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Analysis of the Spot Market's T+1 Trading System Effects on the Stock Index Futures Market

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ABSTRACT

T+0 trading system, or day trading system, which allows the investors to buy and sell shares in one day, is a universal trading system in international markets. By contrast, T+1 trading system, which is implemented in China's stock market, allows investors to sell shares which are bought today only on the next day. T+1 trading system in spot market is a Chinese problem left over by history, and a characteristic in Chinese market. Stock index futures, the financial derivatives based on the stock, are the products of the development of the capital market at certain stage. For the stock index futures are generated based on the stock, they must be closely related. On that basis, what's the impact of the Chinese special T+1 trading system in spot market on the pricing efficiency, market liquidity and market volatility of the stock index futures market? The paper adopted the method based on the agent-based computational finance which's different from the traditional method, and built the agent-based computational cross-market platform which includes both several stocks and stock index futures based on MASON. The paper simulated the experiment on the platform to look out the effect on the market quality of the stock index futures market when T+1 trading system in spot market turned into T+0 trading system, consisting mainly of the efficiency of price discovery, market liquidity, market volatility and arbitrage investors' order submission behavior. The results showed that, compared with the T+1 trading system in spot market, T+0 trading system improved the efficiency of price discovery and market liquidity of stock index futures market, did not raise market volatility, enhance the enthusiasm of arbitrage investors' order submission behavior. From the perspective of the stock index futures market, we believe that we should restore the T+0 trading system in stock market timely, so as to active the market and improve the efficiency of market information diffusion, to promote the steady and sound environment of the stock index futures market.

Keywords: T+1 trading system, T+0 trading system, Agent-based computational finance (ACF), Stock Index Futures

INTRODUCTION

Stock Index Futures, the financial derivatives which based on the stock, are the products which come from the development of the capital market at certain stage. Due to the relatively slow development of China's stock market, the stock index futures also come out late. The first Stock Index Futures in China was officially launched on April 16th 2010 - the Shanghai and Shenzhen 300 Stock Index futures. This Stock Index Futures make great sense to the improvement of China's capital market since it fills the gap on the financial derivatives of the capital market.

T+0 trading system, or daily trading system is a system which allows the investors to buy and sell shares in one day, it is a universal trading system in international market. By contrast, T+1 trading system, which is implemented

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Contribution of this paper to the literature

- The price discovery efficiency rise: T+1 trading system could restrain the arbitrage activity and affect the pricing efficiency of the stock index futures market while the T+0 trading system would help investors to make better and more appropriate investment decision.
- The liquidity of stock index futures market rise: T+1 trading system could restrain the arbitrage activity and lower the liquidity of the stock index futures market, while the T+0 trading system allows several transactions in one day, thus the liquidity would rise.
- Little effect is brought to the volatility of the stock index futures market: T+1 trading system and T+0 trading system in spot market would not bring significant effect on the fluctuation of stock index futures market.
- The enthusiasm of arbitrage investors rise: the spot market T+1 trading system restrains arbitrage investors' order submission behavior, in the spot market T+0 trading system, an increase of nearly 1 times arbitrage opportunities, enhance the enthusiasm of arbitrage investors.

in China's stock market currently, allows investors to sell shares which bought today only on the next day. Between 1990 and 1991, both of the two Stock Exchanges carried on the T+1 trading system in their early days. The amount of stocks and trading volume was quite small and the transactions are not active at that time due to the initial stage of the stock market. In order to increase the liquidity of the stock market, Shanghai Stock Exchange applied T + 0 trading system in May 1992, after that, in November 1993, Shenzhen Stock Exchange applied T + 0 trading system as well. During the period of the implementation of T + 0 trading system, the trading volume was increased in the A-share market while the trend of speculation also rose. In order to prevent speculation, China Securities Regulatory Commission abolished the T+0 trading system in terms of A-share market in January 1995 and started to use T+1 trading system from then on. B-share market practiced the T+0 trading system since it launched in 1992, however B share market is also prohibited the usage of the T+0 trading system and turned to the T+1 trading system in December 2001.

The spot market's T+1 trading system is a historical issue and it's also a unique characteristic in China. In this way, seldom foreign researches were about this trading system. Meanwhile in China, the scholars' researches are focused on the two trading systems' effects on the pricing efficiency and market volatility of the stock market. Some scholars insist that China should resume T+0 trading system through empirical studies since it improves the pricing efficiency and liquidity of the stock market. What's more, it would active the stock market and improves the quality of the security market's operation. For instance, Liu et.al (2008) did the empirical study using the 10 trading days' data from Shanghai Stock Exchange and analyzed the two trading systems' effects on stock market through four aspects such as liquidity, pricing efficiency, price volatility and investment risk. Liu proved that T+0 system could effectively activate the stock market and increase the pricing efficiency and liquidity while it cause little impact on the market fluctuation. Bian (2010) applied the high frequency trading data between stock and warrants to calculate the share price covered by the warrants and regarded it as the share price in T+0 trading system. By comparing the share price in the T+1 trading system in the real asset market, the results showed that T+1 trading system lowered the liquidity of the stock market, thus resulting in low stock liquidity discount. Gai et.al (2006) used Shanghai Stock Exchange and Shenzhen Stock Exchange's data to evaluate the trading risk in T+0 trading system and T+1 trading system respectively. The results demonstrated that T+1 would neither reduce the investors' risk nor protect their interests. However, there were small numbers of researchers believe that T+0 trading system is not yet suitable for the stock market in China currently. Ge (2009) studied the fluctuation of stock market in T+0 and T+1 trading system by the data attained from A share and B share in Shanghai Stock Exchange. The results showed that T+1 trading system could reduce the fluctuation in stock market. Zhang et al. (2014) did the feasibility analysis of T+0 trading system and evaluated its advantages and disadvantages. He pointed out T+0 trading system could active the stock market while it also intensifies the speculation, leading to damage of the interests of small and medium investors, thus, at current stage, the implement of this trading system in China stock market must be kept on strict supervision.

Researches on the impact of different trading systems for futures market pricing efficiency and volatility are more extensive in worldwide, mainly focus on the price limits affect system, margin settings, position limits and other trading systems for futures markets. In terms of the price limits system, Hua et.al (2006), Chen (1998) and Balakrishnan (2014) proved that the price limits system disturbs the transfer of information for the futures market and reduce the price efficiency of the futures market. Meanwhile, Hua found that price limits system would aggravate the fluctuation of the futures market while Chen showed that price limits system inhibited the liquidity of the futures market from the perspective of overreaction. As for the research on margin system, Zhang et.al (2013) built a mathematical analysis model based on the empirical study and proved that margin level would lower the liquidity of the stock index futures market and increase the market fluctuation. Phylaktis et.al (2010)'s empirical study applied bivariate GARCH-M model, obtained that margin level is just a mechanism to prevent default and

would have no impact on trading volume and market fluctuation. Concerning the setting method of the margin level, Xue (2013) proposed the binary extreme value BETV method; Yang et.al (2008) demonstrated that the ARMA-EGARCH is the most stable and accurate model among the extreme value theory, EWMA and ARMA-EGARCH model. Pang et.al (2014) explored the Hill model and the VaR→x model, found that it's not necessary to set the margin level for short and long position using the Hill's model while VaR→x model had obtained a different conclusion. There were few literature concerning the optimal position limit, Dutt et.al (2005) constructed a position limit model for index futures market which is calculated by cash to explore the effect on different position limit and obtained the optimal position limit.

To summarize the literature on the impact of the trading system on the futures market we can see that, most researches focus on how the trading system affect the futures market's trading volume, liquidity, volatility and pricing efficiency itself. Few studies related to the spot market's trading system's cross-market effect on the futures market. Because stock index futures are generated by the stock spot, there must be a close connection between them. Relationship about price discovery between spot market and stock index futures market is always the concentration of the academia all over the world. Abundant material could be found in this field, mainly reflected in the price guidance, price discovery and volatility spillover between spot market and stock index futures market. Since there exists a close connection between the spot market and the stock index market, what kind of influences would be brought to stock index futures market's pricing efficiency, liquidity and fluctuation by the special T+1 trading system in China?

Literatures about the trading system's impacts on futures market are basically divided into two research methods. One is the event study method which is to explore the real stock market's reflections to the change of the trading systems in terms of pricing efficiency and volatility. The other is to observe the differences brought by the different trading systems through building market model. During 1992 and 1995, Chinese A share market applied T+0 trading system. After that, T+1 trading system was implemented, it is feasible to use the incident method to compare these two trading system, as mentioned before some scholars in China had already done the research in this way. However, China officially established the stock index futures market on 16th April, 2010, since the first stock index futures— Hushen300 stock index futures officially listed on Chinese asset markets, T+0 trading system was adopted. That is to say between 1992 and 1995, China did not have stock index futures and it is infeasible to compare T+0 and T+1 trading systems' effects on stock index futures market. The second method built a dynamic model to study the market but there are also some limitations, this model only investigates individual indicators, and cannot be a good characterization of the real market, so the conclusion can only provide a general guide. Because of these limitations, there is no research on the T+1 trading system's effects on stock index futures market yet.

Then how to construct an experimental environment to imitate the investors behavior and the order flow characteristics in real market while testing the two trading system in this kind of environment? That is the most difficult point of this theme. Due to the legal and policy restrictions couple with high cost of study it would be unrealistic to do the research in real market. In recent years, the rise of the agent-based computational finance (ACF) provides a new solution for this problem. ACF's advantage is to construct model from bottom level to upper level and explore the impacts on macro-markets based on the micro-behavior of investors. Computational experiment finance simulation platform designed by the ACF method could imitate the real market accurately and adopt different trading system according to the experiment requirement and comparing their advantages and disadvantages. ACF is a very useful approach that has a great future development prospect. Using ACF method to imitate stock index futures market and analyzing the effects on the market applying different trading systems and trading strategies is quite feasible. Some scholars in the worldwide had investigated this field in this way as well.

Yeh C H et.al (2010), Mizuta et.al (2013) and Mizuta et.al (2015) built the ACF model to investigate the impact of the price limits on the stock market. All of the studies mentioned above demonstrated that price limit could decrease the market volatility. Meanwhile, Yeh C H's results showed that reasonable price limits would increase the market liquidity and pricing efficiency; Mizuta's results pointed out that the short-selling rules, the uptick rule and the Blackpool systems can play a role in stabilizing the market. Wei (2015) constructed a stock index futures computational experimental model to explore the optical position limit of Hushen300 stock index futures and found that the market quality would be improved when the position limit is between 100 and 300. Kobayashi et al. (2007) and Kobayashi et al. (2011) applied U-mart platform to explore the effect of breaker mechanism on the market fluctuation and trading volume. The results showed that though the breaker mechanism could lower the market fluctuation, it would also decrease the total trading volume. Yagi et al. (2010) explored the influence on the market quality of the short selling restriction through artificial market; indicating that short selling system not only prevent the decline of the price but also cause the severe fluctuations of the stock price, thus lead to market instability. Wei et al. (2014) and Xiong et al. (2014) constructed and integrated a stock and futures financial simulation system, and explored the impacts on the stock index futures market through minimum bid unit and the number of the cross-time arbitragers respectively. Wei's research indicated that lower the minimum bid units would increase the liquidity of the futures market, but it would also reduce the speed of information dissemination and affect the

pricing efficiency. Xiong et al. believed that whether the number of cross-time arbitragers is too large or too small, both would aggravate the market volatility. Controlling the number of the arbitragers within the range of 10% to 20% could reduce market volatility.

This essay aims to investigate T+1 trading system's effects of the spot market on the efficiency of price discovery, liquidity and volatility of the stock index futures, applying the approach of Agent-based computational finance to do the secondary development on the basis of MASON system, constructing and integrating the stock and the futures cross-market computational experimental financial platform to imitate the trading experiment in real market, comparing and analyzing the influences of the T+1 and T+0 trading system of the spot market on stock index market's efficiency and proposing valuable suggestions.

DESIGN OF THE CROSS-MARKET AGENT-BASED COMPUTATIONAL FIANCE PLATFORM

This essay takes advantage of the ACF research method and adopts Xu H C et al.'s (2014) cross-market ACF platform which combined stock market and stock index futures market to imitate the real financial markets.

This platform contains a stock market which allows the trading among several shares and a stock index futures market which allows one stock index future's trading. Both markets have the three kinds of investors: namely value investors, technical traders and noisy traders. Cross-time arbitragers manipulate both of these two markets by building position and closing position in the same time. Therefore, this operation achieves the dynamic linkage between the spot market and the futures market. All types of traders' investment demands are internally determined by the entrust order and restricted by fortune, risk management and market trading system. Furthermore, these demands basically meet current trading regulations of Chinese stock market and stock index futures market.

Capital

There are 5 shares and one stock index futures in the market; the object of the stock index futures is constituted by the stock index of the five shares. The evolution process of the stock public value information $v_{i,t}^*$ is determined by the following formula:

$$v_{i,t+1}^* = (1 + \phi_i + \sigma_{i,\varepsilon}\varepsilon_{t+1})v_{i,t}^* \quad (1)$$

In the formula, ϕ_i means the growth rate of share i, namely the random walk draft item of the public value. The time unit "t" equals 5 seconds in reality in this model, thus the growth rate can be approximately set to 0, that is to say $\phi_i = 0$. $\varepsilon_t \in N(0,1)$, $\sigma_{i,\varepsilon} > 0$ represents the standard deviation drawn from the diffusion process. The parameters of the five shares are shown in **Table 1**:

Table 1. Design of the five stocks' parameters

Number of Stocks	Initial Value	Disturbance Standard Deviation	Shares（0.1 Billion）
1	10	0.002	50
2	20	0.002	40
3	30	0.001	50
4	40	0.001	45
5	50	0.001	50

The arrangement of the stock index adopts the same pattern as the HS300 stock index. But the sample space includes all the five shares. The stock index use "point" as a unit, time 0 is the base time and the base point is 1000, the base period involves these five shares' market price in time 0. The stock index is calculated by weighted composite price index formula, which is given below:

$$I_t = \frac{M_t}{M_0} \times 1000 = \frac{\sum p_{i,t} S_{i,t}}{M_0} \times 1000 \quad (2)$$

In the formula, Mt represents the constituent stock's value in time t, M0 represents the base period.

The public value of the stock index futures is calculated by the formula of the futures value theory. The formula is as follow:

$$v_{F,t} = I_t(1 + r)^{T-d+1} \quad (3)$$

Among the formula, It represents the real-time index, T represents the maturity, d represents the number of days that the stock index futures contract has been listed.

Design of the Market

(1) Both the stock market and stock index futures market are involved. The stock market owns 5 shares while the stock index futures market has a futures which would be delivered in the end of the month. Both of the two markets adopt the continuous bidirectional auctions trading mechanism. T+0 trading system is used in the stock index futures market in accordance to China real financial market, while the T+0 and T+1 trading systems are selected respectively in the stock market according to the experiment's requirements. Traders could submit the limit order or market order, and both the buy limit order whose price is higher than the optimal selling price and the sell limit order whose price is lower than the optimal buying price are regarded as the market order (the deal could be done at once). According to the regulations of the China Financial Futures Exchange, the market orders would be canceled if their transactions could not be done entirely. The limit order has the largest life cycle and the record of market order would be cleared out at the end of each trading day.

(2) The experiment time t is approximately equal to 5 seconds in the real market, during that time there is a possibility of several transactions or no transaction. The stock market does not allow sell short while the stock index futures market allows sell short, so the arbitrage traders could only do the positive arbitrage, which refers to open to buy stock and sell short.

(3) The stock index futures market takes the mode of margin trading, after closing quotation of each day the balance of the margin account would be liquidated, if the customer equity is lower than the minimum margin required by the position, then it's position would be forced to close progressively after the second day's opening until the customer equity is not less than the minimum margin required by the position.

(4) The market trading price $p_{i,t}$ is an average price comes from several transactions happened in time t. If there's no trade in time t, then it's regarded as the market price of previous time t-1, that is $p_{i,t} = p_{i,t-1}$. There is a 10% price limit of the trading price.

(5) There is no transaction cost of stocks and futures.

(6) An investors could be declared bankruptcy if his wealth is lower than a certain amount and has no position in hand, thus the investor would exit from the market. In order to ensure a stable amount of the investors and an appropriate proportion of different kinds of investors, another investor whose risk preference, wealth and investment portfolio are in the same pattern with the previous bankrupt investor would be in the market.

Traders

There are 7 kinds of investors in the market in total, 3 kinds of investors only invest in the stock market, including value investors, technical traders and noisy traders. Each investor pick one stock in random and keep a fixed investment on this stock. Accordingly, there are also three kinds of investors only invest in the stock index futures market. Another kind of investors both invest in the stock market and the stock index futures market, which are called cross-time arbitragers.

The cross-time arbitragers observe the relationship between the stock index and the price of stock index futures in time. Once the price of stock index futures is higher than the arbitrage upper limit and reach the arbitrager's expected profit point, the arbitrager would open position to buy stock portfolio and sell futures; and balance the payoffs at the end of each period, when the price of the futures drop to the arbitrage upper limit, the arbitrager would close position to sell stock portfolio and buy futures in advance. Otherwise the investors would hold the position until maturity. The cross-time arbitragers pursue the immediate executive of the order, so cross-time arbitragers only take market orders. The cross-time arbitragers allocate their assets to stock portfolio and futures according to their wealth to achieve riskless arbitrage and in order to ensure the futures account's safety, the proportion of the margin is controlled in a certain range. Followings are the settings of the investors' expectation, principal amount, wealth and the regulations of taking order.

Expectations of investors on asset prices

Due to the similar expectations of the three kinds of investors in the stock market and the stock index futures market respectively, the price expectations could be discussed together. To be more straight-forward, the subscript under the asset parameter was removed. Assume that all the investors know the public value of the current asset but have different information on the asset's public value in the future.

The value investor i can acquire the accurate asset's public value $v_{t+\tau}$ in the future time τ, and the expected price is:

$$\hat{p}_{t+\tau}{}^{i} = v_{t+\tau} \tag{4}$$

However, as for the settings of the value investors who invest in the futures market, since they cannot estimate $I_{t+\tau}$ accurately, so $v_{t+\tau}$ cannot be acquired. Thus, we could obtain $\hat{I}_{t+\tau}$ by the public value of the stocks, further to get the expected price $\hat{p}_{t+\tau}$, that is:

$$\hat{p}_{t+\tau}{}^{i} = \hat{I}_{t+\tau}(1+r)^{T-d+1} = \frac{\sum v_{i,t+\tau} S_i}{M_0} \times 1000 \times (1+r)^{T-d+1} \tag{5}$$

The technical traders i forecast the changes of the assets' public value through the average transaction price $\bar{p}_\tau$ of time τ which contains the historical information and the median bid price p_m which reflect the newest market information. The technical traders' expected price is listed as follow:

$$\hat{p}_{t+\tau}{}^{i} = \frac{1}{a^i + b^i + c^i}(a^i v_t + b^i \bar{p}_\tau + c^i p_m) \tag{6}$$

The expected price of the noisy trader i is picked as a random value in the five degrees of market quotation, which is shown in the formula (2.7):

$$\hat{p}_{t+\tau}{}^{i} = bid_5 + rand_t^i \times (ask_5 - bid_5) \tag{7}$$

The amount of investors authorized and regulations of order placement

In a certain given price p, the investor's optimal amount of position is determined by the choice of the utility function. Here, we apply Chiarella C (2009) et al.'s determination of demand, assuming that investors are always risk averse, and they make the investment decision by maximize the CARA utility function, thus the investor's optimal position is shown in (2.8):

$$\pi^i(p) = \frac{ln(\hat{p}^i_{t+\tau^i}/p)}{\alpha^i V_t^i p} \tag{8}$$

In the formula, α^i is the absolute risk aversion coefficient of investor i, V_t^i is the the expected return variance of investor i, $\hat{p}^i_{t+\tau^i}$ is the price expectation of investor i in the future time $t+\tau^i$. As discussed previously, different kinds of investors have different expectations, p is the order price. If the quantity demanded $\pi^i(p)$ is greater than (or less than) the current position of the investors, the investors would then decide to buy (or sell). We can estimate V_t^i by the historical return's variance, which is shown below:

$$V_t^i = \frac{1}{\tau^i}\sum_{j=1}^{\tau^i}[r_{t-j} - \bar{r}_t^i]^2 \tag{9}$$

$$\bar{r}_t^i = \frac{1}{\tau^i}\sum_{j=1}^{\tau^i} r_{t-j} = \frac{1}{\tau^i}\sum_{j=1}^{\tau^i} ln\frac{p_{t-j}}{p_{t-j-1}} \tag{10}$$

DESIGN OF EXPERIMENTS AND RESULT ANALYSIS

Experiment Parameters' Setting

In order to explore the effects on the stock index futures market brought by the T+1 and T+0 trading systems of the stock market respectively, two types of experiment are taken into consideration. One is to examine the T+1 trading system in the stock market, the other is to test the T+0 trading system in the stock market. Each type of imitation experiment would be run 10 times, there are 21 trading days (one month) in each experiment, 60522 times in total.

Selection of the Experiment Indicators

This essay explores the T+1 trading system's effects of the stock market on the stock index futures market, three indicators—price discover efficiency, liquidity and volatility are chosen as the measurable standards. Finally, through the arbitrage investors' order submission behavior, to further explore the T + 1 trading system's effects on the market quality of stock index futures market.

Price discover efficiency index

Price discovery efficiency refers to the degree through which the asset price could reflect the real value. This essay applies Theissen (2000)'s three indices to measure price discover efficiency.

(1) MAE: Mean Absolute Error

$$MAE = \frac{1}{T}\sum_{t=1}^{T}|p_t - v_t| \tag{11}$$

(2) MRE: Mean Relative Error

$$MRE = \frac{1}{T}\sum_{t=1}^{T}\frac{|p_t - v_t|}{v_t} \tag{12}$$

(3) RMSE: Root Mean Squared Error

$$RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\frac{p_t - v_t}{v_t})^2} \tag{13}$$

In these formulas, p_t represents the market price, v_t represents the public value.

Liquidity index

The market liquidity is always regarded as the core indicator in measuring the market quality. Market liquidity means the ability that the traders could run the transactions smoothly as well as in low cost. Asset with low liquidity would have a high transaction cost, so its transaction price would be higher that the asset which has a higher liquidity. According to Lei (2010), there are mainly four methods of measuring liquidity: price method, including the bid-ask spread; trading volume method, including the turnover rate, the depth of the deal, the depth of the market; price amount method, containing the liquidity ratio; time method, including the trading frequency, executive time. This essay chooses the bid-ask spread and the turnover rate as the liquidity measuring indicators.

(1) Bid-ask Spread

Bid-ask spread means the gap between the highest bidding price and the lowest selling price. This is the most common liquidity measuring indicator in the market. Basically, there are two kinds of bid-ask spread methods:

One is the absolute bid-ask spread, which is to calculate the absolute value of the gap:

$$Spread = a - b \tag{14}$$

a represents the lowest selling price and b is the highest buying price.

The other is called relative bid-ask spread. Which is the value of the absolute bid-ask spread divided by the mean of the lowest selling price and the highest buying price.

$$PS = (a - b)/[(a + b)/2] \tag{15}$$

This essay uses the absolute bid-ask spread to measure the market liquidity, its advantage is that it could directly measure the immediate transaction cost in the market, the larger the bid-ask spread, the higher the transaction cost, thus the lower the market liquidity would be.

(2) Turnover rate

Measuring the stock index futures market's liquidity could also through the perspective of the time dimension, taking the time cost by the transaction of the market orders as the measuring standard. Under the circumstance that other conditions are the same, the shorter the time cost on trading an asset, the higher the market liquidity. So the turnover rate is chosen as the measuring indicator of the stock index futures market liquidity, the higher the possibility of the orders' transaction the shorter the transaction time, thus the higher the market liquidity.

This essay applies the method which was proposed by Hamao and Hasbrouck (1995). That is, measuring the turnover rate by measuring the rate that the immediate dealt orders account for the total orders during one period. The calculation process is shown below:

$$P_b = deal/Order_b \tag{16}$$

$$P_s = deal/Order_s \tag{17}$$

$$P = (P_a + P_s)/2 \tag{18}$$

Among these formulas, $deal$ means the total amount of the successful transactions during one period; $Order_b$ means the buying orders during one period; $Order_s$ means the selling orders during one period. P_b indicates the possibility of successful transaction for a long position holder during one period while P_s indicates the possibility of successful transaction for a short position holder during one period. P represents the possibility of successful transaction in the futures market.

Table 2. Descriptive Statistical of MAE, MRE, RMSE of Two Groups

Comparative Types	Statistics	T+1	T+0
MAE	Average Value	19.1612	9.1057
	Standard Deviation	5.5720	2.0948
	Maximal Value	30.2220	11.8133
	Minimum Value	13.3167	5.5793
	Median	16.5739	9.3102
MRE	Average Value	0.0178	0.0096
	Standard Deviation	0.0046	0.0018
	Maximal Value	0.0273	0.0119
	Minimum Value	0.0129	0.0062
	Median	0.0160	0.0098
RMSE	Average Value	0.0203	0.0107
	Standard Value	0.0052	0.0018
	Maximal Value	0.0306	0.0129
	Minimum Value	0.0144	0.0075
	Median	0.0181	0.0109

Volatility index

Volatility is an essential indicator of measuring the market risk and the market mature degree, high volatility indicates the market is lacking of stability; It's of great importance to measure the market volatility accurately for maintaining a stable development of the market.

Market volatility usually measured by the standard deviation of the change of the price. Xiong (2014) used the logarithm return's time series of the stock index futures to measure the volatility and did the ANOVA variance analysis and the volatility cluster analysis for the research about the cross-time arbitrage's effects on Chinese stock index futures market. Wei et al. (2012) adopted the time-sharing price's standard deviation as the measurement index in analyzing the smallest quote unit's effects on the stock index futures market volatility. Based on the previous researches, this essay would analysis the stock index futures volatility through the following two aspects:

(1) The standard deviation analysis of the price change: volatility analysis applies the price (update every 5 seconds) changes' standard deviation from each experimental group.

(2) ANOVA variance analysis of the volatility: Using variance analysis method in the purpose of comparing the differences of the sample data from two experimental groups.

Result Analysis

Analysis of the price discovery efficiency

Price discovery efficiency is measured by the degree of deviation between the trading price and basic value, the smaller the deviation is, the higher the price discovery efficiency would be. **Table 2** shows 10 experimental groups' descriptive statistics results, including MAE, MRE and RMSE between the trading price and the basic value under the trading system of T+1 and T+0 in the spot market respectively. To observe the group differences between the two types of experiments better, ANOVA variance analysis is applied to find the price discovery efficiency of these two types of experiments, the data is listed in **Table 3** in detail. It can be seen from the **Table 3**, there exists significant differences of the MAE, MRE and RMSE under the T+1 trading system and T+0 trading system in the spot market, and the differences of the price discover efficiency are also quite large. When the T+1 trading system turns to the T+0 trading system in the spot market, the indices of the price discover efficiency would significantly decline while the price discover efficiency of the stock index futures market would increase apparently.

This is because, on the one hand, when the spot market carries out T+0 trading system, investors buy stocks, in the same day, if they find the trends of the stock prices and the basic values of the stocks they hold has changed, they could sell the stocks that day. In this way, it accelerates the speed of information delivery in the spot market, thus increase the price discovery efficiency of the spot market. Because of the close connection between the spot market and futures market, the price discovery efficiency in the stock index futures market would also rise; On the other hand, short selling is forbidden in the stock market while it's allowed in the stock index market, so the arbitragers in the market could only operate the cash and carry arbitrage, that is, buying stock spot and selling futures in the process of opening position. When the stock index futures market implements T+1 trading system, if the arbitragers find that the futures' price fall to the arbitrage upper limit in the day of opening position, due to the restrictions of the T+1 trading system, those stock portfolios bought in the same day cannot be sold and thus the

Table 3. ANOVA Variance Analysis of MAE, MRE, RMSE of Two Groups

Comparative Types	Types of Variance	Sum of Squares of Deviations	Free Degree	Mean square deviation	F Value	P Value
MAE	Cross-Groups Variance	505.564	1	505.564	25.68	8.02104e-05
	Group Variance	354.349	18	19.686		
	Total Variance	859.914	19			
MRE	Cross-Groups Variance	0.00034	1	0.00034	25.3	8.69494e-05
	Group Variance	0.00024	18	0.00001		
	Total Variance	0.00058	19			
RMSE	Cross-Groups Variance	0.00046	1	0.00046	27.85	5.11051e-05
	Group Variance	0.0003	18	0.00002		
	Total Variance	0.00076	19			

Table 4. Descriptive Analysis of Mean Value and Variance of Two Groups

	T+1		T+0	
Statistics	Mean Value	Variance	Mean Value	Variance
Mean Value	2.4091	2.5299	1.5564	1.8879
Standard Deviation	0.3663	0.4286	0.1286	0.1471
Maximal Value	3.0800	3.4694	1.7653	2.0845
Minimum Value	1.9171	2.0059	1.3320	1.5305
Median	2.4488	2.5163	1.5268	1.9167

Table 5. ANOVA Variance Analysis of Bid-Ask Spread of Two Groups

Comparative Types	Types of Variance	Sum of Squares of Deviations	Free Degree	Mean square deviation	F Value	P Value
Mean Value of Bid-Ask Spread	Cross-Group Variance	3.63497	1	3.63497	43.42	3.44964e-06
	Group Variance	1.50697	18	0.08372		
	Total Variance	5.14195	19			
Variance of Bid-Ask Spread	Cross-Groups Variance	2.06069	1	2.06069	18.06	0.0005
	Group Variance	2.05344	18	0.11408		
	Total Variance	4.11413	19			

position cannot be closed. Therefore, the arbitrage activity would be restricted and the price discovery efficiency of the stock index futures would decrease. On the contrary, if the spot market applies T+0 trading system, the price discovery efficiency would be improved.

Analysis of the liquidity

Liquidity is an essential character in measuring the operation quality of the equity market, it could reflect the liquidation ability in a reasonable price which only cause moderate losses. This essay analyze the futures market liquidity through the aspects of the bid-ask spread and the turnover rate.

(1) The Bid-Ask Spread

Table 4 reflects the 10 experimental groups descriptive statistic results of the mean and the variance drawn from the bid-ask spread under the T+1 trading system and the T+0 trading system respectively. **Table 5** shows these two types of experiments' empirical results of the mean of the bid-ask spread and the ANOVA variance. It can be easily found from the table, under the systems of T+0 and T+1, there exists significant differences in the mean and the variance of the bid-ask spread, that is to say the differences of the bid-ask spreads obtained by these two types of experiments is quite large. When the T+0 trading system replaces the T+1 system in the spot stock market, both the mean and the median of the bid-ask spread's mean and variance significantly decrease, which shows the rise of the futures market liquidity.

(2) The Turnover Rate

Table 6 is the descriptive statistics of the turnover rate obtained by the 10 groups of experiments in spot stock market under the trading systems of T+0 and T+1. **Table 7** is the ANOVA variance analysis of the turnover rate for the two types of experiments. As can be seen from the results, there is a significant difference of the turnover rate in the spot market under the T+1 trading system and the T+0 trading system, when the T+1 trading system turns into the T+0 trading system, both the value of the mean and the median increase, which reflects the rise of the futures market liquidity.

Table 6. Descriptive Calculation of Turnover Rate of Two Groups

Statistics	T+1	T+0
Mean Value	0.2718	0.3145
Standard Deviation	0.0134	0.0129
Maximal Value	0.2990	0.3358
Minimum Value	0.2556	0.2963
Median	0.2674	0.3155

Table 7. ANOVA Variance Analysis of Turnover Rate of Two Groups

Comparative Types	Types of Variance	Sum of Squares of Deviations	Free Degree	Mean square deviation	F Value	P Value
Turnover Rate	Cross-Groups Variance	0.0091	1	0.0091	47.54	1.90186e-06
	Group Variance	0.00345	18	0.00019		
	Total Variance	0.01255	19			

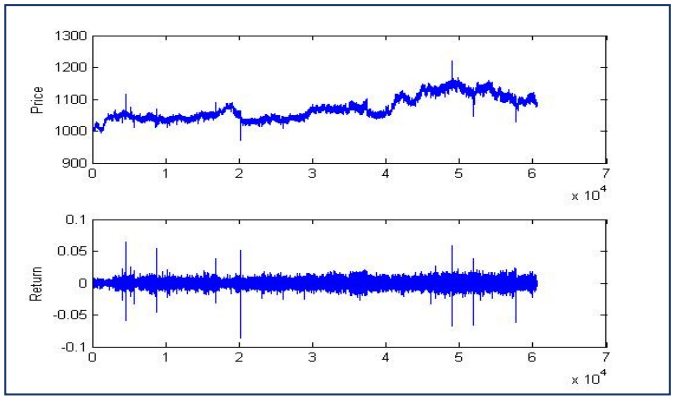

Figure 1. The Stock Index Future Market Price and Rate of Return in T+1 System

According to the analysis of these two liquidity measurement indices, the liquidity of futures market would rise when the T+1 trading system turns into T+1 trading system in the spot market. This is because: on one hand, when the spot market implements T+0 trading system, the investors in the stock market would have more trading opportunities without the restrictions of the T+1 trading system, especially trading in one day could provide the stock market with adequate liquidity, owing to the close relation between the spot market and the futures market, the liquidity of the futures market has also been raised correspondingly; On the other hand, when the spot market carries out the T+0 trading system, the arbitrager in the market can close position freely without the restrictions of the T+1 trading system, the arbitrage activities won't be inhibited, thus the liquidity of the futures market would increase.

Analysis of volatility

Figure 1 and **Figure 2** are the stock index futures market price chart and the return chart of two types of experiments in the spot market under the T+1 trading system and T+0 trading system respectively. As can be seen from the charts, both the stock index futures prices and its returns have the characteristic of volatility clustering. However, it's hard to find significant difference in the stock index futures price's volatility clustering in these two types of experiments under the trading systems of T+1 and T+0.

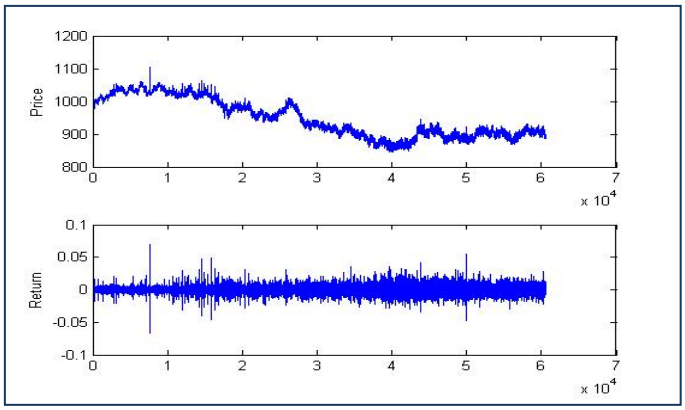

Figure 2. The Stock Index Future Market Price and Rate of Return in T+0 System

Table 8. Descriptive Calculation of Standard Deviation of Market Price Change

Comparative Types	Statistics	T+1	T+0
Standard Deviation of Market Price Change	Mean Value	28.9049	42.3621
	Standard Deviation	11.4546	17.8305
	Maximal Value	45.0970	70.7627
	Minimum Value	11.8235	20.6186
	Median	33.3988	35.1245

Table 9. ANOVA Variance Analysis of Market Price Change

Comparative Types	Types of Variance	Sum of Squares of Deviations	Free Degree	Mean square deviation	F Value	P Value
Standard Deviation of Market Price Change	Cross-Groups Variance	905.48	1	905.48	3.63	0.0729
	Group Variance	4491.33	18	249.518		
	Total Variance	5396.81	19			

To further analyze the effects of the spot market's T+1 trading system and the T+0 trading system on the stock index futures market's volatility, this essay would compare the stock index futures price changes' standard deviation in the 10 groups of experiments under the T+1 system and T+0 system respectively (see **Table 8**). **Table 9** is the results of the ANOVA variance analysis for the 10 groups of experiments in two categories.

As shown in the table, from 10 times of experiments, the mean and the median of the stock index futures market price changes' standard deviation of the T+0 trading system is larger than that of the T+1 trading system, but the P-value obtained by the variance analysis is equal to 0.0729, bigger than 0.05, which indicates no significant difference of the market price changes' standard deviation in these two kinds of experiments.

Therefore, the transformation from T+1 trading system to T+0 trading system in the spot market would not cause obvious influence on the stock index futures market's volatility. To further validate this conclusion, this essay would take a day as a time series unit for the returns obtained by the two types of experiments to analyze the difference of the futures market daily fluctuation under two different trading systems.

To examine whether there exist significant difference of the volatilities in these two kinds of experiments more accurately, this essay would take a day as a time series unit for the returns obtained by the two types of experiments to do the ANOVA variance analysis. As mentioned above, each imitation experiment has 60522 periods which indicates 21 trading days in one month. Each experiment's return time series is divided into 21 parts, thus we could get the volatility data of 21days, so under the T+1 trading system and the T+0 trading system, one group of experiment would gain two 21 days' day volatility data. The next step is to choose one experiment group and do the ANOVA variance analysis for the day volatility data of the two experiments, for the purpose of testing whether the futures markets' volatilities have significant difference between the T+1 trading system and the T+0 trading system.

Figure 3 is a Box-Plot for the day volatility of two experiments in one group, it can be directly seen from the graph, under the T+1 and T+0 system in this experiment group, there are slightly differences in the median and the quartile of the stock index futures' volatilities. As can be seen from **Table 10**, the P-value obtained by the ANOVA analysis is equal to 0.3426, which is much bigger than 0.05, indicating there is no significant difference of the day volatility data between the two experiments.

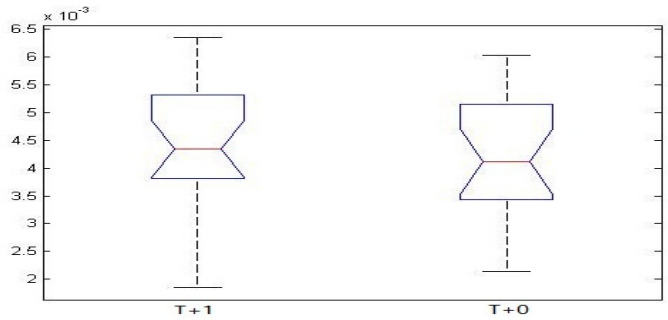

Figure 3. Box-Behnken of Two Daily Fluctuation Rate

Table 10. ANOVA Avoidance Analysis of Daily Fluctuation Rate of Two Groups

Types of Variance	Sum of Squares of Deviations	Free Degree	Mean square deviation	F Value	P Value
Cross-Groups Variance	1.11032e-06	1	1.11032e-06	0.92	0.3426
Group Variance	4.81395e-05	40	1.20349e-06		
Total Variance	4.92498e-05	41			

Table 11. Descriptive Calculation of Number of Trades, Trading Volume and Average Trading Volume per Order

Comparative Types	Statistics	T+1	T+0
Number of Trades	Mean Value	74.3	101.8
	Standard Deviation	20.50501	16.65866
	Maximal Value	103	133
	Minimum Value	46	85
	Median	75	98.5
Trading Volume	Mean Value	647.8	2280.7
	Standard Deviation	285.5777	238.9007
	Maximal Value	1188	2638
	Minimum Value	309	1832
	Median	611.5	2341.5
Average Trading Volume per Order	Mean Value	8.518038	22.75122
	Standard Deviation	2.063785	3.201335
	Maximal Value	12.375	27.02353
	Minimum Value	5.76667	17.87218
	Median	8.141139	22.70797

Above all, when the trading system in spot market turns into T+0 from T+1, there is no regular pattern for the changes of the stock index future market's volatility. That is mainly because: on one hand, when the investors buy stocks to open position, if there is a large fluctuation in market price on that day, but he cannot sell the stocks to close the position, then the investors can only sell the stocks to close the position until the next trading day. That would lead to a large fluctuation in market price while the T+0 trading system would solve this problem and reduce the fluctuation; On the other hand, under the T+0 trading system in the spot market, investors could buy and sell stocks several times in the same day or manipulate the stock price by arbitrage behavior, but that would trigger reckless over speculation and aggravate the market fluctuation. Therefore, it is impossible to gain the regular features of the stock index futures market volatility under the trading systems of T+0 and T+1 in spot market.

Analysis of order submission behavior of arbitrage investors

The above empirical results show that, compared with the T+1 trading system in spot market, T+0 trading system improved the efficiency of price discovery and market liquidity of stock index futures market, but did not raise market volatility. Further, the impact of the T+0 and T+1 trading systems on the market quality of the stock index futures market can be analyzed by investors' order submission behavior. The arbitrage investor is the link between the spot market and the stock index futures market, which is the important type of investors fixing basis. Therefore, it is the object of our research.

Table 11 shows 10 experimental groups' descriptive statistics results, including arbitrage investor's number of trades, trading volume, and average trading volume per order under the trading system of T+1 and T+0 in the spot market respectively.

Table 12. ANOVA Variance Analysis of Number of Trades, Trading Volume and Average Trading Volume per Order of Two Groups

Comparative Types	Types of Variance	Sum of Squares of Deviations	Free Degree	Mean square deviation	F Value	P Value
Number of Trades	Cross-Groups Variance	3781.25	1	3781.25	10.84	0.0041
	Group Variance	6281.7	18	348.98		
	Total Variance	10062.95	19			
Trading Volume	Cross-Groups Variance	1.33318e+07	1	13331812.1	192.34	4.75184e-11
	Group Variance	1.24765e+06	18	69314.1		
	Total Variance	1.45795e+07	19			
Average Trading Volume per Order	Cross-Groups Variance	1012.92	1	1012.92	139.64	6.46172e-10
	Group Variance	130.57	18	7.25		
	Total Variance	1143.49	19			

Table 11 shows that, in the spot market T + 0 trading system, arbitrage investors found arbitrage opportunities and traded 101.8 orders, 1.14 times than under the T + 1 trading system; the arbitrage investors' trading volume was 2280.7 in T+0 trading system, 3.5 times than under the T + 1 trading system, the arbitrage investors' average trading volume per order is 22.75 in T+0 trading system, 2.67 times than under the T+1 trading system. It can be easily found from the table, compared with the T+1 trading system, the arbitrage investors in the T+0 trading system are more active to submit orders.

To observe the group differences between the two types of experiments better, ANOVA variance analysis is applied to find the order submission behavior of these two types of experiments, the data is listed in **Table 12** in detail. It can be seen from the **Table 12**, there exists significant differences of the arbitrage investor's number of trades, arbitrage investor's trading volume, and arbitrage investor's average trading volume per order under the T+1 trading system and T+0 trading system in the spot market. It is confirmed that under the different trading systems of T+0 and T+1, the enthusiasm of arbitrage investors to participate in the market is different.

Above all, whether number of trades, trading volume or average trading volume per order, compared with the T + 0 trading system, the spot market T + 1 trading system restrains arbitrage investors' order submission behavior. On the contrary, in the spot market T + 0 trading system, an increase of nearly 1 times arbitrage opportunities, and thus enhance the enthusiasm of arbitrage investors. These more active arbitrage investors to participate in the transaction, will be helpful to correct the stock index futures wrong pricing and improve the quality of the market.

CONCLUSION

This essay applies Agent-based computational finance (ACF) method to explore the effects on the stock index futures market's price discovery efficiency, liquidity, volatility and arbitrage investors' order submission behavior of the T+1 trading system in spot market. The results showed that when the spot market's trading system turned to T+0 from T+1:

(1) The price discovery efficiency rise: T+1 trading system could restrain the arbitrage activity and affect the pricing efficiency of the stock index futures market while the T+0 trading system would help investors to make better and more appropriate investment decision.

(2) The liquidity of stock index futures market rise: T+1 trading system could restrain the arbitrage activity and lower the liquidity of the stock index futures market, while the T+0 trading system allows several transactions in one day, thus the liquidity would rise.

(3) Little effect is brought to the volatility of the stock index futures market: T+1 trading system and T+0 trading system in spot market would not bring significant effect on the fluctuation of stock index futures market.

(4) The enthusiasm of arbitrage investors rise: the spot market T+1 trading system restrains arbitrage investors' order submission behavior, in the spot market T+0 trading system, an increase of nearly 1 times arbitrage opportunities, enhance the enthusiasm of arbitrage investors.

In conclusion, the T+0 trading system in the spot market increase the stock index futures market's pricing discovery efficiency and liquidity without leading large fluctuation in market. The spot market T + 0 trading system enhance the enthusiasm of arbitrage investors, these more active arbitrage investors to participate in the transaction, will be helpful to correct the stock index futures wrong pricing and improve the quality of the market.

From the perspective of the stock index futures market, we believe that the stock market is supposed to reuse the T+0 trading system in a proper way to active the market and increase the market information delivery efficiency through the function of this trading system. There is no doubt that, the T+0 trading system would also increase the risk of reckless speculation, however, based on the research results, the fluctuation of the stock index futures market hadn't been exacerbated when the T+0 trading system replaced the T+1 trading system in the spot market,

therefore, the implementation of the T+0 trading system in the spot stock market would be beneficial. The supervision institution should consider recovering the T+0 trading system to enhance the market efficiency and the market vitality in the condition of effective supervision, therefore, promoting a stable and healthy development of the stock index futures market.

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