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How do premium subsidies affect crop insurance demand at different coverage levels: the case of corn

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Abstract
This study explores the relationship between the demand for federal corn insurance and premium subsidies at each coverage level using county-level data. The study shows that the elasticities of demand with respect to per U.S. dollar net premium vary across insurance plans, coverage levels, and regions. The results indicate that corn producers in riskier regions are more sensitive to premium changes for crop insurance. However, the heterogeneity of demand was overlooked in the majority of existing insurance demand studies, which could result in biased conclusions. In addition, this study estimates the changes in producers' corn insurance purchases if premium subsidy rates were to be reduced by 10 percentage points. The expected change in corn revenue insurance demand at the 75% coverage level in the Southern Plains (− 12.182%) would be three times greater than it is at the 80% coverage level in the Corn Belt (− 4.167%) with a 10 percentage point reduction in premium subsidy rates, similar to the corn yield insurance demand.

Keywords Crop insurance · Premium subsidies · Demand · Coverage level · Demand heterogeneity

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Introduction

The U.S. Federal Crop Insurance Program (FCIP) is the central piece of the farm safety net that provides farmers with protection against agricultural risks. To encourage participation, federal premium subsidies have been increased through several policies to reduce producers' premium payments (producer premium = gross premium − premium subsidy). Figure 1 shows the insured acres and the federal premium subsidies for corn from 1989 to 2013. Although participation experienced significant increases with higher premium subsidies, this programme has been criticised as inefficient because of the heavy government expenses (see Figure 1) and its poor actuarial performance (Glauber 2004). Figure 2 presents the loss ratio (the ratio of indemnities to gross premium) and adjusted loss ratio (the ratio of indemnities to producer premium) for the FCIP over all crops. On average, the adjusted loss ratio is 2.07 over the period

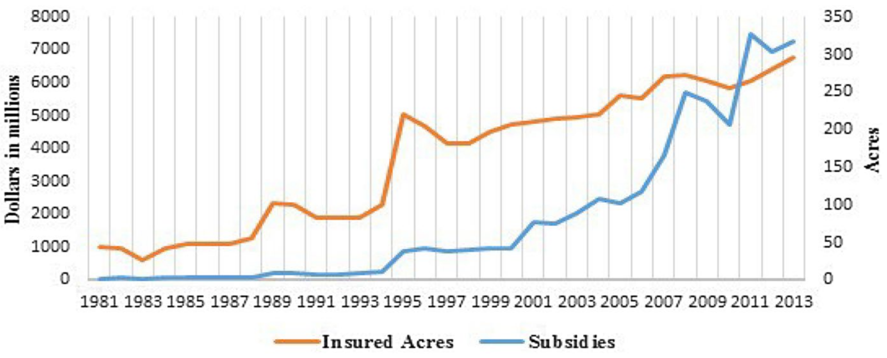

Fig. 1 Federal premium subsidies and insured acres for the U.S. Corn Crop Insurance Program. *Source* USDA, Risk Management Agency, Summary of Business files, 1989–2014

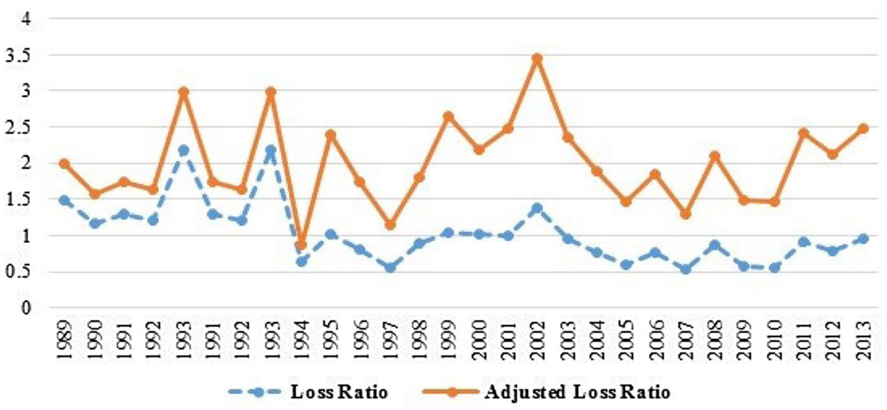

Fig. 2 Loss ratio and adjusted loss ratio for the U.S. Crop Insurance Program. *Source* Glauber and Collins (2002)

2000–2013, implying that producers tend to collect USD 2.07 in indemnity payments for each dollar of their premium payment.

A large insurance demand literature concluding that the demand for federal crop insurance is price-inelastic plays a critical role in developing the mainstream perspective that the federal insurance premium subsidies should be reduced without significant changes to federal crop insurance (FCI) participation (Barnett and Skees 1995; GAO 2014). However, the majority of existing insurance studies applied the framework of demand models developed for typical commodities (Woodard 2015) that may not apply to federal crop insurance. First, a typical commodity usually follows the law of one price, whereas the premium rates of FCI vary over regions, insurance plans, unit structures, coverage levels, and subsidy rates. The varying premium rates were not taken into account in most of the existing studies and demand was simply aggregated by these aspects. Second, the primary purpose of purchasing a typical commodity is to obtain its usefulness. By the same token, federal crop insurance can be purchased to mitigate production and/or price risks. This demand incentive is referred to in the literature as the risk reduction effect. However, another important incentive for participating in the FCIP is to receive subsidies, because the programme is heavily subsidised by the federal government and it is disputably argued to be an alternative to the "direct payment" programme. The incentives associated with the subsidy effect and the adverse selection effect are referred to as the income effect in this study[1]. Just et al. (1999) found that the risk reduction impact is lower than the income effect or the adverse selection. The demand for FCI may vary across coverage levels and regions as the risk reduction and income effects change. It follows that the majority of existing studies may have yielded biased results, since traditional demand models were applied to analyse FCI, and the potential heterogeneity of demand across regions and coverage levels was overlooked.

The hypothesis of varying demand can be supported by the literature. Empirically, the two known studies which accounted for the differences across coverage levels found that the demand for grape insurance in eleven California counties is price-elastic at the catastrophic (CAT) level of insurance, while the demand is price-inelastic among higher coverage levels (Knox and Richards 1999; Richards 2000). O'Donoghue (2014) found different subsidy effects on the demand for crop insurance across regions. Theoretically, as the FCI rate-making methodology estimates the gross premium rate for each rate-making area at the 65% coverage level, then adjusts the rates for other coverage levels and individual farms, the premium rates vary across regions and coverage levels. Additionally, producers in different production regions experience various production risks. Thus producers' demand for FCI would vary across regions and coverage levels according to Woodard and Yi (2018), proving that a producer's optimal coverage level is influenced by the premium rate curve, the slope of a premium rate curve, the decision maker's utility function, and the distribution of the underlying asset.

[1] We do not distinguish between the different mechanisms of the subsidy effect and the adverse selection effect, since they are not the major objective of this study.

Table 1 Subsidy levels pre- and post-ARPA. *Source* Kelley (2001) and Jose (2001)

Coverage level	Pre-ARPA		Post-ARPA	
	APH (%)	CRC (%)	Basic or optional (%)	Enterprise (%)
50/100	55	67	67	80
55/100	46	64	64	80
60/100	38	64	64	80
65/100	42	59	59	80
70/100	32	59	59	80
75/100	24	55	55	77
80/100	17	48	48	68
85/100	13	38	38	53

1. The basic, optional and enterprise units of federal crop insurance shared the same subsidy rates pre-ARPA. The basic and optional units apply the same subsidy rates post-ARPA, while the enterprise unit has higher subsidy rates. 2. Due to the data limitation, the insurance demand with different unit structures is not differentiated in this study

Furthermore, federal premium subsidy rates change across coverage levels as well as insurance policies. If the federal expenses on premium subsidies have to be reduced, various reductions could be applied at different coverage levels to minimise the negative effect on FCI participation. However, it is impossible to analyse the different changes in subsidy rates across coverage levels based on the aggregated demand analysis in the literature. Considering the profound influence of the insurance demand analysis on policy development, a disaggregated study of the relationship between premium subsidies and farmers' demand is important. This is the first study to differentiate between the demand for corn insurance policies across coverage levels, insurance policies (yield and revenue insurance policies), and regions to reveal the heterogeneity of demand.

Background of the Agricultural Risk Protection Act (ARPA)

To encourage higher participation, the Agricultural Risk Protection Act (ARPA) of 2000 increased crop insurance premium subsidies (Babcock et al. 2004; Coble and Barnett 2012). According to Babcock and Hart (2005), "One of the policy objectives of the ARPA was to induce producers to buy more insurance coverage in which one measure of 'more insurance' is the proportion of acres insured at levels greater than 65%." Table 1 provides a comparison between the percentages of the premium paid by the government at various coverage levels at 100% of price coverage pre- and post-ARPA. For corn insurance, coverage is available in 5% increments from 50 to 85%. Before the ARPA, the dollar amount of subsidies was the same among coverage levels higher than or equal to 65%. The constant dollar amount of subsidies was accomplished by setting different subsidy rates at each coverage level pre-ARPA

(Babcock and Hart 2005). Under the ARPA, the increase in the insurance premium at higher coverage levels was generally less than the associated increase in subsidy rates. Therefore, producers would benefit more from purchasing higher coverage levels (Babcock et al. 2004). Another significant change is that the subsidy level, as a percentage of the full premium, is the same for both the yield insurance programme (APH) and the revenue polices (CRC) under the ARPA.

Although the ARPA was implemented in 2000, it remains the most recent and broadest reform of crop insurance premium (O'Donoghue 2014). A few studies have explored the impacts of subsidy changes on crop insurance demand but none of them have differentiated coverage levels and insurance plans. Therefore, this study examines the demand for crop insurance at each coverage level and insurance plan to provide insights into how premium subsidies influence producers' insurance demand.

Empirical modelling framework

Expected utility maximisation is usually the theoretical framework in insurance demand analysis. A representative producer is subject to constraints imposed by characteristics of marketing and production environment, such as commodity prices. Following Goodwin (1993), the maximisation of the expected utility yields a linear equation, a function of the representative producer's risk attitudes and production as well as marketing characteristics. The demand for corn insurance is given by

$$y_i = \alpha + X\beta_i + \varepsilon_i,$$

where y_i is the insurance purchase decision made by the producer under the utility maximisation problem, X_i is a vector of factors that influence the expected utility of insurance, and ε_i is a random error term.

Following Gardner and Kramer (1986) and Goodwin (1993), each county is treated as a representative farm. Although the use of county-level data could reduce the variation compared to farm-level data, given the data availability, the county-level data set is the best one for estimating crop insurance demand.

In previous studies, the term defined to quantify the crop insurance demand varies, such as the percentage of insured acres used in Gardner and Kramer (1986), and the premium less expected indemnities per dollar of liability in Cannon and Barnett (1995). In this study the quantity variable is constructed as the per dollar liabilities (liabilities divided by projected prices) per enrolled acre. Considering that it is the maximum amount of indemnities if all losses occur, insurance liability could be a good candidate to measure producers' demand.

In Goodwin (1993) the dependent variable is the liability per planted acre of corn. However, insured acres should be preferred to planted acres to adjust liability, because liabilities are determined by the characteristics of the insured acres rather than the total planted acres, and the total corn planted acres are also controlled in the model. Moreover, the liability per enrolled acres is divided by the projected price of corn in each county to estimate the per dollar purchases.

The definitions of the price variable in the analysis of crop insurance demand are as diverse as the measure of the quantity. The premium rate per acre is a commonly used term to measure the cost of insurance, such as in Smith and Baquet (1996). In this study the normalised net premium (gross premium less subsidies) per insured acre divided by the projected price is used to estimate the cost of insurance per insured dollar. The premium per acre is the acre unit price, while the net premium per acre per (insured) dollar is the dollar unit price. Therefore, the normalised net premium per insured acre per insured dollar is the dollar unit price faced by producers for the selected insurance liability. The net premium is calculated by subtracting the subsidies from the premium. All monetary variables in this study are normalised using the Consumer Price Index (CPI).

Following Babcock and Hart (2005), insurance participation data in 1998 and 2002 are selected for the present analysis for the following reasons. The ARPA was authorised in June 2000, and the implementation was even later. Corn producers already made their decisions on insurance selection in 2000 before the application of ARPA. Since the industry needs time to accommodate the changes, the participation data in 2001 is not as reflective of the changes in subsidies in crop demand as in later years. Therefore, it would be more reasonable to use the 2002 crop year data for the analysis.

An ad hoc premium reduction programme was introduced in both 1998 and 1999. In 1999, some producers might not have been aware of the premium reduction programme. Thus the insurance participation data in the 1999 crop year may not fully reflect producers' decisions with respect to premiums. Although the programme also existed in 1998, it was introduced after producers made their participation decisions (Babcock and Hart 2005). Therefore, we could assume that producers made their participation decisions based on full information in 1998.

In the literature, different estimation approaches were used. For example, a two-stage model was used by Richards (2000) and Serra et al. (2003) to adjust the non-participation problem. However, county-level data are used in this study, and there is no server non-participation problem at the county level. The fixed effects model was used by Goodwin (1993) to estimate the demand for corn insurance by using panel data during the period 1985–1990. In this study a short panel consisting of 1998 and 2002 data is used to analyse the effects of subsidies in the ARPA. Although fixed effects can be controlled in a two-period panel, the year fixed effects would be problematic in this study. Corn crop insurance tended to be cheaper in 2002 than in 1998 because of the changes in subsidy rates and the premium rating system. The estimations would be biased due to the omitted premium trend if year fixed effects are not controlled. However, if we control for year dummies in the fixed effects models, the relationship between demand and premiums would not be fully captured by premium coefficients because the demand is also associated with year dummies, and we are not able to identify the premium trend effects from the year fixed effects. Therefore, Original Least Squares (OLS) regression is used for the estimation of the demand for corn insurance in the present study.

The demand model is estimated at each coverage level and region independently, since we hypothesise that the producers' responses vary across coverage levels and regions. Besides liabilities, coverage levels also influence producer premiums through premium rates. According to RMA's rating method, premium rates are more expensive for higher coverage levels due to the increased risks. Thus coverage levels not only affect liabilities but also influence the premium rates and further affect the

Fig. 3 Simplified relationship between coverage levels and producer premiums

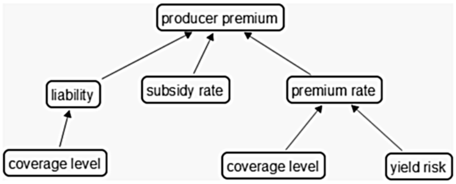

Table 2 Definition of variables in the models

Variables	Definition
Dependent variable	Normalised liabilities per acre/projected price
Unit price of crop insurance	Normalised net premium per acre/projected price
Expected yield	Average yield in the preceding 3 years
Expected revenue	Average revenue in the preceding 3 years
Relative yield risk	Coefficient of variance for corn yield (1989–2013)
Relative revenue risk	Coefficient of variance for revenue (1989–2013)
Planted acres	Planted acres
Enrolled acres in CRP	Enrolled acres in CRP
Percentage of irrigated cropland	The ratio of acres of irrigated cropland to acres of total cropland in each county
Percentage of cropland operated by females	The ratio of acres operated by females to acres of total cropland in each county

producer premiums. The relationship between coverage levels and producer premiums is illustrated in Figure 3. Estimations by coverage level and region also control for the impact of coverage levels on premium rates. Although the changes in subsidy rates pre- and post-ARPA are different across unit structures, this study does not differentiate between unit structures due to data limitations[2].

This study focuses on the demand for APH and CRC insurance policies because they were the two most popular insurance policies in 1998 and 2002.[3] Considering that the APH insurance plan provides yield protection for corn producers, whereas the CRC insurance plan provides revenue protection, demand estimation is separated for different insurance policies.

Table 2 provides a summary of the definition for each variable. The preceding 3-year average yield is incorporated into the model to estimate a producer's expected yield (e.g., for 1998, the years 1997, 1996, and 1995 are used). One-year lagged yield is a common term to estimate producers' expectation of yield in the literature (e.g. Wang et al. 1998). However, the preceding 3-year average yield should be preferable to the 1-year lagged term, because agricultural production is quite variable,

[2] Although the information on unit structure is available in the new version of Summary of Business data, there is no unit structure in the data for the years prior to 2002.

[3] Revenue Assurance (RA) was only underwritten by Iowa corn farmers in 1998, and the total premiums were about 4% of the CRC total premiums in that year.

Table 3 Regional division definition

Regions	States Included
Corn Belt (CB)	Iowa, Illinois, Indiana, Missouri, and Ohio
Lake States (LS)	Michigan, Minnesota, and Wisconsin
Northern Plains (NP)	Kansas, Nebraska, and South Dakota
Southern Plains (SP)	New Mexico, Oklahoma, and Texas

and the preceding 1-year yield does not fully reflect the representative producer's expectation of the yield and the variability of yield. Meanwhile, as technology changes, the preceding 3-year average yield should be preferable to the mean of historical yield used in previous studies, such as the average yield in the preceding 10 years used by Goodwin et al. (2004). Similarly, the preceding 3-year revenue is used to estimate producers' revenue expectation in the CRC insurance demand equations.

O'Donoghue (2014), and Goodwin and Ker (1998) included the yield variance in the study of crop insurance. The coefficient of variation (CV) for yield is included in the current model to estimate the relative yield risk of the county. Using the CV for yield is better than the yield variance because the CV estimates the relative yield risk, whereas the variance of yield reflects the absolute yield risk. Due to the significant difference in the mean yield in the four regions, relative yield risk is preferable to the absolute yield risk. In this study, historical corn yield data from 1989 through 2013 are used to compute the CV for each county, and regions with a larger CV are referred to as riskier regions.

The total corn planted acres variable is incorporated into the model, since a potential correlation is expected between the planted acres and the insurance purchases. The enrolled acres of CRP are used as an independent variable, because it is impossible to purchase insurance protection for acres enrolled in the CRP. The percentage of irrigated cropland in each county is controlled in the model, because this item could reflect the production environment and affect the distribution of yield. Considering that gender difference may impact producers' risk attitudes and further affect their insurance demand (Eckel and Grossman 2002; Charness and Gneezy 2012), the percentage of cropland operated by females is incorporated into the equations.

Data

The data utilised in this analysis were drawn from three major sources. The primary data source was the USDA's Risk Management Agency (RMA) administrative data. The individual farm data are aggregated to the county level by crop type and crop insurance policy at each coverage level. Information about insured acres, total premium, liabilities and subsidies was taken from RMA's Summary of Business (SOB) publications. The SOB data report the FCI participation from 1989 through 2014 and contain spatially identifying information. Thus the participation data can be combined with other data sets. There are about 2,000 observations for each year during the time period in the SOB publication. Among all the counties, the Corn Belt, Lake States, Northern Plains, and Southern Plains are the focus of this study. The states in each region are reported in Table 3.

USDA's National Agricultural Statistics Service (NASS) surveys provide county-level data on crop yield and total planted acres in each crop. The Bureau of Labor Statistics (BLS) provides the annual Consumer Price Index (CPI). In this study all monetary variables are normalised by deflating with the CPI. Data on irrigated cropland and acres operated by females and males were obtained from National Agricultural Statistics Services (NASS) 1997 and 2002 Censuses of Agriculture. County-level data on participation in the Conservation Reserve Program (CRP) were collected from the USDA Farm Service Agency (FSA) to estimate the effect of CRP acreage on insurance demand.

Demand estimation

The demand model is estimated in the double-logarithmic functional form at each coverage level and region to evaluate the relationship between producer premiums and the demand for corn insurance. Then, the Breusch–Pagan (1979) and Cook–Weisberg (1983) test is applied to examine heteroscedasticity. Equal variances of error are assumed in the null hypothesis of the Breusch–Pagan and Cook–Weisberg test. If the regression is rejected by the null hypothesis at the 95% confidence interval, the robust standard errors are applied in the regression. Variance inflation factors (VIF) are used to diagnose collinearity problems. Among all the estimations, the highest VIF is less than 10. Therefore, multicollinearity does not appear to be a considerable problem.

Link tests are applied to test for model specification. The basic idea of the link test is that any additional independent variable should be statistically insignificant if the model is correctly specified (Bruin 2006). According to Bruin (2006), the link test creates two variables: predicted dependent variable ($\hat{y}$); and the square of the predicted dependent variable ($\hat{y}^2$). The model is refit using only these two variables as predictors. In this study the results of link tests suggest that the double-log models for APH insurance are well-specified except at the 55% and 60% coverage levels in the Corn Belt, at the 65%, 70%, and 80% coverage levels in the Lake States, at the 50% coverage level in the Northern Plains, and at the 65% coverage level in the Southern Plains. To address the misspecification problem, linear–linear models are used at the 55% and 60% coverage levels in the Corn Belt, the linear–log models are used at the 65%, 70%, and 80% coverage levels in the Lake States, the linear–log model is used at the 50% coverage level in the Northern Plains, and the log–linear model is used at the 65% coverage level in the Southern Plains. The estimations for corn CRC insurance at the 75% and 80% coverage levels in the Corn Belt and at 65%, 70% and 75% coverage levels in the Northern Plains are rejected by the null hypothesis of link tests at the 95% confidence interval. To solve the misspecification problem, linear–linear models are used at the two coverage levels (75% and 80%) in the Corn Belt, and log–log, linear–log, and linear–linear models are used at the 65%, 70%, and 75% coverage levels in the Northern Plains, respectively.

In order to compare regression results with other regions and coverage levels, Tables 6, 7, 8, 9, 10, 11, 12, and 13 in Appendix report estimated elasticities of demand for corn APH and CRC insurance, respectively, in each region. For double-log functional forms, the coefficients from regression are the estimated elasticities. For linear–log and linear–linear functional forms, the elasticities are calculated based on the average values of corresponding variables in each estimation. For example, a linear–linear form is used for corn APH demand estimation in the Corn Belt at the 60% coverage level. The estimated coefficient of premium is − 2.070, and it is statistically significant at the 0.01 level. The insurance premium elasticity is calculated as 2.070 * 3.392/66.270 = 0.106, where 3.392 and 66.270 are the average premium (specifically, net premium per acre per projected dollar) and average demand (specifically, liability per enrolled acre per projected dollar), respectively, for corn APH in the Corn Belt at the 60% coverage level.

The demand estimation for corn APH insurance

In the Lake States, there are only nine observations at the 85% coverage level, resulting in limited power for the F-test (0.30). Among all the other coverage levels and regions, the p-values of the F-tests are 0–4 decimal places, meaning that the models are statistically significant. The coefficients of determination, or *R*2, range from 0.399 (at the 80% coverage level in the Northern Plains) to 0.894 (at the 75% coverage level in the Southern Plains), which suggests that the model could explain from 39.9 to 89.4% of the total variation in the demand for liabilities by the variation in the independent variables. The results indicate that explanatory variables explain the demand for corn APH insurance fairly well.

The demand estimation for corn CRC insurance

Overall, the model explains the demand for corn CRC insurance well. The coefficients of determination, or R^2, range from 0.227 (for 55% coverage level in the Northern Plains) to 0.946 (for 55% coverage level in the Southern Plains), which suggests that the model could explain from 22.7 to 94.6% of the total variation in the demand of per dollar liabilities by the variation in the independent variables. The F-tests are statistically significant (p-values are 0–4 decimal places) except for the 85% coverage level in the Lake States and the 55% coverage level in the Northern Plains (the p-value of the F-test is 0.5352 and 0.0288), respectively.

Elasticities of demand

The elasticities of corn APH and CRC insurance with respect to per dollar net premium are summarised in Table 4. (The elasticities of demand for corn APH and CRC insurance with respect to each independent variable are reported in Tables 6, 7, 8, 9, 10, 11, 12, 13 in Appendix) First, results in Table 4 suggest that producers in riskier regions are more responsive to the change of per dollar net premium. The elasticities of demand for corn APH insurance with respect to per dollar net

Table 4 Estimated elasticities of demand for APH and CRC insurance with respect to per dollar of net premium

Region	Policy	50%	55%	60%	65%	70%	75%	80%	85%
Corn Belt	APH	− 0.047**	− 0.028	− 0.106***	− 0.114***	− 0.137***	− 0.149***	− 0.230***	0.017
	CRC	− 0.015	0.033	− 0.040	− 0.083**	− 0.167***	− 0.146***	− 0.200***	− 0.083
Lake States	APH	− 0.180***	− 0.138***	− 0.138***	− 0.147***	− 0.094**	− 0.157***	− 0.158**	
	CRC	− 0.213***	− 0.323***	− 0.190***	− 0.239***	− 0.285***	− 0.229***	− 0.208***	− 0.177
Northern Plains	APH	− 0.170***	− 0.004	− 0.305***	− 0.038	− 0.097	− 0.188*	− 0.259**	− 0.284**
	CRC	− 0.042	− 0.205	− 0.290***	0.017	− 0.044	0.097	0.075	0.009
Southern Plains	APH	− 0.221**	− 0.131	− 0.248*	− 0.227**	− 0.155	− 0.654***		
	CRC	− 0.331**	− 0.094	− 0.373***	− 0.242*	− 0.501***	− 0.670***		

Statistical significance * at the 10%, ** at the 5%, *** at the 1% level

premium are − 0.230, − 0.158, and − 0.259 at the 80% coverage level in the Corn Belt, Lake States, and Northern Plains, respectively. The corresponding elasticity at the 75% coverage level in the Southern Plains is − 0.654. The elasticities of demand for corn CRC insurance with respect to per dollar net premium are − 0.200, − 0.208 at the 80% coverage level in the Corn Belt and Lake States, respectively, and − 0.670 at the 75% coverage level in the Southern Plains. For instance, with a 1% decrease in the per dollar net premium, producers in the Corn Belt would increase their purchase for corn APH insurance at the 50% coverage level by 0.047%, while producers in the Southern Plains would increase the purchase by 0.221%. Thus the change in the Southern Plains is quadrupled compared to the change in the Corn Belt. In O'Donoghue (2014), the elasticities of demand for corn insurance measured as liabilities per acre are − 0.13, − 0.24, and − 0.25 in the Midwest, Lake, and Northern Plains, respectively, which also exhibit the pattern that producers in riskier regions tend to be more responsive to corn insurance.

Second, the elasticities of demand with respect to per dollar net premium also vary across coverage levels. For example, in the Corn Belt (Table 4) the elasticity of demand for corn yield insurance with respect to per dollar net premium at the 50% coverage level is small (− 0.047), and the elasticity at the 55% coverage level is statistically insignificant (− 0.028). The results in Table 4 imply that corn producers in the Corn Belt are not likely to significantly change their demand for corn APH insurance at the 50% and 55% coverage levels due to the changes in subsidies. These producers may purchase the low coverage levels to meet the requirements for loan applications. As shown in Table 4, the price elasticities are statistically significant but inelastic at the 60%, 65%, 70%, 75%, and 80% coverage levels (0.106, 0.114, 0.137, 0.149, 0.230, respectively). Although they are all price-inelastic, the elasticity at 80% coverage level (− 0.230) is about five times that of the elasticity at the 50% coverage level (− 0.047). The results imply that producers are more sensitive to changes in premium at high coverage levels (e.g. 80% coverage level) than low coverage levels (e.g. 50% and 55%) in the Corn Belt. The results also prove the importance of differentiating coverage levels in the analysis of demand for corn insurance (Table 4).

The elasticities of demand for insurance with respect to per dollar net premium not only change across coverage levels and regions but also change between insurance plans (Table 4). In the Corn Belt and Northern Plains, the demand for corn APH insurance is more price-responsive than the demand for corn CRC insurance, while the elasticities of demand for corn CRC insurance with respect to per dollar net premium are larger than the corresponding elasticities for corn APH insurance in the Lake States and Southern Plains. For example, in the Southern Plains, the elasticity of corn APH insurance with respect to per dollar net premium is 0.248, while the corresponding elasticity for corn CRC insurance is 0.373 at 60% coverage (Table 4).

Results presented in Table 4 indicate the necessity of separating insurance plans, regions, and coverage levels in the analysis of corn insurance demand, which was overlooked in previous studies. The elasticity of demand for CRC insurance at the 75% coverage level in the Southern Plains is − 0.670, more than 14 times the elasticity of demand for APH insurance at the 50% level in the Corn Belt (− 0.047). Although the elasticities are price-inelastic, a 1% change in the net premium would

Table 5 Estimated changes of corn insurance demand with a 10 percentage point decrease in premium subsidies

Insurance	Region	50%	55%	60%	65%	70%	75%	80%	85%
APH	Corn Belt	− 0.701	–	− 1.656	− 1.932	− 2.322	− 2.709	− 4.792	–
	Lake States	− 2.687	− 2.156	− 2.156	2.492	− 1.593	− 2.855	–	–
	Northern Plains	− 2.537	–	− 4.766	–	–	− 3.418	− 5.396	− 7.474
	Southern Plains	− 3.299	–	− 3.875	− 3.847	–	− 11.891	–	–
CRC	Corn Belt	–	–	–	− 1.407	− 2.831	− 2.655	− 4.167	–
	Lake States	− 3.179	− 5.047	− 2.969	− 4.051	− 4.831	− 4.164	− 4.333	–
	Northern Plains	–	–	− 4.531	–	–	–	–	–
	Southern Plains	− 4.940	–	− 5.828	− 4.102	− 8.492	− 12.182	–	–

Only statistically significant coefficients are used to estimate the demand changes in this table

induce a 14 times larger effect at the 75% coverage level in the Southern Plains than the effect at the 50% coverage level in the Corn Belt (Table 4).

Different elasticities were found by previous studies. For example, the estimated average demand elasticity for liability per planted acre is − 0.73 in Iowa in Goodwin (1993), − 0.24 in the Heartland in Goodwin (2001), and − 0.13 in Illinois, Idaho, Iowa, and Ohio according to O'Donoghue (2014). Because this study is the only one that separates coverage levels in the analysis of corn insurance demand, it is difficult to compare the estimated elasticities of corn insurance demand at each coverage level with existing studies at each coverage level. Considering that the major objective of this study is to provide insights into the relationship between FCI participation and subsidy rates, the expected changes in corn insurance demand with a 10 percentage point decrease in premium subsidies are calculated based on the regression results and are discussed in the next section.

Policy implications

FCI reforms were proposed in the Obama Administration's 2017 Budget for a USD 18 billion cut to the programme over 10 years. Other bills such as Senate Bill 666 and Senate Bill 2244 in the 114th Congress also proposed to cut government premium subsidies. In CRS Report R43951 (Shields 2015), a 10 percentage point reduction in crop insurance premium subsidies is proposed. In this situation, estimating the changes in demand based on this disaggregated demand analysis would provide important insights for policymakers. Table 5 summarises the expected changes of corn insurance with a 10 percentage point decrease in federal premium subsidies.

A uniform percentage point reduction in the federal premium subsidy rate across coverage levels would result in significantly different responses in producers' participation in the FCIP by region and insurance type. For example, in the Corn Belt the changes at relatively high coverage levels (75% and 80%) are greater than they are at the 50% coverage level, both for corn yield and revenue insurance policies. Thus a small reduction in premium subsidy rates across coverage levels would result in a greater reduction in participation in high coverage policies in the Corn Belt, contradicting a major purpose of the 2000 ARPA. Besides, one of the major objectives of the 2000 ARPA was to encourage more participation at coverage levels higher than the 65% coverage level.)

A uniform percentage point reduction in the premium subsidy rates across coverage levels would also lead to significantly different purchase decisions across regions. For example, for yield insurance the expected change at the 75% coverage level in the Southern Plains (− 11.891%) would be 17 times greater than it is at the 50% coverage level in the Corn Belt (− 0.701%). The significantly different effects could also be expected for the demand for revenue insurance. Therefore, the government may consider applying different changes to the subsidy rates across regions, coverage levels, and insurance types to ensure significant use of crop insurance.

Conclusions

Although a few studies have examined the elasticities of crop insurance demand, overlooking the demand heterogeneity may yield biased results and undermine the effectiveness of research conclusions. In contrast, this study estimates the demand for corn insurance by region, insurance plan, and coverage level to provide a better understanding of the relationship between producer premiums and the demand for federal corn insurance.

First, this analysis provides evidence that the demand for federal corn insurance varies among coverage levels, insurance plans, and regions. Therefore, changes in subsidies would result in various purchase responses. The demand for corn yield insurance at low coverage levels in less risky regions is expected to have a modest response to changes in subsidies (e.g., at the 50% coverage level in the Corn Belt), while the demand for corn yield insurance at high coverage levels in riskier regions, such as the 75% coverage level in the Southern Plains, would be more price-sensitive. The varying elasticities are consistent with the implications of Woodard (2015), which incorporated soil productivity index into the demand estimation and found a statistically significant association between demand and soil index.

The preference heterogeneity in corn FCI demand could be related to the differing characteristics of corn farms in the different regions. For a typical county in Iowa, a corn farm would be a large, professional, more highly leveraged operation[4], while

[4] For example, according to the 2011 Agricultural Resource Management Survey, the average net worth is USD 911,000 and USD 5,600,000 for all farms and large farms, respectively (see Table 7 in Hoppe 2014). The average gross farm income is USD 153,000 and USD 2,000,000, respectively. The ratio of net worth to gross income is about 6.0 for all farms, and 2.7 for large farms, implying that large farms are more leveraged on average.

a corn farm in the Southern Plains would typically be smaller, less full-time professional, less leveraged. These smaller semi-professional operations may not rely on operating loans and therefore may not need to comply with bank requirements for operating loans. Second, the smaller corn farms are likely to be less well capitalised and less able to put up a higher up-front cost of the premiums if producer premiums increase. Third, although relatively the yield risk is lower in the Corn Belt, the large-scale and heavily leveraged operations are associated with more risks and are less risk-tolerant. Also, the large-scale farms in the Corn Belt may be managed more professionally, including the use of crop insurance to hedge risks, while the semi-professional operations in the riskier regions may pay less attention to risk management. Moreover, although they did not differentiate between geographic locations, Just et al. (1999) found that the income effect is larger than the risk-reducing effect in inducing insurance demand. The income effect might be greater for semi-professional and smaller farms in the riskier regions with minimum bank requirements, compared with professionally managed and highly leveraged farms in the less risky regions.

GAO (2015) criticised that the federal government costs of the Crop Insurance Program are "substantially" higher in regions with greater production risks. However, results of this study imply that high participation and coverage level would be difficult to achieve in riskier regions if the government subsidies are equally distributed. Although the interpretation of the results challenges the traditional attitude towards income effect and adverse selection, FCI is not merely a public insurance product; it is also the core of the U.S. agricultural safety net. The gross premium rates should be actuarially fair, but the distribution of subsidies to meet society's expectations calls for further research.

Endogeneity is a potential caveat in this study. Independent demand estimation by coverage level and region would lessen the problem but would not solve it completely, as the observed premiums from historical purchasing data are also influenced by producers' demand.[5] Future studies may consider using premium rates at each coverage level, insurance plan, and unit structure, or including the parameters of rate curves as instrument variables proposed in Woodard and Yi (2018).

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Appendix

See Tables 6, 7, 8, 9, 10, 11, 12, and 13.

[5] The authors sincerely thank the anonymous reviewers for pointing out the problem and proposing potential solutions to the endogeneity problem.

Table 6 Estimated elasticities of demand for corn APH insurance in the Corn Belt

Variable	50%	55%	60%	65%	70%	75%	80%	85%
Net premium	− 0.047**	− 0.028	− 0.106***	− 0.114***	− 0.137***	− 0.149***	− 0.230***	0.017
Yield expectation	0.416***	0.377***	0.347***	0.276***	0.300***	0.534***	0.730***	0.237
Relative yield risk	− 0.080*	− 0.096	− 0.128*	− 0.130***	− 0.097*	− 0.112**	0.035	− 0.204*
Planted acres	0.067***	0.088***	0.050***	0.063***	0.030**	0.021	0.029	0.100***
Enrolled acres	− 0.012**	− 0.024***	− 0.022**	0.0004	0.004	0.01	− 0.01	− 0.022
Percentage of irrigated cropland	− 0.100	− 0.172	− 0.016	0.065	0.06	0.112	− 0.159	− 0.174
Percentage of cropland operated by female	− 0.148	0.105	0.095	0.064	− 0.705	− 0.843	0.075	− 0.671

Statistical significance * at the 10%, ** at the 5%, *** at the 1% level

Table 7 Estimated elasticities of demand for corn APH insurance in the Lake States

Variable	50%	55%	60%	65%	70%	75%	80%
Net premium	− 0.180***	− 0.138***	− 0.138***	− 0.147***	− 0.094**	− 0.157***	− 0.158**
Yield expectation	0.418***	0.336***	0.644***	0.540***	0.558***	0.756***	0.557
Relative yield risk	− 0.098**	− 0.188**	0.056	0.037	− 0.031	0.019	− 0.201
Planted acres	0.023*	0.055***	0.055**	0.042***	0.068***	0.033	0.204***
Enrolled acres in CRP	− 0.014**	− 0.018*	− 0.020**	− 0.008*	− 0.016**	− 0.002	− 0.078**
Percentage of irrigated cropland	− 0.273**	− 0.121	− 0.166	− 0.022	− 0.093	− 0.031	0.156
Percentage of cropland operated by female	− 0.172	0.418	0.606	0.301	0.752	− 1.171	3.709**

Statistical significance * at the 10%, ** at the 5%, *** at the 1% level

Table 8 Estimated elasticities of demand for corn APH insurance in the Northern Plains

Variable	50%	55%	60%	65%	70%	75%	80%	85%
Net premium	− 0.170***	− 0.004	− 0.305***	− 0.038	− 0.097	− 0.188*	− 0.259**	− 0.284**
Yield expectation	0.538***	0.724***	0.599***	0.809***	0.720***	0.530***	0.890**	− 0.257*
Relative yield risk	− 0.289***	− 0.257	− 0.164	− 0.137***	− 0.057	− 0.174	0.082	− 0.618***
Planted acres	0.041***	0.047	0.051**	0.015***	0.067***	0.071***	0.002	− 0.005
Enrolled acres in CRP	− 0.018*	− 0.092***	0.0005	− 0.006	− 0.007	− 0.026	0.005	− 0.041*
Percentage of irrigated cropland	− 0.03	− 0.238	− 0.039	0.057	− 0.007	− 0.054	0.142	− 0.237
Percentage of cropland operated by female	0.581	0.543	0.65	0.07	1.247	1.209	2.436	1.366

Statistical significance * at the 10%, ** at the 5%, *** at the 1% level

Table 9 Estimated elasticities of demand for corn APH insurance in the Southern Plains

Variable	50%	55%	60%	65%	70%	75%
Net premium	– 0.221**	– 0.131	– 0.248*	– 0.227**	– 0.155	– 0.654***
Yield expectation	0.469***	0.569**	0.455**	0.711	0.781***	0.850***
Relative yield risk	– 0.474***	– 0.026	– 0.167	0.09	0.0898	0.00228
Planted acres	– 0.00714	0.0333	– 0.0209	0.007	0.0012	– 0.0298
Enrolled acres in CRP	0.0286**	– 0.0047	0.0402*	0.016	0.0456***	0.0287*
Percentage of irrigated cropland	0.312**	0.634**	0.615**	0.569***	0.525**	0.232
Percentage of cropland operated by female	0.426	– 0.121	– 1.175	0.01	1.553	– 2.079*

Statistical significance * at the 10%, ** at the 5%, *** at the 1% level

Table 10 Estimated elasticities of demand for corn CRC insurance in the Corn Belt

Variable	50%	55%	60%	65%	70%	75%	80%	85%
Net premium	− 0.015	0.033	− 0.040	− 0.083**	− 0.167***	− 0.146***	− 0.200***	− 0.083
Revenue expectation	− 0.088	− 0.082	− 0.194***	− 0.113***	− 0.152***	− 0.195***	0.432***	0.440***
Relative revenue risk	− 0.009	0.226**	0.168*	− 0.023	0.033	− 0.020	0.051	− 0.054
Planted acres	0.148***	0.127***	0.110***	0.108***	0.088***	0.086***	0.009	0.061**
Enrolled acres in CRP	− 0.037***	− 0.059***	− 0.045***	− 0.022***	− 0.017***	− 0.023***	− 0.001	0.004
Percentage of irrigated cropland	− 0.204	− 0.177	− 0.109	0.099	0.004	0.080	− 0.054	0.099
Percentage of cropland operated by female	1.239*	− 0.066	− 0.305	− 0.902*	− 1.469***	− 0.572	− 1.551***	− 1.635*

Statistical significance * at the 10%, ** at the 5%, *** at the 1% level

Table 11 Estimated elasticities of demand for corn CRC insurance in the Lake States

Variable	50%	55%	60%	65%	70%	75%	80%	85%
Net premium	− 0.213***	− 0.323***	− 0.190***	− 0.239***	− 0.285***	− 0.229***	− 0.208***	− 0.177
Revenue expectation	− 0.129	0.014	− 0.005	0.031	− 0.113	0.052	1.104***	0.363
Relative revenue risk	0.018	− 0.023	0.295**	0.221***	0.406***	0.334***	0.123	− 0.066
Planted acres	0.120***	0.078**	0.077**	0.105***	0.075*	0.031	− 0.075	0.043
Enrolled acres in CRP	− 0.021*	− 0.015	− 0.037***	− 0.019*	− 0.011	0.029**	0.04	0.014
Percentage of irrigated cropland	− 0.227	− 2.096***	− 0.307	− 0.176	− 0.258**	− 0.193	− 0.238	0.029
Percentage of cropland operated by female	1.283	3.198**	0.675	0.583	0.212	0.829	− 0.308	− 0.562

Statistical significance * at the 10%, ** at the 5%, *** at the 1% level

Table 12 Estimated elasticities of demand for corn CRC insurance in the Northern Plains

Variable	50%	55%	60%	65%	70%	75%	80%	85%
Net premium	− 0.042	− 0.205	− 0.290***	0.017	− 0.044	0.097	0.075	0.009
Revenue expectation	0.074	0.14	0.186**	0.236***	0.132***	0.058	0.839***	0.686***
Relative revenue risk	− 0.014	− 0.011	0.046	− 0.129**	0.006	− 0.025	0.061	− 0.108
Planted acres	0.024	0.039	0.035	0.049***	0.01	0.061***	0.069***	− 0.004
Enrolled acres in CRP	0.002	0.011	0.014	− 0.020**	0.020**	0.001	0.002	0.020
Percentage of irrigated cropland	0.491***	0.241	0.348***	0.263***	0.480***	0.503***	− 0.031	0.176
Percentage of cropland operated by female	0.314	0.043	2.140*	0.923*	0.588	2.406***	1.045	− 3.308**

Statistical significance * at the 10%, ** at the 5%, and *** at the 1% level

Table 13 Estimated elasticities of demand for corn CRC insurance in the Southern Plains

Variable	50%	55%	60%	65%	70%	75%
Net premium	– 0.331**	– 0.094	– 0.373***	– 0.242*	– 0.501***	– 0.670***
Revenue expectation	0.333***	0.564***	0.797***	0.519***	0.819***	0.613**
Relative revenue risk	0.229*	– 0.067	– 0.005	0.160**	– 0.171*	0.023
Planted acres	0.074**	0.050	0.021	0.080***	– 0.008	– 0.021
Enrolled acres in CRP	0.072***	0.068	0.036**	0.041***	0.021	0.053**
Percentage of irrigated cropland	0.741***	0.738*	0.361*	0.471***	0.669***	0.364
Percentage of cropland operated by female	– 0.031	– 3.435	3.341**	3.776***	1.629	2.844*

Statistical significance * at the 10%, ** at the 5%, and *** at the 1% level

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