Study on the Risk Transmission Mechanism of Rural Banks in China

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Abstract. This paper studies the rural banks’ credit risk factors and risk transmission path, sets up a nonlinear differential dynamical system model for the transmission and analyzes its equilibrium by phase-plane method, then discusses how credit risk dynamically configures to reach equilibrium among the nodes in the transmission process. The paper’s main conclusions are as follows: the sources of rural banks’ credit risk are transmitted inside the banks by virtue of the carriers of capital flow and information flow, and the recipients in the banks’ internal credit risk transmission may become new risk sources and lead to regional financial risks; the credit risk dynamic configuration may reach equilibrium among the nodes in the transmission subsystem. Finally, this paper gives suggestions on credit risk management of rural banks in China.

Credit Risk Factors of Rural Banks

Credit risk transmission of rural banks refers to the risk generated from credit activities of rural banks being transmitted to distinct nodes and their external associated parties. It possesses specific carriers and paths, and leads to deviation from expected profits of rural banks and related parties.

A complete risk transmission system consists of five elements: sources, transmission carriers, transmission nodes, risk recipients and risk threshold. Risk transmission path is interpreted as the process that risk flow based on transmission carriers transfers among nodes and finally exerts effects on some recipients.

Credit Risk Sources of Rural Banks

To exactly define risk sources is the foundation of research on credit risk transmission of rural banks. The uncertain factors, which affect the operation of rural banks both internally and externally, may become the credit risk source. In this paper, credit risk sources of rural banks are categorized into external sources and internal sources.

External risk sources include:
- Natural environment. Agricultural production is naturally weak, susceptible to impacts of natural environment. Farmers would suffer great damage when they encounter droughts, floods, epidemic diseases, fires and insect outbreaks.
- Market environment. With long production cycle, farmers who generally lack risk hedge instruments could only passively accept price fluctuation in agricultural product market.
- Policy environment. Domestic agricultural production is backward and strongly subjected by national agricultural policies. Farmers’ revenue is sensitive to the changes of the policies.

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Credit environment. Rural credit system in China is not perfect, and national credit system is still under construction. Less educated farmers are lack of credit consciousness and largely dependent on agricultural support policies. If the intended use of the loan is arbitrarily changed by borrowers to high risk projects, or if the repayments of the principal and interests are not on time, it may trigger the outbreak of credit risks.

Internal risk source refers to lack of awareness and sound credit risk management system, shortage of qualified risk management personnel, employers’ lower operating capability, etc., which leads to imperfect execution of credit review, poor credit check management and consequently exposes rural banks to credit risk.

**Credit Risk Transmission Carriers**

Transmission carriers are those tangible substances or intangible effects that transfer information and knowledge. In the process of risk transmission, carriers bear risks created by sources and then deliver it out.

Capital flow is an important carrier of risk transmission since capital is rural banks’ operation object. When the lenders are stimulated by external risk sources or the borrowers fail to evade internal risk sources, capital chain will break, then credit risk will occur. Similarly, human resources flow and information flow could be credit risk carriers of rural banks. A well-performing system of information management contributes to comprehensive collection of borrowers’ information, which would be helpful to reduce adverse selection and moral hazards due to information asymmetry. Highly qualified professionals could identify risk factors of a loan so that the credit risk could be prevented and controlled.

**Credit Risk Transmitting Nodes**

Transmitting nodes are joints that internal and external risk overlaps and mutually penetrates. Since risks are gathered and released at nodes, the control of nodes concerns risk transfer effects being weakened or enhanced.

If a transmitting node could actively absorb and resist credit risk transferred from other nodes, it could weaken transfer effects of credit risk or even terminate risk transmission of the system. Conversely, if a transmitting node is incapable of reducing or shifting risks, it would be significantly shocked by the risks. And the shock may converse into a new risk source and transfer to other nodes, which would bring huge loss to the system.

**Credit Risk Recipients**

If the credit risks are not released at previous nodes in the transmission, they will be accepted at some nodes, which are called credit risk recipients. When risks on some recipients accumulate to a certain degree (risk threshold), the previous recipients become new sources of risks and impact other recipients.

Combing all factors mentioned above, we will obtain a logic diagram of risk transmission:

![Figure 1. Logic Process of Risk Transmission.](image-url)
Credit Risk Threshold

Risk threshold is the upper limit of risk that a transmission node or a risk recipient could bear. Risks will flow through invisible “valves” during the transmission. If the physical energy of risk flow surpasses the threshold, it passes the valve and approaches the next node or recipient. If the physical energy does not reach the upper limit, the valve will terminate the process and eliminate influences on the recipients. One point needed to be addressed is that if a risk flow ceased at one node encounters another flow and forms a strong coupling effect, it will lead to a greater risk flow to affects the recipients.

Risk threshold is not fixed since external or internal environment of rural banks may often cause some changes to the threshold value. A decrease of risk threshold indicates a decline of defense ability against risk. While an increase of the threshold indicates strengthening of risk defense ability, which produces positive effects on risk transmission control.

Credit Risk Transmission Path of Rural Banks

The path of risk transmission refers to the route from risk sources through transmission nodes to risk recipients. Credit risk of rural banks can be classified into pre-loan risk and post-loan risk. The former is caused by adverse selection, and the latter is attributed to moral hazards. This paper emphasizes the analysis of post-loan risk. We divide the credit risk transmission of rural banks into two aspects: internal credit risk transmission and regional financial risk transmission outside rural banks.

We firstly hypothesize that: (1) There is only one rural bank and one borrower within the system, and loan application of borrower has been approved; (2) The bank fails to identify the usage of credit loan; (3) The bank and the borrower are rational; (4) The borrower is willing to take corresponding risks for higher return; (5) No collateral is needed when applying for a loan. Under these assumptions, the transmission path of credit risk in rural banks can be depicted as Figure 2:

![Figure 2. Internal Transmission Path of Credit Risk of Rural Banks.](image)

A borrower would use the fund for other purpose to maximize his benefit after he got the loan. Then, speculative information becomes a risk source which creates stimulus to the borrower via information flow. If the borrower is aware of higher return project which is not compliant with lending contract, he potentially chooses to breach covenants. Under the circumstances a deviation in loan usage from the expectation of rural banks will occur, and consequently physical energy of risk in this node will exceed the threshold value and pose credit risk to rural banks. [2]
Even if the borrower uses the fund according to covenants, credit risk would emerge. In such condition, the borrower is confronted with new risk sources, including natural environment deterioration, unfavorable change of market prices of products, introduction of adverse policies. These sources together with information flows will stimulate the nodes. If physical energy of risk exceeds threshold value, the borrower faces losses and will choose a passive breach, which exposes rural banks to credit risk. If the threshold value is not reached, the borrower is capable of resisting risks and acquiring expected benefits.

New risk sources would also arise after the borrower acquires the expected benefits. He would intend to refuse repayments with the belief that he will not be severely punished, which results from the borrower’s weak credit consciousness. Similarly, the borrower will not repay the loans if the threshold value is exceeded, and vice versa.

As above, there are three cases that would trigger the borrower to default the loan, which may lead to credit risks for rural banks. If the risks are not controlled promptly, they would be converted to new risk sources and react with external ones, then initiates another risk transmission process.

**Transmission Path of Regional Financial Risks**

Analysis above is based on the assumption that there is only one rural bank and one borrower within the system while the actual credit risk transmission is far more sophisticated. Thus, we will relax the assumption to a number of rural banks, depositors and borrowers while keeping other assumptions the same. When physical energy of risks reaches the threshold value at each node, path of credit risk transmission can be depicted as Figure 3:

![Figure 3. Transmission Path of Regional Financial Risks.](image)

Rural banks are risk recipients in the internal credit risk transmission. The aftermath of risk transmission is that credit risk occurs if borrowers’ default on loans is not punished. Meanwhile, recipients being exposed to credit risk may become a new risk source and continue spreading.

Borrowers’ not being punished for default initiates the effect of broken window that if bad phenomena are left unregulated, more and more people will be tempted to behave badly. Therefore, one borrower defaulting on his debt potentially leads to imitation of other borrowers, creating problems for capital chain and inducing liquidity risk.\(^4\)
A network of relationships is formed among farmers due to blood and regional factors. Information inside the farmer group is complete so that any bad news of rural banks will be quickly spread, which will also accelerates the spread of risk information. Banks would face a risk of runs.

On the other side, liquidity risk will undoubtedly result in other borrowers with good credit records incapable of acquiring loan. If there exist a large number of farmers who are heavily dependent on bank loan in one area, the break of capital chain would directly result in frustration in regional production and deterioration of economic environment.

Liquidity risk induced by credit risk of rural banks and other financial institutions, together with deterioration of economic environment, would lead to regional economic crisis.

Summarily, credit risk sources of rural banks, through the medium of information flow and capital flow, transmit in a particular route inside the bank. Those sources exert effects on individuals and related departments outside the banks through financial transactions, which will generate credit risk and may even amplify the risk. Recipients of credit risk transmission inside the bank may become new risk sources, which would consequently lead to regional financial risks.

**Credit Risk Transmission Model and Equilibrium Analysis**

**Model of Credit Risk Transmission**

The general model of credit risk between two conductive nodes is constructed subsequently, and equilibrium process of risk dynamic configuration is explored.

Model assumptions and symbols are given as follows:

Firstly, transmission of credit risk between two nodes has no friction. And \( R_1(t) \), \( R_2(t) \) are the risk values of two transmission nodes at time \( t \) respectively.

Secondly, \( R_1^m \) and \( R_2^m \) are risk thresholds of two transmission nodes.

Thirdly, each transmission node has a certain ability of risk immunity owing to some factors such as risk management level at the node, which contributes to a better withstanding of risk. Nonetheless, the ability of risk immunity is finite, which means that the transmission node is not fully immunized against credit risk. \( \delta_1, \delta_2 \) stands for coefficients of risk immunity for two nodes and \( 0 < \delta_i < 1 (i = 1, 2) \) holds obviously.

Lastly, risk transmission is mutual between two nodes within the subsystem. \( \lambda_1 \) stands for coefficients of risk transmission from node A to node B, and \( \lambda_2 \) stands for coefficients from node B to node A.

There are three effects in credit risk transmission process, namely transmission effect, retarding effect and immunity effect.

**Transmission Effect** In the transmission system, the risk accumulation rate at each node is proportional to the risk status of adjacent node. For instance, the higher the risk level at node 1, the faster the risk accumulation at node 2. This reflects the transmission effect of the subsystem of risk transmission. We denote credit risk accumulation rate at node 1 and 2 as \( \dot{R}_1(t) \) and \( \dot{R}_2(t) \) respectively, with

\[
\begin{align*}
\dot{R}_1(t) &= \frac{dR_1}{dt}, \\
\dot{R}_2(t) &= \frac{dR_2}{dt}.
\end{align*}
\]

The correlation that represents the transmission effect of credit risk is that \( \dot{R}_1(t) \) and \( \dot{R}_2(t) \) are positively correlated with \( \lambda_1 R_1 \) and \( \lambda_2 R_2 \) respectively.

**Retarding Effect** Risk management measures are adopted in each node in risk transmission subsystem. With the conduction and accumulation of credit risk, its spread speed attenuates gradually. The retarding factor at node 1 and node 2 can be defined as \( R_1^m / R_1 \) and \( R_2^m / R_2 \) respectively.
Retarding effect of credit risk transmission implies that $\dot{R}_t(t)$ is negatively correlated with $R_i / R_i^m$, and $\dot{R}_r(t)$ is negatively correlated with $R_j / R_j^m$.

**Immunity effect** Not only retarding effect works at each node, the node can also be immunized with limits against risk transmitted from other nodes, which means that the risk-bearing capability at each node is expanded and the risk threshold is increased. To be more specific, the increased risk threshold at node 1 is $R_i^m + \delta_1 R_1$, and that at node 2 is $R_j^m + \delta_2 R_2$.

Based on analysis above, the rural banks’ of credit risk subsystem transmission model is constructed as follows:

$$
\begin{align*}
\dot{R}_t(t) &= \lambda_1 R_2 (1 - \frac{R_t}{R_i^m + \delta_1 R_2}) \\
\dot{R}_r(t) &= \lambda_2 R_1 (1 - \frac{R_r}{R_j^m + \delta_2 R_1})
\end{align*}
$$

Differential equation set (2) is a nonlinear differential dynamic system model, which is difficult to solve using regular differential equation methods. Therefore we choose phase-plane method to analyze its trajectory characteristics in order to reveal the risk transmission process between two nodes and the status of risk equilibrium configuration.\[^5\]

**Equilibrium Analysis of Credit Risk Transmission**

The Equilibrium Point and its characteristics of Credit Risk Transmission Model According to the distinguishing theorem, the equilibrium point of differential equation set (1) should satisfy following conditions:

$$
\begin{align*}
f(R_t, R_r) &= \lambda_1 R_2 (1 - \frac{R_t}{R_i^m + \delta_1 R_2}) = 0 \\
g(R_t, R_r) &= \lambda_2 R_1 (1 - \frac{R_r}{R_j^m + \delta_2 R_1}) = 0
\end{align*}
$$

Solving equation set (3) we obtain two equilibrium points, namely the origin point (0,0) and point $Q(R_t^*, R_r^*)$, with

$$
R_t^* = \frac{R_i^m + \delta_1 R_2^m}{1 - \delta_1 \delta_2}, R_r^* = \frac{R_j^m + \delta_2 R_1^m}{1 - \delta_1 \delta_2}.
$$

Considering the external risk sources and risk transmission, credit risk cannot be completely eliminated. Hence the origin point (0,0) is not a rational solution, which indicates that point $Q(R_t^*, R_r^*)$ is the unique equilibrium point of the model. Since the model is a two-dimensional nonlinear differential dynamic system, the characteristic matrix $\tilde{Z}$ is introduced to further explore the stability characteristics of equilibrium point Q.

$$
\tilde{Z} = \begin{bmatrix} f_{R_t} & f_{R_r} \\ g_{R_t} & g_{R_r} \end{bmatrix} = \begin{bmatrix} -\frac{\lambda_1 R_2}{R_i^m + \delta_1 R_2} & \lambda_1 \left[1 - \frac{R_t^m R_2}{(R_i^m + \delta_1 R_2)^2}\right] \\ \frac{\lambda_2 R_1}{(R_j^m + \delta_2 R_1)^2} & -\frac{\lambda_2 R_1}{R_j^m + \delta_2 R_1} \end{bmatrix}.
$$

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Substitute Q into corresponding characteristic root equations of matrix (5), discriminants are expressed as:

\[
m = -\left[ \frac{\lambda_1(R_{i} + \delta_i R^m_i)}{R_{i} + \delta_i R^m_i} + \frac{\lambda_2(R_{i} + \delta_i R^m_i)}{R_{i} + \delta_i R^m_i} \right].
\] (6)

\[
n = \lambda_1 \lambda_2 (1 - \delta_i \delta_i).
\] (7)

\[
m^2 - 4n \geq 4 \lambda_1 \lambda_2 (1 - \delta_i \delta_i).
\] (8)

Taking into account the above third assumption as \(0 < \delta_i < 1\) (\(i = 1, 2\)), then \(0 < \delta_1 \delta_2 < 1\), therefore \(m^2 - 4n > 0\) and \(m < 0, n > 0\). According to the distinguishing theorem, the unique equilibrium point Q is the stable node of this differential dynamic system.

**Trajectory Evolution and the Equilibrium of Credit Risk Transmission Model** A two-dimensional phase-plane is built on the plane set \(\{(R_1, R_2) | R_1 > 0, R_2 > 0\}\) and is divided into four regions by boundary lines \(L_1\) and \(L_2\). \(L_1\) is determined by

\[
R_2 = \frac{1}{\delta_1} (R_1 - R^m_1).
\] (9)

and \(L_2\) determined by

\[
R_2 = \delta_2 R_1 + R^m_2.
\] (10)

The intersection of two boundary lines is the equilibrium point \(Q(R_1^*, R_2^*)\). The distribution of trajectory gradient of four regions is shown as follows:

\[
S_1: \dot{R}_1 > 0, \dot{R}_2 > 0 \quad S_2: \dot{R}_1 > 0, \dot{R}_2 < 0 \\
S_3: \dot{R}_1 < 0, \dot{R}_2 > 0 \quad S_4: \dot{R}_1 < 0, \dot{R}_2 < 0
\]

The trajectory evolution of the phase-plane of credit risk transmission is displayed in Figure 4.

![Figure 4. The Evolution of the Phase-plane Trajectory of Credit Risk Transmission.](image)
initial risk of the subsystem is located within region \( S_3 \), the transmission trajectory will either enter into \( S_1 \) through boundary line \( L_1 \) or enter into \( S_4 \) through boundary line \( L_2 \). If the initial risk of the subsystem is located within region \( S_1 \) or \( S_4 \), the transmission trajectory will move towards the equilibrium point \( Q \). Since the gradient direction of point \( Q \) is \( \dot{R}_1 = 0 \) and \( \dot{R}_2 = 0 \), the trajectory would stop at equilibrium point once it reaches there. Consequently the trajectory evolution of risk transmission reaches equilibrium.

The following conclusions can be drawn accordingly. In the transmission subsystem, credit risk dynamically configures and reaches equilibrium between two nodes, and its accumulation speed at each node is positively correlated with the transmission effect and immunity effect but negatively correlated with the retarding effect. The accumulation speed of credit risk is the synthetic effect of risk transmission, risk retarding and risk immunity.

Policy Suggestions for Credit Risk Management of Rural Banks

Based on the analysis of transmission mechanism of credit risk, policy suggestions about the credit risk management of rural banks can be made in the following three aspects: minimizing influences of risk sources, controlling risk transmission nodes and improving risk thresholds.

**Minimizing Influences of Risk Sources**

*Establishing and Improving Agricultural Risk-sharing Mechanism* The primary measure of agricultural risk-sharing taken by rural banks is the agricultural insurance. It can compensate the loss from risks and curb the risk transmission in a certain degree when farmers’ economic condition gets worsen.\[6\]

Government should improve the policy to support agricultural insurance system, in which the policy insurance dominates and commercial insurance supplements. Moreover, government should guide farmers, small and medium rural enterprises to participate in agricultural insurance. Government should subsidize the insured individuals and enterprises to increase their enthusiasm and induce the uninsured to purchase insurance. A sound agricultural insurance system contributes to protecting farmers’ interest and minimizing the occurrence of credit risk.

*Complementing the Rural Credit System* The People’s Bank of China should cooperate with local government and related departments to jointly set up a working group to construct a sound credit system in rural areas.

Rural bank should establish electric archives household by household, and share the credit database of the People’s Bank of China and establish electronic credit records in accordance with its demand, which can help the rural bank to comprehensively grasp customers’ credit information and accurately determine their credit level.

Rural bank should cultivate farmers’ credit awareness with the help of local government. It needs to do some work such as promoting credit knowledge, conducting credit knowledge contest and farmers’ credit rating competitions, etc.

**Controlling Risk Transmission Nodes**

Pre-loan investigation mechanism should be strictly implemented. When a rural bank receives a loan application, it should conduct a rigorous assessment to the borrower’s credit status through a comprehensive survey. The assessment should include the legitimacy of borrowing, the safety of loan usage, the profitability of borrowing projects, etc. The details are illustrated as follows: legitimacy of the borrower, the existence of valid collateral, financial status, operating conditions and repayment ability.

Post-loan supervision should be strengthened. After the loan distribution, staff members of the bank should regularly visit the borrower, pay special attention to changes of the borrower’s operating conditions and financial status, and the changes in collateral price. The rural bank should
appropriately manages repayments of loan and roll over loans for qualified borrowers. Collections and punishments are necessary for overdue payments.

The punishment mechanism for dishonesty should be strengthened. Credit information database should be constructed and shared as soon as possible. Classify borrowers with good credit records into the “red list” and borrowers with poor records into the “black list” or “grey list” according to the seriousness of default. Interest of loan, credit line and transaction process should differ for customers with different credit ratings so as to increase costs of dishonesty and encourage trustworthiness.

**Improving Risk Thresholds**

The rural bank’s inner control system should be improved. With respect to the internal governance structure, rural bank should promote diversity of its ownership structure, improve corporate governance mechanism, perfect internal rules and regulations, and increase the intensity of internal audit\[7\]. The separation of review, credit lending and check follows.

Three links in loan process, such as pre-loan survey, in-loan processing and post-loan supervision, must be strictly separated, and each link’s responsibility must be implemented on different persons to form mutual restraint mechanism for loan officers and transaction procedures. This can achieve multiple effect to control credit risk. All these work would be helpful to improve the risk thresholds.

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