How Does Crop Insurance Enrollment Affect Marketing Contracts Participation: Theory and Empirical Evidences

Xiaoxue Du, UC Berkeley, duxiaoxue1515@berkeley.edu

Jennifer Ifft, Cornell University, jifft@cornell.edu

Liang Lu, UC Berkeley, lld2x1515@berkeley.edu

David Zilberman, UC Berkeley, zilber11@berkeley.edu

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Abstract

Agricultural contracts and crop insurance are important ways for farmers to mitigate risks in modern U.S. agriculture. In this paper, we investigate the effect of crop insurance enrollment on farmers' participation of marketing contracts. Following Ligon (2003), we setup a mechanism design framework to demonstrate an integrator's contract design problem where farmers are assumed to be expected utility maximizing agents. We use a Babcock (2012) style specification to depict farmers' optimal choice of insurance coverage and the incentive compatibility and participation constraints for the integrator. Our model shows that, under certain assumptions, a lower crop insurance premium rate could induce higher compensation from integrators. Moreover, crop insurance subsidy allows for higher marketing contract participation. The rationale is that when farmers purchase crop insurance, they rely less on contracts to mitigate risk and become more independent from integrators. Therefore, integrators may revise their contract offers so that the they are more attractive and incentive compatible. This result indicates that the use of one risk management tool may not crowd out the use of the other.

For the empirical estimation, we use various data sources and 2SLS to see how crop insurance enrollment affects farmers' participation in marketing contracts. We use pre-growing season weather variables as IV for insurance enrollment. The second stage result indicates that farms with higher possibility of insurance enrollment will have about 40 percent higher chance of participation in marketing contracts as well. Moreover, we show that the subsidy effect of crop insurance is heterogeneous among different crops.

Keywords: Agricultural Contract; Crop Insurance; Instrumental Variable

JEL Classification Numbers: Q12, Q18.

Introduction

With the fast pace of technological innovation and rapid movement of industrialization, modern agriculture in the United States is characterized by tremendous uncertainty in the production and marketing process. It is then crucial for farmers to utilize risk management tools to make optimal decisions under uncertainty. Among risk management tools, agricultural contracts and crop insurance are two important ways for farmers to mitigate risks. According to MacDonald and Korb (2011), about 39 percent of value of agricultural production is achieved through contracts. At the same time, crop insurance participation drastically increased after the approval of the Agricultural Risk Protection Act (ARPA) in May of 2000 from 182 million acres to 265 million acres in 2011 (Glauber 2013).

It is well documented in literature (MacDonald and Korb 2011, Anderson et al. 2004) that mitigating risk is one of the major incentives for farmers to adopt agricultural contract. Meanwhile, crop insurance also has the effect of reducing farmers' risk. From this perspective, the use of one risk management tool may crowd out the use of the other. However, this view can be misleading if farmers are buying crop insurance for other reasons. In fact, there is evidence (Just et al. 1999) that farmers participate in crop insurance program for the subsidy effect. Moreover, because of the subsidy effect of crop insurance, farmers become more independent from integrators. Consequently, integrators may have to revise their contracts so that the participation constraint can be met and the contracts are more attractive and incentive compatible. In this sense, farmers may combine the use of the two risk management tools to gain higher expect profit. From an integrator's point of view, the key question is to balance the trade-off between maintaining farmers' incentive to join the contract and potentially higher contracting cost. Previous theoretic literature on agricultural contracts and crop insurance often neglect the interaction between the two tools.

Given the key question for integrators, we first formulate a mechanism design framework to find the optimal agricultural contracts under the availability of crop insurance. Our theoretic model combines the contract design framework of Ligon (2003) and the crop insurance model of Babcock (2012). Our preliminary results show that, under certain assumptions, integrators are willing to compensate more for realized yield that is above the insured yield level than the case of without crop insurance and pay less for realized yield under insured yield level. Moreover, the compensation plan is uniformly decreasing as crop insurance becomes more expensive. Finally, our model preserves the main feature of Ligon (2003): even if crop insurance is available, integrators do not intend to offer farmers a contract that would eliminate all the risk that farmers are facing.

We empirically test our theory using a combined data set of Agricultural Resource Management Survey (ARMS) data, Risk Management Agency (RMA) data, and weather data from National Oceanic and Atmosphere Administration (NOAA). We implement an instrumental variable (IV) approach to account for the endogeneity of farmers' choice of insurance. The pre-growing season weather IV results report a positive impact of crop insurance enrollment on the use of marketing contracts, which are consistent with our theoretic predictions. Meanwhile, we further explore the heterogeneous impact for different crops of pre-growing season weather on crop insurance enrollment. This investigation may shed light on measuring the subsidy effect for different crops.

Our study contributes to the existing literature in three important ways. First, to our knowledge, this is the first study, combining contract theory and crop insurance models, that demonstrates the interaction between farmers' optimal choice on crop insurance and integrators' optimal contract design. Second, our empirical study has practical implications for crop insurance policy designs. We demonstrate in which crops the subsidy effect of insurance is higher and we show that subsidized insurance may stimulate higher contract participation. Third, the implication of our model is not limited to existing crop insurances, but may also help in designing new insurance programs. For instance, recent studies (Miao and Khanna 2013) have shown that crop insurance can be an efficient policy instrument to promote energy grass production, while other studies (Du et al. 2013) find contracting an attractive business model in stabilizing biofuel feedstock supply as well. Our model provides a comprehensive view on how to combine the two risk management tools to encourage the introduction of novel crops.

The rest of the paper is arranged as follows: in section 2, we give a brief discussion on the background of agricultural contracts and crop insurance. In section 3, we will demonstrate the theoretic model and discuss the implications of the model. In section 4 and 5, we will introduce the construction of the data set, empirical strategy, and regression results. Finally, we will provide some concluding remarks in section 6.

Background

Contract farming is one of the most profound relationships between processors and producers in modern industrial organizations. In the United States, the share of agricultural production value through contracts is 39 percent in 2008, but the number was merely 11 percent in 1969 (MacDonald and Korb 2011). Based on the involvement of integrator in production activities, the form of contracts in contract farming can be divided in two categories: namely, marketing contracts and production contracts (Farm Business Economics Branch, Rural Economy Division, ERS 1996). In marketing contracts, agreement has to be made between growers and buyers on 'what to be made' and 'what are the commitments for future sale' (da Silva 2005). i.e., market contracts specify the quantity and quality of the designated crop in transaction and set either a predetermined price for the crop or a formula for pricing based on market price at the time of transferring. Consequently, contractors share price risks with contractees. In the case of production contracts, arrangements will be made on 'how to produce' certain products (da Silva 2005). Buyers are more involved in the production process under production contracts. They may specify inputs being used in production and, in most cases, the buyers own the crop themselves. Personal service contract and bailment are some frequently used production contracts (Kunkel et al. 2009). Different factors that motivates contractors and contractees could induce demand for different type of contract. If the main aim of an integrator is to stabilize price, then marketing contract is more appealing; if producers are more capital oriented whereas integrators are more concerned about specific crop characteristics, then production contracts become more likely.

There has been a growing literature analyzing the effects of risk aversion on contract choices. Using a simulation model, Buccola (1981) shows that the share of output a farmer (processing firm) would sell (buy) under a fixed price or cost-plus pricing contract and on the spot market depends on the degree of risk aversion of the farmer and the firm and the covariances between market price of the raw product, final product, and production costs. Anderson et al. (2004) show that preferences for a contract may differ between a principal and an agent due to differences in the risks faced and in risk aversion; they find that while pasture owners prefer grazing contracts to owning cattle as their risk aversion increases, cattle owners prefer leasing land to contract grazing because the risk reducing benefits of contract grazing were insufficient to compensate for its costs.

Other studies use survey data to show the importance of risk aversion as a determinant of contract choice. Katchova and Miranda (2004) find that highly leveraged (more risk) crop producers were more likely to adopt marketing contracts and that marketing contracts were used not only to reduce price risk but also to have an outlet for the harvested crop. Reliance on fixed contracts instead of the spot market has been found to be significantly related to the level or price risk, risk aversion and risk perception among hog producers (Franken et al. 2009; Pennings and Smidts 2000; Pennings and Wansink 2004). Much of this research has focused on a producer's choice between a contract and selling on the spot market. Zheng et al. (2008) analyze the choice among alternative types of contracts by hog producers and find that the most risk averse hog producers prefer production contracts that are less risky than marketing contracts.

Advanced literature looks at contract farming from transaction cost theory and agency theory perspectives. The transaction cost literature started from the seminal paper by Coase (1937) which explains the use vertical integration to deal with the transaction cost problem. Accumulated empirical evidence also shows that transaction cost is a major factor in shaping the contract design. Allen and Lueck (1995) compare risk aversion assumption with transaction cost framework in contract theory. They summarize the empirical evidence in several industries including agriculture, gold mining, natural gas, and timber. Their conclusion is that the transaction cost framework rather than risk preference theory is more reliable to interpret the existence of sharecropping contract. Goodhue (2000) and Ligon (2003) among others discuss the role of moral hazard and adverse selection in agricultural contracts. An implication of moral hazard assumption is that workers with full insurance against risks will not exert their full efforts. Thus, as shown in Ligon (2003), farmers are not fully insured under optimal contract design.

Contract farming is not the only way for farmers to mitigate their risks. The U.S. crop insurance program aims to help farmers managing their financial risk and reduce the ad hoc disaster assistance. The first Federal Crop Insurance Program was established while Congress passed The Federal Crop Insurance Act in 1938. However, the program failed due to the high program costs and the low participation rates among farmers. Researchers have found that the root of the failure lies in the unsolved adverse selection and moral hazard problems in the insurance system (Miranda 1991, Goodwin 1993). Moreover, farmers who enroll in the crop insurance program are mostly interested in getting the subsidy effect of the insurance program rather than risk mitigation (Just et al. 1999). In order to increase the demand of crop insurance, Congress approved the Agricultural Risk Protection Act (ARPA) in May of 2000. The objectives of ARPA are making higher insurance coverage more affordable to farmers and allowing them accessing different types of insurance products easier.

Prior to 2000, it is well known for economists that the fundamental failure of the federal crop insurance program lies in the simple fact that the benefit from crop insurance does not worth the premium rate (Wright and Hewitt 1994 for instance). After the year of 2000, Glauber (2013) and O'Donoghue (2013) show that subsidizing crop insurance boosts enrollment rate, while Wright (2014) and Goodwin and Smith (2013) are some recent articles that discuss the potential distortion comes with the insurance subsidies. On another line of research, scholars have found that the enrollment of crop insurance affects many aspects of farmers' business decisions. Ligon (2011) show that crop insurance has a negative impact on the price of the crop for various specialty crops in California. Ifft et al. (2013) find that the use of crop insurance leads to higher debt taken by farmers. Katchova and Miranda (2004) demonstrates an insignificant correlation between use of crop insurance and forward contracts. Finally, Babcock and Hennessy (1996) utilize a theoretic model to show the impact of crop insurance on input uses. In this paper, we aim to go further on this line and discuss how crop insurance affects marketing contract participation.

Model

Consider an integrator's expected profit maximization problem. The integrator provides farmers a contingent compensation plan by paying $w(q)$ for the received production quantity q. That is, for a realize production quantity q, the integrator pays the farmer an amount of $w(q)$. We assume that q is stochastic and use $\bar{q}$ to denote the expected quantity. And we use $f(q|a)$ to denote the conditional distribution of q, where $q \in [0, q_M]$ and a is the effort level that farmers put in the growing activities and is not observed by the integrator. Let p be the price of the crop, then the integrator's problem is to maximize the expected profit:

$$(1) \qquad \max_{a,b,\{w(q)\}} \int_0^{q_M} [pq - w(q)] f(q|a) dq.$$

Let $U(\pi)$ be the utility function for a farmer where π is the farmer's net compensation. We normalize the cost of effort to be 1. Then, for a realized production level q, the farmer receives utility of $U(w(q) - a)$. Since q is stochastic, the farmer's expected utility is characterized by the function $EU = \int_0^{q_M} U(w(q) - a) f(q|a) dq$. As soon as we add the participation constraint and incentive compatibility constraint for the integrator, we will reach the original setup of Ligon (2003).

In order to capture farmer's choice of crop insurance under agricultural contracts, we use the Babcock (2012) framework and modify the farmer's expected utility function in the following way: let b be the percentage of expected yield (i.e., the coverage level) that a farmer would like to put insurance on and $r(b)$ be the premium of the insurance. The insurance pays the indemnity $I = \max(b\bar{q} - q, 0)$ at the market price p, then the farmer's expect utility can be rewritten as:

$$(2) \qquad EU = \int_0^{b\bar{q}} U(\pi_1) f(q|a) dq + \int_{b\bar{q}}^{q_M} U(\pi_2) f(q|a) dq,$$

where $\pi_1(a,b,q) = p(b\bar{q} - q) + w(q) - a - r(b)$ is the payment from both the contractor compensation and indemnity payment and $\pi_2(a,b,q) = w(q) - a - r(b)$ is the payment from the contractor only. Notice that π_2 does not involve any indemnity payment because the realized yield q is greater than the insured level of yield $b\bar{q}$.

Let $\underline{U}$ be some reserved utility level for the farmer, which may come from the farmer's off-farm income or the farmer marketing the crop on his/her own, then the participation constraint for the contract design can be written as:

$$(3) \quad EU(a,b) \geq \underline{U}.$$

When the integrator has full information about farmers' activities, it is well known in contract theory (Hueth and Ligon 1999 for instance) that the integrator will provide full insurance for farmers. Adding crop insurance choice for farmers would not alter this result. In fact, the first order condition for the full information case is:

$$(4) \quad U'(\pi_i) = \frac{1}{\lambda},$$

where $i = 1,2$. That is, although crop insurance enrollment splits the farmers' net compensation into two pieces (with and without indemnity payments), the optimal contract will guarantee that the farmer a constant level of utility under any realized production quantity. Since the participation constraint is binding in optimal contract, this constant utility level is nothing but the farmer's reservation utility.

When farmers have private information over efforts, Ligon (2003) has shown that farmers will bear some risk in the the optimal contract. The rationale is that if full insurance is provided then farmers will choose the lowest possible effort, which is not optimal for the integrator. When farmers also have private information on their choice of crop insurance, it is easy to see that, following the same logic as above, integrator would still not provide full insurance otherwise the farmers would pick the lowest possible effort and crop insurance coverage combination. To characterize the optimality condition for farmers with private information, we need the incentive compatible (IC) constraints. Following Ligon (2003), we assume that the integrator gives farmers recommendation on the effort level and insurance coverage level. In order for the contract to be incentive compatible, the recommended a, b must be utility maximizing, so we have the IC constraints:

$$(5) \quad a, b \in \arg\max EU(a, b),$$

which yield FOCs:

$$(6) \quad EU_b = \int_0^{b\bar{q}} U'(\pi_1)(p\bar{q} - r')f dq - \int_{b\bar{q}}^{q_M} U'(\pi_2)r' f dq = 0.$$

$$(7) \quad EU_a = \int_0^{b\bar{q}} [U(\pi_1)f_a - U'(\pi_1)f]dq + \int_{b\bar{q}}^{q_M} [U(\pi_2)f_a - U'(\pi_2)f]dq = 0.$$

Let λ be the Lagrange multiplier for the participation constraint, and μ_1, μ_2 be the Lagrange multipliers for the incentive compatibility constraints ($EU_b = 0, EU_a = 0$ equations) respectively. Then the Lagrangian for the integrator's problem can be written as:

$$(8) \quad \max_{a,b,\{w(q)\},\lambda,\mu_1,\mu_2} \int_0^{q_M} [pq - w(q)]f(q|a)dq + \lambda(EU - \underline{U}) + \mu_1 EU_b + \mu_2 EU_a.$$

Our immediate question at hand is how would the optimal compensation plan $w(q)$ change when crop insurance becomes available. The first proposition is aimed at answering this question.

Proposition 1 *Let $w^*(q)$ denote the payment schedule without crop insurance. Then under crop insurance, the new payment schedule $w^{**}(q)$ pays more than $w^*(q)$ for realized q that are higher than insured level $b\bar{q}$; and pays less than $w^*(q)$ for realized q that are less than insured level, i.e.,*

$$(9) \quad [w^{**}(q) - w^*(q)](q - b\bar{q}) > 0, \forall q \in [0, q_M].$$

Moreover, as long as crop insurance premium rate equals or under actuarially fair premium rate[1]*, farmers are more like to participate in contracting when crop insurance is available.*

See appendix 1 for proof.

Figure 1 gives an illustration for this proposition. In figure 1, the two compensation plans cross at $b\bar{q}$. Whenever realized quantity is above this level, compensation should be higher with crop insurance and the opposite is true when $q < b\bar{q}$. Comparing this result to the optimal compensation plan in Ligon (2003), we find that farmer's compensation still depends on the output level after insurance becomes available, which implies that farmers still face risk under contracts as discussed above. But in Ligon (2003), when IC constraint is binding, the compensation depends on the likelihood ratio $\frac{f_a(q|a)}{f(q|a)}$, which measures farmers' likelihood of putting in the recommended level of effort. In our model, the likelihood ratio at different level of output quantities is isolated by farmers' choice on purchasing insurance. As a result, the payment schedules are separated for quantities higher than insured level and lower than insured level. Moreover, when the realized production quantity is higher than insured level, farmers need higher compensation to cover their cost of crop insurance; when the realized production quantity is lower than insured level, integrators tend to provide less compensation as the crop insurance would generate indemnity payments for farmers. Overall, as long as the crop insurance premium is not prohibitive, farmers tend to use it as another dimension of source of private information, which allows farmers to gain extra compensation.

In proposition 1, we have demonstrated that the design of crop insurance premium rate could affect the contract outcomes. It is easy to see that when insurance premium rate is prohibitive, the problem reduces to the model without insurance(i.e., the Ligon 2003 model)[2]. Therefore, it is also necessary to examine how payment schedule responses to an exogenous crop insurance rate change. Say there is a crop insurance premium subsidy c such that $r(b,c)$ satisfies $r_c < 0, r_{bc} = 0$, we could analyze how this shifter would affect the optimal payment schedule and we have the following proposition.

Proposition 2 *Under the assumption that farmers' utility functions are Constant Absolute Risk Aversion (CARA), then as crop insurance becomes less expensive, farmers are more likely to participate in marketing contracts, and the payment schedule $w(q)$ is higher for all $q \in [0, q_M]$.*

See appendix 2 for proof.

This proposition is relevant especially for analysis about the effect of crop insurance subsidies on farmers' choice of risk management tools. The intuition for this result is that, when higher subsidy is imposed on the crop insurance premium, contracts become a less attractive risk management tool. In order to keep farmers being interested in signing the contract, a tighter incentive compatibility constraint must be satisfied. Consequently, higher compensation is needed from the integrator. Conventional economics wisdom has taught us that when two commodities are perfect substitutes, a rational consumer would only purchase the cheaper one. If we apply the logic in the context of choosing crop insurance or signing contract, the theory seems to suggest that crop insurance would crowd out agricultural contracts as soon as the crop insurance is subsidized enough. However, integrators may also use the compensation schedule to keep farmers interested in signing the contract. Thus, the subsidy on crop insurance does not only reduce farmers' cost of managing risk, but also it brings farmer bargaining power over contract design.

Data and Empirical Strategy

In the empirical section, we mainly want to investigate two things: first, as we learned from Just et al. (1999), farmers are mostly interested in the subsidy effect of crop insurance, but is there any heterogeneity among different crops? As Babcock (2012) argued, the political economy perspective of crop insurance should not be underestimated. A direct implication is that, due to heterogeneous political powers, the subsidy effect for different crops could be quite different. Second, we want to empirically test whether crop insurance enrollment has a significant impact on farmers' decision of participation in marketing contracts[3]. Our data come mainly from three sources: farm level marketing contract related data are collected from the Agriculture and Resource Management Survey (ARMS) conducted by National Agricultural Statistics Service (NASS) and Economic Research Service (ERS) of United States Department of Agriculture (USDA). The Risk Management Agency (RMA) provides the record of crop insurance purchase and administration information at county level. Finally, our historical weather data come from annual summary of National Climatic Data Center (NCDC), National Oceanic and Atmosphere Administration (NOAA) at weather station level. The unit of the merged data set is county by year.

ARMS Data

The Agricultural Resource Management Survey (ARMS) is by far the only data that contain farmers' financial status and marketing decisions. The annual survey has three phases, where the third phase collects information on contract farming. In order to reduce burdens on farms being surveyed, a sampled farm typically does not appear in subsequent survey years. Thus, the survey is repeated cross-sectional by nature of its design. From the 2002-2011 versions of the survey data, we collect the following variables for the empirical estimation: total value of production under marketing contract, crop insurance enrollment status, primary operator's gender and education level, type of crop that the farm is primarily growing.

RMA Data

The Risk Management Agency (RMA) administrates the implementation of crop insurance policies and annually publishes the use of crop insurance at county level. For each crop, the RMA data record the type of crop insurance being purchased, coverage level, total covered acreage, policies sold, liability, total premium, total amount of subsidized premium, and the amount of loss. Two most commonly used type of insurance are Actual Production History (APH) insurance and Revenue Protection (RP) insurance. The APH insurance protects farmers from yield risk and the RP insurance protects farmers from revenue risk. It should be noted that not all types of insurance are available for all crops. In each crop year, the RMA reports the liability, indemnity paid to farmers, and calculates the loss ratio. The main use of RMA data in this paper is to show the county level heterogeneous impact of pre-growing season weather on enrolled acreage in crop insurance. Thus, for the RMA data, we collect the 1999-2013 county level aggregate acreage enrolled in crop insurance[4].

Weather Data

The historical weather data (1999-2013) comes from National Climatic Data Center (NCDC). In any given year, we collect the mean value of the first three month maximum and minimum temperature and total precipitation from each reporting weather stations. Then we calculate the three month average temperatures and total precipitations. Then we merge the farm contract data and weather data using the nearest weather station observation. The descriptive statistics of all the variables can be found in table 1. Meanwhile, we calculate the county level averages of the first three month temperature and precipitation variables, and merge the data set with RMA county level data.

Empirical Strategy

We analyze the effect of crop insurance enrollment on the farmers' marketing contract decisions using a 2SLS model:

(10) $$MP_{ist} = \beta \hat{I}_{it} + X_{it}'\gamma + T_t + S_s + \varepsilon_{it}$$

(11) $$I_{it} = IV_{it}\delta + X_{it}'\eta + T_t + S_s + e_{it},$$

where MP_{it} denotes farmer i's marketing contract participation ($MP = 1$ if the value of production under marketing contract is greater than zero) at time t. I is a farmer's enrollment in crop insurance ($I = 1$ if a farmer enrolls positive acreage in crop insurance). X_{it} is a set of control variables, which includes farm characteristics: gender, education level, farm size, and the type of crop the farm is growing.T_t and S_s are year and state fixed effects respectively. The IV variables denote the instrumental variables used for predicting the insurance enrollment. Our main variable of interest here is the β. If $\beta > 0$, it implies that crop insurance enrollment and marketing contract participation goes in the same direction. On the contrary, if $\beta > 0$ then enrollment in crop insurance may actually crowd out farmers' participation in marketing contracts.

We consider two instrumenting strategies here. The first set of instruments we use is the first three month average of maximum and minimum temperature, and total precipitation. Since the inclusion of maximum temperature lowers the overall goodness of fit in the first stage regressions, our second set of IVs excludes the maximum temperature variable.[5]. In order for the variables to be valid instruments, we need the assumption that the weather conditions do affect farmers' crop insurance enrollment. Figure 2 provides an illustration of the relevance of precipitation on enrollment in crop insurance. The figure provides geographic variation of total area enrolled in crop insurance and total precipitation from January to March in the year of 2008[6].From the figure, it is clear that crop insurance enrollment in terms of enrolled acreage is often higher when the pre-growing season total precipitation is low. Meanwhile, the weather variables should meet the exclusion restriction condition to be valid instruments. We argue that the weather condition in pre-growing season should not directly affect farmers' participation in signing contracts.

In order to test whether there is heterogeneous subsidy effect among different crops, we run the following regression:

$$(12) \quad Insured\ Acreage_{ict} = \phi Precipitation_{ict} \times Crop_i + T_t + C_c + e_{ict},$$

where $Insured\ Acreage_{ict}$ is the total insured acreage of some crop category i in county c at time t. $Precipitation$ is the county level average of January to March total precipitation. The variable $Crop_i$ is a crop category dummy for each crop type i. For simplicity, we put all crop types into 11 categories: barley, corn, grain sorghum, peanuts, potatoes, rice, soybeans, tobacco, upland cotton, wheat, other crops. Notice that, under this categorization, the category of other crops coincides with RMA's conventional definition of specialty crop. T_t and C_c are time and county fixed effects respectively.

For each crop i, we are interested in the estimated ϕ_i. We argue that if farmers cares more about the risk reducing effect of crop insurance rather than subsidy effect, then lower precipitation would imply higher acreage under crop insurance as lower precipitation before growing season indicates higher risk of low yield during the growing season. In this estimating equation, we want to see if $\phi_i < 0$ for each crop.

Results

Table 2 and 3 provide the first and second stage regression results respectively. From table 2, it is clear that when pre-growing season minimum temperature is higher or total precipitation is more affluent, the probability a farmer would enroll in FCI reduces. Despite the small magnitudes, the impact of the IVs are significant at one percent level and the F-statistics for the instruments are well above 10. The maximum temperature variable is not significant in any case. Dropping the maximum temperature variable and including the farm demographics do not have much influence on the point estimates, but reduce estimation standard errors. Moreover, from the crop type fixed effects, we can see that, comparing the grain sorghum farms, soybean, general crop, fruits and tree nuts, vegetables, and nursery and greenhouse farms have lower chance of FCI enrollment; cotton farms have high probability of enrollment and the difference is insignificant for the rest of farm types.

From table 3, we can see that, for farms enrolled in FCI, the farm's probability of participating in marketing contract is about 40 percent higher. This result is consistent with our theoretic prediction that farmers may treat crop insurance and agriculture contracts as complementary risk management tools. The farm type fixed effect indicates that wheat, nursery and greenhouse farms have insignificant contract participation rate comparing to grain sorghum farms, while all of the other categories have significantly higher contracting probabilities.

Table 4 gives the estimation result of equation (12). It confirms our hypothesis that there is, in fact, heterogeneous impact of pre-growing season weather on crop insurance enrollment. Among the eleven crop categories, we find that the estimated coefficient on barley, grain sorghum, potatoes, and specialty crops are negative, which suggests that risk reducing effect may be more prevalent for these kinds of crops. However, it is worth noting that, for corn, soybean, and cotton, more pre-growing season precipitation leads to higher acreage enrolled in crop insurance. This evidence indicates that subsidy effect might be the more important factor for farmers growing these crops to enroll in crop insurance.

Discussion and Concluding Remarks

The main theme of this paper is to investigate the relationship between agricultural contracts and crop insurance. Using an agency theory framework and expected utility maximization, we utilizes the contract design model of Ligon (2003) and the crop insurance decision model of Babcock and Hennessy (1996) and are able to characterize the features of optimal agricultural contracts under the availability of crop insurance. We show that farmers would still bear risk in the optimal contract design even if under the availability of crop insurance. The comparative statics analysis show that, when an exogenous subsidy makes crop insurance cheaper, the compensation plan for farmers must uniformly increase for each level of realize yield. One future direction of this research is to implement numerical analysis for the theoretic model. Prescott (1999) and Hueth and Ligon (1999) are some good examples of using numerical methods to investigate the optimal contract design under different parameter settings. Especially, numerically analysis could allow one to show how much percentage of integrator's profit goes to farmers' compensation for various crop insurance subsidy schemes. However, in our model, the computational burden could be heavy as we add a dimension of private information, the choice of crop insurance coverage.

We empirically test our theory using data from various sources. We implement a 2SLS approach and use pre-growing season weather as instruments to account for the endogeneity of farmers' choice of crop insurance. The results report a positive impact of insurance enrollment on marketing contracts participation, which are consistent with our theoretic predictions. Moreover, using county level estimates, we show that the subsidy effect of crop insurance could be heterogeneous among different crops. Note that our empirical results look different from Katchova and Miranda (2004), which reports a negative correlation between crop insurance purchase and use of forwarding contracts. There are several explanations to account for the difference: first, our empirical estimation uses both cross sectional variation and time variation in the data where the variation in Katchova and Miranda (2004) is mainly cross-sectional; second, marketing contract is a broader concept than forwarding contract, thus, it should not be surprising that the estimates are different in the two papers. One possible future work on the empirical portion is to see whether heterogeneous subsidy effect exists for different insurance plans and difference coverage levels.

In sum, both our theoretic model and empirical results suggest that crop insurance and agricultural contracts could be complementary tools for farmers. Crop insurance may increase farmers' bargaining power and allow farmers for gaining better contract deals from integrators.

Notes

[1]crop insurance premium rate being equal to or under actuarially fair premium rate is a sufficient but not necessary condition for the problem

[2]There is another symmetric extreme case: when subsidy is too high. In that case, farmers will not participate in contracting as the crop insurance itself would cover all of the farmers' risk at no cost.

[3]Here, we excluded the discuss of production contracts because, in production contracts, the compensation scheme is quite different from what we analyzed above.

[4]a drawback of such aggregation is that we cannot distinguish coverage level or insurance plan for a given unit of acreage enrollment.

[5]A recent survey of using weather variable as instruments can be found at Dell et al. (2013).

[6]The variations in other years have very similar patterns.

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AJAE Appendix for How Does Crop Insurance Enrollment Affect Marketing Contracts Participation: Theory and Empirical Evidences

A1. Proof for Proposition 1

Proof. We first let $T_i = \frac{1}{U'(\pi_i)} + \lambda + \mu_1 \frac{U''(\pi_i)}{U'(\pi_i)}[p\bar{q}(2-i) - r'] - \mu_2[\frac{U''(\pi_i)}{U'(\pi_i)} - \frac{f_a}{f}]$ for $i = 1, 2$. Then the first order condition for the maximization problem can be written as:

$$(13) \quad U'(\pi_1)\int_0^{b\bar{q}} T_1 dq + U'(\pi_2)\int_{b\bar{q}}^{q_M} T_2 dq = U'(\pi_2) - U'(\pi_1).$$

Note that if there is no crop insurance, then the IC constraint for insurance purchase $EU_b = 0$ is always non-binding, and we should have $\mu_1 = r(\alpha) = 0$. In this case, from Ligon (2003), we know that the optimality condition implies that $T_1 = T_2 = 0$ for all $q \in [0, q_M]$. But this cannot happen with crop insurance as the right hand side of the FOC is $U'(\pi_2) - U'(\pi_1)$, which can be zero only at the point $q = b\bar{q}$. Note that the difference between π_1 and π_2 is $p(b\bar{q} - q)$. Thus, whenever $q > b\bar{q}$, we have $\pi_2 > \pi_1$, which in turn implies that $U'(\pi_2) < U'(\pi_1)$. Also note that the Lagrangian is concave in $w(q)$ and $\mathscr{L}_{w^*(q)} = 0, \mathscr{L}_{w^{**}(q)} < 0$, we must have $w^*(q) < w^{**}(q)$ for all $q > b\bar{q}$. And similarly, we have $w^*(q) > w^{**}(q)$ for all $q < b\bar{q}$.

For the second part of our claim, notice that the actuarially fair premium rate is defined to be

$$(14) \quad r(b) = \int_0^{b\bar{q}} b\bar{q} - qfqdq.$$

As shown in Babcock (2012), when premium rate is actuarially fair, we must have $b^* > 0$. When there is no crop insurance available, we have $b = r(b) = 0$. Then the participation constraint implies that

$$(15) \quad EU(a,b) > \underline{U}.$$

Therefore, the participation constraint: $EU(a,b) > \underline{U}$ is more likely to be satisfied when crop insurance is available, as we must have

(16) $EU(a,b^*) > EU(a,0)$.

Therefore, as long as crop insurance premium rate equals or under actuarially fair premium rate, farmers are more like to participate in agricultural contracts when crop insurance is available. ■

A2. Proof for Proposition 2

Proof. First of all, notice that $EU_c > 0$, thus, when c increases from c_0 to c_1, we have $EU(c_1) > EU(c_0)$, which makes the participation constraint more likely to be satisfied.

To show the second part of the claim, we rewrite the FOC as:

(17) $$\mathscr{F} = U'(\pi_1)(\int_0^{b\bar{q}} T_1 dq + 1) + U'(\pi_2)(\int_{b\bar{q}}^{q_M} T_2 dq - 1) = 0.$$

By the second order condition of the problem, we know that $\frac{d\mathscr{F}}{dw(q)} < 0$.

Note that

(18) $$\frac{d\mathscr{F}}{dc} = U''(\pi_1)(-r_c)(\int_0^{b\bar{q}} T_1 dq + 1) + U'(\pi_1)\int_0^{b\bar{q}} \frac{r_c}{U''(\pi_1)} dq + U''(\pi_2)(-r_c)(\int_{b\bar{q}}^{q_M} T_2 dq - 1) + U'(\pi_2)\int_{b\bar{q}}^{q_M} \frac{r_c}{U''(\pi_2)} dq$$

By the assumption of CARA, we must have $R = \frac{U''(\pi_1)}{U'(\pi_1)} = \frac{U''(\pi_2)}{U'(\pi_2)}$. Therefore, using the FOC (equation 10), we have:

(19) $$U''(\pi_1)(-r_c)(\int_0^{b\bar{q}} T_1 dq + 1) + U''(\pi_2)(-r_c)(\int_{b\bar{q}}^{q_M} T_2 dq - 1) = -r_c R[U'(\pi_1)(\int_0^{b\bar{q}} T_1 dq + 1) + U'(\pi_2)(\int_{b\bar{q}}^{q_M} T_2 dq - 1)] = 0$$

Finally, putting equation (12) into equation (11), we get:

(20) $$\frac{d\mathscr{F}}{dc} = U'(\pi_1)\int_0^{b\bar{q}} \frac{r_c}{U''(\pi_1)} dq + U'(\pi_2)\int_{b\bar{q}}^{q_M} \frac{r_c}{U''(\pi_2)} dq > 0,$$

as $U''(\cdot) < 0$ and $r_c < 0$. Therefore, we have $\frac{dw^{**}}{dc} = -\frac{d\mathscr{F}}{dc} / \frac{d\mathscr{F}}{dw(q)} > 0$ for all $q \in [0, q_M]$. ■

Figures

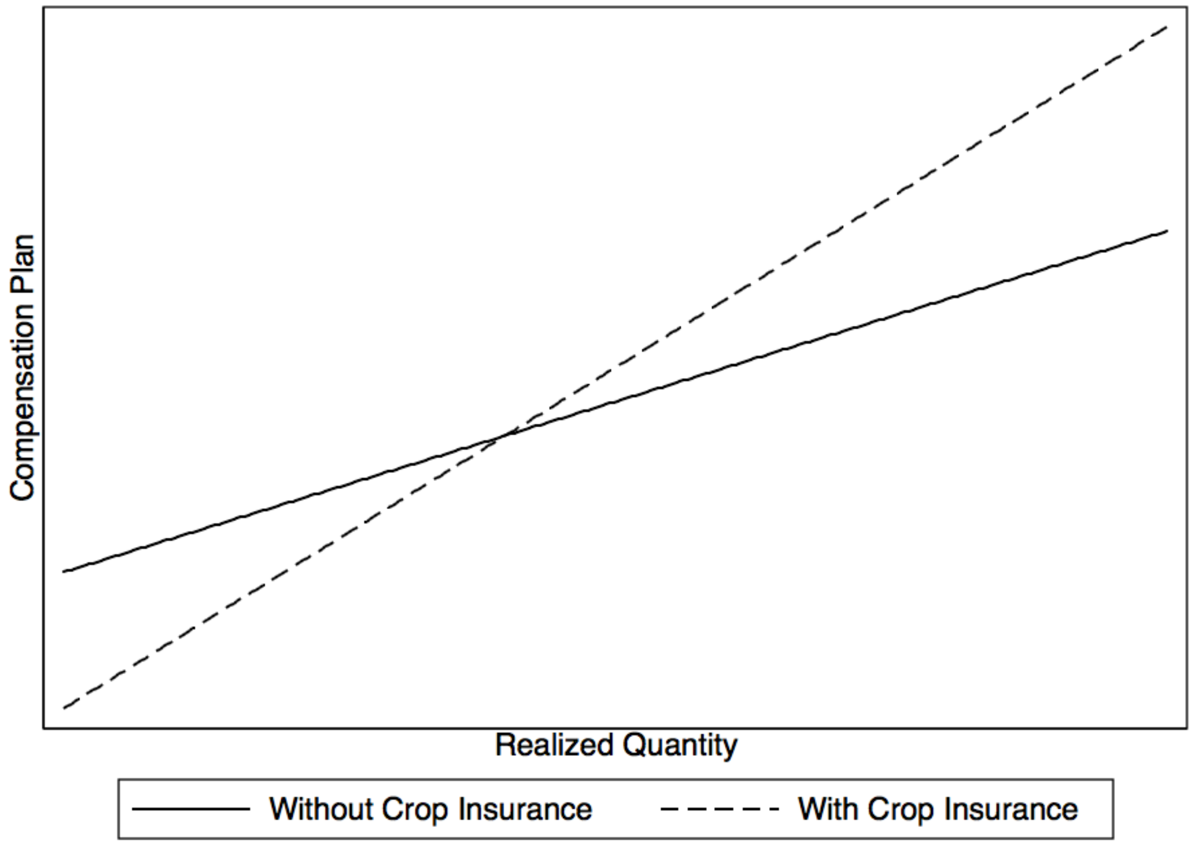
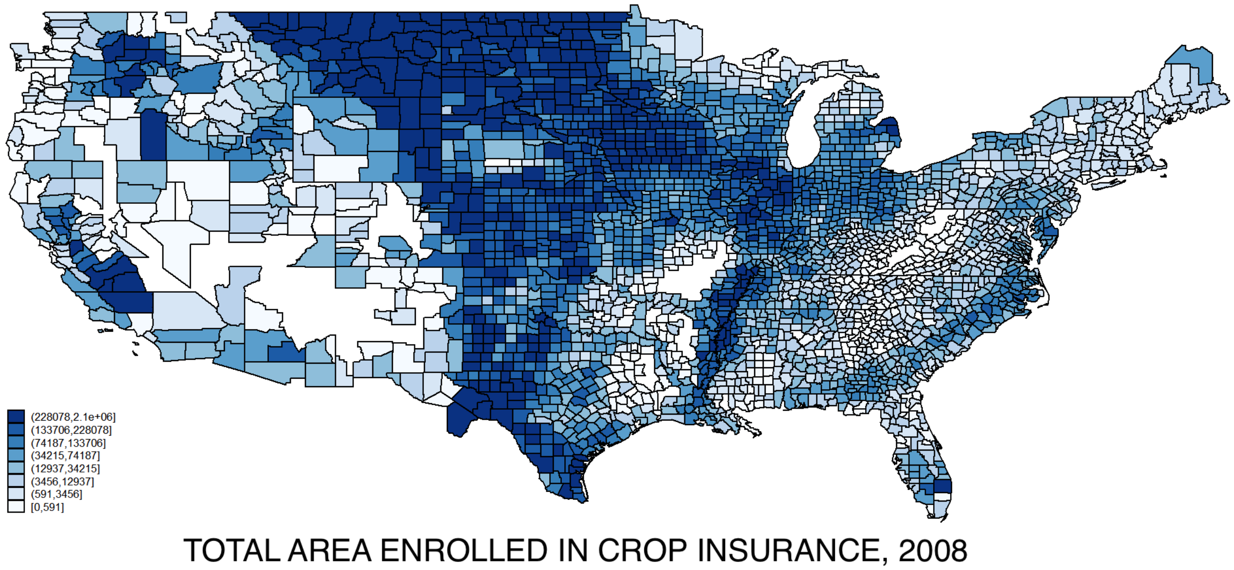


Figure 1. Compensation Plan With and Without Crop Insurance



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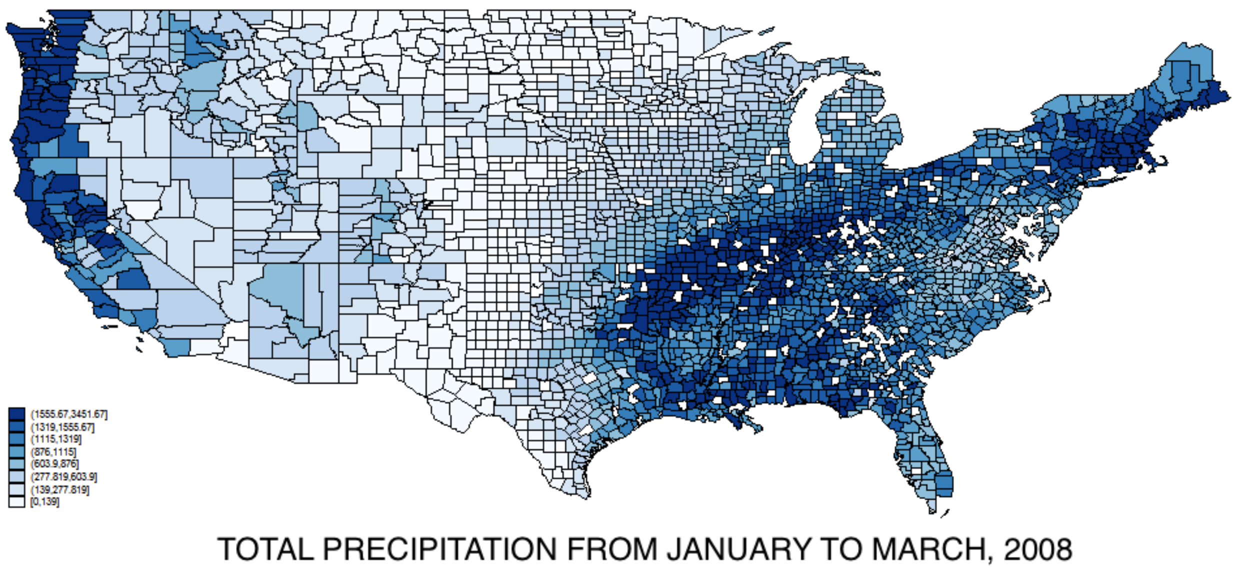

Figure 2. Crop Insurance Enrollment and Total Precipitation, 2008

Tables

Table 1. Summary Statistics

Variable	Farms without FCI enrollment Mean	Farms without FCI enrollment Std. Dev.	Farms with FCI enrollment Mean	Farms with FCI enrollment Std. Dev.
Marketing Contract Participation	0.23	0.42	0.49	0.50
Max. Temperature(°F)	50.29	12.81	46.31	12.91
Min. Temperature(°F)	29.87	11.41	25.30	11.55
Total Precipitation(inches)	844.35	536.83	632.95	444.82
Farm Type (Percentage in the sample)				
General Cash Grain	0.07	0.26	0.18	0.39
Wheat	0.03	0.17	0.10	0.30
Corn	0.10	0.31	0.26	0.44
Soybean	0.07	0.26	0.10	0.30
Grain Sorghum	0.002	0.04	0.006	0.08
Rice	0.02	0.13	0.02	0.15
Tobacco	0.02	0.12	0.03	0.16
Cotton	0.02	0.13	0.07	0.26
Peanut	0.004	0.07	0.01	0.10
General Crop	0.24	0.43	0.08	0.27
Fruits and Tree Nuts	0.18	0.38	0.10	0.30
Vegetables	0.06	0.25	0.03	0.16
Nursery and Greenhouse	0.18	0.38	0.02	0.14
Principal Operator's Education				
Some High School or Less	0.06	0.25	0.04	0.19
Completed High School	0.41	0.49	0.39	0.49
Some College	0.26	0.44	0.31	0.46
Completed College	0.25	0.43	0.26	0.44
Graduate School	0.02	0.13	0.01	0.10
# of Observations	35679		48643	

Years of observations are from 2003 to 2011. The maximum and minimum temperature are averaged over January to March in an given year, the precipitation is the sum over January to March in an given year.

Table 2. First Stage: Using Weather Variables to Predict FCI Enrollment

	FCI Enrollment			
	(1)	(2)	(3)	(4)
Min. Temp.	-0.004***	-0.0031***	-0.0036***	-0.0034***
	(0.00009)	(0.0005)	(0.001)	(0.0008)
Max. Temp.			-0.0003	0.00026
			(0.0007)	(0.0005)
Total Precipitation	-0.00012***	-0.00008***	-0.0001***	-0.00008***
	(0.00001)	(0.0000)	(0.00001)	(0.0000)
General cash grain		0.012		0.012
		(0.031)		(0.031)
Wheat		0.021		0.021
		(0.024)		(0.024)
Corn		0.016		0.016
		(0.029)		(0.029)
Soybean		-0.068***		-0.067***
		(0.023)		(0.023)
Grain Sorghum		0.000		0.000
		(.)		(.)
Rice		-0.002		-0.002
		(0.035)		(0.036)
Tobacco		0.038		0.039
		(0.039)		(0.039)
Cotton		0.080**		0.081**
		(0.039)		(0.039)
Peanut		-0.015		-0.015
		(0.033)		(0.033)
General crop		-0.413***		-0.413***
		(0.047)		(0.047)
Fruits and tree nuts		-0.255***		-0.255***
		(0.033)		(0.033)
Vegetables		-0.348***		-0.347***
		(0.036)		(0.036)
Nursery and greenhouse		-0.561***		-0.561***
		(0.039)		(0.039)
Constant	0.735***	0.702***	0.772***	0.796***
	(0.050)	(0.058)	(0.070)	(0.064)
Year and State FE	Y	Y	Y	Y
Farm Demographics	N	Y	N	Y
# of obs.	80386	80386	80333	80333
R^2	0.144	0.282	0.144	0.282
F-stat for IVs	91.43	77.03	80.31	50.37

Standard errors in parentheses, clustered at strata level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3. Second Stage: Effect of FCI Enrollment on Contract Participation

	Marketing Contract Participation			
	(1)	(2)	(3)	(4)
Predicted FCI Enrollment	0.437***	0.376***	0.439***	0.374***
	(0.058)	(0.068)	(0.058)	(0.067)
General cash grain		0.180***		0.180***
		(0.028)		(0.027)
Wheat		-0.021		-0.021
		(0.025)		(0.025)
Corn		0.200***		0.200***
		(0.026)		(0.026)
Soybean		0.102***		0.102***
		(0.027)		(0.027)
Grain sorghum		0.000		0.000
		(.)		(.)
Rice		0.174***		0.174***
		(0.036)		(0.036)
Tobacco		0.517***		0.518***
		(0.031)		(0.031)
Cotton		0.320***		0.320***
		(0.033)		(0.033)
Peanut		0.443***		0.443***
		(0.037)		(0.037)
General crop		0.128**		0.127**
		(0.062)		(0.062)
Fruits and tree nuts		0.134***		0.134***
		(0.035)		(0.035)
Vegetables		0.184***		0.184***
		(0.064)		(0.064)
Nursery and greenhouse		-0.063		-0.064
		(0.047)		(0.046)
Constant	0.137***	-0.022	0.135***	0.021
	(0.042)	(0.067)	(0.042)	(0.063)
N	80386	80386	80333	80333
R^2	0.046	0.141	0.046	0.141
Year and State FE	Y	Y	Y	Y
Farm Demographics	N	Y	N	Y

Standard errors in parentheses, clustered at strata level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4. Impact of Total Precipitation on Crop Insurance Enrollment

	Total Acreage Enrolled in Crop Insurance
Barley×Precipitation	-11.55***
	(3.162)
Corn×Precipitation	11.12**
	(3.564)
Grain Sorghum ×Precipitation	-5.449***
	(1.206)
Peanuts ×Precipitation	0.285
	(2.291)
Potatoes ×Precipitation	-10.63***
	(2.773)
Rice×Precipitation	4.031
	(2.780)
Soybeans ×Precipitation	14.71***
	(3.442)
Tobacco ×Precipitation	0.0858
	(1.399)
Cotton ×Precipitation	6.831***
	(1.180)
Wheat ×Precipitation	2.597
	(2.599)
Other Crops×Precipitation	-8.144***
	(2.194)
Constant	14460.3***
	(1248.1)
Year and County FE	Y
N	259156
R^2	0.169

Standard errors in parentheses, clustered at state level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$