Analysis Of The Spreading Process Of Investor Sentiment With Delayed Changes

Yuan Zhao[1]
School of science, Jiangsu University, Zhenjiang 212013, China
E-mail: 2669063842@*qq.com*

***Abstract*—The process of investor sentiment communication is necessary to study the investment decision-making of investors. This article introduces a type of untrusted group in the investment process and considers the influence factors of investor sentiment propagation under the action of a reasonable delay function. Finally, the model Numerical analysis of the influence of each parameter in the paper found that the average delay is within the threshold value less than 1, The emotion spreads faster, the higher the recovery rate, the smaller the peak value reached by the emotional communicator, so the suggestion is given: reasonable control of the delay time lag Make the average value within a reasonable threshold, and increase the recovery rate by popularizing investment theory, to control the bad mood in the investment process.**

Keywords—Financial Investment; sentiment spreading; delayed changes; Stability analysis

I. Introduction

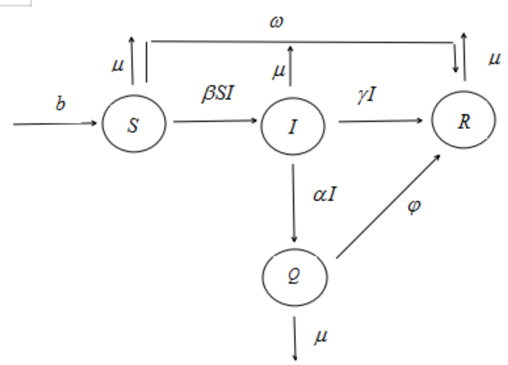
The process of investor sentiment communication has always been an important means of studying investor decision-making because emotions in real life have a great influence on the change of decision-making, and the emotions of the stock market decision-making process are easily affected by the suggestions of relatives and friends or even the so-called "investment and financial advisors". , And in the financial investment market, there are self-proclaimed senior experts called National Wealth Management to carry out voluntary investment knowledge and give stock selection recommendations. Of course, some of them are purposeful fraudulent frauds against the false news of these self-proclaimed senior financial advisers the government has been cracking down on it.

II. Literature Review

Previously, Li and Ma [1] discussed the influence of government punishment and individual sensitivity on rumor propagation and took into account some rumors related to hot events. The results showed that increasing the severity of government punishment and individual sensitivity could effectively control rumor propagation. Afassinou [2] believes that compared with educated people, uneducated people have a great chance to receive the information. He investigated the influence of education level on the final scale of the rumor and concluded that the more educated people inside, the smaller the final scale of the rumor. Zhou and Yao [3] considered the global asymptotic stability of neutral inertial BAM neural network with time-varying delay. Using the theory of variation and homomorphism, a suitable Lyapunov functional is proposed. Based on the matrix equation, the delay correlation sufficient conditions for the existence and global asymptotic stability of a class of neutral inertial BAM neural networks are established. Hu_a et al., [4] established a rumor propagation model considering the proportion of the wise in the crowd, believing that the velocity of rumor propagation is a variable that changes with time in our model. Sahafizadeh and Tork Ladani [5] extended the SIR information propagation model to analyze the influence of network structure on rumor propagation when considering group propagation, and studied the basic reproduction times of rumor propagation in the model, indicating that rumor propagation with larger groups is more effective than with more groups. In the small world network, Zhao et al., [6] studied a rumor propagation model that considered the change of forgetting rate over time. The larger the initial forgetting rate or the faster the forgetting rate, the smaller the final size of rumor propagation. The numerical solution also shows that the final scale of rumor propagation is much larger under the variable forgetting rate than under the constant forgetting rate. Chen [7] studied the influence of rumor control measures on rumor propagation through numerical simulation and proposed the method of crisis management. Huo et al., [8] proposed a dynamic model of rumor propagation I2SR, considering that each communicator in the network rotates between a high active state and low active state according to a certain probability. Considering that exposed nodes can become removed nodes at a rate, Liu, Li, and Sun, [9] presented a new SEIR model of rumor propagation on heterogeneous networks. Zhang and Zhu [10] proposed the I2S2R rumor propagation model with a general correlation function in a homogeneous network and I2S2R rumor propagation model in the heterogeneous network. The dynamic model of rumor propagation I2S2R is established in homogeneous networks, and the free equilibrium problem is discussed by considering two general correlation functions. Hu_b et al., [11] considered the different attitudes of individuals to rumor propagation, analyzed the local and global stability, balance, and rumor existence balance of rumors, and found that those who hesitated to spread rumors had a positive impact on rumor propagation. Gao, Chen and Teng [12] proposed a time-delayed SEIRS epidemic model with changes in pulse inoculation and total population size. The results show that short - time or large - pulse vaccination rate is a sufficient condition for disease eradication. Chen et al., [13] proposed a non-Markov model to describe the complex contagion adopted by a sensitive node that must take into account social reinforcement from different levels and neighbors. Zan [14] studies the kinetics of double the spread of rumors and at the same time, this paper introduces the two double rumor spreading model: DSIR model and C - DSIR model. Provided by the state vector expressions and double rumors spread mechanism, introduced a select parameters theta to express differences attractive, results show that the new rumors the start time of the closer it gets to the best of time, so the more strongly they depend on each other. By analyzing the characteristics and modes of rumor propagation with forgetting effect,

III. Model Description

This article considers the government's role in isolating proponents who propagate for profit. S: Susceptible state (easy to be emotionally infected by suggestions from relatives and friends) I: Infected persons (already affected by certain emotions) R: resisters (because they have investment theories and will not be influenced by others and will not spread emotions) Q: quarantined (because people Aware that their suggestions will not benefit oneself or be isolated due to dissemination of false investment market trend information and ultimately not trusted) The number of people entering the investment market is b the probability that a susceptible person is affected by their emotions due to contact with an infected person is β, the probability that a susceptible person becomes a resister is γ (also called recovery rate), and the probability that an infected person is distrusted by people and becomes an isolated person is α, the probability that the quarantined person will self-reflection and stop spreading emotions and become a boycotter is φ, the probability that a susceptible person may become a boycotter due to contact with the boycotter or due to accumulation of experience is ω, the probability that people in each state will withdraw from the system is μ, so the system has the following propagation process:



According to the propagation process, the following propagation equation is constructed from the mean field theory:

$$\begin{cases} \frac{dS}{dt} = b - \beta S(t)I(t) - \mu S(t) - \omega S(t) \\ \frac{dI}{dt} = \beta S(t)I(t) - \mu I(t) - \alpha I(t) - \gamma I(t) \\ \frac{dQ}{dt} = \alpha I(t) - \mu Q(t) - \varphi Q(t) \\ \frac{dR}{dt} = \omega S(t) + \gamma R(t) + \varphi Q(t) - \mu R(t) \end{cases} \quad (1)$$

The situation of emotion transmission is more complicated and there may be potential unpredictable factors. The Investors who are exposed to certain emotions may not make changes immediately and therefore have a certain incubation period. This situation is not difficult to detect in real life. Many people when encountering things, they will accumulate emotions, ranging from a few days to a long period of several years. When certain factors appear to re-stimulate after a period of time, investors will react to the accumulated emotions before. The emotional response in the investment market is expressed as for financial decision-making, the following hypotheses are proposed for this situation:

(1) There is an incubation period among susceptible people, and the incubation period is constantly changing, which varies from person to person. Here I use the following integral form to reflect the delay change

$$\int_{-\infty}^{t} S(\tau)D(t-\tau)d\tau \quad (2)$$

Here is the delay kernel function, which is the distributed time delay, which represents the influence of the previous value.

(2) Choose a typical delay core here

$$D(t-\tau) = \frac{\{\sigma^{n+1}(t-\tau)^n \exp(-\sigma(t-\tau))\}}{n!}$$

$t \geq 0, n = 0,1,2\cdots$

Here is a normal number, which represents the average delay of emotions. We use weak cores in this article:

$$D(t-\tau) = \sigma e^{-\sigma(t-\tau)} \quad \sigma > 0$$

Means that the impact of previous events decreases exponentially

So the model (2.1) becomes

$$\begin{cases} \frac{dS}{dt} = b - \beta \int_{-\infty}^{t} S(\tau)D(t-\tau)d\tau I(t) - \mu S(t) - \omega S(t) \\ \frac{dI}{dt} = \beta \int_{-\infty}^{t} S(\tau)D(t-\tau)d\tau I(t) - \mu I(t) - \alpha I(t) - \gamma I(t) \\ \frac{dQ}{dt} = \alpha I(t) - \mu Q(t) - \varphi Q(t) \\ \frac{dR}{dt} = \omega S(t) + \gamma R(t) + \varphi Q(t) - \mu R(t) \end{cases} \quad (3)$$

Note here $U(t) = \int_{-\infty}^{t} S(\tau)D(t-\tau)d\tau$

Then (3) becomes

$$\begin{cases} \frac{dS(t)}{dt} = b - \beta \int_{-\infty}^{t} S(\tau)D(t-\tau)d\tau I(t) - \mu S(t) - \omega S(t) \\ \frac{dI(t)}{dt} = \beta \int_{-\infty}^{t} S(\tau)D(t-\tau)d\tau I(t) - \mu I(t) - \alpha I(t) - \gamma I(t) \\ \frac{dQ(t)}{dt} = \alpha I(t) - \mu Q(t) - \varphi Q(t) \\ \frac{dU(t)}{dt} = \frac{1}{\sigma} S(t) - \frac{1}{\sigma} U(t) \\ \frac{dR(t)}{dt} = \omega S(t) + \gamma R(t) + \varphi Q(t) - \mu R(t) \end{cases} \quad (4)$$

Because it does not appear in the first four equations, it is enough to focus on the first four, which will not affect the research results. Add the first three equations to get:

$$\frac{d(S(t)+I(t)+Q(t))}{dt} = b - \mu(S(t)+I(t)+Q(t)) - \omega S(t) - (\gamma+\alpha)I(t) - \varphi Q(t)$$

$$\leq b - \mu(S(t)+I(t)+Q(t))$$

Thereby: $S(t)+I(t)+Q(t) \leq \frac{b}{\mu}$.

From the third equation of the system (4), we know:

$$\frac{dU(t)}{dt}=\frac{1}{\sigma}S(t)-\frac{1}{\sigma}U(t)\le\frac{1}{\sigma}S(t)\le\frac{b}{\sigma\mu} \quad (5)$$

In summary, we can get $S(t), I(t), Q(t), U(t)$ all bounded, that is, the following set

$$\Omega=\left\{(S(t),I(t),Q(t),U(t))\in R_4^+, S(t),I(t),Q(t)\le\frac{b}{\mu}, U(t)\le\frac{b}{\sigma\mu}\right\}$$

Ω is the maximum invariant set of the system (4).

A. The equilibrium point of the system and its local stability

It is easy to know that when the infected person and the infected person in the system are both 0, then the emotion in the system will eventually disappear and no longer spread so that there is no emotional balance point $E^0=(\frac{b}{\mu+\omega},0,0,\frac{b}{\mu+\omega})$

$R_0=\frac{\beta b}{\mu(\mu+\omega)}$, we can get the following theorem:

Theorem 3.1 At that time $R_0<1$, the point of non-emotional equilibrium was partially gradual and stable.

Proof: The Jacobian matrix of the system (4) is

$$J(E^0)=\begin{pmatrix} -\mu-\omega & \frac{\beta b}{\mu} & 0 & 0 \\ 0 & \frac{\beta b}{\mu}-(\gamma+\alpha+\mu) & 0 & 0 \\ 0 & \alpha & -\varphi-\mu & 0 \\ \frac{1}{\sigma} & 0 & 0 & -\frac{1}{\sigma} \end{pmatrix} \quad (6)$$

$J(E^0)$ is the upper triangular matrix, and its characteristic equation is

$$(\lambda+\mu+\omega)\left[\lambda+(\mu+\gamma+\alpha)(1-R_0)\right](\lambda+\mu+\varphi)(\lambda+\frac{1}{\sigma})=0 \quad (7)$$

Each parameter is greater than zero, thus

$$\lambda_1=-(\mu+\omega)>0,\lambda_3=-(\mu+\varphi)>0,\lambda_1=-\frac{1}{\sigma}>0 \quad (8)$$

At that time $R_0<1$, $\lambda_2=1-R_0>0$ was true, and the eigenvalues Routh-Hurwitz were all negative. Therefore, it can be known from the criterion that the non-emotional balance point is locally and gradually stable.

Let the right end of the system (4) be zero, and the positive balance point $E*$ of the system can be obtained. At this time, the emotion will not disappear but will continue to exist.

$$E*=(\frac{\gamma+\alpha+\mu}{\beta},\frac{b}{\gamma+\alpha+\mu}-\frac{\mu+\omega}{\beta},\frac{\alpha b}{(\mu+\varphi)(\gamma+\alpha+\mu)}-\frac{\alpha(\mu+\omega)}{\beta(\mu+\varphi)},\frac{\gamma+\alpha+\mu}{\beta})$$

$$=(\frac{b}{\mu R_0},\frac{\mu}{\beta}R_0-\frac{\mu+\omega}{\beta},\frac{\alpha}{(\mu+\varphi)}\left[\frac{\mu}{\beta}R_0-\frac{\mu+\omega}{\beta}\right],\frac{b}{\mu R_0})$$

The Jacobian matrix of the system (4) $E*$ is

$$J(E*)=\begin{pmatrix} -\mu-\omega & -\frac{\beta b}{\mu R_0} & 0 & -\mu R_0+(\mu+\omega) \\ 0 & 0 & 0 & \mu R_0-(\mu+\omega) \\ 0 & \alpha & -\varphi-\mu & 0 \\ \frac{1}{\sigma} & 0 & 0 & -\frac{1}{\sigma} \end{pmatrix} \quad (9)$$

Then the characteristic equation $J(E*)$ is organized as:

$$\lambda^4+A_1\lambda^3+A_2\lambda^2+A_3\lambda+A_4=0 \quad (10)$$

Where

$$A_1=2\mu+\omega+\varphi+\frac{1}{\sigma}$$

$$A_2=\frac{\mu R_0}{\sigma}+(\mu+\varphi)(\mu+\omega+\frac{1}{\sigma})$$

$$A_3=\frac{1}{\sigma}\left[\frac{\beta b(\mu+\varphi)+(\mu+\omega)-\mu R_0}{\gamma+\alpha+\mu}\right]$$

$$A_4=\frac{\beta b(\mu+\varphi)}{\sigma}\left(\frac{\mu+\omega}{\mu R_0}\text{-}1\right)$$

All parameters are positive, so $A_1, A_2, A_3, A_4>0$

Knowing from the fourth-order Routh-Hurwitz criterion, we must also ask for:

$$H_1 = A_1 > 0$$

$$H_2 = \begin{vmatrix} A_1 & A_3 \\ 1 & A_2 \end{vmatrix} = A_1A_2 - A_3$$

$$= \left(2\mu+\omega+\varphi+\frac{1}{\sigma}\right)\left(\frac{\mu R_0}{\sigma}+(\mu+\varphi)(\mu+\omega+\frac{1}{\sigma})\right)-\frac{1}{\sigma}\left[\frac{\beta b(\mu+\varphi)+(\mu+\omega)-\mu R_0}{\gamma+\alpha+\mu}\right]$$

To make $A_1A_2 - A_3 > 0$, that is $\sigma < \sigma^*$,

$\sigma^* = \dfrac{\mu R_0(\gamma+\alpha+\mu)}{\mu\beta b - \mu R_0}$ to be satisfied, and $\sigma^* > 0$,

which equivalent to $R_0 > \dfrac{\beta b}{\gamma+\alpha+\mu+1}$

$$H_3 = \begin{vmatrix} A_1 & A_3 & 0 \\ 1 & A_2 & A_4 \\ 0 & A_1 & A_3 \end{vmatrix} = A_3H_2 - A_1A_4$$

$$H_4 = \begin{vmatrix} A_1 & A_3 & 0 & 0 \\ 1 & A_2 & A_4 & 0 \\ 0 & A_1 & A_3 & 0 \\ 0 & 1 & A_2 & A_4 \end{vmatrix} = A_4H_3$$

Theorem 3.2. At that time $R_0 > \dfrac{\beta b}{\gamma+\alpha+\mu+1}$,

(1) the establishment of the Routh-Hurwitz criterion condition is guaranteed when $\sigma < \sigma^*$, so the positive equilibrium point E^* is gradually stable locally.

(2) When $\sigma > \sigma^*$ E^* is unstable.

B. Global stability of the equilibrium point

Theorem 4.1. When the $R_0 < 1$ non-emotional equilibrium point E^0 was gradually stable globally.

Proof: Definition $V(S,I,Q,U) = \dfrac{1}{2}I^2$

$$\dot{V}(S,I,Q,U) = (\beta U(t) - \gamma - \alpha - \mu)\ I^2 \le (\beta\frac{b}{\mu} - (\gamma+\alpha+\mu))I^2$$

$$\le \left[(\mu+\gamma)(R_0 - 1)\right]I^2 \quad (11)$$

It can be seen that $V(S,I,Q,U) = \dfrac{1}{2}I^2 \ge 0$ at that time $R_0 < 1$, $V(S,I,Q,U)$ is the Lyapunov function of the system (2.3) on the set and satisfies the Lassalle invariant set theory, so it is globally stable on time.

The global stability of E^* is discussed below, because sometimes the Lyapunov function is difficult to construct, so this article uses a geometric method to discuss the global stability of the positive equilibrium point, thus introducing the following method:

Lemma 1. Mapping: $x \to f(x) \in R^n$, $f(x)$ is a univariate continuous function on the open set $D \subset R^n$, consider the differential equation:

$$\dot{x} = f(x)$$

The differential equation is determined by the initial value $x(t, x_0) = x_0$, assuming;

(H_1) D is simple connectivity.

(H_2) There is the last tightly attractive set K in D, $K \subset D$

(H_3) Differential equations have unique solutions $\tilde{x}$, $\tilde{x} \in D$.

Let $x \to A(x)$ be a $\binom{n}{2} \times \binom{n}{2}$ matrix-valued function, assuming $A^{-1}(x)$ exists, is for $\forall x \in K$ is continuous, defining

$$\bar{q} = \lim_{x\to\infty} \sup \sup_{x_0 \in K} \frac{1}{t} \int_0^t \mu(B(s, x_0))ds$$

Among them $B = A_f A^{-1} + A \frac{\partial f^{[2]}}{\partial x} A^{-1}$, replace each A with its derivative in the direction to get A_f , here $\frac{\partial f^{[2]}}{\partial x}$ is the second additive compound matrix of the Jacobian matrix of the equation solution. $\mu(B) = \lim_{h\to 0} \frac{|I + hB| - 1}{h}$ is the Loinskill measure of the vector norm, satisfying the above assumptions can lead to the theorem:

Theorem 4.1. (H_1) 、(H_2) 、(H_3) and all hold, when the system's solution Can ensure $\bar{q} < 0$ such that the solution is globally stable.

Proof:

$$\Omega = \left\{ (S(t), I(t), Q(t), U(t)) \in R_4^+, S(t), I(t), Q(t) \le \frac{b}{\mu}, U(t) \le \frac{b}{\sigma\mu} \right\}$$

is simply connected, and the solutions in Ω are all bounded, so there must be a tightly attractive set in Ω. Therefore, (H_1) 、(H_2) also holds.

Since when $R_0 > 1$, E_0 is unstable, at that time $R_0 > 1$, the positive equilibrium point $E*$ is the only solution of the system (2.3), then (H_3) holds.

In addition, the Jacobian matrix of the system (2.3) at the solution $E*$ is:

$$\begin{pmatrix} -\mu-\omega & -\beta U(t) & 0 & -\beta I(t) \\ 0 & \beta U(t) - (\gamma+\alpha+\mu) & 0 & \beta I(t) \\ 0 & \alpha & -(\varphi+\mu) & 0 \\ \frac{1}{\sigma} & 0 & 0 & -\frac{1}{\sigma} \end{pmatrix}$$

$$= -(\varphi+\mu) \begin{pmatrix} -\mu-\omega & -\beta U(t) & -\beta I(t) \\ 0 & \beta U(t) - (\gamma+\alpha+\mu) & \beta I(t) \\ \frac{1}{\sigma} & 0 & -\frac{1}{\sigma} \end{pmatrix} \quad (12)$$

Its second additive compound matrix:

$$J^{[2]} = -(\varphi+\mu) \begin{pmatrix} \beta U(t) - (2\mu+\omega+\gamma+\alpha) & \beta I(t) & \beta I(t) \\ 0 & -\mu-\omega-\frac{1}{\sigma} & -\beta U(t) \\ \frac{1}{\sigma} & 0 & \beta U(t) - (\gamma+\alpha+\mu+\frac{1}{\sigma}) \end{pmatrix}$$

$$= \begin{pmatrix} \beta U(t) - (2\mu+\omega+\gamma+\alpha) & \beta I(t) & 0 & \beta I(t) \\ 0 & -\mu-\omega-\frac{1}{\sigma} & 0 & -\beta U(t) \\ 0 & 0 & -(\mu+\varphi) & 0 \\ \frac{1}{\sigma} & 0 & 0 & \beta U(t) - (\gamma+\alpha+\mu+\frac{1}{\sigma}) \end{pmatrix}$$

Obtainable

$$A(x) = A(S, I, Q, U) = diag\left\{ \frac{S}{I}, \frac{S}{I}, \frac{S}{I}, \frac{S}{I} \right\}$$

$$A_f A^{-1} = diag\left\{ \frac{S'}{S} - \frac{I'}{I}, \frac{S'}{S} - \frac{I'}{I}, \frac{S'}{S} - \frac{I'}{I}, \frac{S'}{S} - \frac{I'}{I} \right\}$$

$$= \begin{pmatrix} \frac{S'}{S} - \frac{I'}{I} + \beta U(t) - (2\mu+\omega+\gamma+\alpha) & \beta I(t) & 0 & \beta I(t) \\ 0 & \frac{S'}{S} - \frac{I'}{I} - \mu - \omega - \frac{1}{\sigma} & 0 & -\beta U(t) \\ 0 & 0 & \frac{S'}{S} - \frac{I'}{I} - (\mu+\varphi) & 0 \\ \frac{1}{\sigma} & 0 & 0 & \frac{S'}{S} - \frac{I'}{I} + \beta U(t) - (\gamma+\alpha+\mu+\frac{1}{\sigma}) \end{pmatrix}$$

$$B = A_f A^{-1} + A_f J^{[2]} A^{-1}$$

$$=\begin{pmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{pmatrix}$$

Among them

$$B_{11}=\frac{S'}{S}-\frac{I'}{I}+\beta U(t)-(2\mu+\omega+\gamma+\alpha)$$

$$B_{12}=(\beta I(t),0,\beta I(t))$$

$$B_{21}=(0,0,-\frac{1}{\sigma})^T$$

$$B_{22}=\begin{pmatrix} \frac{S'}{S}-\frac{I'}{I}-\mu-\omega-\frac{1}{\sigma} & 0 & -\beta U(t) \\ 0 & \frac{S'}{S}-\frac{I'}{I}-(\mu+\varphi) & 0 \\ \frac{1}{\sigma} & 0 & \frac{S'}{S}-\frac{I'}{I}+\beta U(t)-(\gamma+\alpha+\mu+\frac{1}{\sigma}) \end{pmatrix}$$

Select norm on selection R^3 :

$$|x,y,z|=\max\{|x|,|y|+|z|\}$$

The loinskill measure of B is:

$$\mu(B)=\sup\{g_1,g_2\}=\sup\{\mu(B_{11})+|B_{12}|,\mu(B_{22})+|B_{21}|\}$$

wecan easy to get $\mu(B_{11})=\frac{S'}{S}-\frac{I'}{I}+\beta U(t)-(2\mu+\omega+\gamma+\alpha)$,

$$|B_{12}|=\beta I(t)$$

When $U(t)<\frac{\mu+2\gamma+2\alpha-\omega}{2\beta}$,

$$\mu(B_{22})=\frac{S'}{S}-\frac{I'}{I}+\beta U(t)+\beta I(t)-(\mu+\omega+\frac{1}{\sigma})$$

$$|B_{21}|=\frac{1}{\sigma}$$

Therefore,

$$g_1=\mu(B_{11})+|B_{12}|=\frac{S'}{S}-\frac{I'}{I}+\beta U(t)+\beta I(t)-(2\mu+\omega+\gamma+\alpha)$$

$$g_2=\mu(B_{22})+|B_{21}|=\frac{S'}{S}-\frac{I'}{I}-(\mu+\omega)$$

From the second equation of the system (4), we can get $\frac{I'}{I}=\beta U(t)-(\gamma+\alpha+\mu)$, Substitute it in g_1,g_2 to get

$$g_1=\frac{S'}{S}-(\beta U(t)-(\gamma+\alpha+\mu))+\beta U(t)+\beta I(t)-(2\mu+\omega+\gamma+\alpha)=\frac{S'}{S}+\beta I(t)-\mu-\omega$$

$$g_2=\frac{S'}{S}-(\beta U(t)-(\gamma+\alpha+\mu))-(\mu+\omega)$$

$$\le\frac{S'}{S}-(\gamma+\alpha+\mu)\left[\frac{\beta b}{\mu(\gamma+\alpha+\mu)}-1\right]-\mu-\omega$$

$$\le\frac{S'}{S}-(\gamma+\alpha+\mu)[R_0-1]-\mu-\omega$$

$$\le\frac{S'}{S}-\mu-\omega$$

Thereby $\mu(B)\le\frac{S'}{S}-(\mu+\omega)$

At this time

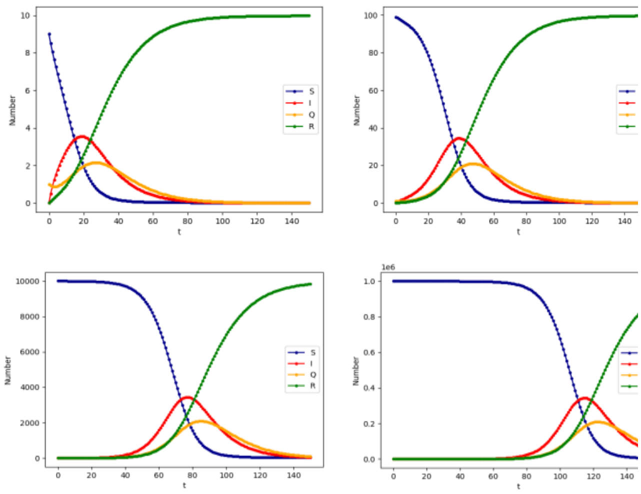
$$\bar{q}=\frac{1}{t}\int_0^t\mu(B)ds=\frac{1}{t}\int_0^t[\frac{S'}{S}-(\mu+\omega)]ds\le\frac{1}{t}\log S(t)-(\mu+\omega)$$

When $R_0>1$, the system (2.3) is consistent and continuous, so it exists $c>0,T>0$, so that at that time $t>T$, there is $S(t)\ge c,I(t)\ge c$, and $\frac{1}{t}\log S(t)<\frac{(\mu+\omega)}{2}$, so the following formula holds

Therefore, the positive equilibrium solution of the system (2.3) is globally stable.

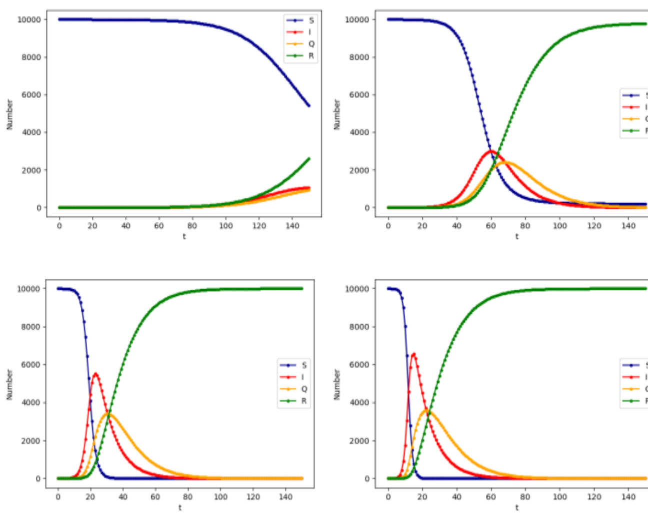
C. Numerical simulation

(1) b represents the number of people entering the communication system, the following study its influence on the communication:



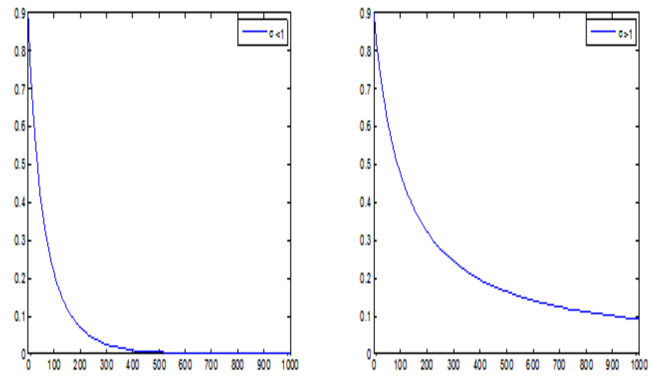
It can be seen from the figure that b only affects the time lapse of the spread scale, and the speed of the influence process does not affect the number of groups.

(2) The influence of transmission rate β:



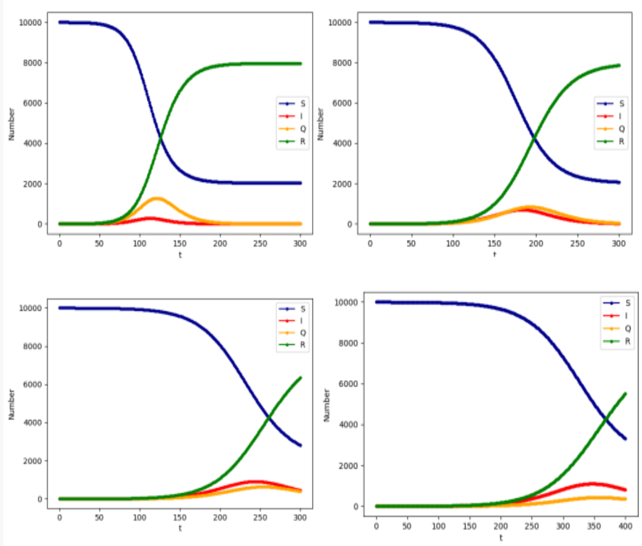
The magnitude of directly affects the magnitude and change trend of the value, and further affects the magnitude and change trend of the value. In addition, the value that can be intuitively understood from the figure has a great influence on the trend of the entire model.

(3) The effect of average delay on propagation rate:



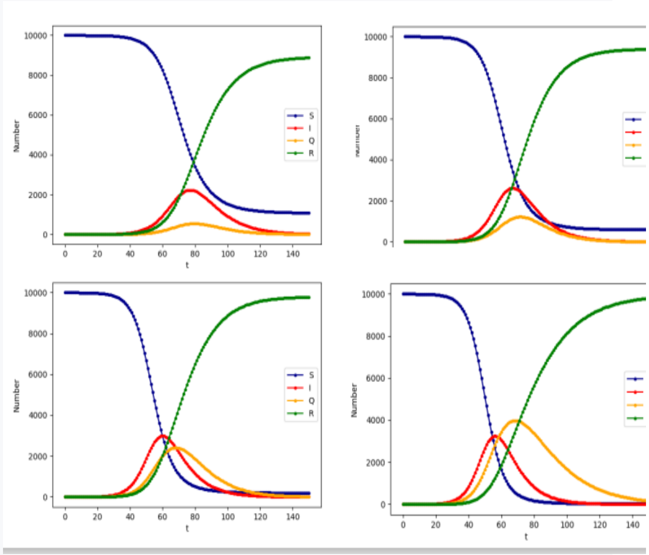
Compared with greater than 1, the propagation rate is significantly greater when the value is less than 1.

(4) The influence of propagation delay on the process of emotion propagation:



It can be seen from the figure that the propagation delay affects the time when the propagation peak arrives. Excessively long propagation delay is actually not conducive to the rapid end of the emotional propagation process.

(5) The impact of recovery rate on the transmission process:



It can be seen from the figure that the size of the recovery rate mainly affects the extreme value of the spreader, which is equivalent to that increasing the recovery rate can reduce the number of spreaders.

IV. Conclusion

Through numerical simulation, we know that the transmission rate has the greatest impact on emotional transmission, and the recovery rate affects the transmission process by affecting the number of communicators. Therefore, we can popularize investment theories to reduce the transmission rate of bad emotions, increase stockholders' awareness of, and increase the probability of resistance. By controlling the delay time within a reasonable threshold through news propaganda methods such as the Internet and TV, the influence of investor sentiment on the stock market can be reduced.

Acknowledgment

The topic selection, writing and final writing of this paper are all completed under the careful guidance of Professor. His rigorous attitude, excellent financial professional knowledge and accomplishment, and tireless guidance have benefited me a lot, which is worthy of lifelong learning. In addition, I would like to thank my senior colleagues for generously providing relevant materials and helping me solve many difficult problems in my papers. From them, I learned the importance of helping each other overcome academic difficulties.

References

[1]Li, D.; Ma, J. How the government's punishment and individual's sensitivity affect the rumor spreading in online social networks. *Physica A: Statistical Mechanics and its Applications* **2017**, *469*, 284-292, doi:10.1016/j.physa.2016.11.033.

[2]Afassinou, K. Analysis of the impact of education rate on the rumor spreading mechanism. *Physica A: Statistical Mechanics and its Applications* **2014**, *414*, 43-52, doi:10.1016/j.physa.2014.07.041.

[3]Zhou, F.; Yao, H. Stability analysis for neutral-type inertial BAM neural networks with time-varying delays. *Nonlinear Dynamics* **2018**, *92*, 1583-1598.doi:10.1007/s11071-018-4148-7.

[4]Hu, Y.; Pan, Q.; Hou, W.; He, M. Rumor spreading model considering the proportion of wisemen in the crowd. *Physica A: Statistical Mechanics and its Applications* **2018**, *505*, 1084-1094, doi:10.1016/j.physa.2018.04.056.

[5]Sahafizadeh, E.; Tork Ladani, B. The impact of group propagation on rumor spreading in mobile social networks. *Physica A: Statistical Mechanics and its Applications* **2018**, *506*, 412-423, doi:10.1016/j.physa.2018.04.038.

[6]Zhao, L.; Xie, W.; Gao, H.O.; Qiu, X.; Wang, X.; Zhang, S. A rumor spreading model with variable forgetting rate. *Physica A: Statistical Mechanics and its Applications* **2013**, *392*, 6146-6154, doi:10.1016/j.physa.2013.07.080.

[7]Chen, G. ILSCR rumor spreading model to discuss the control of rumor spreading in emergency. *Physica A: Statistical Mechanics and its Applications* **2019**, *522*, 88-97. doi:10.1016/j.physa.2018.11.068.

[8]Huo, L.a.; Wang, L.; Song, N.; Ma, C.; He, B. Rumor spreading model considering the activity of spreaders in the homogeneous network. *Physica A: Statistical Mechanics and its Applications* **2017**, *468*, 855-865. doi:10.1016/j.physa.2016.11.039.

[9]Liu, Q.; Li, T.; Sun, M. The analysis of an SEIR rumor propagation model on heterogeneous network. *Physica A: Statistical Mechanics and its Applications* **2017**, *469*, 372-380, doi:10.1016/j.physa.2016.11.067.

[10]Zhang, Y.; Zhu, J. Stability analysis ofI2S2Rrumor spreading model in complex networks. *Physica A: Statistical Mechanics and its Applications* **2018**, *503*, 862-881, doi:10.1016/j.physa.2018.02.087.

[11]Hu, Y.; Pan, Q.; Hou, W.; He, M. Rumor spreading model with the different attitudes towards rumors. *Physica A: Statistical Mechanics and its Applications* **2018**, *502*, 331-344, doi:10.1016/j.physa.2018.02.096.

[12]Gao, S.; Chen, L.; Teng, Z. Impulsive vaccination of an SEIRS model with time delay and varying total population size. *Bull Math Biol* **2007**, *69*, 731-745. doi:10.1007/s11538-006-9149-x.

[13]Chen, L.-J.; Chen, X.-L.; Cai, M.; Wang, W. Complex contagions with social reinforcement from different layers and neighbors. *Physica A: Statistical Mechanics and its Applications* **2018**, *503*, 516-525. doi:10.1016/j.physa.2018.03.017.

[14]Zan, Y. DSIR double-rumors spreading model in complex networks. *Chaos, Solitons & Fractals* **2018**, *110*, 191-202. doi:10.1016/j.chaos.2018.03.021.