Effects of Crop Insurance Premium Subsidies on Crop Acreage

Jisang Yu, Aaron Smith, and Daniel A. Sumner

Crop insurance premium subsidies affect patterns of crop acreage for two reasons. First, holding insurance coverage constant, premium subsidies directly increase expected profit, which encourages more acreage of insured crops (direct profit effect). Second, premium subsidies encourage farms to increase crop insurance coverage. With more insurance coverage, farms obtain more subsidies, and farm revenue becomes less variable as indemnities offset revenue shortfalls, so acreage of insured crops likely increases (indirect coverage effect). By exploiting exogenous policy changes and using approximately 180,000 county-crop-year observations, we estimate the sum of these two effects of premium subsidies on the pattern of U.S. acreage across seven major field crops. We estimate that a 10% increase in the premium subsidy causes a 0.43% increase in the acreage of a crop in a county holding the premium subsidy of its competing crop constant. Taking into account the small share of premium subsidies in expected crop revenue, this subsidy impact is analogous to an own-subsidy acreage elasticity of 1.24, which exceeds own-price acreage elasticity estimates in the literature. One explanation for the larger acreage response to premium subsidies is that insurance causes an indirect coverage effect in addition to a direct profit effect.

Key words: Crop insurance, premium subsidies, farm policy, supply response, crop acreage.

JEL codes: Q11, Q18.

The U.S. federal crop insurance program expanded rapidly in last twenty-five years, with substantial increases in insured acres, liability, and insurance subsidies (Glauber 2013). Indeed, the total crop insurance premium subsidy increased from $205 million in 1989 to $6.2 billion in 2014 (RMA 2015), while the Agricultural Act of 2014 replaced major commodity programs with "risk management programs", and enhanced existing federal crop insurance programs.

Crop insurance premium subsidies affect crop acreage in two ways. The first is by increasing expected returns to insured crops, holding constant the share of insured crop revenue (the direct profit effect). The second way is by encouraging farms to insure more of their crop revenue, thereby increasing the subsidy received and reducing the riskiness of insured crops, which in turn stimulates more acreage of those crops (the indirect coverage effect).[1]

This article estimates the effects of crop insurance premium subsidies on the pattern of

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[1] Farms can insure more of their crop revenue by increasing either coverage levels or insured acres. In this paper, we define "coverage" as the share of crop revenue insured. For the term "coverage level", we follow the definition of the Federal Crop Insurance Program, which is the share of insured crop revenue per insured acre. Therefore, coverage is equal to the share of insured acreage times coverage level. Below we denote the coverage level as θ and the share of insured acreage as δ. Thus, coverage equals $\theta\delta$.

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U.S. field crop acreage. One objective of this article is to investigate whether the total response to crop insurance subsidies exceeds the direct profit effect. We use county-crop-year observations for seven major field crops for the years 1989 through 2014 to estimate the total elasticity of acreage with respect to policy-induced changes in the premium subsidy. In principle, the direct profit effect is the same as the response of acreage to output prices or fully coupled subsidies, on which there is an extensive literature (e.g., Nerlove and Bessler 2001; Hendricks, Smith, and Sumner 2014; and Hendricks and Sumner 2014). This body of literature provides estimates of the direct profit effect; we add to the literature with our own estimates, which are similar in magnitude.

The main challenge in identifying the response of acreage to premium subsidies is that farmer-received subsidy is endogenous to acreage. Farmers choose acreage and insurance coverage simultaneously. To overcome the endogeneity bias, we use the fact that several times in the past three decades, U.S. Congress or the USDA has increased crop insurance subsidy rates per dollar of premium. We take these government policy changes as exogenous to acreage and use them in our regression models to instrument for changes in the received premium subsidy.

Many previous studies have developed the conceptual and empirical foundations for how crop insurance programs may affect input demand in the context of risk aversion, information asymmetry, or credit market imperfections.[2] Important articles in this respect include Chambers (1989); Horowitz and Lichtenberg (1993); Ramaswami (1993); Babcock and Hennessy (1996); Smith and Goodwin (1996); Coble et al. (1997); Cornaggia (2013); and Weber, Key, and O'Donoghue (2016).

Research on the acreage effects of U.S. crop insurance, which is directly relevant to the present article, is much more limited. Significant articles include Wu (1999), Young, Vandeveer, and Schnepf (2001), Goodwin, Vandeveer, and Deal (2004), and Goodwin and Smith (2013). Using data from Central Nebraska in 1991, Wu (1999) estimates a system of equations of crop shares and crop insurance choices, and finds that making crop insurance available for corn leads to 5% to 27% increases in the share of corn acreage. The simulations of Young, Vandeveer, and Schnepf (2001) imply that the total acreage of eight major field crops would fall by about 0.4% as a response to the removal of all federal crop insurance subsidies.

Goodwin, Vandeveer, and Deal (2004) empirically investigate the responses of acreage to U.S. federal crop insurance programs for corn, soybeans, and wheat. Based on data from the Corn Belt and the Northern Great Plains in 1985–1993, these authors find that premium subsidies increase crop insurance participation, and higher crop insurance participation rates induce acreage expansions. These authors' simulations imply that a 30% decrease in the farm-paid premium (an increase in subsidy) for corn and soybeans would increase corn acreage by 0.28% to 0.49%. Goodwin and Smith (2013) present preliminary empirical estimates that also suggest positive effects of premium subsidies on acreage.

We next describe how the U.S federal crop insurance program changed over time, highlighting the growing importance of understanding the effects of crop insurance on crop acreage. We then motivate our empirical strategy using a conceptual framework for how premium subsidies affect crop acreage. Next, we present our data and the estimation strategy, followed by the empirical findings and the interpretations.

The U.S. 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 market and deliver crop insurance products to farms. The government subsidizes the administrative and operation costs, the reinsurance cost, and the insurance premium (FCIC 2014; RMA 2015).

U.S. crop insurance products are developed by either the FCIC or private insurance providers with the approval of the FCIC; the FCIC and the RMA set premiums and

[2] There is also an extensive body of literature on demand for U.S. crop insurance (e.g. Goodwin 1993; Just, Calvin, and Quiggin 1999; Sherrick et al. 2004; Babcock 2015; and Du, Feng, and Hennessy 2016). However, our focus in this article is not on demand for crop insurance, but rather on the economic consequences of crop insurance, particularly the effects of premium subsidies on crop acreage.

specify the provisions for these crop insurance products. Premium rates are specified per dollar of insured liability. The rating practice has gone through several changes, with the goal of getting closer to actuarially fair premium rates (Goodwin 1994; Glauber 2013).

The two most common products for major field crops are yield protection and revenue protection, which together accounted for about 78% of total liability in 2014 (RMA 2015). For yield protection, formerly called actual production history, the indemnity is triggered when actual yield is smaller than historical average yield. For revenue protection, the indemnity is triggered when actual yield times harvest price is less than historical average yield times the larger of either projected price or harvest price. Revenue protection generally has a higher premium rate per dollar of liability than yield protection.

Farm-paid premium is equal to total premium minus premium subsidy. The total premium for a particular crop on a farm is the premium rate multiplied by the insured liability. The insured liability is the maximum possible indemnity. The insured liability for a particular crop is proportional to (*a*) the insured acreage of that crop, (*b*) the coverage levels elected by the farm, (*c*) the insured price of the crop, and (*d*) the historical yield.

The RMA sets the premium rate based on the riskiness of the insured crop in the county, the farm's chosen coverage level, the insurance product, and certain practices (such as irrigation) of the farm. The RMA attempts to specify actuarially fair premium rates, which means the premium rates should be equal to the expected indemnities per dollar of liability. In particular, premium rates are higher for riskier crops or crops in riskier counties (Coble and Barnett 2013).

The premium subsidy received by the farm equals the subsidy rate times the total premium. Subsidy rates vary across coverage levels, crop insurance products, and unit types.[3] Each crop faces the same subsidy rate for a given coverage level, holding insurance product, and unit type equal. Subsidy rates are determined by legislation. Group or area-based products, which have indemnity payout schedules tied to county-level yields or revenue, have higher subsidy rates.

By definition, if the premium rate were actuarially fair, the expected net profit gain to the farm from buying insurance would be equal to the premium subsidy. Premium rates and subsidy rates determine how much subsidy per dollar of insured liability participating farms receive. As we show in the conceptual framework section, the subsidy per dollar of liability is a good measure of the premium subsidy relative to crop revenue.

The premium rates and the subsidy rates that participating farms face are endogenous to their production decisions. In this article, we focus on how the subsidy per dollar of insured liability affects planted acreage by exploiting policy changes in the subsidy rates. We address endogeneity issues and relevant exogenous policy changes in detail.

Institutional Changes

The U.S. federal crop insurance program experienced several large policy changes in the period from 1989 to 2014 (Glauber 2013). We use these exogenous changes to identify the impacts on planted acreage of our main explanatory variable, which is the subsidy per dollar of insured liability, on planted acreage. As explained above, premium rates and subsidy rates are set by the FCIC and the RMA based on legislation. Legislative changes and introductions of new crop insurance products led to significant changes in the average premium rate and the average subsidy rate across crops and counties.

Major Legislative Changes

The Federal Crop Insurance Act of 1980 specified that private insurance providers would deliver crop insurance products. The 1980 Act added coverage levels and expanded crop insurance to more crops and regions, and mandated the FCIC to pay 30% of the total premium for any coverage level up to 65% (Glauber 2013). However, insurance participation rates increased slowly in the 1980s, so Congress created a mandatory risk protection program and increased the premium subsidy (Glauber 2013).

Figure 1 illustrates the changes in subsidy rates for three coverage levels, 65%, 75%,

[3] The term "unit" refers to a bundle of parcels that operators can insure. The unit type is determined based on how farmers bundle or divide parcels for the purpose of their crop insurance application.

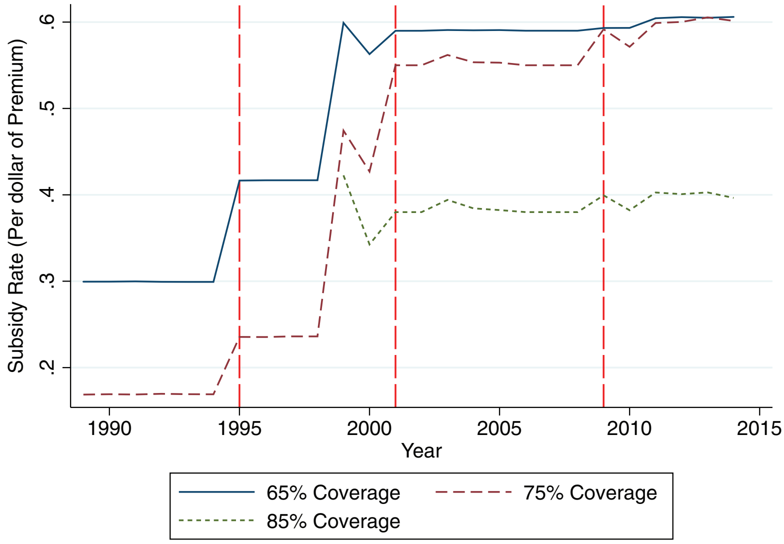

Figure 1. Subsidy rate by coverage level (1989–2014)

Note: The subsidy rates are computed by "National Total Subsidy" divided by "National Total Premium" for each coverage level. Subsidies and premiums for the group insurance products are excluded. Note that except for 1999 and 2000 and years after 2008, the subsidy rates are equal to the legislatively-determined subsidy rates.

and 85%, of yield protection or revenue protection since 1989. The Crop Insurance Reform Act of 1994 created the "catastrophic" risk protection program (CAT) with a 100% subsidy rate that protects 50% of historical yield at 60% of the projected price (Lee, Harwood, and Somwaru 1997).[4] The 1994 Act made CAT mandatory for commodity program participants, but this mandate was repealed in 1996. The 1994 Act also increased the subsidy rates for "buy-up" coverage levels, which have positive farm-paid premiums. For example, the subsidy rate increased from 30% to 42% for the 65% coverage level for all except area-based products.

Supplementary legislation in 1998 and 1999 provided ad hoc premium reductions for crop years 1999 and 2000 in response to bad weather and low prices (Glauber, Collins, and Barry 2002). The Agricultural Risk Protection Act of 2000 codified the ad hoc premium reductions that had been introduced in 1998 and 1999 and led to a 25% reduction of premiums (O'Donoghue 2014). These codified ad hoc premium reductions in the 2000 Act implied increases in subsidy rates.

[4] Since 1999, the price coverage of the CAT program has been 55% of the projected price.

There were slight changes in subsidy rates in 2003, 2004, and 2005 based on administrative decisions of the RMA to undertake financial assistance programs for fifteen states listed in the 1980 Act (RMA 2003, 2004, and 2005). The 2008 Farm Bill included a new Title XII "Crop Insurance and Disaster Assistance Programs." The new title directed the RMA to undertake research and development on designing crop insurance products. The 2008 Farm Bill also increased the subsidy rates for enterprise and whole farm units.[5] Moreover, the 2008 Farm Bill reduced the subsidy rates for area-based products.

In our regressions, we use the average subsidy per dollar of liability across all coverage levels for each county-crop-year as an explanatory variable. This variable responds to the major legislative changes and periodic ad hoc premium reductions, but is also affected by

[5] Usually, operators insure each crop in each farm separately. However, operators may choose to have a single insurable unit for all acreage of the same crop in the same county (enterprise unit). Operators may also choose to have a single insurable unit for all insurable crops in the same county (whole farm unit). Enterprise and whole farm units have low premium rates. The 2008 Farm Bill raised the subsidy per dollar of premium for the enterprise and whole farm units such that the subsidy per unit of liability became similar to those for the basic and optional units. Thus, an increase in the number of enterprise or whole farm units would raise the average subsidy per dollar of premium, but would have little effect on the average subsidy per dollar of liability.

changes in the composition of coverage levels chosen by farms. For example, between 2000 and 2008, corn and soybeans producers shifted toward higher coverage levels, whereas wheat producers continued with lower coverage levels. We provide a figure with details about average subsidy rates across all coverage levels for corn, soybeans, and wheat in the online supplementary appendix A.

Introductions of New Crop Insurance Products

Introductions of new crop insurance products also affect the premium subsidy that farms face because the new products may have premium rates and subsidy rates that are different from existing products. In 1996, crop revenue coverage for corn and soybeans was introduced. Since then, revenue products expanded across crops and counties. The subsidy rates for revenue products are the same as for the yield products at the same coverage levels. Premium rates for revenue products are generally higher than those of analogous yield products (Coble and Barnett 2013).

Area-based products are based on area-level yields or revenues. The FCIC and the RMA introduced the first area-yield products—Group Risk Plan—in 1993 and the first area-revenue products (Group Risk Income Plan) in 1999 (Glauber 2013). For the same coverage level, the area-based products have higher subsidy rates than other products.

In a recent empirical study, Cornaggia (2013) treats the introduction of new products as a quasi-experiment. The study classifies crops that faced an introduction of a new crop insurance product as a "treatment" group, and finds a positive relationship between availability of crop insurance and crop yield. In the empirical model below, we do not use the introductions of new products as experimental events directly. Rather, we use variation in the subsidy rates as experimental events.[6]

Increases in subsidy rates and the development of new products affect how much premium subsidies participating farms receive. Increases in subsidy rates and the shift to revenue or area-based products increase the subsidy per acre or per dollar of insured liability, *ceteris paribus*. With county-crop-year panel data, we estimate the acreage effects of premium subsidies by exploiting changes in subsidy rates induced by legislative changes. In other words, we exploit the quasi-experimental nature of the changes in subsidy rates for the U.S. federal crop insurance program.

Conceptual Framework on How Premium Subsidies Affect Crop Acreage

To develop our empirical strategy, we first investigate how premium subsidies affect crop acreage. The simple derivation here is designed to motivate and provide background for our empirical analysis. We describe two channels of the effect of premium subsidies on crop acreage: a direct profit effect and an indirect coverage effect. Later in our empirical analysis, we compare the estimated overall effect of premium subsidies on crop acreage and the estimated acreage elasticity with respect to price to infer the magnitude of the indirect effect.

Consider a representative farmer in a representative year who chooses to plant A_j acres of each crop j for $j = 1, 2, \ldots, J$. Each crop is insured with coverage level θ_j, which is the share of expected per acre revenue insured by crop insurance.[7] For simplicity, we assume that the farm faces stochastic per acre crop revenue, R_j, with mean, $\bar{R}_j$, and the farm insures all of its planted acres at the same coverage level.[8]

Crop revenue from an insured acre equals the maximum of realized market revenue in that year, R_j, and insured liability, $\theta_j \bar{R}_j$. The fair premium for crop insurance is increasing in the level of risk and the insured liability. To focus on the effect that risk has on the price of insurance, we standardize the premium by insured liability, that is, we focus on the premium rate, $p_j(\theta_j)$, which equals the

[6] There were other institutional changes in crop insurance markets that could have affected crop acreage. For example, subsidies in research and development of crop insurance products, subsidies in administrative and operating costs, and reduced transaction costs of purchasing crop insurance. Our estimation strategy isolates and identifies the effect of premium subsidies on crop acreage.

[7] In this section, we show how premium subsidies affect crop acreage with revenue-based crop insurance. This illustration can nest a similar and perhaps simpler derivation that applies to yield-based crop insurance.

[8] This assumption implies that the share of insured acres, δ_j, is equal to one and the share of insured revenue, that is, coverage, is $\theta_j \delta_j = \theta_j$.

premium in dollars per dollar of insured liability. This is consistent with the U.S. crop insurance market, in which farmers are quoted a premium rate. Insurance premiums are subsidized by the government at a rate, $s(\theta_j)$, which varies depending on the chosen coverage level, θ_j, but does not vary across location or crop.[9] Thus, to insure an acre of crop j, the farmer pays a premium rate of $(1-s(\theta_j))p_j(\theta_j)$.

Farm profit is given by

$$(1)\quad \pi = \sum_{j=1}^{J} max(R_j, \theta_j \bar{R}_j)A_j - (1-s(\theta_j))p_j(\theta_j)\theta_j\bar{R}_jA_j - C_j(A_j)$$

where $C_j(A_j)$ denotes the cost function. Suppose the farmer maximizes the following mean-variance utility function (Meyer 1987),

$$(2)\quad \max_{\{A_j,\theta_j\}} U = \mu - \kappa\sigma$$

where μ is the expected profit, κ is the risk-aversion parameter of the farmer, and σ denotes the standard deviation of profit.[10]

Noting that $max(R_j, \theta_j\bar{R}_j) = R_j + max(0, \theta_j\bar{R}_j - R_j)$, we write the expected profit as

$$(3)\quad \mu = \sum_{j=1}^{J}((\bar{R}_j + \int_0^{\theta_j\bar{R}_j}(\theta_j\bar{R}_j - R_j)f(R_j)dR_j)A_j - (1-s(\theta_j))p_j(\theta_j)\theta_j\bar{R}_jA_j - C_j(A_j))$$

which is the sum of crop revenue and crop insurance revenue, minus a sum of subsidized crop insurance premium and production cost. The actuarially fair premium per dollar of liability (i.e., the actuarially fair premium rate) is

$$(4)\quad p_j(\theta_j) = \frac{1}{\theta_j\bar{R}_j}\int_0^{\theta_j\bar{R}_j}(\theta_j\bar{R}_j - R_j)f_j(R_j)dR_j,$$

where $f_j(R_j)$ denotes the probability density function of R_j.[11] Also, note that $p_j'(\theta_j) > 0$.

We simplify equation (3) using equation (4) to obtain

$$(5)\quad \mu = \sum_{j=1}^{J}(1 + \Gamma_j(\theta_j)\theta_j)\bar{R}_jA_j - C_j(A_j)$$

where $\Gamma_j(\theta_j) = s(\theta_j)p_j(\theta_j)$ is the premium subsidy per dollar of insured liability.

The variance of profit is

$$(6)\quad \sigma^2 = var(\sum_{j=1}^{J} max(R_j, \theta_j\bar{R}_j)A_j) = \sum_{i=1}^{J}\sum_{j=1}^{J} A_iA_j cov(max(R_i, \theta_i\bar{R}_i), max(R_j, \theta_j\bar{R}_j)).$$

Thus, the variance of profit depends on the variance of revenues of each crop and the covariance of revenues between crops. The cross-crop covariance terms would equal zero if revenues were uncorrelated across crops.

The first-order conditions are

$$(7)\quad \frac{\partial U}{\partial A_j} = (1 + \Gamma_j(\theta_j)\theta_j)\bar{R}_j - \frac{\partial C_j}{\partial A_j} - \kappa\frac{\partial \sigma}{\partial A_j} = 0, \ and$$

$$(8)\quad \frac{\partial U}{\partial \theta_j} = \left(\Gamma_j(\theta_j) + \frac{\partial \Gamma_j}{\partial \theta_j}\theta_j\right)\bar{R}_jA_j - \kappa\frac{\partial \sigma}{\partial \theta_j} = 0.$$

Condition (7) shows that the marginal value of planting an additional acre of a crop depends on the subsidy per liability, the coverage level, marginal cost, and the variance

[9] The 1994 Act, the 2000 Act and the 2008 Farm Bill shifted $s(\theta j)$.

[10] The mean-variance utility function assumption is useful to keep the exposition simple. Meyer (1987) shows that a wide range of expect utility models are consistent with this two-moment utility function. Recent studies such as Babcock (2015) and Du, Feng, and Hennessy (2016) suggest that prospect theory may explain the insurance demand behavior of farmers better. The mean-variance tradeoff under prospect theory would be different from that under expected utility theory. However, our empirical strategy does not depend on the form of the mean-variance tradeoff.

[11] Woodard et al. (2012) find evidence of systematic misratings of crop insurance premiums, which means that premium rates differ from actuarially fair rates. For simplicity, our conceptual framework assumes that premiums reflect expected indemnity. Without this assumption, we would carry though an additional term for any systematic difference from misrating. However, despite such misratings, the actual premium rates and the expected indemnities remain highly correlated. If the premium rate were a poor indicator for the expected indemnity, then we would expect a null effect of the premium subsidy on crop acreage. Our empirical results show that this is not the case and in fact the premium subsidy has a significant and positive effect on acreage.

of revenue. In turn, the subsidy per liability depends on the coverage level, as does the variance of revenue. Condition (8) shows that the marginal value of increasing insurance coverage depends on the subsidy per liability, the coverage level, the planted acreage, and the variance of revenue. Solving conditions (7) and (8) for acreage and coverage gives the optimal quantities of each.

Condition (7) reveals the two channels through which insurance subsidies affect the marginal utility from a planted acre. First is a direct profit effect. Holding crop insurance coverage level θ_j constant, an increase in the subsidy rate raises the subsidy received per liability ($\Gamma_j(\theta_j)$ in (7)), which increases the expected net return from the insured crop. The magnitude of this increase varies by crop because, even though the subsidy rate is constant across crops, the dollar value of the subsidy to the farmer for each crop equals the subsidy rate times the premium rate for each crop, and the premium rates vary across crops.

The second effect is an indirect coverage effect. An increase in premium subsidies can encourage non-participating farms to participate in crop insurance or encourage participating farms to increase their coverage, θ_j, for given crop acreage. An increase in crop insurance coverage causes an increase in the subsidy received and thus increases the marginal utility of a planted acre through the $\Gamma_j(\theta_j)$ term in condition (7). Moreover, an increase in coverage reduces the riskiness of the revenue from the crop that is covered by crop insurance, which increases the marginal utility of a planted acre through the term $\partial\sigma/\partial A_j$ in condition (7).[12]

The overall effect of premium subsidies on the pattern of crop acreage is the sum of the direct profit effect and the indirect coverage effect. In our empirical setting, we first estimate the overall effect of premium subsidies and then present a comparison of the estimated effect and the own-price elasticity. The comparison allows us to uncover the magnitude of the additional indirect coverage effect.[13]

Data and Variable Construction

We use annual county-level information on crop acreage and crop insurance characteristics for major field crops from surveys of the USDA National Agricultural Statistics Service (NASS) and the RMA's Summary of Business (SOB). We use data on barley, corn, cotton, sorghum, soybeans, rice, and wheat for the period of 1989–2014.[14] NASS also reports the average price received by farms for each crop at the state level. We use futures price data for corn, cotton, soybeans, rice, and wheat, which are obtained from Commodity Research Bureau (CRB 2016). Each price is deflated by the Producer Price Index from the Bureau of Labor Statistics (BLS 2016).

We construct each expected price variable using both futures prices and average prices received by farms. We regress the state-level annual prices received by farms on state dummies and futures prices for 1989–2014. We use the predicted values from this regression as the expected prices. We use similar futures prices as those used by the RMA in their price projection, and we use the average price from January to the sign-up deadline of crop insurance contracts. Due to the absence of relevant futures markets, the RMA uses CBOT corn futures prices to project prices of barley and sorghum (RMA 2016). We follow the RMA's practice and use CBOT corn futures to construct farmers' price expectations of barley and sorghum. The underlying assumptions are: (*a*) the state-level basis relationships do not change, (*b*) the relationship between the realized prices and the futures prices do not change, and (*c*) the farms know these relationships.[15,16]

[12] This is consistent with standard expected utility theory, which suggests that farmers with any non-increasing absolute risk aversion preference would increase acreage of the crop as the riskiness decreases (Hennessy 1998). 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.

[13] We compare the estimated effect of premium subsidy per dollar of liability with the estimated own-price elasticity in the interpretation section. As illustrated above, farms choose acreage and coverage level simultaneously, and thus subsidy per dollar of liability is endogenous to the acreage. Note that we do not compare the estimated coefficients across different regressions to infer the magnitude of the indirect effect.

[14] An Im-Pesaran-Shin panel unit root test (Im, Pesaran, and Shin 2003) on the balanced panel rejects at 1% significance level the null that states all panels contain unit roots. We therefore proceed under the assumption that our data are panel-stationary.

[15] To justify this assumption, we regressed state average prices received for corn and soybeans on state fixed effects and the national average price. This regression produced R^2 values of 0.97 for soybeans and 0.99 for corn, which indicates that time variation in the basis explains a tiny proportion of the price variation.

[16] Carter, Rausser, and Smith (2017) estimate that biofuel policies caused a 30% increase in the corn price from 2006 to 2014. We consider the possibility of a change in the basis relationship after 2006. The results appear in supplementary online appendix B.1. Our main specification remains robust to a change in the basis relationship.

In the SOB dataset, the RMA reports detailed information on crop insurance by insurance product and by coverage level for each crop in each county (RMA 2015). The SOB includes 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. We constructed county-crop panels from the NASS and the RMA data. The NASS combines counties with small planted acreage into a single county-crop observation for each state in each year, and the counties in these combined observations change over time. We exclude these combined observations because we do not know which counties are in these observations. Therefore, our panel dataset is unbalanced.

Table 1 shows the descriptive statistics of all 179,180 county-crop-year combinations. Table 1 also shows the 72,228 county-crop-year combinations from county-crop combinations that remain in the dataset for all twenty-six years (balanced panel). The average planted acreage for a crop in a county is about 35,000 acres. The overall average subsidy per dollar of insured liability is about 6 cents. Farms received about 2% of insured liability as the premium subsidy during 1989 through 1993, whereas they received about 9% of insured liability as the premium subsidy during 2010 through 2014. The share of the expected revenue covered by crop insurance clearly increased over time. The descriptive statistics by crop are contained in online supplementary appendix A.

Planted acreage in the balanced panel of county-crop combinations that are available for all twenty-six years in the NASS dataset tends to be larger than the average acreage for the full sample. The average is about 64,000 acres. The average subsidy per dollar of insured liability is slightly smaller than the full-sample average for the later periods and the share of expected revenue insured is slightly higher than the entire sample average.

Table 1. Means and Standard Deviations of County-Crop Panels

Variables	1989–1993	2010–2014	Overall
Full Sample			
Planted Acreage	28,123	44,196	34,661
(A_{ijt})	(49,192)	(57,367)	(52,855)
Subsidy per	0.021	0.088	0.062
Liability (Γ_{ijt})	(0.018)	(0.052)	(0.052)
Buy-up Subsidy	0.021	0.089	0.056
per Liability* (Γ_{ijt}^{Buyup})	(0.018)	(0.052)	(0.050)
Share of Revenue	0.100	0.484	0.275
Insured ($\theta_{ijt}\delta_{ijt}$)	(0.150)	(0.411)	(0.304)
Number of County-crop Combinations	9,456	6,573	10,030
Number of Observations	43,060	25,820	179,180
Balanced Panels			
Planted Acreage	60,137	65,977	63,663
(A_{ijt})	(64,824)	(64,764)	(64,446)
Subsidy per	0.021	0.076	0.056
Liability (Γ_{ijt})	(0.014)	(0.043)	(0.040)
Buy-up Subsidy	0.021	0.077	0.054
per Liability* (Γ_{ijt}^{Buyup})	(0.014)	(0.043)	(0.039)
Share of Revenue	0.136	0.546	0.362
Insured ($\theta_{ijt}\delta_{ijt}$)	(0.155)	(0.352)	(0.288)
Number of County-crop Combinations	2,778	2,778	2,778
Number of Observations	13,890	13,890	72,228

Note: Standard deviations are in parentheses. The table includes seven field crops: barley, corn, cotton, sorghum, soybean, rice, and wheat. Asterisk * indicates that buy-up subsidy per dollar of liability is equal to subsidy per dollar of liability in 1989–1993 period since catastrophic risk protection is introduced in 1994.
Source: NASS (2016) and RMA (2015).

Estimation Strategy

This section describes our econometric model and the potential sources of endogeneity in the premium subsidy. In this context, we develop our identification strategy to mitigate the endogeneity bias.

Econometric Model Specification

We specify the dependent variable as planted acreage, A_{ijt}, for county i, crop j, and year t. The main explanatory variable is subsidy per dollar of liability, Γ_{ijt}, which is defined as the total premium subsidy for crop j in county i in year t, divided by the insured liability of crop j in county i and in year t. We include expected price, EP_{ijt}, as one of the control variables. The subsidy per dollar of liability for the competing crop for crop j and the expected price for the competing crop for crop j are also included as control variables, as well as crop-specific time trends and county-crop fixed effects. The regression equation is

$$(9)\quad \ln(A_{ijt}) = \beta_0 + \beta_1 \ln(\Gamma_{ijt}) + \beta_2 \ln(\Gamma_{ij't}) + \beta_3 \ln(EP_{ijt}) + \beta_4 \ln(EP_{ij't}) + \beta_5 \ln(A_{ijt-1}) + \sum_j \beta_{j6} Time_{jt} + v_{ij} + u_{ijt}.$$

where $Time_{jt}$ is crop-specific time trends, v_{ij} is county-crop fixed effects, and u_{ijt} denotes random errors. The county-crop fixed effect captures unobserved heterogeneity across counties for each crop and across crops for each county.

We define the competing crop, j', for crop j using the following rules. If crop j is the most planted crop among our seven field crops in county i, the competing crop for crop j is the second most planted crop in county i among our seven field crops. If crop j is not the most planted crop among our seven crops in the county, the competing crop for crop j is the most planted crop. The ranking of "most planted" is based on the five-year moving average planted acreage in each county. If a county has only one of our seven crops, we use the state-level ranking.

We use a logarithmic transformation because the scales of acreage and price are different across crops and counties. For the zero values of subsidy per dollar of liability, the zeros 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 yield statistically and economically similar outcomes.[17]

Endogeneity of Γ_{ijt}

The subsidy per dollar of liability Γ_{ijt} is the weighted average of $\Gamma_j(\theta_j)$ in equation (5) across farms and coverage levels for each crop in each county in each year. As explained above, farmers can choose from a menu of potential subsidies depending on the coverage level they choose and the premium rates they are quoted. We do not observe the quoted premium rates, so we cannot reconstruct the menu of available subsidies. Instead, we observe county-level aggregates for the insurance products chosen by farmers, which we use to construct the total subsidy received each year in each county for each crop. For each county-crop-year combination, we divide the total subsidy by the total liability to get a statistic that represents the subsidy per dollar of liability received.

Figure 2 illustrates the variation of the subsidy per dollar of liability over time and in the cross-section that stems from subsidy rates, riskiness, and choice of coverage level. Its dependence on both riskiness and coverage level make Γ_{ijt} potentially endogenous to acreage. A more risky crop or a more risky county has a higher premium rate for a given crop insurance choice. Farmers tend to plant less of riskier crops and plant less in riskier counties, *ceteris paribus*. Thus, omitting the "riskiness" variable would cause a downward bias in OLS estimates of the coefficient on Γ_{ijt}, because riskiness is positively correlated with Γ_{ijt} and negatively correlated with A_{ijt}. Our model includes county-crop fixed effects, which control for any differences in riskiness that are constant over time, but differ by county or crop. The fixed effects cannot control for any changes in county-crop riskiness over time.

The dependence of Γ_{ijt} on the choice of coverage level may also bias OLS estimates of the effect of premium subsidies on planted acreage. An increase in the chosen coverage level for a crop may cause the received subsidy rate, $s(\theta)$, to decrease because the subsidy rate is lower for the higher coverage levels (see figure 1). Recall that the premium rate, p, increases as the coverage level, θ, increases. Thus, the sign of the relationship between the subsidy per dollar of liability, Γ, and the coverage level, θ, is indeterminate. If Γ and θ are positively (negatively) correlated, and θ has a positive impact on crop acreage, the OLS would underestimate (overestimate) the impact of Γ on crop acreage.

We treat the subsidy per dollar of liability of the competing crop, $\Gamma_{ij't}$, as exogenous to acreage. The riskiness of the competing crop, which is correlated with the subsidy per liability of the competing crop, may affect the planted acreage. The county-crop fixed effect controls for this correlation. We also assume that the coverage level for the competing crop does not affect the planted acreage directly. We present results both with and without the subsidy per liability of the competing crop and we find little

[17] The results from the specification without logarithmic transformations on the explanatory variables appear in supplementary online appendix B.2.

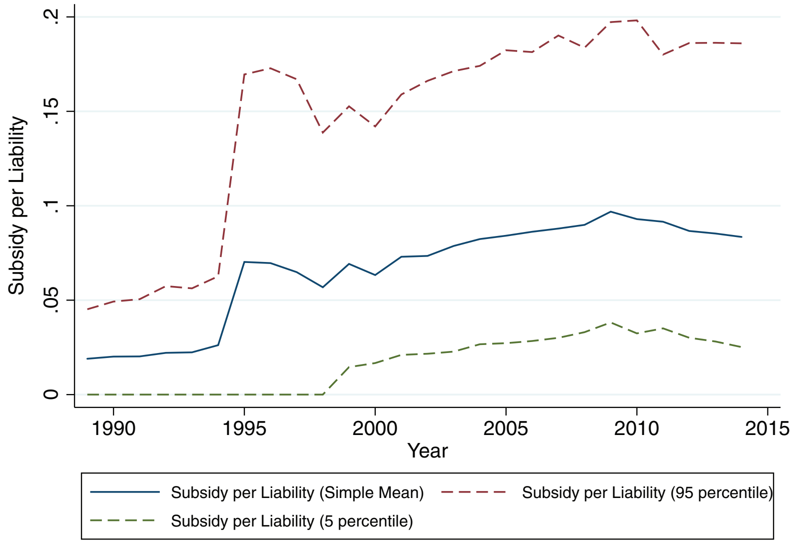

Figure 2. Subsidy per dollar of insured liability (1989–2014)

Note: The mean, 95 percentile, and 5 percentile are computed from unweighted distribution of the subsidy per dollar of insured liability. The figure represents the distribution of county-crop combination for each year and its change over time.

difference between the estimated coefficients on $ln(\Gamma_{ijt})$.

Identification Strategy

We exploit the exogenous government-set variations in the subsidy rates that were illustrated in figure 1 to deal with the endogeneity of the premium subsidy.[18] The legislative changes shift the suite of subsidy rates exogenously. These shifts are not driven by endogenous factors related to county-level crop production.

We instrument $\ln(\Gamma_{ijt})$ with $s65_t$ and $s75_t$, which are the subsidy rates for yield protection and revenue protection with 65% and 75% coverage levels. Subsidy rates for other coverage levels experienced similar changes. We choose the 65% and 75% coverage levels because they are the most common coverage levels and span the full twenty-six-year sample. We define the variable $s65_t$ as the total subsidy paid for 65% coverage divided by the total premium paid for 65% coverage. The variable $s75_t$ is defined analogously.

We do not include the ad hoc premium reductions in 1999 and 2000 in the calculation of the instrumental variables $s65_t$ and $s75_t$.[19] These two premium reductions occurred due to bad weather and market conditions that were endogenous to production decisions (Glauber, Collins, and Barry 2002). Furthermore, the final reductions were calculated and reported after planting in these years (RMA 1999). Therefore, including these reductions would make the instruments endogenous.

The financial assistance programs in 2003, 2004, and 2005 are included in the instrumental variables $s65_t$ and $s75_t$. Unlike the ad hoc premium reductions in 1999 and 2000, detailed reduction rates were announced in February of each year. We consider the change in national-level subsidy per dollar of premium for each coverage level due to these financial assistance programs for the fifteen states to be exogenous to county-crop level planted acreage.

After 2008, basic and optional units, enterprise units, and whole farm units face

[18] To our knowledge, O'Donoghue (2014) is the only study that empirically addresses the endogeneity of the premium subsidy. To estimate 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 to 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.

[19] We include the ad hoc premium reductions when we compute our main explanatory variable, $\ln(\Gamma_{ijt})$, because they are parts of the premium subsidy that insurance-participating farms receive.

different subsidy rates. Our instruments, $s65_t$ and $s75_t$, depend on the national distribution of units in the post-2008 period. Such dependence may raise a concern about the exogeneity of instruments. However, we do not believe that changes in the national distribution of units are caused by changes in the county acreage distribution. Moreover, as shown in figure 1, the post-2008 variations in the instruments are small, so the identification of the causal effects mostly hinges on legislation changes.[20]

One may question the exogeneity of the financial assistance programs and the national distribution of units. To confirm robustness, the supplementary online appendix provides the results from using instruments as the codified subsidy rates in the 1980 Act, the 1994 Act, and the 2000 Act as instruments, excluding the 2003–2005 financial assistance programs. The results are unaffected (see supplementary online appendix B.3).

We include county-crop fixed effects (FE) in our models; hence, our identification comes from the correlation between the legislative changes in subsidy rates and county-level planted acreage of our seven crops. To interpret our estimates as causal effects, we assume that the legislative changes in subsidy rates were not caused by changes in acreage. This assumption is reasonable because the legislative process is slow, because the legislative changes are finalized significantly before planting decisions are made, and because we control for the expected price of the crop.

The instrumental variables and the $\ln(\Gamma_{ijt})$ variable both trended upwards over time. Because acreage of the seven crops also displays trends, we are concerned that we might find significant coefficient estimates that are due to coincident trends rather than an effect of subsidies on acreage. We include crop-specific trends in our models to mitigate this potential omitted variable bias.[21]

The potential bias of the estimated coefficients from including the lagged dependent variable in panel fixed-effects models, that is, the Nickell bias, is less problematic because we have a relatively long panel. The Nickell bias is proportional to the inverse of T (Nickell 1981). Also, our interest is to identify the causal relationship between the planted acreage and the crop insurance premium subsidy not the dynamic relationship between the current planted acreage and its lag. The bias in the coefficient of the premium subsidy is less problematic when the covariance of the demeaned premium subsidy variable and the demeaned lagged dependent variable is small. Nonetheless, we also estimated our models using the Arellano-Bond estimator (Arellano and Bond 1991) (we present the results in supplementary online appendix B.5; the results remain robust).

Table 2 shows the first stage regression results of the $\ln(\Gamma_{ijt})$ with and without controlling for the expected price and the premium subsidy of the competing crop. The instruments ($s65_t$ and $s75_t$) are strongly correlated with the variable of interest, $\ln(\Gamma_{ijt})$. The F-statistics for the null hypothesis that the coefficients on the instrumental variables equal zero are 147 and 141 (table 2), which are far above the common rule of thumb of ten for strong instruments.[22]

We employ the two-step generalized method of moments (GMM) estimator to estimate the parameters in equation (9). The standard errors are clustered at the state level. The sample has more than one cluster and there are multiple ways to cluster the standard errors. As Cameron, Gelbach, and Miller (2012) discuss, for nested clusters one should simply cluster at the highest level of cluster. For example, there is no gain to clustering at the county level, when we already cluster at the state level.

Estimation Results for the Acreage Effect of the Premium Subsidy

Table 3 shows alternative estimated results for equation (9). Columns (1) and (2) report

[20] In 2009, for corn and soybeans, about 10% of the total premium of the 65% coverage level belongs to enterprise or whole farm units (yield protection).

[21] As a part of the sensitivity analysis, we estimate the effect of premium subsidies on crop acreage without trend variables and report the results in supplementary online appendix B.4. Omitting the trend variables decreases the coefficient on $\ln(\Gamma_{ijt})$, because this regression confounds the downward trends in acreage for sorghum, cotton, rice, and barley with the increasing premium subsidies.

[22] The variable $s75_t$ increased more rapidly during our sample period than did $s65_t$ (see figure 1). This rapid increase caused farms to choose relatively more policies with 75% coverage level (or higher), even though the subsidy per liability was lower for those policies. Thus, we obtain a negative coefficient on $s75_t$. To show robustness, we report results with only one instrument in supplementary online appendix B.6. The results indicate that $s65_t$ alone is strong, but $s75_t$ alone is a weak instrument. This is because 75% or higher coverage levels were not popular in the earlier period of our data, so with $s75_t$ as a single instrument, we would be unable to capture variation from earlier policy changes.

Table 2. The first-stage regression

VARIABLES	Dependent Variable: Ln of Subsidy per Liability, $\ln(\Gamma_{ijt})$ (1)	(2)
Subsidy Rate 65%, $s65_t$	14.9***	13.2***
	(1.21)	(1.08)
Subsidy Rate 75%, $s75_t$	−7.50***	−6.60***
	(0.71)	(0.64)
Ln of Competing Crop Subsidy per Liability, $\ln(\Gamma_{ij't})$		0.11***
		(0.012)
Ln of Expected Price, $\ln(EP_{ijt})$	0.21***	0.20***
	(0.045)	(0.046)
Ln of Competing Crop Expected Price, $\ln(EP_{ij't})$		−0.0067
		(0.016)
L.Ln of Planted Acreage, $L.\ln(A_{ijt})$	0.17***	0.17***
	(0.027)	(0.026)
Time Trends		
$Time_{i\,Corn\,t}$	0.011**	0.0060
	(0.0040)	(0.0041)
$Time_{i\,Soybeans\,t}$	0.015***	0.011***
	(0.0038)	(0.0037)
$Time_{i\,Wheat\,t}$	0.040***	0.038***
	(0.0042)	(0.0044)
$Time_{i\,Barley\,t}$	0.031*	0.029*
	(0.018)	(0.016)
$Time_{i\,Cotton\,t}$	0.010*	0.0063
	(0.0050)	(0.0045)
$Time_{i\,Rice\,t}$	0.012	0.0096
	(0.0082)	(0.0077)
$Time_{i\,Sorghum\,t}$	0.038***	0.037***
	(0.0087)	(0.0087)
F-statistics (Null: The Coefficients of Excluded Instruments=0)	147.21	141.03
Number of Observations	160,014	159,942
Number of County-crop Combinations	8,994	8,994

Note: Cluster robust standard errors are in parentheses. County-crop fixed effects included.

the estimation results without controlling for the competing crop's premium subsidy and expected price. Columns (3) and (4) report the results with the competing crop variables included. The results from the panel FE estimation without instrumenting are presented in columns (1) and (3). The panel FE model's estimated coefficients for $\ln(\Gamma_{ijt})$ are smaller than those of the panel FE-IV, which are reported in columns (2) and (4). The differences suggest that either time-varying "riskiness" or crop insurance choices cause downward bias of the key coefficient.

Using our best estimate, which controls for potential biases, the average changes in crop acreage as responses to changes in the premium subsidy per dollar of insured liability is 0.043 (column [4]). Hence, a 10% increase in the premium subsidy induces about 0.43% more planted acres. Failure to account for the endogeneity of the premium subsidy from the county-crop-specific riskiness and the choice of crop insurance results in underestimation of the acreage effect of the premium subsidy by between 64% and 69%.[23]

The estimates of the own-price elasticity of crop acreage reported in table 3 are between 0.19 and 0.22 and are stable across the different specifications. This stability implies that the distribution of expected prices for each crop in each county is independent of (*a*) unobserved heterogeneity such as the

[23] The calculations refer to the differences between the estimates from FE and the estimates from FE-IV. Hence, we compare column (2) to column (1) and column (4) to column (3).

Table 3. Effect of the Premium Subsidy on Crop Acreage

	Dependent Variable: Ln of Planted Acreage, $\ln(A_{ijt})$			
VARIABLES	(1) (FE)	(2) (FE-IV)	(3) (FE)	(4) (FE-IV)
Ln of Subsidy per Liability, $\ln(\Gamma_{ijt})$	0.013***	0.037***	0.013***	0.043***
	(0.0022)	(0.0061)	(0.0022)	(0.0075)
Ln of Competing Crop Subsidy per Liability, $\ln(\Gamma_{ij't})$			0.00014	−0.0057***
			(0.0012)	(0.0021)
Ln of Expected Price, $\ln(EP_{ijt})$	0.20***	0.19***	0.22***	0.21***
	(0.030)	(0.025)	(0.029)	(0.023)
Ln of Competing Crop Expected Price, $\ln(EP_{ij't})$			−0.031***	−0.029***
			(0.0053)	(0.0052)
L.Ln of Planted Acreage, $L.\ln(A_{ijt})$	0.71***	0.71***	0.71***	0.71***
	(0.028)	(0.027)	(0.028)	(0.027)
Time Trends				
$Time_{i\,Corn\,t}$	0.00026	−0.0013*	0.00054	−0.00091
	(0.00097)	(0.00078)	(0.0010)	(0.00080)
$Time_{i\,Soybeans\,t}$	0.0058***	0.0043***	0.0060***	0.0046***
	(0.0013)	(0.0012)	(0.0013)	(0.0012)
$Time_{i\,Wheat\,t}$	−0.0066***	−0.0092***	−0.0067***	−0.0095***
	(0.0012)	(0.0013)	(0.0012)	(0.0013)
$Time_{i\,Barley\,t}$	−0.014***	−0.015***	−0.014***	−0.015***
	(0.0021)	(0.0021)	(0.0022)	(0.0022)
$Time_{i\,Cotton\,t}$	−0.0037	−0.0071***	−0.0031	−0.0063**
	(0.0029)	(0.0027)	(0.0029)	(0.0028)
$Time_{i\,Rice\,t}$	−0.0047**	−0.0060***	−0.0043*	−0.0056***
	(0.0021)	(0.0021)	(0.0022)	(0.0022)
$Time_{i\,Sorghum\,t}$	−0.012***	−0.013***	−0.012***	−0.013***
	(0.0029)	(0.0027)	(0.0029)	(0.0027)
First Stage F-statistics		147.21		141.03
Number of Observations	160,014	160,014	159,942	159,942
Number of County-crop Combinations	8,994	8,994	8,994	8,994

Note: Cluster robust standard errors are in parentheses. County-crop fixed effects included. Columns (1) and (3) estimated by OLS; columns (2) and (4) estimated by IV-GMM. Asterisks indicate the following: *** = 1% significance level, ** = 5% significance level, and * = 10% significance level.

riskiness and the choice of crop insurance coverage of the crop in the county, and (*b*) the competing crop price and premium subsidy. The estimated own-price elasticity of crop acreage is not directly comparable with most estimates reported in the literature, because the estimates in table 3 represent the average responsiveness across county-crop combinations for the seven field crops. There is an extensive body of literature on the supply response to prices of corn and soybeans that will be discussed later in this section.

Controlling for the price and premium subsidy of the competing crop does not change the estimated coefficient of $\ln(\Gamma_{ijt})$ by much. We find significant effects of the competing crop price and premium subsidy, but the magnitudes are relatively small.

The number of observations in table 3 is smaller than that of table 1. The lagged dependent variable accounts for most of the lost observations. We also lose some observations from panels with only one year with the lagged dependent variable when we implement the county-crop fixed effects estimation. There are additional losses in the number of observations after introducing the competing crop variables. Recall that the competing crop is determined by a ranking that is based on the five-year moving average planted acreage in each county or state. In some states, there are some years with no planted acres for the competing crop for some county-crop combinations.

Goodwin, Vandeveer, and Deal (2004) provide the only comparable estimates to ours. The study uses data on corn and soybeans in the Corn Belt and wheat and barley in the northern Great Plains in 1985–1993, whereas we use nationwide data for the seven

Table 4. Effect of the Premium Subsidy on Crop Acreage by Crop: Subsamples

	Dependent Variable: Ln of Planted Acreage, $\ln(A_{ijt})$			
	Corn, Soybeans, and Wheat		Corn and Soybeans	
	(1)	(2)	(3)	(4)
VARIABLES	(FE)	(FE-IV)	(FE)	(FE-IV)
Ln of Subsidy per Liability, $\ln(\Gamma_{ijt})$	0.011***	0.045***	0.0096***	0.046***
	(0.0028)	(0.0096)	(0.0035)	(0.012)
Ln of Competing Crop Subsidy per Liability, $\ln(\Gamma_{ij't})$	−0.00030	−0.0058***	−0.00057	−0.0068**
	(0.0013)	(0.0022)	(0.0016)	(0.0028)
Ln of Expected Price, $\ln(EP_{ijt})$	0.21***	0.20***	0.18***	0.21***
	(0.030)	(0.023)	(0.028)	(0.021)
Ln of Competing Crop Expected Price, $\ln(EP_{ij't})$	−0.026***	−0.023***	−0.036***	−0.036***
	(0.0052)	(0.0050)	(0.0081)	(0.0081)
L.Ln of Planted Acreage, $L.\ln(A_{ijt})$	0.72***	0.72***	0.78***	0.77***
	(0.027)	(0.026)	(0.030)	(0.029)
Time Trends				
$Time_{i\,Corn\,t}$	0.00061	−0.0011	0.00063	−0.0015**
	(0.00092)	(0.00074)	(0.00069)	(0.00065)
$Time_{i\,Soybeans\,t}$	0.0058***	0.0041***	0.0049***	0.0029***
	(0.0012)	(0.0012)	(0.00099)	(0.0010)
$Time_{i\,Wheat\,t}$	−0.0060***	−0.0093***		
	(0.0012)	(0.0014)		
First Stage F-statistics		174.10		194.82
Number of Observations	124,980	124,980	84,262	84,262
Number of County-crop Combinations	6,517	6,517	4,233	4,233

Note: Cluster robust standard errors are in parentheses. County-crop fixed effects included. Columns (1) and (2) report results for corn, soybeans, and wheat using counties that grow at least one of these three. Columns (3) and (4) report results for corn and soybeans using counties that grow at least one of these two. Columns (1) and (3) estimated by OLS; columns (2) and (4) estimated by IV-GMM. Asterisks indicate the following: *** = 1% significance level, ** = 5% significance level, and * = 10% significance level.

major crops and include more recent years. These authors' simulation results indicate that a 30% decrease in farm-paid premium rates for corn and soybeans leads to a 0.28% increase of corn acreage in the corn belt. This is substantially smaller than what table 3 reports. The estimated coefficient, 0.043, implies that an equivalent 30% decline in premiums would cause a 1.1% acreage increase, on average, for the listed field crops.[24] In addition to the differences in subject crops and periods, our estimate is larger than that of Goodwin, Vandeveer, and Deal (2004) due to a conceptual reason: we capture both the direct profit effect and the indirect coverage effect that are described in our conceptual section. In the framework of Goodwin, Vandeveer, and Deal (2004), recall that the premium subsidy affects planted acreage only by inducing farms to buy more insurance.

Of course, acreage responses across crops may be heterogeneous. Recall that the estimated acreage effect in table 3 is an average of acreage responses to the premium subsidy across 8,994 county-crop combinations, including all seven crops. To check the robustness of our results, we also estimate equation (9) with subsamples that consist of subsets of crops.[25]

Table 4 reports the results with subsamples. Columns (1) and (2) report the results for corn, soybeans, and wheat using counties that grow at least one of these three. Columns (3) and (4) report the results for corn and soybeans using counties that grow at least one of these two. The direction of differences is consistent with the prediction in

[24] The effect is computed by $0.043 * \left(\frac{Subsidy\ Rate-1}{Subsidy\ Rate} * (-30\%)\right) = 1.1\%$, where *Subsidy Rate* is measured at its overall average, which is 54%.

[25] We also check for regional heterogeneity. The results appear in supplementary online appendix B.7.

the previous section. The estimation results from the subsample suggest that corn, soybeans, and wheat are just as responsive to crop insurance subsidies as the other field crops. The estimates for the coefficient of $\ln(\Gamma_{ijt})$ in columns (2) and (4) of table 4 from panel FE-IV estimation are greater than those of table 3.

Recall that the estimates in table 4 show that short-run own-price elasticities range from 0.18 to 0.21. The own-price elasticities in the recent literature range from 0.17 to 0.45 for corn, from 0.30 to 0.63 for soybeans, and from 0.25 to 0.34 for wheat (Lin and Dismukes 2007; Hendricks, Smith, and Sumner 2014; and Miao, Khanna, and Huang 2016). Although there are some differences in data and interpretation, our estimates of own-price elasticities in table 4 are consistent with the recent literature.

Interpretation of the Acreage Effect of the Premium Subsidy

The coefficient on $\ln(\Gamma_{ijt})$ in equation (9) indicates how a change in the crop insurance premium subsidy for a crop in a county affects the planted acreage of that crop in that county. The effect occurs through substitution across our seven crops and expansion of the total acreage of the seven crops. Also, recall that the effect of the premium subsidy on the pattern of crop acreage is the sum of the direct profit effect and the indirect coverage effect, as our conceptual framework describes.

The estimated coefficient on $\ln(\Gamma_{ijt})$ in column (4) of table 3 indicates that if a policy increases subsidy per dollar of liability by 10% for a crop in a county, then the planted acreage of that crop in that county would be 0.43% greater than otherwise. This coefficient also implies that if an increase in subsidy per dollar of liability for a specific crop, for example corn, in a specific county is 10% greater than increases for other crops in that county, then an increase in the corn acres in that county would be 0.43% greater than the changes in the planted acres of other crops. Similarly, if a policy increases subsidy per dollar of liability by 10% more for corn in a certain county than some other counties, the planted acreage of corn in the county with the 10% greater increase would have a 0.43% greater increase in the corn acreage than the other counties. The estimation results from the subsample of crops in table 4 indicate limited heterogeneity across crops.

An increase in subsidy per dollar of liability of the competing crop has a small but statistically significant effect on planted acreage. A 10% increase in the competing crop premium subsidy results in a 0.06% reduction in the own-planted acreage. This implies that if a policy changes both the own-subsidy and the subsidy for the competing crop by 10%, the planted acreage would increase by about 0.37%.

We suspect that the increases in planted acreage due to the subsidy increases come mostly from lands that would have hay or pastures or would have been left fallow. Since we observe a significant and negative estimated coefficient of subsidy per dollar of liability of the competing crop, it is also possible that some of the increases in planted acreage come from reallocation among the seven major crops. For example, reallocation occurs if a crop in a county had relatively small subsidy increases and its competing crops experienced substantially larger subsidy increases.[26]

To better interpret the economic importance of the estimated coefficient of $\ln(\Gamma_{ijt})$, we convert it into units that can be directly compared to an own-price acreage elasticity. The elasticity representation of our coefficient estimate is

$$(10) \quad \varepsilon_S = \frac{\partial A_{ij}}{\partial \Gamma_{ij}} \frac{\Gamma_{ij}}{A_{ij}}$$

which is the own-subsidy elasticity.

Define the own-revenue acreage elasticity, ε_{TR}, as

$$(11) \quad \varepsilon_{TR} = \frac{\partial A_{ij}}{\partial TR_{ij}} \frac{TR_{ij}}{A_{ij}}$$

where TR_{ij} is a sum of per acre crop revenue and per acre expected revenue from crop insurance subsidies for county i and crop j. For county i and crop j, let us denote the historical average revenue per acre as $\bar{R}_{ij}$, the average crop insurance coverage level over farms as θ_{ij}, and the share

[26] We only include subsidy per dollar of liability of one competing crop in our econometric model. In reality, it is possible that one or more than one competing crops affect planted acreage of the crop.

Table 5. Comparing the Own-subsidy Elasticity to the Own-price Elasticity

	(1) Own-subsidy elasticity ε_S	(2) Converted own-subsidy elasticity ε_{TR}	(3) Own-price elasticity ε_P	(4) Difference ε_{TR}-ϵ_P
All Crops				
Panel FE	0.013***	0.40***	0.23***	0.17***
	(0.0021)	(0.068)	(0.027)	(0.079)
Panel FE-IV	0.042***	1.24***	0.22***	1.027***
	(0.0090)	(0.25)	(0.021)	(0.26)
Corn and Soybeans Only				
Panel FE	0.0097***	0.28	0.18***	0.095
	(0.0036)	(0.10)	(0.027)	(0.11)
Panel FE-IV	0.045***	1.29***	0.21***	1.081***
	(0.012)	(0.33)	(0.022)	(0.33)

Note: Cluster robust standard errors are in parentheses. The estimation is done by 1,000 bootstrap replications, therefore the estimates are slightly different from those in tables 3 and 4. For the computation of ϵ_R, $(1+\Gamma_{ij}\theta_{ij}\delta_{ij})/(\Gamma_{ij}\theta_{ij}\delta_{ij})$ is bootstrapped from the 2010–2014 subsample. Asterisks indicate the following: *** = 1% significance level, ** = 5% significance level, and * = 10% significance level.

of insured acreage as δ_{ij}.[27] Similar to equation (5), we have

$$(12)\quad TR_{ij} = \bar{R}_{ij}(1+\Gamma_{ij}\theta_{ij}\delta_{ij}).$$

Holding $\bar{R}_{ij}$, θ_{ij}, and δ_{ij} constant, we can write the elasticity of acreage with respect to revenue from insurance subsidies as

$$(13)\quad \varepsilon_{TR} = \frac{1}{\bar{R}_{ij}\theta_{ij}\delta_{ij}}\frac{\partial A_{ij}}{\partial \Gamma_{ij}}\frac{\bar{R}_{ij}(1+\Gamma_{ij}\theta_{ij}\delta_{ij})}{A_{ij}} = \frac{\partial A_{ij}}{\partial \Gamma_{ij}}\frac{(1+\Gamma_{ij}\theta_{ij}\delta_{ij})}{\theta_{ij}\delta_{ij}A_{ij}} = \varepsilon_S\frac{(1+\Gamma_{ij}\theta_{ij}\delta_{ij})}{\Gamma_{ij}\theta_{ij}\delta_{ij}}$$

from equations (10)–(12). Thus, multiplying the estimated coefficient on $\ln(\Gamma_{ijt})$ in equation (9) by $(1+\Gamma_{ij}\theta_{ij}\delta_{ij})/(\Gamma_{ij}\theta_{ij}\delta_{ij})$ gives the elasticity of acreage with respect to revenue from insurance subsidies ε_{TR}. We call this expression the converted own-subsidy elasticity.

Table 5 reports the estimates of the own-subsidy elasticity, ε_s, the converted own-subsidy elasticity, ε_{TR}, the own-price elasticity, ε_P, and the difference between ε_{TR} and ε_P from the panel FE model and the panel FE-IV model for all crops and for corn and soybeans only. To generate the converted own-subsidy elasticity, we use data for the average of $(1+\Gamma_{ij}\theta_{ij}\delta_{ij})/(\Gamma_{ij}\theta_{ij}\delta_{ij})$ during the period 2010–2014. Using equation (13), we obtain a converted own-subsidy elasticity that ranges from 1.24 to 1.29. This estimate is substantially greater than the estimated own-price elasticity of 0.21 to 0.22.

The elasticities reported in table 5 are estimated using a bootstrap procedure. We use 1,000 bootstrap replications to test whether the converted own-subsidy elasticity is significantly different from the own-price elasticity. For each bootstrap replication, we construct a bootstrap sample by sampling with replacements from the observed data.[28] The bootstrap samples are clustered at the state level, which means that we preserve all within-state correlations. For each bootstrap sample, we estimate our main specification, equation (9), and obtain the converted own-subsidy elasticity by using equation (13). The difference between the converted own-subsidy elasticity and the own-price elasticity is computed for each bootstrap sample. We estimate the standard error of the difference between the two elasticities by using the standard deviation of the differences across 1,000 bootstrap samples. For both the all-crops and the corn-and-soybean models, we find that the converted own-subsidy elasticity is significantly greater than the own-price elasticity.

[27] Note that in our conceptual framework, for simplicity of exposition, we assume that the share of insured acreage is equal to one, which makes the share of insured revenue over total revenue equal θ_{ij}. In our empirical analysis, the share of insured revenue over total revenue is equal to $\theta_{ij}\delta_{ij}$.

[28] The estimated own-subsidy elasticity and the estimated own-price elasticity are slightly different from those of tables 3 and 4, since table 5 reports the average of the estimated coefficients from 1,000 bootstrap samples. The estimates from the bootstrap procedure and the two-step GMM estimates converge as the number of replications increases.

The economically large and statistically significant difference between ε_{TR} and ε_P indicates that the indirect coverage effect is substantial. Crop acreage is more responsive to revenue earned by the farm through a premium subsidy than revenue from the output price. If the indirect coverage effect were negligible, which would occur if an increase in crop insurance coverage and the corresponding risk reduction had no effect on crop acreage, then we would expect the converted own-subsidy elasticity and the own-price elasticity to be similar.

As noted above, our estimated own-price elasticities in tables 3 and 4 are smaller than the own-price elasticities in previous studies. For example, Hendricks, Smith, and Sumner (2014) find short-run own-price elasticities of 0.40 for corn and 0.36 for soybeans using field-level data, whereas our own-price elasticities in tables 3 and 4 are about 0.2.[29] However, even the Hendricks, Smith, and Sumner (2014) estimates for ε_P, are much smaller than ε_{TR}. Our finding of a large indirect coverage effect is thus robust to alternative price elasticity estimates.

Sensitivity Analysis and Robustness of the Results

In this section we conduct four sets of analysis: (*a*) estimations controlling for the Acreage Reduction Program, which required farmers to leave a portion of land idled, (*b*) estimations with balanced panel of our data, (*c*) estimations excluding the premium subsidies from Catastrophic Risk Protection, and (*d*) changes over time.

Acreage Reduction Program

For wheat, feed grains, cotton, and rice, the Acreage Reduction Program (ARP) required farms that participated in federal commodity programs to keep idle a nationally-set portion of the crop acreage base. Here, we determine whether the estimated coefficient of $\ln(\Gamma_{ijt})$ is affected by including a policy variable to control for the ARP.

The nationally-set portion of land idled by the ARP was crop-specific and changed over time until the program ended in 1996. We include the annual crop-specific land share, ARP_{jt}, as an additional control variable in equation (3). The variable ARP_{jt} is measured as a percentage, which we obtain from the USDA Economic Research Service (ERS; 1995a, 1995b, 1995c, 1995d). Table 6 shows the results. The estimated coefficient of ARP_{jt} indicates that a one-percentage-point increase in ARP_{jt} decreases planted acreage by 0.5% to 0.7%, which is consistent with the operation of the program.

The estimated coefficients of $\ln(\Gamma_{ijt})$ are smaller than those of tables 3 and 4, and the corresponding standard errors are larger. We suspect the increase in standard errors is due to the high correlation between *ARP* and the instruments, and the possibility of endogenous *ARP*. However, despite some losses in the statistical significance and the reduction in the point estimate, the results still remain positive and significant. Moreover, the converted own-subsidy elasticities remain much greater than the own-price elasticities.[30]

Balanced Panel

As discussed in the data section, the county-crop panel of planted acreage is unbalanced. Some county-crop combinations with small planted acreage dropped out of 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 a robustness check, we restricted the sample into a balanced panel of county-crop combinations that have observations for every year.

Table 7 shows results analogous to tables 3 and 4, but only with the balanced panel sample. The estimated coefficients of $\ln(\Gamma_{ijt})$ in table 7 are about 20% larger than in the unbalanced panel. For all crops or subsamples of corn, soybeans, and wheat, the difference indicates that county-crop combinations with greater planted acreage are more responsive to the premium subsidy changes.

[29] Their price variable includes the loan deficiency payments. Given the negative correlation between the crop prices and the government payments, the estimated coefficients for the own-price elasticities in tables 3 and 4 would likely be larger if the government payments are included in the price variables.

[30] There are other government programs that may have affected crop acreage. Most of the effects of these programs would be captured through crop-specific trend variables and the expected price variables. We think that the other government programs are not correlated enough with our instruments and other regressors to cause a bias of the coefficient of $\ln(\Gamma_{ijt})$. Note that the ARP directly affected the planted acreage for each crop differentially and stopped at the same time that the crop insurance program started to expand.

Table 6. Effect of the Premium Subsidy on Crop Acreage Controlling for Acreage Reduction Program

	Dependent Variable: Ln of Planted Acreage, $\ln(A_{ijt})$		
	All Crops	Corn, Soybeans, and Wheat	Corn and Soybeans
	(1)	(2)	(3)
VARIABLES	(FE-IV)	(FE-IV)	(FE-IV)
Ln of Subsidy per Liability, $\ln(\Gamma_{ijt})$	0.028***	0.030***	0.031***
	(0.0071)	(0.0085)	(0.012)
Ln of Competing Crop Subsidy per Liability, $\ln(\Gamma_{ij't})$	−0.0041**	−0.0044**	−0.0050*
	(0.0019)	(0.0020)	(0.0026)
Ln of Expected Price, $\ln(EP_{ijt})$	0.21***	0.19***	0.20***
	(0.025)	(0.024)	(0.022)
Ln of Competing Crop Expected Price, $\ln(EP_{ij't})$	−0.026***	−0.021***	−0.035***
	(0.0049)	(0.0048)	(0.0078)
ARP_{ij}	−0.0047***	−0.0051***	−0.0070***
	(0.00097)	(0.00087)	(0.0021)
L.Ln of Planted Acreage, $L.\ln(A_{ijt})$	0.71***	0.73***	0.78***
	(0.027)	(0.026)	(0.029)
Time Trends			
$Time_{i\,Corn\,t}$	−0.0016*	−0.0018**	−0.0029***
	(0.00081)	(0.00074)	(0.00060)
$Time_{i\,Soybeans\,t}$	0.0057***	0.0052***	0.0037***
	(0.0012)	(0.0011)	(0.00099)
$Time_{i\,Wheat\,t}$	−0.0092***	−0.0091***	
	(0.0013)	(0.0014)	
$Time_{i\,Barley\,t}$	−0.015***		
	(0.0022)		
$Time_{i\,Cotton\,t}$	−0.0079***		
	(0.0029)		
$Time_{i\,Rice\,t}$	−0.0066***		
	(0.0020)		
$Time_{i\,Sorghum\,t}$	−0.013***		
	(0.0027)		
Converted Own-subsidy Elasticity ε_{TR}	0.79***	0.81***	0.85***
	(0.22)	(0.22)	(0.33)
First Stage F-statistics	139.33	173.48	194.67
Number of Observations	159,942	124,980	84,262
Number of County-crop Combinations	8,994	6,517	4,233

Note: Cluster robust standard errors are in parentheses. Column (2) reports results for corn, soybeans, and wheat using counties that grow at least one of these three. Column (3) reports results for corn and soybeans using counties that grow at least one of these two. Converted own-subsidy elasticities and standard errors are obtained by bootstrapping with 1,000 replications similar to table 5. All three columns estimated by IV-GMM. Asterisks indicate the following: *** = 1% significance level, ** = 5% significance level, and * = 10% significance level.

The estimated coefficients for the other variables are close to those of tables 3 and 4. Although restricting the sample into a balanced panel does not solve the attrition bias completely, table 7 indicates that the results are not driven by the observations with missing years.

Catastrophic Risk Protection

Catastrophic Risk Protection (CAT) is a crop insurance product with a 100% subsidy rate that insures 50% of historical yield at 55% of the projected price. We investigate the sensitivity of our results to the introduction of CAT and the mandatory provision of CAT due to the 1994 Act. We estimate the effect of the premium subsidy excluding the CAT premium subsidy. The new premium subsidy variable, $\ln(\Gamma_{ijt}^{Buyup})$, only captures the premium subsidy from buy-up products, which are those products with non-zero farm paid premiums.

Table 8 reports the results, which suggest that acreage is more responsive to the

Table 7. Effect of the Premium Subsidy on Crop Acreage with Balanced Panel

	Dependent Variable: Ln of Planted Acreage, $\ln(A_{ijt})$		
	All Crops	Corn, Soybeans, and Wheat	Corn and Soybeans
VARIABLES	(1) (FE-IV)	(2) (FE-IV)	(3) (FE-IV)
Ln of Subsidy per Liability, $\ln(\Gamma_{ijt})$	0.056***	0.054***	0.050***
	(0.0071)	(0.0096)	(0.014)
Ln of Competing Crop Subsidy per Liability, $\ln(\Gamma_{ij't})$	−0.0044***	−0.0042***	−0.0037**
	(0.0014)	(0.0014)	(0.0017)
Ln of Expected Price, $\ln(EP_{ijt})$	0.18***	0.17***	0.15***
	(0.014)	(0.016)	(0.018)
Ln of Competing Crop Expected Price, $\ln(EP_{ij't})$	−0.032***	−0.024***	−0.041***
	(0.0048)	(0.0052)	(0.0078)
L.Ln of Planted Acreage, $L.\ln(A_{ijt})$	0.74***	0.75***	0.80***
	(0.026)	(0.030)	(0.026)
Time Trends			
$Time_{i\,Corn\,t}$	−0.0019***	−0.0018***	−0.0017**
	(0.00048)	(0.00056)	(0.00076)
$Time_{i\,Soybeans\,t}$	0.0014	0.0014	0.00080
	(0.00096)	(0.0010)	(0.00099)
$Time_{i\,Wheat\,t}$	−0.0091***	−0.0087***	
	(0.0010)	(0.0012)	
$Time_{i\,Barley\,t}$	−0.012***		
	(0.0017)		
$Time_{i\,Cotton\,t}$	−0.0051**		
	(0.0024)		
$Time_{i\,Rice\,t}$	−0.0063***		
	(0.0017)		
$Time_{i\,Sorghum\,t}$	−0.0094***		
	(0.0018)		
Converted Own-subsidy Elasticity ε_{TR}	1.69***	1.55***	1.48***
	(0.23)	(0.29)	(0.41)
First Stage F-statistics	273.91	308.25	327.11
Number of Observations	69,423	61,200	46,875
Number of County-crop Combinations	2,778	2,448	1,875

Note: Cluster robust standard errors are in parentheses. Column (2) reports results for corn, soybeans, and wheat using counties that grow at least one of these three. Column (3) reports results for corn and soybeans using counties that grow at least one of these two. Converted own-subsidy elasticities and standard errors are obtained by bootstrapping with 1,000 replications similar to table 5. All three columns estimated by IV-GMM. Asterisks indicate the following: *** = 1% significance level, ** = 5% significance level, and * = 10% significance level.

buy-up premium subsidy. Similar to table 5, we converted the estimated subsidy elasticity into a comparable estimate with the own-price elasticity by considering the small share of buy-up premium subsidy in revenue. This analogue to the own-price elasticity is about 5.6, and it is considerably larger than that of table 5.

Possible explanations are behavioral differences between responses to zero and non-zero farm paid premium, between responses to catastrophic and non-catastrophic losses, or the difference in the premium rate-setting procedures between the "buy-up" and catastrophic products. Further research is required to analyze the difference in the acreage responses.

Variation over Time

Figure 1 shows that there were three major legislation changes in our sample period: the 1994 Act, the 2000 Act, and the 2008 Farm Bill. We report results from three regressions comparing acreage just before and just after these legislation changes. For the 1994 Act, we compare 1994 with 1996 instead of 1994 and 1995 because the mandatory provision of

Table 8. Effect of the Premium Subsidy on Crop Acreage Excluding the Catastrophic Risk Protection Premium Subsidy

	Dependent Variable: Ln of Planted Acreage, $\ln(A_{ijt})$		
VARIABLES	All Crops (1) (FE-IV)	Corn, Soybeans, and Wheat (2) (FE-IV)	Corn and Soybeans (3) (FE-IV)
Ln of Buy-up Subsidy per Liability, $\ln(\Gamma_{ijt}^{Buyup})$	0.12***	0.11***	0.10***
	(0.020)	(0.025)	(0.030)
Ln of Competing Crop Buy-up Subsidy per Liability, $\ln(\Gamma_{ij't}^{Buyup})$	−0.0079***	−0.0075***	−0.0086***
	(0.0024)	(0.0027)	(0.0033)
Ln of Expected Price, $\ln(EP_{ijt})$	0.32***	0.31***	0.29***
	(0.035)	(0.039)	(0.043)
Ln of Competing Crop Expected Price, $\ln(EP_{ij't})$	−0.017***	−0.014**	−0.024***
	(0.0053)	(0.0058)	(0.0091)
L.Ln of Planted Acreage, $L.\ln(A_{ijt})$	0.67***	0.69***	0.74***
	(0.027)	(0.027)	(0.028)
Time Trends			
$Time_{i\,Corn\,t}$	−0.0080***	−0.0080***	−0.0073***
	(0.0016)	(0.0019)	(0.0021)
$Time_{i\,Soybeans\,t}$	−0.0026	−0.0028	−0.0022
	(0.0017)	(0.0020)	(0.0021)
$Time_{i\,Wheat\,t}$	−0.018***	−0.017***	
	(0.0022)	(0.0027)	
$Time_{i\,Barley\,t}$	−0.025***		
	(0.0029)		
$Time_{i\,Cotton\,t}$	−0.0059**		
	(0.0030)		
$Time_{i\,Rice\,t}$	−0.014***		
	(0.0024)		
$Time_{i\,Sorghum\,t}$	−0.025***		
	(0.0034)		
Converted Own-subsidy Elasticity ε_{TR}	4.53***	4.18***	3.79***
	(1.071)	(1.14)	(1.42)
First Stage F-statistics	163.15	133.48	124.54
Number of Observations	159,942	124,980	84,262
Number of County-crop Combinations	8,994	6,517	4,233

Note: Cluster robust standard errors are in parentheses. Column (2) reports results for corn, soybeans, and wheat using counties that grow at least one of these three. Column (3) reports results for corn and soybeans using counties that grow at least one of these two. Converted own-subsidy elasticities and standard errors are obtained by bootstrapping with 1,000 replications similar to table 5. All three columns estimated by IV-GMM. Asterisks indicate the following: *** = 1% significance level, ** = 5% significance level, and * = 10% significance level.

CAT in 1995 does not allow us to identify the effect of the premium subsidy increase. For the 2000 Act, we compare 1998 with 2001 since the 2000 Act codified the ad hoc premium reductions that already happened in 1999 and 2000. For the 2008 Farm Bill, we compare 2008 with 2009. Note that the 1994 Act, the 2000 Act, and the 2008 Farm Bill became effective for the crop years 1995, 2001, and 2009.

The variables are transformed into the differences between *pre* and *post* legislations. For example, the estimation model for the 1994 Act is

$$(14)\quad \ln(A_{ij1996}) - \ln(A_{ij1994}) = \alpha_0 + \alpha_1(\ln(\Gamma_{ij1996}) - \ln(\Gamma_{ij1994})) + \alpha_2(\ln(\Gamma_{ij'1996}) - \ln(\Gamma_{ij'1994})) + \gamma(X_{ij1996} - X_{ij1994}) + (u_{ij1996} - u_{ij1994}).$$

Table 9. The Estimated Acreage Effects of the Major Legislation Changes

	Dependent Variable: D.Ln of Planted Acreage, $D.\ln(A_{ijt})$		
	1994 vs. 1996	1998 vs. 2001	2008 vs. 2009
VARIABLES	(1)	(2)	(3)
D.Ln of Subsidy per Liability, $D.\ln(\Gamma_{ijt})$	0.0071	0.033***	0.020**
	(0.0044)	(0.0076)	(0.0089)
D.Ln of Competing Crop	−0.0053*	−0.0022	0.0030
Subsidy per Liability, $D.\ln(\Gamma_{ij't})$	(0.0028)	(0.0052)	(0.0048)
Number of County-crop Combinations	7,382	6,592	4,376

Note: Cluster robust standard errors are in parentheses. The log of expected price and that of the competing crop are included as control variables. All three columns estimated by OLS. Asterisks indicate the following: *** = 1% significance level, ** = 5% significance level, and * = 10% significance level.

The vector $\boldsymbol{X}$ in equation (14) includes the log of the own expected price and the log of its competing crop price.[31]

Table 9 shows positive effects of premium subsidies on planted acreage. The results imply that the increase in the premium subsidies due to the legislative changes induced more crop acreage. The effects are similar across the three events, which shows that our results are not driven by a single observation. The magnitudes for the latter two events are similar to those in table 3, and the estimate for the 1994–95 event is smaller. The 1994–95 event was dominated by the increase in CAT subsidies, so the smaller effect in this case is consistent with the results in table 8.

Online supplementary appendix B contains additional regression results that support the robustness of our empirical results.[32]

Conclusions

The U.S. federal crop insurance program has grown markedly in the last twenty-five years. This article estimates the acreage effects of the growth of the crop insurance program and subsidies embedded in the program. We exploit the exogenous policy changes that increased the premium subsidy in the U.S. federal crop insurance program and resolve potential identification issues of estimating the effects of premium subsidies. This approach mitigates endogeneity concerns caused by (*a*) the omission of variables related to the riskiness of crops in each county, and (*b*) the simultaneity across planted acreage and the choice of crop insurance.

Our estimates imply that crop insurance premium subsidies have economically significant effects on crop acreage. The estimated coefficient of the premium subsidy on planted acreage from our main specification indicates that a 10% increase in the subsidy per dollar of liability increases the planted acreage by 0.43%. This estimate can be used to understand the impacts of the crop insurance-related legislations. For example, the Agricultural Risk Protection Act of 2000 increased subsidy per dollar of insured liability for corn by about 19%. Our estimated acreage effect indicates that this subsidy increase caused planted acreage to increase by about 0.82%, holding the competing crop subsidy constant. Whereas, for wheat, the 2000 Act increased subsidy per dollar of insured liability by about 10% and thus, the implied increase in the planted acreage is about 0.43% smaller than for corn, also holding the competing crop subsidy constant.[33]

Our results highlight the importance of considering the two distinct effects of crop insurance premium subsidies on crop acreage. First, our estimated effect is substantially greater than the effects found by Young, Vandeveer, and Schnepf (2001) and Goodwin, Vandeveer, and Deal (2004) that were estimated using older data on a subset of counties and focusing on only part of the

[31] For the comparison between 1994 and 1996, the vector $\boldsymbol{X}$ includes a variable representing the Acreage Reduction Program.

[32] All sensitivity analysis specifications have smaller estimated coefficient of $\ln(\Gamma_{ijt})$ in the panel FE model than that in the panel FE-IV model. This is consistent with the discussion on the endogeneity of $\ln(\Gamma_{ijt})$.

[33] This calculation is based on the assumption that the 2000 act affected subsidy per dollar of liability only through the shift in the subsidy rate schedule and the corresponding coverage level changes. More rigorous counterfactual simulations would give more precise estimates on how shifts in the subsidy rate schedule affect subsidy per dollar of liability for different crops.

impact of the subsidy. The direct profit effect of the premium subsidy on the crop acreage, which is described in the earlier section, explains how the larger overall acreage effects compare to their estimates. Second, we find that increases in premium subsidies have a larger effect on planted acreage than increases in prices that change expected revenue by an equal amount. Hence, these data indicate that there is an economically significant indirect coverage effect of crop insurance subsidies. This effect arises because higher premium subsidies induce higher insurance coverage, which lowers risk faced by farms and induces more planted acreage of the insured crops. Our estimates provide useful parameters for evaluating the incidence of crop insurance premium subsidies in the past, and for assessing the economic consequences of further changes in insurance and other subsidies.

Supplementary Material

Supplementary material are available at *American Journal of Agricultural Economics* online.

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