Increased availability and demand for low-deductible crop insurance policies have increased focus on crop insurance rating methods. Actuarial fairness cannot be achieved if constant multiplicative factors are used to determine how premiums change as coverage levels increase. A comparison of premium rates generated by the factors used by the two most popular crop insurance products with those generated by a standard yield distribution shows that the popular insurance products overcharge for low-deductible policies in most counties. This overpricing may explain why large premium subsidies were required to induce farmers to move from low-deductible to high-deductible policies beginning in 2001.

Key words: crop insurance, moral hazard, premium rates, rating methods, subsidies.

Crop insurance is by far the most popular risk management tool used by the U.S. crop producers. In 2003, the U.S. crop insurance program insured more than 200 million acres, representing more than $37 billion in value, with total premium of over $3.14 billion. The two most popular crop insurance products are Actual Production History (APH), which provides insurance against low yields, and Crop Revenue Coverage (CRC), which is a revenue insurance product. Both of these products offer coverage in 5% increments from 65% to 85% of expected yield or revenue. Beginning with the 2001 crop year, Congress greatly increased subsidy levels to induce producers to purchase more insurance coverage. Producers responded as expected. For example, only 2.3% of Kansas wheat was insured at levels in excess of 65% in 1998. This proportion rose to 71.6% in 2003.

This policy change has increased focus on the methods used by the Risk Management Agency (RMA) of USDA to set insurance rates at higher coverage levels. APH premium rates are calculated by multiplying the premium rate at the 75% coverage level by a rate “relativity factor.” The rate relativities are constant across regions for a given crop. For example to find an 85% APH premium rate, one simply multiplies the 75% rate by 1.60. The 65% rate equals the 75% rate multiplied by 0.65. CRC premium rates for a given coverage level are based on the corresponding APH rates. So to calculate an 85% CRC premium requires knowledge of the 85% APH premium rate. Thus changes in APH premium rates as coverage levels increase are directly reflected in changes in CRC premium rates.

Congress has given RMA an objective of charging farmers a total premium (pre-subsidy) that would generate a loss ratio of 1.075. That is, insurance indemnities paid to farmers should exceed total premiums by 7.5%. To hit this actuarial target under the new subsidy regime, RMA needs to determine how losses change as coverage levels increase. The key question addressed in this article is whether RMA’s use of constant rate relativities to determine premium rates at different coverage levels is consistent with its need to hit its actuarial target.

The approach that we take is to abstract from reality and treat the 65% premium rates charged for yield insurance for corn, soybeans,
and wheat as reasonable estimates of the losses that result from natural yield variations when insurance is purchased at the 65% coverage level. We then determine if constant rate relativities across regions applied to these 65% premium rates are consistent with actuarial fairness by deriving a basic set of rules that premium rates for yield insurance must follow if they are to be consistent with the laws of probability. We show that premium rates at coverage levels above 65% generated with constant rate relativities cannot be justified due to increases in insurance losses from natural yield variations.

Some support for our abstraction is that almost all of the historic experience in the crop insurance program has been at the 65% coverage level. Thus the current 65% premium rates reflect past losses. However, the 65% premium rates also reflect losses due to losses from fraud, moral hazard, and adverse selection because they are based on historical losses on insured acreage. Could it be that constant rate relativities are simply a device used by RMA to make actuarial sense in a world of moral hazard and adverse selection? We address this issue by examining the pattern of insurance claims across regions that would have to be generated from moral hazard and adverse selection to justify the use of constant rate relativities. We find the pattern implausible leading us to conclude that constant rate relativities are inconsistent with actuarial fairness.

**Institutional Background**

The Agricultural Risk Protection Act (ARPA) of 2000 increased crop insurance premium subsidies significantly and changed them on coverage levels above 65% from a fixed per-acre dollar amount to a percent of premium. The percent subsidy depends on the coverage level as follows: 59% subsidy for coverage levels of 65 and 70%; 55% subsidy for 75% coverage; 48% for 80% coverage; and 38% for 85% coverage. This policy change has two implications. First, the move to a subsidy expressed as a constant percent for a given coverage level means that the per-acre subsidy varies, and likely increases, with the per-acre premium, thus increasing the incentive for farmers to purchase more expensive insurance products. The particular subsidy levels used for the different coverage levels cause the second effect. The decline in percent subsidy associated with increased coverage level is generally less than the increase in the insurance premium. Thus per-acre subsidies also increase as coverage levels increase. This change encourages farmers to purchase higher coverage levels.

Crop insurance rates under USDA’s APH program are empirically determined in that they depend upon the level of indemnities paid to farmers. They are set so that they would generate adequate premiums to cover average historical losses (Josephson, Lord, and Mitchell). Figure 1 shows the number of acres that have been insured at less than the 65% coverage level.
level, at the 65% coverage level, and greater than the 65% coverage level. Until recently, the coverage level most in demand by farmers was the 65% level. The 1995 increase in acres insured at less than 65% was a result of a rule that made eligibility for federal farm program payments contingent on participation in the crop insurance program. The increase in popularity of coverage levels greater than 65% in 2000 and 2001 can be attributed to the increase in subsidies that were available on an emergency basis in 2000 and as part of ARPA in 2001. This increase in participation at coverage levels greater than 65% is consistent with the finding of Just, Calvin, and Quiggin that the main motivation for farmers’ purchase of crop insurance is to increase their net income by capturing the value of subsidies rather than to decrease risk.

Figure 1 suggests that RMA has by far the most historical information about losses at the 65% coverage level. This means that the 65% rate is likely to best reflect historical losses. The significant acreage covered at greater than the 65% level suggests that there is some information about how losses and hence, rates, should increase as coverage levels increase. However, a substantial portion of the acreage insured at greater than 65% comes from just a few states. For example, in 1993, 40% of the acres insured at more than 65% coverage were in two states, Iowa and Illinois. This means that much of the knowledge about how losses increase as coverage increases above 65% resides in relatively few states.

In 2001, CRC acreage increased by 26% from 60 million acres to 75.6 million acres, and coverage at the 75%, 80%, and 85% coverage levels increased from 30% to 39% of total acres. Acreage at 80% and 85% coverage increased from 10% to 13% of total acreage.

Insurance Rates and Probability Rules

The actuarially fair insurance rate per unit of yield guarantee is defined as the ratio of expected indemnity to liability, where expected indemnity is the level of insurance payment that the insurer expects to pay out to the insured at the time the insurance contract is signed and liability is the maximum payout that can be made. For a yield insurance policy that covers against yield losses below some guaranteed level, \( Y_I \), the actuarially fair rate is given by

\[
 r_I = (1/Y_I) \Pr(y < Y_I) \frac{E[Y_I - y | y < Y_I]}{Y_I},
\]

where the price paid per unit of yield loss is normalized to one, and \( \Pr(y < Y_I) \) denotes the probability that yield is below the yield guarantee. Then

\[
 (1) \quad \Pr(y > Y_I) = \frac{r_I Y_I}{Y_I - E[y | y > Y_I]}
\]

Equation (1) shows that given an actuarially fair insurance rate and a yield guarantee, there is a one-to-one relationship between conditional expected yields and the probability that yields are below the yield guarantee.

The laws of probability and the definitions of conditional expectation put bounds on the permissible values of probability and conditional expected yield. We know that if the insurance guarantee is less than the median yield, then

\[
 \Pr(y < Y_I) \leq 0.5.
\]

For symmetric and negatively skewed distributions, we also know that the mean yield is no greater than the median. This implies that if the insurance guarantee is less than the median, it is also less than the expected value of yields and \( \Pr(y < E[y]) \leq 0.5 \). For positively skewed distributions, \( \Pr(y < E[y]) > 0.5 \), and it could be the case that \( \Pr(y < Y_I) > 0.5 \) if the insurance deductible (the difference between expected yields and the yield guarantee) is small enough.

Equation (1) can be rewritten as

\[
 r_I = \Pr(y < Y_I) \left[ 1 - \frac{E(y | y < Y_I)}{Y_I} \right]
\]

which clearly shows that the actuarially fair rate associated with any yield guarantee cannot exceed the probability that yield is less than the guarantee. Thus, if the yield guarantee is such that the probability of falling below it is no greater than 0.5, then 0.5 is an upper bound on the actuarially fair rate \( r_I \).

For U.S. yield insurance products, the maximum guarantee for individual yield products is 85% of APH yields. Given this built-in deductible, and given that APH yields are generally less than expected yields (Just, Calvin, and Quiggin), 0.5 places a practical upper bound on \( \Pr(y < Y_I) \).

In addition, from the definition of a conditional expectation, we know that \( E[y | y < Y_I] < Y_I \). From equation (1), if \( r_I = 0.5 \), then the upper limit (practical or absolute) on \( \Pr(y < Y_I) \) of 0.5 implies that the only permissible value of \( E[y | y < Y_I] \) is 0. Thus, for negatively skewed and symmetric yield distributions, actuarially fair insurance rates greater than 0.5 for insurance coverage less than expected yield cannot be supported by a
well-defined yield distribution. For positively skewed distributions, if the insurance guarantee is less than the median yield, then actuarially fair rates greater than 0.5 cannot be supported by a well-defined yield distribution. This result may seem trivial, but the APH program includes many premium rates that exceed this upper limit. For example, in Hettinger County, North Dakota, a safflower farmer with an APH yield of 470 pounds per acre or less will be charged a crop insurance rate of greater than 0.5 for a yield guarantee equal to 75% of APH yields. Of course, the vast majority of APH rates depend on a farmer’s APH yield. For a given APH yield, knowledge of one coverage level’s APH base rate is sufficient to calculate all other coverage level rates because RMA uses constant rate relativity factors to calculate rates at different coverage levels. These factors do not vary across base rates, crops, or regions. The ratio of 70% rates to 65% rates is 1:21. The ratio of 75% rates to 65% rates is 1:53. The ratio of 80% rates to 65% rates is 1:93. And the ratio of 85% rates to 65% rates is 2:44. Currently for many crops and counties, available coverage levels are 65, 70, 75, 80, and 85%. In some locations, coverage levels are only available at 65, 70, and 75%. The method that we use to examine the actuarial fairness of APH rates can best be illustrated with the example given below.

A barley farmer in Becker County, Minnesota, with an APH yield of 55 bushels per acre would pay an APH rate of 0.103 for 65% coverage and 0.125 for 70% coverage. The corresponding yield guarantees are 35.75 and 38.5 bushels per acre. Suppose the conditional expected yield in equation (3) is 37 bushels per acre. Substituting these numerical values into equation (3), and expressing $F(Y_2)$ as a function of $F(Y_1)$ results in:

$$F(Y_2) = 0.75 - 0.833 F(Y_1).$$

There are solutions to this equation that satisfy the restrictions that $0.5 > F(Y_2) \geq F(Y_1)$, for example, $F(Y_1) = 0.35$ and $F(Y_2) = 0.458$. So there exists some underlying yield distribution that could support these rates and we cannot conclude that the 65% and 70% APH rates are not supported by a yield distribution that violates the laws of probability for actuarially fair rates.

Now suppose that we have a barley farmer in Hubbard County, Minnesota, with an APH yield of 40 bushels per acre. This farmer faces an APH rate of 0.172 at 65% coverage and 0.210 at 70% coverage. Suppose the conditional expected yield in equation (3) is 27 bushels per acre. Substituting these values into (3) results in:

$$F(Y_2) = 1.408 - F(Y_1).$$

Clearly there is no solution to this equation that satisfies $0.5 \geq F(Y_2) \geq F(Y_1)$. Hence, there does not exist a yield distribution function that could support the given rates and yield guarantees. That is, from the perspective of generating premiums sufficient to cover yield losses, the rates would not be actuarially fair.

### Analysis of APH Rates

APH rates depend on a farmer’s APH yield. For a given APH yield, knowledge of one coverage level’s APH base rate is sufficient to calculate all other coverage level rates because RMA uses constant rate relativity factors to calculate rates at different coverage levels. These factors do not vary across base rates, crops, or regions. The ratio of 70% rates to 65% rates is 1:21. The ratio of 75% rates to 65% rates is 1:53. The ratio of 80% rates to 65% rates is 1:93. And the ratio of 85% rates to 65% rates is 2:44. Currently for many crops and counties, available coverage levels are 65, 70, 75, 80, and 85%. In some locations, coverage levels are only available at 65, 70, and 75%.

The left-hand side of equation (3) shows the increase in premium as coverage increases. With actuarially fair rates, this increase is a function of two cumulative probabilities and the conditional expectation of yield given that it falls between the two yield guarantees. Again, there are permissible limits on both. From equation (1) we know that $0.5 \geq F(Y_2) \geq F(Y_1)$ for symmetric and negatively skewed distributions, and $Y_2 \geq E[y | Y_1 \leq y < Y_2] \geq Y_1$ for all distributions.

Equation (3) is useful because for any two insurance rates and corresponding yield guarantees, it defines the combinations of probabilities and conditional yields that are consistent with actuarially fair rates generated by yield losses that are generated from some probability distribution. If there is no combination of cumulative probabilities and conditional expectations that solve (3) then there does not exist a yield distribution function that could support the given rates and yield guarantees.
not exist a yield distribution that supports these rates that is consistent with a conditional expected yield of 26 bushels per acre and actuarial fairness. Suppose the conditional expected yield equals the lowest possible level of 26 bushels per acre. Then equation (3) becomes $F(Y_2) = 0.704$, which is not admissible. There is no combination of conditional expected yield and cumulative probabilities that solve equation (3) and that satisfy the two conditions $0.5 \geq F(Y_2) \geq F(Y_1)$ and $Y_2 \geq E[y \mid Y_1 \leq y < Y_2] \geq Y_1$.

If we assume that the 65% rate in Hubbard County is actuarially fair, then we can conclude that the 70% rate is not. It is too high in that there is no conditional expected yield in Hubbard County that can satisfy equation (3). Is there a 70% rate that could satisfy equation (3)? Suppose the rate for 70% coverage is 0.18 and the conditional expected yield is 26.5 bushels per acre. Then equation (3) becomes $F(Y_2) = 0.379 - 0.333 F(Y_1)$ and clearly there exist solutions to this equation. This counterexample illustrates that the problem with the 70% APH rate in this county is that it is simply greater than can be justified by the laws of probability and the definition of actuarially fair insurance. That is, the rate relativity factor is too high for consistency.

Equation (3) can be normalized by dividing through by unconditional expected yield. Thus, normalized mean yield is 1.0 and the coverage level (e.g., 0.65) also refers to the yield level which triggers an indemnity payment. This results in

$$(4) \quad r_2C_2 - r_1C_1 = C_2G(C_2) - C_1G(C_1) - (G(C_2) - G(C_1))E[z \mid C_1 \leq z < C_2]$$

where $C_1$ and $C_2$ are coverage levels, $z = y/ E[y]$, and $G(z)$ is the distribution function for $g(z) = E[y] f(E[y]z)$. As discussed above, because RMA has the most loss experience with the 65% rates, then presumably the 65% premium rates come closest to reflecting actual crop insurance loss experience. For expository purposes, we treat the 65% premium rates as being actuarially fair, as defined by equation (1). We can then ask the question, given RMA rate relativities, for what range of RMA’s 65% premium rates does there exist the possibility that rates at higher coverage levels are also actuarially fair? Table 1 provides the answer to this question.

For each combination of coverage levels in table 1, we conducted a grid search over all 65% rates to find the rates for which there is at least one feasible solution to equation (4). For example, equation (4) at a 65% rate of 0.125 and a 70% rate of 0.1515 and a conditional yield of 0.65001, results in a feasible solution of $F(Y_1) = 0.45$ and $F(Y_2) = 0.497$. Of course, this solution means that there is almost no possibility of having yields between 0.85 and 1.0, which illustrates the weakness of the conditions we are imposing.

The first four results in table 1 show that as the coverage level increases the range of feasible 65% rates is reduced. This reduced range implies that the rate relativity factors are becoming more and more restrictive as the coverage level increases. For there to be the possibility that 85% pure premium rates are actuarially fair requires that the 65% rate be less than 0.07.

The pairwise consideration of rates in the first four rows of table 1 put no restrictions on the underlying distribution function for intermediate coverage levels. If we require that there be the possibility of actuarial fairness for intermediate coverage levels as well, then the range of feasible 65% rates becomes even narrower. For example, in counties where the maximum coverage level is 75%, the range of feasible 65% rates for which there is the possibility of actuarial fairness for the 65% rate, the 70% rate, and the 75% rate is 0.010 to 0.084. If we require the possibility of actuarial fairness for 65, 75, and 85% rates, then the maximum 65% rate is 0.053. And if we require the possibility of actuarial fairness for all coverage levels, then the maximum 65% rate is 0.047.

### Effects of Further Restrictions

The maximum 65% rates reported in table 1 were obtained by setting the conditional yield equal to the minimum possible. This is

<table>
<thead>
<tr>
<th>Rate Combination</th>
<th>Feasible Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>65% and 70%</td>
<td>0.010 to 0.126</td>
</tr>
<tr>
<td>65% and 75%</td>
<td>0.010 to 0.101</td>
</tr>
<tr>
<td>65% and 80%</td>
<td>0.010 to 0.083</td>
</tr>
<tr>
<td>65% and 85%</td>
<td>0.010 to 0.070</td>
</tr>
<tr>
<td>65%, 70% and 75%</td>
<td>0.010 to 0.084</td>
</tr>
<tr>
<td>65%, 75% and 85%</td>
<td>0.010 to 0.053</td>
</tr>
<tr>
<td>65%, 70%, 75%, 80% and 85%</td>
<td>0.010 to 0.047</td>
</tr>
</tbody>
</table>

Note: No pure premium rates less than 0.01 exist in the APH program.
equivalent to assuming that the probability of yields between the considered coverage levels is zero. In addition, no restrictions were placed on yields between 0.85 and 1.00. At the upper end of the ranges reported in table 1 there is no probability that yields would fall between 0.85 and 1.00. This can be seen from figure 2 which shows graphs of the cumulative distribution function for yields given 65% insurance rates and conditional yields when yields fall below 65% (denoted by CY 0–65). The yield distributions at the 65% rate of 0.047, which is at the upper end of the potentially acceptable range of rates for coverage up to 85%, show little possibility of yields falling between 0.80 and 1.00, regardless of the conditional yield level. The yield distribution at a 65% rate of 0.025, which is in the middle of the table 1 range, shows a distribution with positive weight across all coverage levels. Can yield distributions exhibit the characteristics of those associated with 65% rates of 0.047?

The distribution of farm-level yields and their effect on crop insurance has been the focus of much effort by agricultural economists (Zanini et al.). But no consensus has been reached on how crop yields are distributed. Early on, Day estimated that crop yields are skewed, although recently Just and Weninger demonstrate how data used to measure skewed yields are subject to a number of possible problems. Ker and Coble, Goodwin and Ker, and Ker and Goodwin use nonparametric methods to estimate the distribution of county average yields. Their empirical estimates support the notion that historical crop yields at the county level follow a mixture of distributions. A mixture of distributions can exhibit a wide variety of shapes. For example, a mixture of two normal distributions may not overlap, which would imply a flat CDF. Or if there is significant probability that yields equal zero, then the CDF between zero and the next lowest yield will be flat. And there may be some special cases where producers may face a situation where the probability that yield is below the yield guarantee is greater than 0.5, particularly where actual yields have been replaced by transitional yields in the calculation of a farmer’s APH yield.

In empirical work, use of flat CDF curves is rare. Rather, continuous, unimodal, “standard” density functions are employed, with the beta distribution perhaps being the most popular (see Babcock and Blackmer, Borges and Thurman, Babcock and Hennessy, and Coble et al.). Such distributions are likely appropriate for the many crops where one would expect a significant amount of distribution mass to be located around mean yields.

Given that the implied CDFs at the upper end of the ranges reported in table 1 do not conform to prior expectations about how many yield distributions should we look, we examine five further restrictions regarding the probability of yields between the highest allowed coverage level (0.75 or 0.85) and 1.00. These five scenarios are that the probability of yields between the highest allowed coverage level and 1.00 is at least 0.05, 0.10, 0.15, 0.20, and 0.25. These scenarios provide a range of cases where some weight is distributed just below the APH

\[ \text{At 65\% rate of } 0.047 \text{ and CY 0-65 of 0.455} \]
\[ \text{At 65\% rate of } 0.047 \text{ and CY 0-65 of 0.005} \]
\[ \text{At 65\% rate of } 0.047 \text{ and CY 0-65 of 0.325} \]
\[ \text{At 65\% rate of } 0.025 \text{ and CY 0-65 of 0.325} \]

Figure 2. Graphs of CDFs at various insurance rates and conditional yields
yield in the yield distributions. For example, a normal distribution with a mean of 1.00 and a standard deviation of 0.25 would have 22.57% of its weight between 0.85 and 1.00.

Rewriting equation (4) for \(C_2 > C_1\) gives an expression for cumulative probability at one coverage level as a function of cumulative probability at a lower coverage level and the conditional expectation of yield given that yield is between the two coverage levels:

\[
G(C_2) = \frac{r_2C_2 - r_1C_1 - G(C_1)(E[y | C_1 \leq y < C_2] - C_1)}{C_2 - E[y | C_1 \leq y < C_2]}.
\]

Given a conditional yield for yields below the 65% coverage level we can solve for \(G(0.65)\) using

\[
G(0.65) = \frac{r_{0.65} \cdot 0.65}{0.65 - E[y | y < 0.65]}.
\]

Then \(G(0.70)\) as a function of the conditional yield between 65% coverage and 70% coverage can be obtained through direct substitution into (5). \(G(0.75), G(0.80),\) and \(G(0.85)\) can be obtained with subsequent substitutions. All the scenarios require a value for the conditional expectation of yield for yields below the 65% coverage level, and values for the conditional expectation of yields between coverage levels.

The task is to determine the range of feasible 65% rates that are consistent with a given set of probability restrictions. This task can be accomplished by searching over all possible values for expected yield conditional on yield being below 65% for each given 65% rate. If any of the conditional yields are consistent with the restrictions, then we can say that there is an underlying yield distribution that could be consistent with actuarially fair APH rates.

Table 2 presents the range of feasible pure premium rates. For the first five scenarios, a grid search is performed across all possible conditional yields at 0.005 unit intervals.

Comparison of the results given in table 1 with table 2 results show that adding reasonable requirements for an underlying yield distribution decreases the maximum rate substantially. For crops and counties where 75% is the maximum coverage level, rates could possibly be actuarially fair if the 65% rate is less than 0.042 given the strongest restrictions. For crops and counties that have 85% coverage, the maximum 65% rate for which actuarial fairness is possible is only 0.023 when the strongest restrictions are put in place.

Do Crop Insurance Rates Reflect Losses from Yield Variability?

Given the bounds on rates indicated in the previous section, we would like to compare these bounds to current crop insurance rates throughout the country. However, these bounds are based purely on yield distribution arguments and do not include adjustments for insurance loading and prevented planting, whereas the current crop insurance rates do contain such adjustments. To create comparable rates, we have adjusted the current crop insurance rates to reflect pure premium rates by subtracting the county-crop specific prevented planting adjustment (provided by USDA–RMA) and multiplying by 0.88 to capture the insurance loading adjustment. These adjustments follow the rate-setting procedure outlined in Josephson, Lord, and Mitchell.

We examined the 2000 crop year APH 65% coverage level insurance rates for corn, soybeans, and wheat for the typical producer in each county (as determined by the R05 yield span, the middle yield span per county for these crops). Figures 3–5 show maps of

| Table 2. Range of 65% Pure Premium Rates for which Actuarial Fairness Is Possible |
|-----------------------------------|------------------|------------------|
| Rate Range                        | 65, 70, and 75%  | 65, 70, 75, 80, and 85% |
| No further restrictions (see table 1) | 0.010 to 0.083 | 0.010 to 0.047 |
| 0.5 – \(G(\text{highest coverage level})\) > 0.05 | 0.010 to 0.075 | 0.010 to 0.042 |
| 0.5 – \(G(\text{highest coverage level})\) > 0.10 | 0.010 to 0.067 | 0.010 to 0.037 |
| 0.5 – \(G(\text{highest coverage level})\) > 0.15 | 0.010 to 0.058 | 0.010 to 0.033 |
| 0.5 – \(G(\text{highest coverage level})\) > 0.20 | 0.010 to 0.050 | 0.010 to 0.028 |
| 0.5 – \(G(\text{highest coverage level})\) > 0.25 | 0.010 to 0.042 | 0.010 to 0.023 |
Figure 3. Sixty-five percent APH rates for corn—No further restrictions

Figure 4. 65% APH rates for soybean—No further restrictions

des rates across the country and illustrate whether they fall into the bounds outlined above. The counties shaded in black have 65% APH rates that fall within the bounds of actuarially fair rates for all coverage levels from 65% to 85%. The counties shaded in gray have 65% APH rates that fall within the bounds of actuarially fair rates for all coverage levels from 65% to 75%. The counties shaded in white have 65% APH rates that exceed either of these bounds. Counties that are not outlined do not have insurance coverage for that crop. RMA provides these rates through their Actuarial Data Master.
website (http://www.rma.usda.gov/tools/utils/grepadm/). These 2000 rates are indicative of current rates that are calculated with a formula without reference to a yield span.

Table 3 shows that the majority of counties where APH insurance is available do not have actuarially fair rates over all coverage levels. For corn, only 22.6% of counties have potentially fair rates up to 85% coverage and 49.8% have potentially fair rates up to 75% coverage. As shown in figure 3, these counties primarily reside in the Corn Belt. The proportions of soybean and wheat counties with potentially fair rates are similar as shown in table 3.

For corn and soybeans, because the counties that have APH rates that could be actuarially fair are located in the Corn Belt, the proportion of production that they represent is high. For corn, over 90% of production comes from counties that could have actuarially fair rates up to 75% coverage and almost 70% of production comes from counties with APH rates that could be actuarially fair up to 85% coverage. For wheat, the story is different. As shown in figure 5, much of the major wheat growing areas in Kansas and North Dakota have 65% APH rates that fall outside the possible fair range for coverage levels up to 85%.

Based on the results given in table 3, one would expect that wheat farmers would be less likely to buy 75% coverage than corn and soybean farmers before the additional ARPA subsidies were available for the simple reason that moving to 75% coverage meant that incremental costs exceeded the incremental benefits. Examination of RMA data bears out this conjecture. In 1998, 5.7% of wheat crop insurance policies were at the 75% coverage level, whereas 9.8% of corn policies and 10.7% of soybean policies were at that level.

Table 3. Proportion of Counties and Production with Possibly Actuarially Fair APH Premiums

<table>
<thead>
<tr>
<th>Crop</th>
<th>Criteriona</th>
<th>Under 0.047</th>
<th>Under 0.083</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Number</td>
<td>572</td>
<td>1,259</td>
</tr>
<tr>
<td></td>
<td>Percentage of counties</td>
<td>22.6</td>
<td>49.8</td>
</tr>
<tr>
<td></td>
<td>Percentage of productionb</td>
<td>67.9</td>
<td>90.6</td>
</tr>
<tr>
<td>Soybeans</td>
<td>Number</td>
<td>372</td>
<td>832</td>
</tr>
<tr>
<td></td>
<td>Percentage of counties</td>
<td>18.9</td>
<td>42.3</td>
</tr>
<tr>
<td></td>
<td>Percentage of production</td>
<td>59.4</td>
<td>81.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>Number</td>
<td>302</td>
<td>1,124</td>
</tr>
<tr>
<td></td>
<td>Percentage of counties</td>
<td>12.5</td>
<td>46.6</td>
</tr>
<tr>
<td></td>
<td>Percentage of production</td>
<td>23.4</td>
<td>70.7</td>
</tr>
</tbody>
</table>

a0.047 is the upper limit on actuarially fair APH rates up to 85% coverage levels. 0.083 is the upper limit on actuarially fair APH rates up to 75% coverage levels.
bProportion of production is the share of national production from 1998 to 2000.
Table 4 presents the actuarially fair pure premium rates for ten measures of yield uncertainty as expressed by a 65% pure premium rate shown in the first column. At low levels of yield uncertainty the actuarially fair premiums are low at all coverage levels. However, the rate at which the premium rates increase is high. At higher levels of yield uncertainty rates are high but the rate at which they increase in coverage levels is low. Figure 6 provides the intuition for this result by presenting the cumulative distributions for two rates. The low rate of 0.03 shows the standard S-shaped curve that we expect when looking at a yield distribution. This curve is quite convex over the range of yields from 0.65 to 0.85 as shown. The probability of yield being below 0.65 is about 13%. This probability rises to about 30% at a yield of 0.85. This means that the chances of receiving a crop insurance indemnity increases by a factor of 2.3.

Now observe the CDF associated with a 10% pure premium rate at the 65% coverage level. The probability of receiving an indemnity with 65% coverage is 32%. This probability does not grow rapidly as coverage increases because the CDF is concave over this range. The probability only grows by a factor of 1.3 as coverage increases to 85%. This demonstrates why actuarially fair crop insurance rates should increase by a lesser amount for crops and regions that have high initial rates compared to crops and regions in lower-risk areas. Note, however, that we make no specification about how beta-based premium rates

<table>
<thead>
<tr>
<th>Table 4. Actuarially Fair Pure Premium Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>0.020</td>
</tr>
<tr>
<td>0.030</td>
</tr>
<tr>
<td>0.040</td>
</tr>
<tr>
<td>0.050</td>
</tr>
<tr>
<td>0.060</td>
</tr>
<tr>
<td>0.080</td>
</tr>
<tr>
<td>0.100</td>
</tr>
<tr>
<td>0.150</td>
</tr>
<tr>
<td>0.200</td>
</tr>
<tr>
<td>0.300</td>
</tr>
</tbody>
</table>

Rate Relativities Derived from a Density Function

A comparison of APH rate relativities with those derived from a density function will illustrate the magnitude of difference between rates derived from a well-behaved yield distribution and those faced by farmers.

The beta density function has always been used as the basis for determining revenue assurance (RA) premiums and was used as the basis for CRC corn and soybean premiums beginning with the 2003 crop year. Details on how we generated rates using the beta density can be found in a longer version of the paper that is available on request. The approach was used to generate 5,000 draws from a beta density with a mean of 100 bushels.

Figure 6. Beta CDFs for two APH rates and an expected yield of one
might vary across crops, only across the degree of yield risk.

Impact of Information Asymmetries

The analysis presented above does not account for the losses due to moral hazard and adverse selection, which we refer to henceforth as simply information asymmetries (IA). We now address the question whether constant rate relativities make sense as a means of adjusting for losses due to increasing IA as coverage increases.

It is reasonable to expect that insurance claims due to IA will increase as insurance coverage increases. Constant rate relativities might be able to account for such claims. The implied loading for IA under the APH rate relativities can be calculated under alternative scenarios regarding the 65% pure premium rate, defined as the rate that covers losses from natural yield variations, and the proportion of the insurance claims paid out at the 65% coverage level that are generated by IA.

To make these calculations, first assume that the pure premium rates reported in table 4 accurately capture expected insurance claims from natural yield variations. Thus, if expected insurance claims from yield variability at 65% coverage justifies a premium rate of 0.04, then a premium rate of 0.085 at 85% coverage is also justified. Now suppose that insurance claims due to IA at the 65% coverage level equal 50% of the premium rate justified by yield variability. Thus, the premium rate that would cover all insurance claims at 65% is 0.06. Given a long enough historical record, the premium rate based on actual losses would also be approximately 0.06. Using the constant rate relativity of the APH program, the 85% insurance rate would be 0.146. Thus, the implied increase in premium rate due to moral hazard is 72.2% at the 85% coverage level \([0.722 = (0.1464 - 0.085)/0.085]\). That is, 72.2% of losses at 85% would have to be generated by IA to justify the use of a constant rate relativity.

Figure 7 repeats these calculations for different 65% pure premium rates and different 65% IA loads. For example, if the premium rate required to cover insurance claims from yield variability at the 65% coverage level is 0.10, and the percent IA load at the 65% coverage is 25% (denoted as MH65 = 25% in figure 7), then the implied IA load from the APH rate relativities at the 85% coverage level is almost 98%.

Two features of figure 7 cast doubt on whether constant rate relativities make sense in this context. The first feature is that when yield variability is quite low, then the implied IA load at 85% is less than at 65%, which contradicts the notion that IA should increase with the coverage level. The second feature is that the implied IA load when yield variability is

![Figure 7. Implied moral hazard loads from constant rate relativities at 85% coverage](image)
high is extremely large. At a pure premium rate of 0.2, the implied IA load ranges from a minimum of 94% to a maximum of 190%.

It is difficult to conclude that constant rate relativities are supportable as a means for accounting for IA given the results in figure 7. For example, consider the implications for two wheat farmers: one farmer who irrigates wheat in Idaho and one who grows dryland wheat in western North Dakota. Suppose there is no IA at all in the 65% premium rates charged for these two farmers. The figure 7 results suggest that the Idaho farmer will actually make fewer claims than he or she is entitled to at the 85% coverage level and that the North Dakota farmer will generate nearly double the claims that he or she is entitled to. What would make these two farmers so different? If anything, one would tend to think that the Idaho wheat farmer would have a greater IA load than the North Dakota farmer because of greater control over the crop outcome because of irrigation. But the pattern of IA that is suggested by the use of constant rate relativities suggests otherwise.

**Implications and Conclusions**

Increased subsidies under ARPA have brought increased public attention to the implications of an unsound APH rate structure. For example, Barnaby demonstrates that RA with the harvest price option can actually cost 20% less than simple yield insurance and 32% less than CRC for Kansas dryland corn production at the 85% coverage. Clearly farmers in these regions will select the product that gives them the most coverage per dollar of premium.

We demonstrate that a large part of the difference in premium rates at high coverage levels is due to the use of fixed rate relativities used to set APH rates. Moreover, we demonstrate that these relativities cannot be supported if rates at all coverage levels are to be actuarially sound. Farmers that plant crops in regions where the 65% pure premium rate is above 0.03 (which corresponds to an APH rate of about 0.04) face unsubsidized premiums that are too high at 80% and 85% coverage levels. The higher the yield risk, the greater is the discrepancy between actuarially fair rates and actual APH rates for coverage levels greater than 65%. This discrepancy could explain why 65% coverage was the most popular coverage level in higher risk areas. Farmers in high-risk areas were being charged too much at higher coverage levels. We demonstrate that this conclusion likely holds even in a world of subsidies, moral hazard, and adverse selection. Farmer reluctance to increase their coverage above 65% could also explain why Congress felt the need to move away from a fixed per-acre premium subsidy to the current subsidy structure that increases per-acre subsidies as coverage levels increase. That is, the higher subsidies are used to offset the excessive premium charge, making higher coverage levels more attractive.

If APH rates were made actuarially fair by allowing rate relativities to vary by crop and region, then perhaps Congress could revert back to fixed per-acre subsidies which would induce farmers to select the crop insurance product that gave them the biggest risk management return per premium dollar rather than having that decision distorted by proportionate premium subsidies.

Accurate rate making procedures should measure how increased coverage levels affect insurance claims from yield variability as well as from increased moral hazard and adverse selection. Steps could then be taken to have rates reflect both exogenous risk and endogenous behavior. Farmers that agree to follow insurance rules that are designed to decrease moral hazard and adverse selection could then be charged a lower rate than farmers who do not.

[Received April 2002; accepted September 2003.]

**References**


