Study on optimal risk sharing policy of Chinese crop insurance: a case study from government perspective

Ke Wang, Ran Huo, and Qiao Zhang

Ke Wang is a Ph.D. Student of Graduate School of Chinese Academy of Agricultural Science (CAAS), assistant professor at Agricultural Information Institute of CAAS and Key Laboratory of Digital Agricultural Early-warning Technology of Ministry of Agriculture of China. Address: No.12 South Zhongguancun St. Beijing 100081 China. Tel: 86-10-5949 2969; Fax: 86-10-8210 6261. E-Mail: wangke01@caas.cn ; wangkeable@yahoo.com.cn

Ran Huo is a Master Student of Graduate School of Chinese Academy of Agricultural Science (CAAS), Address: No.12 South Zhongguancun St. Beijing 100081 China. E-Mail: hr_096@163.com

Qiao Zhang is a Ph.D and professor at Agricultural Information Institute of Chinese Academy of Agricultural Science (CAAS) and Key Laboratory of Digital Agricultural Early-warning Technology of Ministry of Agriculture of China. Address: No.12 South Zhongguancun St. Beijing 100081 China. Tel: 86-10-8210 9883; Fax: 86-10-8210 6261. E-Mail: zhangqiao@caas.cn
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1. Introduction

Considered as an effective risk management tool for stabilizing farmers income, increasing the food production and ensuring food security, crop insurance has been developed or piloted in more than half of all counties in the world (104 countries in 2008) since the first non-private crop insurance was success in the United States in 1938 (Mahul and Stutley, 2010). However, since the risk that agricultural insurance against have the properties of both independence and correlation, agricultural disasters are usually spatially dependent, affecting the crop production in adjacent regions simultaneously (Skess and Barnett, 1999). Because of the systemic features of agricultural risk, the crop insurance was estimated twenty to fifty times riskier than the conventional property insurance with independent risk exposures (Miranda and Glauber, 1997). Therefore, agriculture reinsurance is extremely needed to be developed for diversifying the risk of crop insurance otherwise the insurers cannot afford the high indemnity and will be doomed to bankrupt (Turvey, Nayak, and Sparling, 1999; Xie, 2003; Feng, 2004; Deng, 2006; Xu, 2008).

From the experience of forerunners of crop reinsurance, such as U.S. and Canada, government plays a dominant role in developing a sound agricultural reinsurance system because no private reinsurer or pool of reinsurers has the capacity to cover such a large liability when the risks may be difficult to diversify. In additional to premium subsidy, Chinese government also plans to contribute more on the developing of crop insurance risk diversification mechanism including crop reinsurance for decreasing insurers’ risk exposures, and to prompt the development of Chinese crop insurance program. But the establishment of agricultural reinsurance system has been just started in China, and the provincial governments instead of central government begin to share the risk of crop insurance with insurers. The primary way of provincial governments in decreasing the shock of catastrophic (CAT) events on crop insurance is to exclude the payout obligations of insurers when the loss ratio (Indemnity/Premium) of crop insurance at the year when the loss ratio goes beyond a given threshold (above 100% of course). For example, Beijing municipality stipulates that crop insurance companies only need to pay up to 1.6 times of its premium income and the government as a reinsurer will pay for the rest of indemnity if the loss ratio of crop insurance are above 160%. Similarly, in Henan province, the government will take 50% of indemnity responsibility when the crop insurance loss ratio of insurers is above 200% at that year. In practice of China’s crop insurance, the responsibility boundary (e.g. 160% in Beijing
and 200% in Henan) between insurers and government in terms of indemnity are determined intuitively, judged by policymaker’s experiences and negations. But does the practical responsibility boundary between insurer and government make sense? How to divide the appropriate responsibility of crop insurance indemnity between insurers and government? Those are important questions for China to develop appropriate and sound crop reinsurance system.

In our opinion, the above questions are similar to the determination of optimal stop-loss ratio in Chinese agricultural reinsurance programs. Optimal reinsurance strategy has always been an interesting topic for economists and actuaries. Many studies was done to discuss the optimal reinsurance strategies in layer reinsurance and stop loss reinsurance under the criterion of the minimum of Value at risk (VaR) or conditional tail expectation (CTE) (Cai and Tan, 2007; Cai et al, 2008; Porth, Tan and Weng, 2012, Hi and Tan, 2011). Some scholars also investigated the optimal reinsurance behaviors in the context of SRA reinsurance policy (Coble, Dismukes and Glauber, 2007; Pai and Boyd, 2010). Most of these studies, however, rest on the standpoint of insurance companies. Notable exceptions are Hayes, Lence and Mason (2003) and Mason, Hayes, and Lence (2003) who estimated the probability density function (pdf) of FCIC reinsurance exposures that ceded by crop insurance companies though the Stand Reinsurance Agreement (SRA). Although from the view of government, their studies pay little attention to the indemnity boundary between FCIC and insurer. In China, most studies on crop reinsurance are to conduct the qualitative discussion on how to establish agriculture reinsurance system (Tuo and Li, 2003; Xie, 2003; Dai, 2006; Liu, 2006; Li et al., 2004; Long, 2007; Huang, 2009). An exception is Gao, Xing and Li (2009) who tried to find out the appropriate threshold in the indemnity sharing of Beijing’s crop insurance by policy simulation, but their study were criticized because their conclusion are made using the short period and inconsistent of crop insurance loss ratio data (Indemnity/ premium). This paper will be the first one to conduct quantitative investigation on the optimal stop loss of crop reinsurance for Chinese policy-makers from government perspective. The multivariable pdf generated by Copula approach, Monte Carlo simulation and nonlinear programming will be used to calculate the optimal sharing ratio between insurer and government in terms of crop insurance indemnity. It is believed that this paper has significant implications for China to set up crop reinsurance system because we proposed a suitable methodology to identify the responsibility of government and insurers in crop reinsurance.

The remainder of this paper is organized as follows. The second part is the overview of current crop insurance and reinsurance policy of China. Following this, the model and studying approach of this paper are discussed. Then, the sample data simulation and empirical results are
demonstrated in the fourth section. The fifth section presents the discussion based on empirical results, and the conclusion and policy implications are presented in the final section.

2. Crop insurance and reinsurance in China

Since 2007 when central government began to provide premium subsidy, Chinese agricultural insurance has been experiencing a soaring growth. Before that, agricultural insurance was operated by private sector and the scale of agricultural insurance market was very small with a slow pace of development. In 2005, Chinese agricultural insurance premium was mere 729 million yuan which took account of 0.6 percent of non-life insurance premiums of 123 billion yuan. However, in 2007, only two years later, with implement of the subsidy policy this percentage skyrocketed to 5.2%. In 2012, the crop insurance with government subsidy was officially implemented in national wide and both the number of crop variations insured and insurance coverage increased. According to CIRC, accumulative premium of Chinese agriculture insurance since 2007 had exceeded 84 billion yuan and accumulative indemnity was over 54 billion yuan (available at website of CIRC1).

Although China’s agricultural insurance are developing at a rapid pace since 2007, it still needs to be improved and perfected. As for reinsurance system construction, a few of provincial governments have introduced some policies (the forerunners include Beijing, Henan, Zhejiang, Jiangsu). In Beijing, Henan and Zhejiang provinces, governments cap the indemnity of agriculture insurance companies and introduce risk sharing policy. In Beijing, the municipal government, acting as the last insurer, undertake the remaining liability if the loss ratio exceeds 160% in the year when the catastrophes occur. In addition, the municipal government purchases reinsurance in private reinsurance market to cover the indemnity risk between 160% and 300%, they also established reserve fund for the risk over 300%. In Henan, the government caps the loss ratio of crop insurance at 300%. If the loss ratio exceeds 300%, the actual indemnity will be shrinking. In the period between 200% and 300%, local government and insurer will pay 50% of the indemnity, respectively. In Zhejiang province, the risk sharing arrangement is more complicated. Government and insurer will pay farmers with the proportion of 1 to 1 when insurer’s loss ratio is between 200% and 300%, and pay with the proportion 1 to 2 when insurer’s loss ratio is from 300% to 500%. Different from the three provinces, Jiangsu government participates into insurance operation activities and shares 50% of premium and indemnity of crop insurance. Table 1 summary the reinsurance arrangement in sample provinces of China.

Table 1. Reinsurance arrangement in four provinces of China

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<table>
<thead>
<tr>
<th>loss ratio</th>
<th>Henan</th>
<th>Zhejiang</th>
<th>Beijing</th>
<th>Jiangsu</th>
</tr>
</thead>
<tbody>
<tr>
<td>above 500%</td>
<td>-</td>
<td>-</td>
<td>Gov:Insurer=1:2</td>
<td>Gov:Insurer=1:1</td>
</tr>
<tr>
<td>300%-500%</td>
<td>-</td>
<td>Gov:Insurer=1:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200%-300%</td>
<td>Gov:Insurer=1:1</td>
<td>Gov:Insurer=1:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>160%-200%</td>
<td>Insurer</td>
<td>Insurer</td>
<td>Insurer</td>
<td></td>
</tr>
<tr>
<td>100%-160%</td>
<td>Insurer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%-100%</td>
<td>Insurer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Insurer represents agricultural insurance companies; Gov represents government; Gov:Insurer denotes the ratio of liability shared between government and agricultural insurance companies; - means none and beyond the cap of liability.

3. Methodology

As mentioned above, government should provide some reinsurance support to insurers because of the systemic feature and significant spatial correlation of crop risk. In China, the mainly support of government to insurers is sharing part of crop insurance indemnity when catastrophic risk occurs. But as a public agency, the main objective of government when providing the reinsurance support to insurers should be the maximization of social welfare. Therefore the government should be set appropriate sharing ratios of crop insurance indemnity with insurers because it will be criticized and insurers will earn more many if he take more risk and the insurers may be bankrupt if he take less risk. In our opinion, the optimal risk sharing ratio can be achieved by minimizing the stand derivation of insurer’s loss ratio (Indemnity/Premium) among alternative reinsurance polies with the help of Monte Carlo simulation and nonlinear programming.

In this paper, we assume the provincial government will act as reinsurer to sharing the crop insurance indemnity loss with insurer. We take Shandong, a main crop province in China, as example to analyze how the optimal crop reinsurance ratio is estimated from government perspective. One company, SDCI, was fabricated to run the crop insurance business in five counties of Shandong, and provides the insurance of wheat, corn and cotton which are the main crops in Shandong. Because of the actual loss data (Indemnity/Premium) of Chinese crop insurance are in very short period and poor-quality due to moral hazard and fraud during loss claiming, the simulation data instead of actual loss data of crop insurance insurers are used in this paper. The optimal risk sharing ratio between SDCI and Shandong government in crop insurance indemnity can be estimated following the steps shown in table 2.

| Table 2 Main steps to estimate optimal crop reinsurance ratio from Gov.’ perspective |
|-----------------|----------------------------------|
| Step            | Describe                         |
| 1.              | Estimation of yield pdf at county-level for each crop and each county |
2. Calculate the joint yield pdf using copula method for each crop
3. Generate the simulated yield using Monte Carlo Simulation
4. Estimate the crop insurance indemnity for each crop and each county
5. Estimate the loss of insurer and reinsurer with crop reinsurance policy
6. Calibrate the optimal risk sharing ratio using nonlinear programming

- The first step consists of estimating the probability density function (pdf) of yields at the county level for three crops and five counties in Shandong. This is accomplished by parametric approach using detrended county-level historical yields data. The most appropriate parametric distributions are selected according to the goodness-of-fit test, and the specific parametric values are estimated using the method of maximum likelihood.

- The second step is to calculate the combined pdf using Copula method for each crop. Because of the significant spatial correlation in terms of crop risk exposures, the multivariable probability distribution which taking account of the yield correlation of five counties should be established before Monte Carlo simulation. As the advantage of copula to establish multivariable distribution, Copula was adopted in this paper to estimate the joint pdf of five counties for each crop.

- The third step is to generate 1000 random yields using Monte Carlo method according to the joint pdf established in step two for each crop and each county.

- The fourth step is to estimate the possible crop insurance indemnity and loss ratio for each crop and each county according to the practical crop insurance policy in Shandong. The premium were estimated using the simulated yield data, and simple moving average with five years lag were adopted to calibrate the yield trend with the aiming of make the estimation of yield trend consistency with practical operation in Chinese crop insurance program.

\[
\text{Indemnity} = P \ast A \ast \max(0, c \ast \bar{Y}_i - y_i)
\]

\[
\text{Premium} = P \ast A \ast (1 + \theta) \int_0^{c\bar{Y}} (c\bar{Y} - y) f(y)dy
\]

Where, P indicates the price of crop insured; A indicates the coverage area; c indicates the coverage level; y_i denotes the actual yield, \( \theta \) is the administration and safe loading, and

\[
\bar{Y}_i = \sum_{t=0}^{4} y_{i-t} / 5 \quad (i > 5).
\]

- The fifth step involves calculation of the loss or LCR of the SDCI insurance company with the
policy of stop-loss reinsurance. Let $X$ denote the loss of crop insurance. Because insurer cedes part of its losses to government and capped losses at $D$, say, then the insurer’s loss $X_I$ equals to

$$X_I = \begin{cases} 
(X + R(D)) & \text{if } X \leq D \\
(D + R(D)) & \text{if } X > D 
\end{cases}$$

Where $R(D)$ means the reinsurance premium and can be calculated as the following formula.

$$R(D) = E[X_R] = E[(X - D)^+] = (1 + \rho) \int_{D}^{\infty} (X - D)^+ \cdot f(X) \, dX$$

Where $\rho$ denotes the loading factors for reinsurer, and $f(X)$ is the pdf of crop insurance.

The sixth step is to calculate the optimal risk sharing ratio $D$ in crop reinsurance from government perspective using nonlinear programming. As mentioned earlier, the objective of government as a reinsurer is to stabilize the risk of crop insurance business and decrease the risk of insurers. Thus, the programming function can be demonstrated as following.

$$\text{Min } SD \left( \frac{X_I}{\text{Premium}} \right) \quad s.t. \begin{cases} 
0 \leq X_I \leq D \\
R(D) \leq R^* \\
\text{VaR}_{X_R}(95\%) \leq G^* 
\end{cases}$$

Where $R^*$ denotes the insurer’s budget constraint of reinsurance premium which rely on insurer’s size, financial capability and risk perception. $G^*$ indicates the loss constraint of government which is now set by provincial governments of China, and $G^*$ is assumed to equals 1% of the accumulated agricultural GDP in this paper.

Reference