Optimizing Crop Insurance under Climate Variability: CVaR Model

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Abstract— We proposed CVaR model to help farmers decide about buying crop insurance products to reduce climate and price risks, according to realistic risk aversion levels included in the CVaR function. In addition to the optimal crop insurance selection, the model would help farmers to allocate land to different planting dates for the included crops. The climate variability was caused by ENSO. Only a few studies have explored some interactions between common crop insurance contracts and the farm value of ENSO-based. CVaR has been shown to have a number of advantages compared to the more traditionally applied value at risk in decision settings that involve choices among truncated revenue distributions. Crop insurance contracts with minimized losses were75% actual production history (APH) during El Niño and neutral years and 65% APH during La Niña years for peanut and 75% APH in all ENSO phases for cotton. In addition, risk-averse farmers could select 75% APH for peanut during La Niña years as a means of attaining expected loss.

Index Terms— Crop insurance, Climate Risk, CVaR, ENSO.

INTRODUCTION

Crop insurance is a major component of risk management that farmers could use together with climate information to optimize their risk-return characteristic (Changnon et al., 1999). Farmers face climate and market risks that are out of their control. There are numerous crop insurance products farmers could use to reduce these risks. Consequently it is meaningful to optimize the farmers' crop insurance selection. The El Niño - Southern Oscillation (ENSO) phenomenon is a global event arising from large-scale interactions between the ocean and the atmosphere. Kane, Eshel, and Buckland (1994), Hansen, Hodges, and Jones (1998), Hansen (2002), and Jones et al. (2000) have investigated the connection between ENSO-based climate predictions and crop yields. More recently, some researchers have studied the impacts of the ENSO-based climate information on the selection of optimal crop insurance policies.Cabreraet al. (2006) examined the impact of ENSO-based climate forecast on reducing farm risk with optimal crop insurance strategy. Cabrera, Letson, and Podesta (2007) included the interference of farm government programs on crop insurance hedge under ENSO climate forecast.). Cabrera et al. (2005) presented a systematic study to strategize the selection of crop insurance products in a whole farm portfolio under climate variability. They analyzed risks associated with each ENSO phase, based on long series of synthetic crop yields and independent synthetic commodity prices. They identified optimal planting dates and crop insurance products by maximizing the farmers' expected utility for different risk aversion levels. The risk preference is specified in simple monetary terms with some confidencelevel (farmers might find it easy to decide by selecting their own level of per-sonal risk). For example, the statement 90% CVaR is less than 100$"means the average of the worst 10% outcomes must be less than 100$. CVaR is a coherent measure of risk, as defined by Artzner, et. al (1999), with Axiomatic-mathematical properties desirable for a perfect risk measure ".CVaR of a discrete random variable is a convex piece-wise linear function that can be optimized with linear programming. CVaR is more conservative than VaR due to the fact that CVaR greater than Var. and that it measures outcomes in the tail (beyond VaR). CVaR is an exceptional Risk measure and it is gaining popularity in various applications, especially in finance.

Three main types of crop insurances are the actual production history (APH) or multiperil crop insurance (MPCI), the crop revenue coverage (CRC), and the catastrophic coverage (CAT). APH assures a percentage of the farmers 'historic yield.
If the yield becomes lower than the insured percentage, the insurance pays an indemnity covering the difference between the insured percentage and the low yield. CRC assures income by indemnifying farmers based on historical yield and a prefixed market price, which is also called the price election. [This price is set by the Federal Crop Insurance Corporation (FCIC) before the sales closing date for the crop.] If the actual yield multiplied by the actual market price is lower than an indemnified income level, farmers are entitled to an indemnity payment. CAT can be defined as an APH policy at 50% yield coverage with 55% price-base election.

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Notations:
K = number of crop types;
Tk = number of planting dates for crop k;
Ik = number of insurance policies for crop k;
J = number of scenarios;
qk = planting area (in acres) available for crop k;
Ck = planting cost per acre of crop k;
Rki = premium of insurance policy i for crop k per acre;
Zkti = (random) revenue of crop k per acre planted on date t and insured by policy i;
Zktij = revenue of crop k per acre planted on date t and insured by policy i under Scenario j;
L_ = threshold of losses in probability exceeding penalty constraint;
p = the upper bound of the probability exceeding penalty constraint;
b = upper bound on CVaRc (L(x; Z))
v = upper bound on VaRc (L(X; Z))
Ykti = yield of crop k per acre planted on date t under scenario j;
Yk = (historical) average yield of crop k per acre;
Pki = market price of crop k per pound under scenario j;
pk = price base of crop k per pound.

Formulation:

Maximizing expected profit

$$\max X_{kti} \sum_{k=1}^{K} \sum_{t=1}^{T_k} \sum_{i=1}^{I_k} E\, Z_{kti} X_{kti} \qquad (1)$$

Subject to

Planting area constraint for each crop k

$$\sum_{t=1}^{T_k} \sum_{t=1}^{I_k} X_{kti} = q_k; k = 1,2 \ldots \ldots \ldots \ldots \ldots \ldots .., K \qquad (2)$$

Joint constraint on planting area and insurance policy

$$\sum_{t=1}^{T_k} X_{kti} \leq q_k X_{ki}^{@}; i = 1,2, \ldots \ldots \ldots \ldots .. i_k; k = 1,2, \ldots \ldots .. K \qquad (3)$$

Each crop k can be insured by at most one policy

$$Cardinalitypositivity(X_k^{@}, w) \leq 1; k = 1,2, \ldots \ldots \ldots \ldots .. K \qquad (4)$$

Risk constraint ($CV_aR, V_aR, and\ Probability\ Exceeding\ Penalty$)

$$CV_aR_c\big(L(x,Z)\big) \leq b; \qquad (5)$$

Or

$$V_aR_c\big(L(x,Z)\big) \leq v; \qquad (6)$$

Or

$$Prob(L(x,Z)) \geq L^*) \leq p; \qquad (7)$$

Constraint on additional variables

$$0 \leq X_{ki}^{@} \leq 1; i = 1,2, \ldots \ldots \ldots .. I_k; k = 1,2, \ldots \ldots .., K \qquad (8)$$

Lower bounds on variables

$$0 \leq X_{kti} \leq q_k; i = 1,2, \ldots \ldots \ldots .. I_k; k = 1,2, \ldots \ldots ., T_k \qquad (9)$$

Numerical Result:

Results of calculations using mat-lab programming are in the following tables and graphs.

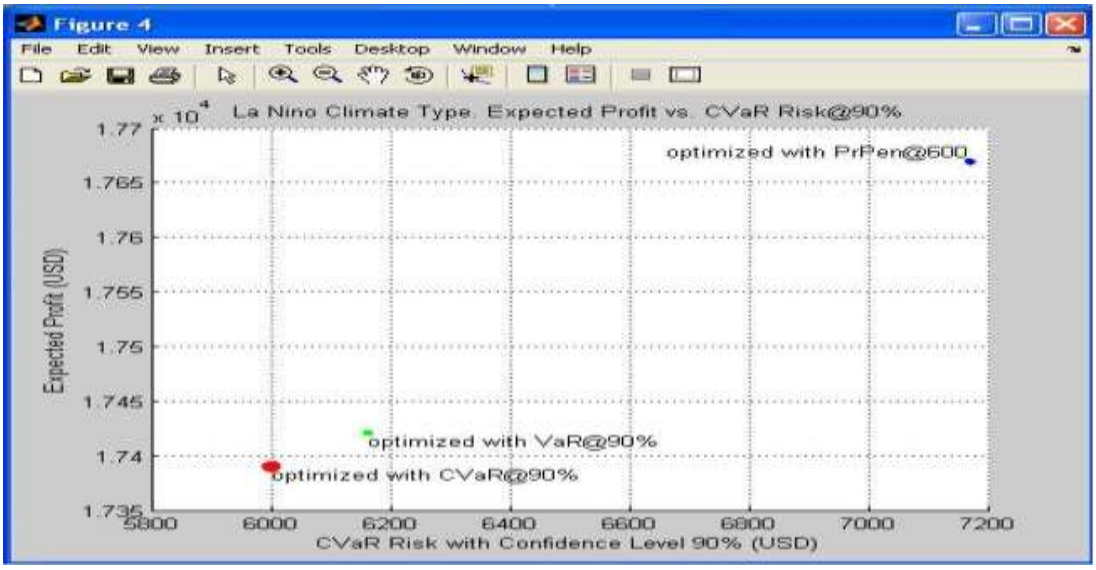
Planting area (in acre)variable	Crop Type	Planting Date	Insurance Policy	CVaR	PrPen	VaR
^{x}00	cotton	April,16	No-insurance	50.00	50.00	50.00

0						
x_{134}	peanut	May,8	75%APH	3.40	4.88	0.57
x_{144}	peanut	May,15	5%APH	0.00	0.00	1.00
x_{154}	peanut	May,22	75%APH	2.67	2.73	0.00
x_{164}	peanut	May,29	75%APH	13.01	11.11	16.98
x_{174}	peanut	Jun,5	75%APH	30.93	31.28	31.45

Table 1. Optimal Crop Production and Insurance Coverage for El Nino Climate Type.

Planting area (in acre)variable	Crop Type	Planting Date	Insurance Policy	CVaR	PrPen	VaR
x_{020}	cotton	May,1	No-insurance	0.00	1.13	0.00
x_{030}	cotton	May,8	No-insurance	50.00	48.87	50.00
x_{134}	peanut	May,8	75%APH	5.88	2.40	6.94
x_{144}	peanut	May,15	75%APH	27.41	38.00	29.33
x_{154}	peanut	May,22	75%APH	6.73	4.36	6.87
x_{164}	peanut	May,29	75%APH	9.98	4.59	6.11
x_{174}	peanut	Jun,5	75%APH	0.00	0.65	0.75

Table 2. Optimal Crop Production and Insurance Coverage for La Nina Climate Type



Conclusion:

This study analyzed the potential tradeoffs between farmers and insurers in the selection of an optimal crop insurance contract in the presence of climate variability. Our results show that our representative farmer's net returns is significantly affected by the crop insurance policy purchased and the risk aversion level selected. Long-run gains for insurers are directly related to the premium received and risk levels. In addition, year-to-year, ENSO-based climate variability affected farmer returns and insurer gains according to crop insurance contracts. This research studied the impact of the accuracy of the ENSO-phase forecasts and uncertain prices on crop-insurance decisions. A stochastic model was created to select optimal crop-insurance products for a certain year based on the ENSO-phase forecast. Taking advantage of the ENSO-based climate forecasts, the model can identify optimal crop-insurance products available in the crop-insurance industry.

Results showed that the insurance choices vary under different ENSO phases and risk-aversion levels. For a risk-neutral farmer, buying no insurance for cotton and 75% APH for peanut is the optimal solution for neutral and El Niño years and buying no insurance for cotton and 65% APH for pea-nut is the optimal solution for a La Niña year. The

Insurance strategy for peanut in La Niña years changed to 70% APH for a risk-averse farmer and to 75% APH for a highly risk averse farmer.

Although we did find evidence of conflicting interests between insurers and farmers regarding crop insurance selection, their best choices are seldom contradictory. So, if both parties are willing to show flexibility regarding their best selections, then farmers and insurers can both attain long-term sustainability without jeopardizing their economic stability. However, only the insurer has the capacity to change the underwritten crop insurance policy contracts under the commitment to help farmers attain economic stability. Therefore, the insurer would have a greater ability to resolve these conflicts of interests. Using ENSO-based climate forecast would be a factor in this decision selection process

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