

# Game Analysis and Agent-based Modeling Simulation Model Design for the Regulation of Inside Trading in Stock Market

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**Abstract**—Since the stock market has become an important component of financial system in one country, it is very critical for the regulator to keep the market stability and avoid the illegal behaviors in order to maintain the national financial security. This paper analyzes the regulation of inside trading in stock market through building a dynamic game model involved investor and regulator, and proposes the effective regulation methods based on the game analysis. Finally, an agent-based modeling simulation model is designed for simulating the game model in virtual environment in order to verify the effect of the regulation methods proposed from game analysis.

**Keywords**—regulation; game theory; inside trading; financial security; simulation

## I. INTRODUCTION

Stock market has become one of the most important components of the national financial system, which now is the important investment market for investors and financing market for companies. So the regulator should keep the market running smoothly and avoid the illegal behaviors in order to protect the benefits of investors and the national financial security. There are various kinds of illegal behaviors in the stock market and inside trading is a common kind. Inside trading is the behavior that insider who knows non-public information of stock or listed company makes use of the non-public information to make extortionate profit.[1] The inside trading will destroy the fair principle of stock market and the benefits of other investors, even the market order of the whole financial system. So the effective regulation is necessary. Game theory is an effective method of studying the interests and decision-making features among players, and simulation model can simulate the game model dynamically in virtual computer environment, these two methods are used for researching the regulation of inside trading in this paper. Firstly, a dynamic game model involved with investor and regulator is built to analyze the scientific regulation strategy which is a kind of self-adaptive strategy. After the game analysis, an agent-based modeling

simulation model is designed for verifying the research conclusions.

## II. GAME ANALYSIS

In this part, a complete but imperfect information dynamic game model is established for researching the effective regulation strategies. Firstly, the components of game model including players, strategies and payoffs of each player, sequences of actions and the information environment will be described. After the game description, we will solve the mixed strategy perfect Bayesian Nash equilibrium to get the key factors which can avoid the inside trading of investor. Finally, a self-adaptive regulation strategy is proposed.

### A. Description of the Game

There are two main kinds of economic entity in stock market which are investors and market regulator. So we assume that the game model for researching the regulation of inside trading in stock market includes investor and regulator as the players. The player investor will choose inside trading or regular trading, and the player regulator will choose investigating or not. If the regulator chooses to investigate the inside trading carried out by investor, the investigation will be successful or failed. We also assume that the investor chooses his strategy firstly and the regulator makes his decision afterward. And the regulator has imperfect information what means that the regulator does not sure the investor's decision.

If the investor chooses to carry out inside trading he will face two possible scenarios. When the inside trading is investigated successfully by the regulator, the investor will lose profits as  $-U_{it1}$  which includes the punishment or trading constraints and so on; on the contrary, if the inside trading is not investigated by regulator, the investor will get profits from violating rules as  $U_{it2}$ . In order to carry out inside trading, the investor also needs to pay  $C_{it}$  as the cost of getting inside information and violating behavior.

In the face of the potential inside trading, the regulator will choose to investigate or not to. If the regulator chooses to investigate he will face two possible scenarios, one is

successful investigation the other is failed. The probability distributions of successful and failed investigation is  $(P_S, 1-P_S)$  which will be decided by the virtual player “Nature” and reflect the regulatory capacities. If the regulator investigates the inside trading successfully he will get positive utility as  $U_{R1}$ , the utility includes good reputation and positive influence on the market; if the regulator investigates the inside trading unsuccessfully or chooses not to investigate the inside trading which has happened, the regulator will get negative utility as  $-U_{R2}$  which includes bad reputation and so on. In addition, it will take regulator  $C_R$  as the cost to carry out the investigation, and the  $C_R$  also reflects the regulatory capacity to a certain degree.

Finally, we assume the players involved in the game have complete information of payoffs but imperfect information of real decision-making between each other. In conclusion, this is a complete but imperfect information dynamic game model. If the probability distributions of investor’s decision in the first step of the game that (inside trade, regular trade) is  $(P_{it}, 1-P_{it})$ , and the probability distributions of regulator’s decision of the second step of the game that (investigate, not to investigate) is  $(P_R, 1-P_R)$ , the game will be described as Figure 1.

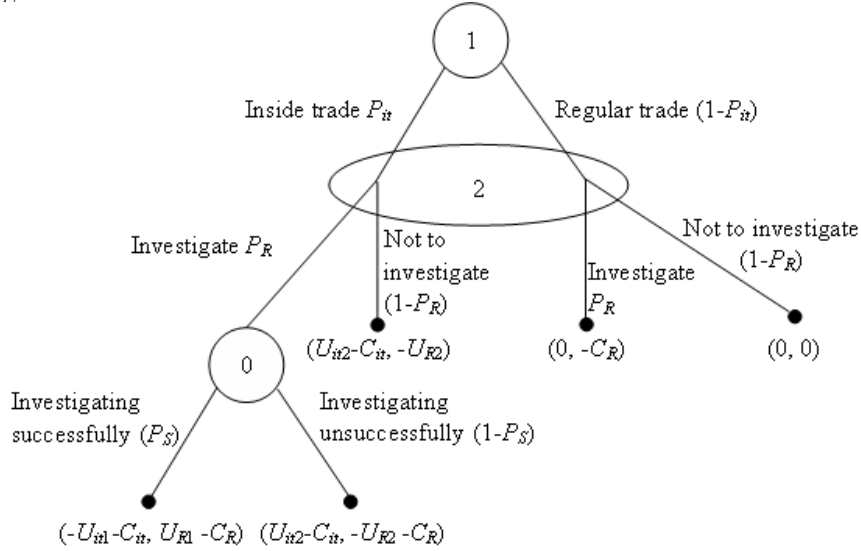


Figure 1. The structure of the game.

In Figure 1, Player 1 stands for the investor; Player 2 stands for the regulator; Player 0 stands for the virtual game player “Nature” who will choose the probability of whether the investigation successful or failed.

### B. Nash Equilibrium of the Game

To solve the mixed strategy perfect Bayesian Nash equilibrium of this game, we must know the payoffs of each player in different decision situations.

Firstly, we solve the decision-making probability of investor in equilibrium through making the payoffs get by investor when regulator chooses to investigate equal the payoffs when the regulator chooses not to investigate. The condition is shown as formula (1).

$$P_{it} \cdot [P_S \cdot (U_{R1} - C_R) + (1 - P_S) \cdot (-U_{R2} - C_R)] + (1 - P_{it}) \cdot (-C_R) = P_{it} \cdot (-U_{R2}) + (1 - P_{it}) \cdot 0 \quad (1)$$

Then we get the probability of inside trading in equilibrium from the condition above, the result is shown as formula (2).

$$P_{it}^* = \frac{C_R}{P_S \cdot (U_{R1} + U_{R2})} \quad (2)$$

Secondly, we solve the decision-making probability of regulator in equilibrium through making the payoffs get by regulator when investor chooses to inside trade equal the payoffs when the investor chooses to regular trade. The condition is shown as formula (3).

$$P_R [P_S \cdot (-U_{it1} - C_{it}) + (1 - P_S) \cdot (U_{it2} - C_{it})] + (1 - P_R) \cdot (U_{it2} - C_{it}) \quad (3)$$

Then we get the probability of investigating in equilibrium from the condition above, the result is shown as formula (4).

$$P_R^* = \frac{U_{it2} - C_{it}}{P_S \cdot (U_{it1} + U_{it2})} \quad (4)$$

Finally, we get the mixed strategy perfect Bayesian Nash equilibrium which is shown as formula (5).

$$\left( P_{it}^* = \frac{C_R}{P_S \cdot (U_{R1} + U_{R2})}, P_R^* = \frac{U_{it2} - C_{it}}{P_S \cdot (U_{it1} + U_{it2})} \right) \quad (5)$$

### C. Structural Analysis of the Game

The purpose of game analysis is to find effective regulation strategy of avoiding inside trading, so we will focus on the effect given by regulator on the probability of inside trading in game equilibrium. From formula (5), we know that lower investigation cost  $C_R$  and higher probability of successfully investigation  $P_S$  will reduce the probability of inside trading expressed as  $P_{it}^*$ . The reason why we focus on the investigation cost  $C_R$  and probability of successfully investigation  $P_S$  is these two factors reflect the regulatory capacity of regulator. So it is relatively easy for the regulator to adjust  $C_R$  and  $P_S$  during the investigation. Based on the structural analysis, the effective regulation strategy of avoiding inside trading is a kind of self-adaptive regulation which requires regulator to adjust his  $C_R$  and  $P_S$  in time according to the market situation.

Following the game analysis, we will design a simulation model on Swarm platform for studying the effect of self-adaptive regulation strategy from a perspective of continuity and repetition.

### III. THE AGENT-BASED MODELING SIMULATION MODEL DESIGN

The simulation model will be established based on the one-time game model. According to the game model, there are two simulation agents who are investor named as “Investor” and regulator named as “Regulator” in simulation model. In order to simulate the decision-makings and behavioral features of economic agents, a functional simulation agent named as “Genetic Algorithm Learning Classifier System (GALCS)” is used to endow “Investor” and “Regulator” with self-adaptability. The principle of GALCS is to enhance the probability of better decision of agent when facing to the same situation. So the decision of agents will be optimized gradually. Finally, we use a functional simulation agent named as “StockMarket” for the information transfer among simulation agents. The main properties and actions of simulation agents are described in Table 1 and Table 2.

TABLE I. THE MAIN PROPERTIES OF THE SIMULATION AGENTS

Agent	Main Properties	
	Variable in simulation model	Property
Investor	PIT	the probability of inside trading in current simulation cycle
	profit	the expected profit of current simulation cycle
	lastprofit	the expected profit of last simulation cycle
Regulator	PR	the probability of investigating
	PS	the probability of investigating successfully
	profit	the expected profit of current simulation cycle
StockMarket	public information	

TABLE II. THE MAIN ACTIONS OF THE SIMULATION AGENTS

Agent	Main Actions		
	Action	Function description	Action type
Investor	-insidetrade	deciding the change of the probability of inside trading PIT	simulation action
	-compare	computing the profit in current simulation cycle and providing evidence for optimizing decision-making in next cycle	simulation action
Regulator	-setPR	deciding the change of probability of investigating PR	simulation action
	-setPS	deciding the change of probability of investigating successfully PS	simulation action
	-compare	computing the properties	simulation action
StockMarket	-get	getting the public information	functional action

The environment and relationships among the agents of simulation model may be described as Figure 2.

As the simulation model system is designed by OOP and the simulation process involves action calls among agents, so the best measure of describing the simulation process is to use action sequence and information flow, which is shown as Figure 3.

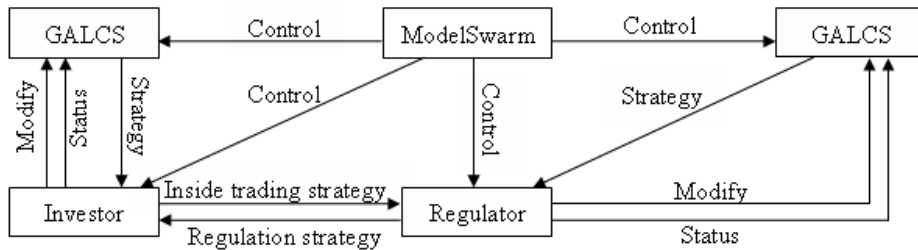


Figure 2. The environment of the simulation model in Swarm.

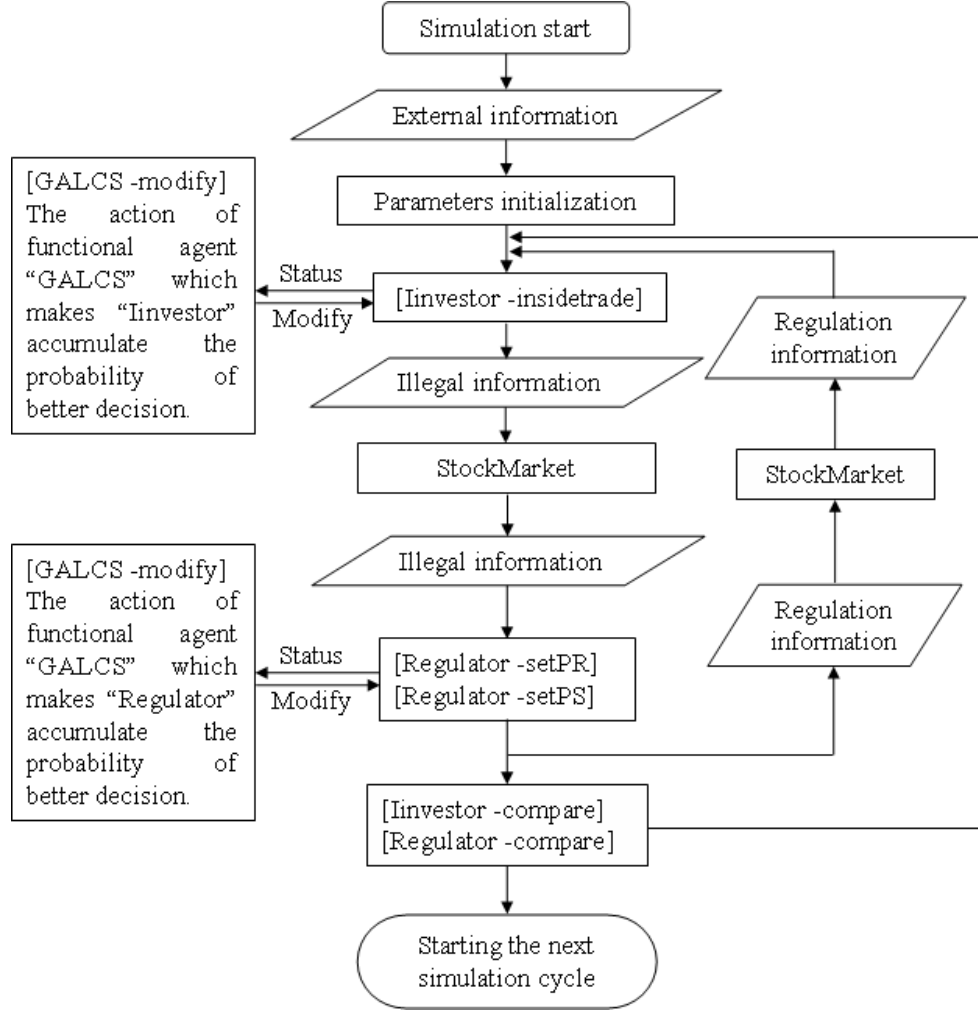


Figure 3. The process and information flow of the simulation.

After setting the properties and action sequences of agents, and the simulation environment and relationships among agents, it requires researcher to program the simulation model in the Swarm platform. Then we can activate the model and set parameters for various simulation researches.

#### IV. CONCLUSION

As a common illegal behavior in stock market, inside trading will destroy the market order and benefits of investors, so it is necessary to reduce the probability of inside trading. According to the game analysis, we have known that lower investigation cost  $C_R$  and higher probability of successfully investigation  $P_S$  will reduce the probability of inside trading. So we propose a self-adaptive

regulation strategy which requires the regulator to adjust his capacity reflected as  $C_R$  and  $P_S$  in time according to the market situation. Finally, an agent-based modeling simulation model on Swarm platform is designed for simulating the game model continuously in order to verify the conclusions from theoretical research. Game theory and simulation have been becoming ideal methods for the research of financial security.

#### REFERENCES

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