Using SIRS Model to Study the Risk of Cross-Contagion in Financial Markets

Haorui An*

New Channel-UIBE Qingdao A-level Centre, Qingdao, China
**1136791815@qq.com*

Abstract
As financial markets become increasingly interconnected, the possibility of cross-contamination of financial risks is also rising. This paper uses the medical SIRS infectious disease model to study the risk cross-infection mechanism between financial markets and conduct simulation simulations. To effectively prevent the cross-market transmission of financial risks, it is necessary to improve the financial market infrastructure and improve the natural immunity of the financial market; establish a scientific risk monitoring and early warning mechanism to prevent financial risks in advance effectively; establish a risk isolation mechanism to reduce the risk of Risk contagion probability; optimise the financial market supervision system and improve the overall prevention ability of financial risks.

***Keywords**-SIRS; Cross-Contagion; Financial Market*

1. INTRODUCTION

With the continuous increase of commercial banks, securities market and insurance business, and some financing products spanning the money market, capital market, insurance market and other financial markets, as well as banking, securities, insurance, trust and other business fields Issuance, resulting in cross-market and cross-industry cross-financial risks. At the same time, as the cross-market linkage effect becomes stronger and stronger, the contagion and destructiveness of risks are also doubled. The current global macroeconomic slowdown is under great pressure, and the risk of outbreaks and cross-sector transmission is increasing. From the perspective of transmission mechanisms, there are similarities between the contagion of market risk and the contagion of infectious diseases. Accordingly, the SIR model of infectious diseases can be used to study the risk of cross-transmission in the market.

2. THE MECHANISM OF THE FINANCIAL CRISIS AND THE LITERATURE ON THE USE OF MEDICAL MODELS

2.1. On the mechanism of communication between financial markets

1) The contagion mechanism of financial crisis based on macroeconomic fundamentals

The research on the transmission mechanism of financial crisis based on macroeconomic fundamentals focuses on the investigation of macroeconomic correlations within countries or regions, mainly involving foreign trade and Internet financial markets. Such surveys also point out that economic linkages between regions are the main prerequisite for the contagion of financial crises.

- Foreign trade channels. The foreign trade channel infection can be divided into two types, one is the transaction partner infection, and the other is the competitor infection. Here, direct trading partner infection refers specifically to infection between countries or regions with direct business dealings; direct competitive infection generally refers to, although not a direct trading partnership, but has a competitive relationship and occupies a similar position in the trade network infection between countries or regions.
- Channels of capital flow. Including the contagion of financial crises through common creditor contagion, cross-market hedging contagion, and capital flight contagion. For example, the European economic, financial and monetary economic crisis in 1992, the dangerous operation of the Mexican market economy in 1994, and the dangerous operation of the Thai exchange rate

G. Vilas Bhau et al. (Eds.): MSEA 2022, ACSR 101, pp. 286–291, 2023.
https://doi.org/10.2991/978-94-6463-042-8_42

economy in 1997, all also used the channel of capital flow in the same region or similar countries or countries. Between regions, the risk of economic operation is transmitted.

2) Contagion mechanism of financial crisis based on investor behaviour

- The first way is contagion through risk aversion. Under the information asymmetry in the securities market, the practice of investors adjusting their investment portfolios in order to avoid securities market risks will significantly reduce the investment value, resulting in the reduction of investment value in high-risk regions or countries, resulting in financial crises.
- The second is based on the spread of the herd effect. Including rational and irrational herd affect transmission. The rational herd effect points out that herd behaviour has become the optimal decision-making method for decision-makers due to the existence of information barriers for decision-makers, the stimulating influence of financial markets on decision-makers, and the externality of capital payment. When there is good news for a certain group of funds in the financial market, investors will take the same asset adjustment action, which will cause the concentration of funds and increase the potential feasibility of risk contagion when the financial market fluctuates. The irrational herd effect points out that when some investors sell investment mergers, some irrational investors begin to sell the same asset merger due to misunderstanding financial market news, resulting in a substantial decrease in asset value, and eventually Producing the spread of the financial crisis.
- The third case is natural contagion due to rational prediction. Due to the rational expectations of investors, investors readjusted their asset portfolios, which triggered the spread of financial crises.
- The fourth type is crisis contagion caused by common shocks. Some major events have a common impact on a country's macro economy, thus triggering the spread of the financial crisis. For example, some major events such as the bankruptcy of Lehman Brothers and the US economic recession have directly led to the US subprime mortgage crisis, which has spread around the world.

2.2. Research on risk contagion between financial markets.

Zhang Jinlin, He Genqing, etc. used a progressive econometric analysis framework composed of cointegration, Granger test and VEC-GARCH(1,1)-BEKK model, and a progressive econometric analysis method framework to systematically analyze the risk spillover in China's market economy It is believed that there is a long-term balance mechanism and a short-term interactive relationship in China's financial market [1]. Cai Zexiang, Cao Yuanfang (2014) Based on the characteristics of financial market volatility with biased, sharp peaks and thick tails, through the Granger causality verification of the biased t - distribution APARCH model, the transaction prices in China, the stock market, and foreign exchange transactions and currency markets The risk transfer relationship between economies has been studied. The analysis results show that: in the rising and falling stages, there are differences in the power of business risk transfer in each financial market; the national debt market, The stock market and the currency market have a particularly strong risk transmission power in the rising and falling stages; the foreign exchange market does not have an obvious risk transmission function for other financial markets in the rising stage, but in the falling stage, it has a strong risk transmission function for the entire securities market. Risk transfer function: Generally speaking, the risk transfer function of China's Internet financial market in the declining stage is greater than that in the rising stage [2]. Cao Yuanfang and Cai Zexiang (2013) used the multivariate VAR model to test the existence of the spread effect of financial risk in various regions within China. The survey results show that financial risk also has an obvious spread effect among various regions within China [3].

2.3. Research on the application of the Guan and Infectious Disease Model in the field of financial market risk.

The research group of the Nanning Central Sub-branch of the People's Bank of China (2017) used the medical SIRS infectious disease simulation to conduct in-depth research on the cross-propagation mechanism of the financial markets and realized the simulation modelling [4]. Liu Xiaoyu, Lv Lin (2018) analyzed and studied the complex financial network risk propagation model composed of a class of SIR and SIS, and obtained the conditions for the emergence of a disease-free equilibrium point and a non-zero disease-free equilibrium point, and thus obtained the risk appearance. The smaller the threshold point of risk propagation, the more conducive to risk resolution and control. Based on this, this paper puts forward suggestions such as establishing a comprehensive risk warning system and an effective supervision system, building a reasonable risk isolation system, and optimizing the supervision system. In order to control the threshold point of risk propagation, so as to prevent and control financial risks [5].

3. CONSTRUCTION AND ANALYSIS OF FINANCIAL MARKET RISK CROSS-CONTAGION MODEL BASED ON SIRS

3.1The feasibility of using the SIR model to study financial market risks

In the SIR model, people in areas where infectious diseases are prevalent are divided into three types : Type S , susceptible , refers to those who have never gotten sick , but due to lack of autoimmunity , are susceptible to infection after communicating with susceptible persons ; Type I , Influenza patients , i.e. people who contract and transmit the disease , but may also infect members of the S category ; R category , those who have been removed , i.e. people who have been isolated , or who have recovered and become immune. In the dynamics of infectious diseases, Kermack and McKendrick used the dynamic method to form the SIR infection disease model in 1927. The SIR model is still widely adopted and continues to evolve. The SIR model divides the population into the following three groups : susceptible , the total amount is recorded as S(t), to represent the population that is not infected but still has the opportunity to be affected by this type of disease in time t ; among the infected , the total amount is recorded as I(t), indicating that at moment t The population that has been transmitted to become diseased and is contagious ; the total number of recovered persons , denoted as R(t), indicates the total number of infected persons removed before time t . Suppose the total population is N(t), then $N(t) = S(t) + I(t) + R(t)$ [6].

Similarities between financial market risk and the spread of infectious diseases: First, people need to understand that financial risk is contagious because financial institutions act as intermediaries between people and financial markets, cutting off people's original funds Relationships, and when a risk occurs anywhere on this network, it can be detrimental to others. After the global financial crisis in 2008, the theory of infectious diseases has also entered the attention of many international financial scholars. There are certain linkages and similarities between financial crises and infectious disease outbreaks. The wide-ranging impact of major infections such as SARS can be compared to the 2008 financial crisis. The commonality is that when external events strike suddenly, fear is Produced, and finally swept the whole system. Infectivity is a social process. As a group of animals, human beings are easily influenced by others, especially the group, in their psychology, way of thinking, and behaviour. The same goes for people who play various roles in financial markets. They will follow the " herd effect " to make the market fluctuate, and individuals with financial risks and infectious diseases can be found to have certain similarities and differences [7].

3.2 Research hypothesis

Assumption 1: The total number of financial sub-markets must be assumed.

Assumption 2: Some financial markets have defensive measures in advance, and they are directly immune. Some financial markets have taken relevant defensive measures after being infected and have entered an immune state (immune to be affected). Some financial markets have not taken relevant measures after being infected. Defensive measures enter a susceptible state; some immunized groups have a chance to re-enter a susceptible state; divide risks into systemic risks and unsystematic risks. The probability of infection is different, and some financial markets are directly in an immune state.

3.3. Model construction

1) Variables and Parameters

- Vulnerable state (S): financial markets without the ability to defend against financial risks, financial markets that are easily infected but not infected
- Infection status (I): A financial market that has been infected and is likely to infect other markets
- Out of state (R): Gain immune function in financial risk contagion.
- When S(t) is t, that are at risk of being infected but not infected,$0 \leq S(t) \leq K$.
- Let I(t) be the number of infected financial submarkets at time t,$0 \leq I(t) \leq K$.
- Let R(t) be the number of immune financial submarkets at time t,$0 \leq R(t) \leq K$。
- K is the total amount of financial sub-markets,$S(t) + I(t) + R(t) = K$.

2) According to the state change of each sub-market in risk propagation, the cross-flow of risk propagation in the sub-market is shown in figure 1 as follows :

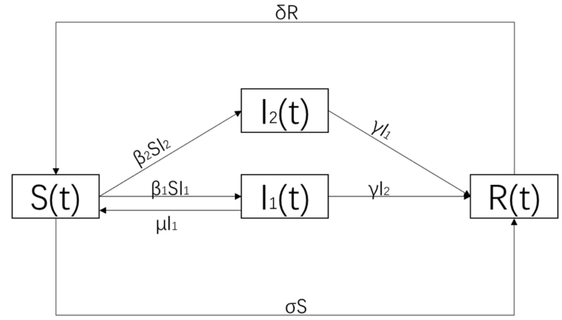

Figure 1. the cross-flow of risk propagation in the sub-market

3) Model setting parameters:

- δ: It is expressed as the financial sub-market with decreased immune function, that is, the financial sub-market transferred to the susceptible population due to the decreased immune function in the immune state.
- β: represents the probability of risk contagion, which represents the probability of contagion between financial markets.
- γ: Indicates the probability that the financial submarket in the infected state enters the immune state.
- μ: Indicates the probability that the financial sub-market in the infected state enters the susceptible state.
- σ: Indicates the probability of direct immunity of susceptible groups, that is, the probability that the financial sub-market will become immune to infection by taking appropriate defensive measures before being infected by the risk.

4) Model derivation:

According to the above financial market risk contagion mechanism, the dynamic equation can be listed as:

$$\begin{cases} \frac{dS}{dt} = \delta R - \beta_1 S I_1 - \beta_2 S I_2 + \mu I_1 - \sigma S \\ \frac{dI_1}{dt} = \beta_1 S I_1 - (\mu+\gamma) I_1 \\ \frac{dI_2}{dt} = \beta_2 S I_2 - \gamma I_2 \\ \frac{dR}{dt} = \gamma(I_1 + I_2) + \sigma S - \delta R \end{cases}$$

5) Basic reproduction number solution and analysis:

solution of disease-free equilibrium point:

$$\frac{dS}{dt} = \delta R - \beta_1 S I_1 - \beta_2 S I_2 + \mu I_1 - \sigma S = 0$$
$$\frac{dI_1}{dt} = \beta_1 S I_1 - (\mu+\gamma) I_1 = 0$$
$$\frac{dI_2}{dt} = \beta_2 S I_2 - \gamma I_2 = 0$$
$$\frac{dR}{dt} = \gamma(I_1 + I_2) + \sigma S - \delta R = 0$$

$$I_1 = 0$$
$$I_2 = 0$$
$$\delta R = \sigma S$$
$$S = \frac{\delta}{\sigma} R$$

So the disease-free equilibrium point is: $I_1, I_2, S, R = \left(0, 0, \frac{\delta}{\sigma} R, R\right)$

The analysis of the equations by the method of Van den Driessche P, Watmough J. Reproduction will never be reported. The portion of the infected financial sub-market transferred into the infected financial market (from positive to negative) is picked out and defined as F, and the remaining portion is V. as shown below.

$$F = \begin{bmatrix} \beta_1 S I_1 \\ \beta_2 S I_2 \\ 0 \\ 0 \end{bmatrix} \text{ and } V = \begin{bmatrix} (\mu+\gamma) I_1 \\ \gamma I_2 \\ -\delta R + \beta_1 S I_1 + \beta_2 S I_2 - \mu I_1 + \sigma S \\ -\gamma(I_1 + I_2) - \sigma S + \delta R \end{bmatrix}$$

Derivation of F and V at disease-free equilibrium

$$DF = \begin{bmatrix} F_{(2\ x 2)} & 0_{(2\ x 2)} \\ 0_{(2\ x 2)} & 0_{(2\ x 2)} \end{bmatrix}, \text{ where } F = \begin{bmatrix} \beta_1 S & 0 \\ 0 & \beta_2 S \end{bmatrix}$$

$$DV = \begin{bmatrix} V_{(2\ x 2)} & 0_{(2\ x 2)} \\ J_{(2\ x 2)} & J_{(2\ x 2)} \end{bmatrix}, \text{ where } V = \begin{bmatrix} \mu+\gamma & 0 \\ 0 & \gamma \end{bmatrix}$$

Solving for the basic reproduction number ($R_0 = \rho(FV^{-1})$)

$$V^{-1} = \begin{bmatrix} \frac{1}{\mu+\gamma} & \\ & \frac{1}{\gamma} \end{bmatrix}$$

$$FV^{-1} = \begin{bmatrix} \beta_1 S & 0 \\ 0 & \beta_2 S \end{bmatrix} \begin{bmatrix} \frac{1}{\mu+\gamma} & \\ & \frac{1}{\gamma} \end{bmatrix} = \begin{bmatrix} \frac{\beta_1 S}{\mu+\gamma} & \\ & \frac{\beta_2 S}{\gamma} \end{bmatrix}$$

$$\lambda_1 = \frac{\beta_1 S}{\mu+\gamma} \quad \lambda_2 = \frac{\beta_2 S}{\gamma}$$

R_0 is classified according to systematic risk and unsystematic risk, when the probability of occurrence of systematic risk β_1 is less than the probability of occurrence of unsystematic risk β_2, and the financial sub-market infected by systemic risk turns into a susceptible state When the probability of μ is relatively large , then the basic reproduction number R_0 is:

$$\frac{\beta_1}{\mu+\gamma} < \frac{\beta_2}{\gamma}, \rho(FV^{-1}) = \frac{\beta_2}{\gamma} = R_0$$

When the probability of occurrence of unsystematic risk β_2 is less than the probability of occurrence of systematic risk β_1, the basic reproduction number is:

$$\frac{\beta_1}{\mu+\gamma} > \frac{\beta_2}{\gamma}, \rho(FV^{-1}) = \frac{\beta_1}{\mu+\gamma} = R_0$$

The basic reproduction number $R_0 = 1$ is a threshold for risk contagion in financial markets. When $R_0 < 1$, the sub-market risk is effectively controlled and gradually resolved. When $R_0 < 1$, the sub-market risk will infect other markets and form a spreading trend.

3.4. Analysis of financial market risks based on the basic reproduction number

1) From the above model, the trend of risk propagation between financial markets mainly depends on the probability of systemic risk occurrenceβ_1, the probability of unsystematic risk occurrence β_2, the probability that the financial sub-market in the infected state will transfer to the immune state, The probability μ of a financial submarket infected by systemic risk turning into a vulnerable state.
2) which is related to the probability μ of the financial sub-market infected by systemic risk turning into a susceptible state. When the probability of occurrence of unsystematic risk β_2 is less than the probability of occurrence of systematic risk β_1, $R_0 = \frac{\beta_1}{\mu+\gamma}$, which is related to the probability μ of the financial sub-market infected by systemic risk turning into a susceptible state.

4. CONCLUSION

Whether financial risks are controllable depends on the probability of systemic risks, the probability of non-systematic risks, the probability that the financial sub-market in the infected state will be transferred to the immune state, and the financial sub-market infected by systemic risk will be susceptible to infection. probability of the state. Effective prevention of financial risks is to reduce the number of basic regenerations and manage key parameters. Coordinate and formulate crisis prevention countermeasures from the two levels of crisis event prevention and post-event disposal , including improving the infrastructure of financial market construction , increasing immunity, forming a scientific risk isolation system , reducing the risk of contagion, and commercial banks should quickly improve their own In order to fight against the crisis , we should take measures such as a reasonable increase in the capital provision ratio and adequate asset preparation to improve the strength to fight against the crisis, improve the financial market control system , and enhance the early warning awareness of systemic financial risks [8].

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