22-23 October 2024
2024 IEEE Computational Intelligence
for Financial Engineering and Economics (IEEE CIFEr)
https://www.stevens.edu/page-right-nav/cifer-conference-2024

An interaction between a leveraged ETF and futures in a crash investigated by an agent-based model

Takanobu Mizuta SPARX Asset Management Co. Ltd.
mizutata[at]gmail.com https://mizutatakanobu.com

Isao Yagi Kogakuin University

Note that the opinions contained herein are solely those of the authors and do not necessarily reflect those of SPARX Asset Management Co., Ltd.

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

(1) Introduction

(2) Our Model

(3) Simulation Results

(4) Conclusion

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

(1) Introduction

(2) Our Model

(3) Simulation Results

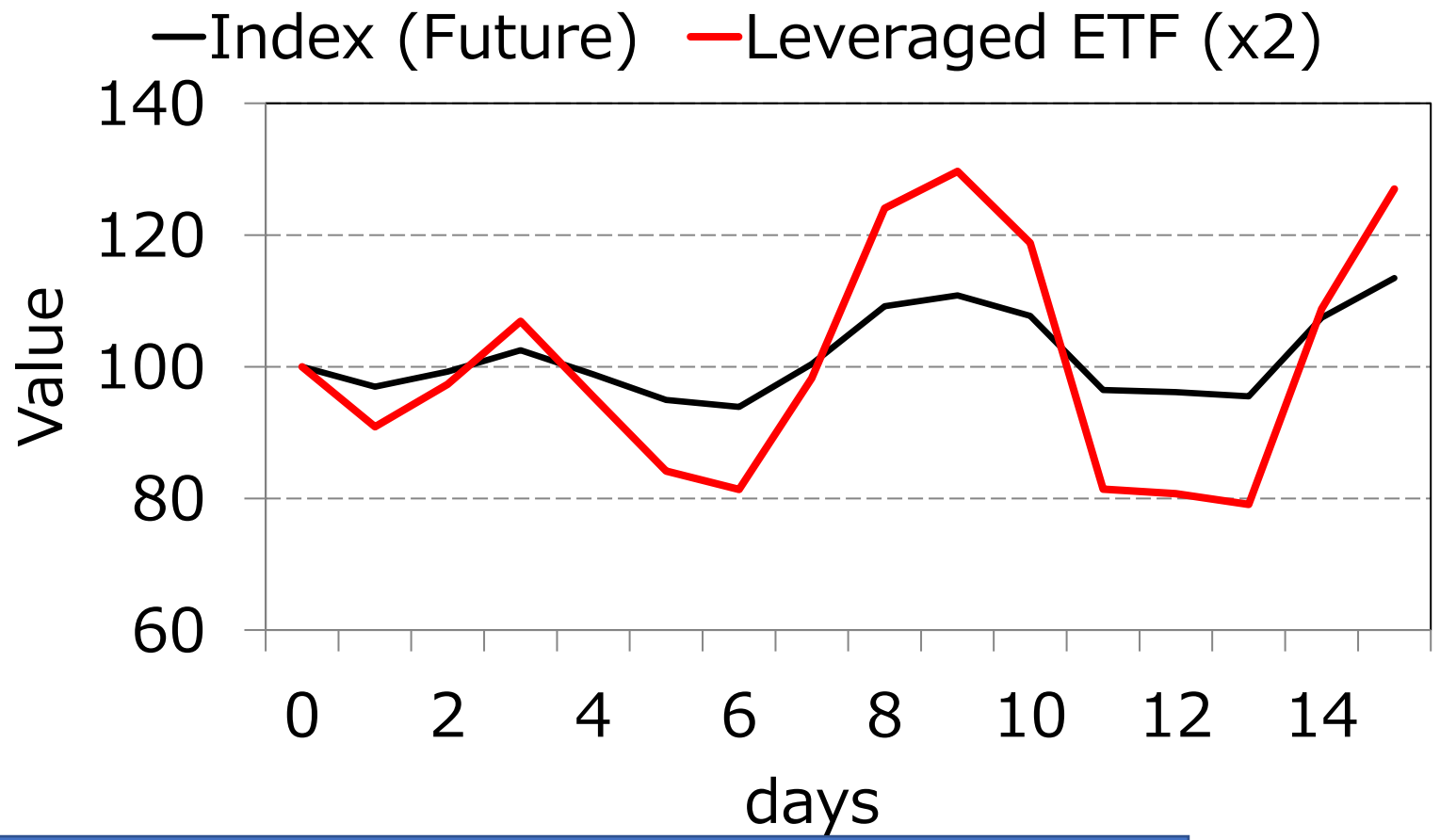
(4) Conclusion

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

Leveraged ETF (L-ETF)

ETF = Exchange Traded Funds is an investment fund traded on stock exchanges, much like stocks

A Leveraged ETF is designed to deliver several times the return of its benchmark index (future), e.g. S&P 500, Euro Stoxx 50, FTSE 100, Nikkei 225



Actually, Leveraged ETF has to trade the index on daily to maintain its leverage

Rebalance

Rebalance to maintain its leverage

For example, when the index returns are +10% on day 1 and -10% on day 2
The Leverage is twice (x2)

Days	Index (a) Return	Leveraged ETF (x2) is Designed as (b) Return = 2x(a)	(c) Value Will be by (b)	Leveraged ETF (x2) Holding Index (future) Value (d) **Should** have = 2x(c)	(e) **Will** be by (a)	(f) Rebalance = (d)-(e)
0			$100	x 2 $200	+10% $200	
1	+10%	+20%	+20% $120	x 2 $240	$220	+20
2	-10%	-20%	-20% $96	x 2 $192	-10% $216	-24

So, leveraged ETF

Buy the futures when its price goes up
Sell the futures when its price goes down

This leads

Momentum Trading

This momentum trading Rebalance concern some people,

This Rebalance makes Financial Market Unstable?

Difficulty of Empirical Study

There are many empirical studies that produce both opposite results

Difficulty of Empirical Study

Empirical studies cannot be conducted to isolate the pure contributions of L-ETFs due to the many diverse factors affecting price formation in actual markets

Artificial Market Model can

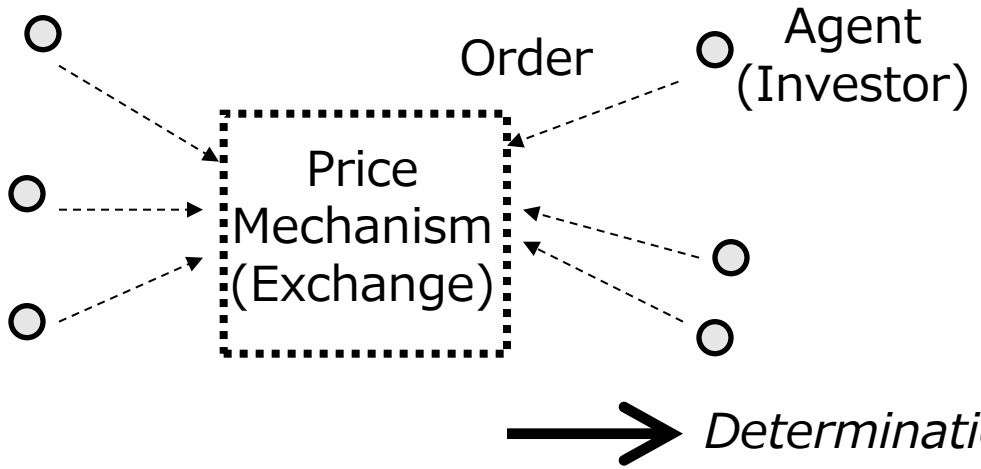
agent-based model for a financial market

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

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 pure contributions of L-ETFs
- ✓ can be conducted to investigate situations that have never occurred in actual financial markets
- ✓ can effectively handling micro-macro feedback loops

Previous Studies by Artificial Market Models

[Yagi 2016]

When a L-ETF impacts market prices more than their volatility
Market will be crushed

[Yagi 2020]

Using a continuous double auction
Investigated rebalance-trades to less impact to market prices

However, no previous study implemented a market in which a L-ETF itself is traded in an artificial market model and investigated effects of falling market prices of L-ETFs to those of futures.

Therefore in this study

[Yagi 2020] + L-ETF market Arbitrage Agent

We investigated that sharply falling of the futures or the L-ETF affects the another market and effects of rebalancing trades of the L-ETF

(1) Introduction

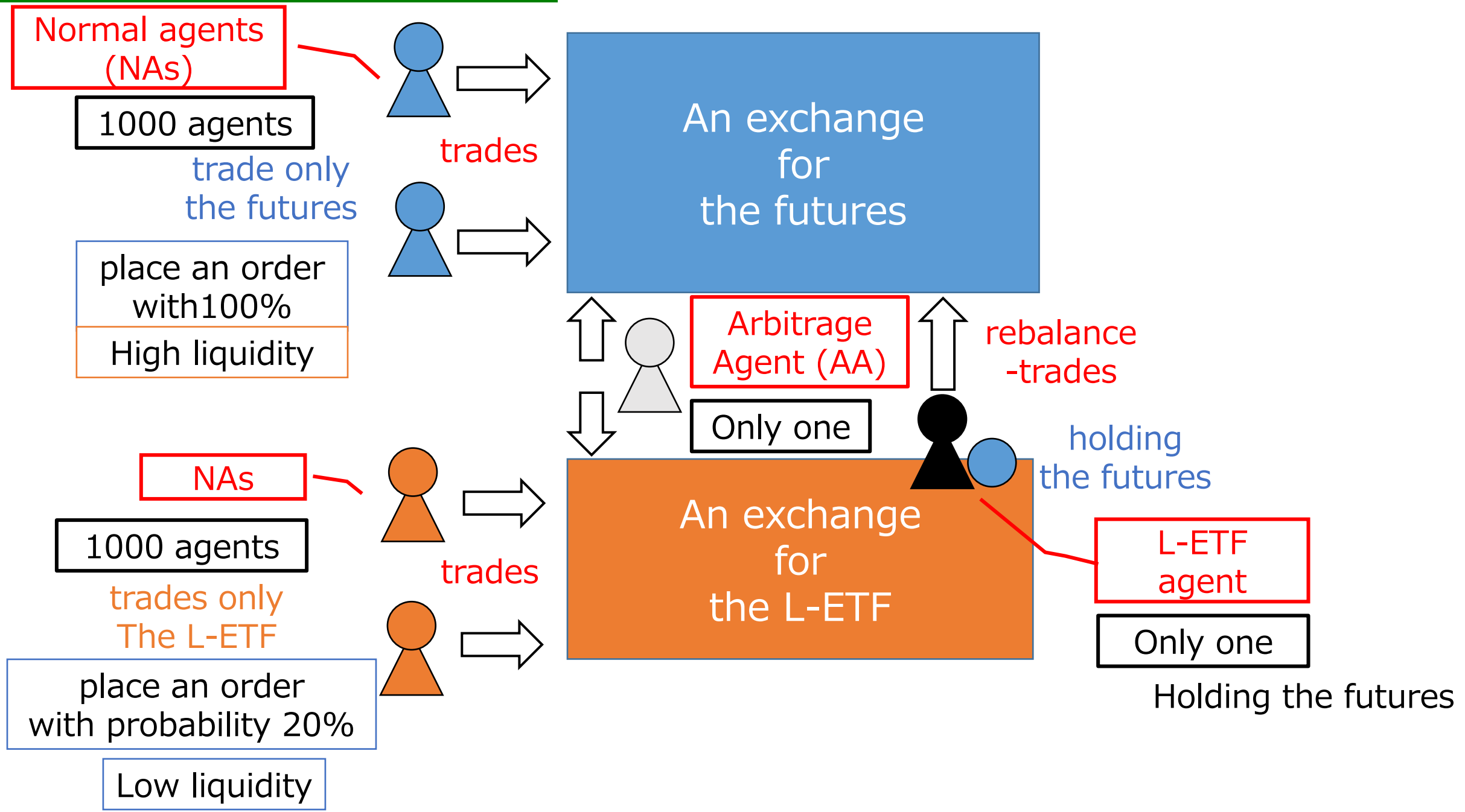
(2) Our Model

(3) Simulation Results

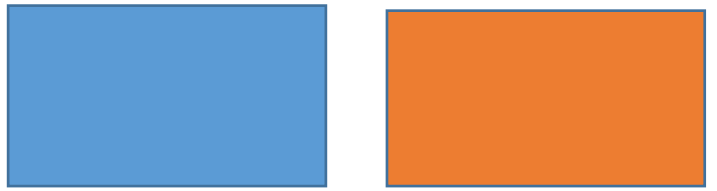
(4) Conclusion

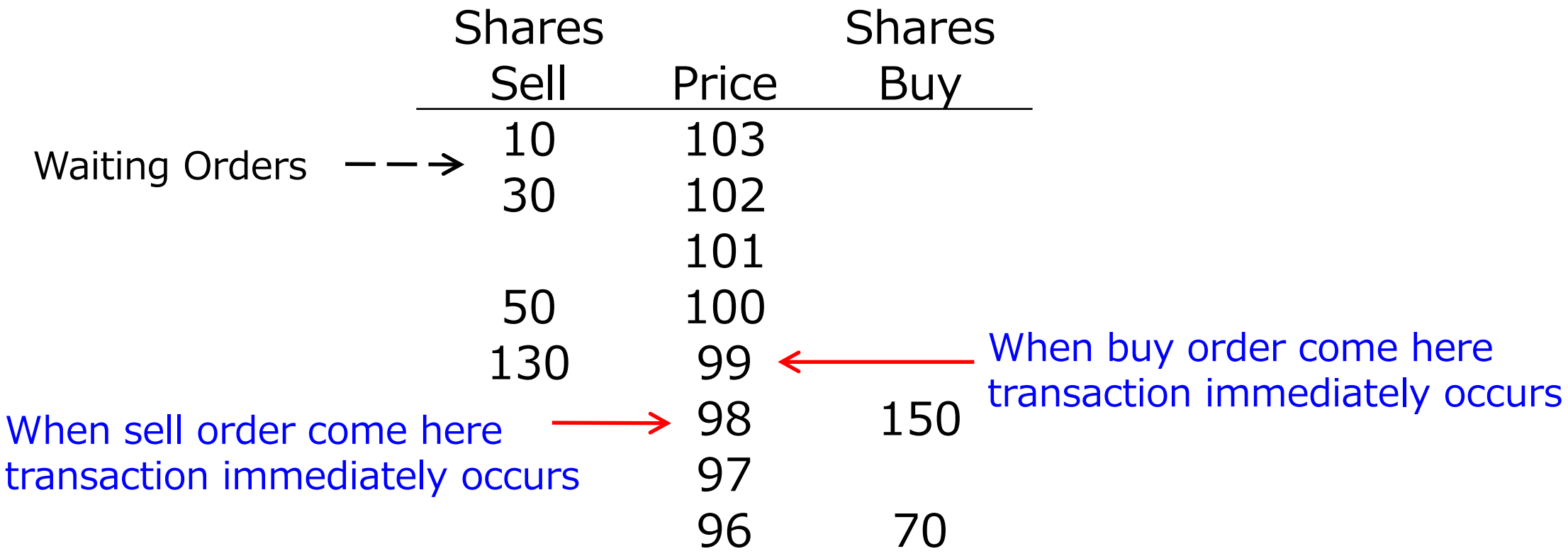
You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

Overall view of our model



Continuous Double Auction





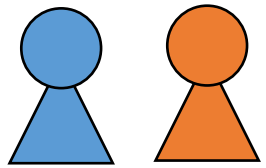
Multiple buyers and sellers compete to buy and sell stocks in the market, and transactions can occur at any time whenever an offer to buy and an offer to sell match.

Normal Agents (NAs)

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

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

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

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_j^t

Random of Normal Distribution
Average=0
σ=3%

To keep agents varied
To keep simulation runs stably

Expected Price of each agent

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

Fundamental Strategy

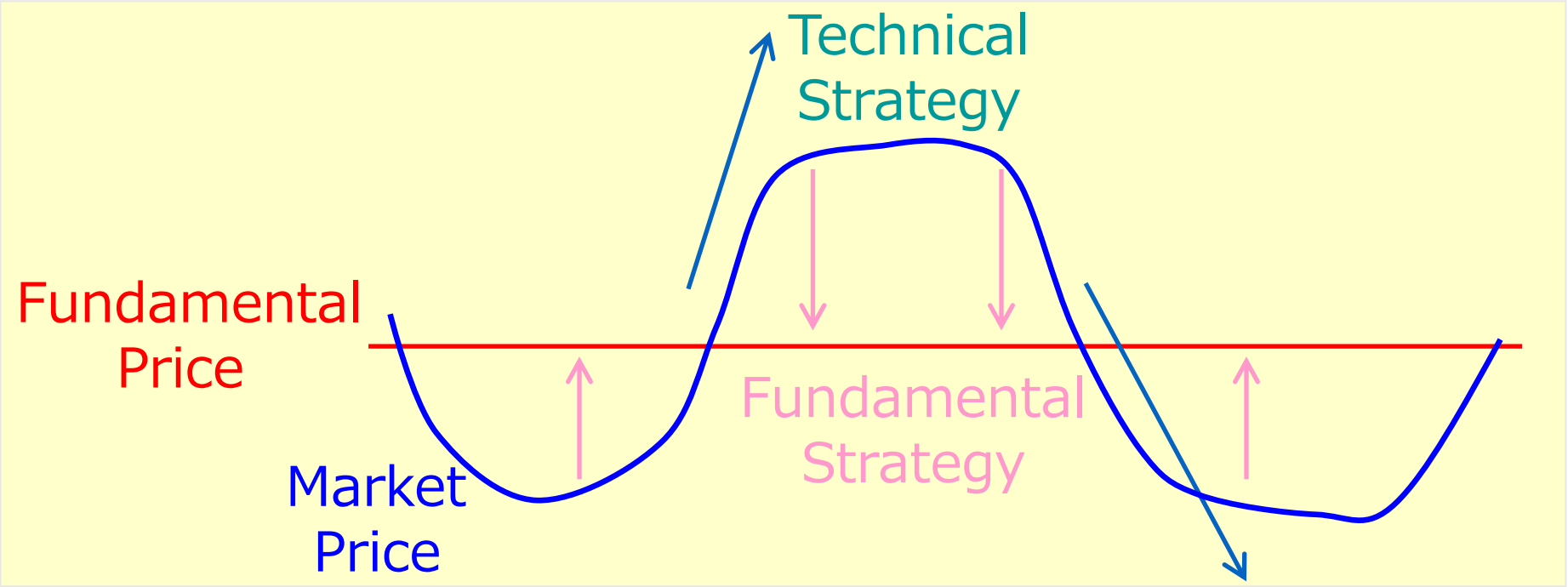
Fundamental Price > Market Price -> Expect + return

Fundamental Price < Market Price -> Expect - return

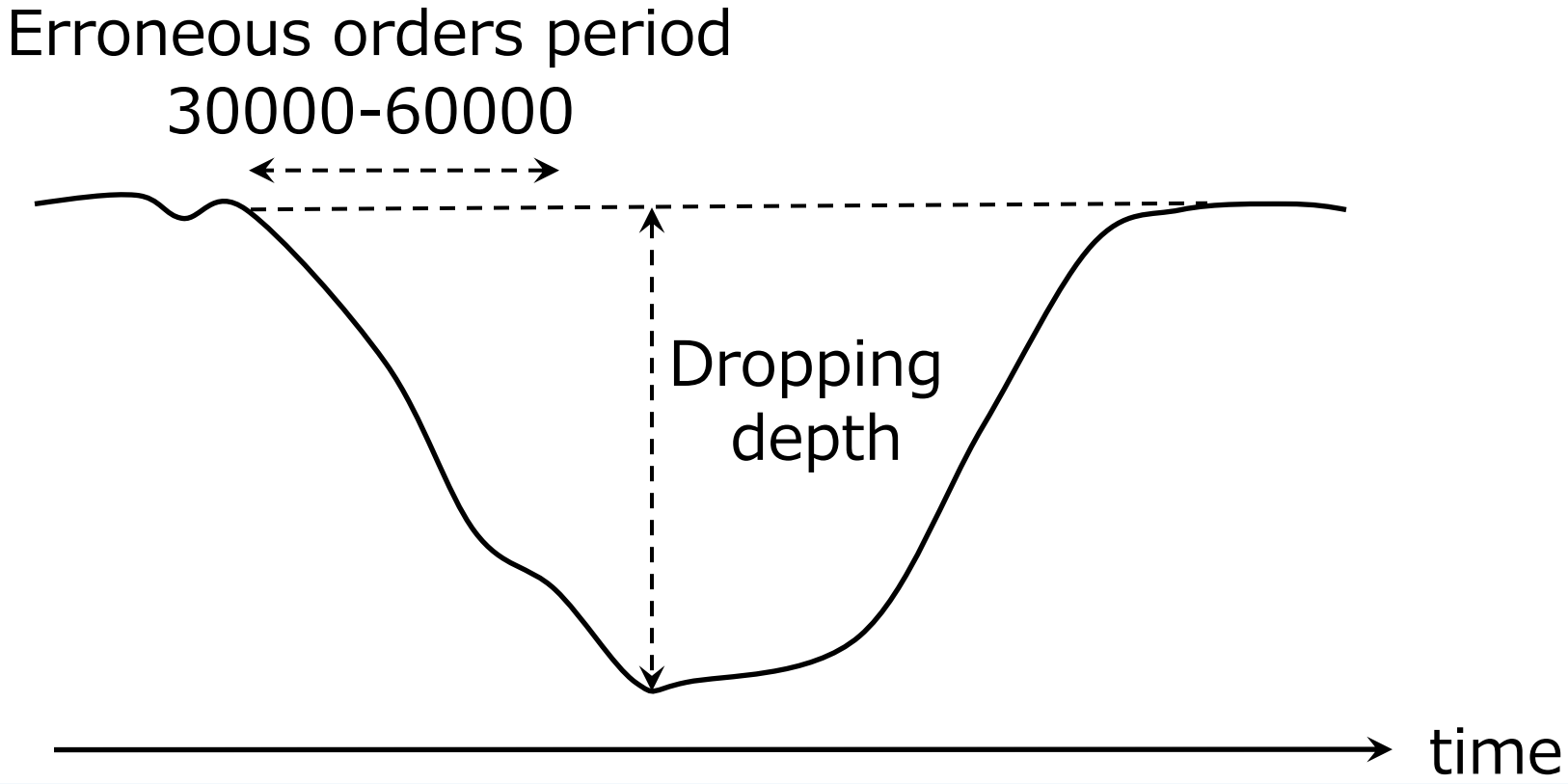
Technical Strategy (Historical Return)

Historical Return > 0 -> Expect + return

Historical Return < 0 -> Expect - return



Erroneous orders

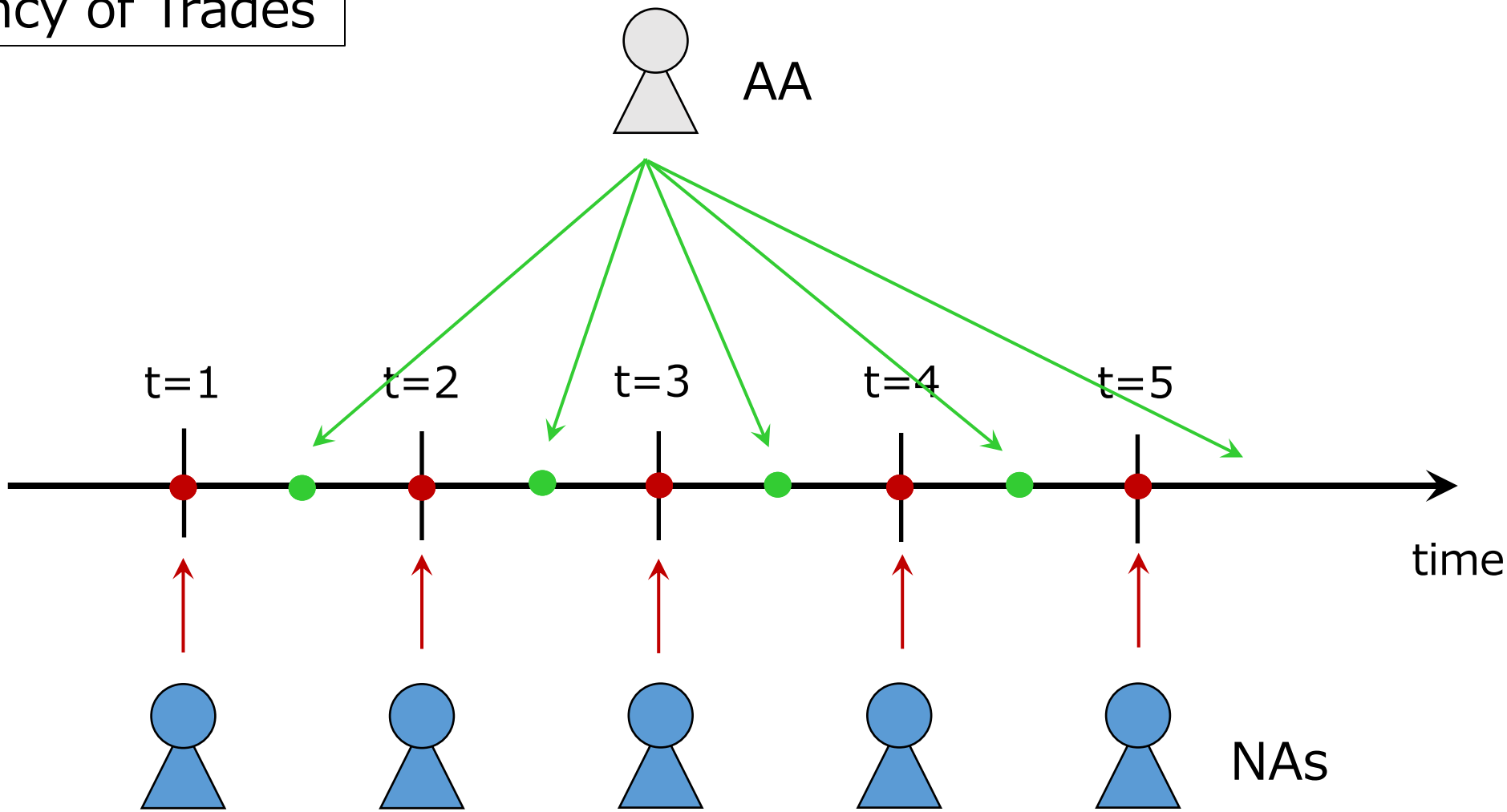


Within the period, with a constant
probability 8% for the future, 40% for the L-ETF
<- same total erroneous orders
each order of the NAs is changed to sell with very low price

Increasing such erroneous sell orders is what makes market prices fall

Arbitrage Agent (AA)

Frequency of Trades



The AA places an order and cancel an order any time

Price Relationship between L-ETF and Futures

Process of an arbitrage in real financial markets is very complex, e. g., a ratio that investors can equivalent-exchange the L-ETF for the futures are pass-depended of time evolution of their market prices.

In this study, the process of an arbitrage was modelized very simply

The Leverage is twice (x2)

L-ETF Return = 2 × Futures Return

	Fundamental P	Market Prices	Price Change Range	Example of Price Change	Example of Return
Futures	10000	about 10000	---	+500	5%
L-ETF	5000	about 5000	same as futures	+500	10%

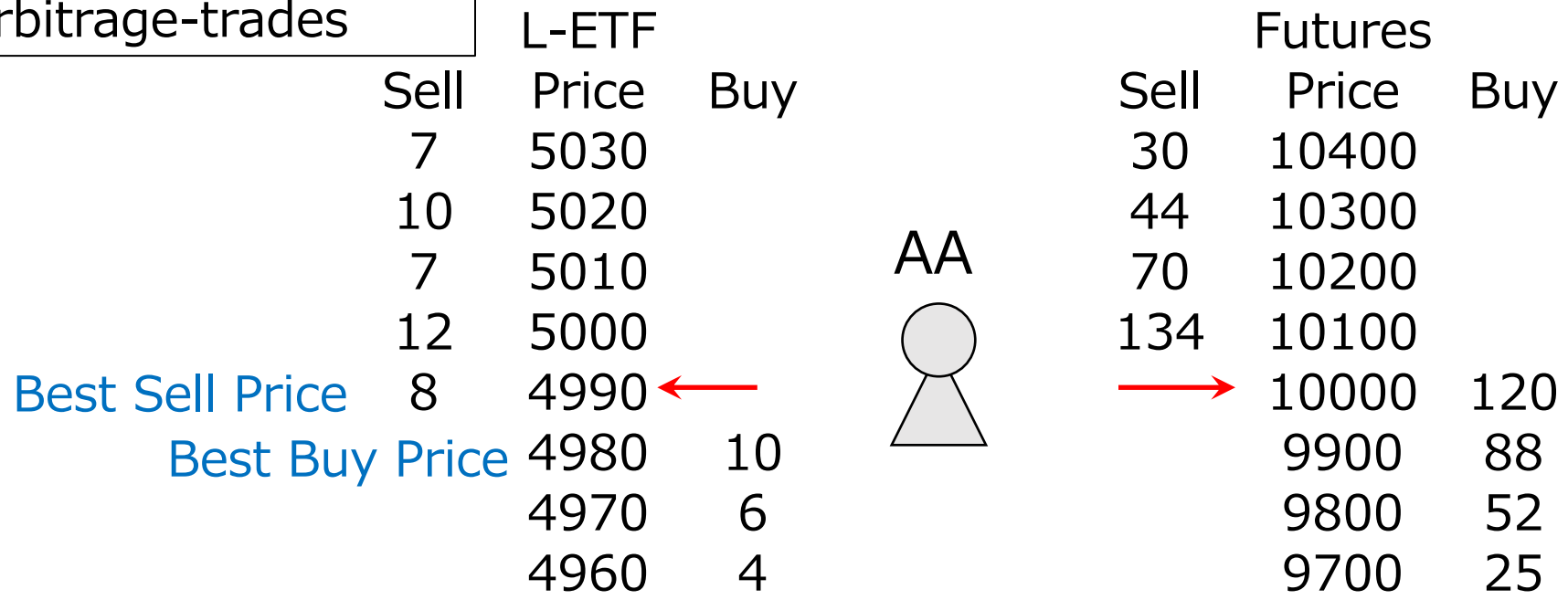
same

Twice

This means L-ETF Price = Futures Price - 5000

Arbitrage Agent place orders to maintain the price relationship

Immediately executed arbitrage-trades



Usually best sell price > best buy price, rarely can be reversed when orders from two different exchanges are combined

AA can earn to buy at the best sell price and sell at the best buy price

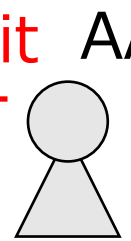
If L-ETF best Sell + 5000 < Future best Buy → Buy L-ETF Sell Futures

If Futures best Sell - 5000 < L-ETF best Buy → Buy Futures Sell L-ETF

Taking all arbitrage opportunities at that moment

Arbitrage-trades by waiting orders

L-ETF Sell	L-ETF Price	L-ETF Buy
7	5030	
10	5020	
	5010	
	5000	1
	4990	
	4980	10
	4970	6
	4960	4



Immediately Sell After waiting order executed

Futures Sell	Futures 価格	Futures Buy
30	10400	
44	10300	
70	10200	
134	10100	
	10000	120
	9900	88
	9800	52
	9700	25

AA places the waiting order to earn by immediately executing for another asset

If L-ETF best Buy < Futures best Buy - 5000 < L-ETF best Sell

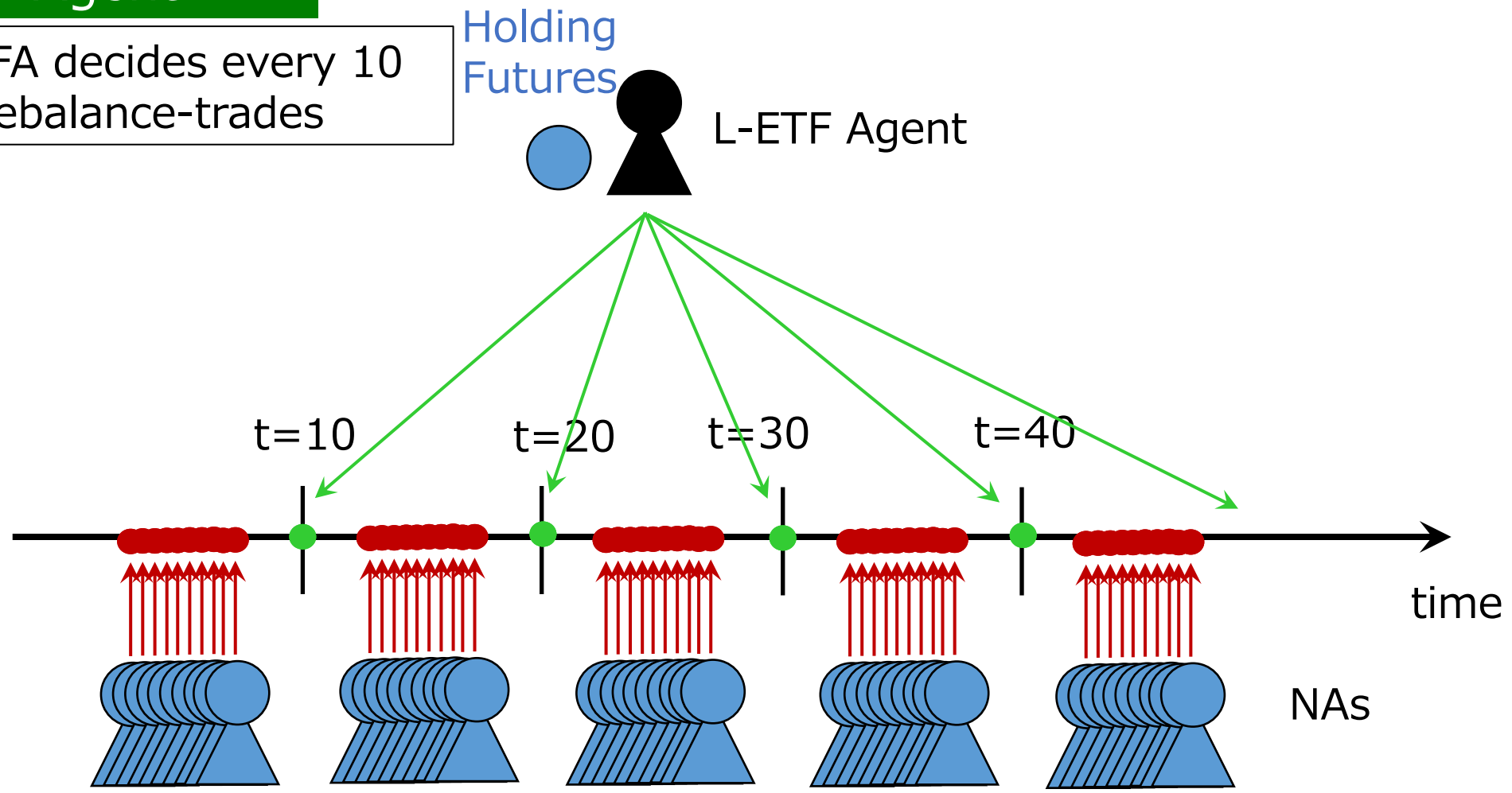
Placing buy waiting order at Futures best Buy – 5000 on L-ETF

When the waiting order is executed, AA sells Futures

L-ETF best Buy < Futures best Sell - 5000 < L-ETF best Sell, vice versa

L-ETF Agent

The L-ETFA decides every 10 if it rebalance-trades



To maintain leverage twice, it should holds

$S_0 \times$(Future Price/10000)

It trades when different more than 1%

Buy the futures when its price goes up
Sell the futures when its price goes down

This Rebalance makes Financial Market Unstable?

(1) Introduction

(2) Our Model

(3) Simulation Results

(4) Conclusion

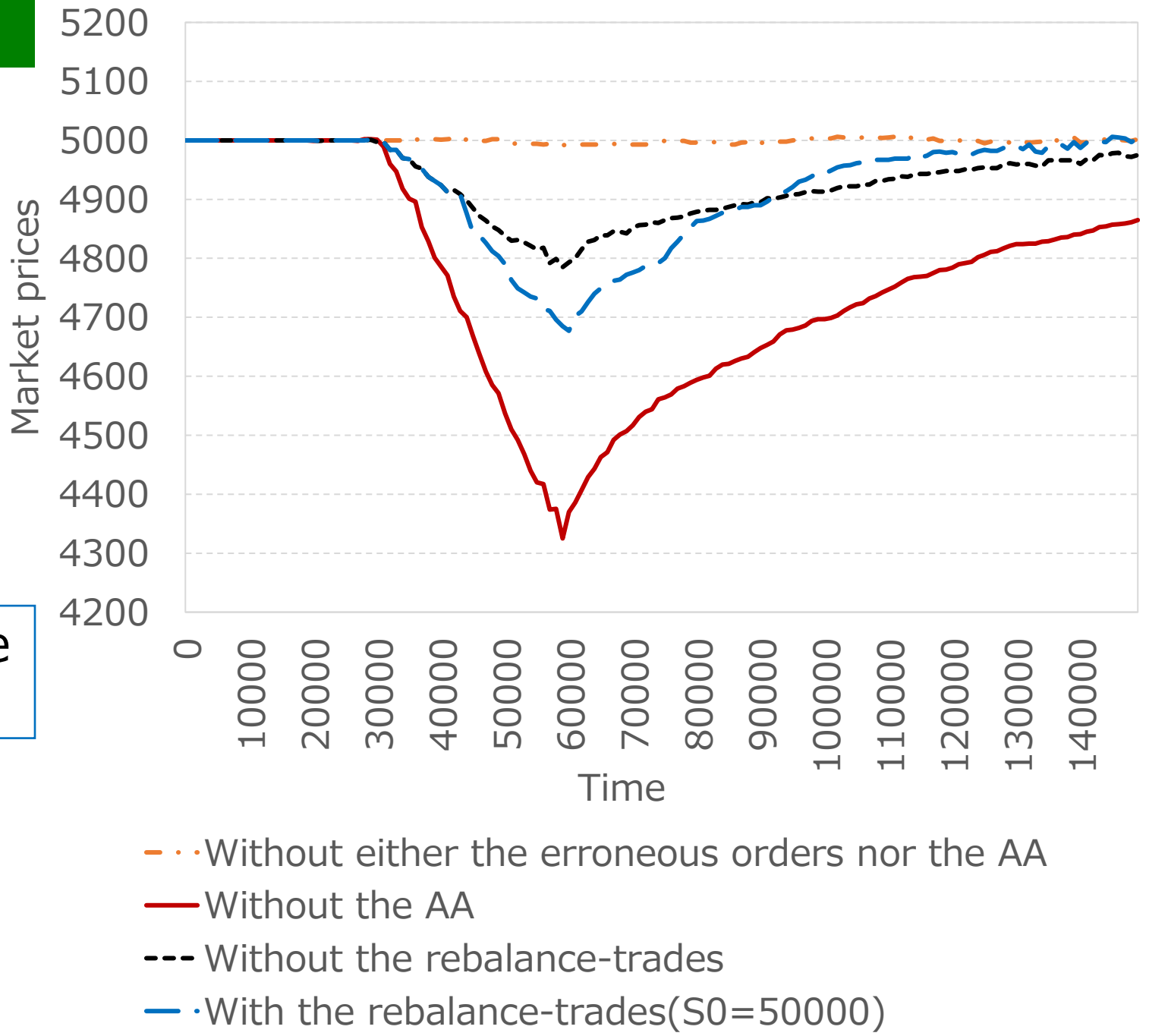
You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

Time evolution of L-ETF prices

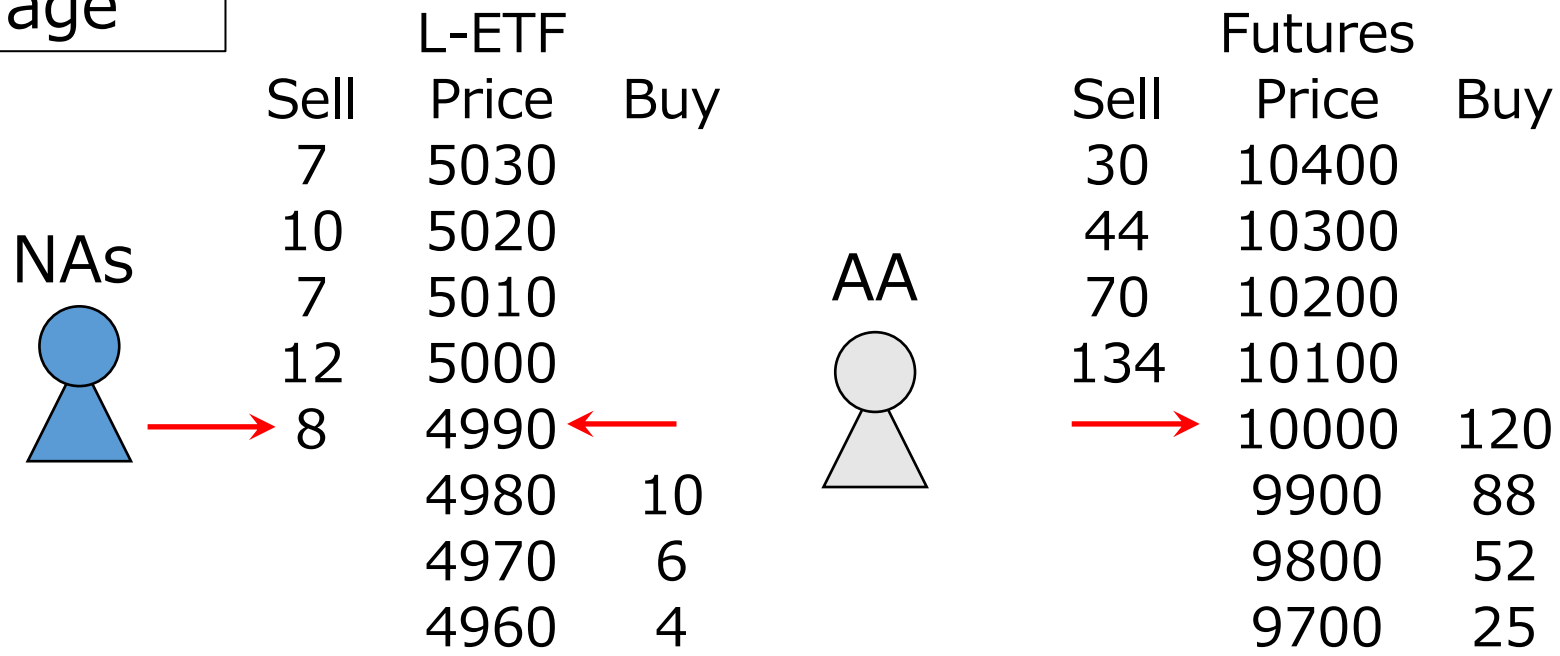
AA reduces the fall

Liquidity of the futures is consumed to prevent the fall of the L-ETF

Rebalance-trades make enlarge the fall of market prices



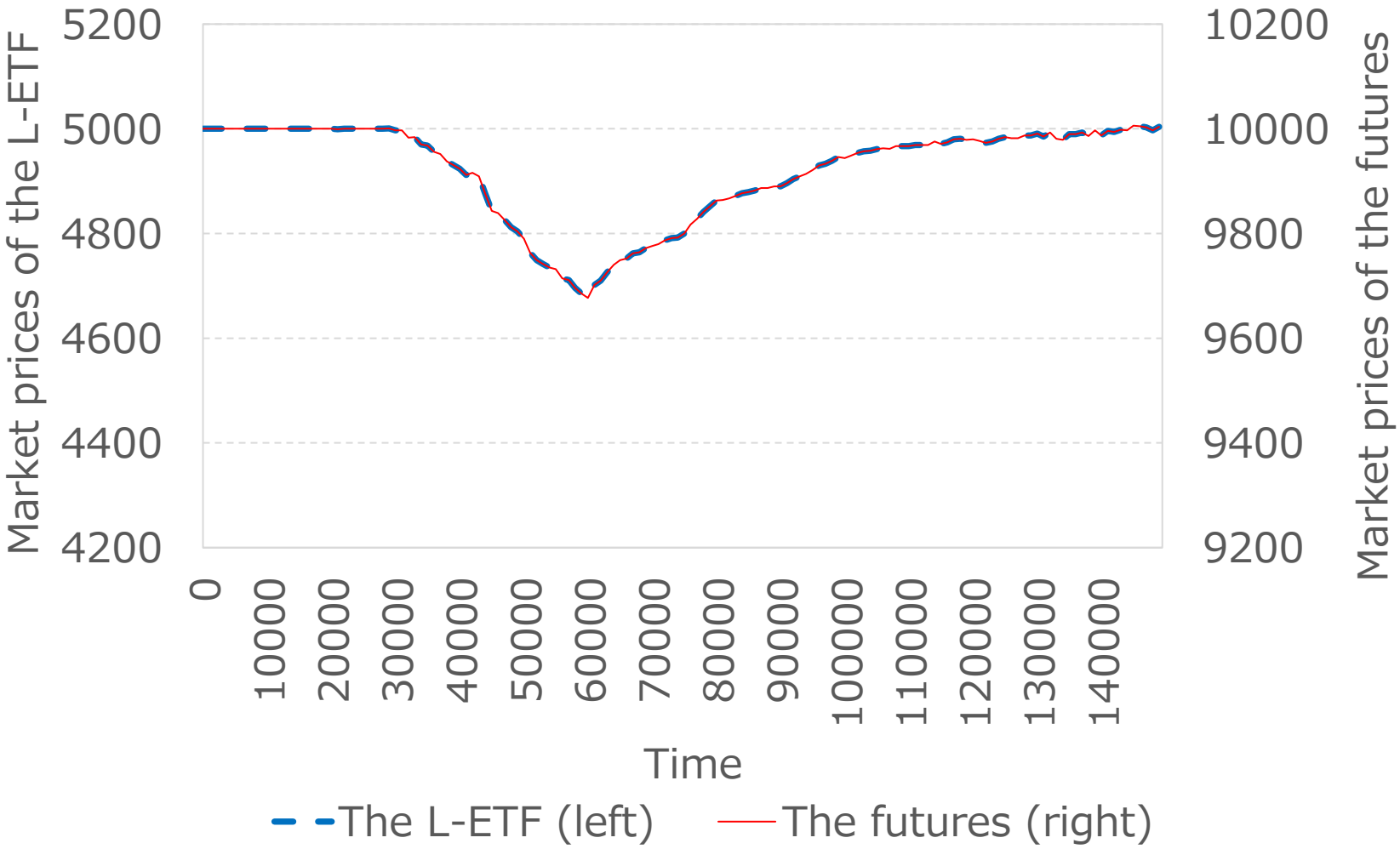
Arbitrage



NAs sell L-ETF -> AA buy L-ETF -> AA Sell Futures
So, NAs sell futures indirectly

Liquidity of the futures is consumed to prevent the fall of the L-ETF
Liquidity of the futures is used as hidden liquidity of the L-ETF

Time evolution of L-ETF and Futures prices with AA



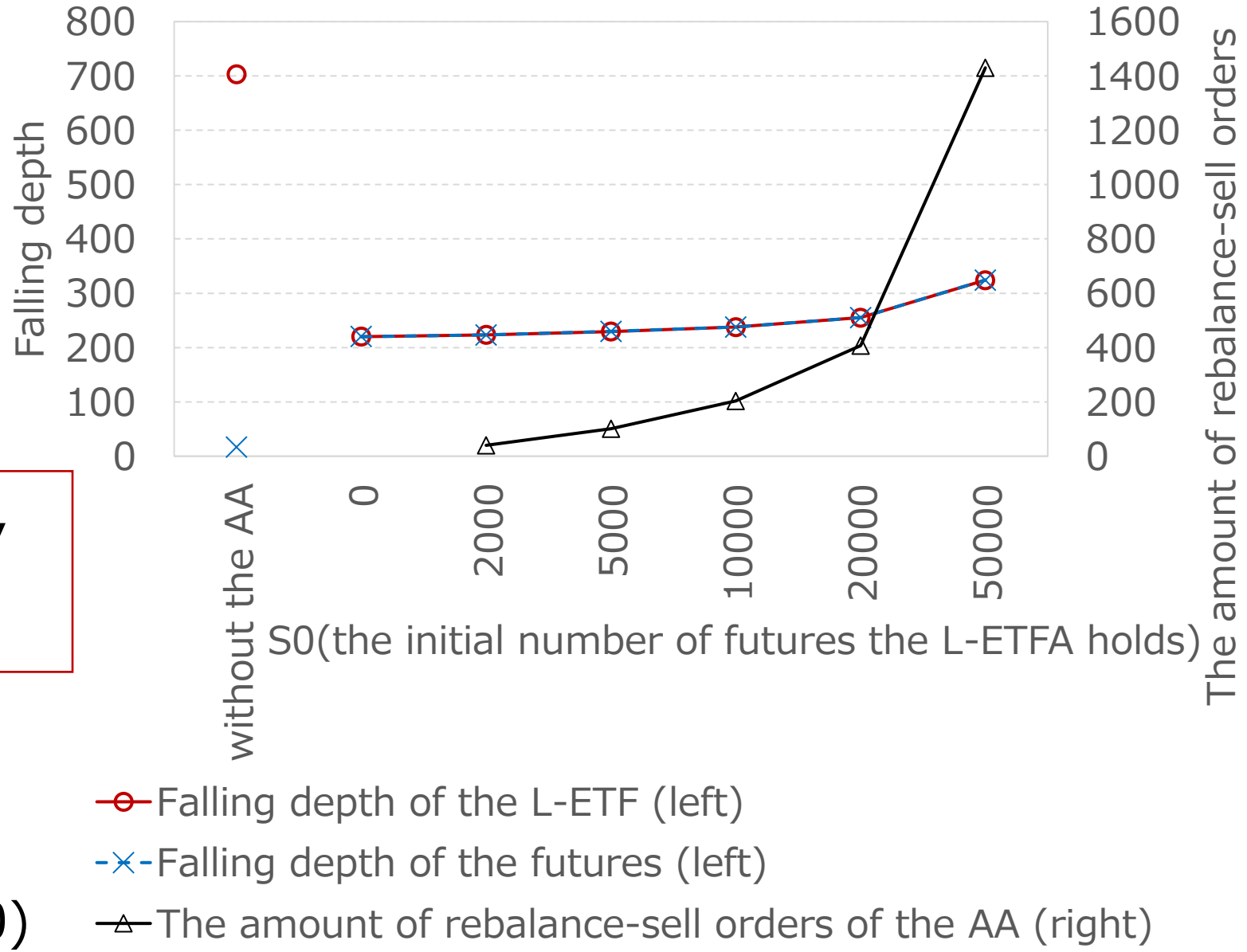
The two lines overlap each other
when the market prices of the L-ETF change double
with those of the futures

Case with the erroneous orders to the L-ETF for several S0

Consuming liquidity of the futures reduces falling of the L-ETF,
on the other hand, the futures also fall.

Larger the L-ETF (larger S0), larger falling for both the L-ETF and the futures

Destroying markets with too big L-ETF (S0>100000)

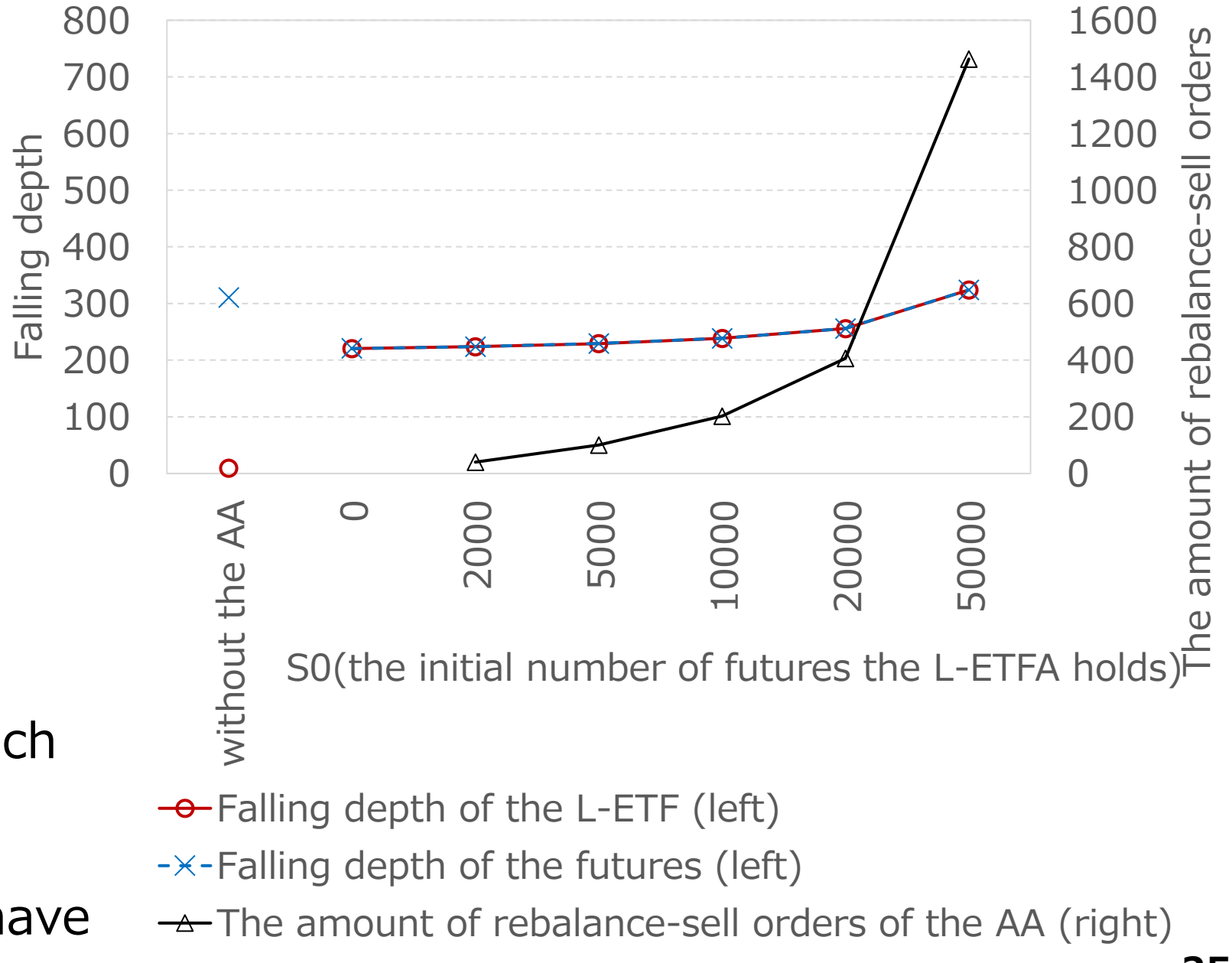


Case with the erroneous orders to the Futures for several S0

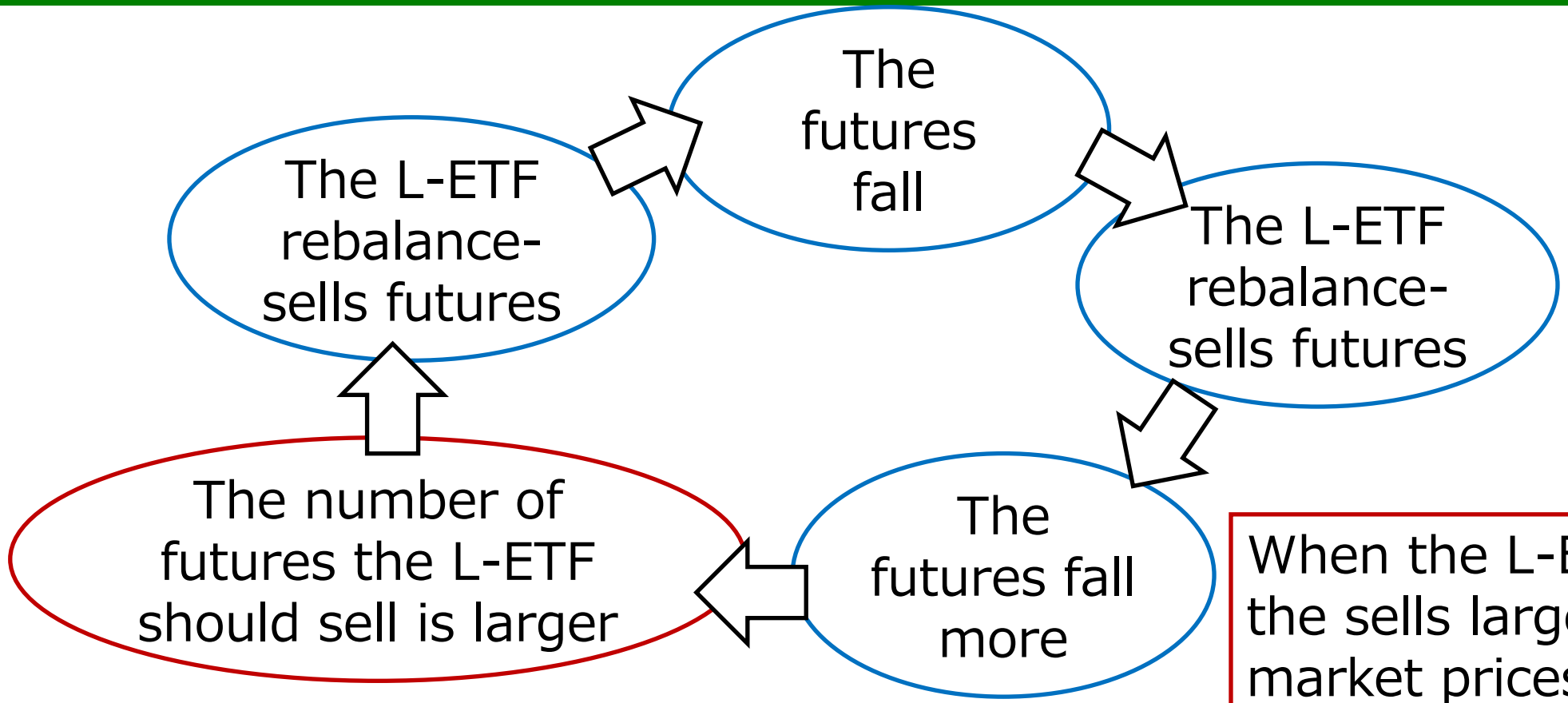
Without AA,
The falling is not so deep than the case of L-ETF.
Erroneous orders to Futures are less than L-ETF

But with AA the results are almost same as the previous case

Investors of L-ETFs have great benefit by gaining much liquidity of futures.
On the other hand,
Investors of futures do not have



Mechanism of destroying markets with too big L-ETF (S0>100000)



When the L-ETF is so big, the sells largely impact to market prices of the futures

Sells largely impact to market prices, the futures fall more, the L-ETF should additionally sell the futures

Such process continues as loop and falling can not stop

This result is consistent with [Yagi 2016]

(1) Introduction

(2) Our Model

(3) Simulation Results

(4) Conclusion

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

Summary (1/2)

- ✓ In this study, the artificial market model was built by adding a market in which a L-ETF itself is traded and adding a erroneous orders leading turmoil implemented by the model of [Mizuta 2016] to the prior model of [Yagi 2020]. We investigated that sharply falling of the futures or the L-ETF affects the another market and effects of rebalancing trades of the L-ETF.

- ✓ In the result, the erroneous orders to the L-ETF leads that market prices of the L-ETF fall, but the arbitrage-trades reduce the fall. Here, waiting buy orders to the futures, not to the L-ETF, are executed and reduced because a sell order of a normal agent executes a buy order of the AA and then the AA sells the futures. The buy orders of the AA to the L-ETF reduce the fall of the L-ETF. The reason why the AA can buy the L-ETF is that the AA can consume the waiting buy orders of the futures. In short, liquidity of the futures is consumed to prevent the fall of the L-ETF. This means that liquidity of the futures is used as hidden liquidity of the L-ETF.

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

Summary (2/2)

- ✓ In the case that the erroneous orders to the futures, the arbitrage-trades by the AA mix and combine liquidity of the L-ETF and futures, therefore, same falling happens even which to the L-ETF or the futures the erroneous orders come. The futures can gain only a less liquidity from the L-ETF that has a less liquidity, then this leads not to reduce falling so much. In real financial market, this means that investors of L-ETFs have great benefit by gaining much liquidity of futures, on the other hand, investors of futures do not have so benefit by gaining low liquidity of L-ETFs.

- ✓ Larger the L-ETF, larger falling for both the L-ETF and the futures. When S0 > 100000, the simulation can not run due to too large falling of market prices. This means that markets are destroyed. When the futures fall, the L-ETF sells futures. Here, when the L-ETF is so big, the futures also fall, and then the number of futures the L-ETF should sell is larger, finally, the L-ETF should additionally sell the futures. Such process continues as loop and falling can not stop. This leads to destroy the markets.

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

Future Works

- ✓ The difference in results in the case of erroneous orders to the futures or L-ETF may depend only on the lower liquidity. This is a future work.

- ✓ Note that an arbitrage in real financial markets is extremely more complex than our model. In the actual, market prices of L-ETFs do not track preciously like as our model. Some process existing in real financial market but not included in our model could be important. All of them are future works.

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

References

- [Yagi 2016] Yagi, I., Mizuta, T., “Analysis of the Impact of Leveraged ETF Rebalancing Trades on the Underlying Asset Market Using Artificial Market Simulation”, 12th Artificial Economics Conference, September 20-21, 2016 http://ae2016.it/public/ae2016/files/ssc2016_Mizuta.pdf

- [Yagi 2020] Yagi, I., Maruyama, S., Mizuta, T., “Trading strategies of a leveraged ETF in a continuous double auction market using an agent-based simulation”, Complexity, 2020 https://doi.org/10.1155/2020/3497689

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

References (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

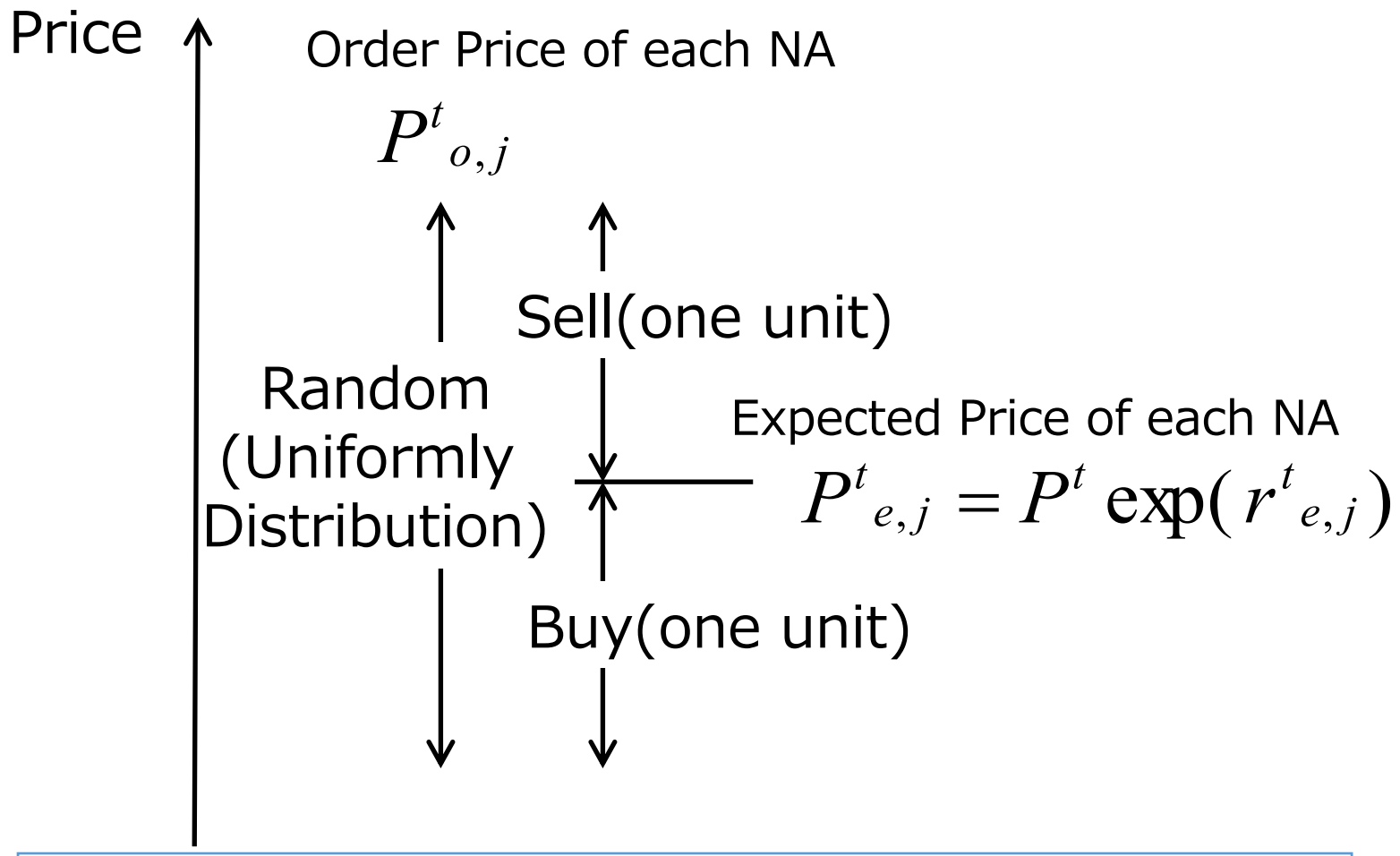
Mizuta (2016) A Brief Review of Recent Artificial Market Simulation Studies for Financial Market Regulations And/Or Rules, SSRN Working Paper Series
https://ssrn.com/abstract=2710495

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

Appendix

You can download this presentation material from
https://mizutatakanobu.com/2024CIFEr.pdf

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 order price > expected price
NA places one **sell** order when order price < expected price

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 I

STYLIZED FACTS WITHOUT THE ERRONEOUS ORDERS FOR THE FUTURES

kurtosis or returns		4.32
	lag	
autocorrelation coefficient for square returns	1	0.130
	2	0.081
	3	0.065
	4	0.054
	5	0.045

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.