**Comparative Analysis of Producer Welfare Benefits of Yield Substitution and Yield Exclusion**

Shyam Adhikari

Associate Director, Aon Benfield, Chicago

Kishor Luitel,

Graduate Research Assistant,

Texas Tech University

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## Abstract

*Farm Bill 2014 introduced yield exclusion option to exclude the catastrophic year yield from APH yield to mitigate its impact on lowering the insurance guarantee. With high prevalence of yield substitution for the low yield; yield exclusion offers another option for producers to choose to enhance their welfare. We take the case of two crops and counties with different risk profile and conducted a comparative analysis on welfare gain by these two options for yield and revenue protection insurance. Our analysis suggests that the yield exclusion provides the higher welfare gain to the producer and likely to replace yield substitution. However, yield substitution is still a valid option when yield exclusion does not change the effective coverage level enormously.*



Keywords: Crop insurance, yield exclusion, yield substitution

*JEL codes:* G22, Q14, Q18


## Introduction

The farm level crop insurance products, including Yield Protection (YP), Revenue Protection (RP), and Revenue Protection with Harvest Price Exclusion (RP-HPE), offer comprehensive protection against yield risk due to multiple perils such as weather, pests, and most other natural perils. RP and RP-HPE also afford protection against revenue shortfalls below expectations due to price fluctuations that occur within the production year. These yield and revenue insurance products coverage is based on actual production history (APH) yield. These products dominate the U.S. Federal Crop Insurance Program, accounting for more than 75% of premium collected and liability insured. The insurance guarantees under the APH yield and revenue product designs are based on an 'expected' yield, which is the simple average of four to ten years of historical yields for the insured unit. Thus, the APH yield, which plays a critical role in determining the coverage offered to a producer, is based on a small sample of historical yields. The

properties of this sample are critical in determining the value of the insurance products to producers. Two major issues such as yield trend and small sample bias have been examined in the literature relating to the use of APH-yield based coverage (Skees and Reed 1986; Carriquiry, Babcock, and Hart 2008).

The yield trends can affect the appropriateness of the insurance guarantee because if a trend is present, the simple average APH yield may not accurately reflect the expected yield in the upcoming crop year. Risk Management Agency (RMA) addressed this issue with trend adjusted endorsement from insurance year 2012. Similarly, small sample bias has the potential to result in APH yields that are highly fluctuating. Prior research on small sample properties suggested that there is larger likelihood of over-insurance and potentially gives rise to adverse selection and increased premiums. Adhikari, Knight, and Belasco (2013) examined the welfare effect of a small sample and found that there is a welfare loss with small sample in the APH yield. They suggested that yield substitution and yield floors are designed to mitigate the negative impact of small samples in determining yield guarantees using APH by censoring the APH yield.

The yield substitution provision allows producer to use 60 percent of county proxy yield (T-yield) as substitute for the actual historical yield in any year when the actual yield falls below that level. This causes the historical yield for any year in the database to be censored at 60 percent of a pre-established county yield for the crop. Thus, yield substitution sets a minimum value for any single year's yield used in the APH yield calculation. The average of APH yield with substitution is biased upward resulting in the higher yield or revenue guarantee.

Farm Bill 2014 introduced another measure known as APH Yield Exclusion. This measure is designed to help farmers mitigate the impact of catastrophic years by allowing farmers to exclude the APH yields in the years when a specific county or contiguous county yield fall below 50 percent of county average planted acre yield for past 10 consecutive years. Eligible years for yield exclusion are predetermined by RMA. This eliminates the very low yield in the APH yield history which impacts in increasing the average of APH yield and reducing the variance. The insurance guarantee with yield exclusion becomes larger than without yield exclusion. Both of yield substitution and yield exclusion are

asymmetric in that left-censoring occurs, as down-side risk is limited while no restrictions are placed on upside risk.

In this study we examine the impact yield substitution and yield exclusion on the benefits of yield and revenue insurance products for corn and cotton producers in the Texas High Plains and Midwest corn. This analysis is conducted under two different scenarios: (1) assuming that farmers have two basic choices either to opt for yield substitution or yield exclusions; and (2) imposing each of these options the additional welfare gain with respect to the available coverage level options.

**Conceptual Framework and Empirical Implementation**

Risk Management Agency (RMA) yield-history data shows that in 2008 approximately 62% of APH yields for dryland cotton in the Texas High Plains made up of yield substitution, compared with 15% for Illinois corn and 46% for dryland wheat in Kansas (Adhikari, Knight, and Belasco 2013). The 2015 participation in yield exclusion in respect to total policy sold was approximately 56%, 7%, and 2% of corn, cotton and wheat, respectively (USDA-RMA, 2016). The number of YE policy sold for corn was extremely high compared to other crops. Yield substitution has been widely used in the very risky crop producing areas like Texas and also significantly used in low risk areas like Nebraska and Illinois (Adhikari, Knight, and Belasco 2013). Farmers who choose yield exclusion are not allowed to use yield substitution. RMA revised the premium rating procedure in order to address the additional risk arising from elevated guarantee level (Knight et al. 2014). However, there is no premium adjustment for yield substitution. With the premium rating differences with these two policy provisions, the net impact in producer welfare can be the determinant for the participation in yield exclusion option for those producers who have been using yield substitution in the past.

Let producer yield be represented by $y$ with mean $\mu$ and standard deviation $\sigma$ for any crop in the county. The rate yield ($\overline{y_r}$)is the average of 4 to 10 years of producers' actual production history (APH) yield. When a producer choses to use yield substitution, then s/he can replace any yield from APH yield

history that fall below 60% of T- yield (county proxy average yield). This censors the APH yield distribution at 60% of T-yield and average yield after substitution (referred as approved yield) becomes larger than the rate yield. Let $\bar{y}_{ys}$ is approved yield with yield substitution.

$$\bar{y}_{ys} > \bar{y}_r$$

RMA's premium rate is not affected by yield substitution but it increases the yield or revenue guarantee which increase premium per acre.

$$Premium\ rate\ = Reference\ rate * \left(\frac{Rate\ yield}{Reference\ yield}\right)^{-exponent} + Fixed\ rate \quad (1)$$

$$Premium\ per\ acre$$
$$= Premium\ rate\ x\ Yield\ or\ revenue\ Gaurantree\ x\ Coverage\ level\ adjustment\ factor$$
$$x\ (1 - subsidy)\ x\ Unit\ discount\ factor \quad (2)$$

If a producer chooses yield exclusion instead of yield substitution, the eligible low yields are excluded from the APH yield and average yield after exclusion ($\bar{y}_{ye}$) becomes larger than average yield with yield substitution.

$$\bar{y}_{ye} > \bar{y}_{ys}$$

There is twofold impact in the premium; it increases the yield guarantee by adjusting coverage level with the ratio of $\left(\frac{\bar{y}_{ye}}{\bar{y}_{ys}}\right)$ and it also increases the premium by adjusting the premium for increased coverage level (effective coverage level). Further, subsidy is not adjusted for the increased coverage level. The indemnity for yield protection insurance under yield substitution is:

$$I_{ys} = Max(0, \alpha\bar{Y}_{ys} - Y_i) \quad (3a)$$

While indemnity for yield exclusion is:

$$I_{ye} = Max(0, \alpha_e\bar{Y}_{ye} - Y_i) \quad (3b)$$

Where, $\alpha_e$ is the effective coverage level, which is nominal coverage level times $\left(\frac{\bar{y}_{ye}}{\bar{y}_{ys}}\right)$. As $\bar{y}_{ye} > \bar{y}_{ys}$ then $\alpha_e > \alpha$, and $I_{ye} > I_{ys}$ . The yield exclusion increases the premium as well as indemnity, the net welfare effect of yield exclusion, as compared with yield substitution, becomes ambiguous. Farmer as rational decision maker evaluates the net welfare gain from each of these policy options and choose one or the other.

This study uses average county yield as a producer average yield. Standard deviation of producer yield is derived from RMA's premium rate by using backward iterative approach. We assumed that RMA's premium rate is actuarially fair premium that reflect the risk in crop yield. In our simulation we assumed crop yield has a truncated normal distribution while price follow log normal distribution. We simulate the 10 year of APH yield for 100 sample farmers and choose a farmer, which has two years of yield fall below 50 percent of county average yield. This allows to apply both yield substitution and yield exclusion for the analysis. We have used a multivariate simulation approach developed by Phoon, Quek, and Huang (PQH) to draw 10,000 correlated producer yield and price series in order to calculate revenue for Revenue Protection insurance analysis. PQH presents a very flexible technique for simulating correlated random variables that have mixed marginal distributions by using a prior spearman rank correlation, and offer the benefit over traditional Iman and Conover process (Phoon, Quek, and Huang 2002; Anderson, Harri, and Coble 2009).

Our analysis assumes the expected utility framework to compute the certainty equivalent for the individual farm at different levels of coverage, where each farmer is assumed to maximize their expected utility of wealth. We assume that farmers' risk preferences are represented by a power-utility function, which implies Constant Relative Risk Aversion (CRRA). The approximation of risk aversion characteristics of farmers' in the CRRA utility function requires ending wealth (Chavas 2004). The CRRA utility function per acre net return ($\pi_p$) for farmers is represented as:

$$U_p(\alpha) = -\pi_p(x)^{1-R} \qquad \text{Where, } R > 1. \qquad (4)$$

The producer has a choice to select either yield substitution or yield exclusion. Net return is the net of the farm revenue, insurance indemnities received, premium paid and initial wealth and is dependent upon the producers' choice of the one of these two options. We assume $R = 2$ to represent a moderate level of risk aversion. Producers' expected utility from the equation (4) is:

$$E\left[U_p(\alpha)\right] = E\left[-\pi_p(x)^{1-R}\right] \qquad (5)$$

The producer maximizes the expected utility by changing the coverage level. Mathematically, the producer's problem is:

$$\max_x EU_i(x) = \max_x \int_\pi -\pi_p(x)^{1-R} dF(\pi_p|x) \qquad (6)$$

These maximized utilities for each of option are converted into the associated certainty equivalent in terms of dollar/acre:

$$CE^* = (-EU_i^*)^{1/(1-R)} \qquad (7)$$

The certainty equivalent was estimated for a range of insurance products and coverage levels for two scenarios: (1) yield substitution, and (2) yield exclusion. Our welfare measure is based on the difference in the certainty equivalent per acre for each policy regime compared with the per acre certainty equivalent for the uninsured case.

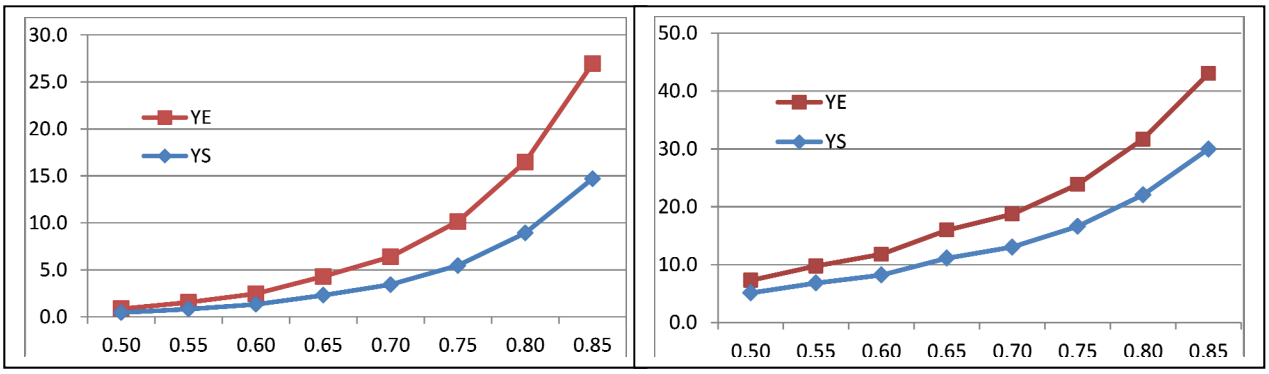
This analysis uses McLean County, Illinois to study corn and Lubbock County, TX to study cotton. Both of these counties are the largest corn and cotton producing counties, respectively, but differ in risk profile. Corn yield in McLean, IL has very small coefficient of variation compared to cotton in Lubbock, TX. Similarly, implied yield standard deviation based on RMA's premium rate is also larger in Lubbock County cotton (Table 1). These differences provide the interesting comparison of yield substitution and yield exclusion under different risk profile of the crops.

**Table 1. Yield and Price Parameters**

| County/ Crop | County Yield | | Farm Yield | | Price | |
|---|---|---|---|---|---|---|
| | Avg. | Stdev. | Avg. | Stdev. | Proj. Price | Volatility Factor |
| McLean, IL/Corn | 192.01 | 24.88 | 192.01 | 48.77 | 3.86 | 0.17 |
| Lubbock, TX/Cotton | 458.16 | 151.90 | 458.16 | 416.20 | 0.60 | 0.14 |

**Results and Discussion**

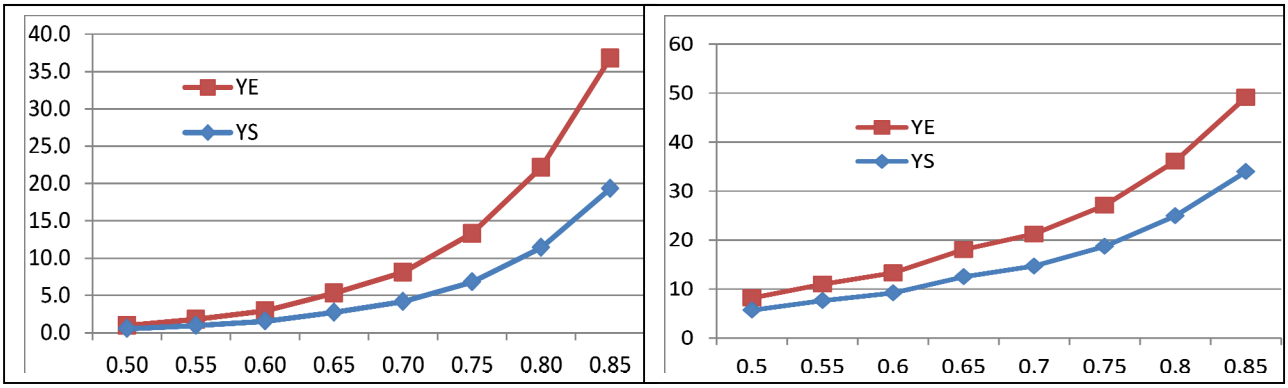
We have computed actuarially fair premium rate for yield protection and revenue protection crop insurance products for both yield substitution and yield exclusion. The comparison of premium per acre after applying subsidy is presented in the Figure 1 and 2. Figure 1 presents the premium for yield protection for corn and cotton in the left and right pane, respectively. Both yield substitution and yield exclusion, the premium per acre increases with the increasing rate from 50 percent to 85 percent coverage level for corn, but with the larger rate of increase in case of yield exclusion. This corroborates with our a priori expectation. Corn in McLean County, Illinois has a smaller yield variability which is reflected by very small premium rate. For the lower coverage level (less than 65%) the premium per acre is very negligible for yield protection insurance. In case of cotton in Lubbock County, Texas, the yield is highly variable and thus premium per acre is larger even for the smaller coverage level. For both crops, premium increases moving towards the larger coverage level. In case of cotton, similar trends can be seen for both of these options. However, the rate at which premium increases while moving towards higher coverage level is larger in corn than cotton.




A: Corn B: Cotton

**Figure 1. Premium per acre for Yield Protection**

Premium for revenue protection for corn and cotton also reveals a similar pattern of increment for yield substitution and yield exclusion. However, the dollar amount of premiums are larger due to additional risk (price risk) associated with revenue protection (Figure 2). In case of both insurance plans for both crops, we have seen a significant increase in the premium per acre while choosing the yield exclusion. The pattern and proportionate increment depends on the coverage level and risk profile of the crop yield.

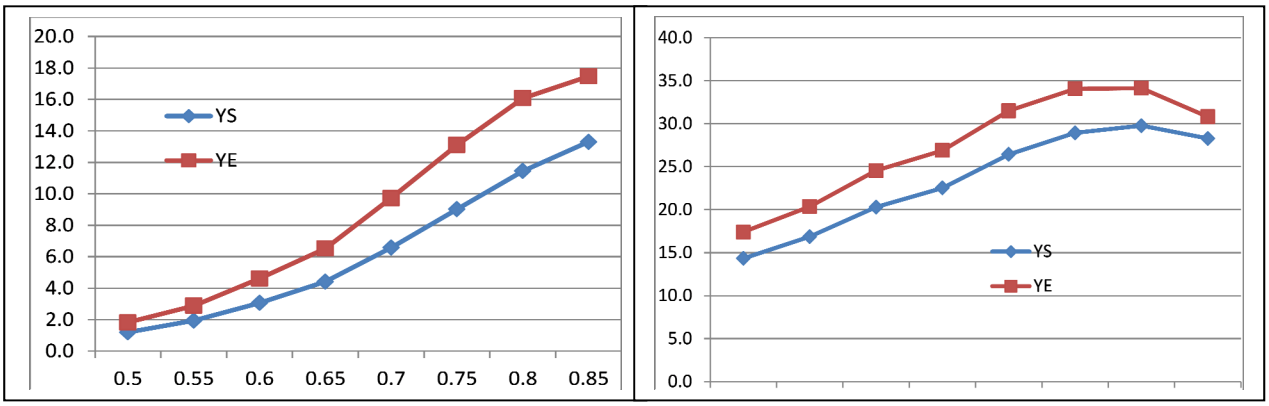



A: Corn B: Cotton

**Figure 2. Premium per acre for Revenue Protection**

**Welfare Gain from Yield Substitution and Yield Exclusion**

We assess the net welfare gain from each of crop insurance plan and options the producer has in order make the decision to either choose one or the other. We have attempted to compare the net welfare gain by assuming the risk taking behavior of the producer. Our analysis uses CRRA utility function with a moderate level risk aversion. Comparing welfare gain with and without crop insurance provides the insight into the welfare gain after making the decision to buy crop insurance. Our study revealed that yield exclusion option outperforms yield substitution in cases of both corn and cotton. There is smaller gain of additional dollar amount for the smaller coverage level and increases with higher coverage level for yield protection (Figure 3). There is smaller dollar amount of gain in corn than cotton. This is obvious that corn has a very small yield standard deviation than cotton, and thus larger welfare gain from crop insurance. However, percent welfare gain due to yield exclusion is larger in cotton. Net dollar gain from crop insurance increases from 50 to 75 percent coverage level and gradually declines after 75 percent coverage level. This reveals that the optimal coverage for cotton is 75 percent. For example, at the 75 percent coverage level, producer welfare in dollar amount rises from $9 to $13 for corn while it increases from$28 to $34 for cotton by choosing yield exclusion. Same is true for all other coverage levels. In the case of revenue protection, we have also found similar trends of welfare gain. The approved yield to adjusted yield ratio for corn and cotton are 1.09 and 1.12, respectively. This larger ratio causes higher effective coverage and also higher yield guarantees. The ratio varies by producers and number of APH yield years that are eligible to exclude. Our previous result suggested that there is increase in premium for yield exclusion which is more than compensated with additional dollar gain in revenue due to increase in indemnity and subsidy on premium.

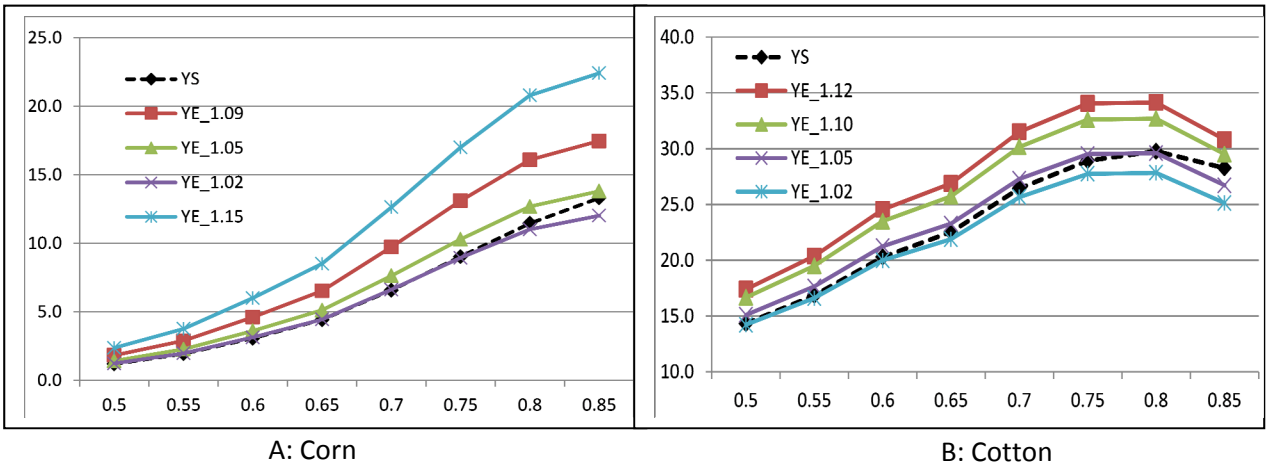



A: Corn B: Cotton

**Figure 3. Certainty Equivalent Differences in Yield Protection**

**Sensitivity Analysis with Approved Yield to Adjusted Yield Ratio**

Approved yield to adjusted yield ratio plays a pivotal role to change the yield guarantee and premium for yield exclusion. However, yield substitution increases the yield guarantee in cases of yield protection crop insurance. Producers can choose these options based on the expectation of additional dollar from either of them. We evaluate the welfare gain with respect to yield substitution by varying the approved yield ratio and compared with welfare gain from yield substitution. Sensitivity analysis of the dollar gain with respect of the approved yield ratio shows that yield exclusion outperforms yield substitution between the certain ranges of approved yield ratio. In our analysis for YP for corn, we have found that approved yield ratio was above 1.02, which gives larger welfare gain by yield exclusion, and below that threshold level of ratio yield substitution provides larger welfare gain. For approved yield ratio 1.05, the welfare gain for both options is the same at 85 percent coverage level. However, cotton has little different welfare gain than corn. Approved yield ratio above 1.05 can only provide the significant welfare gain from yield exclusion compared with the yield substitution (Figure 4). It is interesting to notice that unlike corn, cotton yield protection insurance does not provide the largest welfare gain with the highest available coverage level. This may be true for all the high risk crops and counties, where larger coverage level makes the insurance costly, resulting in the decline of the net gain.




A: Corn B: Cotton

**Figure 4. Sensitivity of Approved to adjusted yield ratio on welfare benefits in yield protection**

Revenue protection crop insurance has a similar story as of yield protection with regard to the welfare gain with varying the approved yield ratio. Corn with yield substitution performs better when approved yield ratio is less than 1.02, while for the cotton the threshold ratio is larger than corn (1.05). In case of cotton, the coverage level of 75 percent or smaller provides larger welfare gain with yield exclusion for approved yield ratio 1.05 while 80 and 85 percent coverage level gives more dollars with yield substitution (Table 2).

**Table 2. Certainty Equivalent Differences with Yield Substitution and Yield Exclusion in Revenue Protection**

| | Ratio | Coverage level | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Corn | | **0.5** | **0.55** | **0.6** | **0.65** | **0.7** | **0.75** | **0.8** | **0.85** |
| YS | | 1.4 | 2.2 | 3.5 | 5.2 | 8.0 | 11.3 | 14.8 | 17.7 |
| YE | 1.02 | 1.4 | 2.2 | 3.6 | 5.3 | 8.1 | 11.2 | 14.2 | 15.9 |
| YE | 1.05 | 1.6 | 2.6 | 4.2 | 6.1 | 9.4 | 13.0 | 16.5 | 18.4 |
| YE | 1.09 | 2.1 | 3.3 | 5.4 | 7.9 | 12.2 | 16.9 | 21.3 | 23.5 |
| YE | 1.15 | 2.7 | 4.4 | 7.2 | 10.5 | 16.2 | 22.4 | 27.9 | 30.3 |
| Cotton | | | | | | | | | |
| YS | | 15.7 | 18.5 | 22.4 | 24.9 | 29.2 | 32.1 | 33.1 | 31.6 |
| YE | 1.02 | 15.6 | 18.3 | 22.0 | 24.2 | 28.4 | 30.8 | 30.9 | 28.0 |
| YE | 1.05 | 16.5 | 19.4 | 23.4 | 25.7 | 30.2 | 32.7 | 32.9 | 29.8 |
| YE | 1.10 | 18.3 | 21.5 | 25.9 | 28.5 | 33.4 | 36.2 | 36.4 | 32.9 |
| YE | 1.12 | 19.1 | 22.5 | 27.1 | 29.7 | 34.9 | 37.9 | 38.1 | 34.4 |

## Conclusion

The results have provided insight into the benefits of alternative options like yield substitution and yield exclusion for the most prominent crop insurance products for producers. Further, results of our analysis reveal the net impact of legally-mandated yield restrictions on producer welfare. There are evidences of prevalence of yield substitution in the APH based crop insurance products. This research suggests that yield exclusion is a beneficial option for the producers and increases their welfare. However, the magnitude of welfare gain depends on the riskiness of the producer, coverage level choice and the crop. We found that welfare gain for the low risk crop is at its maximum for the largest available coverage level, but this is not true for the high risk crops, like upland cotton of Lubbock County, TX. Our study also suggests that the ratio of approved yield to the adjusted yield plays significant roles to determine the welfare gain from yield substitution. For the smaller approved yield to adjusted yield ratio, we have found that yield substitution provides more net dollar gain than yield exclusion. Increased cost of yield exclusion is not compensated well below threshold ratio, resulting into smaller gain than yield substitution. This work will quantify potential trade-off between yield substitution and yield exclusion with farmers' current level of coverage choice, and the risk taking behavior. Further, exploration by

varying producer risk aversion level and inclusion of additional crops will provide additional insight in our further research.

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