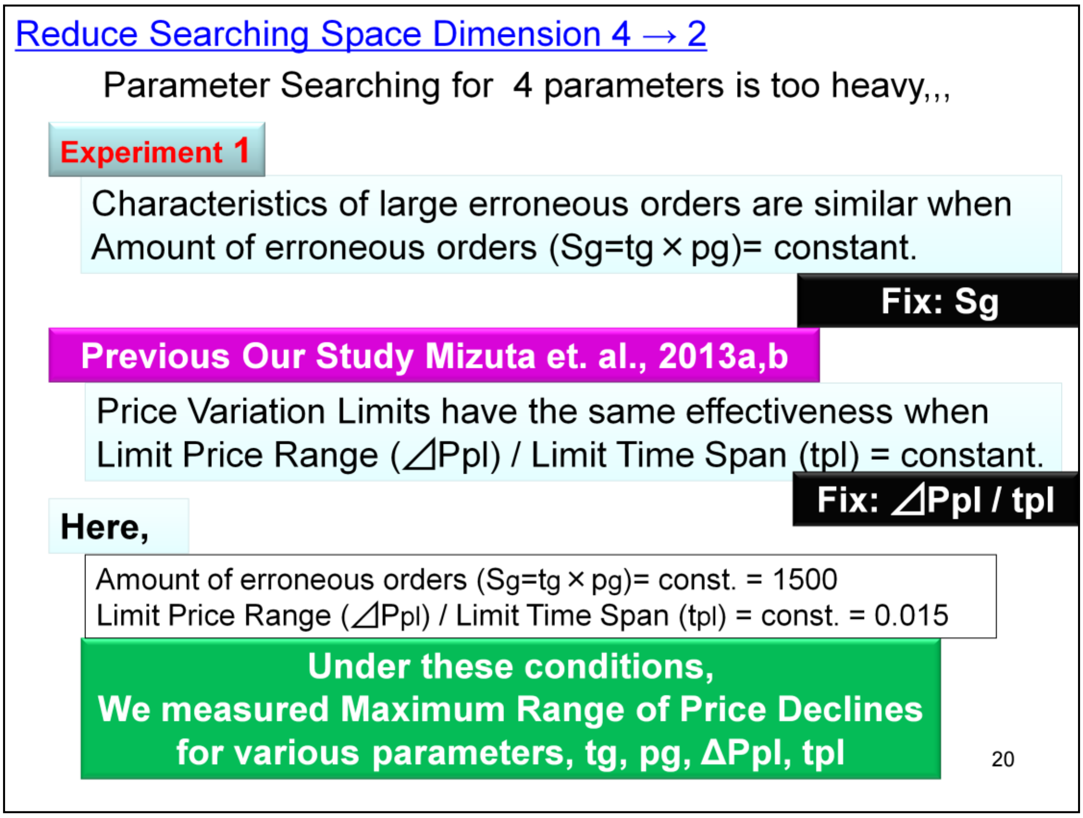
We want to know

How should we set ΔPpl, tpl to prevent inducing

Large price fluctuation?

We measured Maximum Range of Price Declines

for various parameters, tg, pg, ΔPpl, tpl



Parameter Searching for 4 parameters is too heavy,

[Therefore, we] Reduce Searching Space Dimension 4 → 2

[As mentioned in] Experiment 1,

Characteristics of large erroneous orders are similar when Amount of erroneous orders (Sg=tg×pg)= constant.

[Therefore, we] fix Sg.

[As mentioned in] Previous Our Study Mizuta et. al., 2013a,b

Price Variation Limits have the same effectiveness when Limit Price Range (⊿Ppl) / Limit Time Span (tpl) = constant.

[Therefore, we] ⊿Ppl / tpl

Under these conditions,

We measured Maximum Range of Price Declines for various parameters, tg, pg, ΔPpl, tpl

Maximum Range of Price Declines for various Parameters

			erroneous orders						
		tg	2,000	5,000	10,000	20,000	30,000	40,000	50,000
		pg	75%	30%	15%	7.5%	5.0%	3.75%	3.00%
	tpl	⊿Ppl							
price variation limit	1,000	15	92	158	241	370	497	616	719
	2,000	30	95	175	243	380	513	638	751
	5,000	75	147	152	222	368	515	654	784
	10,000	150	174	175	181	339	502	666	795
	20,000	300	317	317	315	321	615	642	788
	30,000	450	457	468	467	463	470	664	850
	40,000	600	610	618	614	617	615	619	755
	50,000	750	765	770	760	766	760	765	770
	100,000	1,500	1,494	1,454	1,447	1,393	1,375	1,345	1,326
	non		1,656	1,594	1,526	1,437	1,398	1,390	1,331

Green Area : $t_{pl} < t_g$ ⇒ Small Price Decline

Condition to Prevent the Large Turbulence

$t_{pl} < t_g$

Limit Time Span should be Shorter than Time of Erroneous Orders Existing

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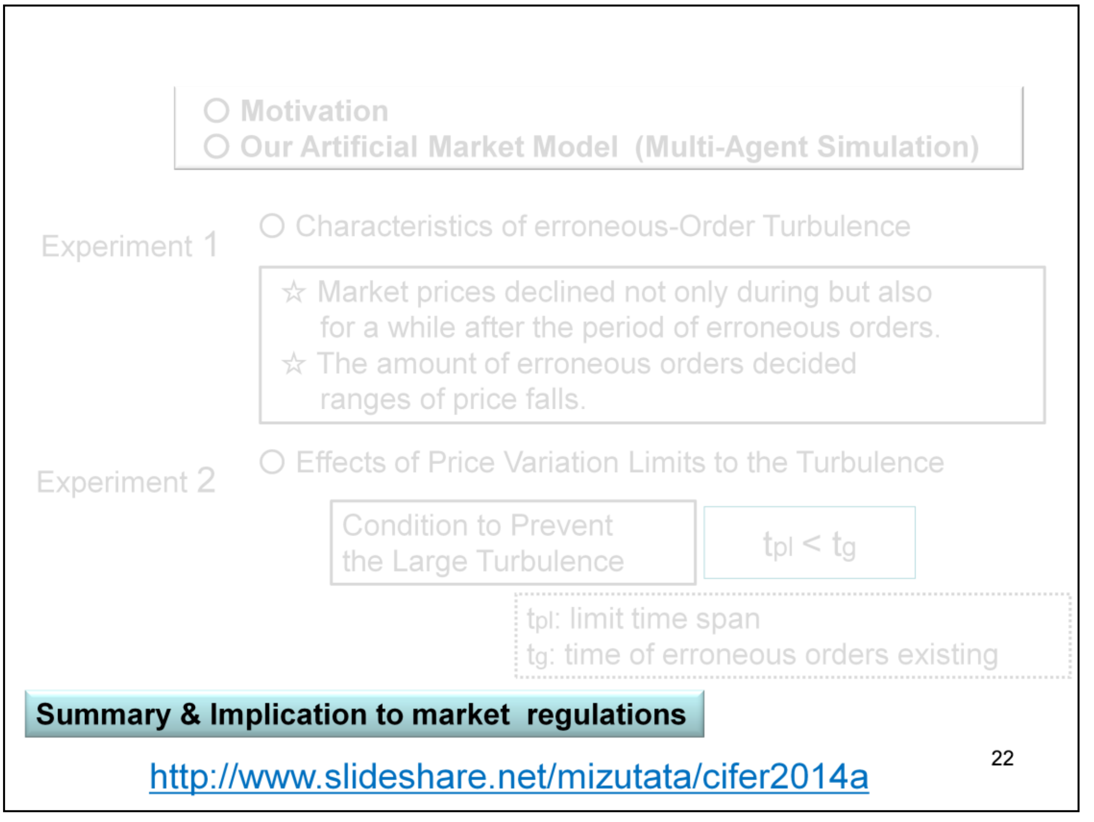
[This table lists] maximum ranges of price declines for various parameters.

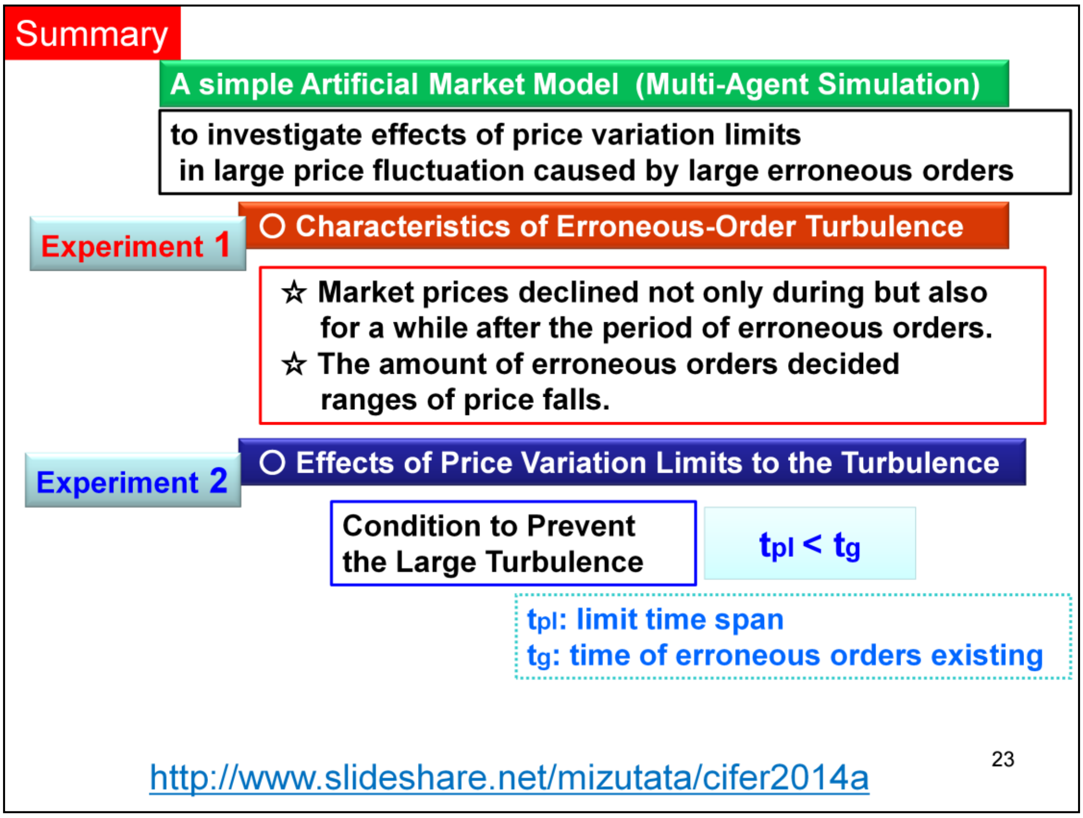
Green Area [satisfy], tpl smaller than tg. [In these regions], Small Price Decline.

Condition to Prevent the Large Turbulence

[is the] limit time span should be shorter than [the] time of erroneous orders existing.



[Lastly, I will mention] Summary & Implication to market regulations.



[We built a simple] artificial market model to investigate effects of price variation limits in large price fluctuation caused by large erroneous orders.

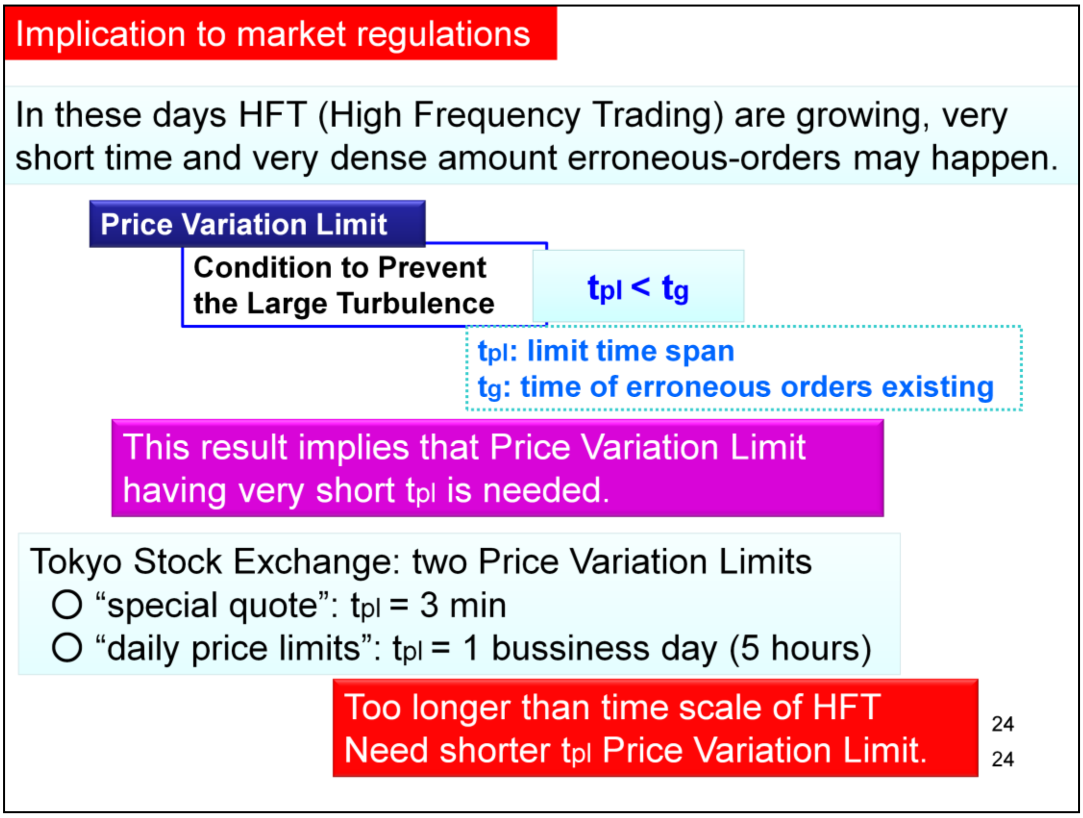
[In] Experiment 1, [we investigated about] Characteristics of Erroneous-Order Turbulence [and showed that]

Market prices declined not only during but also for a while after the period of erroneous orders.

[And], The amount of erroneous orders decided ranges of price falls.

[In] Experiment 2, [we investigated about] Effects of Price Variation Limits to the Turbulence [and showed that]

[The] Condition to Prevent the Large Turbulence is, the limit time span should be shorter than the time of erroneous orders existing.



[Lastly, I will mention] Implication [of this study result] to market regulations

In these days HFT (High Frequency Trading) are growing, very short time and very dense amount erroneous-orders may happen.

[As I mentioned], price variation limit [should have] smaller limit time span [than] time of erroneous orders existing.

This result implies that Price Variation Limit having very short tpl is needed.

[For Example], Tokyo Stock Exchange: two Price Variation Limits

○ “special quote”: t_{pl} = 3 min

○ “daily price limits”: t_{pl} = 1 bussiness day (5 hours)

That's all for my presentation.

Thank you very much
for your cooperation !

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Could you say that again? (もう一度、おっしゃっていただけますか？)

I don't quite understand your question. (ご質問の趣旨が良く分からないのですが)

Could you please rephrase your question? (ご質問を分かりやすく言い換えていただけますか)

So, you are asking me about.... (つまり、お尋ねの内容は...ですね)

I totally agree with you. (私も全くあなたと同意見です)

That's a very challenging question for me to answer. (それは私にとって非常に答えがいのある質問です)

That's a question I'm not sure I can answer right now. (そのご質問にすぐお答えできるかどうか分かりません)

It would require further research. (さらなる研究結果を待ちたい)

You are right on that point. (その点に関してはあなたが正しい)

Our method will not solve the problem. (我々の方法ではその問題は解決できない)

References

Mizuta, T., Izumi, K., Yoshimura, S., Price Variation Limits and Financial Market Bubbles: Artificial Market Simulations with Agents' Learning Process, IEEE Symposium Series on Computational Intelligence, Computational Intelligence for Financial Engineering and Economics (CIFEr), 2013a.
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Mizuta, T., Izumi, K., Yagi, I., Yoshimura, S., Design of Financial Market Regulations against Large Price Fluctuations using by Artificial Market Simulations, Journal of Mathematical Finance, Scientific Research Publishing, Vol.3, No. 2A, 2013b.
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Chiarella C., G. Iori and J. Perello: The impact of heterogeneous trading rules on the limit order book and order?, Journal of Economic Dynamics and Control, 33, 3, 525-537, 2009.

Appendix

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Artificial Market Model (Agent Based Model)

On basis of Chiarella et. al. [2009]

+ Learning Process of agents

comparing between the case with Learning Process and without

Feature of our model

○ agent model is Simple

→ to avoid arbitrary result "Keep it short and simple"

Models should explain stylized facts as simply as possible

● pricing mechanism is Continuous Double Auction

→ not simple to implement realistic price variation limit

☆ Learning process

→ agents switch strategy, fundamental or technical

An overshoot occurred in the case with the learning process but did not occur in the case without the process

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We built an artificial market model on basis of Chiarella et. al. [2009].

Chiarella's model did not include Learning Process, however,

We built Learning Process of agents.

And we are comparing between the case with Learning Process and without it.

Our Agent Model is Simple. This is to avoid arbitrary result, "Keep it short and simple" principle.

We think Artificial Market Models should explain Stylized Facts as Simply as possible,

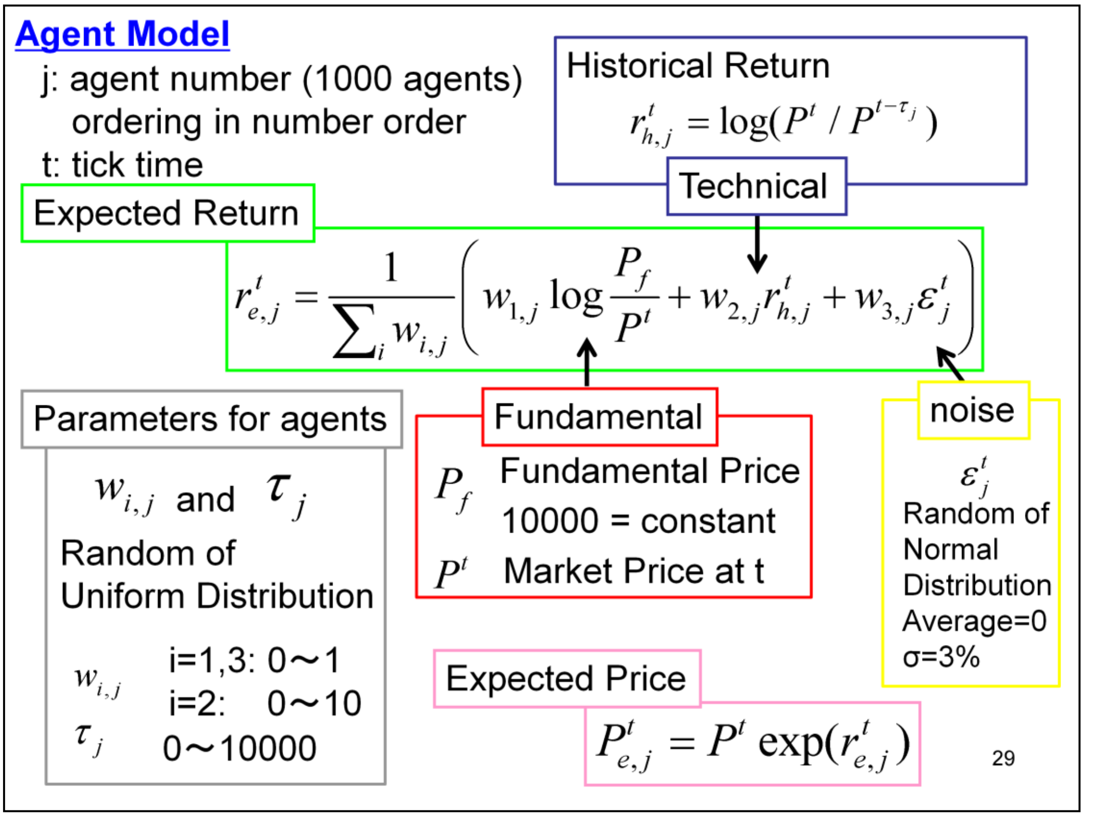
Our pricing mechanism is Continuous Double Auction

It is not simple, but, we need to implement realistic price variation limit

Learning process

Here, Learning process means agents are switching strategy, fundamental strategy or technical strategy.

We will show that, an Overshoot occurred in the case With the learning process, however, overshoot did not occur in the case WithOut the process



Next, I will describe agent model.

All agents calculate Expected Return using this equation.

First term is a Fundamental Strategy:

When the market price is smaller than the fundamental price, an agent expects a positive return , and vice verse.

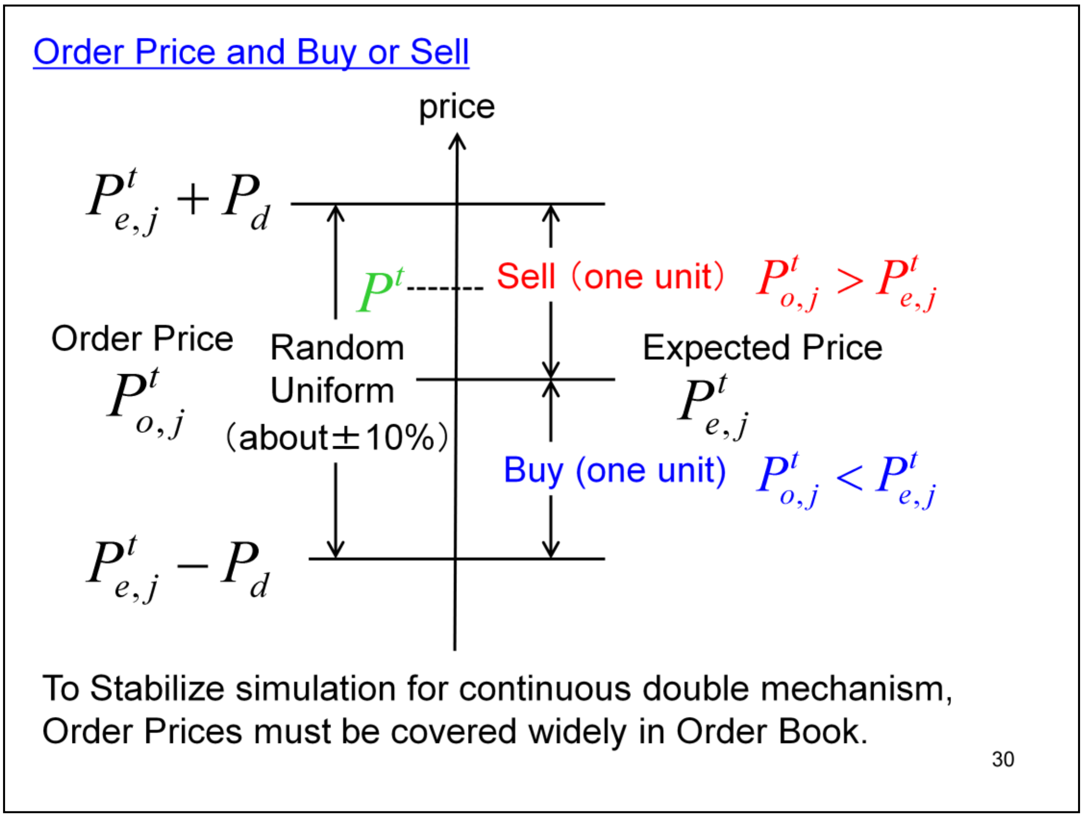
Second term is a technical strategy:

When historical return is positive, an agent expects a positive return, and vice verse.

Third term is noise,

After the expected return has been determined, an expected price is determined like this.

And, agents order base on this Expected Price.



Next, agents determine order price and, buy or sell.

To Stabilize simulation runs for the continuous double mechanism,
Order Prices must be covered widely in Order Book.

We modeled an Order Price, Po, by Random variables of Uniformly distributed in the interval from Expected Price, Pe, minus constant, Pd, to Pe plus Pd.

And then,
When Po lager than Pe, the agent orders to sell one unit.
When Po smaller than Pe, the agent orders to buy one unit.

Traditional Stylized Facts

		Non Mistaken orders	Mistaken orders
kurtosis		5.39	5.54
	lag		
autocorrelation coefficient for square return	1	0.13	0.49
	2	0.11	0.42
	3	0.09	0.40
	4	0.07	0.40
	5	0.06	0.38
	6	0.05	0.38
	q		
hazard rate	1	55%	55%
	2	53%	48%
	3	49%	42%
	4	47%	36%
	5	44%	30%
	6	44%	25%

All cases replicated: Fat Tail and Volatility Clustering

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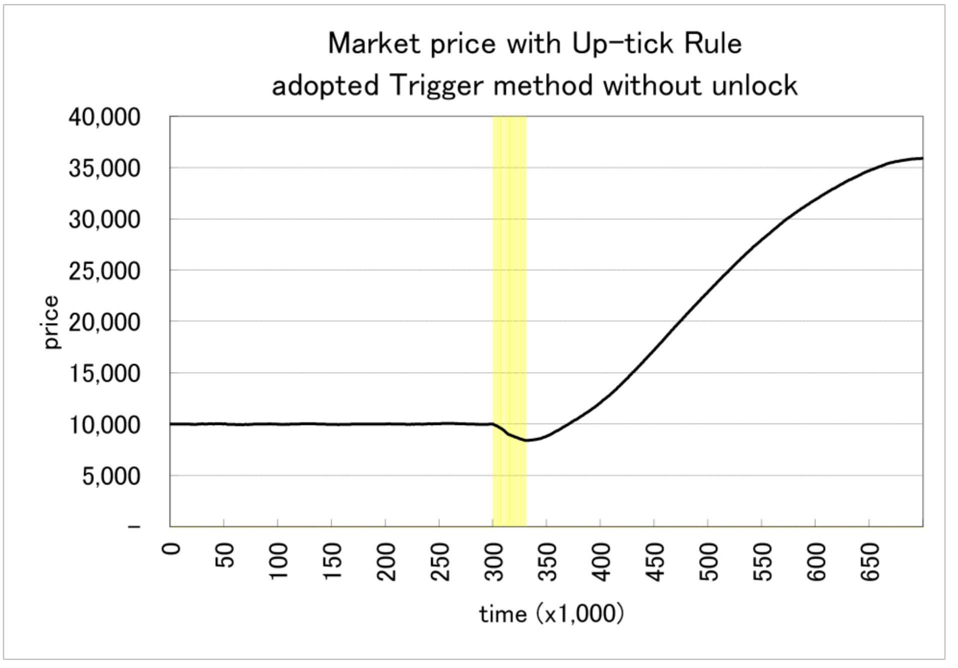
This Table lists Traditional stylized facts in each case.

In all cases, both kurtosis and autocorrelation for square returns for all i are positive.

This means that all cases replicate Traditional stylized facts: fat-tail and volatility-clustering.


Market price with Up-tick Rule
adopted Trigger method without unlock
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
–
price
0
50
100
150
200
250
300
350
400
450
500
550
600
650
time (x1,000)

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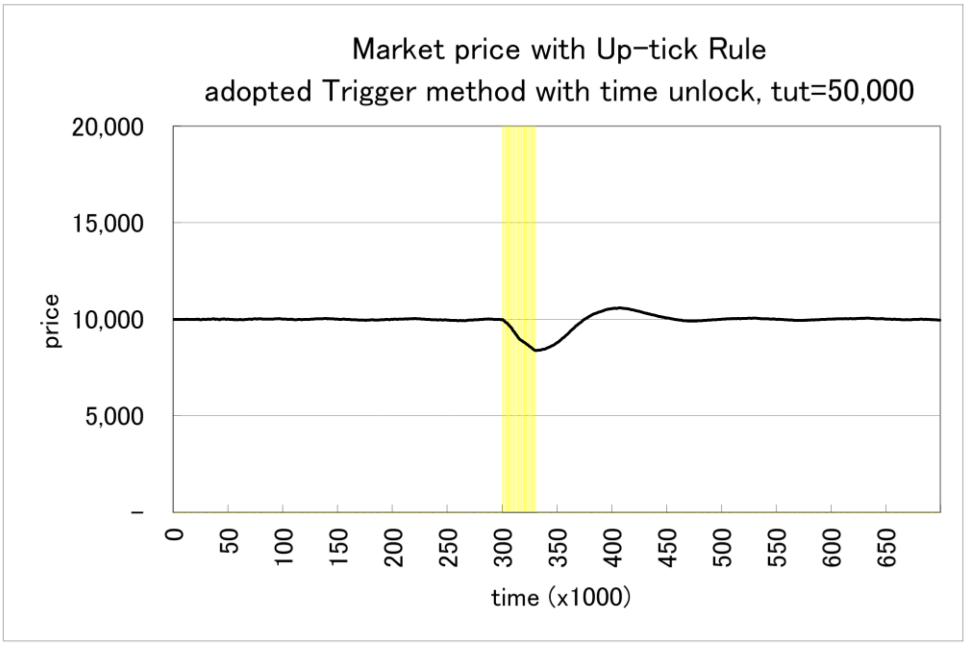
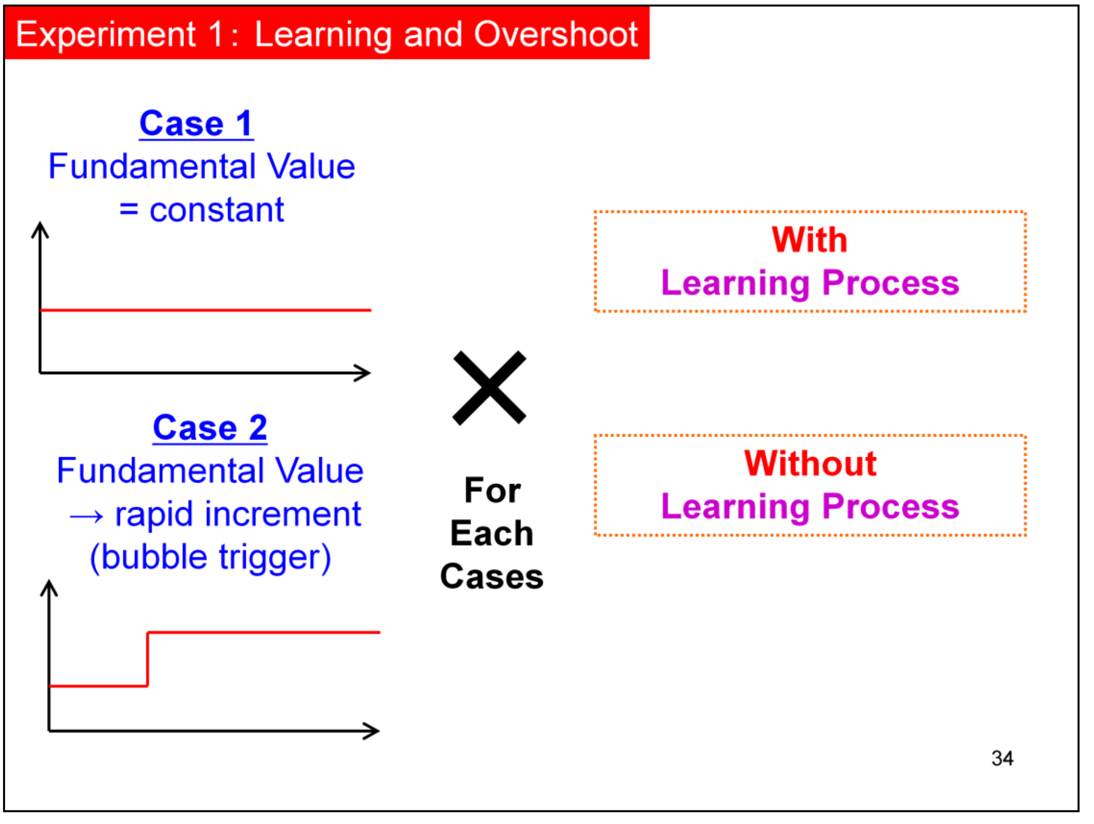


Market price with Up-tick Rule
adopted Trigger method with time unlock, tut=50,000
20,000
15,000
10,000
5,000
–
price
0
50
100
150
200
250
300
350
400
450
500
550
600
650
time (x1000)



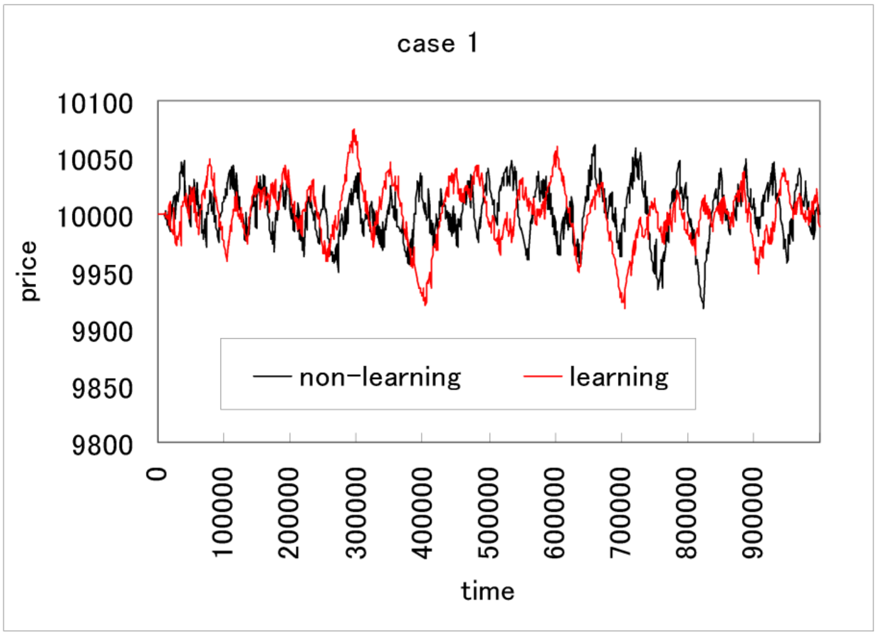
We examined two Cases, Case 1, Fundamental Value is constant,

Case 2, Fundamental value is rapid incremented like this. This is bubble inducing trigger.

For Each cases, we examined With learning process And WithOut learning process.

Therefore, we examined four cases in all.

Case 1 : Fundamental Value = constant



Small fluctuating around Fundamental Value

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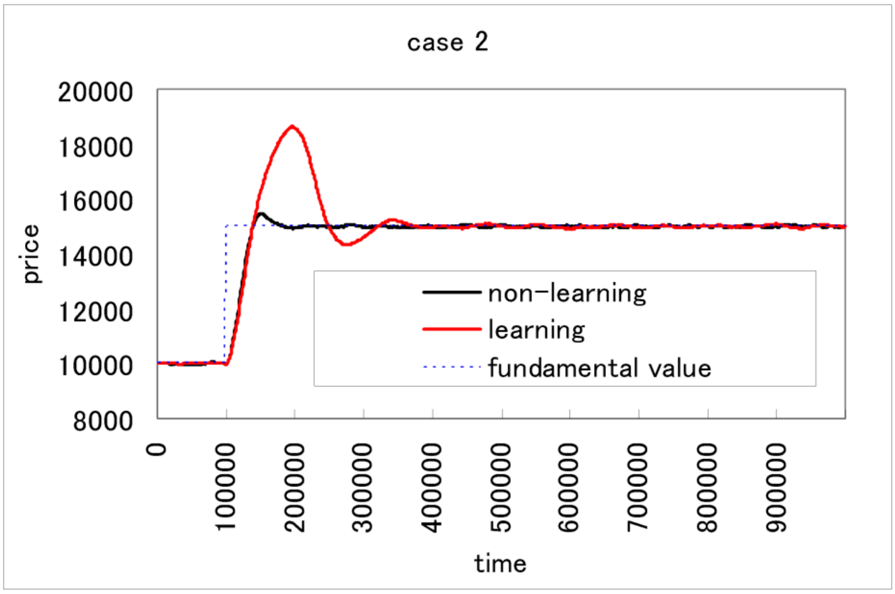
This Figure shows time evolution of market prices in case 1, Fundamental Value is constant.

In both cases, With learning process and without learning process. the results are very similar,

The prices were small fluctuating around Fundamental Value, here, Ten Thousand

Case 2 : Fundamental Value → rapid increment (bubble trigger)



Only with learning process, Overshoot occurred

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This Figure shows time evolution of prices in case 2.

Fundamental value was changed at this time, increased to New Fundamental Value, Fifteen Thousand.

This is the bubble inducing trigger.

Without Learning Process, Black line, Overshooting was not occurred.

On the other hand, with Learning Process, Red line,

the price went far beyond the new fundamental value.

Only with learning process, Overshoot occurred.

Traditional Stylized Facts

		case 1		case 2	
		non-learning	learning	non-learning	learning
kurtosis		3.018	5.394	2.079	3.180
	lag				
	1	0.134	0.125	0.219	0.325
	2	0.101	0.105	0.164	0.293
	3	0.076	0.087	0.133	0.274
autocorrelation coefficient for square return	4	0.060	0.074	0.118	0.261
	5	0.052	0.061	0.108	0.253
	6	0.040	0.054	0.100	0.247
	7	0.036	0.048	0.092	0.241
	8	0.030	0.045	0.087	0.237
	9	0.026	0.039	0.082	0.238

All cases replicated: Fat Tail and Volatility Clustering

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This Table lists Traditional stylized facts in each case.

In all cases, both kurtosis and autocorrelation for square returns for all i are positive.

This means that all cases replicate Traditional stylized facts: fat-tail and volatility-clustering.

Hazard Rate (similar to "run test")

New Stylized fact to verify model replicating overshoot

H(i) conditional probability that
sequence of positive return ends at *i*, given that it lasts until *i*.

For Example *i*=3、*H(3)*

Time	・・・・	1	2	3	4	
Return	↘	↗	↗	↗	↘	*H(3)*: Probability of 4th Return Negative

Empirical Studies:
- Any cases: *H(i)* < 50%,
- Overshoot period: *H(i)* decline with *I* rapidly

McQueen and Thorley [1994], Chan et. al. [1998]

⇒ Overshoot returns tend to continue to be positive
this tendency stronger continuing positive returns longer

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We propose Hazard Rate as New Stylized fact to verify model replicating overshoot

Hazard Rate Hi is conditional probability that sequence of positive return ends at i, given that it lasts until i.

For Example i=3, H3 means like this.

1st, positive return, 2nd, positive, 3rd positive,

In this condition, H3 is probability of 4th return become negative.

Empirical Studies showed that, Any cases, Hi for most of i are smaller than 50%

And when including overshoot period, Hi decline rapidly with i,

This show that the overshoot returns tend to continue to be positive

And this tendency stronger continuing positive returns longer

New Stylized Facts: Hazard Rate H(i)

		case 1		case 2	
		non-learning	learning	non-learning	learning
	i				
hazard rate	1	56%	55%	56%	55%
	2	55%	52%	55%	50%
	3	55%	50%	53%	45%
	4	54%	49%	52%	40%
	5	54%	45%	48%	36%
	6	53%	44%	45%	29%
	7	52%	41%	40%	26%
	8	52%	40%	35%	22%
	9	53%	40%	30%	19%

Only with Learning process → Verified by Hazard Rate
And Only Case 2 with Learning ⇒ Replicating Overshoot

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This Table lists New Stylized Facts: Hazard Rate in each case.

In case 2 with learning, hazard rate declined rapidly.
This case can replicate a significant Overshoot like actual markets.
On the other hand, the case without learning, hazard rate dose not declined rapidly.
The case can not replicate Overshoot.

Case 1, without learning, Hazard rates are upper 50% for all i.
This is Not consistent with empirical study.
On the other hand, Case 1, with learning, Hazard rates for most of i are smaller than 50%, even when price fluctuations are stable.

This consistent with empirical study.

Therefore, only cases with Learning Process were verified by Hazard Rate,
and only Case 2 can replicate overshoot.

Result Summary Experiment 1 : Learning and Overshoot

	Not-Consistent with Empirical study ↑ Without Learning Process	Consistent with Empirical study ↑ With Learning Process
Case1 Fundamental Value = constant	Stable Not-Verified by Hazard Rate	Stable Verified by Hazard Rate
Case2 Fundamental Value → rapid increment	No-Overshoot Not-Verified by Hazard Rate	Overshoot (Bubble & Crush) Verified by Hazard Rate

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Result Summary Experiment 1 relationship between Learning process and replicating Overshoot

The cases With learning process, both case 1 and case 2, were Consistent with Empirical study verified by Hazard Rate.

And case 2 can replicate overshoot, bubble and crush

The cases Without Learning Process were Not consistent with Empirical study Not verified by Hazard Rate.