

# Evaluation of Crop Insurance Yield Guarantees and Producer Welfare with Upward-Trending Yields

Shyam Adhikari, Thomas O. Knight, and Eric J. Belasco

Actual Production History (APH) yields play a critical role in determining the coverage offered to producers by the Risk Management Agency's yield-based crop insurance products. Using both county and individual insured unit data, we examine the impact of APH yield trends for Texas cotton and Illinois corn. Our findings indicate that biases due to using simple average APH yields when yields are trending upward reduce the expected indemnity and actuarially fair premium rate. The estimated welfare effect also varies significantly with different commonly used detrending approaches. This study demonstrates that producer welfare can be enhanced through proper treatment of yield trends in crop insurance programs.

**Key Words:** actual production history, crop insurance, yield trend, yield guarantee

Insurance products offered under the Federal Crop Insurance Program have been a primary tool used by agricultural producers in mitigating risk for more than twenty years. As these products have grown in popularity, a number of program features have been criticized. While recent program modifications have addressed a number of criticisms, some argue that further refinements would increase the effectiveness of these insurance products.

One frequent criticism of individual yield and revenue based insurance products including Yield Protection (YP), Revenue Protection (RP), and Revenue Protection-Harvest Price Exclusion (RP-HPE) is that the coverage being offered is biased downward because crop yields are upward trending, while the insurance guarantee is based on the simple average of from 4 to 10 years of historical yields for the insured unit. Yield trends pose a problem because when a significant upward trend exists there is potential for the simple average historical APH yield to be biased downward relative to the actual expected yield for the insured

unit. This downward bias results in a tendency toward under-insurance and reduces the expected indemnity. Since the effective coverage level is tied to the APH yield, farmers with positive yield trends are not able to cover their actual risk without choosing nominal coverage levels above the desired real coverage level (Skees and Reed 1986). Because farmers with significant yield trends have lower expected indemnities, they have less incentive to participate in the insurance program.<sup>1</sup>

Skees and Reed (1986) were the first to examine the effects of yield trends in the U.S. crop insurance program. They asserted that since coverage levels are intertwined with APH yields, the APH yield is an estimate of expected yield for farmers with positive yield trends. This means that farmers with positive yield trends are not able to purchase as much protection as is implied in their coverage level choices. Skees and Reed provided an example illustrating the effects of trend

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<sup>1</sup> Since the research reported here was done, the Risk Management Agency (RMA) has announced approval of a Trend-Adjusted APH Yield Endorsement for corn and soybeans in most counties of the Midwest. This Endorsement adjusts for trends at the county level, as in our analysis. Therefore, the analysis reported here is timely in that it coincides with an effort by the RMA to address product shortcomings relating to yield trends. This emphasizes the importance of the issue examined in this paper. However, our analysis should not be interpreted as an evaluation of the newly introduced product because the procedures followed presumably do not perfectly mirror those used in developing the Endorsement.

bias. Farmers with an expected yield of 100 bushels per acre and a trend of two bushels per year would have an APH yield of only 90 bushels based on ten years of data (i.e.,  $100 - [2 \times 5] = 90$ ). If the farmer purchased 75 percent coverage (75 bushels), the effective protection would be only 67.5 bushels.

Woodard (2009) argues that rate-making procedures used by the Risk Management Agency (RMA) produce biased rates when the yield exhibits an upward trend. He estimated that the current rate-making procedure produces rates that are 75 percent to 180 percent in excess of actuarially fair premiums in Illinois. He proposed a correction factor based on the magnitude of the upward trend in crop yield. Umarov (2009) examined the yield protection offered with a small sample APH and corn yield trend in six Illinois counties. He found that the protection level guaranteed by the insurance dropped by 21 percent as the base period increased from 4 to 10 years, and that counties with larger yield trends tended to experience larger reductions. His results also revealed that premium rates were not highly influenced by yield trend. Therefore, he concluded that incorporating a yield trend adjustment improves the insurance protection and also discourages farmers from reporting only the most recent yields.

Previous research on APH yields and yield trends has been limited in scope to the assessment of existing yield guarantees versus appropriate yield guarantees and effects on premium rates and indemnities. In the present study we expand upon previous research by analyzing the overall producer welfare effect of trend-related bias in APH yields as well as the effects of using different trend adjustment approaches including linear, quadratic, and bi-linear spline.

### Theoretical Framework

Three crop insurance products—Yield Protection (YP), Revenue Protection (RP), and Revenue Protection-Harvest Price Exclusion (RP-HPE)—base coverage on the APH yield for the insured unit. This insured yield is based on 4 to 10 years of historical yield experience for the insured unit. For YP, an indemnity is paid when the actual farm yield falls below the guarantee level. We assume that a farmer is risk-averse with preferences char-

acterized by a Von Neuman-Morgenstern utility function that is strictly decreasing, concave, and twice differentiable. Further, the producer's yield is a random variable  $y$  described by a distribution function  $f(y)$  with mean  $\mu$ . Let the APH yield  $y_{APH}$  have the distribution  $g(y)$  with mean  $\mu_{APH}$ . The ranges of offered guarantee levels in APH-based insurance are  $\alpha = 0.50$  to  $0.85$  in increments of  $0.05$ . For YP, if the yield falls below the guarantee level ( $\alpha y_{APH}$ ), the farmer receives an indemnity of  $p(\alpha y_{APH} - y)$  per acre, where  $p$  is the price guarantee level (projected price). Let the insurance premium be denoted as  $\gamma$  and price of output as  $p$ , then per acre farm returns  $\pi_i$  for coverage level  $i$  with insurance can be written as

$$\pi_i(y) = \begin{cases} py - c - \gamma & \text{if } y \geq \alpha y_{APH} \\ py - c - p_\alpha(\alpha y_{APH} - y) - \gamma & \text{if } y < \alpha y_{APH} \end{cases},$$

where  $c$  is production costs.

The APH yield distribution can be split into the following two special cases:

CASE 1: When there is no trend in the APH yield, then

$$(1) \quad y_{APH} = \mu_{APH} + \varepsilon_t,$$

where  $\varepsilon_t$  is a stochastic error term. Though there might be trend in the APH yield, the RMA uses this case for deciding the guarantee level.

CASE 2: When a linear trend exists in the APH yield, then the distribution of APH yield  $y_{APH}$  is assumed to come from the following equation:

$$(2) \quad y_{APH} = \mu_{APH} + \delta_0 w + v_t,$$

where

$$w = \left(\frac{T+1}{2}\right),$$

$t$  denotes time, and  $v_t$  is a stochastic error term.

$$E[y_{APH}] = \mu_{APH} + \delta_0 E[w] + E[v_t]$$

$$E[v_t] = 0.$$

Under this scenario, the expected APH yield is  $\mu_{APH} + \delta_0 E[w]$ , which is greater than  $\mu_{APH}$  when

there is a positive yield trend. Given that we are generating a guarantee for period  $T + 1$  that uses information from  $1, 2, \dots, T$ ,  $E[y_{APH}]$  is unambiguously higher than  $\mu_{APH}$  when a positive slope is present. As a result, insured producers are underinsured (i.e., the effective coverage level is less than the nominal coverage level). If we assume that the indemnity and premium are denominated in production units and the producer covers the yield risk by paying  $\gamma$  units of premium per acre, the farmers' indemnity is

$$(3) \quad I = \max(\alpha \bar{y}_{APH} - y, 0).$$

Assume the premium is actuarially fair (i.e., equal to the expected indemnity). The producers' net yield ( $y^n$ ) is equal to actual farm yield ( $y$ ) plus indemnity ( $I$ ) minus insurance premium ( $\gamma$ ), as given below in equation (4):

$$(4) \quad y^n = y + I - \gamma.$$

The farmers' yield risk is measured by the variance of the net yield. The variance of net yield in equation (4) is as given in Miranda (1991):

$$(5) \quad \text{Var}(y^n) = \text{var}(y) + \text{var}(I) + 2\text{cov}(y, I).$$

The yield risk reduction offered due to insuring yield is the variance of yield minus variance of net yield. By insuring, the producer reduces yield risk by

$$(6) \quad \Delta = \text{var}(y) - \text{var}(y^n) = -\text{var}(I) - 2\text{cov}(y, I).$$

The covariance of actual farm yield and indemnity is negative, while the value of  $\Delta$  can be positive or negative depending on the magnitude of both terms in equation (6). Since the APH yield consists of yield trend as given in Case 2, the variance of the indemnity is also inflated by the magnitude of trend. Given the censored nature of the indemnity function shown in equation (3), it can be shown that a higher expected value of yields (associated with a positive trend) can also be associated with a lower percentage of lower-bound yield observations where indemnities do not occur. A higher variance can be attributed to fewer limit observations in the sample. Due to the

increased variance of indemnity, the risk reduction from crop insurance is less in the presence of a positive trend.

RMA's rate-making procedures utilize the rate yield rather than the APH yield. The rate yield is the simple average of the historical yields.<sup>2</sup> The premium rate at the 65 percent coverage level is the base rate which is given as

$$\text{Rate}_{65} = \text{Reference Rate} \times \left( \frac{\text{APH Yield}}{\text{Reference Yield}} \right)^{-\text{exponent}} + \text{Fixed Load}.$$

The yield ratio has policy-mandated lower and upper bounds of 0.5 and 1.5 respectively. The negative exponent in the yield ratio produces a convex curve over the range 0.5 to 1.5, with constant rates below and above the variable range of 0.5 to 1.5.

## Methodology

We decompose National Agricultural Statistics Service (NASS) county yield data into systemic and idiosyncratic components in order to approximate farm yields. This approach is taken due to the unavailability of a long series of farm-level yield data. The decomposition used in Miranda (1991), Mahul (1999), and Carriquiry, Babcock, and Hart (2008) can be written as

$$(7) \quad \begin{aligned} y_{it} &= \mu_i + \beta_i (y_{ct} - \mu_c) + \varepsilon_{it} \\ &= \mu_c + \delta_i + \beta_i (y_{ct} - \mu_c) + \varepsilon_{it}, \end{aligned}$$

where  $\mu_c$  and  $\mu_i$  are the mean county and farm yield,  $\delta_i$  is the difference between county mean yield and farm mean yield,  $y_{it}$  and  $y_{ct}$  are the farm and county yield in year  $t$ , and  $\varepsilon_{it}$  is the farm yield deviation in year  $t$ . It is assumed that  $E[\varepsilon_{it}] = 0$ ,  $E[y_{it}] = \mu_i$ ,  $E[y_{ct}] = \mu_c$ ,  $\mu_i = \mu_c + \delta_i$ ,  $\text{Cov}(\varepsilon_{it}, y_{ct}) = 0$ ,  $\text{Var}(y_{ct}) = \sigma_c^2$ , and  $\text{Var}(y_{it}) = \beta_i^2 \sigma_c^2 + \sigma_{\varepsilon}^2$ . We

<sup>2</sup> Yield substitution enters into APH yields in any year when the actual yield falls below 60 percent of county proxy T-yield. In such cases the farmer can replace the individual year's yield by 60 percent of T-yield. A yield floor is used if the computed APH yield falls below a given percentage of the county T-yield. We do not incorporate yield substitution and yield floors into the analysis reported in this paper. Thus, our results are an abstraction from reality to the extent that yield substitution and yield floors influence the effect of yield trend.

assume that the variance of the idiosyncratic shock is uniform across insured units within a county. The regression residual  $\varepsilon_{it}$  is used to estimate the variance as a weighted average of the error variance ( $\hat{\sigma}^2$ ) estimated for each of the insured farm units.

For this study we chose Lubbock County, Texas, for cotton and Adams County, Illinois, for corn because Texas and Illinois are major producing states for these crops, and yield variability and insurance parameters vary substantially between these states and crops. Both of the counties chosen for our analysis have the yield data series that is required for our analysis. Cotton yields exhibit smaller trends, while corn yields generally have much more significant and larger trends. County yield data are from 1972 to 2009. Farm-level data from 1998 to 2008 were made available by the RMA. The  $\mu_c$  is the county mean yield and is estimated from the county yield series. Both farm- and county-level data are used to fit equation (7) to estimate  $\beta_i$  and  $\delta_i$ .

We assumed three functional trend relationships: linear, quadratic, and bi-linear spline. The linear trend is given as in equation (2):

$$(8) \quad y_{APH} = \mu_{APH} + \delta_0 t + v_t.$$

The quadratic trend equation is

$$(9) \quad y_{APH} = \mu_{APH} + \delta_0 t + \delta_1 t^2 + v_t.$$

The bi-linear spline is

$$(10) \quad y_{APH} = \mu_{APH} + \delta_0 \min(0, t - t^*) + \delta_1 \max(0, t - t^*),$$

where  $t$  is the time,  $t^*$  is the breakpoint between linear segments, and  $\delta_0$  and  $\delta_1$  are slopes of the trend lines and segments. Each county yield series is then regressed as a function of time for the 37-year period for all three alternative trend relationships. After estimating the predicted yield, both the farm- and county-level yield series are multiplicatively detrended and normalized to the base year 2009 predicted yield. We generate the yield series from the detrended and normalized county yield data.

Debates regarding appropriate distributional assumptions for crop yields and the implications for

crop insurance have received great emphasis in the agricultural economics literature (Goodwin and Ker 1998, Ker and Goodwin 2000, Atwood, Shaik, and Watts 2002, Goodwin and Mahul 2004). Researchers have used parametric distributions, semi-parametric distributions, and non-parametric distributions in order to avoid the conflicting arguments for and against the normal distribution. We used non-parametric bootstrapping to construct our yield series.

For each county, 10,000 simulated observations were constructed from the detrended yield series for the county using a bootstrapping method. The residuals ( $\varepsilon_{it}$ ) were simulated by assuming normal distributions with mean zero and variance of ( $\hat{\sigma}^2$ ) for the respective counties. By assuming  $\beta = 0$  and  $\delta = 0$  we construct the farm yield series using the relationships given in equation (8). We construct yield series of length 11 years, where years 1 to 10 are used to estimate the expected yield and year 11 is used as the insurance yield. After constructing 11 years of yields, we introduce the three different trends (linear, quadratic, and bi-linear spline). These yield samples are used to simulate actuarially fair premium rates and indemnities for each of the yield realizations. Price series were constructed by assuming a lognormal distribution with mean price and coefficient of variation based on futures and options market quotes for the 2008 crop year. Monte Carlo integration was used to approximate the insurance indemnity, farmers' utility, and certainty equivalents.

The indemnity with APH is computed as

$$(11) \quad I(\alpha) = p_G \times \text{Max}(\alpha \mu_y - y, 0),$$

where  $p_G$  is the price guarantee,  $\mu_y$  is the APH expected yield, and  $y$  is the realized farm yield. We refer to farm returns per acre (the product of random yield and random price), minus per acre production costs, plus the insurance indemnity, minus premium ( $\gamma$ ) paid, minus production cost. Our analysis uses an expected utility framework to compute the certainty equivalent for the individual farm at different levels of coverage. A risk-averse farmer maximizes expected utility of wealth. We assume that farmers' risk preferences are represented by constant relative risk aversion (CRRA). The CRRA utility function requires initial wealth in order to reflect appropriate risk

aversion of farmers (Chavas 2004). We assume that initial wealth is equal to the net worth per acre of the Agricultural and Food Policy Center (AFPC) representative farm that is located closest to our study counties (Richardson et al. 2008). Let initial wealth be  $w$ , and  $c$  be production cost<sup>3</sup> per acre. Farm revenue per acre with insurance is

$$(12) \quad \pi_i(\alpha) = w + p \times y + I(\alpha) - \gamma - c$$

and the CRRA utility function is

$$(13) \quad U_i(\alpha) = -\pi_i(\alpha)^{1-R},$$

where  $R > 1$  is the coefficient of relative risk aversion and  $\pi_i$  is revenue per acre as a function of the APH guarantee level. We use  $R = 2$  as moderate risk aversion. The insurance guarantee level is the product of expected yield and APH coverage level. Assuming that a farmer chooses the APH insurance coverage level to maximize his or her expected utility, the farmer's decision problem is given by

$$(14) \quad \max_{\alpha} EU_i(\alpha) = \max_{\alpha} \int -\pi(\alpha)^{1-R} dF(\pi_i | \alpha).$$

The maximized expected utilities in equation (14) are converted into associated certainty equivalents for each case:

$$(15) \quad CE^* = (-EU_i^*)^{1/(1-R)}.$$

The certainty equivalent was estimated for a range of coverage levels under different scenarios: linear, quadratic, and bi-linear spline trend adjustment, and with a simple average APH yield. Our welfare measure is based on the difference in the certainty equivalent per acre for each of the cases compared with the per acre certainty equivalent for the uninsured case.<sup>4</sup>

<sup>3</sup> Production costs per acre were taken from Texas A&M University and University of Illinois extension crop budgets.

<sup>4</sup> Our assumption of homoskedastic errors is contrasted with some studies [including Goodwin and Ker (1998)], while others such as Harri et al. (2009) show empirically that both heteroskedastic and homoskedastic errors are found across commodities and regions. More recent research by Yu and Babcock (2010) has demonstrated that decreasing heteroskedasticity is present in some crops such as corn where new technologies have developed higher-yielding and more drought-resistant varieties. Given these ambiguous findings and the fact that APH yields incorporate a relatively short time series of yields (4 to 10 years), we believe our homoskedasticity assumption is reasonable.

## Data Description

County yield data from 1972 to 2009 were obtained from NASS. Individual farm yield data were obtained from the RMA as Type15 crop insurance data for 2008 cotton and corn. APH yield history data for the YP, RP, and RP-HPE insurance products were included in the analysis. For example counties in our analysis we selected Lubbock County in Texas for cotton and Adams County in Illinois for corn. The yield trend in Lubbock County cotton is very modest in magnitude, while for Adams County corn it is large (Figure 1).

## Results and Discussion

### Effects on Expected Indemnity

Our analysis compares expected indemnities when the insurance guarantee is based on a trend-corrected yield versus the simple average APH yield. Table 1 shows the ratio of expected indemnities with a simple average APH yield guarantee to expected indemnities with a trend-corrected yield guarantee. Results for Lubbock County cotton show that at the 50 percent coverage level, indemnities based on a 4-year simple average APH yield guarantee are 82 percent of indemnities based on a trend-corrected guarantee. The ratio increases with coverage level, with values of 88 percent, 90 percent, and 93 percent, respectively, for coverage levels of 65 percent, 75 percent, and 85 percent. Values based on a 10-year yield history show even larger under-insurance effects of ignoring trend in calculating the yield guarantee. This is the expected result since the simple average APH yield understates the trend-corrected expected yield by a larger amount when a longer history of "older" data is used. The results for Adams County corn follow a similar pattern but the indemnity reduction based on using a simple average APH yield is much larger in this case where the yield trend is stronger (see Figure 1). The implication of our results is that use of a simple average APH yield guarantee reduces expected indemnities compared with indemnities that would be paid if trend were taken into account in computing the insurance guarantee. The reduction in indemnities due to failure to correct for trend is

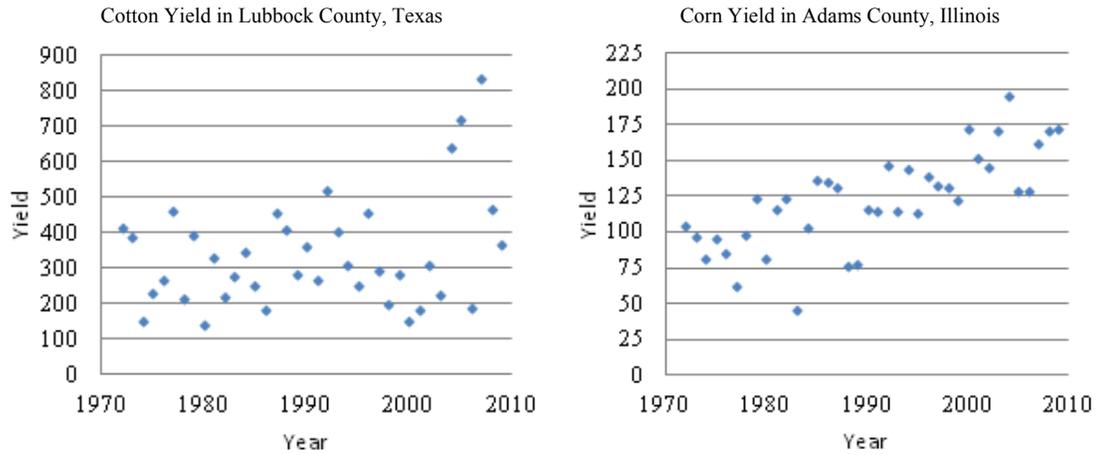


Figure 1. Crop Yields in Sample Counties

Table 1. Ratio of Expected Indemnity Based on Simple Average APH Yield to Indemnity with Trend-Corrected Yield Guarantee

County/Crop	APH size	Ratio by Coverage Level			
		50%	65%	75%	85%
Lubbock / Cotton	4	0.82	0.88	0.90	0.93
	10	0.77	0.82	0.85	0.87
Adams / Corn	4	0.50	0.61	0.69	0.77
	10	0.41	0.50	0.55	0.62

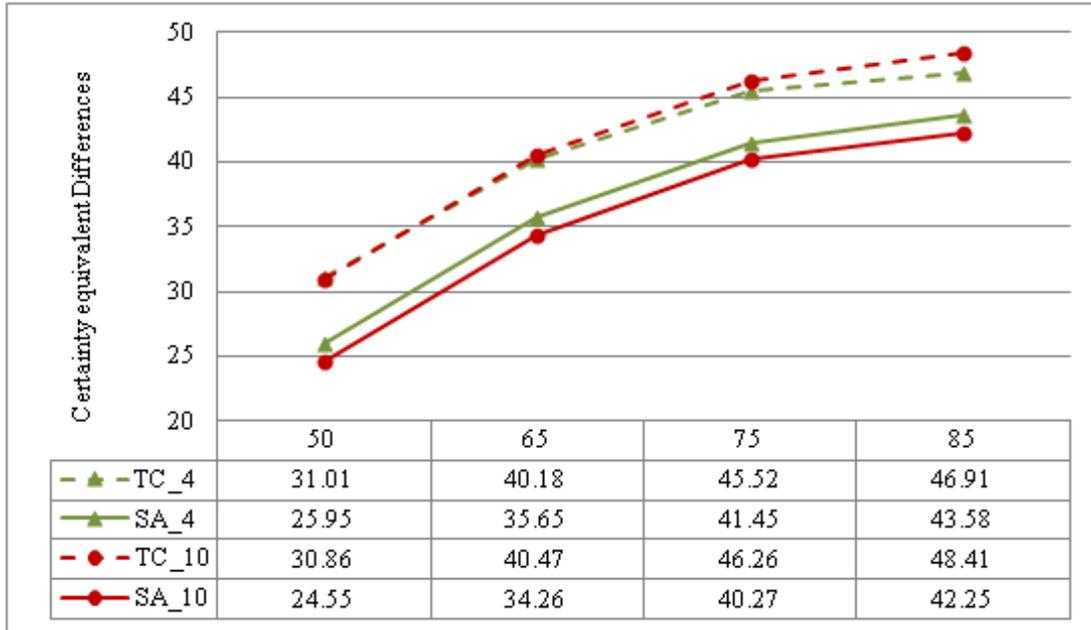
largest (i) at lower coverage levels, (ii) when a longer yield history is used in computing the guarantee, and (iii) when the yield trend is strong (e.g., Adams County corn versus Lubbock County cotton).

*Welfare Effects with Linear Yield Trend*

Certainty equivalent differences with and without insurance provide a measure of the producer welfare effects of insurance. Similarly, the certainty equivalent difference between coverage based on a trend-corrected yield guarantee versus a simple average APH yield measures the difference in welfare benefits of adjusting the guarantee for trend versus using the simple average APH yield. Figure 2 shows our simulated certainty equivalent differences for cotton with versus without insurance assuming a linear yield trend. These results

show, for example, that with a trend-corrected yield guarantee based on 4 years of history (TC\_4), the benefit of Yield Protection coverage at the 50 percent level is \$31.01 per acre, compared with \$25.95 per acre if the guarantee is based on a simple average APH yield (SA\_4). Fifty percent coverage level results based on a 10-year yield history show a trend-corrected certainty equivalent benefit (TC\_10) of \$30.86 per acre versus a \$24.55 per acre benefit of insurance when the guarantee is based on a simple average 10-year APH yield (SA\_10). Certainty equivalent benefits of the insurance coverage increase with coverage level but the added benefit of a trend-corrected guarantee over a simple average APH yield-based guarantee is relatively stable.

With the existence of a significantly greater yield trend, the welfare loss from using a simple average APH yield versus a trend-corrected yield



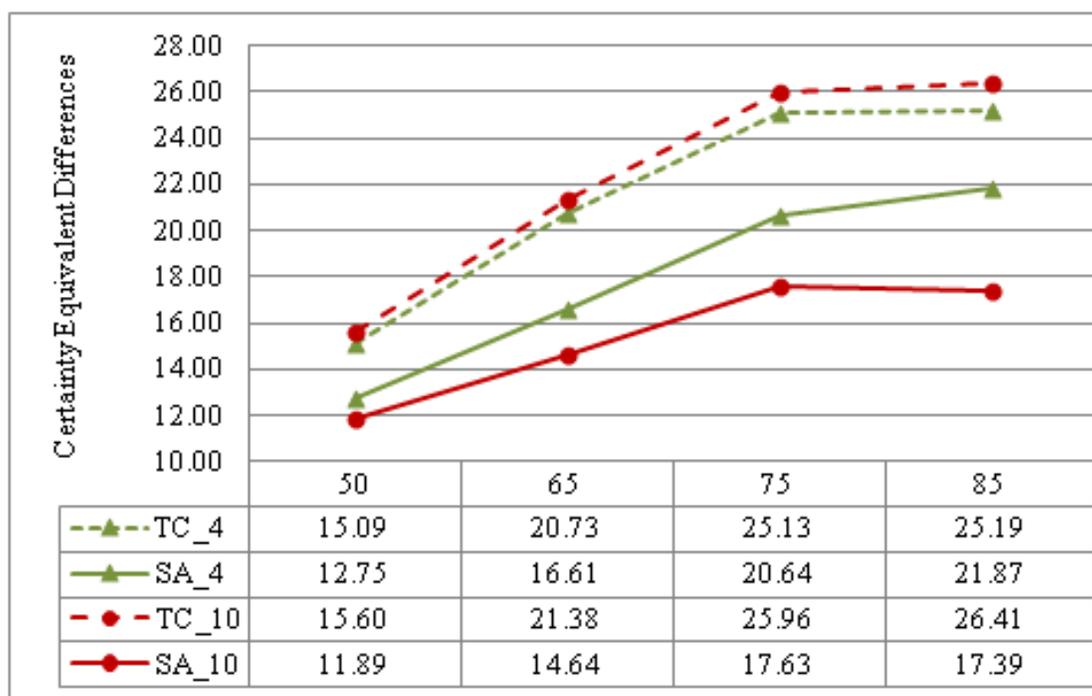
**Figure 2. Lubbock County Cotton Certainty Equivalent Differences by Coverage Level for Alternative Yield Guarantee Computation Methods and Sample Sizes**

guarantee is expected to be greater for Adams County corn than for Lubbock County cotton. Our simulated results for Adams County corn in Figure 3 are consistent with this expectation. Assuming a linear trend, these results show that with a trend-corrected yield guarantee based on 4 years of history (TC\_4), the benefit of Yield Protection coverage at the 50 percent coverage level is \$15.09 per acre, compared with \$12.75 per acre if the guarantee is based on a simple average APH yield (SA\_4). As with Lubbock County cotton, the certainty equivalent difference is larger when the trend-corrected and simple average APH yield is based on 10 versus 4 years of yield history. This result is attributed to the fact that the simple average APH yield has greater downward bias compared with the trend-corrected yield guarantee when the “older” data in a 10-year series form the basis for the guarantee. Certainty equivalent benefits of the insurance coverage increase up to the 75 percent coverage level and, unlike Lubbock County cotton, the additional benefits arising from trend correction versus a simple average APH yield guarantee increase with coverage level, at least up to the 75 percent coverage level. Benefits of trend correction tend to level out between

the 75 percent and 85 percent coverage levels, with 4-year yield history results indicating a narrowing of the difference between trend-corrected and simple average guarantee based certainty equivalents at the highest coverage level.

*Comparison of Alternative Trend Corrections*

The results presented thus far compared producer welfare benefits of insurance when trend is and is not incorporated into the insurance guarantee. All of this analysis was based on use of a simple linear yield trend correction. In this section we continue to focus on the issue of producer welfare benefits with and without incorporation of yield trend, but here we explore the effects of non-linear trend corrections including the quadratic and bi-linear spline. Our results for Lubbock County cotton with a 10-year yield history are presented in Table 2. The results for a linear trend match those presented in Figure 2. They show a welfare loss of approximately \$6.00 per acre when the guarantee is based on a simple average APH yield versus a trend-corrected yield guarantee. Estimated certainty equivalent differences between the insured versus uninsured case are larger with



**Figure 3. Adams County Corn Certainty Equivalent Differences by Coverage Level for Alternative Yield Guarantee Computation Methods and Sample Sizes**

**Table 2. Certainty Equivalent Differences for Lubbock County Cotton with 10-Year Yield History**

Trend Type	Guarantee	Coverage Level			
		50%	65%	75%	85%
Linear	Trend Corrected	30.86	40.47	46.26	48.41
	Simple Average APH	24.55	34.26	40.27	42.25
Quadratic	Trend Corrected	38.56	51.49	59.69	63.73
	Simple Average APH	34.84	46.36	53.70	59.18
Spline	Trend Corrected	42.70	57.40	66.90	72.19
	Simple Average APH	35.40	48.80	56.50	60.60

either quadratic or bi-linear spline trends than with the linear trend correction. This is due to the fact that Lubbock County cotton yields have increased at an increasing rate in recent years (see Figure 1). In this case the linear trend correction dampens the effect of a trend that has increased over time on the yield guarantee which is based on the last 4–10 years of data. Other patterns that appear in the results are: (i) the largest difference between the trend-corrected and simple average

APH results are associated with the bi-linear spline trend estimator, and (ii) the differences based on trending versus no trending are fairly constant across coverage levels with the linear and quadratic trend estimators but increase with coverage level when the bi-linear spline trend correction is used.

Our results for Adams County corn are shown in Table 3. The results for a linear trend repeat those given in Figure 3. The estimated welfare

**Table 3. Certainty Equivalent Differences for Adams County Corn with 10-Year Yield History**

Trend Type	Guarantee	Coverage Level			
		50%	65%	75%	85%
Linear	Trend Corrected	15.60	21.38	25.96	26.41
	Simple Average APH	11.89	14.64	17.63	17.39
Quadratic	Trend Corrected	16.08	22.96	28.44	30.31
	Simple Average APH	14.18	19.67	24.57	26.01
Spline	Trend Corrected	16.68	23.38	28.48	29.00
	Simple Average APH	12.71	16.15	19.39	19.49

loss for a guarantee based on a simple average APH yield versus a linear trend-corrected yield guarantee range from \$3.71 per acre (\$15.60–\$11.89) at the 50 percent coverage level to \$9.02 per acre (\$26.41–\$17.39) at the 85 percent coverage level. Estimated welfare losses with a quadratic trend correction are smaller, ranging from \$1.90 per acre (\$16.08–\$14.18) at the 50 percent coverage level to \$4.30 per acre (\$30.31–\$26.01) at the 85 percent coverage level. The magnitude of estimated welfare losses based on a bi-linear spline yield trend are very similar to those for the linear trend, ranging from \$3.97 per acre at the 50 percent coverage level (\$16.68–\$12.71) to \$9.51 per acre at the 85 percent coverage level (\$29.00–\$19.49).

Our results comparing alternative trend corrections indicate that welfare benefits of trend correction are sensitive to the trend estimator used. Which trend estimator is best is an empirical question that is data-specific and likely not robust across crops and counties.

### Conclusion

The results for two example cases presented in this paper suggest that when crop yields exhibit an upward yield trend there is a potential loss in producer welfare benefits of Yield Protection insurance coverage. This loss occurs because effective coverage is less than the nominal coverage level chosen (i.e., producers are underinsured relative to the nominal coverage level chosen). These results suggest that producer welfare benefits of Yield Protection coverage could be increased through incorporation of a trend correc-

tion into the yield guarantee. It is likely that this general result also applies to the Revenue Protection and Revenue Protection-Harvest Price Exclusion insurance products, though magnitudes of benefits may differ significantly. Our results further suggest that if a yield trend correction is incorporated into the insurance offering, the results will vary substantially depending upon the trend estimator used in developing the correction. Therefore, choice of an appropriate trend estimator for each crop and county would be essential in order to effectively implement county trend corrections.

Several caveats are important at this stage of our analysis. First, it should be recognized that the results presented here are limited in scope to two example crops and counties. As this work is further developed, it will be important to test the robustness of the results. Second, an astute reader might argue that it would be possible for a producer to avoid the welfare loss associated with use of a simple average APH yield by simply adjusting his or her nominal coverage level upward to achieve the desired effective coverage level. We believe this argument would be valid under the following conditions: (i) actuarially fair premium rates at each nominal coverage level, (ii) constant subsidy rates across coverage levels, and (iii) no coverage level limits. The first of these conditions depends upon accurate base rates and accurate coverage level differentials. This paper does not purport to address the accuracy of these rate components, but any inaccuracies would limit producers' ability to fully compensate for trend bias through simple adjustments to nominal coverage choices. The second condition is not satisfied. Subsidy rates decline in discrete steps as

the nominal coverage level increases. Therefore, a producer who finds it necessary to purchase higher nominal coverage in order to compensate for under-insurance caused by trend bias could realize a welfare loss due to reduced subsidization of his or her insurance coverage. Finally, there is a limiting case in which the third condition is not satisfied. Specifically, a producer who wants 85 percent effective coverage cannot adjust the nominal coverage level upward to achieve the desired protection. Therefore, producers who want maximum coverage will realize a welfare loss if their simple average APH yields provide a downward-biased yield guarantee.

Given our results and the caveats discussed above, we believe it is reasonable to conclude that there are potential benefits associated with incorporation of yield trend adjustments into the Risk Management Agency's APH yields. These benefits would have to be weighed against the costs of developing and implementing such trend adjustments.

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