Hindawi
Discrete Dynamics in Nature and Society
Volume 2020, Article ID 7957282, 9 pages
https://doi.org/10.1155/2020/7957282

Research Article

Evolutionary Game Model of Stock Price Synchronicity from Investor Behavior

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Received 28 October 2019; Accepted 16 January 2020; Published 13 February 2020

Academic Editor: Rigoberto Medina

Institutional and individual investors are the two important players in the stock market. Together, they determine the price of the stock market. In this paper, an evolutionary game model that contains the two groups of players is proposed to analyze the stock price synchronicity considering the impacts of investors' decisions on stock investment. Factors affecting investors' decisions include the potential revenue or loss, the probability of gain or loss, and the cost of corresponding behavior. The proposed game model is analyzed by replicator dynamics equations and simulation of the evolutionary equilibrium strategy under different circumstances. The analysis shows that the operating cost of institutional investors, the cost of information collection before trading, and the expected loss that may be punished by regulators are the key factors that affect the evolutionary game system between institutional investors and individual investors. In addition, reducing the speculation in the market and increasing the information access of investors through the serious operation mode of institutional investors and the strengthening of the market information disclosure mechanism are beneficial to alleviate price synchronicity in stock market.

1. Introduction

A growing number of scholars have recently begun to extend the research on stock price synchronicity to explore the impact of investors' trading behaviors. Differences constantly exist in the information collection ability, the cost of information collection, and the investment concept. Consequently, in contrast to information investors, noise investors constantly exist in various countries' financial markets. Thus, the real financial market can hardly become an effective market, and the stock price of individual stocks can hardly reflect the actual situation of enterprises. Given this logic, the academic community has gradually formed two kinds of explanations, namely, the explanation based on idiosyncratic information trading and the explanation based on noise trading. Morck et al. [1] stated that the former holds that the variation of stock characteristic returns reflects the degree of inclusion of the company's characteristic information or private information in the stock price. Moreover, low stock price synchronicity indicates a high tendency that the investors receive the company's characteristic information, which they analyze from the two aspects of information disclosure quantity [2–6] and information disclosure environment [7–12]. For example, Kim et al. [5] believed that companies have an incentive to hide unfavorable information such as corruption and scandal, while freedom of news as an external supervision mechanism will increase the disclosure of the companies' private information and reduce the synchronicity of stock price changes. Lin et al. [12] found that countries with weak property right system protection reduce the transmission speed of company characteristic information and increase the synchronous stock movement. Such scholars generally emphasize that the change of security price is driven by incremental information and regard investors in the market as rational investors, whose reference information content of enterprise characteristics determines the synchronous change of stock price in the market. West [13] expounded on the latter explanation and believed that low stock price synchronicity indicates that the stock price changes substantially and that the stock price deviates from the company's basic value to an increasing extent. Given that noise cannot be clearly quantified, scholars who hold the view of "noise-based trading" often start from the anomalies in the stock market to explore the abnormal phenomena when financial anomalies occur and consequently become the supporter of their own views [14–19]. For example, Li et al. [19] found through econometric model research that low stock price synchronicity is negatively correlated with information environment agent indices, including liquidity risk, which supports the explanation of the influence of noise on stock price synchronicity.

The rapid development of behavioral finance in the 1990s has encouraged investors' behavioral deviations, including irrational characteristics such as overconfidence, anchoring, and loss avoidance, as a supplement to the noise trading school, to propose a new theoretical interpretation of the research on the synchronicity of stock prices. Behavioral finance scholars believe that investors' cognition is limited and their investment behaviors often deviate from the rational track, which is in contrast to the view of "idiosyncratic information trading." Barberis et al. [20] and Greenwood [21] similarly found that when the basic value of enterprises is constant, the linkage degree of enterprise stock prices with the market would change once the enterprise stocks are included in (or excluded from) Standard and Poor's 500 index and other credit rating indices. Scholars attributed the lack of significant increase or decrease of the external enterprise characteristic information to the convergence trading results under the influence of investor sentiment. This attribution is consistent with the perspective of investor attention [22–24], overconfidence [25–27], herd effect [28–30], and other perspectives to carry out the analysis. On the basis of existing research results in the theoretical field, this paper combines stock price synchronism with investors' herd behavior to explore the direct influencing factors and evolution mechanism of stock price synchronism [31, 32].

The price linkage phenomenon in the stock market is manifested as the same rise and fall of stock prices in different blocks or within the same block of the stock market. However, this paper argues that the convergence of stock investors' investment direction is the decisive factor that leads to the synchronicity of stock prices based from the perspective of its origin. Under certain incentives, when most investors provide similar analysis on some related blocks or related enterprises, they will buy or sell certain stocks in a similar period of time, thereby resulting in intrablock and interblock fluctuations that lead to the linkage of stock prices. In particular, investors in the stock market are classified into two categories, namely, individual investors and institutional investors. Although individual investors are many in number, they have few personal funds and limited information, thereby exhibiting less influence in the stock market. At the same time, individual investors often follow the trend according to other investors' investment actions, leading to the herd effect in the stock market. Institutional investors, who are led by financial institutions and possess all kinds of funds, cannot compete with individual investors in terms of number. However, institutional investors have inherent advantages in terms of funds, information gathering, and investment judgment that individual investors cannot match. They often use their dominant position to influence the market and take advantage of individual investor behavior to profit.

When certain individual stocks or industries show good information in the stock market, institutional investors will rely on their ability to invest for the first time and thus make the first move on these stocks' price. After a period of time, the investment trend of institutional investors spreads outward through various channels, thereby becoming public information that is captured by individual investors. Owing to the lack of independent judgment ability of some individual investors, they tend to imitate the investment strategy of institutional investors and invest in the same type of stocks. This herding behavior in the stock market, which mimics the direction of institutional investors, leads to a rapid concentration of an excessive amount of money in a particular class of stocks and eventually causes their prices to move in the same direction. Therefore, this paper constructs the evolutionary game model of institutional and individual investors in the stock market from the perspective of institutional investors and individual investors. The replicator dynamic equations of the proposed evolutionary game and the evolutionary stable strategy are obtained to analyze the properties of the model. To better describe the price linkage mechanism in the stock market from the perspective of investor behavior, this paper uses MATLAB to simulate the stable strategy evolution behavior of institutional investors and individual investors in the stock market.

2. Evolutionary Game Model for the Investment Behavior of Institutional and Individual Investors

We discuss the formulation of the evolutionary game model for the investment behavior of institutional and individual investors in this section. We first make assumptions about the parameters of the model. Then we construct the payment matrix of the model and calculate the replicator dynamics of strategies. Finally, we analyze and elaborate the stability of equilibrium point.

2.1. Basic Model Assumptions. On the basis of the above analysis, investors in the stock market are assumed to be classified as institutional (O) and individual (I) investors. They choose and adjust their strategies in the space of possible strategies based on the expected profit. When faced with investment opportunities, the institutional investors' strategy space is capital injection (M) and noncapital injection (NM), whereas the individual investors' strategy space is imitation (F) and nonimitation (NF). Specifically, the possible action strategies of both sides are as follows.

Assumption 1. Institutional investors choose noncapital injection, whereas individual investors choose nonimitation. In this case, we assume that the expected return of institutional investors is R_1, and that of individual investors is R_0. The following hypothesis is developed on this basis.

Assumption 2. Institutional investors choose capital injection, whereas individual investors choose imitation. In this case, for the purpose of opening positions, the institutional investors will buy the stocks in batches from individual investors at lower prices. Then, they will gradually push up the stock prices, inducing individual investors to keep watching. As the stock prices gradually rise, the initially cautious individual investors will be attracted by the high returns and start buying the institutional investors' stocks in small quantities. However, as the vast majority of individual investors are timid, institutional investors need to continue to foil the market atmosphere and continue to inject capital to enhance the investment atmosphere of individual investors. When a major good news is announced, or the overall stock market is good, the institutional investors will take advantage of this opportunity and quickly stretch the stock price. Relying on the buying behavior of the individual investors, the institutional investors continue to sell their shares before prices fall, forming the ultimate gain. Based on this analysis, we set the expected profit of institutional investors as $R_M - C_M$, where R_M represents the expected profit of the capital injection and C_M represents the expected cost. For individual investors, we believe that their profit relies on the time of their selling, expressed as $R_0 - \beta R_M$, where $\beta \in [-1, 1)$. When $\beta > 0$, it means that the individual investors sell too late, and their imitation results in a loss of earnings. When $\beta < 0$, it means that the individual investors sell the stock at the right price, and their imitation brings the positive returns.

Assumption 3. Institutional investors choose capital injection, whereas individual investors choose nonimitation. In this case, given that individual investors do not follow the stocks they trade, institutional investors cannot gain profits by manipulating the stock price but should still pay for the expected cost of their trading C_M. Thus, the expected profit of institutional investors is $R_1 - C_M$. And the individual investors choose not to follow, which means that they invest independently and can obtain a certain profit. Therefore, the expected return of individual investors is R_0.

Assumption 4. Institutional investors choose noncapital injection, whereas individual investors choose imitation. When the market is depressed or the market situation is unclear, institutional investors will abandon the original intensive capital investment and diversify their investment strategies to seek capital preservation. Although at this time individual investors choose to imitate the investment behavior, limited by time, capital, and other factors, it cannot have a huge impact on the returns of institutional investors. Therefore, we assume that the return of institutional investors is R_1. On the contrary, since most of the stocks selected by institutional investors at this time are for the purpose of preserving the value of assets, we assume that the return of individual investors at this time is δR_1, where $\delta \in [0, 1]$ represents the profit brought by following institutional investors.

2.2. Model Construction and Evolution Analysis. According to the above discussion, the evolutionary game payment matrix of the investment behavior of institutional and individual investors in the stock market is shown in Table 1.

We must calculate the equilibrium point of this evolutionary process when the payoff matrix is obtained. Suppose that in the group of institutional investors, the proportion of choosing capital injection is $x\,(0 < x < 1)$ and the proportion of choosing not to trade is $1 - x$. In the group of individual investors, the proportion of choosing imitation is $y\,(0 < y < 1)$, and the proportion of choosing nonimitation is $1 - y$. Thus, the expected return of institutional investors choosing capital injection is

$$\begin{aligned} u_{OM} &= y(R_M - C_M) + (1 - y)(R_1 - C_M) \\ &= (R_M - R_1)y + (R_1 - C_M). \end{aligned} \tag{1}$$

The expected return of institutional investors choosing noncapital injection is

$$u_{ONM} = R_1. \tag{2}$$

On the basis of equations (1) and (2), the average expected return of institutional investors is expressed as follows:

$$\begin{aligned} \overline{u_O} &= x u_{OM} + (1 - x)u_{ONM} \\ &= x\left[(R_M - R_1)y + (R_1 - C_M)\right] + (1 - x)R_1. \end{aligned} \tag{3}$$

Similarly, the average expected return of individual investors can also be written in the form of following equation:

$$\begin{aligned} \overline{u_I} &= y u_{IF} + (1 - y)u_{INF} \\ &= y\left[x(R_0 - \beta R_M) + (1 - x)\delta R_1\right] + (1 - y)R_0. \end{aligned} \tag{4}$$

The Malthusian equation indicates that the growth rate of the number of institutional investors who choose to inject capital is equal to the expected return (u_{OM}) minus the average expected return ($\overline{u_O}$). Therefore, the replication dynamic equation of institutional investors' choice of capital injection is

$$\begin{aligned} \dot{x} &= \frac{\mathrm{d}x}{\mathrm{d}t} = x(u_{OM} - \overline{u_O}) = x(1 - x)(u_{OM} - u_{ONM}) \\ &= x(1 - x)\left[y(R_M - R_1) - C_M\right]. \end{aligned} \tag{5}$$

Similarly, the replication dynamic equation of individual investors' choice of imitation is

$$\begin{aligned} \dot{y} &= \frac{\mathrm{d}y}{\mathrm{d}t} = y(u_{IF} - \overline{u_I}) = y(1 - y)(u_{IF} - u_{INF}) \\ &= y(1 - y)\left[x(R_0 - \beta R_M) + (1 - x)\delta R_1 - R_0\right] \\ &= y(1 - y)\left[x(R_0 - \beta R_M - \delta R_1) + \delta R_1 - R_0\right]. \end{aligned} \tag{6}$$

Table 1: Payoff matrix of the evolutionary game.

	Individual investor I	
Institutional investor O	Imitation (F)	Nonimitation (NF)
Capital injection (M)	$R_M - C_M$, $R_0 - \beta R_M$	$R_1 - C_M$, R_0
Noncapital injection (NM)	R_1, δR_1	R_1, R_0

On the basis of equations (5) and (6), the two-dimensional dynamic system of the evolutionary game model can be written in the form of the following equation:

$$\begin{cases} F(x) = \dfrac{\mathrm{d}x}{\mathrm{d}t} = x(1-x)\left[y\left(R_M - R_1\right) - C_M\right], \\ \\ G(y) = \dfrac{\mathrm{d}y}{\mathrm{d}t} = y(1-y)\left[x\left(R_0 - \beta R_M - \delta R_1\right) + \delta R_1 - R_0\right]. \end{cases} \tag{7}$$

On the basis of dynamic system theory, the game system achieves partial equilibrium under the following condition. The strategy learning rate of all parties who participate in the game remains static; that is, the result of replicating dynamic equation is 0. Therefore, by combining A and B, the system reveals five local equilibrium points, namely, $E_1(0,0)$, $E_2(0,1)$, $E_3(1,0)$, $E_4(1,1)$, and $E_5(x_1, y_1)$. Among them, $x_1 = ((\delta R_1 - R_0)/(\delta R_1 + \beta R_M - R_0))$ and $y_1 = (C_M/(R_M - R_1))$.

2.3. Stability Analysis of Local Equilibrium Points. The equilibrium point obtained by replicating the dynamic equation is not necessarily the evolutionary stability strategy (ESS) of the system. Following the method proposed by Friedman, the solution for the stability problem of the equilibrium points of the two-dimensional dynamic system can be obtained by analyzing the Jacobian matrix (expressed as J) of the system:

$$J = \begin{bmatrix} \dfrac{\partial F}{\partial x} & \dfrac{\partial F}{\partial y} \\ \\ \dfrac{\partial G}{\partial x} & \dfrac{\partial G}{\partial y} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}, \tag{8}$$

where $a_{11} = (1-2x)\left[y\left(R_M - R_1\right) - C_M\right]$, $a_{12} = x(1-x)\left(R_M - R_1\right)$, $a_{21} = y(1-y)\left(R_0 - \beta R_M - \delta R_1\right)$, and $a_{22} = (1-2y)\left[x\left(R_0 - \beta R_M - \delta R_1\right) + \delta R_1 - R_0\right]$.

The local equilibrium point of the replicated dynamic equation is a sufficient condition for the ESS:

$$\mathrm{tr}J = a_{11} + a_{22} < 0, \tag{9}$$

$$\det J = \begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix} = a_{11}a_{22} - a_{12}a_{21} > 0. \tag{10}$$

To determine whether the above five local equilibrium points meet the aforementioned conditions, we initially calculate the value of the Jacobian matrix at each local equilibrium point. Table 2 presents the list.

In Table 2,

$$\begin{aligned} A &= x_1\left(1 - x_1\right)\left(R_M - R_1\right) \\ &= \frac{\left(\delta R_1 - R_0\right)\beta R_M\left(R_M - R_1\right)}{\left(\delta R_1 + \beta R_M - R_0\right)^2}, \\ B &= y_1\left(1 - y_1\right)\left(R_0 - \beta R_M - \delta R_1\right) \\ &= \frac{C_M\left(R_M - C_M - R_1\right)\left(R_0 - \beta R_M - \delta R_1\right)}{\left(R_M - R_1\right)^2}. \end{aligned} \tag{11}$$

Given that at point $E_5(x_1, y_1)$, $a_{11} + a_{22} = 0 + 0 = 0$, equation (9) is not satisfied. Therefore, point $E_5(x_1, y_1)$ cannot possibly become ESS. Consequently, we only have to consider the other four local equilibrium points. Obviously, we can obtain the following five propositions.

Proposition 1. *When $R_0 > \delta R_1$ and $\delta R_1 < C_M + R_0$, the ESS of the system is $E_1(0,0)$.*

Proof. If the ESS of the system is $E_1(0,0)$, then equation (9) is equivalent to $C_M - \delta R_1 + R_0 > 0$, from which we can derive $\delta R_1 < C_M + R_0$. Similarly, equation (10) is equivalent to $(-C_M)(\delta R_1 - R_0) > 0$, from which we can also derive $R_0 > \delta R_1$. Therefore, when $R_0 > \delta R_1$ and $\delta R_1 < C_M + R_0$, the ESS of the system is $E_1(0,0)$.

Proposition 2. *When $R_M < C_M + R_1$ and $R_0 < \delta R_1$, the ESS of the system is $E_2(0,1)$.*

Proof. If the ESS of the system is $E_2(0,1)$, then equation (9) is equivalent to $R_M - C_M - R_1 + (-\delta R_1 + R_0) < 0$, from which we can derive $R_M < C_M + (1+\delta)R_1 - R_0$. Equation (10) is equivalent to $(R_M - C_M - R_1)(-\delta R_1 + R_0) > 0$. Therefore, this condition should satisfy either $R_M < C_M + R_1$ and $R_0 < \delta R_1$ or $R_M > C_M + R_1$ and $R_0 > \delta R_1$. However, when we place $R_M > C_M + R_1$ and $R_M < C_M + (1+\delta)R_1 - R_0$ together, we will obtain $C_M + R_1 < R_M < C_M + (1+\delta)R_1 - R_0$, which obviously does not follow the previous rule of $R_0 > \delta R_1$. Therefore, considering the equivalence conditions and compatibility of equations (9) and (10), the ESS of the system is $E_2(0,1)$ when $R_M < C_M + R_1$ and $R_0 < \delta R_1$ exist simultaneously.

Proposition 3. *When $R_M > (1/(1-\beta))(C_M + R_1)$ and $\beta < 0$, the ESS of the system is $E_4(1,1)$.*

Proof. If the ESS of the system is $E_2(0,1)$, then equation (9) is equivalent to $-R_M + C_M + R_1 + \beta R_M < 0$, from which we can derive $R_M > (1/(1-\beta))(C_M + R_1)$. Equation (10) is equivalent to $(-R_M + C_M + R_1)\beta R_M > 0$, which should satisfy either $R_M < C_M + R_1$ and/or $R_M > C_M + R_1$ and $\beta < 0$. However, the condition $R_M > (1/(1-\beta))(C_M + R_1)$ is inconsistent with the condition $R_M < C_M + R_1$. Therefore,

Table 2: Specific values of a_{11}, a_{12}, a_{21}, and a_{22} at local equilibrium points.

Equilibrium points	a_{11}	a_{12}	a_{21}	a_{22}
$E_1(0,0)$	$-C_M$	0	0	$\delta R_1 - R_0$
$E_2(0,1)$	$R_M - C_M - R_1$	0	0	$-\delta R_1 + R_0$
$E_3(1,0)$	C_M	0	0	$-\beta R_M$
$E_4(1,1)$	$-R_M + C_M + R_1$	0	0	βR_M
$E_5(x_1, y_1)$	0	A	B	0

when $R_M > (1/(1-\beta))(C_M + R_1)$ and $\beta < 0$, the ESS of the system is $E_4(1,1)$.

Proposition 4. *When $R_0 < \delta R_1$, $R_M > C_M + R_1$, and $\beta > 0$, the ESS is not evident.*

Proof. According to Propositions 1, 2, 3, and 4, two undiscussed ranges exist. The first is $R_0 < \delta R_1$, $R_M > C_M + R_1$, and $\beta > 0$, and the second is $R_0 < \delta R_1$, $R_M > C_M + R_1$, and $R_M > (1/(1-\beta))(C_M + R_1)$. However, the requirement of the latter is actually equivalent to that of the former. Therefore, we should only look at each of these equilibrium points under this constraint. Combined with the previous analysis, we can obtain that $E_1(0,0)$, $E_2(0,1)$, $E_3(1,0)$, and $E_4(1,1)$ are not the ESS of the system. Thus, no ESS exists in this case.

In this section, the payoff matrix for the evolutionary game model is initially discussed, and the replicator equations and conditions of evolutionary stable states are subsequently calculated. Furthermore, we analyze the stability of local equilibrium points. In the succeeding section, the situation at each equilibrium point is analyzed by using MATLAB, and the corresponding explanation is provided based on reality.

3. Model Simulation and Reality Analysis

To further describe the price linkage mechanism in the stock market from the perspective of investor behavior, we use MATLAB to simulate and analyze the stable strategy evolution behavior of these two types of investors in the stock market.

3.1. $R_0 > \delta R_1$ and $\delta R_1 < C_M + R_0$, the Evolution Behavior of the System. Assuming that $R_M = 2$, $C_M = 1$, $R_0 = 0.5$, $R_1 = 1$, $\beta = 0$, and $\delta = 0.3$, then the aforementioned conditions are satisfied. Figure 1 presents the simulation program results. The increase in the number of steps in the evolutionary iteration results in a gradual decrease in the willingness of institutional investors to inject capital and for individual investors to imitate the investment trend. Finally, the evolutionary stability point of the interaction between institutional investors and individual investors is $E_1(0,0)$. Therefore, all institutional investors choose not to trade, and all individual investors choose not to follow the independent investment strategy to gain profits.

Three main assumptions explain this situation:

First, when individual investors find that the return of imitation (δR_1) is lower than the expected return of independent investment (R_0), they are more inclined to choose independent investment strategy to maximize their own utility. At this time, as the decreasing number of individual investors follows the investment strategy of institutional investors, and the latter's profits continue to decline, but the trading costs cannot be reduced. Therefore, institutional investors gradually reduce their capital injection, and the two types of investors finally form a stable state of strategy selection (noncapital injection and nonimitation).

A second explanation is formed from the perspective of institutional investors. When the cost of information is considerably high, the control is strict, and the risk of trading is substantial. Thus, owing to the need to protect their own interests, institutional investors choose to slow down or cease the trading strategy of attracting money from individual investors to drive up share prices and choose a hedge strategy, such as bond market and diversified investment. Under such circumstances, individual investors cannot find suitable targets to imitate and follow. Meanwhile, they cannot obtain expected excess returns if they follow. Therefore, individual investors give up the original strategy choice and choose the independent analysis mode to buy stocks independently.

The last explanation is analyzed from the perspective of information cost. When the overall information collection cost of the stock market is considerably low, any investor can judge individual stocks based on the information of the stock market, industry conditions, and enterprises. Under such a premise, individual investors do not need to imitate and follow a strategy, but they can combine their own knowledge and collected information to freely buy stocks and obtain increased returns. At this point, institutional investors cannot stretch the stock price to a high level and thus cannot obtain the expected profits. Consequently, they will gradually abandon the previous trading strategy.

When the final strategy choice of the two types of investors is stable (noncapital injection and nonimitation), the investment direction of the stock market that is extremely concentrated will gradually disperse. Any investor tends to gradually turn to investment considerations on the basis of corporate performance, and the price synchronicity between stocks will be stable at a reduced level.

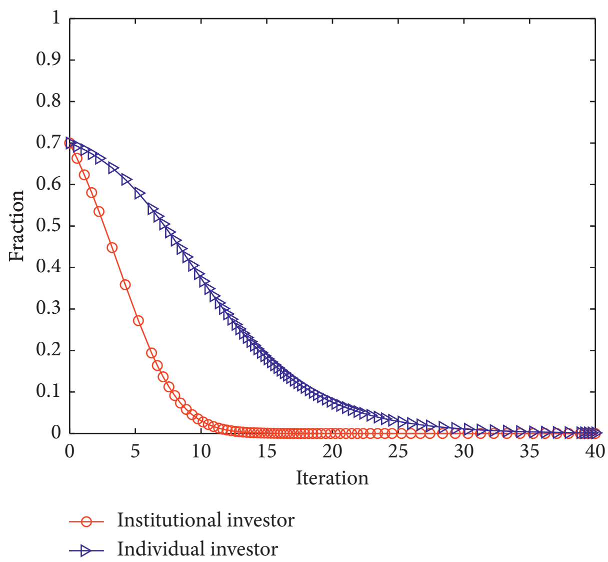

Figure 1: Simulation results for institutional investors and individual investors using the parameters $R_M = 2$, $C_M = 1$, $R_0 = 0.5$, $R_1 = 1$, $\beta = 0$, and $\delta = 0.3$.

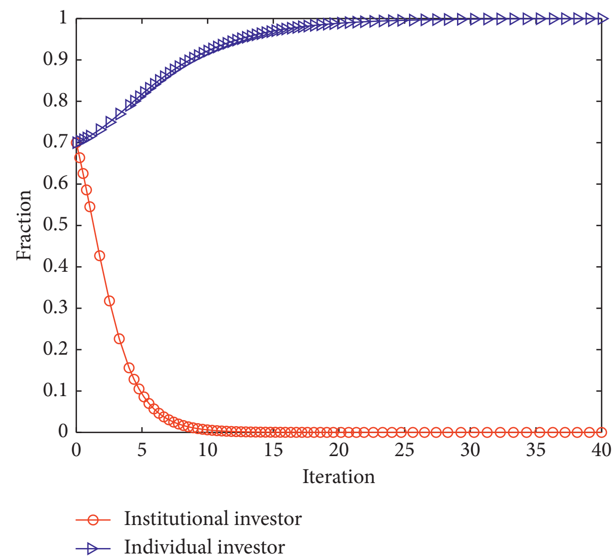

Figure 2: Simulation results for institutional and individual investors using the parameters $R_M = 1.5$, $C_M = 1$, $R_0 = 0.5$, $R_1 = 1$, $\beta = 0$, and $\delta = 0.7$.

3.2. $R_M < C_M + R_1$ and $R_0 < \delta R_1$, the Evolution Behavior of the System. Assuming that $R_M = 1.5$, $C_M = 1$, $R_0 = 0.5$, $R_1 = 1$, $\beta = 0$, and $\delta = 0.7$, then the aforementioned conditions are satisfied. Figure 2 presents the simulation results. The increase in the number of steps in the evolutionary iteration results in the gradual decrease in institutional investors' willingness to inject capital and the gradual increase in individual investors' willingness to imitate. Finally, the evolutionary stability point of the interaction between institutional investors and individual investors is $E_2(0,1)$; that is, all institutional investors choose not to inject, and all individual investors choose to imitate.

When the operation and information costs of institutional investors are considerably high or the operation exhibits a substantial risk, institutional investors will choose to slow down or cease their capital injection and turn to the bond market, diversified investment, and other hedging strategies. However, if individual investors can hardly collect information at this time, if excessive human and material costs are required, and if the final returns are insufficient, then individual investors will still choose to follow the direction of institutional investors and imitate the latter's investment fields. In addition, the strategy choice of the two types of investors will gradually stabilize (noncapital injection and imitation).

At this time, institutional investors have given up their original trading plans and adopted risk-averse strategies to guarantee the basic returns. However, individual investors' blind following and imitating will still lead to the concentration of funds in a certain direction in the stock market. Thus, synchronous changes between individual stocks and the broad market or between stock trading sectors are evident.

3.3. $R_M > (1/(1-\beta))(C_M + R_1)$ and $\beta < 0$, the Evolution Behavior of the System. Assuming that $R_M = 2$, $C_M = -2$, $R_0 = 0.5$, $R_1 = 1$, $\beta = -0.5$, and $\delta = 0.7$, then the aforementioned conditions are satisfied. Figure 3 illustrates the simulation results. The increase of the number of steps in evolutionary iteration results in the gradual increase of institutional investors' willingness to inject capital and the individual investors' willingness to imitate the investment trend. Finally, the evolutionary stability point of the institutional and individual investors' behavior is $E_4(1,1)$; that is, all institutional investors choose to inject capital, and all individual investors choose to imitate the investment strategy.

Similar to the situation above, institutional investors in this case have an expected increased income, while the operating and information costs are relatively small. Thus, institutional investors provide an incentive to maintain or turn to capital injection. Given the variable $\beta < 0$, which means that individual investors can obtain additional returns by imitating institutional investors, the evolutionary stability point of interaction between institutional investors and individual investors is $E_4(1,1)$.

This situation tends to happen when the stock market is in a bull market. When the stock market performs well, institutional investors take advantage of their capital and move between good stocks. Moreover, individual investors are attracted by the good market, thereby imitating institutional investors' behavior to buy stocks. Given that a substantial amount of money is poured into similar stocks or related sectors, these stocks or sectors exhibit a relatively consistent rise and fall. Consequently, the influence between individual stocks and sectors gradually promotes the whole stock market, which results in a serious synchronism of stock prices in the whole stock market.

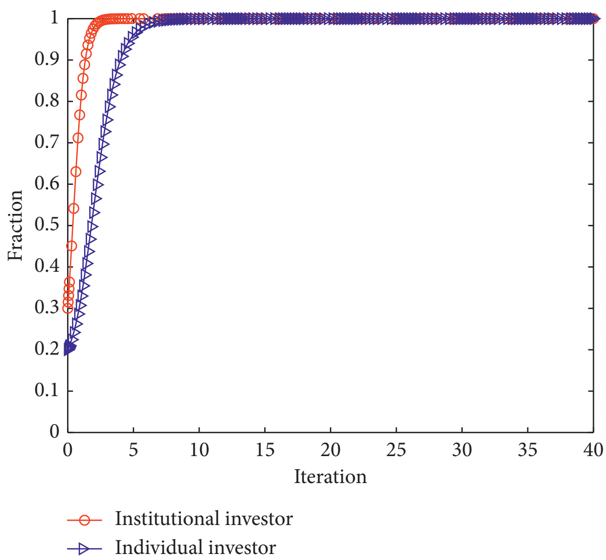

Figure 3: Simulation results for institutional individual investors using parameters $R_M = 2, C_M = -2, R_0 = 0.5, R_1 = 1, \beta = -0.5$, and $\delta = 0.7$.

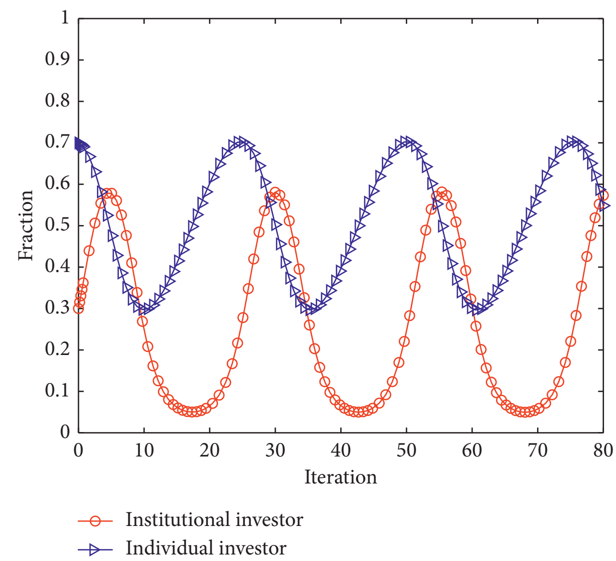

Figure 4: Simulation results for institutional and individual investors using parameters $R_M = 3, C_M = 1, R_0 = 1, R_1 = 2, \beta = 0.2$, and $\delta = 0.6$.

3.4. $R_0 < \delta R_1$, $R_M > C_M + R_1$, and $\beta > 0$, the Evolution Behavior of the System. Assuming that $R_M = 3, C_M = 1, R_0 = 1$, $R_1 = 2$, $\beta = 0.2$, and $\delta = 0.6$, then the aforementioned conditions are satisfied. The increase in the number of evolutionary iteration steps results in changes in the proportion of the strategy choice by institutional and individual investors, while the evolution trend of their interactive behaviors is roughly constant. No ESS is evident in the behavior of institutional and individual investors. Figure 4 illustrates the simulation results.

This situation indicates that when the expected return of individual investors' independent investment is less than the additional return obtained by the following institutional investors, the return of institutional investors' choice of trading is higher than the sum of the expected return of trading and nontrading costs, and when that trading brings negative returns to individual investors, the group proportions of institutional and individual investors are in a state of periodic turbulence without stable evolutionary results.

In reality, when the stock market develops smoothly, institutional investors choose the trading behavior and attract individual investors by injecting capital to seek their own profits. During the early stage, individual investors tend to adopt the imitation strategy and gradually buy similar stocks according to the investment choice of institutional investors. In this process, as the funds of individual investors enter the stock market, institutional investors who choose to invest during the early stage realize the growth of interests and attract additional institutional investors to earn profits with the same strategy. However, the increase in the proportion of institutional investors leads to the gradual decrease in the returns of strategies that individual investors choose to imitate. In particular, individual investors gradually turn to strategies that they do not follow. Therefore, the cost of initial investment by institutional investors cannot be offset from income, and the interests of institutional investors suffer losses. Consequently, several institutional investors change their strategies and do not conduct centralized capital injection. When the number of institutional investors drops to a certain level, individual investors with speculative psychology will start to buy and sell stocks in an imitative manner once more. This process is repeated, and no ESS occurs.

In this section, the model is simulated by MATBLE, which shows the change trajectories of the two types of investor groups. By combining with the reality, we explain the behavior of individual and institutional investors in different situations and deduce the theoretical influence of their behavior on the synchronicity of stock prices. When institutional investors choose to inject capital and individual investors choose to imitate, the stock market has the highest degree of synchronization. Furthermore, when individual investors give up imitating and institutional investors diversify, share prices fall to their lowest levels. Following this feature, we provide corresponding suggestions in the next section to curb stock price synchronicity.

4. Conclusions

In this study, an evolutionary game model is proposed to analyze the price synchronicity in the stock market. From the perspective of institutional and individual investors, we consider various factors that affect their behavior in the stock market. We construct a payment matrix for the two types of investor behaviors and obtain the replicator dynamics of different strategies and ESS conditions. Through stability analysis and program simulation, we further obtain four different ESSs for institutional and individual investors. Result shows that when the market environment is good and the operating cost of institutional investors is low for the whole stock market, the investment income obtained by institutional investors will induce individual investors to imitate them. In the case of insufficient information acquisition ability and limited rationality of individual investors, such high returns drive an increasing number of individual investors to converge their behaviors with institutional investors, thereby resulting in excessive concentration of the types and direction of trading in the stock market. Consequently, a higher degree of synchronization in the stock market occurs, with most stock prices being excessively influenced by the broad market.

To reduce the financial risks of the stock market, the price linkage should be eased among individual stocks and sectors, and a safe and orderly financial market pattern should finally be formed. The following two countermeasures are proposed:

(1) The operating mechanism of institutional investors should be improved. As an important participant in the stock market, institutional investors have incomparable inherent advantages in information collection and capital operation. The main reason is that institutional investors manipulate the stock market with capital advantage, conduct insider trading, and release false information, thereby disturbing the market economic order. The above economic models clearly show that the related costs of institutional investors can reduce the price linkage of the stock market. Therefore, the government regulatory authorities can strengthen the supervision of the operation of institutional investors. Through fines and confiscation of licenses, the capital injection process of institutional investors is restrained to reduce the synchronicity of stock prices in the stock market.

(2) The securities market information disclosure mechanism should be improved. The securities market is essentially an information flow market. Information disclosure in the market is not only an important basis for investors to make rational decisions but also an essential element for securities regulatory authorities to effectively supervise listed companies. The stock exchange market in Asia started late, and defects in the actual information disclosure remain, such as imperfect legislation, lax law enforcement, and untimely and untrue disclosure. This situation not only makes obtaining effective information difficult and expensive for investors but also provides a breeding ground for misinformation spread because of ulterior motives, which ultimately drives the synchronicity of stock prices in Asian stock markets. Therefore, the government regulatory authorities should formulate perfect laws and regulations on the information disclosure center and at the same time intensify law enforcement efforts to ensure that enterprises can truthfully disclose their relevant information with quality and quantity. Furthermore, government regulators can actively cooperate with relevant media, use the power of media supervision to put pressure on enterprises, and jointly build a transparent stock exchange market.

Data Availability

The method employed in this article is computer mathematical simulation. Numerical simulation analysis is the most effective way to test real-time dynamic data without a large number of empirical validations. The authors simulate to analyze the stock price synchronicity considering the impacts of investors' decisions on stock investment by using MATLAB2016b software. This paper does not indicate the data that can be obtained given that the researchers directly use the plot function of MATLAB2016b software to create the images.

Disclosure

All the authors contributed equally to this work and are the co-first authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (nos. 71871115 and 71501094), the Major Project of Philosophy and Social Science Research in Colleges and Universities in Jiangsu Province (no. 2019SJZDA035), and the Innovation Team Project of Philosophy and Social Sciences in Colleges and Universities in Jiangsu Province (no. 2017ZSTD005).

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