Hedging The Price Risk of Crop Revenue Insurance Through the Options Market

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Abstract

Insurance companies typically do not insure systematic risks. However, crop revenue insurance is an exception in that revenue insurance, as specified by the USDA, offers a guarantee subsuming a highly systematic risk- price variability. This study examines how crop insurance companies could use put options to hedge the price risk present in the corn revenue insurance. The behavioral model used to examine hedging optimization behavior of a crop producer with crop insurance by Coble, Heifner and Zuniga is modified to examine the optimal hedge ratio of a company selling revenue insurance. The crop insurance summary of business from 1985-2015 for corn revenue insurance policies is simulated. Data on corn futures prices from the Commodity Research Bureau (CRB) database were used. The results show that regardless of degrees of risk aversion, the insurer maximizing expected utility will not choose to hedge. This suggests hedging the price risk through the put options is not a potentially viable practice for the crop insurers.

Keywords: Crop revenue insurance, price risk, optimal hedge ratio

Introduction

Insurance companies protect insured individuals against losses that result from risky or uncertain situations in exchange for a premium. The purchase of an insurance policy does not mean the risks are completely eliminated but in fact, the risks are transferred from the insured to the insurer. Insurance companies try to mitigate these risks by pooling a large number of independent exposures units. Through risk pooling, a policyholder shares his/her economic burden resulting from the uncertain situation, that could be damaging to him/ her, with a large number of people insured against similar events but who do not suffer losses at the same time. Pooling of a larger number of homogeneous and independent risk units is one of the essential conditions for a risk to be insurable (Rejda 1995). Catastrophic events are not insurable when losses are strongly positively correlated among all individuals at the same time thereby resulting in huge losses to the insurance company. In other words, the insurance company typically does not insure systematic risks. However, revenue insurance is one of the exceptions in the crop insurance industry in that the guarantee subsumes a highly systemic risk- price variability.

In the U.S., crop revenue insurance is designed, rated, and underwritten by the USDA Risk Management Agency. However, the policies are delivered by the private firms who share in the risk exposure of the policies they sell. Crop revenue insurance indemnifies the deficit in the farmer's gross revenue which results from either low yield or low price or a combination of the two. The USDA revenue protection plan uses the change in commodity futures prices from a time period before planting to approximately the harvest month for the price risk component. If the indemnities are triggered by low prices then the crop insurance company has to compensate all of its policyholders holding the revenue insurance at the same time. In such a situation the company might be unable to meet its liabilities towards all of its clients and the company may be declared bankrupt.

The failure of an insurance company potentially costs its policyholders, stakeholders, shareholders, the insurance industry, and the economy as a whole. Massey et al. (2000) have highlighted the following reasons to care about the failure of an insurance company:

- At the time of failure, if the policyholders have an outstanding claim then, there are chances that it will not be paid or paid fully. The unexpired premium may not be paid back to the policyholders. However, in the case of federal crop insurance policies, if the policyholders have an outstanding claim then the federal government would pay the claim.
- Each and every shareholder has invested in the company with the hope of earning a return in the form of a future dividend.
- The general public lose their faith in the insurance company. Fewer people having greater exposure to risk buy the insurance and risk pooling becomes more difficult for the insurance companies.

It is important to understand how the insurance companies hedge their risks. While the U.S. crop insurance companies are partially protected from the insured risk by the standard reinsurance agreement, the companies still retain a significant amount of the risk. In order to hedge their risks, the crop insurance companies can use a wide variety of the derivative instruments. These instruments include negotiated reinsurance and standardized contracts like futures and options. However, until now no detailed study has been conducted to understand the use of the derivative instruments by the crop revenue insurance providers to hedge the price risk.

The question that this study addresses is whether an investment in put options hedges the price risk of corn revenue protection policies. The value of the investment is represented by how much the crop revenue insurer is willing to pay for the risk transferred by the put options.

Literature Review

The literature review section of this study illuminates why the crop insurance companies might use put options or the futures market.

Reasons for Investing in the Options Market

The following are some major reasons for crop revenue insurance providers to invest in the option contracts:

- Increase in the demand for crop revenue insurance providing protection against systematic risks
- Profit motive intentions of crop insurance companies and private reinsurance companies
- Efficiency of the options market to hedge the systematic risks

Increase in the Demand for Crop Revenue Insurance

In recent years, demand for revenue insurance has increased rapidly. RMA data show that the revenue-based policies account for three-quarters of the 2.2 million crop insurance policies that were active in 2015. On a premium basis, revenue policies account for 84%

of all the policies (USDA 2015). Shaik et al. (2008) argued that the farmers who perceived greater yield or price risk are likely to purchase revenue insurance rather than yield insurance because the revenue insurance products like CRC (Crop Revenue Coverage), which has been renamed RA (Revenue Protection) provide greater per unit indemnities if the prices increased prior to harvest.

Further, the crop insurance policies are heavily subsidized by the federal government. The subsidy given to the crop producers differs by the type of policy, unit structure, coverage level and type of coverage, ranging from 100 percent for catastrophic coverage to 38 percent for 85 percent coverage (Lusk 2016).

But the crop revenue insurance policies provide the protection against the risks that are correlated among the exposures units. Crop prices are highly spatially correlated whereas yields may be correlated spatially depending on factors such as weather and disease (Coble and Dismukes 2008). Bulut et al. (2011) argued that despite the natural hedge between price and yield, sometimes large decline in harvest price can result in large aggregate indemnity payments which must be borne by revenue insurance providers and USDA.

Miranda and Glauber (1997) estimated that the insurance portfolio of the ten largest crop insurers was 20 times riskier than the portfolio of the insurers hedging independent risks. In order to hedge the systematic risk present in their portfolio, the insurance companies are purchasing reinsurance or derivative instruments reflecting the risk averse nature of the insurance companies.

Crop Reinsurance Industry

In the US, the private insurance companies who are chosen to write crop insurance policies in a state must offer the policies to any farmer in the state as per the rates and underwriting provisions established by the RMA. To encourage the delivery of crop insurance in all regions of the country, including the areas where potential gains are low or risk exposure is high, the government provides reinsurance to the private companies. The US government has tried to limit crop insurers' exposure to underwriting risk through the SRA (Standard Reinsurance Agreement). According to the SRA, crop insurance companies can transfer their huge risk to RMA by allocating their policies into two different risk-sharing funds: Assigned Risk Fund and Commercial Fund. By assigning risky policies to the Assigned Risk fund, the insurers can transfer about 80 percent of their net losses in exchange for the same percent interest in premium. The insurers can retain at least 35 percent interest in premium and associated net losses in the Commercial fund (SRA 2015). Coble et al (2007) argued that over the past years the insurers have retained more premium themselves, which has increased their exposure to risk dramatically. Thus it seems reasonable to assume that the companies must find an alternative way to hedge their underwriting risks.

Private crop insurance companies can even purchase insurance for their portfolio from the private reinsurance companies. Reinsurance by transferring risks helps the crop insurance companies to stabilize reserves (Duncan and Myers 2000). Porth (2011) shows that private reinsurance is needed to diversify risk and operate a stable crop insurance program in Canada**.**

However, Miranda and Glauber (1997) argued that like small insurers, the reinsurance industry is unwilling or unable to offer policies that compensate systematic risk because it will be costly for reinsurers to hold the sufficient reserves that cover huge losses resulting from systematic risk. Further, there arises an incentive problem: the more risk is transferred to a reinsurer, the less incentive the insurance company has to select low-risk policyholders, to reduce claim costs and to classify losses as being covered under the reinsurance contract (Mann 1992). Reinsurance companies have devised various contractual provisions and business practices such as coinsurance arrangement, deductible arrangement, explicit contingent pricing schemes, experience ratings to deal with this problem (Mann 1992).

Reinsurance contracts whether offered by private reinsurer or the government share risk between the insurance company and the reinsurer. In other words, the insurance companies are not able to transfer all of its underwriting risk or systematic risk to a reinsurer.

Bulut, Schnapp, and Collins (2011) argued that in recent years the federal government has reduced its support and funding for the crop insurers. The 2008 farm bill reduced funding in the reinsurance program by 6.4 billion dollars for the coming years. In 2011, the SRA reduced expected company benefits by an additional 6 billion dollars. This mostly came in the form of a reduced reimbursement for delivery. In 2012, in order to reduce the deficit in the budget, the President suggested cutting an additional 6 billion dollars from the program over ten years. Having taken cuts in the governmental provided reinsurance, crop insurers to look for alternative ways to hedge their risk. A possible way to hedge systematic risk is to use the futures or options instruments.

Efficiency of the Options Market to Hedge the Systematic Risks

According to Carter (2007), hedging entails participating in the futures or options market to neutralize the effects of price risk by transferring the risk from hedgers to speculators. He further argued that the futures and options markets have been developed to correct market inefficiencies in commodity markets through the provision of intertemporal prices. Mann (1992) claimed that the futures and options markets play important role in discovering prices, shifting price risk and disseminating information. Moreover, he asserted that the futures and options contracts are traded on organized exchanges, are highly standardized and the exchange clearing house acts as a guarantor of all the contracts therefore reduced the need of traders for monitoring the other party's creditworthiness. Hence, the futures and option markets can transfer systematic risk more efficiently as compared to the reinsurance.

Even though there are basic similarities between the futures and options, the buyer of the option enjoys more benefits as compared to the buyer of the futures as the buyer of either a put or call faces limited risks, does not have to deposit margin calls, can exercise multiple hedging strategies (Carter 2007). Carter (2007) reasoned that options contract is similar to the traditional price insurance than the futures because either a floor or a ceiling price can be established with options. Thus, options contract is more versatile tool for hedging as compared to the futures.

According to Luna (2012), most insurance companies mainly hedge their underwriting and investment risks through derivative markets. In 2014, the National Association of Insurance Commissioners reported that 94 percent of insurers are hedging at least some of their risk exposure using derivative instruments. Out of that, life insurers accounted for approximately 94 percent of the total industry notional value, property and casualty insurers accounted for 6 percent. Swaps accounted for the largest share (49 percent) of the total industry notional value, followed by options (45 percent), futures (3 percent) and forwards (3 percent).

In the context of the crop insurance industry, many researchers have focused their studies on how crop insurance companies manage their risk through reinsurance, especially through the SRA. Hedging by the crop insurer through derivatives instruments has been rarely examined. Driedger, Porth, and Boyd (2016) recently analyzed the possibility of using futures and options to manage yield insurance losses on Canola in Western Canada. They studied the effectiveness of using the long futures position and long call option position in reducing the losses. They found that these hedge positions added to the insurance losses as compared to unhedged positions when the futures price declined. But the potential use of the put options to mitigate the price risk present in corn revenue protection policies has not been examined till now. This paper appraises whether is it possible to hedge the crop insurer's underwriting risk resulting from price decline through put options and if it is possible, then how much the crop insurer is willing to pay for the contracts.

Conceptual Framework

Expected Utility from the Crop Insurer Perspective

Assuming the von Neumann-Morgenstern axioms of behavior, the crop insurer maximizes its expected utility which is a function of end-of period wealth. The assumption that the crop insurer is risk averse rather than risk neutral implies its utility function is strictly increasing, concave and twice continuously differentiable.

We are considering only the revenue protection policies for corn. The crop insurance company's book of business mentioned below represents the compensation paid by the corn revenue protection policies for covering different coverage out of the total premium paid for the policies when harvest price or expected yield declines.

(1) $$B = \sum_{i=1}^{n}\sum_{j=1}^{n}\left[P_{r_{ij}} - Max\left(0,\left(C_{l_{ij}} Max(f_{0I}, f_1) y_{gi} - f_1 y_i\right)\right)\right]$$

where

B = Insurance Book

$P_{r_{ij}}$ = Premium of ith farm for jth coverage level

j = Coverage level j

$C_{l_{ij}}$ = Coverage level j for ith farm

f_{0I} = Spring futures price determined before sales closing

f_1 = Futures harvest price

y_{gi} = Expected yield for ith farm

i = Number of farms for coverage j

y_i = Actual yield for ith farm

If $C_{l_{ij}} Max(f_{0I}, f_1) y_{gi} > f_1 y_i$, then the indemnity is paid.

If $C_{l_{ij}} Max(f_{0I}, f_1) y_{gi} < f_1 y_i$, then the indemnity is equal to zero.

The indemnity a crop insurance company has to pay depends on the policy holder's coverage levels, his/her yields and the level of price declines. To hedge the price risk, the insurer buys the put options from the futures market at a cost called put options premium. A put option contract provides the owner the right to sell a futures contract on a particular commodity at a specified price (strike price), with the right lasting until the maturity date of the contract (Kolb 1996). The put options will be exercised only when the price of the underlying futures contract falls below the strike price ensuring a certain return to the insurance company. In this way, a put option provides protection against the price decrease. On the contrary, if the price of the underlying futures contract rises above the strike price, the put options will not be exercised and the loss for the buyer equals to the option premium. The net return form a put option contract NP is given below:

(2) $$NP = \delta \times h \times Max\left[0, \left(S_0 - f_{0h}\right)\right] \times Q - PP_{s_o}$$

where

f_{oh} = The futures price of the underlying futures contract

S_0 = Strike price of the put option

PP_{s_0} = Put option premium

h = Percentage of quantity (Q) hedged

Q = Bushels per contract

$\delta = 1$ if $S_0 > f_{oh}$

$\quad = 0$ if $S_0 < f_{oh}$

The crop insurer's initial wealth W_0 is assumed to be one million dollars. End-of period wealth W_e of the company depends on whether the company has to indemnify or not and the return on any put options purchased which can be expressed as follows:

(3) $$W_e = W_0 + \sum_{i=1}^{n}\sum_{j=1}^{n}\left[P_{r_{ij}} - Max\left(0, \left(C_{l_{ij}} Max(f_{0I}, f_1) y_{gi} - f_1 y_i\right)\right)\right] + NP$$

The insurer's utility function is assumed to exhibit constant relative risk aversion (CRRA) and the risk aversion values of 1 to 3 are assigned where the lower value reflects lower degrees of risk aversion and vice-versa. A CRRA utility function is given by

$$(4) \qquad \begin{cases} U(W_e) = \dfrac{W_e^{(1-R)}}{(1-R)} & \text{for } (R \neq 1) \\ U(W_e) = \ln W_e & \text{for } (R=1) \end{cases}$$

where R = degree of risk aversion

Carter (2003) defined the optimal hedge ratio as the most desirable combination of cash and options positions and is chosen based on the shape of the hedger's indifference curve. The insurance company will choose to hedge at the ratio that maximizes its expected utility. Assuming two insured policies, the objective function that maximizes the expected utility is expressed as:

$$(5) \qquad \underset{h}{Max}\ L = \int\int\int U(W_e)\, f(y_1, y_2, f_1)\, dy_1 dy_2 df_1$$

With a first Order Condition

$$(6) \qquad L_h = \int\int\int U(W_e) \times \delta Q(S_0 - f_1)\, f(y_1, y_{2,} f_1)\, dy_1 dy_2 df_1$$

A certainty equivalent is a certain amount of the income that a risk-averse individual finds equally desirable relative to the gamble. The certainty equivalent (CE_R) based on the above utility function is given below:

$$CE_R = e^{U(w_e)} \quad \text{if} \quad (R=1)$$
(7)
$$CE_R = \left[U(W_e)(1-R)\right]^{1/1-R} \quad \text{if} \quad (\text{R} \neq 1)$$

If the hedging through the put options eliminated the downside price risk and simply assured that the company would receive expected level of wealth $E(W_e)$, the company willingness to pay (WTP) for this benefit is equal to the difference between the expected wealth and certainty equivalent.

(8) $$WTP = E(W_e) - CE_R$$

Model and Data

The behavioral model which is used to examine the planting-time optimization characteristics of a crop producer with yield insurance by Coble, Heifner and Zuniga was modified to the examine optimal hedge ratio of crop revenue insurers as both the crop producers and insurers are calculative about their wealth in multiple states of the world (good and bad), and are trying to reduce losses if there is a chance of bad state occurring through futures and options. End-of period wealth of the crop insurer was calculated as the sum of initial wealth, the premium received from selling the insurance and the return from the put option positions minus indemnity paid and the put option premium.

The insurer's expected utility which is the function of end-of period wealth was simulated over the period,1985- 2015, using SAS. First we simulated the crop insurance company's book of business for corn revenue protection policies.

Indemnity Simulation

We simulated each component that determines the indemnity including the projected price, the harvest price, the expected yield and the actual yield.

Yield variability for this study was simulated based on the model constructed by Coble, Dismukes and Thomas (2007) while they were analyzing the policy implications of crop yield and revenue variability at differing levels of disaggregation. The linear time trend was estimated for 538 counties of 28 states having complete yield data series from 1985 to 2015, obtained from USDA'S National Agricultural Statistics Service (NASS). We calculated residuals and predicted yield for 2017 which represents the aggregate yield for each county. The estimated aggregate yield underestimates the individual yield variability of the county. So we added a random variable (residual) to inflate the risk to a level consistent with RMA base rates. The representative farm is assumed to have a mean yield equal to the expected county yield and yield variability consistent with the average riskiness of farms participating in the revenue protection program.

Data on daily corn futures prices were obtained from the Commodity Research Bureau (CRB) database. Following the approach used by RMA to set the projected and harvest time prices for the crop insurance contracts, the daily closing futures price for the harvest month contract was obtained for all trading days in February and a mean value is computed. The same calculation was performed for the month prior to expiration for the same contract in the same year, which allows the computation of the price changes from planting to harvest time. We then normalized the historical prices by around the projected price for 2017 equals to the 3.86 dollars per bushels and the harvest price also normalized to 2017 price levels as the product of the 2017 projected price and the price ratio. The price ratio equals to the ratio of the harvest price to the projected price of each year.

Using 2016 summary of business data obtained from USDA's RMA, the acreage weighted average corn coverage level for revenue protection policies in each county was calculated.

After having computed each component, we then calculated the indemnities that could be indemnified by the corn revenue protection policies with and without harvest price exclusion for each farm. Then the farm level indemnities were weighted by the 2016 net acreages and summed to get the national level indemnities for both the policies for each year.

Premium Simulation

The Revenue Protection policy protects against downside revenue. Thus premium equaled the expected indemnity providing protection against the downside price risk for each farm. Each farm premium was summed to get the national level premium for each year after weighted by the 2016 net acreages.

Liability Simulation

To get the national level liability for each year, the liabilities for each farm was calculated as the product of 2017 projected price, weighted average corn coverage level and 2017 predicted yield of each farm which was then weighted by the 2016 net acreages and were added together.

The national level lability, indemnity and premium were normalized with respect to one million dollars of the liability for every year. The hedge ratio would be a percentage of a one-million-dollar liability.

Put Options Payout

If the crop insurance company wants to protect against the price risk, it would purchase the put options contracts after it sells the revenue protection policies and well before the harvest period. But the actual corn production is unknown for the crop insurer. So we assumed the crop insurer was hedging a certain percentage of one million bushels of corn through the put options contracts. We increased the hedging quantity by ten percent increment and calculated the put option payouts at each percentage as the percentage of one million bushels hedged times the difference between the projected price and the harvest price for each year. We considered the put options contract was at the money. The put options contract premium computed as the mean return of the put options payout from 1985-2015.

Expected Utility Simulation

We calculated expected value of ending wealth representing the multiple state of world and based on expected value of ending wealth we computed expected utility, over the period, 1985-2015, for different degree of risk aversion. Constant relative risk aversion values of 1 to 3 were assigned where the lower value reflects low degree of risk aversion and vice-versa. Then a grid search of the response of expected utility to variations in the hedge ratios was carried out. Then, this ratio was changed up and down in ten percent intervals and, certainty equivalent gain was calculated for every level of hedge ratio. The hedge ratio with highest certainty equivalent was the optimal one.

Results

Both the yield and price components of crop revenue are random variables that are subject to spatial dependence (systematic risk). It is obvious that the price risk is a systematic risk since both projected and harvest prices are derived from the futures markets. Sometimes yield variability is also subject to systematic risk if there is a positive correlation between a farm and nearby farms due to spatially correlated weather events or disease. In major production regions for corn and soybeans there is empirical evidence of a natural hedge between farm yields and aggregate prices (Coble, Heifner and Zuniga 2002). Thus we removed the major corn belt states, Ohio, Indiana, Illinois, Iowa and Missouri from our analysis so that the insurance company's portfolio reflect the price risk of corn revenue protection policies and we could use put options to hedge the risk.

Multiple states of the world were represented by the percentages of the quantities of corn the crop insurance company wants to hedge through the put options contracts. Initial wealth was assumed to be one million dollars. Mean and standard deviation of end-of period wealth for multiple state of world for corn revenue protection policies with and without harvest price exclusion are reported in table 1.

Table 1: Descriptive Statistics of End-of Period Wealth for two Corn Revenue Policies

Percentage of Hedge Quantity (%)	End-of Period Wealth			
	Revenue Protection Policies		Revenue Protection with Harvest Price Exclusion	
	Mean ($)	Standard Deviation (S.d.) ($)	Mean ($)	Standard Deviation (S.d.) ($)
0	992725.59	58222.32	998956.79	51536.39
10	992725.59	64806.70	998956.79	54969.93
20	992725.59	87903.90	998956.79	78131.33
30	992725.59	118200.68	998956.79	109107.44
40	992725.59	151435.88	998956.79	142903.75
50	992725.59	186041.30	998956.79	177920.34
60	992725.59	221375.30	998956.79	213557.79
70	992725.59	257137.71	998956.79	249550.26
80	992725.59	293171.79	998956.79	285763.63
90	992725.59	329388.39	998956.79	322123.40
100	992725.59	365733.29	998956.79	358585.05

Expected values of ending wealth for all possible investments in the put options contracts including the return from insurance business from the revenue protection policies are same, that is 992725.59 dollars. Similarly, mean of end-of period wealth which the crop insurer obtained through selling the corn revenue protection with harvest price exclusion and investing in the put options contracts in all states of the world to hedge the price risk is also same which equals 998956.79 dollars.

When the crop insurer has to choose between various investments alternatives with same expected value, it will always choose the one with a smaller variability of return. Here the size of deviation of ending wealth from the mean value for both the corn revenue policies is smaller when the crop insurer chooses not to invest in the put options contract. Thus the investment in the put options contracts is not worthwhile and thus hedging the price risk of the corn revenue protection policies through the put options is not viable practice.

Expected Utility and Certainty Equivalent gains

The crop insurance companies are assumed to be risk averse. Expected utilities for the both corn revenue protection policies with and without harvest price exclusion were calculated for different degrees of risk aversion and shown in table 2 and 3 to evaluate whether hedging through put option is feasible or not.

Clearly, the insurance company is better off if it does not invest in the put option contracts, regardless of its degree of risk aversion as the expected utility from selling the revenue protection policies with and without harvest price exclusion is greater than the expected utility with the put options contracts for every degree of risk aversion. Similarly, certainty equivalent gain is maximum when the crop insurance company does not hedge signifying the optimal hedge ratio is zero percent. Thus, the put option contracts are not able to eliminate the price risks of the corn revenue protection policies.

The company willingness to pay for the put option is given by the difference between the company's expected wealth and the certainty equivalent gain from hedging. As the crop insurer's expected ending wealth is same for both the revenue policies in each states of the world, the company willingness to pay increases as the certainty equivalent gains decreases for every degree of risk aversion. Similarly, the more risk averse the crop insurer is, more the insurer wants to pay for eliminating the price risk.

We even included the major production regions of corn, Indiana, Illinois, Iowa, Missouri and Ohio, where there is natural hedge between aggregate prices and farm yields, to examine whether put options is able to hedge the price risks of corn revenue protection policies with no harvest price exclusion. We reached to same conclusion, shown in table 4, that the crop insurance company, regardless of degree of risk aversion, is not better off by investing in the put options, certainty equivalent gains is maximum when percentage of quantity hedged is zero thus indicating optimal hedge ratio is zero percentage of liability.

Table 2: Expected Utility, Certainty Equivalent Gains & Willingness to Pay (WTP) for Corn Revenue Protection Policies with No Harvest Price Exclusion

Percentage of Hedge Quantity (%)	R=1			R=2			R=3		
	Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)	Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)	Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)
0	1	990878	1847.59	1	988803.26	3922.33	1	986467.34	6258.25
10	0.99	990389.48	2336.11	0.99	987704.05	5021.54	0.991	984602.25	8123.34
20	0.96	988584.24	4141.35	0.96	983972.10	8753.49	0.963	978788.45	13937.14
30	0.91	985545.01	7180.58	0.91	977852.37	14873.22	0.918	969516.26	23209.33
40	0.83	981330.74	11394.85	0.84	969515.20	23210.39	0.855	957121.66	35603.93
50	0.74	975981.44	16744.15	0.75	959075.21	33650.38	0.774	941831.96	50893.63
60	0.64	969521.36	23204.23	0.65	946603.30	46122.29	0.673	923795.16	68930.43
70	0.51	961960.85	30764.74	0.52	932134.25	60591.34	0.55	903098.78	89626.81
80	0.36	953297.43	39428.16	0.37	915671.01	77054.58	0.4	879781.49	112944.1
90	0.19	943516.03	49209.56	0.20	897186.51	95539.08	0.219	853839.41	138886.18
100	0	932588.47	60137.12	0	876623.08	116102.51	0	825227.91	167497.68

Note: R represents degree of risk aversion. The expected utility data are scaled up in the range 0 to 1 respectively.

Table 3: Expected Utility, Certainty Equivalent Gains & Willingness to Pay (WTP) for Corn Revenue Protection Policies with Harvest Price Exclusion

Percentage of Hedge Quantity (%)	R=1			R=2			R=3		
	Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)	Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)	Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)
0	1	997525.27	1431.52	1	995927.26	3029.53	1	994139.94	4816.85
10	0.995	997292.15	1664.64	0.995	995384.57	3572.22	0.995	993186.58	5770.21
20	0.968	995753.68	3203.11	0.968	992235.13	6721.66	0.969	988325.76	10631.03
30	0.919	992994.73	5962.06	0.920	986729.84	12226.95	0.924	980057.24	18899.55
40	0.849	989076.57	9880.22	0.853	979045.38	19911.41	0.861	968726.59	30230.2
50	0.759	984041.88	14914.91	0.766	969303.27	29653.42	0.779	954571.28	44385.51
60	0.649	977917.91	21038.88	0.658	957582.77	41374.02	0.677	937750.53	61206.26
70	0.518	970718.63	28238.16	0.530	943927.81	55028.98	0.552	918364.69	80592.1
80	0.367	962445.85	36510.94	0.379	928352.87	70603.92	0.401	896467.65	102489.14
90	0.194	953089.75	45867.04	0.204	910845.02	88111.77	0.219	872074.35	126882.44
100	0	942628.69	56328.1	0	891364.55	107592.24	0	845164.12	153792.67

Note: R represents degree of risk aversion. The expected utility data are scaled up in the range 0 to 1 respectively.

Table 4: Expected Ending Wealth & Utility, Certainty Equivalent Gains & Willingness to Pay (WTP) for Corn Revenue Protection Policies with No Harvest Price Exclusion Including Major Corn Production Region

Percentage of Hedge Quantity (%)	Expected Ending Wealth ($)	R=1			R=2			R=3		
		Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)	Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)	Expected Utility (Utils)	Certainty Equivalent Gains ($)	WTP ($)
0	985310.87	1	981969.20	3341.67	1	978077.78	7233.09	1	973552.73	11758.14
10	985310.87	0.982	980782.81	4528.06	0.982	975399.73	9911.14	0.983	969015.94	16294.93
20	985310.87	0.946	978275.96	7034.91	0.947	970085.57	15225.3	0.951	960542	24768.87
30	985310.87	0.891	974521.85	10789.02	0.895	962349.61	22961.26	0.905	948560.78	36750.09
40	985310.87	0.819	969570.33	15740.54	0.827	952333.75	32977.12	0.843	933355.56	51955.31
50	985310.87	0.729	963452.12	21858.75	0.741	940124.17	45186.7	0.765	915104.30	70206.49
60	985310.87	0.621	9561841.42	29129.45	0.637	925761.39	59549.48	0.668	893905.76	91405.11
70	985310.87	0.495	947757.27	37553.6	0.514	909245.68	76065.19	0.548	869794.12	115516.75
80	985310.87	0.350	938163.84	47147.03	0.369	890538.97	94771.9	0.403	842747.75	142563.12
90	985310.87	0.185	92739.75	57941.12	0.199	8695563.27	115747.6	0.223	812690.78	172620.09
100	985310.87	0	915326.32	69984.55	0	846195.43	139115.44	0	779489.12	205821.75

Note: R represents degree of risk aversion. The expected utility data are scaled up in the range 0 to 1 respectively.

Reasons for the Put Options Contract Unable To Hedge

In order to hedge the price risks of the corn revenue protection policies with and without harvest price exclusion, there should be strong positive correlation between the indemnity and the return from the put options contracts.

The correlation between the return from the put options contracts and indemnity paid from the corn revenue protection policies is 0.11321 which is not enough to hedge the price risk. Since the RP provides protection against both upside and downside price risk, the simple put options is not effective enough to transfer the price risk. If that is the case, then reinsuring with a put option would work better for the corn revenue protection policies providing protection against only the downside risk (RP-HPE). But still the correlation between the return from the put options and indemnity paid by RP-HPE is not strong enough for hedging though the correlation coefficient doubles.

Table 5: Correlation Matrix for Corn Revenue Protection Policies with no Harvest Price Exclusion

	Return from the Put Options	Indemnity
Return from the Put Options	1	0.11884
Indemnity	0.11884	1

Table 6: Correlation Matrix for Corn Revenue Protection Policies with Harvest Price Exclusion

	Return from the Put Options	Indemnity
Return from the Put Options	1	0.24862
Indemnity	0.24862	1

Conclusion

Insurance company typically do not insure systematic risks. However, crop revenue insurance is one of the exceptions which offers a guarantee against a highly systemic risk, the price risk. The crop insurance company has to indemnify all of its policy holders holding corn revenue protection policies if the price of corn falls. The best way to hedge systematic risk is to use put options on futures contract. The insurance companies selling the corn revenue protection insurance are not better off by investing in the put options, regardless of the degree of risk aversion as the expected utility and certainty equivalent gains are maximum when the crop insurer does not invest in the put option contracts indicating the optimal hedge ratio is zero percent.

A crop insurance company has multiple policies in each county but might not have a fully national portfolio. But we conduct our analysis based on the assumption that the distribution of business reflects all private crop insurers, thus the results of the study may not be applicable to crop insurers who have regional portfolio.

Further, we assumed the world where USDA reinsurance and other hedging tools for the crop insurer are not available and the insurer had to mitigate the risk through the derivative instrument, especially put options. The results distinctly indicate that considering only put options as a risk management tool is not appropriate. The crop insurers who want to offset price risk inherent in the corn revenue protection insurance should mix wide variety of hedging tools with Standard Reinsurance Agreement and/ or allocate its assets strategically.

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