Empirical Issues in Crop Reinsurance Decisions

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by

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Abstract

This paper investigates the role of reinsurance in the managing the liquidity or reserve fund risks facing a crop insurer. Using 31 years of data, combined with Monte Carlo simulation the paper illustrates a mechanism for calculating reinsurance premiums and determining the post insurance risk profile. The insured event is over a range of loss ratios, and the focus of the paper is on reserve fund balances.

Key Words: Reinsurance, crop insurance, agricultural risks

Empirical Issues in Crop Reinsurance Decisions

In Ontario, the Crown Corporation responsible for crop insurance (Agricorp Ltd.) faces two problems. First, there is a need to reduce the effect of a catastrophic loss on reserve funds and maintain reserve fund liquidity, thereby guaranteeing the self-sustainability of the crop insurance program. Second, crop insurance must minimize year-to-year variation in premium rates to provide stability to farmers and predictability for the budgeting processes of the two levels of governments (federal and provincial) which fund the program. This stability could be achieved only by purchasing private sector reinsurance, as Ontario is not a part of a federal-provincial reinsurance plan.

This paper empirically investigates stop-loss reinsurance strategies under (7) different reinsurance trigger levels and then examines their respective impacts on the reserve fund balance. The objectives are to

1. show how the decision to reinsure and the choice of reinsurance trigger depends on how willing the crop insurer is to take risk,
2. examine how reinsurance meets the business objectives of the agency, and
3. illustrate why the relationship between reinsurance triggers and capital reserve fund balances are important.

The objectives are met using 31 years of historical crop insurance data (e.g. loss ratios) for Ontario. In addition to analyzing the historical data to determine the expected indemnity from a reinsurer's perspective, Monte Carlo simulation is used to determine possible outcomes and likelihood's for variables such as the loss ratio, reinsurance claims, and fund balances. Seven trigger levels based on loss ratios are examined. Since the crop production technology has changed in terms of biotechnology and management techniques (e.g., high yielding, pest, disease and drought resistant varieties), the analysis is also done using the most recent 16 years of data to more realistically represent the present risk profile.

Background

With the exception of Miranda and Glauber (1997) and Turvey, Nayak, and Sparling (1999) no serious academic research has focused on reinsurance in the agricultural marketplace. Miranda and Glauber (1997) argue that if failures in agricultural insurance markets are due to systemic or systematically correlated risks rather than adverse selection then the emerging

reinsurance market, or even exchange traded derivatives based on area yields, can provide a mechanism for the transfer of risks outside of agriculture. They point out that the most efficient type of reinsurance could be based on (U.S.) State average yields. Turvey, Nayak and Sparling (1999) developed an economic theory of the reinsurance problem. An economic model described the risk portfolio of the insurer, was used to explain insurer risk, and posited the actuarial solution for the reinsurance premium calculation if reinsurance were to be purchased on an entire risk portfolio. This extended Miranda and Glauber (1997) to a multiple crop rather than single crop (e.g. a portfolio of 1) reinsurance contract, and accounts for not only the systematic risks of individual crops across spatial lines, but also for systematic correlation across crops. Turvey et al (1999) also show that the significance or benefits of reinsurance may not be explicitly defined by indemnities alone but rather the liquidity of capital held in reserve funds. Consequently, for a crop insurer with significant cash reserves the need to reinsure would be minimal while one with low cash reserves would require reinsurance to provide liquidity.

Approaches to Reinsurance

Quota share reinsurance is mostly used by emerging or growing insurers whose portfolio contains risks with a high level of homogeneity. The reinsurer and the reinsured share in the profits and losses in proportion to the size of their share. It is difficult to place quota share reinsurance and there is little interest or appetite among most reinsurers it. It is also not suitable for Crop insurers with reasonably high reserve fund balances and an ability to offset large liabilities.

    Excess of loss reinsurance is one of the most effective and widely used forms of reinsurance. It provides capacity and stability by capping losses at a fixed retention level. It is simple, easy to administer and is suitable for crop insurers with well diversified portfolios and in a position to absorb average while reinsuring peak losses.

    This paper investigates stop-loss reinsurance strategies for a diversified crop insurer with several possible stop loss layers of reinsurance. The information of interest is the expected indemnity and the possibility/probability of being indemnified from the reinsurer and the effect that the reinsurance/no reinsurance decision has on the crop insurer's reserve fund level.

Calculating the expected indemnity from the reinsurers perspective is crucial to judge whether the premium rates quoted by the reinsurers is reasonable and actuarial for the crop insurer.

Methodology:

Of the several methods of pricing excess of loss reinsurance, loss experience rating is the most common approach.[1] Since Agricorp has substantial historical (and publicly available) information the loss experience rating method is used in this study. One of the basic assumptions made is that the proportion of the crop insurer's crop mix/customer base equals the average weighting of the portfolio over the time horizon used. One of the possible changes to this assumption could have been to set 1999's crop insurance portfolio mix equal to the1998 mix. Turvey et al (1999) show that expected indemnities are conditioned on the proportion and riskiness of crops in the insured portfolio.

The analysis is done using two sets of data. One set of analysis was done using 31 years (1967 to 1997) of aggregate provincial loss history. To account for changes in technology, climate and other factors a second data set comprising the most recent 16 year' loss history (1982 to 1997) is used..

Monte Carlo Simulation:

The data was analysed using Monte Carlo Simulation. The theoretical distribution that best describes the empirical distribution of historical loss ratios was selected using Palisade Corporation's BestFit computer program by conducting three goodness of fit tests: (1) Chi-square test (2) Kolmogorov-Smirnov test (3) Anderson-Darling test. Twenty-eight theoretical distributions were tried and the best-fit distribution was selected by averaging the ranks given by the three tests.

The beta distribution best described the empirical loss distribution for both 31 and 16-year information. The estimated parameters and the distribution function are Beta(0.55,1.56)*2.77+.27 and Beta(0.30,0.79)*2.17+.27 for the 31 and 16 year horizons respectively. Ten thousand observations were drawn using Palisade corporation's @Risk

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[1] Where there are no historical losses available retention exposure rating method is used. This involves setting a price on the values and types of risks that are large enough to potentially impact the treaty.

computer program. Reinsurance claim and reserve fund balances under different stop loss layers are also simulated using the simulation outcomes of loss ratio.

Results

The expected indemnities from the reinsurer calculated using the historical loss ratio and simulated loss ratio under seven stop loss scenarios are given in Table 1. The expected indemnity is highest with 175 x 125 layer and lowest with 50 x 250 layer. (The terminology means that loss ratios above 1.25 are to be insured up to a maximum of 3 (1.25+1.75) in the first case and between 2.50 and 3.00 (2.5+.50) in the second case.)Both of these scenarios may not be of interest to the crop insurer since it would transfer higher risk to the reinsurer with 175 x 125 and hence it will be expensive, while transferring minimal or no risk with the 50 x 250 layer. It may be noted that each of the seven scenarios designed, individually, may not be of interest. However, These scenarios are designed in such a way that it should be able to create many other scenarios without doing further analysis, and the calculated/simulated indemnities serve as a bench mark information set to assess whether the reinsurance premiums quoted by the reinsurance companies are actuarially reasonable.

The reinsurance claim rates (as a % of premium collected) are calculated using 31 and 16 year historical information with the16 year analysis more closely reflecting the current crop plan design and risk profiles of the crop insurer. It is interesting to note that the expected indemnities are the same for 150 x150 and 100 x 150 stop loss layers (Table 2) when 16 years information is used. It indicates that the crop insurer would be transferring the same level of risk to the reinsurer under both these layers.

Loss Ratio Analysis

The minimum, maximum, mean, standard deviation and skewness of empirical and simulated loss ratios are given in Table 2 . The simulation (and also historical information) analysis indicates (for 16 year history) that if the best possible outcome occurs, the loss ratio would be 0.27 and if the worst possible outcome occurs the loss ratio would be 2.44. The average loss ratio is 0.87 with a standard deviation of 0.67.

The distribution of loss ratios is positively skewed. This implies that the probability of a loss ratio less than the mean (i.e., less than 0.87) is higher than the probability that the loss ratio

will exceed the mean. The simulated Beta is less positively skewed than the empirical distribution. The implication of this in interpreting the simulation results is discussed below.

The probability of occurrence of losses is given in Table 3. Based on 16 year information, the probability of a loss ratio being less than 1 is 66.52%; less than 1.25 is 73.23%; less than 1.5 is 79.07%; and the probability of the loss ratio exceeding 2.5 is zero. It should be noted that the Beta distribution used for simulation is more positively skewed than the empirical distribution. This means that the estimated probabilities associated with falling below the above loss ratios may be conservative in a sense that actual probabilities could be higher.

Reinsurance Claim Rates and the Probability of Occurrence

The probabilities of occurrence of different claim rates are given in Table 4. The possibility of "no claim" is high under all stop loss layers studied. The probability of the loss ratio falling below 1.25 is 73%; falling below 1.5 is 79%; falling below 2.0 is 90%; and falling below 2.5 is 100%. This means, for example, that 79% of the time there will be no claim from the reinsurer when the crop insurer is responsible for all the indemnities below a loss ratio of 1.5 and above a loss ratio of 3.0.The results also indicate that there is an 81.3 % chance of claiming less than the premium paid with stop loss layers of 150 x 150 and 100 x 150; 80.78% for 50 x 150; 90.10% for 50 x 200; 74.7% for 25 x 125; and 77.1% for 175 x 125.

Simulation of Fund Balance under Different Stop Loss Layers and NO Reinsurance

The reserve fund balance is simulated assuming that the starting fund balance is $222 million and annual premium collected would be $70 million. The results are given in Tables 5 and 6. Table 5 shows the minimum, maximum, mean, and standard deviations of the simulations under the various stop-loss layers. If the worst case loss occurs (minimum fund balance), then the reserve fund balance will be highest with the 175 x 125 layer ($194.65 million) followed by 150 x 150 and 100 x 150 ($179.83 million), 50 x 150 ($152.12 million), 50 x 200 ($148.91 million), and 25 x 125 ($136.02 million). The fund balance will be lowest with no reinsurance ($121.20 million). If the best case loss occurs the trend will reverse. That is, the fund balance will be highest with no reinsurance ($273.10 million) followed by 25 x 125 ($270.42 million); 50 x 200 ($270.01 million); 50 x 150 ($269.02 million); 150 x 150 and 100 x 150 ($265.93 million); and 175 x 125 ($263.24 million).

It may be noted that the probability of the fund balance going below $100 million is zero with all the stop loss layers including the no insurance strategy (Table 6). The probability of the fund balance going below $150 million is zero with 150 x 150, 100 x 150, 50 x 150 and 175 x 125. There is a 10.75% probability that the fund balance may go below $150 million with 50 x 200, 9.85% probability with no reinsurance, and 5.38% probability with 25 x 125. The possibility of the fund balance falling below the base reserve fund balance ($222 million) is lowest with no reinsurance (33.48%) and highest with the 175 x 125 layer.

The results indicate that the choice of the stop loss layers really depends on the objective(s) of the crop insurer. For example, if the objective is to have a minimum fund balance of $100 million then all strategies are equally preferred (not considering the cost). If the objective is to have a minimum fund balance of $150 million then the strategies 50 x 200, 25 x 125 and no reinsurance could easily be discarded.

It is important to distiguish between probability of loss and actual loss when interpreting Tables 5 and 6, for these are in themselves separate and mutually exclusive corporate objectives. For example if the objective is to minimize the maximum loss in reserve funds then there is a clear signal by the results in Table 5 that to reinsure at some level would be prudent since the no reinsurance scenario does result in the lowest possible fund balance. Capital reserve requirements and agency requirements may force the crop insurer to reinsure against such possibilities. In contrast, if the objective is to minimize the probability that fund balances decrease from current levels then the best alternative would be to do nothing. In fact the no reinsurance scenario not only sets the possibility for the largest fund reserve of $273 million, but also has the greatest probability of seeing an increase in the fund. To rely on the probability of outcomes criteria would likely be imprudent in the real world, especially when it is noted that the no-reinsurance scenario has the lowest mean and the highest standard deviation.

Summary and Conclusions

This paper set out to investigate some empirical issues relating to the problem of reinsuring agricultural crop insurance losses. These objectives were to

1) show how the decision to reinsure and the choice of reinsurance trigger depends on how willing the crop insurer is to take risk,

2) examine how reinsurance meets the business objectives of the agency, and

3) illustrate why the relationship between reinsurance triggers and capital reserve fund balances is important.

This paper used monte carlo simulation to investigate the impact of reinsurance on the fund balances of a crop insurance company. The means of reinsurance was not directed at the reserve balances per se, but rather the loss ratios directly. The industry practice is not to reinsure all losses below a target, but rather to reinsure a range of losses. For example a reinsurance contract may stipulate that the reinsurer will indemnify the crop insurere for all losses above a loss ratio of 1.5 and less than 2.5. The crop insurer would then be responsible for losses between 1.0 and 1.5, as well as those above 2.5.

The extent by which a crop insurer will actually reinsure depends upon a number of factors. The most important factor appears to be reserve fund balances which maintain the liquidity of the insurance company. The higher the reserve fund balances the better able the company is to self-insure and the less likely it will require reinsurance. In addition, the requirement for reinsurance depends upon the nature of the organisation and the attitude of its managers and directors toward risk. On one hand it would be easy to dismiss reinsurance if the objective is to select the strategy which has the least probability of falling below current reserve fund levels. Because a no reinsurance strategy requires no premiums this strategy would be best. However, crop insurer have legislative mandates and boards of directors who view the funds as belonging to the customer base rather than the corporation and their objective is to ensure the maintenance of the fund not in probabilistic terms but in real dollars. In this regime the worst case outcome would be to not reinsure since this has the greatest impact on downside risk and poses the biggest threat to liquidity.

While a great deal of current research investigates the relationship between crop producers and crop insurers, research on the relationship and role of reinsurance is lacking. This paper has provided a realistic assessment of the role that reinsurance (can play) plays in the agricultural economy, and illustrates ways in which reinsurance premiums can be calculated.

References

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Table 1:   Expected Indemnity from the Reinsurer under Different Stop Loss Layers

Particulars	*150 x 150*	*100 x 150*	*50 x 150*	*50x 200*	*50 x 250*	*25 x 125*	*175 x 125*
31 year information							
Expected Indemnity (Historical)	11.72%	10.87%	6.23%	4.64%	0.85%	4.28%	16.01%
Expected Indemnity (Simulation)	12.93%	12.13%	8.43%	3.69%	0.80%	6.65%	19.58%
16 year information *Expected Indemnity (Historical)*	10.25%	10.25%	5.83%	4.42%	0.00%	3.83%	14.08%
Expected Indemnity (Simulation)	10.31%	10.31%	7.81%	2.51%	0.00%	5.95%	16.26%

Table 2:   Historical (H) and Simulated (S) Loss Ratio

No. of Years of Information	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*	*Skewness*
31 Years (H)	0.27	3.04	0.99	0.69	1.34
31 Years (S)	0.27	3.03	0.99	0.69	0.94
16 Years (H)	0.27	2.44	0.86	0.67	1.55
16 Years (S)	0.27	2.44	0.87	0.67	0.94

Table 3:   **Probability of Occurrence of Loss**

No. of Years of Information	Probability of Falling Below the Loss Ratio of									
	0.5	*0.75*	*1.00*	*1.25*	*1.50*	*1.75*	*2.00*	*2.25*	*2.50*	*3.03*
31 Years	33%	48.93%	60.40%	69.40%	77.05%	83.31%	88.52%	92.77%	96.13%	100%
16 Years	46%	58.26%	66.52%	73.23%	79.07%	84.42%	89.57%	94.84%	100% (2.44)	N/A

**Table 4:   Simulated Reinsurance Claim Rates and Probability (in %) of Occurrence
            (16 Years of Information)**

Reinsurance Layers	Claim Rate as a Percentage of Premiums																		
	0%	1%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	60%	75%	80%	85%	90%	94%	Expected Level
150 x 150	79.1	79.3	80.2				84.4					89.6		94.8		97.2	98.5	100	81.3 (10.31)
100 x 150	79.1	79.3	80.2							87.5			91.6		96.0			100	81.3 (10.31)
50 x 150	79.1	79.3	80.2		82.3		84.4	85.5		87.5	88.54	100							80.8 (7.81)
50 x 200	89.6		90.6	91.6	92.7		94.8	96.0	97.2	98.5		100							90.1 (2.50)
50 x 250	100																		100 (0.00)
25 x 125	73.2			75.5	76.8	77.9	100												74.7 (5.95)
175 x 125	73.2						79.1					84.4		89.6					77.1 (16.26)

Table 5: **Simulated Fund Balance under Different Stop Loss Layers and No Re-insurance**
(16 Years Information)

Stop Loss Layers	Minimum	Maximum	Mean	Standard Deviation
150 x 150	179.83	265.93	231.33	34.36
100 x 150	179.83	265.93	231.33	34.36
50 x 150	152.12	269.02	232.68	37.36
50 x 200	148.91	270.01	229.95	43.40
25 x 125	136.02	270.42	232.78	40.49
175 x 125	194.65	263.24	232.82	28.46
No Re-insurance	121.20	273.10	231.29	46.93
Assumptions: Starting Fund Balance = $222 million, Annual Premium = $70 million				

Table 6: Probability (in %) of Fund Balance Falling below the Selected Levels

Stop Loss Layers	Probability (%) Fund Balance Falling Below Millions)													($ in	
	0	50	100	150	200	222	250	255	260	263	265	266	269	270	273
150 x 150	0	0	0	0	27.74	36.62	53.72	58.74			90	100			
100 x 150	0	0	0	0	27.74	36.62	53.72	58.74			90	100			
50 x 150	0	0	0	0	26.63	35.23	51.14		61.08				100		
50 x 200	0	0	0	10.75	26.28	34.79	50.38		59.83				90	100	
25 x 125	0	0	0	5.38	20.56	34.61	50.07		59.34				90	100	
175 x 125	0	0	0	0	28.71	37.87	56.25		71.41	100					
No Re-insurance	0	0	0	9.85	25.21	33.48	48.13				62.32				100