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Liquidity and Arbitrage Cost between ETF and Stocks using Agent-Based Model

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ETF and Liquidity

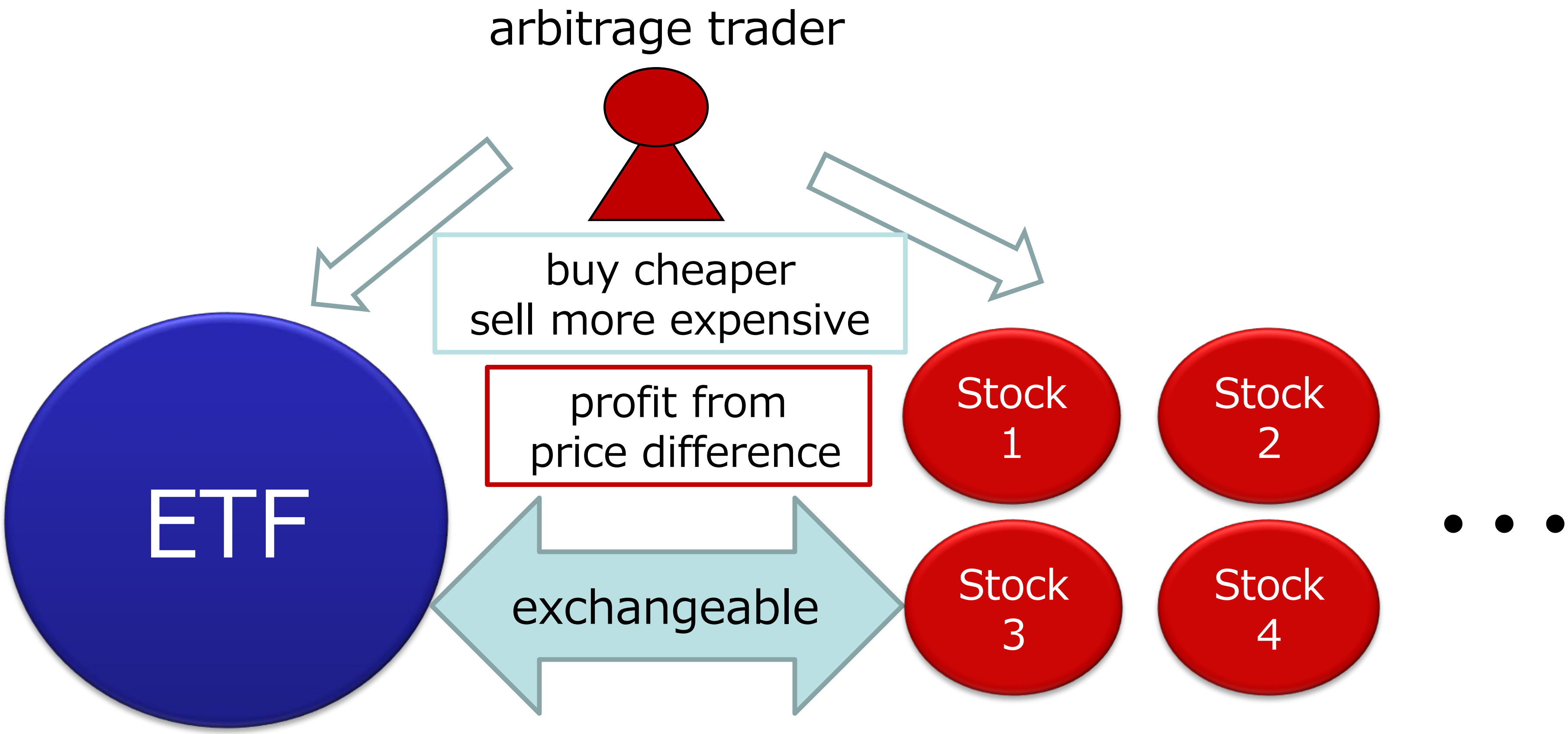
Exchange-Traded Fund (ETF)

- ✓ a mutual fund that invests in a diversified portfolio of many stocks or bonds
- ✓ listed and traded at a stock exchange

ETFs have been widely spread to individual investors as an easy way to diversify their investments.

Some ETFs, however, have not been traded with enough volume to discover an adequate price, making them difficult for individual investors to trade.

Exchangeable, Arbitrage Trades



An ETF is exchangeable with all stocks held by the ETF.

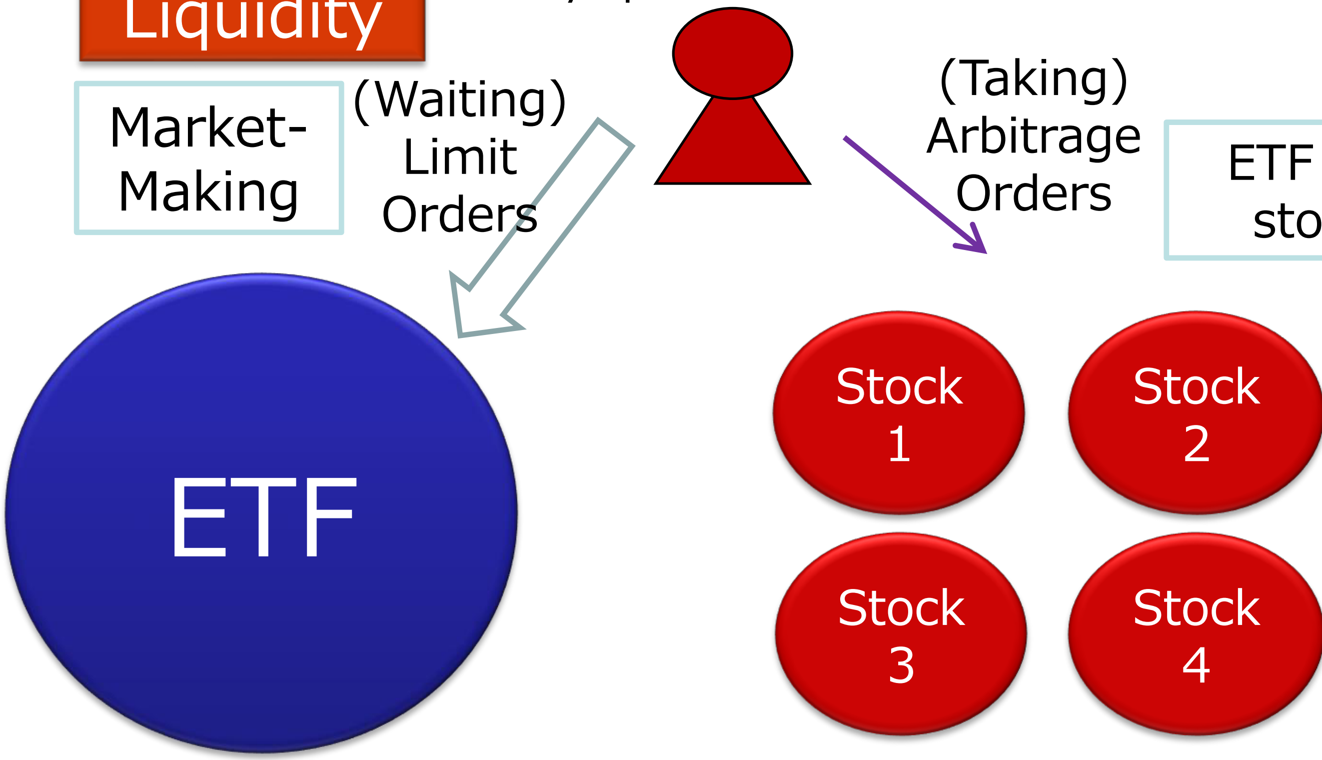
When the price of the ETF and the total value of the stocks held by the ETF differ, a trader can buy the cheaper asset, exchange, sell the more expensive asset, and thus earn a profit from the price difference.

Increasing arbitrage traders is increasing liquidity

Market-making incentive Scheme

Supply Liquidity

Designated market maker
always place orders in return for incentives such as lower fees



ETF is exchanged for stocks to arbitrage

To increase the liquidity of low-liquidity ETFs, in 2018 the Tokyo Stock Exchange introduced a market-making incentive scheme, in which designated market makers always place orders in return for incentives such as lower fees [JPX 17].

The questions, however, of how liquidity changes depending on arbitrage trading costs and of what the mechanism is remain to be answered.

Difficulty of Empirical Study

Empirical Studies

- ✓ cannot be conducted to investigate situations that have never occurred in actual financial markets
- ✓ cannot be conducted to isolate the direct effect on liquidity because so many factors affect price formation and liquidity in actual markets

Therefore, in this study,

I expanded the artificial market model of [Mizuta 13] to include three risk assets, two stocks and an ETF. I also added an arbitrage agent to perform arbitrage trading among these risk assets.

I then investigated the relationship between the liquidity of an ETF and the trading costs.

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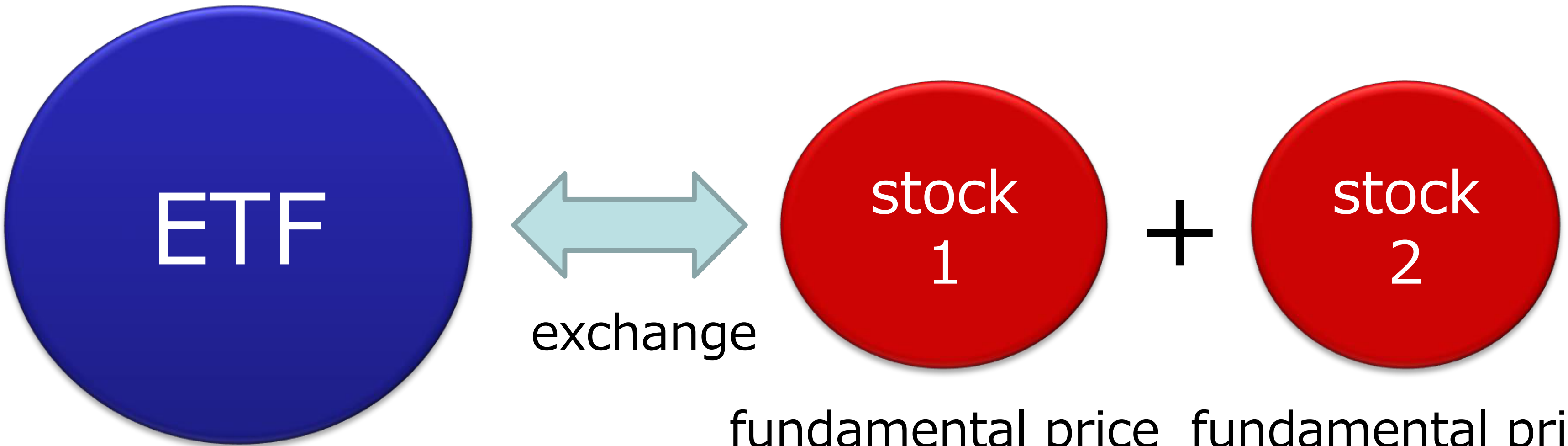
ETF & Stocks

exchangeable

ETF(one share)＝ Stock 1(one share)+ Stock 2(one share)



fundamental price
20000

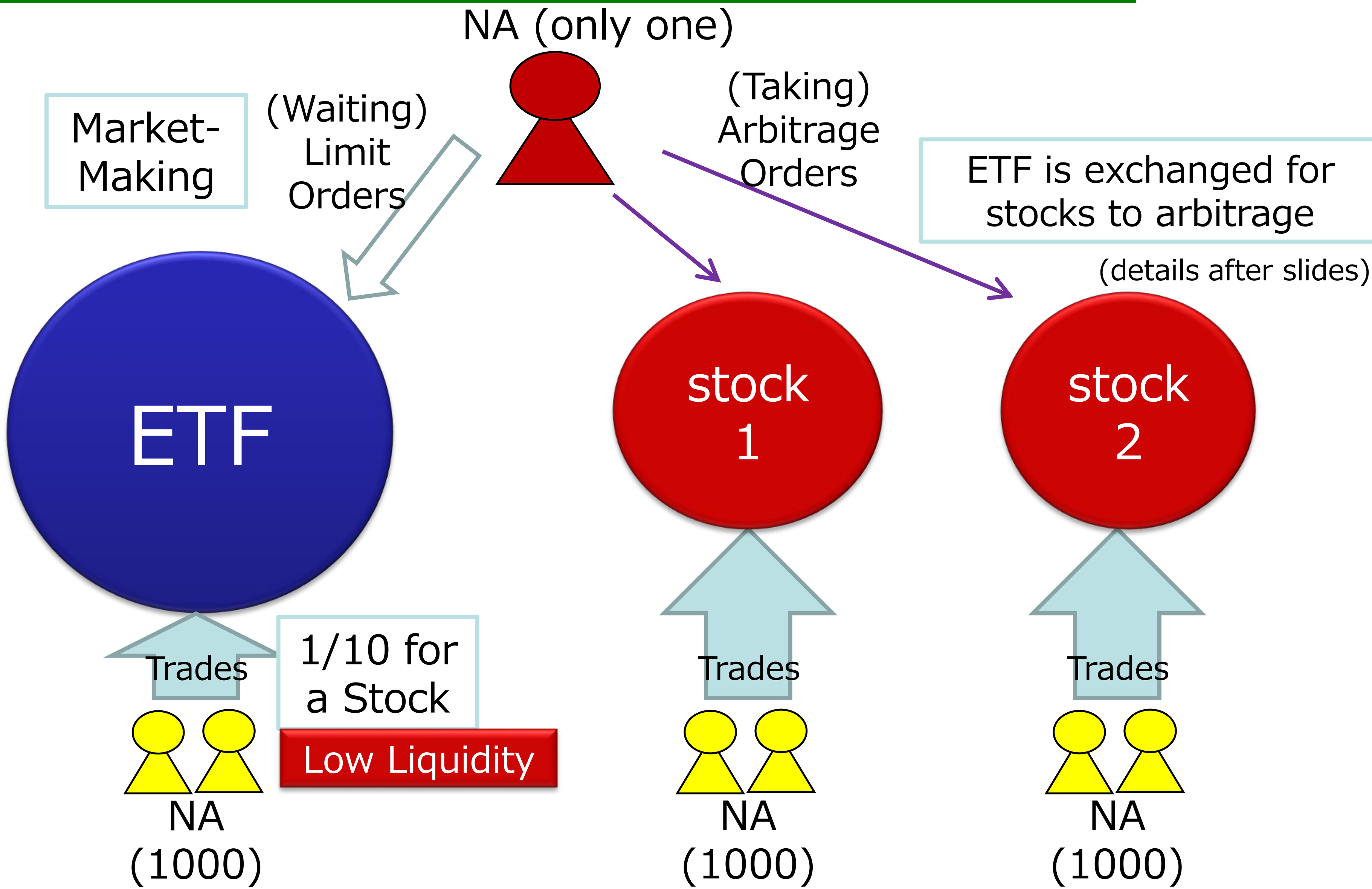
fundamental price
10000

fundamental price
10000

Number of Orders
=1/10 for a Stock

Normal Agent places orders with 10% probability
to investigate for low liquidity

Normal Agent(NA) & Arbitrage Agent(AA)



For each risk asset, the model includes 1000 normal agents (NAs) that trade only that risk asset, giving a total of 3000 NAs.

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 τ_j

Random of
Uniform Distribution

$w_{i,j}$	i=1,3:	0～1
	i=2:	0～10
τ_j		0～10000

Fundamental

P_f Fundamental Price
10000 = constant

P^t Market Price at t

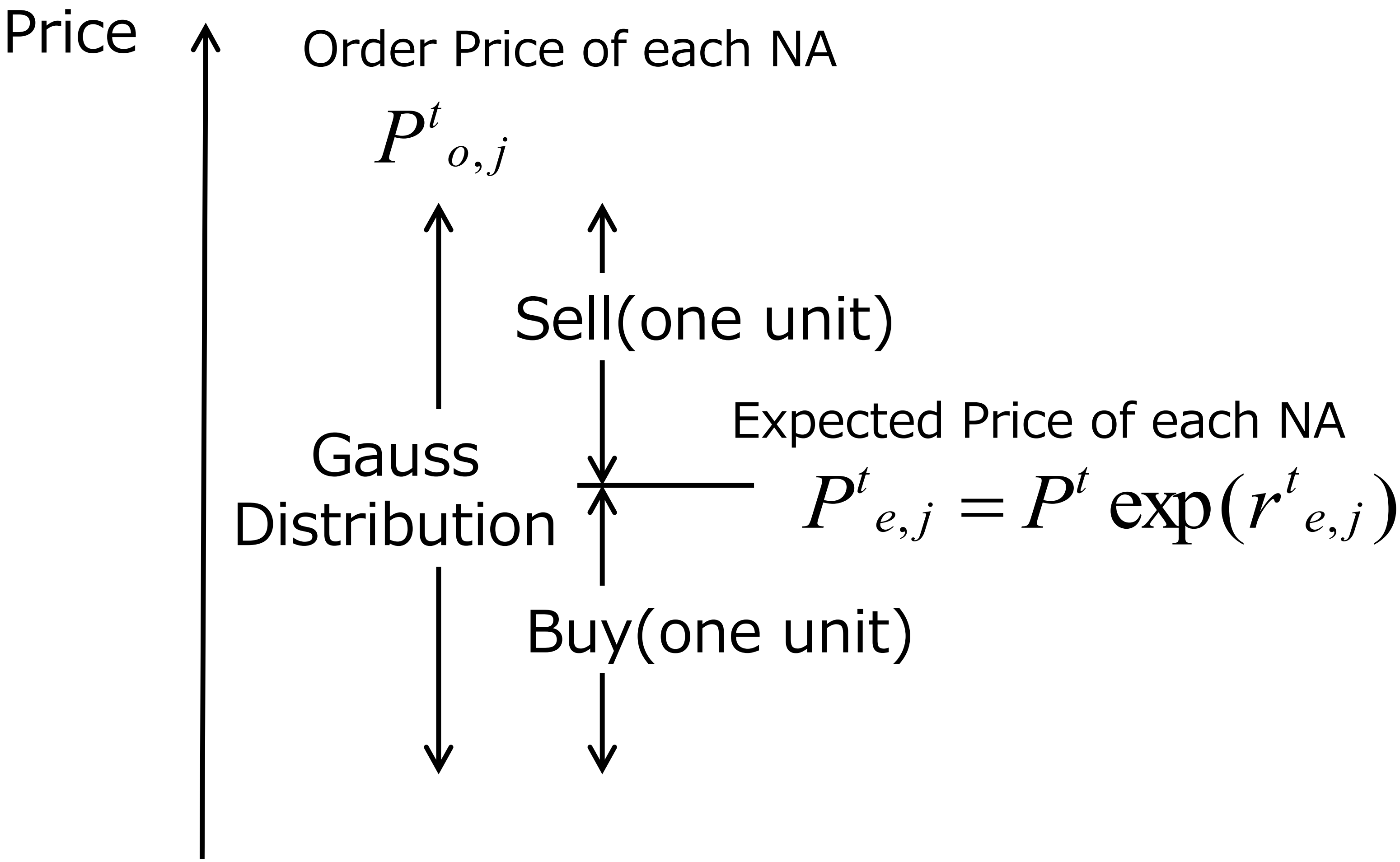
noise

ε_j^t
Random of
Normal
Distribution
Average=0
σ=3%

Expected Price of each NA

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

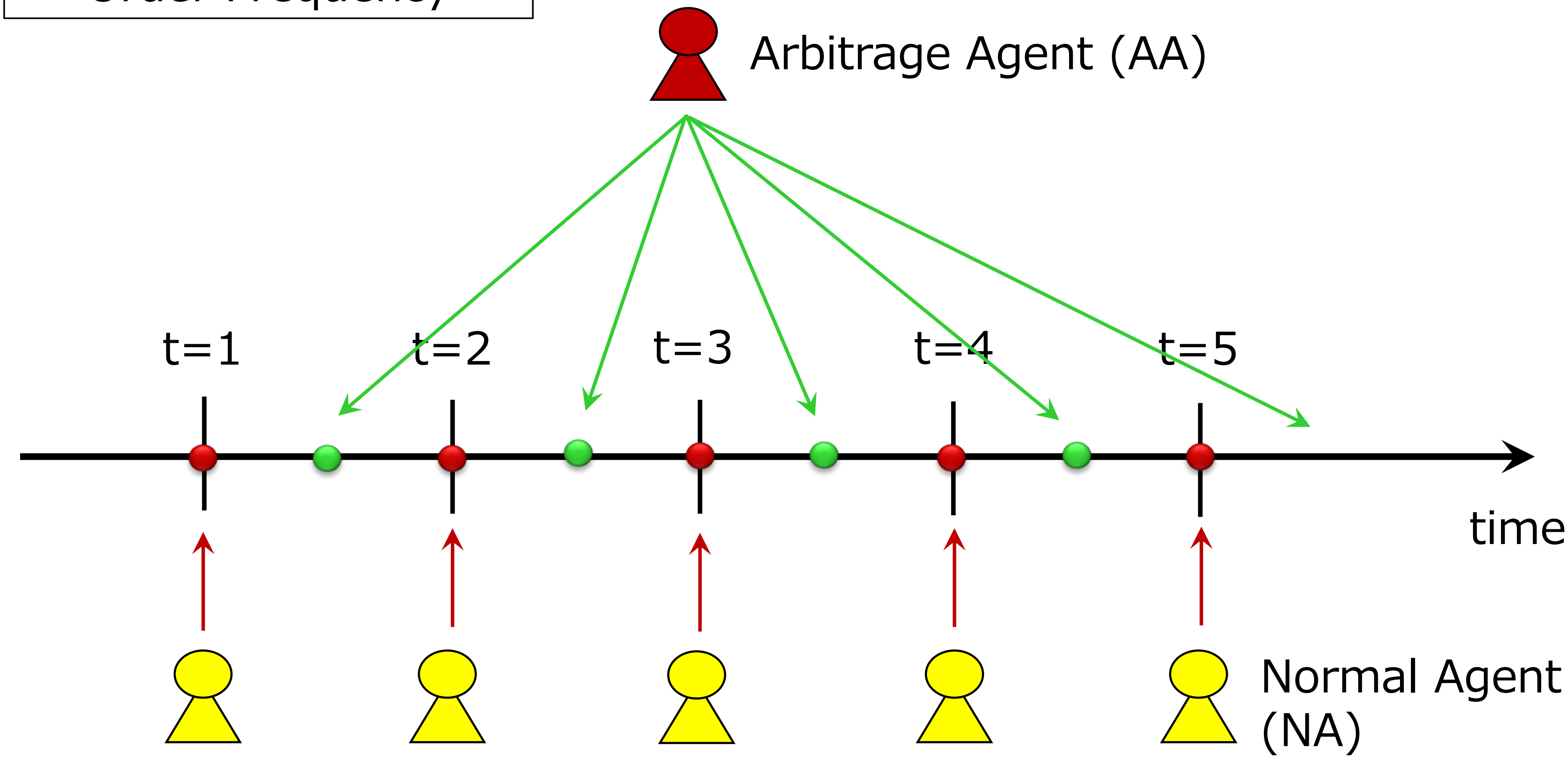
Order Price and Buy or Sell



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

Arbitrage Agent (AA) (1/3)

Order Frequency



The AA can always place, change, or cancel orders.

Arbitrage Agent (AA) (2/3)

ETF(one share)＝ Stock 1(one share)+ Stock 2(one share)

ETF sell	ETF price	ETF buy	stock 1 sell	stock 1 price	stock 1 buy	stock 2 sell	stock 2 price	stock 2 buy
7	20300		30	10400		50	10400	
10	20200		44	10300		70	10300	
	20100		70	10200		90	10200	
	20000		134	10100		116	10100	
	19900			10000	120		10000	154
	19800	10		9900	88		9900	60
	19700	6		9800	52		9800	55
	19600	4		9700	25		9700	31

When Highest buy-order prices(HBPs) consist

HBP for ETF + Cost ＜ HBP for stocks 1 + HBP for stocks 2

AA first places an order to buy one share at 19900 and then waits.

cost

includes the required profit, when the price difference of risk assets is over c, the AA can do an arbitrage trade.

Arbitrage Agent (AA) (3/3)

ETF(one share)= Stock 1(one share)+ Stock 2(one share)

ETF sell	ETF price	ETF buy	stock 1 sell	stock 1 price	stock 1 buy	stock 2 sell	stock 2 price	stock 2 buy
7	20300		30	10400		50	10400	
10	20200		44	10300		70	10300	
	20100		70	10200		90	10200	
	20000		134	10100		116	10100	
→	19900	**1**	→	10000	120	→	10000	154
	19800	10		9900	88		9900	60
	19700	6		9800	52		9800	55
	19600	4		9700	25		9700	31

Once the order is matched and the AA buys ETF,
it exchanges the ETF share for stocks 1 and 2
and then sells them each at 10000.

AA earns a profit of 100 from the price difference,
10000 (Stock 1)+ 10000 (Stock 2) – 19900 (ETF) = 100

Of course, the AA can also earn a profit in the opposite case, by first selling borrowed ETF at a higher price, buying the stocks at lower prices, exchanging the stocks for ETF, and returning the ETF, again earning the price difference as a profit.

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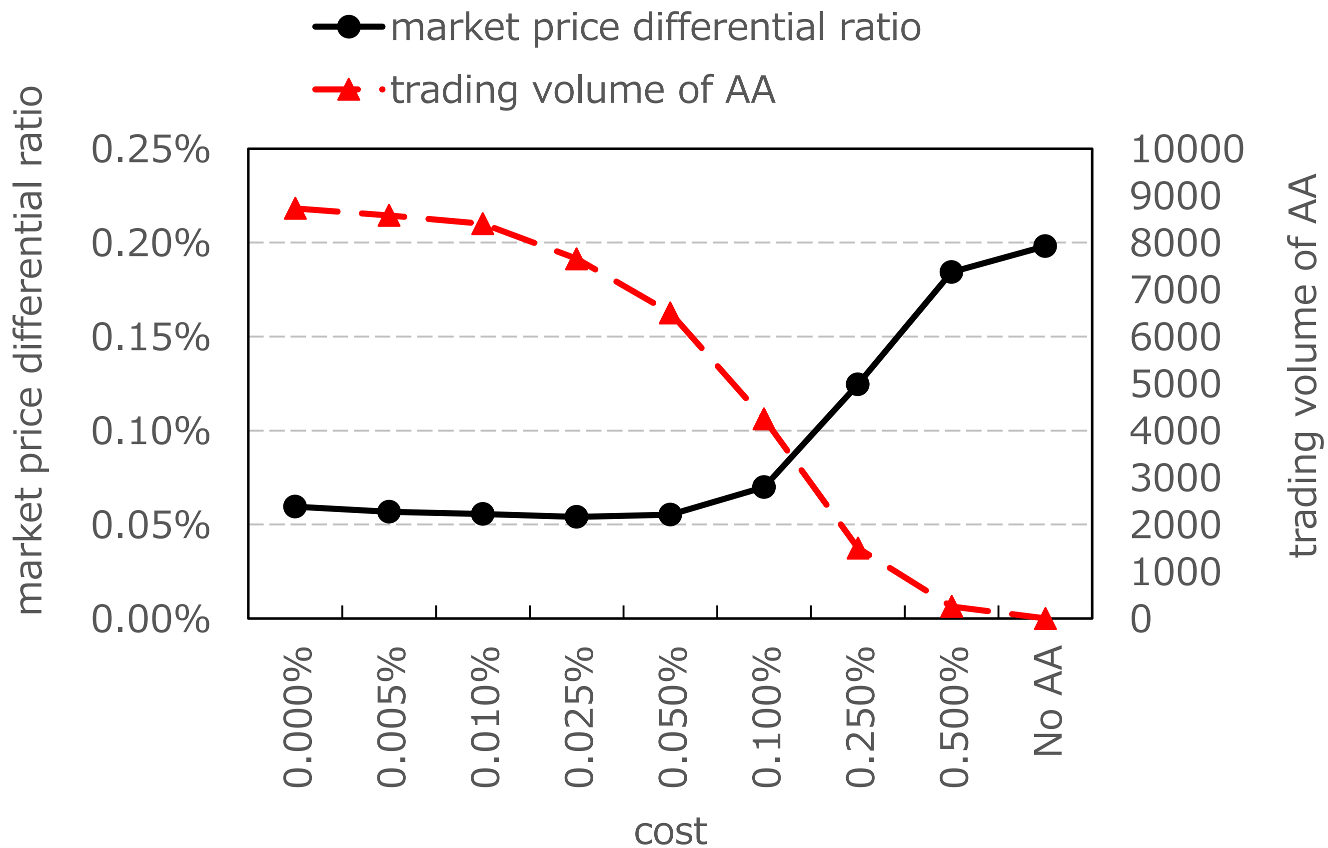
Market Price Differential rate & Trading Volume of AA

Market price differential rate＝Mid price of ETF/Sum of Mid prices of stocks - 1

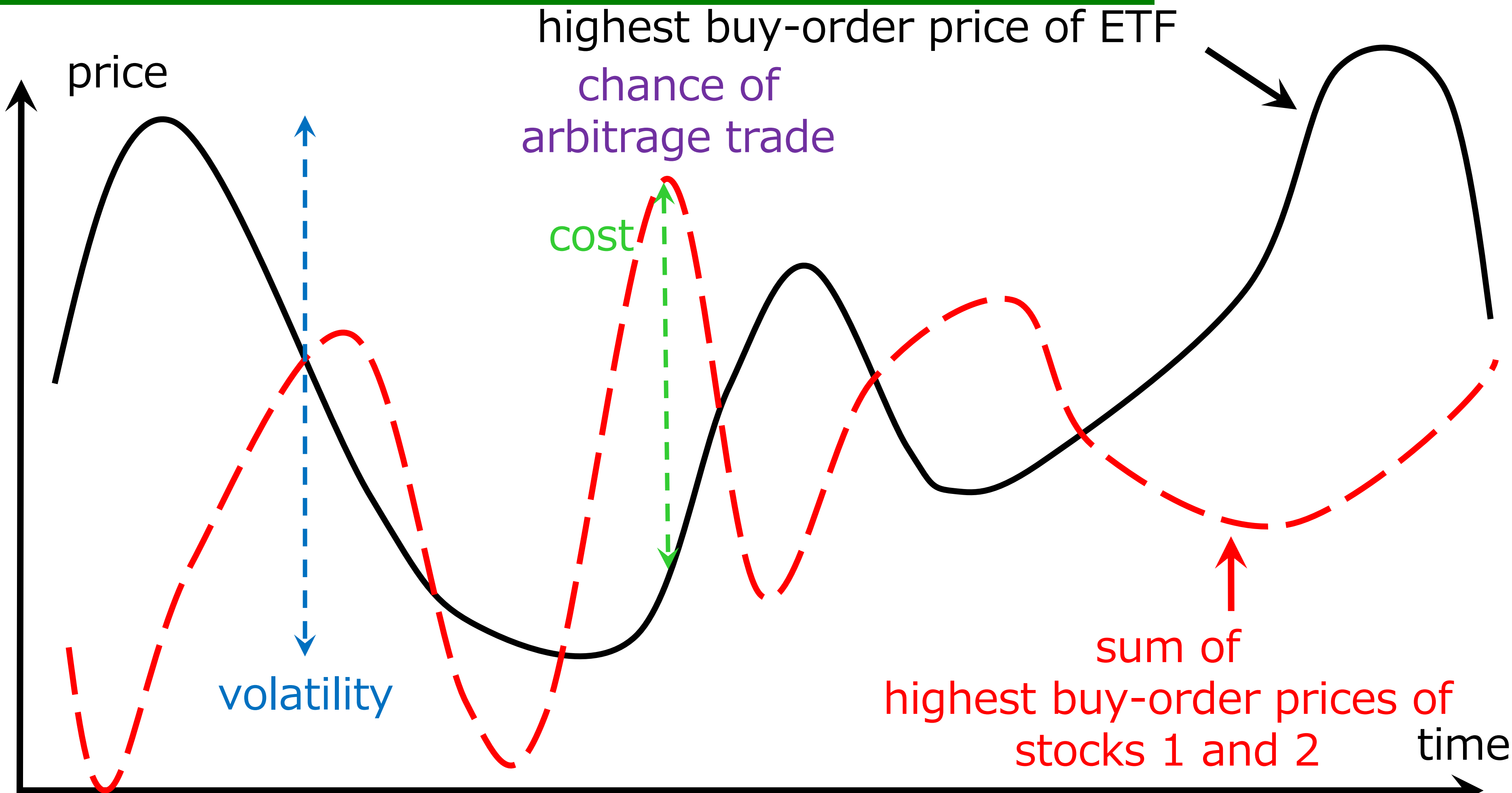


Lower cost meant more trading volume and a lower price differential

The price differential sharply changed when the cost was near 0.1%, similar to the volatility

Whether the cost is higher or lower than the volatility seems to indicate a very important boundary.

Relationship between Cost and Volatility



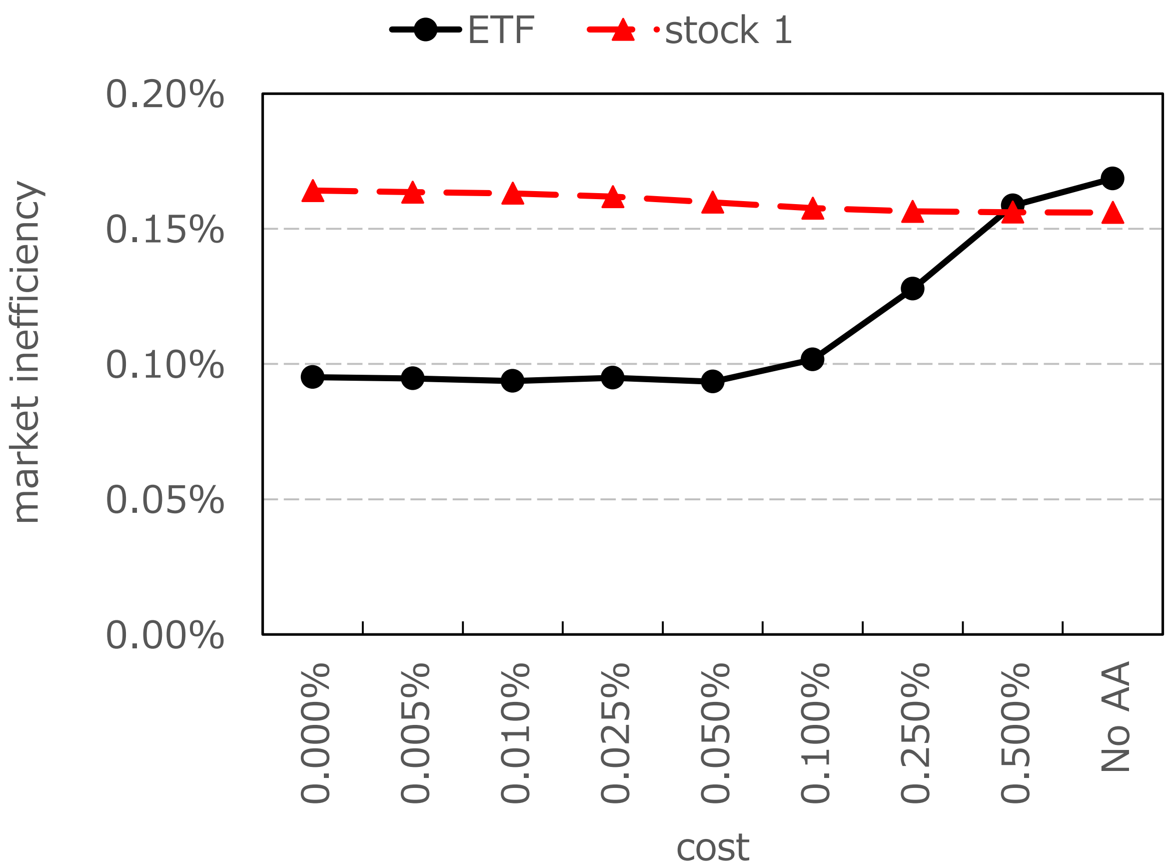
AA can make an arbitrage trade only when the red dashed line is above the black solid line plus the cost.

Prices of each risk asset fluctuate in their volatility

Volatility > Cost | **AA has more chances for arbitrage trades**

Market Inefficiency

Market Inefficiency = Mid Price/Fundamental Price - 1

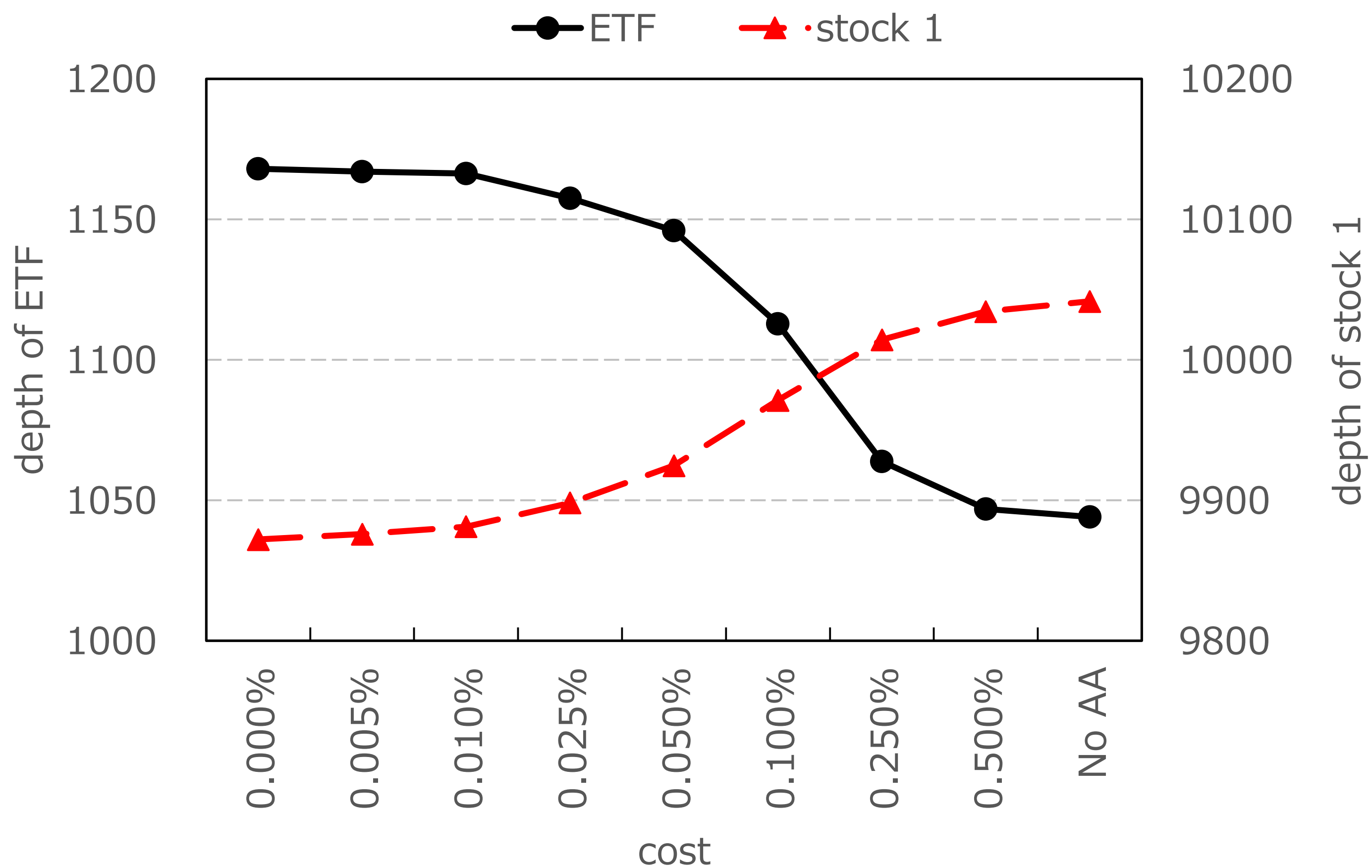


With lower cost, the ETF market became more efficient, but that of stock 1 did not change.

The reason why the ETF market becomes more efficient is NOT because it gains efficiency from the stock 1 market.

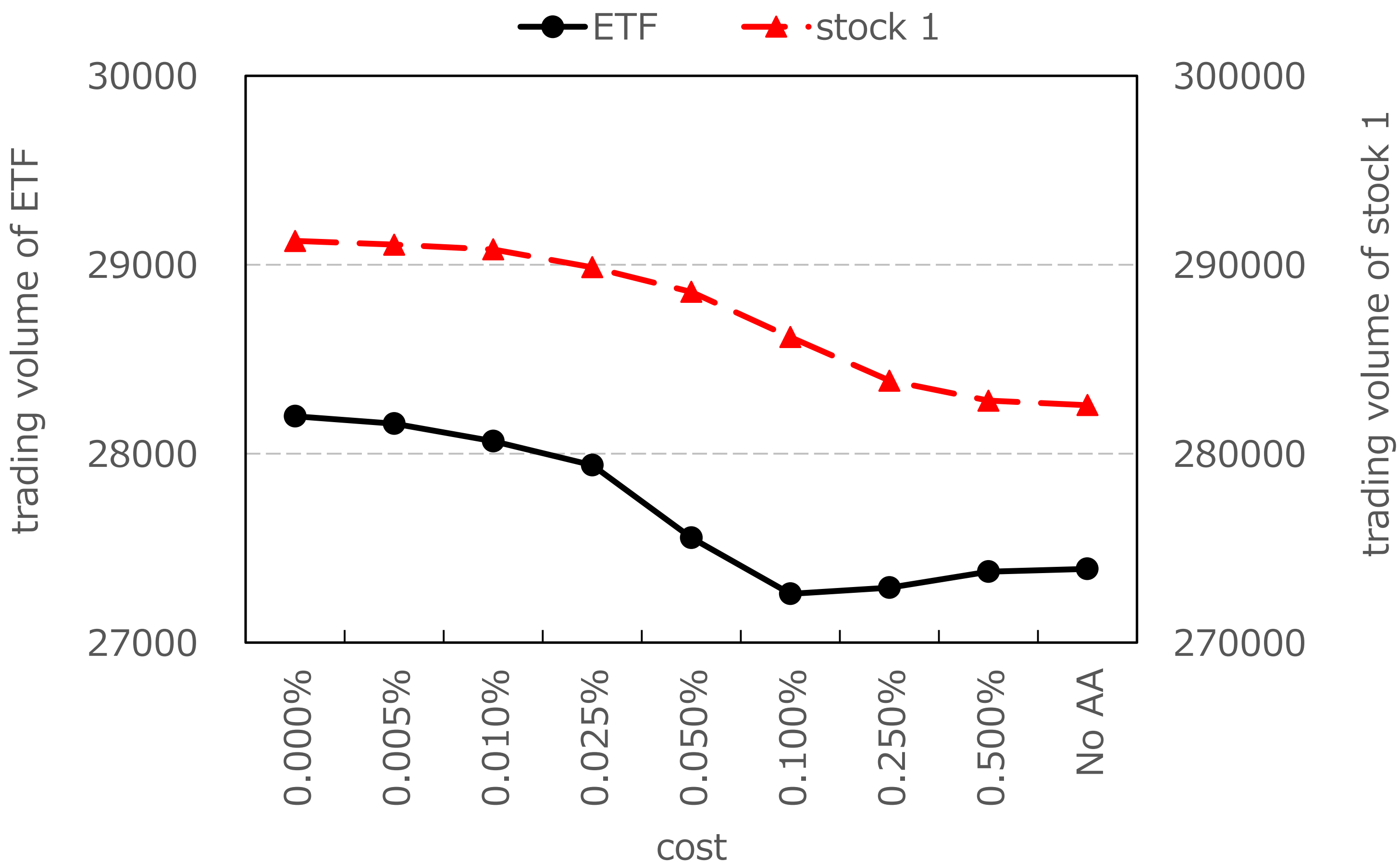
Depths of Waiting Orders

Sum of waiting orders between Mid Price ± 0.1%



The depth for ETF also sharply changed when the cost was near 0.1%.
On the other hand, the depth for stock 1 had the opposite tendency.

Trading Volume

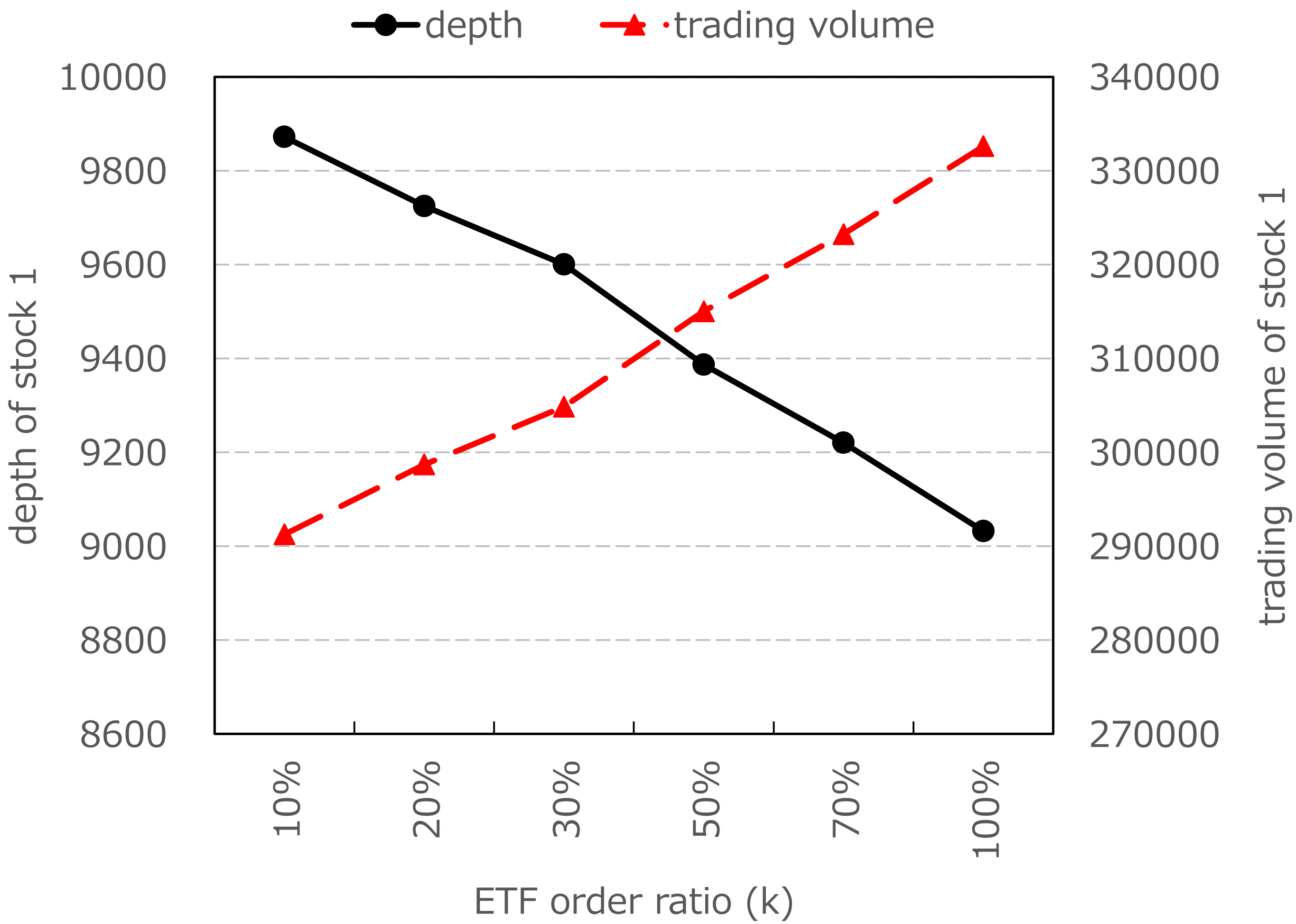


Lower cost meant higher trading volume for both

Lower cost makes the depth for stock 1 thinner and the trading volume larger, because orders for arbitrage trades and waiting orders for stock 1 are matched.

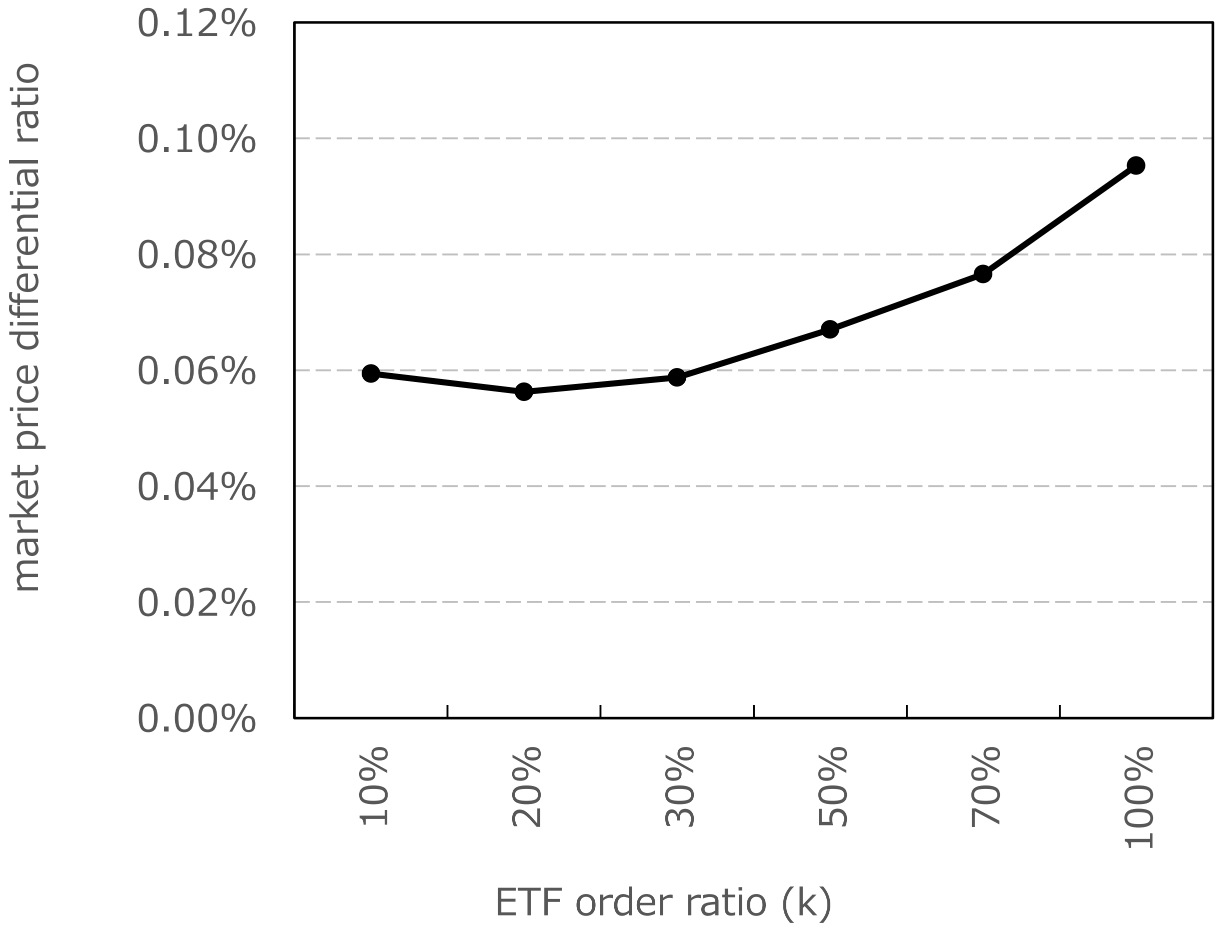
Case with more Liquidity for ETF (Cost=0)

(Actually, I fixed the ETF order ratio to k=0.1)



Larger ETF order ratio meant thinner depth and more trading volume. More ETF orders caused more matching of arbitrage trade orders and waiting orders for stock 1.

Market Price Differential rate



As ETF order ratio increased, market price differential ratio increased.

Even though more arbitrage trades occurred because of the larger ETF order ratio, the market price differential rate did not improve.

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Summary and Future Works (1/2)

- ✓ I expanded the artificial market model of [Mizuta 13] to include three risk assets, denoted as stock 1, stock 2, and ETF, along with an arbitrage agent (AA) that could perform arbitrage trades among these risk assets. I then investigated the relationship between the liquidity of ETF and the trading costs.

- ✓ My results showed that, because the prices of each risk asset fluctuate in their volatility, when the volatility is sufficiently greater than the cost, the AA has more chances to make arbitrage trades. As the AA trades more, the market price differential becomes lower.

- ✓ In addition, lower cost means a thicker depth of waiting trades for ETF, whereas the depth tendency of a stock is the opposite. Furthermore, lower cost increases the trading volume of both. Lower cost makes the depth thinner and the trading volume greater for a stock because the orders for arbitrage trades and the waiting orders for the stock are matched.

Summary and Future Works (2/2)

- ✓ Real financial markets, however, include traders who place more orders when the trading volume increases. My model did not implement this behavior. It is possible that lower cost would increase both the depth and the trading volume with such behavior. This remains for a future work.

- ✓ I also investigated the case with more liquidity for ETF and found that it makes the market price differential larger. Even though more arbitrage trades occur because of the larger ETF liquidity, the market price differential rate does not improve.

- ✓ This result implies that, when the trading volume of ETF increases to near that of a stock, improving the market price differential is more difficult through arbitrage trades like those modeled in this study. This suggests that other ways are needed to improve the market price differential in such cases.

References

-- market-making incentive scheme --

- [JPX 17] Overview of ETF Market Making Scheme, Japan Exchange Group(JPX), https://www.jpx.co.jp/english/equities/products/etfs/market-making/

-- previous model --

- [Mizuta 13] Mizuta, T., Hayakawa, S., Izumi, K., Yoshimura, S.: Investigation of Relationship between Tick Size and Trading Volume of Markets using Artificial Market Simulations, JPX Working Paper, No. 2, Japan Exchange Group(JPX), https://www.jpx.co.jp/english/corporate/research-study/working-paper/index.html