Analysis of Circuit Breakers Using Artificial Stock Market

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Abstract

In various stock markets, there is a system called "circuit breakers" that interrupts dealing of stocks for a certain period when stock price changes greatly. In this paper, we consider the influence of the circuit breakers on a stock market using an agent-based artificial market simulator called "U-Mart", by controlling the period of interruption and the criterion to invoke the circuit breakers. From experiments, we found the following: circuit breakers play an important role in the control of price fluctuations and the stabilization of the settlement system, while the circuit breakers reduce the stock trading volume. We also suggest that the period of interruption is important parameter in an institutional design of the circuit breakers, since the stock trading volume and the volatility are sensitive to the period.

1 Introduction

Financial markets are vulnerable to "bubbles" and excess volatility. In such a case, sharp stock price fluctuations may significantly affect, not only financial markets, but entire socioeconomy. Most systems in a financial market contribute to the stability of a market by eliminating uncertainty from the market fluctuations and from trading. In addition, rapid price fluctuations may cause the fall of liquidity in the market, and may disturb price discovery. Circuit breaker is one of the market systems founded in order to reduce the stock price volatility risk. In this paper, we define the circuit breakers as a temporary stoppage of trading.

Introduction of circuit breakers was advocated in the report of the Brady Committee[1] that investigated "Black Monday". According to the Brady Report, the main purpose of introducing this system is to directly reduce excessive stock price volatility and to mitigate market disruptions. There have been some arguments about the pros and cons of the system since its introduction after Black Monday. However, an extremely large-scale change of a stock price that invokes the circuit breakers is so rare that empirical research on the system has not been possible, and the efficiency of the system has not been confirmed.

It is very difficult to design market systems that contribute to the stability of the market, as a large-scale economic experiment cannot be performed in a real stock market. Therefore, by using a simulation technique, we examined whether the circuit breakers reduce volatility and contribute to the stability of a market.

2 Circuit breakers implemented in "U-Mart"

We incorporated the circuit breakers into the artificial market simulator "U-Mart"[1]. In the U-Mart system, stock index futures are traded, and prices are calculated independently of the actual prices. The U-Mart system adopts the pricing method called "itayose" in which orders are accumulated for a certain period. A price is decided so as to achieve the maximum contracted volume for the accumulated orders. We introduced interruptions of trading stock into the U-Mart system by halting itayose for certain periods. For the conditions of interruption, we referred to the system of the Osaka Securities Exchange (OSE) dealing with Nikkei 225 futures. We halt the trading of stock, when the stock price advances (or declines) in excess of a certain range from the standard price, and at the same time, differs in excess of a certain range from the fair value. The conditions are defined by

$$|P_c - P_s| > R_p \ , \tag{1}$$
$$|P_c - P_t| > R_m \tag{2}$$

where, P_c is the current stock price, P_s is the standard price that is the last day's closing price, P_t is the

[1]For further details, the reader should refer to [2].

theoretical price[2], R_p is the price range determined based on P_s, and R_m is the mispricing range determined based on P_s. When the market prices simultaneously satisfy the two conditions of Eqs.(1) and (2), trading is halted.

3 Outline of simulation

We considered how the operation of the circuit breakers affects a market using our modified U-Mart system. As a main parameter, we controlled the period of interruption (the times of itayose to halt), $T_s = 0$ (no circuit breakers), 1, 2, 3 and 4. We fixed the price range at $R_p = 700$ yen.

The configuration of the machine agents is indicated in Table 1. The standard agent set adopts the simple technical analysis. The contest agent set is a participant in the U-Mart machine agent contest. A random agent has the strategy of placing an order at random around a latest spot price or a futures price[3]. The ratio of two types of random agents, "SpotRandomAgent (SRA)" and "FuturesRandomAgent (FRA)", is set to 1:1. A total of 200 machine agents is prepared.

Table 1: The configuration of the machine agents

Agent Set	Strategy	Ratio
standard agent set	8	3
contest agent set	8	2
random agent set	2	variable

In this simulation, in order to observe the differences in market behaviors among different configurations of agents, we conducted experiments by changing the ratio of random agents to other agents. Ueki et al.[3] have pointed out that random agents may play an important role such as market maker who gives liquidity to the market. Hence, we set the ratios (A_r) of the random agents to the total of number of agents at $A_r = 0\%$, 5%, 10%, 20%, 40%, and 60%, respectively.

We adopted the daily Nikkei Index that showed a downward trend (2000/4/17–2000/10/10) as the spot price series given to the U-Mart system. The other settings are as follows.

- Trading days (period): 15
- Sessions (itayose) per day[4]: 8
- Short-term interest rate: 3-month CD rate
- Dividend yield: Expected yield of the Nikkei Index

4 Simulation with changing periods of interruption

We analyzed the liquidity in the market, which reflects how many orders can be executed without causing stock price change in a market[4]. A high liquidity denotes that a lot of orders are executable in a matter of minutes. In order to realize smooth price discovery after interruption in dealing the stock, it is necessary to ensure the liquidity in a market. Even if the steep fall in stock prices is avoided and the fluctuation in stock prices is reduced by interruption of dealing, the liquidity declines, and this may discourage investing activity if stock trading volume decreases greatly. Thus, we mainly observed the volume of trading and the historical volatility. All experimental results are the averages of 100 trials, and "steps" of the horizontal axis in the figures shows times of itayose.

4.1 Total trading volume

Total trading volume is the total of the stocks traded in 15 days. The changes of the total trading volume are shown in Fig. 1. It turns out that the total trading volume falls when the period of interruption increases, irrespective of the ratio of random agents. This is considered to be the result of simply having lost the opportunity to trade due to the circuit breakers. In changes of the total trading volume according to the ratio of random agents, there is a tendency for the total trading volume to increase as the ratio becomes larger. We surmise that this is because the supply and demand balance is maintained when the SRAs continue to place orders at random around the spot prices, even if the supply and demand is skewed by a large price fluctuation.

4.2 Historical volatility

Proponents of circuit breakers often claim that halting dealings reduces fluctuation of the stock price. Let

[2]theoretical price = latest stock price + theoretical basis
theoretical basis = last day's closing spot price * {(short-term interest rate - dividend yield) * T / 365)}
T: number of days (period)

[3]The agents buy or sell randomly. The SRA sets the limited price on order around the latest spot price. The FRA sets the limited price on order around the latest futures price.

[4]Halting itayose for 4 times means that the market is closed for half a day in this simulation.

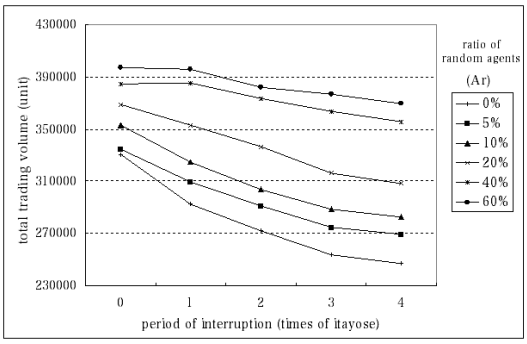

Figure 1: The changes of the total trading volume related to the periods of interruption for various ratios of random agents

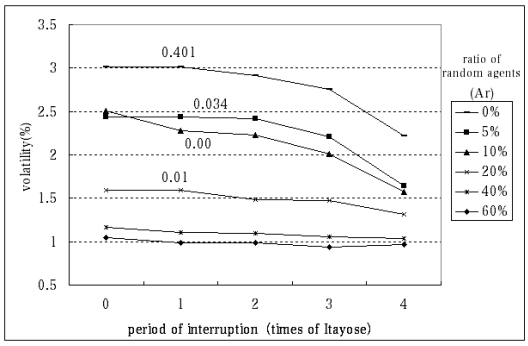

Figure 2: The changes of historical volatility related to the periods of interruption for various ratios of random agents: Only numbered lines show the significant probability according to the Kruskal-Wallis test among the historical volatility of the periods of interruption, $T_s = 1$, 2, and 3.

us examine whether this is actually the case. In general, volatility is used to measure the fluctuation of the price in a market. The following formulas define historical volatility (v_x) in this paper:

$$v_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - m_x)^2} \ , \tag{3}$$

$$x_i = \log S_i - \log S_i' \ (i = 1, \cdots, N) \ , \tag{4}$$

$$m_x = \frac{1}{N}\sum_{i=1}^{N} x_t \ , \tag{5}$$

where S_i is the present stock price, S_i' is the latest stock price, and N is the sample size in a trading period. Equation(4), x_i, calculates the logarithmic rate of change of stock price and Eq.(5), m_x, calculates a sample mean of x_i.

The changes of historical volatility related to the periods of interruption are shown in Fig. 2. The historical volatility decreases as the period of interruption increases, especially for a small ratio of random agents. Due to the interruption of dealing, the stock price recovers to a proper price without falling to the bottom. But this effect is weakened when the ratio of random agents is higher. In such a case, the price fluctuation is extremely low, since the random agents give sufficient liquidity for a market, as we described in the preceding section. Even when the ratio of random agents is small and the fluctuation is relatively large, unless the period of interruption is long enough, historical volatility does not decrease. Thus, in order to suppress a short-term fluctuation, the length of interruption of trading should be flexibly decided.

4.3 Bankruptcy

The circuit breakers give decision-making time to individual investors, so that those who cannot always monitor a market can catch up with change of a market, and they are protected against a drastic loss[4]. The increase of bankrupt may destroy a settlement system of a futures market based on netting. We consider many agents going bankrupt by dealings as a factor to destabilize a settlement system, and investigated how the circuit breakers affect bankruptcy.

As shown in Fig. 3, we found that the number of bankrupt agents decreases greatly after introduction of the circuit breakers, regardless of the ratio of random agents. We confirmed that the difference in the number of bankrupt agents is significant using the Mann-Whitney U test, under the criterion of $P < 0.05$. The circuit breakers may prevent agents with heavy losses from going bankrupt.

5 Simulation with price fluctuations in the spot price series

In this section, we investigated the influence of the circuit breakers on a market under larger price fluctuation. In this experiment, the spot price series of the Nikkei Index is increased range of fluctuation. The amounts of fluctuation are 1%, 3%, and 5%.

In this section, random agents were set to 20%. In this experiment, the tendency for the total trading volume to decrease, as in the former simulations, was ob-

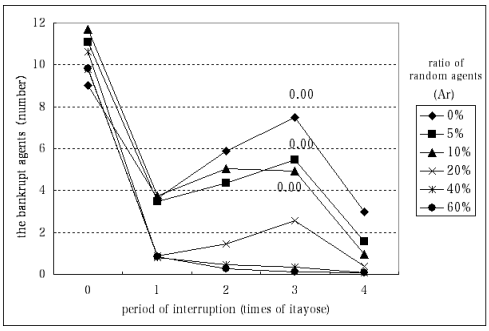

Figure 3: The changes of the number of bankrupt agents related to the periods of interruption for various ratios of random agents: Only numbered lines show the significant probability according to the Mann-Whitney U test between the number of the bankrupt agents of the period of interruption, $T_s = 0$ and 3.

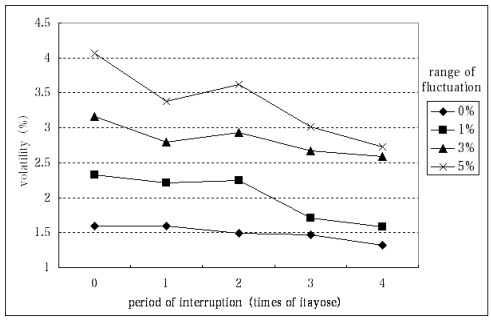

Figure 4: The changes of the historical volatility of the futures price with fluctuation of the spot price series

served whenever the period of interruption increased. Concerning total trading volume, it turns out that the circuit breakers have only the effect of decreasing volume, even if price fluctuation is large.

The changes of the historical volatility of the futures price are shown in Fig. 4. In the case where the expansion rate is 5%, though the interruption period is one period ($T_s = 1$), there is a big effect to control volatility. The significant difference of the historical volatility between no circuit breakers ($T_s = 0$) and circuit breakers with one period ($T_s = 1$) was proved by Mann-Whitney U test. Since fluctuation is artificially added to the spot price, the price fluctuation in 1 time of itayose becomes larger than in the former simulations. Therefore, it is thought that the circuit breakers are critically effective against price fluctuation control. However, when the range of price fluctuation is small, the range of decline of volatility is small. In $T_s = 4$, reduction in volatility has taken place sharply for all rates of change.

From these results, in order to reduce excessive volatility, it is better to invoke a circuit breaker for a short period, in the case that a big price fluctuation happens intermittently. If more fluctuation control is required, the period of interruption should be lengthened, but we must be prepared to decrease the total trading volume.

6 Summary and conclusion

From experimental results, we found the following: The circuit breakers work to suppress the fluctuations of stock prices, but decrease the total trading volume. The longer trading is interrupted, the more effectively the volatility of the stock market is decreased. When the degree of fluctuation is large, the decrease is conspicuous. Since the operation of the circuit breakers lowers the number of bankrupt agents sharply, it is suggested that introducing the circuit breakers prevents the bankruptcy of the agents Therefore, it is thought that the circuit breakers contribute also to stabilization of the settlement system of a market.

It is concluded that the circuit breakers play an important role for the control of price fluctuations and the stabilization of the settlement system, while the circuit breakers reduce the stock trading volume. We also suggest that the period of interruption is an important parameter in institutional design of the circuit breakers, since the stock trading volume and the volatility are sensitive to the period.

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