

Risk analysis on program trading: An agent-based computational finance perspective

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Abstract—Program Trading originates from combination trading technology in 70's in America. It was popular but once it was considered as root of disaster. Nowadays, there are many divergences on program trading risk in international academic world. This essay is to analyze program trading on risk of stock market. The method adopts computational experiment to build artificial stock market under various experimental conditions. The research will consider two strategies: combination insurance strategy and arbitrage strategy to inspect stock index futures' influences on artificial stock market. Through contrast experiments, it finds that program trading will cause abnormal fluctuation of stock market in short-term period but it will have slight impact on fluctuation of stock market in long-term period. On the whole, stock index futures reduce price fluctuation of spot market. Besides, the research finds that combination insurance strategy will increase short selling expectation in pessimistic market to accelerate market collapse when the market gives the same downside price expectation and the market should consider the influence of combination insurance strategy.

Keywords- Agent-based Computational Finance; MATLAB; Program Trading, Risk Analysis

I. INTRODUCTION

Program Trading originates from combination trading technology in 70's in America. It was popular but once it was considered as root of disaster. Nowadays, there are many divergences on program trading risk in international academic world. In the past, scholars adopted traditional financial methodology to research program trading risk. [1] Based on logic inference, the statement that combination insurance strategy will form a link-like collapse under pessimistic market situation was accepted by many professional persons. However, it was hard to describe a fact because a scenario won't happen again.

In normal, to research the relationship between stock index futures market and the price fluctuation in the real market, the traditional method is to compare with price fluctuations without the influence of stock index futures and that with the influence of stock index futures in the real market; to research the relationship between program trading and the price fluctuation of stock market, the method is to adopt independent variable—funding ratio of program

trading strategy and dependent variable—price fluctuation. Indeed, these methods can get persuasive results. But they are limited by numbers of samples and they cannot avoid other factors. Thereby, under conditions of different market and different period, it will be possible to get opposite results and whether stock index futures market will stabilize price fluctuation of spot market or bring downside risk of spot market is still a dispute. To solve this complex problem, a good methodology is Agent-based Computational Finance.

Agent-based Computational Finance (ACF) originated from the research of Santa Fe Institute. In the beginning, it is only a computer model so called 'Artificial Stock Market' (ASM), which is designed by a researcher of Santa Fe used to research on capital market. Although it seems a little bit rough nowadays, in that time, the method opened the door to ACF. [2]

After years of development, ACF is nowadays defined as: A branch of modern finance which uses computer technique by designing program agents to imitate real financial market and studies the Agent's investment behaviors at a micro level to find the cause of macroscopic characteristics of the capital market. Its basic idea is using artificial smart agents to imitate the behavior of real investors, make investment decisions according to the information from the ASM, and in final evolve into a market with the characteristics of real capital market.

ACF requires the artificial smart agents should have their own price decision mechanism and investment decision-making mechanism, and their price decision mechanism must have the capability to adjust the price decision rules to feed the market's need. Computer will begin to simulate the real capital market after initial values have been assigned. [3]

All in all, 'ACF is a finance method whose guide is CAS of complexity theory, based on Multi-Agent-System computer simulation technology, on the basis of finance theory, used to research on the interaction laws in the micro individuals in the finance market and the impact to the hole market.'

At present, ACF is mainly used in the research of foreign exchange market and the stock market. In the research of foreign exchange market, professor J.Arifovic (1996), Simon Fraser university in Canada, inherit the 'foreign exchange market general equilibrium theory' of Karehen & Wallace and on that basis, he propose the 'Rational pricing expectation equilibriums model'; in the research of stock market, scholars and professionals in many countries have developed series of ASM based on the market structure described in Grossan & Stiglitz's (1980) 'Rational pricing

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expectation equilibriums model', such as the ASM of Santa Fe of America and the AIE-ASM of ChengChi university of Taiwan CHINA. From the consideration of the learning mechanisms of the artificial smart agents, agents used by Santa Fe apply an individual learning mode, while agents used by Taiwan's AIE-ASM apply a social learning model. ^[4]

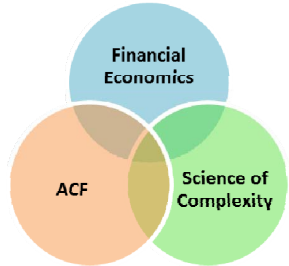


Figure 1. Picture 1-1 The relationship of ACF, Financial Economics and Science of Complexity

Nowadays, ACF in China has developed its own characteristics. Scholars and professionals over the years have traced the formation of the macro characteristics of the real capital market in great detail by taking the factors of China's capital market into the consideration of Santa Fe's ASM. Zhang, Zhang and Xiong (2006) had researched the problem about the strategies and income of chart analysis investors, fundamental analysis investors and BSV investors. ^[5] Y.J. Zhang (2007) had made further research about the problem about the strategies and incomes of investors in the condition that BSV investors, rational anticipated investors, noise investors and buy and hold investors are exist. ^[6] All these researches represent that using ACF to find the risk formation mechanism from the micro agents' individual perspective is viable. These research results were achieved on the basis of a single stock market, while this essay added a stock index future market to a single stock market, bridged the gap in the domestic research using ACF in cross market research.

II. DATA AND INSTITUTIONAL CONSIDERATIONS

The artificial stock market model in this paper was built from three perspectives:

1. Market structure
2. Trading mechanism
3. Main design ^[7]

From the perspective of market structure, the stock market built in this paper contains a stock market with 300 stocks ($k, k \in [1, 300]$) and stock index future market with a stock index future contract (FM). The minimum quoting unit 'e' of the artificial stock market equals to 0.02, and the minimum quoting unit 'ef' of the artificial stock index future contract equals to 0.2. The 300 stocks in the artificial stock market could be divided by their circulation values into three kinds of stock which are large-cap stocks, small-cap stocks and mid-cap stocks.

The considerations are as below:

1. 100 small-cap stocks at the price 10 Yuan and the number of outstanding shares is 40,000,000;
2. 100 mid-cap stocks at the price 20 Yuan and the number of outstanding shares is 80,000,000;

3. 100 large-cap stocks at the price 30 Yuan and the number of outstanding shares are 100,000,000.

Beyond the stock market composed by 300 stocks, in this paper, a stock index future (FM) contract is added to the artificial stock market, which is considered to be never matured in the experimental observation period or it is considered that the experiment is held in a short time when the contract will never be matured so the expiration effect could never be thought in the experiment, in the single stock market, so the research on basis of this model can only be appropriate for a short-term market problem. The subject matter of the FM contract, which is composed by 30 stocks with 10 small-cap stocks, 10 mid-cap stocks and 10 large-cap stocks, whose initial value is the same as value of GZ30, minimum quoting unit is 0.2, price multiplier is 100, is GZ30, and there is no price limits in the artificial stock index future market.

The initial 30 stock index components are selected in the 300 stocks according to the ratio 1:1:1 in large-cap stock, mid-cap stock and small-cap stock.

From the perspective of trading mechanism, the price of the assets in both the artificial stock market and the artificial stock index future market is decided through the call auction way, which is an approximate treatment to the mechanism of the trading mechanism of the domestic stock market. ^[8]

The call auction of the artificial stock market is handled by the main program so called 'main.m', which is compiled by MATLAB. ^[9] 'main.m' will produce the benchmark price according to the declare price following the principle of price precedence. The benchmark price should fit three demands as follows:

1. When it is dealt at the benchmark price, the trading volume must be maximum;
2. The bid exceed the benchmark price and the ask under the benchmark price must be all dealt;
3. The order at the price equal to the benchmark price must be all dealt at least in one side.

Besides, in order to reflect the superiority of program trading in transaction speed, the order from program trading investors will be dealt preferentially.

It should be noted that:

1. This paper assumes that orders arrive at the same time, sort by price in the main program and the orders with the same price will be transacted in a random sequence.
2. In the auction process, if there were two or more reporting price in line with the above three conditions, the Shanghai Stock Exchange used the price which correspond to the minimum volume for the transaction price, when there were still two or more reporting price fit the condition above, used the median price for the transaction price, while the Shenzhen Stock Exchange took the price which is nearest to the recent price as the transaction price.

From the perspective of main design, there are several assumptions:

1. Every investor in this artificial stock market will

- generate a corresponding expected price P_{ijt} (t means the time period, P_{ij} means the expected price of asset j for Agent(i)) for any asset, including cash held by investors, in the market, and the expected price will change as the market situation changes, and be impacted by investor's psychology (risk tolerance, etc.), experts' predict from Expert Agent;
- Every investor ' i ' builds their portfolio and decides the trade direction according to the D-value (Δ_{ijt}) of the expected price to the asset ' j ' (P_{ijt}) and the real price of the asset ' j ' (NP_{jt}).

In this paper we have divided the Agent into four categories^[10], Random Agent, Imitate Agent, Expert Agent and Program Agent. Random Agent could be divided into two categories, which are Stock-Random Agent and Future-Random Agent. Imitate Agent could be divided into two categories as Local-Imitated Agent and Market-Imitate Agent. Program Agent could be divided into three categories as Arbitrage Agent, Portfolio Insurance Agent and Quantitative Investment Agent. The money Random Agent, Imitate Agent and Expert Agent input into the market once should never exceed 100,000 Yuan, while the money Program Agent input into the market once has no limit.

Random Agents are the noise traders of the market. Their investment behavior is perfect rational and no trend. Price in the stock market only has Random Agents in it accord with the characteristic of random walk. Local-Imitate Agent is designed to simulate the investors in real market who used to invest followed the history and impacted by experts' investment behavior.

For Local-Imitate Agent, the booms and busts of an asset ' j ' past will strongly impact its investment behavior, and as a result, they will pursue the assets booms and undersell the assets busts. Besides, different Local-Imitate Agent have different resistance to continuously rise and drop, some agents tend to undersell when the asset have already got a return over 50 percent, while some ones tend to undersell when the asset have only got a return of 5 percent, meanwhile some agents tend to undersell when the price of the asset have already dropped for 5 percent, while another ones will never sell out their stocks even the price of the asset have dropped 20 percent.

Agents could alter their resistance to risk and income by a progress of studying, the good practices past will strengthen the resistance and the bad practices past will weaken it, in the last, there will even have some agents translate to a kind of agent named 'Contrarian investors' whose investment behavior accord with contrarian strategy. Market-Imitate Agent is designed to simulate the investors in the real market who chase hot plate. Their expected price to an asset is also impacted by the investment behaviors of the experts, for example, when the rise and fall in a past time ' T ' of large-cap stocks exceed it of mid-cap and small-

cap stocks, Market-Imitate Agent tend to invest on large-cap stocks rather than invest on small-cap and mid-cap stocks. Expert Agent is a kind of agent who believes in technical analysis, they adjust their expected price to an asset according to the technical index. Besides, the Expert

Agent designed in this paper is assumed that the expected price to an asset ' j ' of one Expert Agent ' i ' reflect the real value of the asset ' j ' in a certain extent, and the mean value of the expected price to the asset ' j ' of all the Expert Agents will generate a plus impact on the expected price of the Imitate Agents. Arbitrage Agent calculates the β of stocks and builds investment portfolio which is simulating the stock index GZ30, by buying and selling portfolio when the price of stock index futures is higher than the price of portfolio.

The Arbitrage Agent get return from this arbitrage behavior. As domestic stock market is still not allowed to short stocks, so arbitrage in domestic only takes place when the futures price is higher than the spot price. Portfolio Insurance Agent acquired and held the stock portfolio simulating the GZ30. When the market is expected to decline, they will purchase the corresponding short billing to ensure the value of the portfolio insurance. Quantitative Investment Agent sets strict approach and appearance conditions and uses the method of portfolio trading. Quantitative Investment Agent studied in this paper will not use dynamic hedging strategies in order to observe the influence of portfolio trading methods to the stock market in separate.^[11]

During the whole stock trading process, Intelligent Agent will reflect market quotations to predict each property price, build investment portfolio based on the difference between prospective price and asset price and finally create orders. Stock market produces new asset price and processes each order by using call auction. Then, this information will give feedback to investors and upgrade investors' combination situation.

Artificial stock market in this paper doesn't consider the factor of investor arrival that investors receive market information at the same time but investors accept information as their preferences. While all investors are carrying out trading orders and trading system is dealing with all trading orders simultaneously, artificial stock market cannot describe high frequent Program Trading and characteristic of immediately placing an order. Therefore, this paper considers that trading system will prior cope with Program Trading Agent order to show the advantage of immediately placing an order. Meanwhile, to present sale combination of single time of sale of Program Trading Agent and large transaction, this system will limit the maximum trading amount of other single time of sales of Intelligent Agent. These factors will make Program Trading Agent have great effect on market in single period and further simulate market fluctuation characteristics by Program Trading in short term. Because this paper doesn't consider the factor of investor arrival, each periodic experiment data is not minute data in the real market and not daily closing quotation data. Each periodic experiment data

can be on behalf of comprehensive market sales situation in short term but the data won't be as the same as daily closing quotation data, however, these two data have similar characteristics by computer simulation because the following reasons:

1. Call auction method can be recognized as successive auction replacement at extreme situation;
2. Successive call auction presents successive auction characteristics, but the successive auction presents call auction's characteristics in certain period.

III. EXPERIMENTS AND RESULTS

After the artificial stock market has been built up, several experiments were designed as follows:

Experiment 1:

For the time range 1~300, there are only Random Agent Imitate Agent and Expert Agent in the artificial stock market. The program will run without the participation of Program Trading Agent and stock index future market.

Table 1. Conditions of experiment 1

Random Agent	2000(number)	2,000,000 Yuan per one
Local-Imitate Agent	500(number)	2,000,000 Yuan per one
Market-Imitate Agent	500(number)	2,000,000 Yuan per one
Expert Agent	100(number)	10,000,000 Yuan per one

The model designed in this paper assumed that all the intelligent agents can receive information from the market and generate their own expected price, which is considered work only in a not too long time range, to different asset according to the information agents get, then agents will trade in the market according to the maximize profit principle.

After 300 phase' simulating, the component of the stock index GZ30 have been adjusted 10 times, and as a result, the standard deviation of the stock market is 0.03662 at last. Characteristics of leptokurtosis and fat-tail could be found in this ASM which leads to a credible real market simulation. On basis of the result above, we get to the next experiment.

Experiment 2:

For the time range 301~400, we have added Arbitrage Agent to the Intelligent Agent and a stock index future contract besides the existing stock market in order to study the influence of the adding of the stock index future market.

The conditions of experiment 2 are as follows:

Table 2. Conditions of experiment 2

Random Agent	2000(number)	2,000,000 Yuan per one
Local-Imitate Agent	500(number)	2,000,000 Yuan per one
Market-Imitate Agent	500(number)	2,000,000 Yuan per one
Expert Agent	100(number)	10,000,000 Yuan per one
Random Agent in FM	2000(number)	2,000,000 Yuan per one
Arbitrage Agent	50(number)	20,000,000 Yuan per one

After 100 phase' simulating, the component of the stock index GZ30 have been adjusted 3 times, and as a result, the standard deviation of the stock market is 0.03025 at last. It is a bit lower than the value when stock index future market is not exist in the model, the main reason may be the condition of domestic market that it is not allowed to sell short the share in China, which leads to the efficacy loss when the futures price below the spot price.

IV. CONCLUSION & FUTURE WORK

Under the controlling conditions of the artificial stock market, the paper researched on the risk of program trading on stock market by the method of computational experiment

Through contrast experiments, it finds that program trading will cause abnormal fluctuation of stock market in short-term period but it will have slight impact on fluctuation of stock market in long-term period. On the whole, stock index futures reduce price fluctuation of spot market. Besides, the research finds that combination insurance strategy will increase short selling expectation in pessimistic market to accelerate market collapse when the market gives the same downside price expectation and the market should consider the influence of combination insurance strategy. All in all, regulators in china should pay attention to the risks of program trading demonstrated above.

The paper proposes a " " assumption for an artificial stock market to figure out the problem. To simplify the operation of the artificial stock market, the market sets a few of intelligent agents. In this case, the liquidity of the artificial stock market is worse than that of the real market. Besides, the artificial stock market doesn't take into account the factor of investor arrival. Therefore, the model built up above cannot be used to research the high frequency trading. However, these existing problems will be improved in future.

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