Reputation risk contagion and control of rural banks in China based on epidemic model

Wu Yu*

School of Economics Henan University of Science and Technology, Luoyang City, Henan Province, China, 471000

Abstract

Rural bank reputation risk is the negative evaluation formed in stakeholders' minds as a result of events which pose both internal and external risks. Regardless of whether or not these risk events have actually occurred, any resulting negative evaluations tend to propagate and accumulate in both the public's mind and within the main financial system. The growing negative opinion can create a herd effect, ultimately creating a reputation crisis. This paper attempts to research the contagion mechanism of rural bank reputation risk based on epidemic model, then explores a simulation study under different situations. The results show that the key to prevent or regulate reputation risk contagion is to reduce the unit available contact rate and the re-entry ratio, as well as the lurker infected rate. Finally, this paper puts forward management and control strategies from the perspective of the entire process. These strategies specifically focus on constructing an early warning mechanism, a dissolving mechanism and a long-term mechanism.

Keywords: reputation risk, reputation risk contagion, reputation risk control, epidemic model, rural bank

1 Introduction

The establishment of rural bank is one product of increment reform of rural finance in China, with a total of over 1000 within less than seven years. Nowadays, rural banks spread to all 31 provinces and more than half of 1880 counties, which have become the new force to support agriculture and SME. However, as the function of a financial enterprise is mainly to manage currency and credit services, rural banks also have the innate characteristics of financial fragility. This is especially true in the county areas, where the banks must cope with the inherent problems of small scale operations, manpower shortages and a lack of capital strength, these deficiencies make it more difficult to cope with liquidity risks, operational risks and credit risks. Once any of these negative events occurs, a reputation crisis is likely to surface as well, even infecting other financial institutions and posing a risk to the entire banking system. Therefore, rural bank reputation risk can be regarded as being the result of other types of risks concentrated to a certain degree, which creates dynamic changes. Another factor is whether or not the events which triggered the reputation risk -whether accurate or not- are controlled in a timely fashion.

Domestic and foreign scholars tend to research commercial bank reputation problems mainly from the perspective of reputation connotation. They emphasize that the root of a reputation crisis is information asymmetry, and that the basis of the crisis is the lessening of other parties' trust. These scholars reveal the mechanism of reputation as one of incentive and punishment by building a reputation model. Bushman and Wittenberg investigated the importance of the role of reputation for borrowers and banks respectively. They found that borrowers with a more reputable standing led the loan arrangers to assume superior performance even before the loan was given, compared to the assumptions made with regard to borrowers with a lesser reputation. Banks with better reputations were associated with greater profitability and superior credit quality in the three years subsequent to the loans' initiation [1]. Reputation risk was not considered to be one of the eight risks associated with commercial banks by the Basel Committee prior to 1997. After that date, reputation risk is defined as a concept whereby, due to the deviations in the understanding of customers, partners, stock holders, bond holders and other relevant personnel, the sustainable management and business development capacity of a financial institution is affected by the subsequent negative impact. CBRC published its "commercial bank reputation risk management guidelines" in 2009, which clearly pointed out that, not only due to the internal factors but also the external factors affecting a bank, reputation risk reflected the perceptions of the stakeholders in the market. Such definitions are both discussed from the cause and effect, which can be showed in Figure 1.
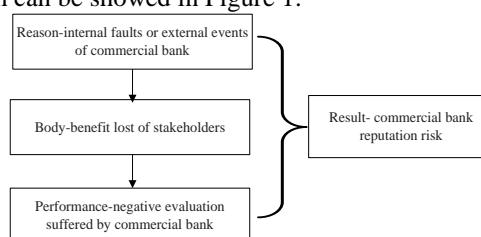

FIGURE 1 Reputation risk formation of commercial bank

* *Corresponding author* e-mail: meiyouyu1987@sina.com

The identification of reputation risk is closely linked to attempts to manage such risks. Reputation surveys suggest that a bank's reputation is constructed around five elements: financial performance, quality of management, social and environmental responsibility, employee quality and the treatment of employees, and the quality of the bank's goods and services [2]. Therefore, from a managerial disciplinary point of view, reputation risk management is a comprehensive approach which involves the anticipation of all potential variables, including taking different stake holders and circumstances into consideration [3, 4]. Ultimately, good management requires foreseeing crises, considering the associated opportunities and threats, and putting control plans into practice. Such an approach is both necessary and valuable to a bank's improving the early warning mechanism and defusing mechanism of reputation risk [5, 6].

The studies mentioned above focus on theoretical analysis, and put forward the corresponding prevention measures through an analysis of the reputation risk causes for commercial banks, rather than dissecting and separating the infectious process and operation mechanism of reputation risk from the dynamic perspective. For rural banks, just as with community banks, whose ability to cope with reputation risk is much less than that of other commercial banks, the key to ensuring steady management is discovering how to master the reputation risk changes effectively and to take timely measures to limit that risk.

2 Reputation risk characteristics of rural bank

Rural bank reputation risk not only has the same characteristics as that of commercial banks, but it also possesses some unique features.

2.1 COMPLEXITY

Many factors induce the reputation risk of a rural bank, the risk may be caused by internal or external factors that cause concern among the public, or the risk can even be caused by the interaction of multiple factors. The effects of these factors may change in terms of their form over time. The main risk factors can be summarized as follows.
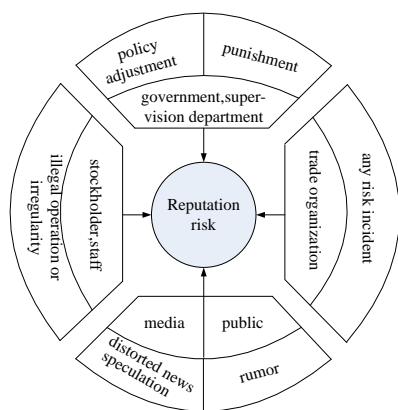

FIGURE 2 Main factors of reputation risk

2.2 INVISIBILITY

Compared with operational risk and credit risk, reputation risk is invisible and therefore extremely difficult to measure. Though some reputation risk evaluation models have been constructed, like the one presented by Harris-Fombrun [7], most banks have not accepted these quantitative analysis methods, and particularly not rural banks with poor technology resources.

2.3 TRANSMISSIBILITY

Reputation risk has strong negative externality, which can be spread via several formats, including television, newspaper, the internet and through the general population. For a rural bank located in a county where the informational development level is relatively low, the latter is the most common way for reputation risk to be disseminated. Apart from the fact that rural residents are gregarious and quick to follow suit, risk incidents are very likely to be distorted or exaggerated in the process of word-of mouth communication, and this can also exacerbate public panic. On March 24 of this year, Sheyang Rural Commercial Bank in Jiangsu suffered a run on the bank by one thousand depositors, merely because of a rumor that the bank was about to fail.

2.4 SUDDENNESS

The suddenness of reputation risk can be reflected in two aspects. On the one hand, there is a process of moving from quantitative changes to qualitative changes in the occurrence of reputation risk without prior warning, which cannot be detected in advance by bank managers. These changes can lead to a sudden outbreak when risk accumulates to a certain level or tipping point. On the other hand, the service objective of rural bank is to give priority to farmers and individual businesses who have a lesser ability to identify information.

3 Reputation risk contagion model of rural bank

The essence of any infectious disease is the transmission of germs from the carrier of pathogens to other individuals through contact. This method of infection is similar to that of rural bank reputation risk contagion. That is, the risk recipients transfer their negative evaluation of a rural bank to other stakeholders via various communication channels. Therefore, rural bank reputation risk contagion is the process of spreading and diffusing a negative evaluation of the bank, which in turn leads to the loss of both capital and customers, and which can even precipitate a rural financial system crisis.

Studies of mathematical models of the spread of infectious diseases began in the twentieth century, and began to flourish in the middle of that period. According to different infectious disease transmission mechanisms, a large number of mathematical models have been produced

in a bid to reveal the causes and systems of disease epidemics to predict development trends, and then to seek the optimal strategies for the prevention and control of epidemics [8]. In general, individuals are divided into several categories in such models, whose basic conditions include susceptible, infected and recovered. Based on the ideas of the infectious disease spread model, this paper establishes parallel dynamic models of rural bank reputation risk contagion.

3.1 SIR MODEL

In this model, the group conditions are divided into three categories, and the classifications can be shown as below.

TABLE 1 Classification of group conditions

Category	Connotation
Spreader	Stands for infector, who has a perceived risk and spreads the negative evaluation to others
Credulous	Stands for susceptible, who is unable to identify the negative evaluation he receives but who continues to spread it to others
Rational	Stands for a recovered ,who can distinguish the authenticity of a negative evaluation

Assumption one: The number of individuals in the model remains unchanged and is given as N.

Assumption two: in the beginning, the number of communicators holding a negative evaluation for a rural bank is i_0; the number of susceptible people who have not been informed of the negative evaluation is s_0 and $i(t)$, $s(t)$, $r(t)$ stands for the proportion of spreader, credulous and rational individuals with time changes respectively.

Assumption three: Each spreader contacts with some credulous individuals in a unit of time, where λ is defined as the unit available contact rate and stays fixed, due to the assumption that each individual can be uniform mixing and contact completely.

Assumption four: A spreader can be transformed into a rational, but the rational also has the chance of being infected again, so using μ to stand for the unit effective removal rate.

Assumption five: The number of the actual dependence of each spreader in unit time can be defined as σ, where $\sigma = \lambda/\mu$.

On the basis of the above assumptions, the model can be built as follows:

$$\begin{cases} di/dt = \lambda si - \mu i \\ ds/dt = -\lambda si \\ dr/dt = \mu i \\ s(t) + i(t) + r(t) = 1 \end{cases}, \tag{1}$$

where $i(0)=i_0$, $s(0)=s_0$. Since the number of rational individuals in the beginning is very small, $i_0+s_0 \approx 1$. In view of the difficulty of solving this problem, we can discuss their properties through the use of phase trajectory. In the

phase plane s-i, its domain can be given as: $D = \{(s,i)|s \ge 0, i \ge 0, s + i \le 1\}$, and eliminating dt can get:

$$\begin{cases} di/ds = 1/\sigma s - 1 \\ i\big|_{s=s_0} = i_0 \end{cases}, \tag{2}$$

where

$$i(s) = (s_0 + i_0) - s + \frac{1}{\sigma} \ln \frac{s}{s_0}. \tag{3}$$

Define s_∞, i_∞, r_∞ as the limit value of s, i, r when $t \to \infty$, so from $ds/dt \le 0$ and $s(t) \ge 0$, s_∞ exists, from $dr/dt \ge 0$ and $r(t) \le 1$, r_∞ exists, also i_∞ exists. Then through simulation and MATLAB software programming, we can draw Figure 3 and Figure 4.
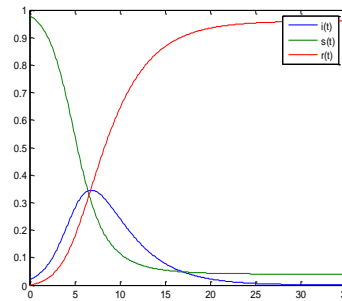

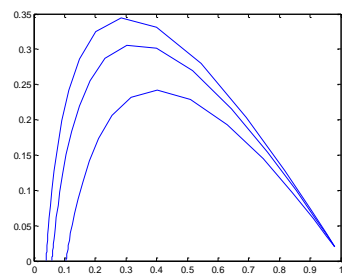FIGURE 3 $i(t)$-$s(t)$-$r(t)$

FIGURE 4 i-s

The parameters in Figure 3 are set as $\lambda=1$, $\mu=0.3$, $s_0=0.98$, $i_0=0.02$; the parameters in Figure 4 are set as $\lambda=0.9$, $\mu=0.3$, and $\lambda=1$, $\mu=0.4$, in addition, with s_0, i_0 unchanged.

Remark one: no matter how much the value of the initial condition changes, the negative evaluation spreader will eventually disappear, due to the assumption of the constant number and no re-entry.

Remark two: Though the results of this model are contradictory to reality, the significance lies in discussing when the spreader number reaches maximization and the seriousness of the spread. When $s_0>1/\sigma$, $i(t)$ is initially on the increase and maximizes at $s(t)=1/\sigma$, then gradually decreases and eventually reaches 0; when $s_0 \le 1/\sigma$, $i(t)$ and $s(t)$ both have monotone decreases, where s_0 is fixed and close to 1.

Remark three: The key to the control of reputation risk contagion caused by the spread of negative evaluations is to increase the value of $1/\sigma$, which can be called the "threshold". If meeting the condition that $s_0 \le 1/\sigma$, the

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negative evaluation will not be extended. Also, from $\sigma=\lambda/\mu$, it is reflected in the sense that we should try to reduce the unit available contact rate of the spreader and improve the unit effective removal rate, in order to effectively prevent the reputation risk contagion.

3.2 SIRS MODEL

In practice, individuals who are removed from the combination could enter it again and hence have a chance of being re-infected. Therefore, against the limitation of the SIR model, we can enhance it, that is to add assumption six based on the assumptions above.

Assumption five: The re-entry ratio of individuals removed from the combination in unit time is set by δ.

The model can be built as follows:

$$\begin{cases} di/dt = \lambda si - \mu i \\ ds/dt = -\lambda si + \delta r \\ dr/dt = \mu i - \delta r \\ i(t) + s(t) + r(t) = 1 \end{cases}. \qquad (4)$$

Since it is difficult to solving, we can use parameter analysis, the values are shown in Table 2.

TABLE 2 Simulated values of different parameters

Parameter	λ	μ	δ	i(0)	s(0)
Simulation one	1	0.3	0.2	0.02	0.98
Simulation two	1	0.3	0.3	0.02	0.98

Through MATLAB software programming, we can draw Figure 5 and Figure 6.
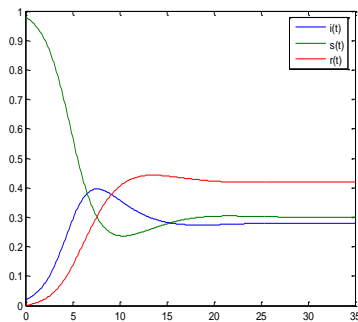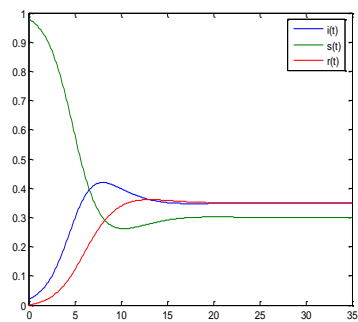

FIGURE 5 *i(t)-s(t)-r(t)* simulation one

FIGURE 6 *i(t)-s(t)-r(t)* simulation two

Remark four: It is reflected that the number of spreaders first increases, then decreases, and finally

stabilizes, both from Figure 5 and Figure 6. Along with the rise of the re-entry ratio, the number of spreaders also becomes larger in succession, not to mention the maximum value. However, the re-entry ratio does not have a significant effect on the occurrence time of the infectious peak. When reaching a steady state, the final number of credulous individuals would be approximately the same, accounting for 30 percent no matter what the re-entry ratio is. Whereas the number of spreader individuals is proportional to the re-entry ratio, which is inversely proportional to the number of rational individuals. From these assumptions, we can see that the re-entry individuals are the rational persons transformed from the spreaders, who may themselves increase the contagion effect.

3.3 SIRS MODEL WITH QUANTITY CHANGE

The number of rural bank stakeholders can change at any time, so adding assumption seven is based on the assumptions above.

Assumption seven: The increased rate of the number of individuals in the combination every unit time is set by α.

The model can be built as follows:

$$\begin{cases} di/dt = \lambda si - \mu i \\ ds/dt = \alpha - \lambda si + \delta r \\ dr/dt = \mu i - \delta r \end{cases}. \qquad (5)$$

Using parameter analysis, the values are shown in Table 3.

TABLE 3 Simulated values of different parameters

Parameter	λ	μ	δ	i(0)	s(0)	α
Simulation three	1	0.3	0.2	0.02	0.98	0.1
Simulation four	1	0.3	0.2	0.02	0.98	0.2
Simulation five	1	0.3	0	0.02	0.98	0.2

Through MATLAB software programming, we can draw Figure 7 and Figure 8.

Remark five: It is shown that the number of spreader and rational persons will increase proportionately with that of individuals in the combination raises in Figure 7, but the number of credulous individuals basically remains unchanged after the eighth period. It is also found that we can effectively control the increase of spreader numbers by reducing the re-entry number under the condition that the increase rate of the number of individuals in the combination stays the same when comparing Figure 7 with Figure 8.
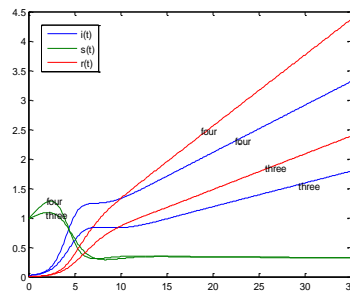

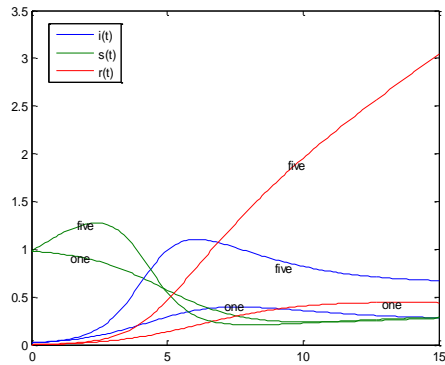FIGURE 7 *i(t)-s(t)-r(t)* simulation three and four

FIGURE 8 $i(t)$-$s(t)$-$r(t)$ simulation one and five

$$\begin{cases} di/dt = \varepsilon e - \mu i \\ ds/dt = \alpha - \lambda se + \delta r \\ dr/dt = \mu i - \delta r + \upsilon e \\ de/dt = \lambda se - \varepsilon e - \upsilon e \end{cases}.$$

Using parameter analysis, the values are shown in Table 4.

TABLE 4 Simulated values of different parameters

Parameter	λ	μ	δ	i(0)	s(0)	α	ν	ε	e(0)
Simulation six	1	0.3	0.2	0	0.98	0.1	0.1	0.6	0.02
Simulation seven	1	0.3	0.2	0	0.98	0.1	0.2	0.6	0.02

3.4 SEIRS MODEL

In general, there is always an incubation period before the credulous becomes the spreader after receiving negative evaluation, and the credulous individual will not infect others during that incubation period. If controlled in a timely manner, the credulous individual could be turned into a rational individual, therefore, adding assumption eight and nine based on the assumptions above.

Assumption eight: The credulous individual during an incubation period can be called a lurker; $e(t)$ stands for the proportion of lurkers with time changes.

Assumption nine: The lurker removal rate is defined as υ, and the lurker infected rate is defined as ε.

The model can be built as follows:

Through MATLAB software programming, we can draw Figure 9.

Remark six: Depending on the actual situation, the credulous individual should initially be a lurker, so it can be found after correcting the parameter values that the changes of different category numbers slows down. If adding the lurker removal rate under the condition that the other parameters remain unchanged, the number of spreaders would reduce in all periods, as well as the peak value, and even the peak period would be delayed. On the whole, the process of rural bank reputation risk contagion can be divided into about six stages, namely 1) incubation period, 2) start period, 3) outbreak period, 4) recession period, 5) fluctuation period and 6) stability period, and this conforms precisely to reality.
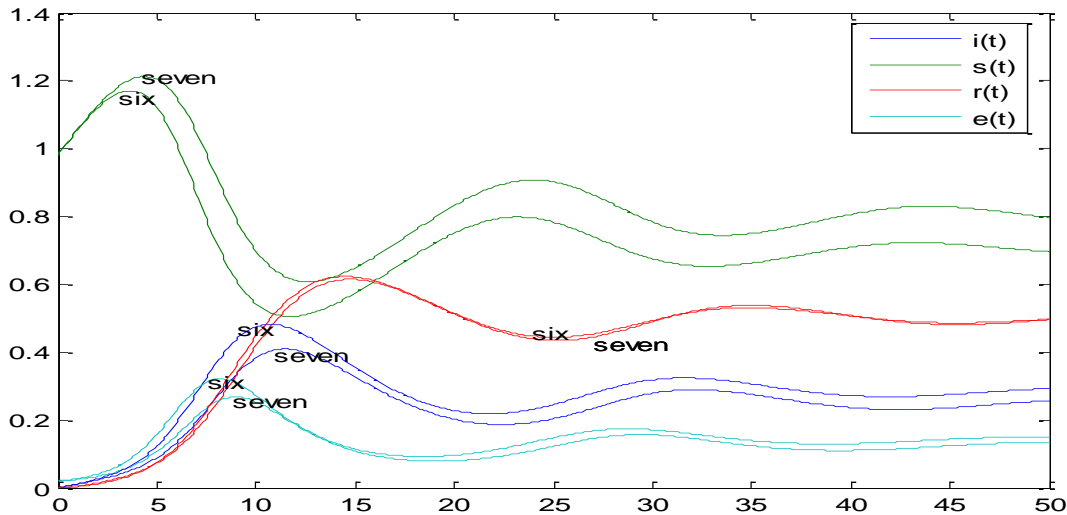

FIGURE 9 $i(t)$-$s(t)$-$r(t)$ simulation six and seven

4 Reputation risk control strategy of rural bank

As a new subject in the rural financial market, rural banks have a greater chance of suffering reputation risk, since given the limits of low recognition and credibility. Moreover, rural banks always tend to focus on business development while ignoring the importance and necessity

of reputation risk management. Therefore, it is essential for these banks to establish a sound set of reputation risk management systems and procedures. According to the study above, we can propose the corresponding countermeasures from three aspects, which are showed in Figure 10
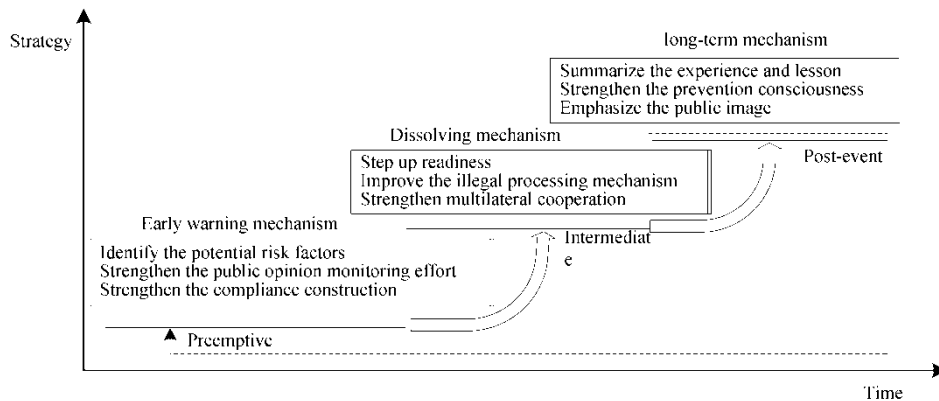
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FIGURE 10 Countermeasures of rural bank reputation risk

4.1 PREEMPTIVE CONTROL - EARLY WARNING MECHANISM

Identify the potential risk factors. Rural banks should make regular investigations into every business unit or sector where reputation risks may be found. Based on the combined methods of quantitative analysis and qualitative diagnosis, the bank can identify the potentially dominant risk factors, as well as the recessive ones, and issue a warning signal, which would enhance the bank's ability to react rapidly and make appropriate decisions.

Strengthen the public opinion monitoring effort. Rural banks should be responsible for the daily dynamic and real-time monitoring of public opinion. They should also strive to excavate and process the spreader individuals while they are still in the incubation period, in order to reduce the contact opportunities and decrease the proportion of spreaders. Such actions could significantly lessen the scale of risk infection and delay the peak time, or even act to curb the reputation risk contagion [9]

Strengthen the compliance construction. The internal reasons which cause rural bank to receive negative evaluation may include illegal operations, poor attitudes with regard to customer service, or withholding information. Therefore, the banks should increase the supervision and detection of abnormal or bad behaviours by their employees.

4.2 INTERMEDIATE CONTROL - DISSOLVING MECHANISM

Step up readiness. When negative evaluations spread, rural banks should promptly and persistently release timely, accurate and scientific information to the general public, to eliminate the negative impact of the poor evaluation as far as possible.

Improve the processing mechanisms for dealing with illegal activity. For those who act maliciously or spread inaccurate information, rural banks should quickly take legal action. Those who break the law must be prosecuted [10].

Strengthen multilateral cooperation. When negative events occur, rural banks should change their approach from one of escape to one of actively responding,

regardless of whether the information is false, partially accurate or completely true. The bank must clarify the true facts via the authorities or the media. Bank executives, village cadres, regulators, the government, TV, newspapers and so on should be used to take practical actions to answer questions and divert discontent. In short, the bank can control the further spread of poor evaluations through good public relations practices.

4.3 POST-EVENT CONTROL - LONG-TERM MECHANISM

Summarize the experience and the lessons to be learned. Rural banks should create a summary and report when reputation risk happens, in order to accumulate work experience which can be used in the future to prevent and defuse the similar crises, as well as to improve their ability to comprehensively dispose of a reputation crisis.

Strengthen the prevention consciousness. The staffs of rural banks are typically new graduates who have limited capacity and experience. Therefore, rural banks should organize for all their staff to participate in professional training or lectures, in order to actively cultivate their awareness of reputation risk prevention and reputation management skills, as well as to sublimate reputation risk management to the business philosophy of the banks' culture. Moreover, the staff should strengthen their service consciousness and disseminate their financial knowledge to the local populace, as this could enhance their own legal awareness and information recognition abilities.

Emphasize the public image. Firstly, rural banks should try to improve customer satisfaction through the creation of obligation informs, to address solutions pro-actively and to protect the legitimate rights and interests of customers. Secondly, the banks should increase external publicity, using the power of public media to improve their social reputation. Thirdly, the bank should exchange and share their reputation risk management experiences with their peers. This could result in the mutual supervision of risks and enhance the anti-risk abilities of the entire industry. Ultimately, building a good reputation for all rural banks would improve customer brand loyalty and help reduce losses to the lowest possible level.

5 Conclusions

Rural bank reputation risk can be defined as negative evaluations by stakeholders that are not only due to internal factors but also to external ones. Since the essence of rural bank reputation risk contagion is similar to that of infectious diseases, this paper uses epidemic models to deduct contagion mechanisms under different situations, in order to excavate the key indicators to prevent or regulate reputation risk contagion, then puts forward an early warning mechanism, dissolving mechanism and long-term mechanism to realize full process control, which could act as an important and significant reference.

Acknowledgment

References

[1] Bushman R. M, Wittenberg M R 2012 The role of bank reputation in 'certifying' future performance implications of borrowers' accounting numbers *Journal of Accounting Research* **50**(4) 883-930

[2] Bebbington J, Larrinaga C, Moneva J M 2008 Corporate social reporting and reputation risk management *Accounting, Auditing & Accountability Journal* **21**(3) 337-61

[3] Okur M E, Arslan M L 2014 Reputation management in global financial institutions *Managerial Issues in Finance and Banking* 173-84

[4] Scandizzo S 2011 A framework for the analysis of reputational risk *Journal of Operational Risk* **6**(3) 217-35

[5] Lu M, Pan X 2010 Construction of reputation risk-resolving mechanisms of commercial banks *Journal of Shijiazhuang University of Economics* **33**(3) 7-11 *(In Chinese)*

[6] Liu M 2013 Research on reputation risk management of commercial banks in post-crisis era *Accounting and Finance* **28**(1) 57-60

[7] Fombrun C J, Gardberg N A, Sever J M 2000 The reputation quotient: a multi-stakeholder measure of corporate reputation *Journal of Brand Management* **7**(4) 241-55

[8] Hethcote H W 2000 The mathematics of infectious diseases *SIMA Review* **42**(4) 599-653

[9] Lan Y 2012 Research on network rumor diffusion model and countermeasures in the emergency *Information Science* **30**(9) 1334-8

[10] Qiao H, Li Y 2013 Research on the conduction and effect of reputation risk of financial enterprises *On Economic Problems* 36(9) 87-92

Author

Yu Wu, born in March, 1987, Luoyang County, Henan Province, China

Current position, grades: the lecturer of school of economics, Henan University of Science and Technology, China.
University studies: doctor's Degree in Management from Wuhan University of Technology in China.
Scientific interest: financial engineering, rural finance.
Publications: more than 7 papers.
Experience: teaching experience of 4 years in spare time, 1 scientific research project.

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