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Estimating Returns under the Standard Reinsurance Agreement

Presented at organized symposium
"Measuring and Spreading Risk: Public-Private Reinsurance of Crop Insurance"
AAEA Annual Meetings 2002

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July 31, 2002

Abstract

The present paper describes the assumptions and modeling structure behind the SRA simulator, a user-friendly computer program developed in cooperation with RMA as a tool to assist policymakers in assessing the economic impact of the Standard Reinsurance Agreement. The simulator uses the historical data on yields, prices, and insurance losses for each district, crop, and insurance product in order to simulate a distribution of the book of business resulting from underwriting crop insurance either in aggregate or for a specific company.

Keywords: *crop insurance, reinsurance, risk management, risk modeling*

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The SRA Historical Simulator is a computer program developed at the Ohio State University by Mario J. Miranda and Dmitry V. Vedenov.

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Estimating Returns under the Standard Reinsurance Agreement

Introduction

The Standard Reinsurance Agreement (SRA) represents a cooperative risk sharing agreement between the Federal Crop Insurance Corporation (FCIC) and private insurance companies to deliver crop insurance under the authority of the Federal Crop Insurance Act. The SRA is periodically renegotiated between the Risk Management Agency and participating companies. The version of the Agreement currently in effect was approved by the RMA and private insurance companies in July 1997 and was subsequently amended by the Agricultural Research, Extension, and Education Reform Act of 1998. In addition, the Agriculture Risk Protection Act of 2000 provided that the Federal Crop Insurance Corporation must renegotiate the SRA once during the 2001 through 2005 reinsurance years.

In order to evaluate the effects of various provisions of the SRA on companies' rates of return, one needs an analytical model that would allow to simulate distributions of the rates of return and analyze how those are affected by the SRA. An SRA Simulator was developed initially at the Ohio State University in cooperation with RMA as a tool to assist policymakers in assessing the economic impact of the Agreement. The simulator uses the historical data on yields, prices, and insurance losses for each district, crop, and insurance product in order to simulate a distribution of the book of business resulting from underwriting crop insurance either in aggregate or for a specific company.

The present paper describes the assumptions and modeling structure behind the SRA simulator. Section 1 briefly outlines the basic principles of the current SRA,

Section 2 presents and discusses the modeling methodology used in the SRA simulator, and Section 3 concludes.

1 Standard Reinsurance Agreement

FCIC provides reinsurance for the participating companies in exchange for a portion of insurance premiums collected by those companies. The reinsurance comes in two forms: proportional and nonproportional. Under the former, the companies cede their liability for ultimate net losses in exchange for an equal percentage of the associated net premiums. In other words, they completely transfer a portion of their book of business to FCIC. The nonproportional reinsurance is then applied to the remaining or *retained* portion of companies' books of business. Nonproportional reinsurance is similar to traditional reinsurance in that FCIC shares losses with the companies in exchange for a portion of their underwriting gain[1].

Under the proportional reinsurance, each company may allocate its contracts to one of the three funds: Assigned Risk Fund, Developmental Fund, and Commercial Fund. Funds differ in the required level of retention and also in the FCIC shares of gains and losses from retained business under the nonproportional insurance. The Assigned Risk Fund is characterized by the lowest required retention rate (20%) which makes it the primary designation for the high-risk contracts. The Developmental and Commercial Funds have higher minimum retention requirements (35% and 50%, respectively). The last two funds are further subdivided into CAT Fund, Revenue Insurance Fund, and All Other Plans Fund, which differ by reinsurance provisions applied to the retained portion of the book of business.

The nonproportional reinsurance is applied to the portion of companies' books of

[1]Underwriting gain is the amount by which net premiums collected by a company exceed its losses or the total indemnities it had to pay.

business retained after the proportional cession. The responsibilities of the companies for the retained losses, as well as their share of the underwriting gain, are specified for each fund and state and depend on the *loss ratio* of each company in a given reinsurance year. The loss ratio is defined as a ratio of the total indemnities paid by the company to the total retained premiums. When the loss ratio exceeds 100%, the company suffers a net underwriting loss, and when the loss ratio falls below 100%, the company earns a net underwriting gain.

For the SRA currently in effect, the schedules of liabilities and underwriting gains retained by companies under different realizations of their loss ratios are shown in Tables 1 and 2. As the loss ratio increases, FCIC assumes a larger fraction of company's losses, up to 100% of the portion of losses in excess of 500% of the total retained premiums. At the same time, FCIC claims a larger fraction of companies' underwriting gains as their loss ratios decrease.

The Assigned Risk Fund provides the highest level of protection against losses but also leaves the insurer the smallest fraction of the gains. The Commercial Fund, on the other hand, gives the insurer the highest return in case of the underwriting gain, but also leaves the largest portion of the net losses on the insurer's balance.

For modeling purposes, the SRA can be completely described by the required retention rates for each fund, the *breakpoints* of the loss ratio ranges, and the *shares* of the underwriting losses or gains retained by the companies within each range.

2 Modeling Methodology

2.1 Overview

The objective of the SRA model is to estimate rates of return for the participating insurance companies. The rates are driven by the net underwriting gains determined

as the difference between the premiums collected and indemnities paid. Since losses depend on the occurrence or nonoccurrence of random events, rates of return are random variables. The purpose of reinsurance is to reduce the downside variability of these random variables and possibly increase their expected values.

Under the SRA, the rate of return is determined by a particular realization of the company's loss ratio and the SRA parameters, i.e. retention rates, breakpoints, and shares. Therefore, in order to analyze the effects of changes in the SRA on the rates of return, one needs to model the distribution of the loss ratios by state and fund for each company reinsured by FCIC.

The random variables that ultimately drive loss ratios are the farm-level yields and prices, since they determine the insurance loss for any given contract and thus the aggregate losses for any company. A naïve approach thus would be to model the distributions of the farm-level yields and then compute the corresponding distributions of companies' rates of return by aggregating over each company's book of business.

Such an approach, however, has been heavily criticized by the industry representatives because simulations based solely on individual contract specifications without actual participation data taken into account neither reflect the adverse selection present in the crop insurance portfolio, nor take into account the additional losses companies incur due to moral hazard. As a result, the losses computed in this way typically underestimate the actual underwriting losses experienced by the companies and need to be adjusted to reflect the composition of insurance companies' portfolios.

Ideally, one would like to have a long series of historical data on companies' premiums and indemnities that can be used either to fit a parametric distribution or to derive an empirical distribution of loss ratios. However, there are several serious obstacles which do not permit this approach. First of all, the number of contract

types available under the crop insurance program have increased dramatically since 1980, with a large portion of products introduced after 1994. Therefore, historical loss data simply are not available for many contracts prior to 1994. Second, program participation has significantly increased over the last two decades both in terms of the acreage insured and coverage levels selected by the producers. This in turn led to broader pool of insured risk and decreasing variation in indemnities. Third, participating companies over time have changed the composition and the geographical distribution of contracts in their books of business as well as allocation across reinsurance funds. Finally, premium rates[2] have also changed over time, thus affecting historical realizations of companies' gains and losses.

In order to circumvent data limitations and derive a distribution of loss ratios that reflects the historical changes in the crop insurance programs, the following strategy is implemented. It is assumed that historical *loss costs*, or ratios of indemnities to the total liabilities, accurately reflect the actual distribution of underwriting losses. Specifically, it is assumed that loss costs by district, crop, and product over the historical period were generated by stationary data-generating processes that are uniform across companies and reinsurance funds.

Historical loss costs are available for the period of 1981–1998 for selected APH yield contracts but only in aggregate, thus providing no information about the distribution of loss costs for specific APH yield contracts, nor other products such as CAT and revenue products. The loss costs for individual products, however, can be simulated and then adjusted to match the available historical data.

The derived distribution of loss costs for each district, crop, and product is then combined with the data on liabilities and premium rates for the base year and ag-

[2]The premium rate of a contract is a ratio of its premium to the liability associated with the contract.

gregated to compute the distribution of loss ratios for each company by state and reinsurance fund[3].

Finally, the derived distribution of the loss ratios can be used along with the SRA parameters to compute the expectations and coefficients of variation of the rates of return by company, state, and/or fund.

2.2 Implementation

The first step in simulating the aggregate loss cost of an insurance company is to simulate loss costs for individual insurance contracts (products) included in company's portfolio. While there are more than 20 types of products available for more than 100 crops, lack of adequate data or limited scope of some programs do not allow to incorporate all of them into a simulation model. For the purposes of analysis, six crops and two major types of products are considered.

The incorporated crops are barley, corn, cotton, soybeans, grain sorghum, and winter wheat. The incorporated insurance products are CAT coverage, APH buy up at $\{50, 55, \ldots, 75\}$% coverage[4] and CRC at $\{50, 55, \ldots, 75\}$% coverage. Together, these combinations of crops and products encompass about 74% of the total FCIC liability for the base year (1998).

Specific details about each contract type as well as analytical formulas describing contract's payoffs and liabilities are presented in the Appendix. These formulas are used to simulate loss cost for each product given corresponding distributions of yields and prices.

[3]The available liability data for insurance companies are not disaggregated by product. However, the total liability data are available by district, crop, and insurance product. Therefore, an implicit assumption is made that the product composition of the book of business is uniform across all companies for each crop within each district.

[4]A 35% APH yield contract, which was introduced for a short period of time in 1993–94 is used for some internal simulations, but is not present in the base year product lineup.

The farm-level yields are modeled using the representative farmer approach. More specifically, it is assumed that for a given crop, district[5], and year, the individual farm's yield can be represented as

$$\log y_f = \log y_d + \log \varepsilon, \tag{1}$$

where y_f is the farm yield, y_d is the district yield, and ε is a normally distributed random shock[6] reflecting variability of yields within the district. Note that the parameters of the shock may vary by crop and year.

For APH products, the distribution of yields is enough to calculate the loss costs. Indeed, the prices enter both the indemnity (6) and the liability (5) as multipliers, and thus cancel out in computing the loss cost. The expected APH yield used in computing the indemnities can be represented as

$$\overline{y}_{APH} = \mathop{\mathbf{E}}_{\varepsilon} \varepsilon \overline{y}_{det}, \tag{2}$$

where $\overline{y}_{det}$ is the expected detrended district-level yield. The data used at this stage include the NASS historical district-level yield series for 1981–1998.

In case of revenue products, yields alone are not enough to calculate the loss costs, since prices enter indemnity under the maximum operator. Therefore, the loss costs for revenue products depend on the base and harvest-time prices used to settle the contracts. The base (or projected) price is determined at or before signing the insurance contract and therefore is a parameter rather than a random variable. Thus the only stochastic component in (7) is the harvest price.

[5]A district is a statistical unit intermediate between a county and a state. Each state is typically split into nine or ten districts and each district typically includes eight to twelve counties.

[6]The parameters of this normal distribution are determined later during the calibration stage.

While historical yield data are readily available at the county level and above for all the crops considered, the associated price series are much less complete. Even when the price series are available for the entire simulation period, e.g. CBOT corn price series, one cannot reliably assume that those are drawn from a stationary distribution due to changing farm policies and support programs, inflation, and other factors. Therefore, instead of deriving the harvest price distribution from historical data, the harvest price movement is modeled for each crop as

$$\log p_h = \log p_b + \alpha(\log y_{nat} - \log \overline{y}_{nat}) + z, \tag{3}$$

where p_h is the harvest price, p_b is the base (projected) price, y_{nat} is the detrended national yield, $\overline{y}_{nat}$ is the expected detrended national yield, α is the elasticity parameter, and z is a random shock independent of y_{nat} and distributed normally with zero mean and some variance σ^2.

The data on the national yields are available from the NASS database. The estimates of the elasticity parameters α and the variances σ^2 of the random shocks were provided by the RMA along with the projected prices for each crop for the base year.

Equations (1)–(3) along with formulas (5)–(8) for indemnities and liabilities of individual products allow one to calculate loss costs for individual products for each district, crop, and year. However, these loss costs need to be calibrated in order to match the available historical data on aggregate loss costs for selected APH products.

The aggregate data include APH products with 35% and $\{55\%, ..., 75\%\}$ coverages in known proportions. The simulated loss costs for these products are aggregated with the same weights and then the mean and variance of the farm-level shock ε in (1) are

selected so that the aggregate simulated loss cost is equal to the historically observed loss cost for each crop, district, and year. A simple iterative procedure is implemented in order to find the unknown shock variance while the shock mean is always chosen so that $\mathbf{E}\, y_d = \overline{y}_{det}$.

More specifically, let $losscostsim(i_d, i_c, i_p, i_y; \mu_\varepsilon, \sigma_\varepsilon)$ be the simulated loss cost for district i_d, crop i_c, product i_p, and year i_y for a given parameterization $(\mu_\varepsilon, \sigma_\varepsilon)$ of the yield shock ε. Let $losscostbu(i_d, i_c, i_y)$ be the historical aggregate loss cost for selected APH buyup products in the district i_d for the crop i_c and year i_y. Finally, let $B \subseteq \{1, \ldots, n_p\}$ be the index subset of products included in the aggregate loss costs data, and let $liabilityhist(i_d, i_c, i_p, i_c)$ be the historical liabilities for products in B. The calibration procedure then can be described as follows.

Step 1. Aggregate simulated loss costs for the products in B using the historical liabilities as weights

$$lostcostsimagg(i_d, i_c, i_y; \mu_\varepsilon, \sigma_\varepsilon) = \frac{\sum_{i_p \in B} liabilityhist(i_d, i_c, i_p, i_y) \times losscostsim(i_d, i_c, i_p, i_y; \mu_\varepsilon, \sigma_\varepsilon)}{\sum_{i_p \in B} liabilityhist(i_d, i_c, i_p, i_y)}.$$

Step 2. Find the shock mean μ_ε and variance σ_ε so that

$$losscostsimagg(i_d, i_c, i_y; \mu_\varepsilon, \sigma_\varepsilon) = losscostbu(i_d, i_c, i_y)$$

and $\mathbf{E} \log \varepsilon = 0$.

The parameters of the random shock calculated in this way are assumed to correctly represent the variability of yields for the specific crop, district, and year and thus can

be used to simulate the loss costs for individual products. For each district, crop, and product, the above procedure results in a series of n_y loss costs, where $n_y = 18$ is the number of years for which yield data are available (from 1980 to 1998). The series is then treated as a discrete empirical distribution of loss costs.

At the next stage the simulated distributions of loss costs are combined with data on base year premium rates and liabilities and then aggregated to arrive at distributions of loss costs and premium rates by state, organization, and reinsurance fund. The resulting arrays include

- $losscost(i_s, i_o, i_f, i_y)$ — equiprobable realizations (indexed by year) of the loss cost distribution by state, organization, and fund;
- $liability(i_s, i_o, i_f)$ — base year liabilities by state, organization, and fund;
- $premrate(i_s, i_o, i_f)$ — base year premium rates by state, organization, and fund.

Combined with the data on base retention rates $pctretain(i_s, i_o, i_f)$, these provide enough information to calculate the distribution of loss ratios by state, organization, and fund, namely

$$\begin{aligned}
indemnity(i_s, i_o, i_f, i_y) &= losscost(i_s, i_o, i_f, i_y) \times liability(i_s, i_o, i_f), \\
retpremium(i_s, i_o, i_f) &= pctretain(i_s, i_o, i_f) \times premrate(i_s, i_o, i_f) \\
&\quad \times liability(i_s, i_o, i_f), \\
lossratio(i_s, i_o, i_f, i_y) &= \frac{indemnity(i_s, i_o, i_f, i_y)}{retpremium(i_s, i_o, i_f)},
\end{aligned}$$

where $indemnity(i_s, i_o, i_f, i_y)$ is the distribution of indemnities (indexed by year) and $retpremium(i_s, i_o, i_f)$ are the retained premiums by state, organization, and fund.

The final stage of the simulation is to apply the SRA to the derived distribution of loss ratios to arrive at the adjusted loss ratios

$$lossratioadj(i_s, i_o, i_f, i_y) = SRA(lossratio(i_s, i_o, i_f, i_y)),$$

where the SRA operator represents the adjustment according to the schedules in Tables 1 and 2.

The corresponding distributions of rates of return by state, organization, and fund can be then calculated as

$$return(i_s, i_o, i_f, i_y) = 1 - lossratioadj(i_s, i_o, i_f, i_y), \tag{4}$$

with the means and coefficients of variations of the rates of return computed as

$$\begin{aligned} mean(i_s, i_o, i_f) &= \frac{1}{n_y} \sum_{i_y=1}^{n_y} return(i_s, i_o, i_f, i_y) \\ cv(i_s, i_o, i_f) &= \sqrt{\frac{1}{n_y} \sum_{i_y=1}^{n_y} (return(i_s, i_o, i_f, i_y) - mean(i_s, i_o, i_f))^2}. \end{aligned}$$

The presented methodology is currently implemented as a Fortran 95 program with a Visual Basic interface. The historical data is used as input files, while SRA parameters can be modified by user in the real time. The program outputs expected returns and their coefficients of variation aggregated either by state and fund or by organization and fund.

3 Conclusion

This paper presents modeling methodology behind the SRA Simulator, an analytical tool designed to assist policymakers in assessing economic impact of the Standard

Reinsurance Agreement. The model uses historical data on yields and prices in order to simulate empirical distribution of insurance companies' loss ratios. The crucial assumption is that the historically observed loss costs, or ratios of indemnities to total liabilities, correctly represent the actual distribution of underwriting losses and are generated by stationary data generating processes.

The representative farmer approach is used to simulate yields for any given district, crop, and year, with parameters of random yield shocks calibrated so that the simulated loss costs match the historically observed ones. The simulated distributions of loss costs are then combined with data on liabilities and retained premiums in order to arrive to distributions of loss ratios aggregated by state, organization, and fund.

The model allows extensive analysis of how changes in SRA provisions and/or the methods used by companies to allocate their books of businesses among reinsurance funds affect companies rates of return. Examples may include changes in SRA shares and/or breakpoints, selective allocation of high-risk contracts in specific funds, and so on.

Loss Ratio between 100% and 160%			
	CAT Plans	**Revenue Insurance Plans**	**All Other Plans**
Commercial	50.0%	57.0%	50.0%
Developmental	25.0%	30.0%	25.0%
Assigned Risk	—	—	5.0%
Loss Ratio between 160% and 220%			
	CAT Plans	**Revenue Insurance Plans**	**All Other Plans**
Commercial	40.0%	43.0%	40.0%
Developmental	20.0%	22.5%	20.0%
Assigned Risk	—	—	4.0%
Loss Ratio between 220% and 500%			
	CAT Plans	**Revenue Insurance Plans**	**All Other Plans**
Commercial	17.0%	17.0%	17.0%
Developmental	11.0%	11.0%	11.0%
Assigned Risk	—	—	2.0%

Table 1: Retained liabilities by fund for different loss ratios.

Note: FCIC assumes the ultimate net losses in excess of companies' retained ultimate losses as determined in the table. In addition, FCIC assumes 100% of the amount by which companies' retained losses in a given state and fund exceed 500% of the retained net book premium for a given reinsurance year.

Loss Ratio between 65% and 100%			
	CAT Plans	**Revenue Insurance Plans**	**All Other Plans**
Commercial	75.0%	94.0%	94.0%
Developmental	45.0%	60.0%	60.0%
Assigned Risk	—	—	15.0%
Loss Ratio between 50% and 65%			
	CAT Plans	**Revenue Insurance Plans**	**All Other Plans**
Commercial	50.0%	70.0%	70.0%
Developmental	30.0%	50.0%	50.0%
Assigned Risk	—	—	9.0%
Loss Ratio less than 50%			
	CAT Plans	**Revenue Insurance Plans**	**All Other Plans**
Commercial	8.0%	11.0%	11.0%
Developmental	4.0%	6.0%	6.0%
Assigned Risk	—	—	2.0%

Table 2: Retained underwriting gain by fund for different loss ratios.

Appendix: Crop Insurance Products

Currently, there are more than 20 types of insurance products available for different crops, although some of the products are in the pilot stage and/or apply to specific crops in specific counties. Discussed below are the insurance plans that comprise the major portion of the FCIC portfolio in terms of total liability. These contracts are also explicitly modeled in the SRA model. More detailed information about these and other products, as well as current and historical participation data, are available from the RMA website at http://www.rma.usda.gov.

APH contracts

The most common class of crop insurance products are the Multiple Peril Crop Insurance (MPCI) contracts, whose indemnities are based on the realization of yield compared to the actual production history (APH). In order to participate in the program, farmers need to submit historical yield data for a period of four to ten years which is then averaged to compute the APH or "expected" yield. Farmers can select the proportion of the expected yield as well as a proportion of the predicted (base) price[7] that they want to insure. MPCI contracts pay indemnities when the realized yield falls below the selected coverage level. If $\overline{y}$ is the APH yield, y is the realized yield, η is the selected yield coverage level, and π is the selected percentage of the predicted crop price $\overline{p}$, then the liability and the payoff of an MPCI contract per insured acre can be expressed as

$$L_{MPCI} = \pi \overline{p} \eta \overline{y} \tag{5}$$

[7]The base prices are established and published annually by the RMA in the beginning of a contract cycle.

and

$$I_{MPCI} = \pi \overline{p} \max\{0, \eta \overline{y} - y\}, \tag{6}$$

respectively. Available yield coverage levels η range from 50% to 75% at 5% intervals. Coverage up to 85% is also available for selected crops in selected counties. The percent of the predicted price π can be chosen between 55% and 100% also at 5% intervals. Recent increases in premium subsidies for higher coverage levels have made such contracts more attractive and have significantly increased program participation.

A special type of MPCI is the Catastrophic coverage (CAT) contract introduced by the Federal Crop Insurance Reform Act of 1994 to replace other Federal disaster assistance programs. Originally, CAT contracts were equivalent to an APH yield product with $\eta = 0.5$ and $\pi = 0.6$, but in 1998 the price election requirement was reduced to $\pi = 0.55$ (current level). The premium on CAT is paid by the federal government, although farmers are required to pay a sign-up fee for each crop insured in each county. Initially, this fee was set at \$50 per crop, but later increased to \$60 in 1999 and \$100 in 2001.

Crop Revenue Coverage contracts

The most common and popular revenue product is the Crop Revenue Coverage (CRC) which is available in all counties where APH contracts are available. Under the CRC plan, farmers can insure a percentage of the projected revenue. The projected revenue is computed as the product of the APH yield and the base price established by the RMA prior to the insurance period. Available coverages range between 50% and 75% at 5% intervals. Coverage up to 85% is available for crops and counties where 85% APH contracts are available.

While the projected revenue is used to establish the revenue guarantee and pre-

miums, the actual payoff of a CRC contract also depends on the harvest-time price realization so as to provide a higher indemnity if the harvest-time price exceeds the base price up to a prescribed maximum. Price differentials between the base and harvest prices are limited to \$1.50 for corn and grain sorghum, \$0.70 for cotton, \$3.00 for soybeans, and \$2.00 for wheat.

Both the base and harvest prices are determined as averages of daily settlement prices for specific commodity futures contracts during a specific period of time. The particular futures contracts and price discovery periods used for the CRC price determination are listed in the insurance contract (see also [12]).

If $\overline{y}$ and y are the APH and realized yields, respectively, η is the coverage level selected by the farmer, and p_b and p_h are the base and harvest prices, respectively, then the liability and payoff of a CRC contract per insured acre are determined as

$$L_{CRC} = \eta \max\{p_b, p_h\}\overline{y} \tag{7}$$

and

$$I_{CRC} = \max\{0, \max(p_b, p_h)\eta\overline{y} - p_h y\}, \tag{8}$$

respectively.

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