# The Acreage Effects of Premium Subsidies in U.S. Crop Insurance

**JOB MARKET PAPER**

**WORKING DRAFT - PRELIMINARY AND INCOMPLETE**

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**Abstract**

The U.S. federal crop insurance program has experienced several policy changes that increased crop insurance premium subsidies over the past three decades. By exploring the exogenous policy changes, this study estimates the acreage effect of premium subsidies in the U.S. federal crop insurance program. Crop insurance premium subsidies encourage farmers to insure more crop acreage or to increase coverage level. With insurance, farm revenue, which includes crop revenues and expected crop insurance indemnity payments, becomes less risky and therefore, crop acreage of the insured crop may increase. Premium subsidies also can directly make the insured crop more profitable by increasing the expected return, which also may increase the acreage of that crop. This study estimates the acreage effect of the premium subsidy in the U.S. federal crop insurance program, which is a mixture of the two different effects of the premium subsidy. The preliminary results indicate that the acreage response to the 10% increase in the premium subsidy is about a 0.7% increase. The results provide some evidence that there is the acreage effect of the premium subsidy is a mixture of the two different effects.

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# 1 Introduction

The U.S. federal crop insurance program expanded rapidly in the last three decades, with substantial increases in insurance subsidies (Glauber 2012). The total crop insurance premium subsidy increased from $205 million in 1989 to $6.2 billion in 2014 (Risk Management Agency 2015). Recently, the Agricultural Act of 2014 eliminated major commodity programs, added risk management programs, and enhanced the existing federal crop insurance program.

This study estimates the acreage effect of premium subsidies offered by the U.S. federal crop insurance program. The U.S. federal crop insurance program is highly subsidized.[1] The program experienced several policy changes that increased crop insurance premium subsidies. The policy changes affected crops and counties differently. I exploit the changes in the U.S. federal crop insurance program to identify the effects of crop insurance premium subsidies on crop acreage. Using the exogenous policy changes, I estimate the acreage elasticity with respect to the premium subsidy in U.S. federal crop insurance for major field crops.

Previous studies established conceptual and empirical foundations for how the U.S. federal crop insurance program affects input demand or crop supply in the context of mainstream insurance issues such as risk-aversion, information asymmetry or credit market imperfection (Chambers 1989; Horowitz and Lichtenberg 1993; Ramaswami 1993; Babcock and Hennessy 1996; Smith and Goodwin 1996; Coble et al. 1997; Wu 1999; Goodwin, Vandeveer and Deal 2004; Cornaggia 2013; Weber, Key, and ODonoghue 2015).

However, the research on the acreage effect of crop insurance is limited (Wu 1999; Young, Vandeveer, and Schnepf 2001; Goodwin, Vandeveer and Deal 2004; Goodwin and Smith 2013). Wu (1999) estimates a system of equations of crop share and crop insurance choice and finds that providing crop insurance for corn leads to 5-27 % increase in the share of corn acreage. The simulation results of Young, Vandeveer, and Schnepf (2001) imply about 0.4% decrease in the acreage of eight major field crops as a response to the removal of all federal crop insurance subsidies.

Goodwin, Vandeveer and Deal (2004) empirically investigate the acreage response to the U.S. federal crop insurance for corn, soybean and wheat and find that higher crop insurance

[1]The financial sustainability of crop insurance products are often in question. Crop insurance products experienced historically poor actuarial performance (Hazell 1992).

participation induces an acreage expansion. Premium subsidies have also positive, but modest acreage effects through higher crop insurance participation rate. Subsequently, Goodwin and Smith (2013) present preliminary empirical estimates indicating potential positive effects of premium subsidies.

Crop insurance premium subsidies can affect crop production by: a) indirectly encouraging farmers to insure their acreage thereby reducing the riskiness of crop production and b) directly increasing the expected return of the insured crop (Yu 2015). In other words, premium subsidies increase the expected return of the insured crop even without increasing crop insurance coverage. This study empirically distinguishes these two effects.

This paper estimates the acreage effect of crop insurance premium subsidies by exploring quasi-experimental nature of the U.S. federal crop insurance program. In the context of federal crop insurance program, Cornaggia (2013) and O'Donoghue (2014) utilize the exogenous policy changes to estimate the effect of crop insurance on farm productivity, or the demand for crop insurance.

## 2 How Premium Subsidies Affect Crop Acreage

There is limited empirical evidence that U.S. crop insurance premium subsidies lead to more crop acreage of insured crops (Young, Vandeveer, and Schnepf 2001; Goodwin, Vandeveer and Deal 2004; Goodwin and Smith 2013). To develop empirical strategy, it is useful to investigate conceptually how premium subsidies affect crop acreage. Yu (2015) derives two ways through which premium subsidies in crop insurance affects crop choices.

### 2.1 Encouragement Effect of Premium Subsidies on Crop Acreage

Premium subsidies affect crop acreage through the encouragement of crop insurance purchase. An increase in premium subsidies can encourage non-participating farmers to participate in crop insurance or encourage participating farmers to increase their coverage level for given crop acreage. Goodwin (1993), Goodwin, Vandeveer, and Deal (2004) and O'Donoghue (2014) find empirical evidence on the positive effect of premium subsidies on the demand for crop insurance. Increases in crop insurance coverage reduce the riskiness of the crop that is covered by crop insurance. The standard expected utility theory suggests that farmers with any non-increasing absolute risk aversion (NIARA) preference would increase the acreage of the crop as the riskiness decreases (Hennessy 1998).

The framework of Yu (2015) assumes a single input and outputs of two crops. Under this framework, farmers allocate the initial resource endowment, $K_0$, into the production of the risky crop and the safe crop with inputs $K_r$ and $K_s$. The returns from both crops are linear to the input and the risky crop has a stochastic return with the expected value greater than the return from the safe crop. For the risky crop, farmers can buy crop insurance, $\theta$, with premium $\pi$ and subsidy $\gamma$.

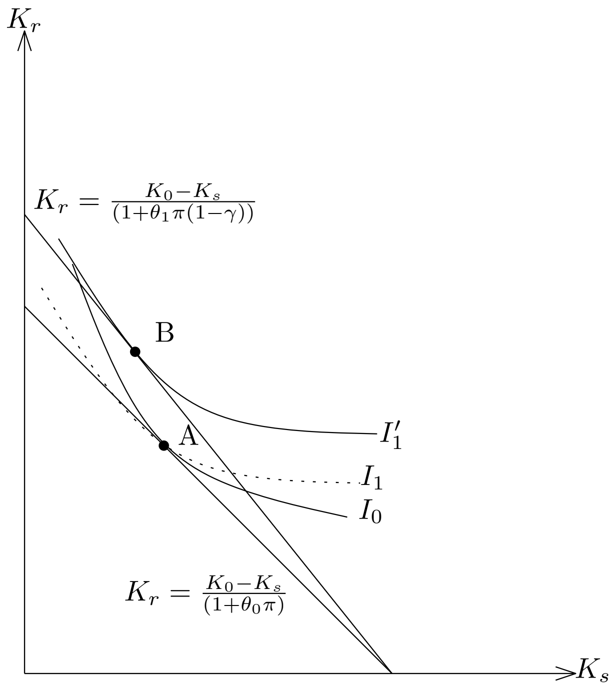


Figure 1: Encouragement effect under NIARA

Figure (1) and (2) represent the allocation of the initial endowment with the illustration of an indifference curve and a budget line. The indifference curve represents the risk-return trade off based on the expected utility framework. The indifference curve would be linear under the risk-neutrality. The slope of the budget line represents the relative cost of the production.[2]

Figure (1) describes the encouragement effect. The slope and the intercept change when the premium subsidy increases since the cost of producing the risky crop changes due to the cheaper price of crop insurance and the increased coverage level from $\theta_0$ to $\theta_1$ for the given

[2]This budget line also indicates the production frontier. The production frontier is linear since the return from each crop is linear to its input.

crop acreage. The risky crop becomes less risky with the increased coverage level and the slope of the indifference curve shifts pivotally. Under NIARA, the point of allocation changes from point A to B with an increase in the premium subsidy.

### 2.2 Relative Profit Effect of Premium Subsidies on Crop Acreage

Premium subsidies also increase the expected net return from the crop that is covered by crop insurance. An increase in premium subsidies increases the expected net return from the insured crop, holding the coverage level constant. Therefore, the participating farmers receive the increased subsidies in terms of expected value without changing their coverage level.

Similar to Figure (1), Figure (2) describes the relative profit effect. For the given coverage level, an increase in the premium subsidy shifts the budget line. The slope of the indifference curve remains unchanged since the risk-return trade off does not change without changes in the coverage level. Under NIARA, the allocation of the resource into the risky crop increases.

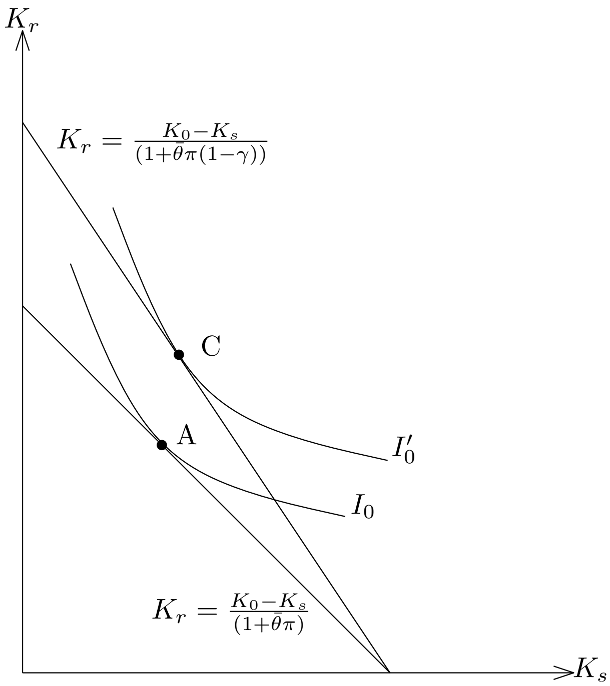


Figure 2: Relative profit effect under NIARA

## 3 Federal Crop Insurance Program

The Risk Management Agency (RMA) and the Federal Crop Insurance Corporation (FCIC) operate the U.S. Federal crop insurance program. Private insurance providers deliver crop insurance products to farmers. Government subsidies are delivered as the administrative and operation cost, the reinsurance cost, and the insurance premium (Federal Crop Insurance Corporation 2015; Risk Management Agency 2015).

U.S. crop insurance products are developed by either the FCIC or private insurance providers with an approval of the FCIC. The FCIC and the RMA set premiums and specify the provisions for these crop insurance products. The premium rating practice went through several changes to have the actuarially fair premium rate (Goodwin 1994; Glauber 2012).

The two most common products across crops and counties are Yield Protection and Revenue Protection. In 2014, they account for 78% of total liability. Yield Protection, formerly called Actual Production History, is the insurance products that insures against yield losses. The indemnity is triggered when the actual yield is smaller than the historical average yield. Typically, premium rates are higher for riskier crops or counties. Revenue Protection insures against revenue losses. The indemnity is triggered when the actual yield times the harvest price is less than the historical average yield times the greater of projected price or harvest price. In general, Revenue Protection has a higher premium rate than Yield Protection.

The participating farmers are required to pay a part of the crop insurance premium, which is equal to the total premium minus the premium subsidy. The total premium is the premium rate multiplied by the total liability that is insured by a crop insurance product. The total liability is proportional to the total insured acres, the coverage level elected by the farmer, projected or harvest prices of the crop, and the historical individual yield.

The premium rate is set by the RMA. In general, the premium rate depends on the riskiness of the insured crop in the county, the coverage level, the insurance product and the practice of the farm. The RMA targets actuarially fair premium rate, which means the premium rate should be equal to the expected indemnity per dollar of liability. For example, the premium rates for the riskier crops or the crops in riskier counties are higher (Coble and Barnett 2013).

The premium subsidy is equal to the total premium multiplied by the subsidy rate. The subsidy rate varies across coverage levels, crop insurance products, and units. The subsidy rate decreases as the coverage level increases. Group or area-based products have higher subsidy rates. Enterprise or whole farm units have higher subsidy rates than others since 2008.

By definition, the actuarially fair premium is equal to the expected indemnity for the participating farmers. Therefore, if the premium is set at the actuarially fair level, the premium subsidy is equal to the expected net gain. The premium rate and the subsidy rate, which are set by the FCIC and the RMA, determine how much subsidy per dollar of liability the participating farmers receive ($Subsidy\ per\ liability = Premium\ Rate * Subsidy\ Rate$). I focus on how the subsidy per dollar of liability affects planted acreage. I exploit policy changes on the subsidy rate. The premium rate and the subsidy rate that participating farmers face are endogenous to their production decisions. I address the endogeneity issues and relevant exogenous policy changes in detail.

# 4 Institutional Changes

The U.S. federal crop insurance program experienced several large policy changes (Glauber 2012). I focus on the policy changes during 1989-2014, and tie the changes to the identification strategy. The subsidy per dollar of liability is the main policy variable of this study. As illustrated above, the premium rate and the subsidy rate are set by the FCIC and the RMA. Legislation changes and introductions of new crop insurance products led significant changes in the average premium rate and the average subsidy rate across crops and counties.

## 4.1 Major Legislative Changes

The Federal Crop Insurance Act of 1980 made private insurance providers to deliver crop insurance products. The 1980 act added more coverage levels and expanded crop insurance to more crops and regions. It mandated the FCIC to pay the 30% of total premium for any coverage level up to 65%. These changes were attempts to increase the participation rate of Federal crop insurance program.

The participation rate grew slowly and the congress created the mandatory risk protection program and increased premium subsidies (Glauber 2012). The Crop Insurance Reform Act of

1994 created "Catastrophic" risk protection program (CAT) with 100% subsidy rate that protects 50% of the historical yield at 60% of projected price. The 1994 act made CAT mandatory for any commodity program participants but this mandate was repealed in 1996. The 1994 act also increased the subsidy rate for "Buy-up" coverage level. For example, the subsidy rate increased from 30% to 42% for 65% coverage level for all products except area-based products.

The Federal Crop Insurance Act of 2000 reduced the premium rate and increased the subsidy rate. The 2000 act codified the ad hoc premium reduction in 1998 and 1999 into the law and led about 25% reduction of premium (O'Donoghue 2014).[3] The 2000 act also increased the subsidy rate for all coverage levels.

The 2008 Farm Bill includes a new title for crop insurance and disaster payments. The new title supported the RMA to undertake research and development on designing crop insurance products. The 2008 Farm Bill increased the subsidy rate for enterprise and whole farm units. [4] Also, the 2008 Farm Bill reduced the subsidy rate for area-based products, which had higher subsidy rate than Yield Protection or Revenue Protection.

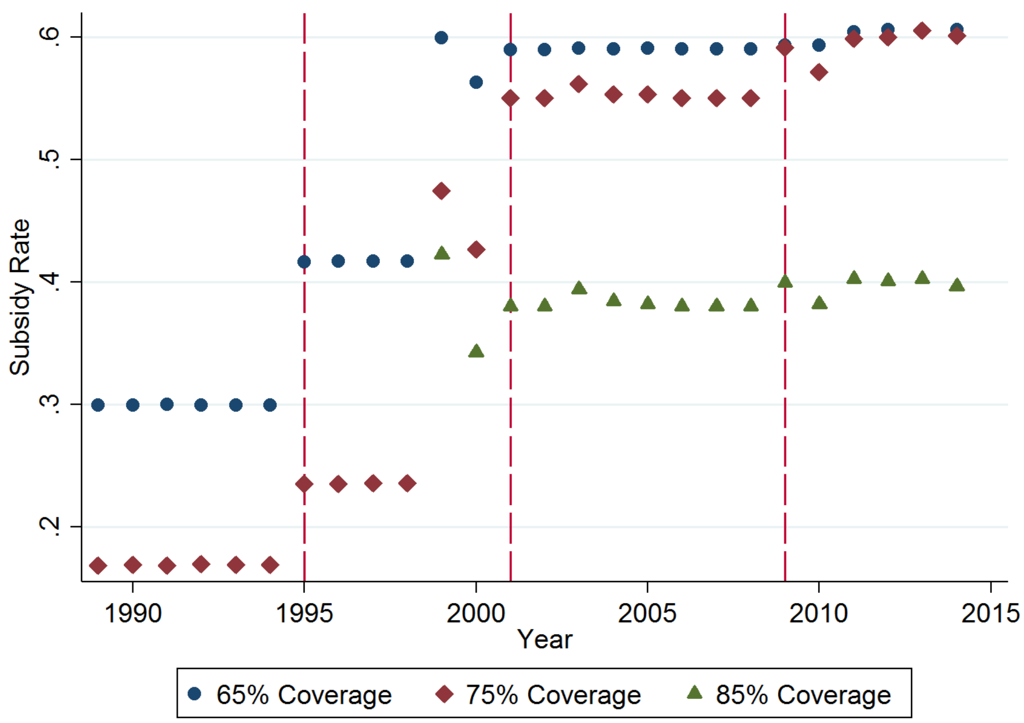


Figure 3: Subsidy Rate by Coverage Level (1989-2014)

[3]The premium reductions in 1998 and 1999 are Emergency Financial Assistant (EFA) premium discount. I consider EFA premium discount as premium subsidy.

[4]Enterprise and whole farm units have low premium per acre and the 2008 Farm Bill made them to receive premium subsidy per acre as much as other two units.

Figure (3) illustrates the changes in subsidy rates for three coverage levels, 65%, 75%, and 85%, of Yield Protection or Revenue Protection since 1989. All coverage levels experience similar changes in subsidy rates. Two significant changes in 1994 and 2000 are observed that are due to the Federal Crop Insurance Act of 1994 and 2000. After 2008, due to the 2008 Farm Bill subsidy rates depend on the proportion of unit structures.

### 4.2 Introductions of New Crop Insurance Products

Introductions of new crop insurance products also affect premium subsidies since the new products have different premium rates and subsidy rates from the existing products. In 1996, Crop Revenue Coverage for corn and soybean was introduced. Since then, revenue products expanded across crops and counties. The subsidy rate is same for the revenue products. The premium rates for revenue products is generally higher than those of yield products (Coble and Barnett 2013).

Area-based products are products that are based on the area-level yield or revenue. The FCIC and the RMA introduced the first area-yield products called Group Risk Plan in 1993 and the first area-revenue products (Group Risk Income Plan) in 1999 (Glauber 2012). For the same coverage level, the area-based products have higher subsidy rate than other products. The changes in subsidy rate were similar to other products except the reduction in the 2008 Farm Bill.

Cornaggia (2013) treats the introduction of new products as a quasi-experiment. The study classifies crops that faced an introduction of the new crop insurance product as "treatment" group and finds a positive relationship between risk management and crop yield. I do not use the introductions of new products as experimental events but use the variations in premium rates and subsidy rates due to the introductions.

The increases in subsidy rates and the development of new products affect how much premium subsidy that participating farmers receive. The increases in subsidy rates and the shift to revenue or area-based products increase the subsidy per acre or per dollar of liability, *ceteris paribus*. With county-crop-level panel data, I estimate the acreage effects of the U.S. crop insurance premium subsidy by exploiting the changes in premium and subsidy rates as results of the legislative changes and expansions of new products. I use a quasi-experimental nature of the changes in the subsidy rates for the U.S. crop insurance premium.

## 5 Data

I use annual county level information on crop acreage and crop insurance characteristics for major field crops from the survey of National Agricultural Statistics Service (NASS) of U.S. Department of Agriculture and RMA Summary of Business (SOB). I focus on major field crops, barley, corn, cotton, sorghum, soybean, rice and wheat since these are the crops that NASS reports county-level planted acreages annually.[5] NASS also reports the price received by farmers at the state-level.

The SOB from RMA includes detailed county-crop level crop insurance characteristics by plan, and coverage level. The SOB reports insured acres, total liability, total premium, premium subsidy, and indemnity paid. From the SOB information, the average premium rate and the average subsidy rate for each crop in each county can be computed.

I constructed the county-crop panel from NASS and RMA data. The county-crop panel is unbalanced since NASS combines counties with small planted acreage into one county-crop observation for each state in each year. I do not include the combined observations since the data cannot be matched with RMA data and also the counties in that combined observations change over time. The issue of unbalanced panel is discussed in the later section.

Table 1: Descriptive Statistics

| Variables | N | Mean | SD |
|---:|---:|---:|---:|
| Planted Acreage | 179,180 | 34,661 | 52,855 |
| Liability per Expected Crop Revenue | 179,180 | 0.34 | 0.30 |
| Average Premium Rate | 179,180 | 0.11 | 0.08 |
| Average Subsidy Rate | 179,180 | 0.50 | 0.24 |
| Subsidy per Liability | 179,180 | 0.06 | 0.05 |

Table (1) shows the descriptive statistics of 179,180 county-crop-year combinations. The average planted acreage is about 35 thousand acres. The average premium rate and the average subsidy rate are 11% and 48% which make farmers get 6% of the total liability as an additional expected return. The descriptive statistics by crop are in Appendix 1.

[5] NASS also reports oats and peanuts at county-level. I exclude these crops for the main analysis since the two crops are largely different from the other field crops. The results are robust to the inclusion of the two crops.

# 6 Estimation Strategy

## 6.1 Model Specifications

The dependent variable of the main specification is *Planted Acreage*. Suppose a farmer allocates the farm's acreage across crops and have option to buy crop insurance for each crop. The farmer choose the planted acreage for crop $j$, $A_j$, and the share the expected crop revenue that is protected by crop insurance, $\theta_j$. The share is defined as $\theta_j = \frac{Insured\ Acres_j}{A_j} Coverage_j$ and $Coverage_j$ is the coverage level of crop insurance for crop $j$. The crop insurance choice is defined as a combination of two choices, which are the

The subsidy rate and the premium rate of the U.S. federal crop insurance program can be represented as

$$Subsidy\ Rate_j = f^s(Coverage_j;\ Z)$$

and

$$Premium\ Rate_j = f^p(Coverage_j;\ M_j,\ Z)$$

where $M_j$ is a vector of parameters defining the distribution of $R_j$, which is the crop revenue per acre for crop $j$, and $Z$ is a vector of crop insurance policy parameters.

The expected profit function for given year for the farm is defined as following:

$$E\pi = E\left(\sum_j (R_jA_j + I_j\theta_jA_j - (1 - Subsidy\ Rate_j)Premium\ Rate_j\theta_jE(R_j)A_j - c(A_j))\right)$$

and for the actuarially fair premium rate, $E(I_j) = Premium\ Rate_jE(R_j)$, the expected profit function becomes

$$(1) \qquad E\pi = \sum_j \left(E(R_j)A_j(1 + Subsidy\ Rate_jPremium\ Rate_j\theta_j) - c(A_j)\right).$$

$R_j$ is the crop revenue per acre, $I_j$ is the indemnity per acre, and $c(.)$ is the cost function. Of course, $R_j$ and $I_j$ are stochastic.

Also, note that $Subsidy\ Rate_j$ times $Premium\ Rate_j$ is equal to $Subsidy\ per\ Liability_j$. The subsidy rate is define as the premium subsidy per dollar of premium and the premium rate is defined as the premium per dollar of liability insured.

The farmer chooses planted acreage, $A_j$, and the crop insurance choice, $\theta_j$. Therefore, they can be characterized as following implicit functions:

$$A_j = f^A(\theta_j,\ \mathit{Subsidy\ per\ Liability}_j;\ X_j)$$

and

$$\theta_j = f^\theta(A_j,\ \mathit{Subsidy\ per\ Liability}_j;\ X_j)$$

where $X_j$ is a vector of other parameters affecting production and crop insurance decisions.

An increase in the product of *Subsidy Rate* and *Premium Rate*, which is *Subsidy per Liability*, increases the expected profit for the given level of acreage and insurance coverage, holding revenue per acre and the cost of production constant. The increase in the product of *Subsidy Rate* and *Premium Rate* implies how much additional expected profit farmers get proportional to their crop revenue from the crop insurance premium subsidy. Similar to the framework of Yu (2015), this characterization indicates that the premium subsidy would affect the planted acreage not only indirectly through crop insurance demand but also directly. In other words,

(2)

$$\frac{\partial A_j}{\partial \mathit{Subsidy\ per\ Liability}_j} = \frac{\partial A_j}{\partial \theta_j} * \left.\frac{\partial \theta_j}{\partial \mathit{Subsidy\ per\ Liability}_j}\right|_{A_j} + \left.\frac{\partial A_j}{\partial \mathit{Subsidy\ per\ Liability}_j}\right|_{\theta_j}.$$

Obviously, the reduced-form representations of $A_j$ and $\theta_j$ are

$$A_j = g^A(\mathit{Subsidy\ per\ Liability}_j;\ X_j)$$

and

$$\theta_j = g^\theta(\mathit{Subsidy\ per\ Liability}_j;\ X_j).$$

I estimate how the additional expected profit from *Subsidy per Liability* affects the planted acreage.

For the estimation equation, $\mathit{Subsidy\ per\ Liability}_{ijt}$ is defined as average *Subsidy per Liability* across farmers in county $i$, who grow crop $j$ in year $t$. For current specification, the control variables are the first order lag of dependent variable and the lag of state-crop-level price received. The expected price at time $t$ is assumed to be equal to the realized price of time $t-1$. The regression equation is

(3)

$$ln(Planted\ Acreage_{ijt}) = \alpha_0 + \alpha_1 ln(Subsidy\ per\ Liability_{ijt}) + \alpha_2 ln(Planted\ Acreage_{ijt-1}) + \alpha_3 ln(Price_{ijt-1}) + \alpha_4 Time_t + v_{ij}^A + u_{ijt}^A.$$

For the regression, the logarithmic transformation is used since the scales of acreage and price are different across crops and counties. For the zero values, the values are replaced with 0.0001 before the transformation. The results are robust with respect to the transformation. The estimations in levels or in the logarithmic transformation without the replacements of zeros provide similar outcomes. The coefficients are interpreted in terms of the elasticities.

## 6.2 Endogeneity Issues and Identification Strategy

The main variable of the interest, $Subsidy\ per\ Liability_{ijt}$, is endogenous to the dependent variable of Equation (3), $Planted\ Acreage_{ijt}$. $Subsidy\ per\ Liability_{ijt}$ is defined as the products of the premium rate and the subsidy rate. The premium rate assigned by RMA reflects the assessed riskiness of the crop in the county and the choice of crop insurance such as product type or coverage levels. The subsidy rate, which also follows the government-determined schedule, is determined by the choice of crop insurance product.

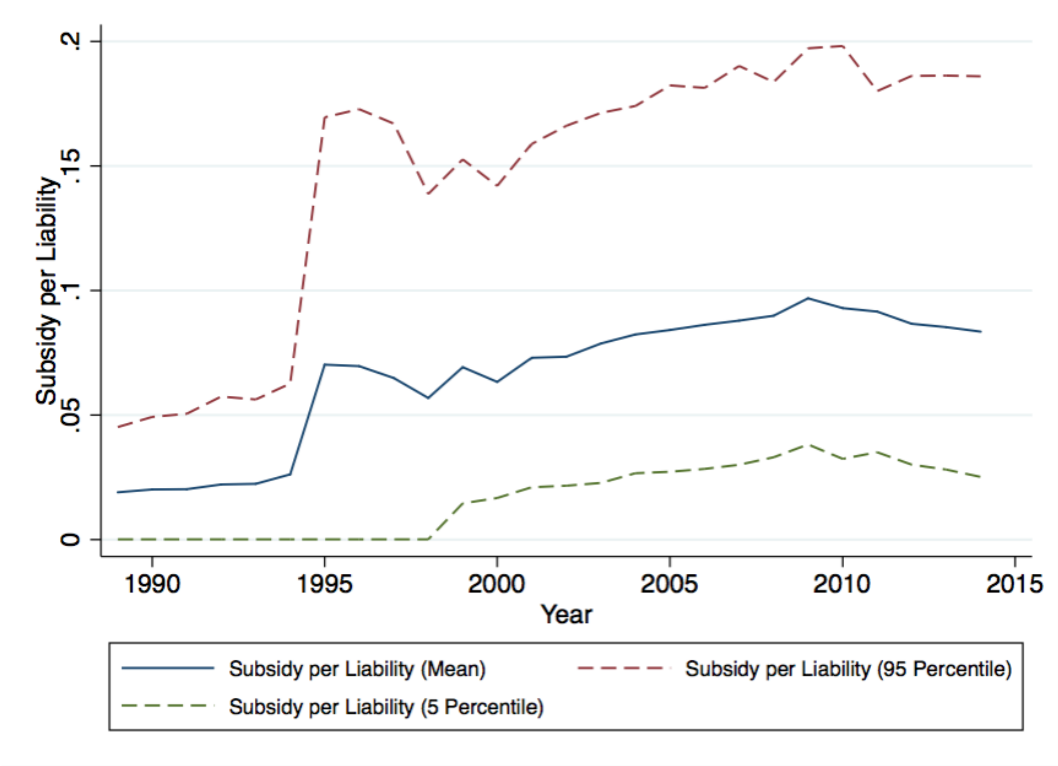


Figure 4: Subsidy Rate and Subsidy per Liability

Figure (4) illustrates large cross-section variations in $Subsidy\ per\ Liability_{ijt}$ and how the variations change over time. The time-series and cross-sectional variations depend on the choices of crop insurance in each county for each crop. The policy changes related to premium and subsidy rates drive the time-series variations of $Subsidy\ per\ Liability_{ijt}$.

Both riskiness and crop insurance choices raise endogeneity concerns. Both riskiness and crop insurance choices cause a downward bias in the estimated coefficient for $Subsidy\ per\ Liability_{ijt}$. A more risky crop or county has higher the premium rate for the given crop insurance choice. Other things equal, farmers tend to grow less of riskier crops or in riskier counties. Thus, omitting the "riskiness" variable causes a downward bias in the coefficient of $Subsidy\ per\ Liability_{ijt}$ since it is positively correlated with $Subsidy\ per\ Liability_{ijt}$ and negatively correlated with $Planted\ Acreage_{ijt}$.

The choice of crop insurance also may cause a downward bias in the coefficient of $Subsidy\ per\ Liability_{ijt}$. An increase in crop insurance coverage decreases $Subsidy\ per\ Liability_{ijt}$ since the subsidy rate is lower for the higher coverage levels. If higher crop insurance coverage affects the crop acreage positively through risk reduction, omitting the variable for the choice of crop insurance induces a downward bias. However, including the variable for the choice of crop insurance is still problematic since it causes a simultaneity bias.

Several studies attempt to deal with the endogeneity issues of crop insurance participation to crop acreage decision (Goodwin, Vandeveer, and Deal 2004; Cornaggia 2013; Weber, Key, and O'Donoghue 2015). In the context of estimating the effects of premium subsidies on the demand for crop insurance, O'Donoghue (2014) uses the lag of the change in the premium subsidy per acre between 2007 and 2012 as the instrument for the change in the premium subsidy per acre between 2007 and 2012 to estimate the effect on the changes in crop insurance participation.

As described above, several legislative changes affected the premium subsidy that farmers face. I exploit the exogenous variation in the subsidy rate to deal with the endogeneity issues of the premium subsidy. I instrument $\textit{Subsidy per Liability}_{ijt}$ with $\textit{Subsidy Rate } 75\%_t$, which is the subsidy rate for Yield Protection or Revenue Protection with 75% Coverage. Subsidy rates for other coverages also experienced similar exogenous changes but 75% coverage is chosen since it is the most common coverage level. $\textit{Subsidy Rate } 75\%_t$ changed only due to the exogenous policy change, which implies

$$E(\textit{Subsidy Rate } 75\%_t u_{ijt}) = 0.$$

Thus, I argue that this variation is only affecting $\textit{Planted Acreage}_{ijt}$ through $\textit{Subsidy per Liability}_{ijt}$ that each crop in each county receives.

The Panel Fixed Effect (FE) regression can mitigate the bias from time-invariant omitted variables such as any variables related to the "riskiness" that are time-invariant. Therefore, I estimate the county-crop FE regression with instrumental variables. For Equation (3), $\textit{Subsidy per Liability}_{ijt}$ and the lag dependent variables are instrumented by $\textit{Subsidy Rate } 75\%_t$ and the second-order lagged dependent variables (Arellano and Bond 1991).

The Panel FE without instrumenting the explanatory variable, *Subsidy per Liability*, is also considered. If there is no acreage effect from increasing crop insurance coverage levels, the estimates from the Panel FE without the instrumenting *Subsidy per Liability* would be consistent. The estimated coefficients from the Panel FE and the Panel FE with instrumenting *Subsidy per Liability* should be close to each other.

Table (2) shows the result of the first stage regression for Equation (3). As expected, the instrument *Subsidy Rate* $75\%_t$ is strongly correlated with the variable of interest, *Subsidy per Liability*$_{ijt}$.

Table 2: The Result of the First Stage Regression with County-Crop Fixed Effects

| | (1) |
|---|---|
| VARIABLES | ln(Subsidy per Liability) |
| ln(Subsidy Rate 75%) | 1.0240*** |
| | (0.0376) |
| L2.ln(Planted Acreage) | 0.0284** |
| | (0.0137) |
| L.ln(Price Received) | 0.4188*** |
| | (0.0410) |
| Time | -0.0061 |
| | (0.0036) |
| Constant | -0.9718*** |
| | (0.2175) |
| Observations | 140,625 |
| Number of county-crop FEs | 8,192 |
| R-squared | 0.2662 |

Cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

For the estimation, I employ two-step Generalized Method of Moment (GMM) estimator. The standard errors are clustered at state-level. The sample has more than one clusters and there is multiple ways to cluster the standard errors. As Cameron, Gelbach and Miller (2011) discuss, for the nested clusters one should simply cluster at the highest level of cluster. For example, the standard errors should be clustered at the state level not at the county level.

However, if the errors are correlated within years, the sample has a non-nested cluster. Since I do not put year fixed effect, I also consider two-way clustering at the state level and at the year level following the multiway robust variance estimator of Cameron, Gelbach and Miller (2011). Appendix 2 reports the results for two-way clustering. The two-way clustering increases the standard errors but the results remain robust.

# 7 Results and Interpretations of the Acreage Effect of the Premium Subsidy

## 7.1 The Estimation Results of the Acreage Effect of the Premium Subsidy

Table (2) shows the estimated results for Equation (3). As expected, the first two columns provide downward biased coefficients for $ln(Subsidy\ per\ Liability)_{ijt}$. The estimated coefficient increases from pooled OLS to Panel FE with instrumenting *Subsidy per Liability*. A small increase in the coefficient from pooled OLS to Panel FE implies there are some time-invariant factors related to the "riskiness". The coefficient increases by larger magnitude when the instrumental variable, $ln(Subsidy\ Rate\ 75\%)_t$, is employed. The time-varying part of the "riskiness" and the choice of crop insurance largely account for the downward bias of the coefficient.

Table 3: Biased and Consistent Estimates for the Effect of the Premium Subsidy on Crop Acreage

| VARIABLES | (1)<br>Pooled OLS | (2)<br>Panel FE | (3)<br>IV Panel FE |
|---|---|---|---|
| ln(Subsidy per Liability) | 0.0044** | 0.0105*** | 0.0669*** |
| | (0.0017) | (0.0025) | (0.0118) |
| L.ln(Planted Acreage) | 0.9858*** | 0.8199*** | 0.8191*** |
| | (0.0030) | (0.0249) | (0.0248) |
| L.ln(Price Received) | -0.0019 | 0.1431*** | 0.1601*** |
| | (0.0028) | (0.0122) | (0.0112) |
| Time | 0.0013*** | -0.0019*** | -0.0057*** |
| | (0.0003) | (0.0005) | (0.0009) |
| Constant | 0.1211*** | | |
| | (0.0310) | | |
| Observations | 152,970 | 140,625 | 140,625 |
| Number of county-crop FEs | | 8,192 | 8,192 |

Cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Column (3) provides consistent estimates. The overall effect of the premium subsidy on crop acreage is 0.0669. This is the acreage elasticity with respect to the premium subsidy, which indicates that one percent increase in the premium subsidy induces about 0.067% increase in the crop acreage.

Goodwin, Vandeveer and Deal (2004) present the policy simulation results that suggest the acreage effect ranging from 0.2% to 1.1% as a response to a 30% decrease in the premium rate.

This is significantly smaller than what Table (3) reports, which is equal to the acreage effect of a 3.87% increase as a response to the same change.[6] The difference suggests that there is an additional effect, which is the relative profit effect proposed by Yu (2015).

## 7.2 The Interpretation of the Acreage Effect of the Premium Subsidy

The estimated coefficient for $ln(Subsidy\ per\ Liability)_{ijt}$ in Equation (3) indicates how the change in the premium subsidy for a crop in a county affects the planted acreage of the crop in the county. The elasticity representation of the coefficient is

$$\varepsilon_S = \frac{\partial Acreage}{\partial Subsidy\ per\ Liability} \frac{Subsidy\ per\ Liability}{Acreage}.$$

Note that the unit of observation is at the county-crop-year level and this indicates that the change in the planted acreage as a response to the change in the premium subsidy can be the relative change across counties, crops and years.

The total planted acreage for the seven crops did not increased in the last 26 years whereas the premium subsidy grew significantly.[7] Thus, the estimated coefficient is mostly the result of the relative changes at the county-crop level as a response to the time-series of the policy events. In other words, the estimated coefficient implies how much additional planted acreage a crop in a county experiences when the crop in the county received an additional increase in the premium subsidy compared to other crops or other counties.

For example, if a policy increases *Subsidy per Liability* by 1% more for corn than for wheat in a certain county, then an increase in the corn acres in the county would be 0.067% greater than the change in the wheat acres. Similarly, if a policy increases *Subsidy per Liability* by 1% more for cotton in a certain county than some other county, the planted acreage of cotton in the county with the 1% more increase would have 0.067% greater increase than the other county. Recall that the estimated effect of the premium subsidy on the crop acreage is the mixture of the encouragement effect and the relative profit effect as Equation (2) describes.

For the better understanding of the estimated coefficient, the acreage elasticity with respect

[6] The effect is computed by $(0.067/Subsidy\ Rate) * 30\%$ where *Subsidy Rate* is measured at its overall average.
[7] The total planted acreage decreased by about 10% and the premium subsidy per dollar of liability increased by about 340% from 1989 to 2014.

to changes in *Subsidy per Liability*, $\varepsilon_S$, can be converted to the acreage elasticity with respect to changes in the expected revenue per acre, $\varepsilon_R$. The conversion allows the direct comparison between the acreage elasticity with respect to changes in *Subsidy per Liability*, $\varepsilon_S$, and the acreage elasticity with respect to price changes.

From Equation (1),

$$Revenue\ per\ Acre = E(R)(1 + Subsidy\ per\ Liability * \theta)$$

and

$$\varepsilon_R = \frac{\partial Acreage}{\partial Revenue\ per\ Acre} \frac{Revenue\ per\ Acre}{Acreage}.$$

Suppose $E(R)$ and $\theta$ are constant. The acreage elasticity with respect to changes in the expected revenue per acre, $\varepsilon_R$, becomes

$$\begin{aligned} \varepsilon_R &= \frac{\partial Acreage}{E(R) * \theta * \partial Subsidy\ per\ Liability} \frac{E(R)(1 + Subsidy\ per\ Liability * \theta)}{Acreage} \\ &= \frac{\partial Acreage}{\partial Subsidy\ per\ Liability} \frac{(1 + Subsidy\ per\ Liability * \theta)}{\theta * Acreage} \\ &= \varepsilon_S * \frac{(1 + Subsidy\ per\ Liability * \theta)}{Subsidy\ per\ Liability * \theta}. \end{aligned}$$

Thus, the estimated coefficient for $ln(Subsidy\ per\ Liability)_{ijt}$ in Equation (3) times $(1 + Subsidy\ per\ Liability * \theta)/Subsidy\ per\ Liability * \theta$ is comparable to the acreage elasticity with respect to changes in the expected revenue per acre, $\varepsilon_R$. Note that the acreage elasticity to price change is equal to $\varepsilon_R$ when yields do not respond to prices.

Table 4: Conversion to the Revenue Elasticity

| | (1) Panel FE | (2) IV Panel FE | (3) Panel FE | (4) IV Panel FE |
|---|---|---|---|---|
| $\varepsilon_S$ | 0.011 | 0.067 | 0.011 | 0.067 |
| | **2010-2014 Average** | | **Overall Average** | |
| *Subsidy per Liability* | 0.08 | | 0.06 | |
| $\theta$ | 0.46 | | 0.27 | |
| Corresponding $\varepsilon_R$ | 0.28 | 1.97 | 0.63 | 4.39 |

Table (4) shows the conversion of the acreage elasticity with respect to changes in *Subsidy per Liability*, $\varepsilon_S$, to the acreage elasticity with respect to changes in the expected revenue per acre, $\varepsilon_R$. The estimate from Panel FE with IV, Column (3) in Table (3), implies the acreage elasticity with respect to changes in the expected revenue per acre of 1.97 evaluated at the 2010-2014 average. Without instrumenting *ln*(*Subsidy per Liability*), Column (2) in Table (3), implies 0.28.

Both implied acreage elasticities are greater than the acreage elasticities with respect to price changes in Table (3), which are 0.16 from Panel FE with IV and 0.14 from Panel FE. This suggests that a higher coverage level of crop insurance induces more crop acreage. Otherwise, the implied acreage elasticities from $\varepsilon_S$ should be close to the acreage elasticities with respect to price changes.

# 8 Sensitivity Analysis

As discussed above, the county-crop panel of planted acreage is unbalanced. Some county-crop combinations with small planted acreage are dropped out from the panel. The unbalanced panel can lead to attrition bias if the reason for observations dropping out from the county-crop panel is correlated with the error term (Cameron and Trivedi 2005). For the robustness check, I restricted the sample into the county-crop combinations that have observations for every year.

Table 5: The Estimated Acreage Effects of the Premium Subsidy with Balanced Panel

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | Pooled OLS | Panel FE | IV Panel FE |
| ln(Subsidy per Liability) | -0.0076** | 0.0135*** | 0.0748*** |
| | (0.0034) | (0.0035) | (0.0113) |
| L.ln(Planted Acreage) | 0.9805*** | 0.8299*** | 0.8291*** |
| | (0.0029) | (0.0265) | (0.0269) |
| L.ln(Price Received) | 0.0252*** | 0.1099*** | 0.1320*** |
| | (0.0042) | (0.0106) | (0.0101) |
| Time | -0.0001 | -0.0014*** | -0.0052*** |
| | (0.0003) | (0.0003) | (0.0007) |
| Constant | 0.0675* | | |
| | (0.0403) | | |
| Observations | 69,087 | 66,361 | 66,361 |
| Number of county-crop FEs | | 2,778 | 2,778 |

Cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table (5) shows the results of the estimations that are equivalent to Table (3) but only with the restricted sample. The estimated parameters are close to those of Table (3). Although restricting sample into balanced panel does not solve the attrition bias completely, Table (5) indicates that the results are not driven by the observations with missing years.[8]

The next sensitivity analysis is related to the mandatory provision of CAT due to the 1994 act. I check whether the results are driven by the mandatory provision of CAT by estimating the parameters of equation (2) with year dummies for 1995 and 1996. The estimated coefficients of Table (6) are not different from those of Table (3). The results are not driven by the mandatory provision of CAT imposed by the 1994 act.

Table 6: The Estimated Acreage Effects of the Premium Subsidy with Year Dummy Variables for 1995 and 1996

| VARIABLES | (1)<br>Pooled OLS | (2)<br>Panel FE | (3)<br>IV Panel FE |
|---|---|---|---|
| ln(Subsidy per Liability) | 0.0031* | 0.0105*** | 0.0656*** |
| | (0.0018) | (0.0024) | (0.0128) |
| L.ln(Planted Acreage) | 0.9850*** | 0.8196*** | 0.8184*** |
| | (0.0031) | (0.0249) | (0.0248) |
| L.ln(Price Received) | 0.0311*** | 0.1296*** | 0.1586*** |
| | (0.0046) | (0.0128) | (0.0132) |
| Time | 0.0015*** | -0.0018*** | -0.0061*** |
| | (0.0003) | (0.0004) | (0.0011) |
| year 1995 | -0.0273** | -0.0445*** | -0.0841*** |
| | (0.0116) | (0.0121) | (0.0147) |
| year 1996 | 0.0924*** | 0.0540*** | 0.0171 |
| | (0.0118) | (0.0093) | (0.0108) |
| Constant | -0.0236 | | |
| | (0.0406) | | |
| Observations | 152,970 | 140,625 | 140,625 |
| Number of county-crop FEs | | 7,232 | 7,232 |

Cluster robust standard errors are in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The choice of the instrument also may affect the results. Table (7) provides the results equivalent to column (3) of Table (3) with *Subsidy Rate* 65% as an instrument and *Subsidy Rate* 65% and *Subsidy Rate* 75% as instruments. The magnitude slightly changes with signs and statistical significances remain unchanged.

[8] For the attrition bias, sample selection methods are recommended such as an early example of Hausman and Wise (1979). Further research with the supplementary data is needed.

Table 7: The Estimated Acreage Effects of the Premium Subsidy with Alternative Instruments

| VARIABLES | (1)<br>65% only | (2)<br>65% and 75% |
|---|---|---|
| ln(Subsidy per Liability) | 0.0421*** | 0.0302*** |
| | (0.0088) | (0.0082) |
| L.ln(Planted Acreage) | 0.8195*** | 0.8256*** |
| | (0.0248) | (0.0247) |
| L.ln(Price Received) | 0.1526*** | 0.1366*** |
| | (0.0109) | (0.0102) |
| Time | -0.0041*** | -0.0031*** |
| | (0.0008) | (0.0007) |
| Observations | 140,625 | 140,625 |
| Number of county-crop FEs | 8,192 | 8,192 |

Cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results of Table (5), (6), and (7) suggest that the estimation results for the acreage effect of the premium subsidy are robust to three major concerns: attrition bias, mandatory provision of CAT in 1995 and its repeal in 1996, and choices of instruments.

## 9 Conclusions and Further Research

The U.S. federal crop insurance program had a significant growth in the last two decades. I estimate the acreage effects of the growth of the crop insurance program and subsidies embedded in the program. The study focuses on the exogenous policy changes that increased the premium subsidy in the U.S. federal crop insurance program.

The study illustrates potential identification issues of estimating the effects of premium subsidies. Exploiting the policy changes that increased the premium subsidy mitigates the endogeneity concerns from the omission of the variables indicating the riskiness of crops in each county and the simultaneity across planted acreage, the choice of crop insurance, and the amount of the expected subsidy that farmers receive.

The estimates of the overall acreage effect imply that the premium subsidy has a significant effect on crop acreage, which indicating the legislative changes with increases in the premium subsidy affected crop acreage. For example, the Federal Crop Insurance Act of 2000 increased *Subsidy per Liability* for corn by about 19% from its average over the time period 1989-2014.

The estimated acreage effect indicates that the 19% increase in *Subsidy per Liability* increases *Planted Acreage* by about 1.3% from its average. For wheat, the 2000 act only increased *Subsidy per Liability* by about 10% and thus the implied increase in the planted acreage is about 0.67%. The subsidy rate increase clearly has differential effects across crops.

The estimated effect is substantially greater than the estimated effects of Wu (1999), Young, Vandeveer, and Schnepf (2001) and Goodwin, Vandeveer, and Deal (2004). The relative profit effect of the premium subsidy on the crop acreage, which is suggested by the conceptual framework of Yu (2015), explains the larger overall acreage effects compare to the estimates in the literature.

The implied acreage elasticities from the estimated acreage effect of the premium subsidy suggests there is an encouragement effect. The implied acreage elasticities from the estimates of Panel FE and Panel FE with instrumenting *Subsidy per Liability* are greater than the acreage elasticity with respect to price changes. A higher crop insurance coverage level seems to induce more planted acreage.

There are other government programs to be considered in the context of estimating the acreage effect of the premium subsidy. The early period of the sample experienced other government policies such as Acreage Reduction Program, Price Support and Direct Payment Program. Omitting the variable related to such policies may lead to inconsistency of the estimated coefficient of the variable of interest, *Subsidy per Liability*. Further research is necessary to analyze the sensitivity of the estimated coefficients with respect to the inclusion of other policy variables.

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## Appendix 1: Descriptive Statistics by Crop

Table 8: Summary Statistics by Crop

| | Mean | Mean | Mean |
|---|---|---|---|
| | **1989-1993** | **2010-2014** | **Overall** |
| **Barley** | | | |
| Planted Acreage | 10,268 | 11,775 | 10,918 |
| Price Received | 87.935 | 115.302 | 88.249 |
| Avg. Subsidy per Liability | 0.016 | 0.074 | 0.045 |
| Avg. Share of Revenue Insured | 0.080 | 0.260 | 0.148 |
| Number of Observations | 4,025 | 940 | 12,141 |
| **Corn** | | | |
| Planted Acreage | 32,826 | 53,394 | 40,388 |
| Price Received | 84.393 | 109.660 | 83.418 |
| Avg. Subsidy per Liability | 0.021 | 0.077 | 0.058 |
| Avg. Share of Revenue Insured | 0.108 | 0.468 | 0.293 |
| Number of Observations | 11,369 | 8,148 | 51,403 |
| **Cotton** | | | |
| Planted Acreage | 24,392 | 32,352 | 28,379 |
| Price Received | 1021.294 | 787.822 | 851.303 |
| Avg. Subsidy per Liability | 0.030 | 0.105 | 0.075 |
| Avg. Share of Revenue Insured | 0.128 | 0.475 | 0.338 |
| Number of Observations | 2,547 | 1,601 | 11,414 |
| **Sorghum** | | | |
| Planted Acreage | 12,169 | 20,267 | 14,573 |
| Price Received | 65.561 | 88.975 | 64.209 |
| Avg. Subsidy per Liability | 0.021 | 0.143 | 0.076 |
| Avg. Share of Revenue Insured | 0.073 | 0.335 | 0.176 |
| Number of Observations | 4,656 | 1,169 | 14,751 |
| **Soybeans** | | | |
| Planted Acreage | 34,192 | 52,161 | 43,803 |
| Price Received | 183.604 | 227.705 | 181.039 |
| Avg. Subsidy per Liability | 0.025 | 0.082 | 0.064 |
| Avg. Share of Revenue Insured | 0.105 | 0.481 | 0.315 |
| Number of Observations | 8,672 | 7,167 | 41,126 |
| **Rice** | | | |
| Planted Acreage | 25,880 | 38,698 | 31,034 |
| Price Received | 120.729 | 140.841 | 122.274 |
| Avg. Subsidy per Liability | 0.008 | 0.038 | 0.028 |
| Avg. Share of Revenue Insured | 0.130 | 0.516 | 0.317 |
| Number of Observations | 561 | 331 | 2,480 |
| **Wheat** | | | |
| Planted Acreage | 32,649 | 36,029 | 34,549 |
| Price Received | 98.701 | 120.066 | 98.757 |
| Avg. Subsidy per Liability | 0.018 | 0.100 | 0.063 |
| Avg. Share of Revenue Insured | 0.090 | 0.433 | 0.227 |
| Number of Observations | 11,230 | 6,464 | 45,865 |

## Appendix 2: Sensitivity Analysis on Clustering Standard Errors

Table 9: The Estimated Results of Column (3) of Table (3) with Different Levels of Clustering Standard Errors

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| VARIABLES | State (Baseline) | State & Year | County | County & Year |
| ln(Subsidy per Liability) | 0.0669*** | 0.0669** | 0.0669*** | 0.0669** |
| | (0.0118) | (0.0306) | (0.0042) | (0.0315) |
| L.ln(Planted Acreage) | 0.8191*** | 0.8191*** | 0.8191*** | 0.8191*** |
| | (0.0248) | (0.0363) | (0.0051) | (0.0298) |
| L.ln(Price Received) | 0.1601*** | 0.1601*** | 0.1601*** | 0.1601*** |
| | (0.0112) | (0.0316) | (0.0035) | (0.0321) |
| Time | -0.0057*** | -0.0057** | -0.0057*** | -0.0057** |
| | (0.0009) | (0.0022) | (0.0003) | (0.0023) |
| Observations | 140,625 | 140,625 | 140,625 | 140,625 |
| Number of County-crop FE | 8,192 | 8,192 | 8,192 | 8,192 |

Cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1