5-8 November 2023 2023 IEEE Symposium on Computational Intelligence for Financial Engineering and Economics (IEEE CIFEr) https://attend.ieee.org/ssci-2023/

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



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Isao Yagi

(1) Introduction

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# (1) Introduction

(2) Our Model

(3) Simulation Results

(4) Conclusion

#### 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 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

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



#### 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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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.



Fundamental Strategy

Fundamental Price > Market Price -> Expect + return Fundamental Price < Market Price -> Expect - return

<u>Technical Strategy (Historical Return)</u> Historical Return > 0 -> Expect + return Historical Return < 0 -> Expect - return





Increasing such erroneous sell orders is what makes market prices fall

#### Stop-loss 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



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

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

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

<u>Circuit breaker</u>

	Limit time range (tr)						Limit time range (tr)						
		1000	2000	5000	10000	20000			1000	2000	5000	10000	20000
rice limit range (Pr)	10	298	157	73	45	33	Ge	10	152	103	57	34	22
	20	577	302	134	79	52	anç	20	297	207	107	58	43
	50	1227	721	313	167	110		50	702	487	266	163	105
	100	2000	1296	612	315	209	Pr	100	1222	<mark>869</mark>	520	315	208
	200	2194	2111	1140	615	408		200	1954	<b>1522</b>	821	614	407
	500	2054	2054	2053	1419	906	ice	500	2054	2054	2038	1061	503
à	1000	2054	2054	2054	2054	1433	P	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



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 — -price limit --- circuit breaker

Price limit version two were almost the same as circuit breaker

the differences between price limit 2 - circuit breaker



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.

D 1		•
Price	lin	nit
1 1100		

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 (1) Introduction

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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.

#### <u>Reference</u>

- [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, <u>https://doi.org/10.1002/isaf.1374</u>
- [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, <u>https://doi.org/10.1016/j.jbankfin.2022.106533</u>

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

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

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

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

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

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## Appendix

#### 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 volatilityclustering) 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. **30** 

#### Stylized Facts

	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		

 Table 1
 Statistics without arbitrage agents

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.