Hedging Downside Risk To Farm Income With Futures And Options: Effects Of Government Payment Programs And Federal Crop Insurance Plans

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Introduction

Price and production uncertainty contribute the two main sources of risk to a crop producer's farming income. Market strategies consider futures and options as the only risk management instruments to protect farmers from undesired low farm income resulting from lower crop prices at harvest. But U.S. crop producers, in addition to futures and options, have access to two additional types of government-supported means to manage the risk of low farm income: government payment programs and subsidized federal crop insurance plans.

By limiting income risk faced by farmers, three major government payment programs – direct payments (DP), loan deficiency payments (LDP), and counter cyclical payments (CCP) – legislated in the current farm bill, the Food Security and Rural Investment (FSRI) Act, provide substantial income support to U.S. crop farmers. In 2005, these three government payments totaled over $14.3 billion, which accounts for almost 20% of the 73.8 billion net farm income of that year[1]. For crop farmers, the percentage of these payments in net farm income would be even higher, because they receive the bulk of these payments but contribute to the net farm income together with livestock farmers.

In the past decade, subsidized federal crop insurance plans have become a promising means for U.S. crop farmers to manage price and production risk, evidenced by the fact that net insured acres, excluding acres under the free catastrophic insurance, have increased from about 105 million acres in 1995 crop year to 158 million acres in 2000 crop year and to over 217 million acres in 2005. Meanwhile, the premium subsidy has increased from $436 million in 1995

[1] Data source: Economic Research Service, U.S. Department of Agriculture.
http://www.ers.usda.gov/briefing/farmincome/data/GP_T6.htm
http://www.ers.usda.gov/briefing/farmincome/data/va_t1.htm

to $686 million in 2000 and to over $2 billion in 2005[2]. Such supports from the U.S. government are expected to reduce the probability of sharp drops in crop income for participating farmers and consequently affect the risk management behaviors of crop farmers.

The effects of government-oriented risk management tools on the use of financial market risk management tools, such as futures and options, concern researchers for several reasons. First, such effects reveal the distortion of government intervention on private market decisions. Second, the large amount of government payments and federal insurance subsidies may lead to substantive influence on the use of futures and options, even if the marginal effects are trivial. Third, acknowledgement of such effects has practical implications to crop farmers, because they could adjust their portfolios of risk management tools accordingly. Fourth, policy makers may be interested in such evaluations, which offer insights into the relative risk management effectiveness of various government payments and insurance policies.

Although understanding the impacts of government payment programs and federal crop insurance plans on the use of futures and options would benefit both crop farmers and policy makers, very few studies examine such effects[3]. Among studies in the literature that examine such issues, the expected utility (EU) hedge model, which assumes that crop farmers hedge with futures and options to maximize expected utility, appears to be the only method used (Poitras, 1993; Hanson et al. 1999; Coble et al. 2000, 2004; Mahul 2003; Wang et al. 2004).

By making assumptions on the utility function and on the distribution of random variables, such as harvest-time yield, spot price, and futures price, optimal hedge ratios can be found numerically. Stochastic simulation and numerical optimization are normally used instead

[2] Data from Summary of Business Report, Federal crop insurance Corp, RMA, USDA
[3] The special issue of European Review of Agricultural Economics in September 2004 claim producer hedging and insurance decisions under multiple uncertainties as a new issue about individual behavior towards risk.

of analytically-derived optimal solutions, because government payments, crop insurance, and options in the risk management portfolio censor the portfolio at multiple points. Such kinks in payoffs restrict the differentiability required for analytical derivation (Coble et al., 2000). While the assumptions on the yield and prices distributions can be tested using historical data, the utility function is usually subjectively determined, since it requires special experiments to delineate any decision maker's utility function (Chavas, 2004). However, because the true utility function is not known, results obtained from a particular utility function may be misleading and lack generality (Sakong et al., 1993).

When examining the effects of government payments and/or insurance on hedging, most of the previous works consider the effects on futures only, disregarding the fact that put options may be used together with futures to achieve optimal hedging. Should options be used together with futures by crop farmers at the planting time, when they attempt to hedge price risk to their crop at harvest? A few studies have suggested that options have a distinct role in the risk management portfolio under price and yield uncertainty or when cash prices received by farmers are truncated (Sakong et al., 1992; Moshini and Lapan, 1995; Hanson et al., 1999). Thus, futures and options should be considered together as available risk management instruments.

To evaluate the effects of government payments and insurance on optimal hedge ratios in futures and options, harvest-time values of several variables, including farm-level yield, spot price, futures price and market year average price, must be simulated. Prior studies typically simulate such harvest-time realizations based on two key assumptions: 1) these random variables have joint normal distribution, or at least they can be transformed to be joint-normally distributed; 2) farm-level yield has the same distribution as county-level yield, except for having a larger variance. The problem with the joint normality assumption is that it is too restrictive, if there is no hypothesis test result to support such an assumption. Also, because county-level yield has a longer record than farm-level yield, such an assumption enables researchers to get more reliable estimates regarding yield distribution and its relationship with other price variables by using county yields rather than farm-level yield data. However, such assumptions may not be appropriate in that the constant variance assumption for farm-level yield contradicts the variance pattern reflected in historical yield data. Figure 1 shows that the variance of farm-level yields is not constant. Instead, the variance varies with the level of county yields.

The objective of this study, then, is to apply a downside risk management framework, the second-order lower partial moment (LPM_2) hedge model to investigate the effects of government payment programs (LDP and CCP) and two federal crop insurance plans, Actual Production History (APH) and Crop Revenue Coverage (CRC), on the optimal use of risk management tools in the financial market, such as futures and options. The motivation of applying a LPM_2 hedge model rather than the EU hedge model is to avoid subjectivity that may be introduced by any particular utility function used in the EU hedge model. In addition, the downside risk hedging criterion employed by the LPM_2 model seems to be more relevant than the expected utility approach when government payments and insurance are considered in the hedge portfolio. Since the ultimate goal of government payment and insurance programs is to protect crop farmers from receiving low farm incomes, one can assume that downside risk to crop income is also the concern of farmers, who lobby for these programs.

Literature Review

The effects of federal crop insurance plans and government payments programs on hedging under the current or previous farm bills have been examined under the expected utility (EU) hedge model by a number of studies (Poitras, 1993; Hanson et al. 1999; Coble et al. 2000, 2004; Mahul 2003; Wang et al. 2004). Most of these studies investigated the effects of government payments and insurance on the use of futures only, although it has been proven by Sakong et al. (1993) that the coexistence of both price and production risk induces the use of futures and options together in the optimal hedge.

Poitras (1993) pointed out that when crop producers face both price and production uncertainty, the analysis of the farmer's hedging problem should not ignore the possibility of using crop insurance. While attempting to obtain the analytical effects of crop insurance on futures hedge, Poitras noted that the impact of the crop yield or revenue insurance on the futures hedge is not clear-cut, due to a number of potential offsetting effects. Coble et al. (2000) examined the impacts of four insurance contracts on futures or options hedging separately, their finding that adding APH into the risk management portfolio always increases the futures hedge ratio regardless of the regional difference, while the effects of CRC on hedging demand for futures or put options are mixed.

Mahul (2003), examining the effects of crop yield and revenue insurance on hedge ratios when both futures and options (using the straddle strategy) are in the portfolio, found the inclusion of APH in the portfolio stimulates the sale of futures but has little effect on straddles. CRC decreases the short positions in futures and shows mixed effects on the use of straddles.

Coble et al. (2004) found that LDP decreases futures hedging by examining hedge ratios in futures from an EU hedge model with the assumption of joint normality for the transformed county yields and futures prices and the assumption that farm-level yields have a constant variance from year to year. Wang et al. (2004) analyzed the effects of LDP and CCP on the optimal hedge in futures by applying an EU hedge model and found that LDP substitutes the use of futures. CCP substitutes futures as long as transaction costs in futures market are low enough so that the futures hedge ratio is still greater than zero before CCP takes effect. Similar to the study by Coble et al. (2004), Wang et al. assumed constant variance of the farm-level yield and joint normality for the county yield and transformed futures price in the simulation.

LPM_2 Hedge Model

An LPM_2 hedge model has as its objective the minimization of the second-order lower partial moment. LPM_2 is a member of the set of lower partial moment risk measures. LPM downside risk measures originate in the investment literature. Roy (1952) proposed to apply a safety-first rule to make an investment decision under uncertainty. Bawa (1978) generalized Roy's downside risk measure by constructing a set of downside risk measures, called lower partial moments, in the form $LPM_n = \int_{-\infty}^{\bar{p}} (\bar{p} - \tilde{p})^n dF(\tilde{p})$, where $n \geq 0$. LPM_0 is equivalent to Roy's down-side risk measure. If n is a positive integer, LPM_n represents the probability-weighted n^{th}-power of the shortfall below a target payoff $\bar{p}$.

The theoretical justification of the LPM criterion in determining an optimal investment portfolio resides in the relationship between LPM risk measures and stochastic dominance. Both Fishburn (1977) and Bawa (1978) noted that LPM_n criterion are consistent with $(n+1)^{th}$ order stochastic dominance rule for n = 0, 1, 2. That is:

If X FSD Y, then $LPM_0(X) \leq LPM_0(Y)$ for all levels of the target payoff;

If X SSD Y, then $LPM_1(X) \leq LPM_1(Y)$ for all target payoffs;

If X TSD Y, then $LPM_2(X) \leq LPM_2(Y)$ for all target payoffs.

Because $(n+1)^{th}$ order stochastic dominance and the expected utility criterion result in the same ranking for all the utility functions with $(-1)^k U^{(k)} \leq 0$ (k = 1, 2, …, n) (Yamai and Yoshiba, 2002; pp.116-117 of Levy, 1998, for the proof), LPM_n criterion is also consistent with the expected utility criterion if the expected utility criterion results in the same ranking across all the utility functions U satisfying $(-1)^k U^{(k)} \leq 0$ (k = 1, 2, …, n). In particular, LPM$_2$ is consistent with the expected utility criterion when the expected utility criterion yields the same ranking for all the utility functions with $U' > 0$, $U'' < 0$, and $U''' > 0$, of which the usually desired decreasing absolute risk aversion utility functions are members (Harlow and Rao, 1989).

Applications of LPM$_2$ hedge models are primarily discussed in the finance literature (Eftekhari, 1998; Lien and Tse, 1998; 2000; Chen et al. 2003), in which prices comprise nearly all the uncertainty for the value of the portfolio. Turvey and Nayak (2003) and Mattos and Garcia (2005) are two of the few studies that examine the LPM$_2$ hedge ratios for agricultural commodities. However, production risk was excluded by both studies.

Distinguished from any existing LPM$_2$ hedge model, the LPM$_2$ hedge model applied in this study incorporates both production and price risks into the portfolio. Specifically, it takes the form $MinLPM_2 = \underset{h_x, h_z}{Min} \int_{-\infty}^{\bar{p}} (\bar{p} - p)^2 dF(p)$, where $\bar{p}$ is the target payoff of the hedged portfolio, which is set to the expected payoff of the hedged portfolio in this study. h_X and h_Z are the hedge ratios for futures and options. h_X (or h_Z) is measured as the ratios of yields hedged with futures contracts (or options contracts) to the expected farm yield. Positive (negative) h_X implies to sell (buy) futures contracts, while positive (negative) h_Z implies buying (selling) put options contracts.

With different combinations of futures, options, government payments, and crop insurance in the portfolio, p has different expressions. For example, assume there are no insurance plans and government payments available to the representative farmer, and the representative farmer is assumed to use only futures and options to manage risk. Then the net value of the hedge portfolio at harvest is

$\pi = py + h_X(f_0 - f_1)Ey + h_Z[\max(f_1 - k, 0) - v_Z]Ey - C(Ey)$, where py is the revenue from selling the crop for cash at harvest, p is the harvest cash price and y is the farm yield at harvest. f_0 and f_1 are the prices of the near-to-harvest futures contract at planting and at harvest, respectively. k is the strike price of the put option, and v_Z is the premium that the farmer pays to have the put option. Harvest cash price p, harvest farm-level yield y and futures price at harvest f_1 are not known at planting and will be simulated based on historical data. The assumption of unbiased futures and options prices will be imposed by simulating f_1 in such a way that $Ef_1 = f_0$ and by setting option premium $v_Z = E(\max(f_1 - k, 0))$. Production cost C is assumed to be determined by the expected farm yield Ey, which is known at planting time. Appendix I shows alternative portfolios of futures, options, government payments and crop insurance examined by this study.

Simulation Methods

Optimal hedging positions of a representative farmer in a county are solved to evaluate the effects of government payments and crop insurance on the use of futures and options. The representative farmer in a county is synthesized in such a way that, for any year, the mean of the yield distribution equals the county yield, but the actual yield could be any actual farm-level yield realized in the county. It has been shown that the dispersions of farm-level yield around county yield vary from year to year (figures 1). This indicates that the representative farm defined above should have variance conditional on the county yield.

Other assumptions made for the representative producer are as follows. First, the crop producer is assumed to make a one-time hedge through the crop year. Second, the representative farmer is assumed to have a portfolio composed of income from selling crops at spot market as well as from four risk management instruments – futures, options on futures, federal crop insurance and government payments. To simplify the analysis regarding government payments, the representative farmer is assumed to produce a single commodity for which he is qualified to receive government payments. Third, the representative farmer makes his/her hedging decision at planting time by utilizing information available at that time. Fourth, the hedge decision for every acre of the crop planted is assumed to be independent of total acres planted. That is, the hedge portfolio based on one acre of the planted crop can be analyzed for simplicity.

In figure 2, a flowchart illustrates the general steps to simulate the random values of four variables, futures price at harvest (f_1), harvest local cash price (p), market year average price (p_{MYA}) and the representative farm's yield at harvest (y_f), which are necessary in order to solve the hedge models. Two important steps in the simulation are first to generate harvest-time futures price and county yields with the copula method, and then to simulate farm yields based on the generated county yield. Copula method is used to simulate county yields and prices so that yields and prices can have more flexible dependence structures than the multivariate normal distribution. The implementation of conditional kernel density approach generates farm yields with variance contingent on county yields, which conforms to the pattern showed in historical county yields and farm yields. After futures price at harvest is simulated, harvest-time cash price and market year average price are generated based on their linear relationships with futures price indicated by the historical data.

In statistics, copula is a function that connects the marginal distributions to the joint cumulative distribution (Nelson, 1999). In particular, suppose that H is a joint cumulative distribution function (CDF) on R^m with marginal CDFs, $F_1, \ldots, F_m$, then

$U_1 = F_1 \sim Unif\,[0,1],...,U_m = F_m \sim Unif\,[0,1]$ and the joint distribution function of $U_1,\ldots, U_m$ is a copula C such that

$$C(u_1,...,u_m) = P(U_1 \le u_1,...,U_m \le u_m) = P[X_1 \le F_1^{-1}(u_1),..., X_m \le F_m^{-1}(u_m)]$$
$$= P[X_1 \le x_1,..., X_m \le x_m] = H(x_1,..., x_m)$$

According to Sklar's theorem (Nelson, 1999), for any continuous multivariate CDF, there is a unique copula; conversely, for any copula, there is a joint distribution with marginal distributions of corresponding dimensions. By associating the marginal CDF with the joint CDF, copula fully describe the dependence among the variables $X_1,\ldots, X_m$ (Chen and Huang) without explicitly specifying the joint cumulative functional form.

The need to model the distribution of harvest-time yields and prices and the distributional flexibility associated with the copula method motivate this study to use copula simulation. Among the many well-known copulas, two copulas, Gaussian copula and Frank copula, were selected to model the dependence between the county yields and the futures prices. The purpose of selecting two copulas is to (i) demonstrate that a variety of joint distributions of yields and prices can exist other than the bivariate normal and (ii) provide a sensitivity analysis of the results.

Bivariate Gaussian copula takes the form $C_G(u,v) = \Phi_r(\Phi^{-1}(u), \Phi^{-1}(v))$, where Φ_r is the bivariate normal CDF with the Pearson's coefficient r, representing the linear correlation between the two variables X_1 and X_2; Φ is the normal CDF; u and v are variates from two independent Uniform (0, 1) distributions. Frank copula is a one-parameter copula function of the form $C_F(u,v) = -\frac{1}{q}\ln(1 + \frac{(\exp(-qu)-1)(\exp(-qv)-1)}{\exp(-q)-1}$, $q \neq 0$. When the r in Gaussian copula and q in Frank copula are positive (negative), the marginal distributions coupled by the copulas are positively (negatively) associated.

In this study, the two marginal distributions coupled by the Gaussian copula or Frank copula are the distribution of county yield F_{y_c} and the marginal distribution of the logarithm difference between the futures prices at harvest and at planting, $F_{d\ln f}$. County-level yields need to be simulated because the representative farm's yields are modeled as conditional on the county yields. The marginal distribution of (*dlnf*) is used here because, on the one hand, this differenced variable has a significant negative correlation with county yields, and conversely, it can be used to generate harvest-time futures price f_1 when the planting-time futures price f_0 is known. Futures prices have been specified by the lognormal distribution in the literature (Coble et al. 2000, 2004; Hauser et al. 2004). Since *dlnf* $(= \ln f_1 - \ln f_0)$ calculated with historical cotton futures data passed several normality tests (Tables 1), this study assumes (*dlnf*) to be normally distributed with mean and variance determined by the historical data. That is, $F_{d\ln f} = \Phi(\hat{m}_{d\ln f}, \hat{s}_{d\ln f})$. Once planting time futures price f_0 is known, harvest futures price can be simulated by $f_1 = f_0 \cdot \exp(d\ln f)$. Significant dependence between y_c and (*dlnf*) found in historical data determines the sign and magnitude of r in Gaussian copula and q in Frank copula. However, this study does not assert that these two copulas make the best fits to the relationships between the sample yields and prices (For copula selection criteria, see Venter, 2002). In the agricultural economics literature, yield distributions have been modeled by both parametric methods and nonparametric approaches (Ker and Goodwin, 2000; Wang et al. 2004). This study applied a nonparametric kernel density approach to estimate the empirical distribution of the detrended county yields. In particular, for any y_c^*, the empirical cumulative probability was estimated by $\hat{F}(y_c^*) = P(y_c \le y_c^*) \approx \int_0^{y_c^*} \frac{1}{n}\sum_{i=1}^{n} K_h(y - Y_{ci})dy$, where $\frac{1}{n}\sum_{i=1}^{n} K_h(y - Y_{ci})$ is the kernel density estimator. Y_{ci} represents the detrended historical county yields, K_h is defined as $K_h(\cdot) = (1/h)K(\cdot/h)$, h is the bandwidth or smoothing parameter which determines the smoothness of the estimated density, and $K(\cdot)$ is referred to as the kernel. In this study, the Epanechinikov density function was used as the kernel with $K(x) = \frac{3}{4}(1 - x^2)1\{|x| < 1\}$. The bandwidth is determined by the Sheather-Jones plug-in method. $\hat{F}(y_c^*)$ was calculated by applying Simpson's rule of numerical integration (Miranda and Fackler, 2002).

By following the simulation algorithms, 10,000 pairs of (y_c, f_i) were simulated from the Gaussian copula and from Frank copula, respectively. In order to investigate the hedging decision under the unbiased futures price assumption, the mean of the simulated futures price was adjusted to equal the futures price at planting time (Wang, et al. 2004). Hedging decisions under biased futures price will also be examined by enlarging or shrinking the mean of the simulated futures by a certain percent.

Data

Farm yield data for cotton in Colquitt County from year 1991 to 2000 were obtained from RMA of USDA. Farm-level yield data were used to estimate the empirical conditional farm yield distribution. County-level yield of cotton in Colquitt County from year 1950 to 2005 were collected on the website of the NASS of USDA. County yield data were used to estimate the empirical distribution of county yield as well as to estimate the correlation between yield and futures price[4]. Daily average futures prices at planting and at harvest were calculated based on the cotton futures data from the New York Board of Trade (NYBOT) from 1978 to 2006[5]. Harvest-time cash price was approximated by the average price received by Georgia producers collected by USDA from 1978 to 2005 for cotton[6]. Market year average prices from 1978 to 2005 were obtained from NASS of USDA[7].

The values of the parameters used in the simulation are listed in table 2 and table 3, while basic distributional statistics of the simulated yields and prices are shown in table 4 and table 5. The empirical density plots of the simulated county yields and farm yields in figures 3 and figure 4 show that simulation by applying conditional kernel density method generate farm yields with variance conditional on county yields as reflected in the historical yields.

Results Analysis

Tables 6 reports the optimal LPM_2 hedge ratios and the magnitude of LPM_2 risk measures under different scenarios for the representative cotton farmer, respectively. Hedge ratios h_x and h_z are the ratios of the hedged yield to the expected yield on a per-acre basis. In the base scenario, the crop farmer manages risk with only futures and put options. The availability of government payments and federal insurance programs reduce the downside income risk faced by crop farmers, as indicated by the decreasing value of LPM_2.

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[4] Speaking more exactly, this is the correlation between detrended county yield and the difference of logarithm of futures price at harvest and at planting that will be estimated because significant correlation is detected between the two variables for cotton but is not found between detrended county yield and futures price at harvest.

[5] Specifically, cotton price of the December futures contract in March and in November were averaged, respectively.

[6] Data source: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1002

[7] Data source: http://www.nass.usda.gov/QuickStats/Create_Federal_Indv.jsp

By comparing the hedge ratios in the base case with the hedge ratios with APH in the portfolio in addition to futures and options in tables 6, it appears that more futures are sold when APH is in the risk management portfolio than when it is not. The result that APH promotes hedging demand for futures is consistent with the results of Coble et al. (2000) and Wang et al. (2004). However, these works did not consider options as a risk management tool to be used together with futures. This study shows that the positive relationship between APH and a futures hedge remains when put options are used together with futures as hedging instruments. This positive relationship can be intuitively understood in light of the negative correlation between harvest-time crop yield and price. Since APH indemnity is triggered when harvest-time crop yield drops below the yield guarantee, the lower the yield, the higher is the APH indemnity. In other words, APH is more valuable when the crop yield is lower. If the crop price and yield are negatively correlated, then APH is more valuable when the harvest price is higher.

Figure 5 shows that a positive relationship can be fitted between the payoffs of APH and cash price. The positive relationship between the value of APH and the crop price implies that owing APH is similar to having a long position in futures or call options. Because a long call can be replicated by a long position in futures and a long position in put options, when the crop farmer has APH insurance, his payoff distribution could be similar to the payoff distribution when he has long positions in futures and maybe in put options. Thus, the producer with APH in his portfolio would optimally sell more futures and buy fewer put options compared to the producer with no APH. The actual effects of APH on the use of put options are not uniform but vary with the simulated data. When both futures and put options are in the portfolio, APH shows mixed effects on put options. This differs from the results by Coble et al. (2004) that suggested APH increases the purchase of put options when the use of futures is excluded.

Results in table 6 suggest that CRC increases selling of futures but decreases hedging in put options. The price replacement feature of CRC and the negative correlation between harvest-time price and yield indicate that the indemnity of CRC is more likely to be triggered when the harvest-time crop price is higher than planting-time price. Different from APH, which only insures against the risk of low yield, CRC may also pay indemnity when the harvest-time price drops so low that the revenue from selling the crop falls below the revenue guarantee in spite of a high yield. Since CRC may pay indemnities at both high and low crop prices, the value of CRC against cash price might resemble a quadratic curve that opens up. Figure 6 shows that the value of CRC on cotton is parabolic in cash price. Thus, the payoff of CRC may be analogous to the combination of long position in futures and in put options. As a result, when the crop farmer has CRC in his portfolio, he tends to sell more futures and put options than when he has no CRC to achieve the optimal minimum LPM_2 portfolio. These effects of CRC on futures and options are comparable to those found by Coble et al. (2000), who assumed that futures and put options are alternative hedging tools. However, the positive effect of CRC on the futures hedge is contrary to Mahul (2003) and Wang et al. (2004). Mahul found that CRC decreases hedging in futures regardless of whether options are used or not. This divergence could result from the difference in the types of portfolio settings modeled, since Mahul used three straddles together with futures, while this study examines only the use of put options together with futures. Wang et al. detected a negative effect of CRC on futures when they gave no consideration to the use of put options. The results of Wang et al. might be biased by the omission of put options from the portfolio.

Because DP is known at planting, the target payoff in the LPM_2 hedge model with DP in the portfolio is set as $E(py) + DP$. Since DP increases the actual portfolio income and the target (expected) portfolio income by the same amount, DP has no demonstrated influence on the LPM_2 hedge ratios.

The availability of LDP to the crop farmer appears to slightly increase hedging with futures but considerably reduces the purchase of put options. The substitution effect of LDP for put options is consistent with the analysis that LDP is an implicit free put option provided to farmers. This finding is consistent with the empirical finding of Hanson et al. (1999) from an EU hedge model. With LDP in the portfolio, the hedger actually appropriates the value provided by LDP by buying fewer put options.

It is possible that the substitution effect of LDP for put options could be so strong that the decision maker shifts from hedging to speculating by means of selling put options. For example, in table 6, when LDP is added to the base portfolio, the hedge ratio in put options changes from 0.26 to -0.23, and the total percentage of the hedged expected yield changes from 40% to negative 8%. This suggests that LDP over protects the crop farmer and converts him from a net hedger to a net speculator in futures/put options. The weak substitution effect of LDP for futures differs from the results of Coble et al. (2004) and Wang et al. (2004). Neither of these studies included put options in the portfolio, and both found that LDP could largely reduce the futures hedging positions.

The effects of CCP are assessed by comparing the hedge ratios from the case (FOD + LDP + LCP) with those from the scenario (FOD + LDP). CCP decreases the hedging demand for futures and put options. The finding that CCP substitutes futures is consistent with previous research by Wang et al. (2004). Anderson et al. (2003) found that CCP is analogous to the difference between a put option against the market year average price with a strike price equal to the target price minus the direct payment and the value of the other put option against local market price with a strike equal to the loan rate. In other words, CCP roughly resembles the trading strategy to buy one put options with a higher strike price and sell the other put option with a lower strike price, since the target price of CCP less the direct payment is higher than the loan rate. CCP in cotton data from a Frank copula in Figure 7 further demonstrates that payoffs of CCP are analogous to the bear spread strategy in options trading. The downward sloping part of CCP against cash price in figure 7 may decrease the hedging use for futures.

Comparing hedge ratios for cotton from different copulas in table 6, the optimal hedge ratios for cotton data simulated from two different copula assumptions are different, even though they are computed based on the same historical data. This suggests that the assumed joint distribution (or, equivalently, copula function) is an important factor affecting the optimal hedge ratios. However, as far as effects of government payments and crop insurance plans on the optimal hedge ratios are concerned, the results are consistent across the different copula functions. Thus, although the exact hedge ratios may not be used to guide actual hedging practice, the effects detected by this study provide valuable information for both crop farmers and policy makers.

In addition to disclosing the effects of government payments or crop insurance on use of futures and options, the results in tables 6 suggest that CRC is more efficient than APH for downside risk reduction. Including CCP decreases risk more than LDP. CRC has the largest downside risk reduction effects among the four government income support programs. Hence, if there is budget competition among the programs, CRC should be given the highest priority among the four government payments and federal insurance programs discussed. Conversely, APH is the least competitive of the four programs in terms of downside risk reduction.

The impacts of perceived bias in futures prices on optimal LPM_2 hedging are next examined for the base scenario. Table 7 reports the optimal hedge ratios with and without futures price bias. The scenario of zero percent bias means no futures price bias; that is, $f_0 = Ef_1$. Negative bias means that the futures price at planting is lower than the expected futures price at harvest; i.e. $f_0 < Ef_1$. If the futures bias is assumed to be -2%, then $Ef_1 = f_0 /(100\% - 2\%)$. On the contrary, positive bias means that the futures price at planting is higher than the expected futures price at harvest; i.e. $f_0 > Ef_1$. Positive-biased futures prices are simulated by following the same method as for negative bias.

As expected, the negative bias of the planting time futures price suppresses the hedging demand for futures and could even convert the hedger to a speculator in the futures market. In contrast, a positive bias in the futures price induces more use of the futures hedge. The substitution effect between futures and put options may be caused by the assumption that put options are fairly priced, although futures prices are biased.

Conclusions and Implications

This study finds that the inclusion of government programs and federal crop insurance in the hedging portfolio always reduces the downside income risk faced by crop farmers. The effects of crop insurance and government payments on the use of futures and options can be evaluated by comparing the optimal hedge ratios in various scenarios with the base scenario. In summary, APH has a positive effect on futures hedge, regardless of the use of put options. The CRC revenue insurance policy consistently increases the hedging position in futures but decreases the hedging position in put options. Direct payments have no effects on the LPM_2 hedge ratios, because it increases both the actual farm income and the expected income by the same amount. The availability of LDP to the crop farmer marginally increases the hedge ratio in futures but considerably reduces the purchase of put options. CCP unequally decreases the hedging demand for futures and put options. Perceived biases in the seasonal futures prices are shown to have substantial effects on the hedging demand for futures. A lower (higher) futures price at planting compared to the expectation of the futures price at harvest decreases (increases) the hedge ratios in futures.

Possible extensions to this study can be made in several directions. First, this study has not allowed crop farmers to decide whether to buy insurance or not. Future research could investigate the interactions of futures, options and insurance by allowing the producer to determine his/her positions jointly over all the feasible risk management tools. Second, this study calculates the payoffs of government payments according to the parameter values in the current farm bill. The effects of changes in the parameter values of the government payments on hedging could be investigated to gain a better understanding of the relationships between government payments and the use of futures and options. This study used actuarially fair premiums for the crop insurance rather than the actual premiums charged by these insurance plans. To use the actual premiums better represent the real portfolio risk management problem faced by crop farmers. Only the effects of government payments and crop insurance on cotton's hedge are evaluated by this study. The same methodology can be extended to other crops to examine the consistency of these effects across crops.

Reference

Anderson, J.D., K.H. Coble, and J.C. Miller. 2003. "Using Private Risk Management Instruments to Manage Counter-Cyclical Payments Risks Under The New Farm Bill." *In Proceedings of NCR-134 Conference*.

Bawa, V.S. 1978. "Safety-First Stochastic Dominance and Optimal Portfolio Choice." *Journal of Financial and Quantitative Analysis* **3**: 255-171.

Chavas, J. P.. 2004. *Risk Analysis in Theory and Practice.* Elsevier Butterworth-Heinimann.

Chen, S., C. Lee, and K. Shrstha. 2003. "Futures Hedge Ratios: A Review." *The Quarterly Review of Economics and Finance,* **43**: 433-465.

Coble, K.H., R.G. Heifner, and M. Zuniga. 2000. "Implications Of Crop Yield And Revenue Insurance For Producer Hedging Demand." *Journal of Agricultural and Resource Economics*, **25**, 432-452.

Coble, K.H., J.C. Miller, M. Zuniga, and R. Heifner. 2004. "The Joint Effect Of Government Federal Crop Insurance Plans And Loan Programmes On The Demand For Futures Hedging." *European Review of Agricultural Economics* **31**: 309-330.

Eftekhari, B. 1998. "Lower Partial Moment Hedge Ratios." *Applied Financial Economics* **8:** 645-652.

Fishburn, P.C. 1977. "Mean-Risk Analysis With Risk Associated With Below-Target Returns." *American Economic Review* **67**: 116-126.

Hanson, S.D., R.J. Myers, and J.H. Hilker. 1999. "Hedging With Futures and Options Under A Truncated Cash Price Distribution." *Journal of Agricultural and Applied Economics* **31**: 449-459.

Harlow, W. V., and R. K. S. Rao. 1989. "Asset Pricing In A Generalized Mean-Lower Partial Moment Framework: Theory And Evidence." *The Journal of Financial and Quantitative Analysis*. **24**: 285-311.

Hauser, R.J., B.J. Sherrick, and G.D. Schnitkey. 2004. "Relationships among Government Payments, Crop Insurance Payments and Crop Revenue." *European Review of Agricultural Economics* **31:** 353-368.

Ker, A. P. and B. K. Goodwin. 2000. "Nonparametric Estimation of Crop Insurance Rates Revisited." *American Journal of Agricultural Economics* **83**: 463-478.

Levy, H. 1998. *Stochastic Dominance: Investment Decision Making Under Uncertainty*. Boston: Kluwer Academic Publishers.

Lien, D.,and Y. K. Tse. 1998. "Hedging Time-Varying Downside Risk." *The Journal of Futures Market* **18**: 705-722.

Lien, D., and Y. K. Tse. 2000. "Hedging Downside Risk with Futures Contracts." *Applied Financial Economics* **10**: 163-170.

Mattos, F., and P. Garcia. 2005. "Relaxing Standard Hedging Assumptions in a Downside Risk Framework." *In proceedings of NCR-134 Conference*.

Mahul, O. 2003. "Hedging Price Risk In The Presence Of Crop Yield and Revenue Insurance." *European Review of Agricultural Economics* **30:** 217-239.

Miranda, M. J., and P. L. Fackler. 2002. *Applied Computational Economics and Finance*. The MIT press.

Moshini, G., and Harvey Lapan. 1995. "The Hedging Role of Options and Futures Under Joint Price, Basis, And Production Risk." *International Economic Review* **36**: 1025-1049.

Nelson, R. B. 1999. *An Introduction to Copulas*. Springer.

Poitras, G. 1993. "Hedging and Crop Insurance." *The Journal of Futures Markets* **13**: 373-388.

Roy, A.D. 1952. "Safety First and The Holding Of Assets." *Econometrica,* **20:** 431-449.

Sakong, Y., D.J. Hayes, and A. Jallam. 1992. “Can Options Be Used As A Hedging Instrument?” *Working Paper 92-WP 85*.

- 1993. “Hedging Production Risk with Options.” *American Journal of Agricultural Economic* **75**: 408-415.

Turvey, C.G. and G. Nayak. 2003. “The Semivariance-Minimizing Hedge Ratio.” *Journal of Agricultural and Resource Economics* **28**: 100-115.

Venter, G. G. 2002. “Tails of Copulas.” *In 2002 Proceedings of Casualty Actuarial Society.* http://www.casact.org/pubs/proceed/proceed02/02068.pdf

Wang, H.H., L.D. Makus, and X. Chen. 2004. “The Impact Of U.S. Commodity Programmes On Hedging In The Presence Of Federal Crop Insurance Plans.” *European Review of Agricultural Economics* **31**: 331-352.

Yamai, Y., and T. Yoshiba. 2002, “Comparative Analysis of Expected Shortfall ad Value-At-Risk (2): Expected Utility Maximization And Tail Risk. *Monetary and Economic Studies* April: p95-115.

Table 1 Normality Tests of *dlnf* for Cotton Futures 1978-2005

Normality test	Distribution	Test statistic	P-value
Shapiro-Wilk	W	0.9533	0.240
Kolmogorov-Smirnov	D	0.1268	0.150
Cramer-von Mises	W-Sq	0.0646	0.250
Anderson-Darling	A-Sq	0.4448	0.250
$\hat{m}_{d\ln f}$	-0.025	$\hat{s}_{d\ln f}$	0.174

Note: $dlnf = lnf_1 - lnf_0$, f_0 and f_1 are the March and November daily average of the futures prices in December contract, respectively.

Table 2 Summary of Parameters in APH, CRC, DP, LDP, and CCP

Crop	Cotton [1] (Colquitt, GA)
Coverage level d	70%
APH yield y_{APH}	768 (lb)
APH price p_{APH}	\$0.53/lb
CRC price f_{CRC0}	\$0.60/lb
Base yield y_{DP}	707 (lb)[4]
DP rate p_{DP}[3]	\$0.0667/lb
Loan rate p_{LDP}[2]	\$0.52/lb
CCP target p_{CCP}[3]	\$0.724/lb

Note : [1] Rates listed are for the upland cotton of a specific grade.
(http://www.fsa.usda.gov/FSA/printapp?fileName=pf_20060301_insup_en_cottdcp06.html&newsType=prfactsheet)
[2] http://www.fsa.usda.gov/FSA/webapp?area=home&subject=prsu&topic=lor
[3] http://www.ers.usda.gov/Briefing/FarmPolicy/programprovisions.htm
[4] Average of the county yields from 1981 through 1985.

Table 3 Estimated Parameters for Simulating Cotton County Yields and Prices

Parameters in Simulation	Coefficient Estimation	P-value
$r_S(r)$	-0.331(-0.345)	0.0852
q	-1.353	0.0197
b_{0_p}	9.420	0.0330
b_{1_p}	0.795	<.0001
Residual $s_{\_p}$	4.088	
b_{0_MYA}	8.286	0.0635
b_{1_MYA}	0.798	<.0001
Residual $s_{\_MYA}$	4.177	

Note: r_S is the Spearman correlation used to calculate Pearson correlation coefficient r in the Gaussian copula simulation.
q is the parameter in the Frank copula.
p is simulated based on the linear regression

$$p = b_{0\_p} + b_{1\_p} f_1 + e_1,\ e_1 \sim \text{Normal}(0,\ s_{\_p}).$$

p_{MYA} is simulated based on linear regression

$$p_{MYA} = b_{0\_MYA} + b_{1\_MYA} f_1 + e_2,\ e_2 \sim \text{Normal}(0,\ s_{\_MYA}).$$

Table 4 Gaussian Copula: Basic Statistics of the Simulated Cotton Yields and Prices

Statistics	County Yield (lb.)	Farm Yield (lb.)	Future Price (cent)	Cash Price (cent)	P_{MYA} (cent)
Mean	848	848	58.52	55.88	54.99
Std Dev	143.94	—	10.15	9.01	9.11
Skewness	-0.001	—	0.568	0.416	0.434
Kurtosis	-1.035	—	0.715	0.436	0.498
Min	566	8	26.18	29.98	26.91
Q1	716	668	51.40	49.57	48.68
Q3	966	1040	64.61	61.50	60.72
Max	1142	1726	110.15	100.04	101.51

Note: Variance, skewness and kurtosis of farm yield are not listed because farm yield distribution is contingent on the level of county yield; P_{MYA} is the market year average price; Q1, Q3 are 25% and 75% quantile, respectively.

Table 5 Frank Copula: Basic Statistics of the Simulated Cotton Yields and Prices

Statistics	County Yield (lb.)	Farm Yield (lb.)	Futures Price (cent)	Cash Price (cent)	P_{MYA} (cent)
Mean	850	850	58.52	55.88	54.99
Std Dev	143.89	—	10.24	9.11	9.17
Skewness	-0.029	—	0.528	0.355	0.389
Kurtosis	-1.040	—	0.473	0.306	0.362
Min	569	1	25.87	23.37	25.68
Q1	717	669	51.24	49.67	48.74
Q3	967	1047	64.78	61.63	60.59
Max	1142	1729	110.61	98.24	100.50

Note: Variance, skewness and kurtosis of farm yield are not listed, because farm yield distribution is contingent on the level of county yield; P_{MYA} is the market year average price; Q1, Q3 are 25% and 75% quantile, respectively.

Table 6 Optimal LPM_2 Hedge Ratios under Different Scenarios for Cotton

Scenarios	Cotton Gaussian Copula			Cotton Frank Copula		
	h_x (chg[1])	h_z (chg[1])	LPM_2	h_x (chg[1])	h_z (chg[1])	LPM_2
Futures + Options (FO)	0.14	0.26	12938.40	0.32	0.16	13050.90
FO + APH	0.27 (0.13)	0.17 (-0.09)	8581.96	0.40 (0.08)	0.13 (-0.03)	8728.21
FO + CRC	0.38 (0.24)	-0.10 (-0.36)	7359.03	0.49 (0.17)	-0.14 (-0.30)	7496.41
Futures + Options + DP (FOD)[2]	0.14	0.26	12938.40	0.32	0.16	13050.90
FOD + LDP	0.15 (0.01)	-0.23 (-0.49)	11524.61	0.33 (0.01)	-0.33 (-0.49)	11608.38
FOD + LDP + CCP[1]	-0.34 (-.48)	-0.02 (0.21)	5961.11	-0.19 (-0.52)	-0.09 (0.24)	6045.10

Note: Mean, Min, Max are values in dollars on a per acre basis. h_x, h_z are hedge ratios in futures and put options, respectively. Positive h_x means sell futures at planting time and positive h_z means buy put options at planting time.

[1] Numbers in parenthesis are changes in hedge ratios compared to the scenario (FOD+LDP).

[2] h_x, h_z are the same as in the case of FO because the target payoff for FOD is increased by the value of DP compared to the target payoff in the FO case. Since DP is known at planting time, it is reasonable to make such adjustment to the target payoff.

Table 7 Optimal LPM_2 Hedge Ratios for Biased Futures Markets

Bias	Cotton Gaussian Copula		Cotton Frank Copula	
	h_x	h_z	h_x	h_z
Futures+Options				
-2%	-0.23	0.69	-0.32	1.13
-1%	-0.16	0.70	0.03	0.63
0	0.14	0.26	0.32	0.16
1%	0.44	-0.18	0.62	-0.29
2%	0.52	-0.18	0.93	-0.73

Figure 1 Cotton in Colquitt County: Conditional Farm-level Yields in 1991-2000 (pounds)

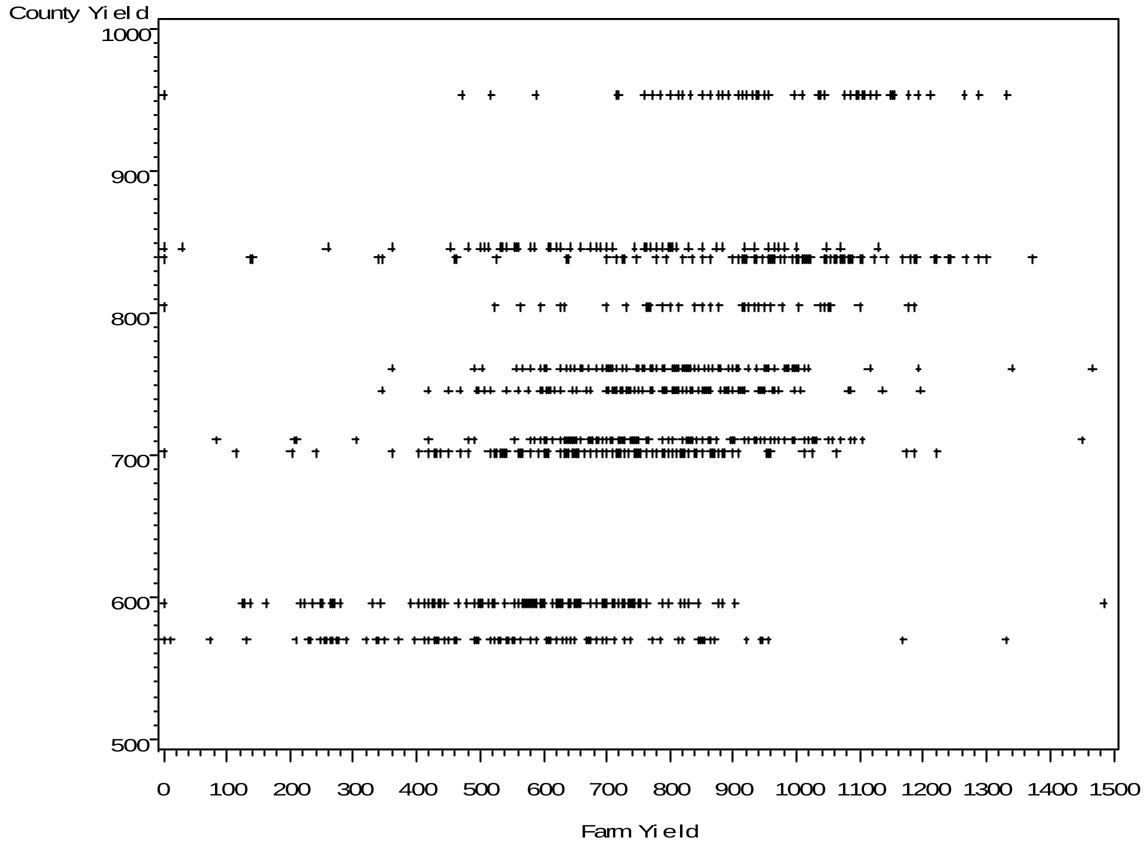
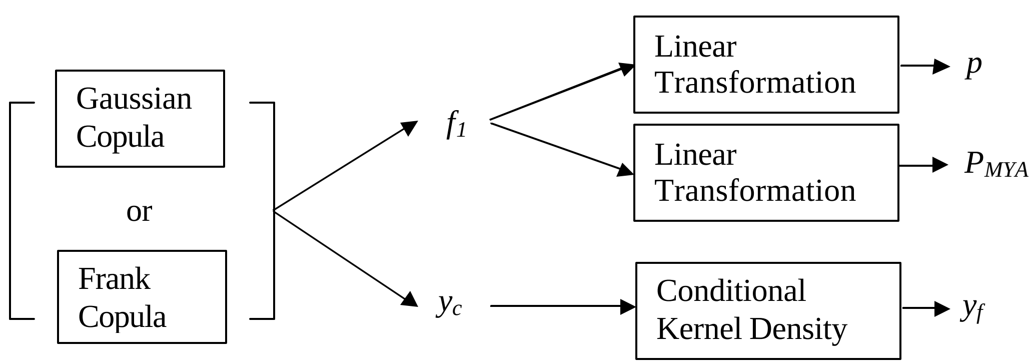


Figure 2 Simulation Flowchart



Note: y_c is the simulated county yield; y_f is the farm yield; f_1 is futures price; p is the cash price; and p_{MYA} is the estimated market year average price.

Figure 3 Density Plots of Simulated Farm and County Cotton Yields (Gaussian Copula)

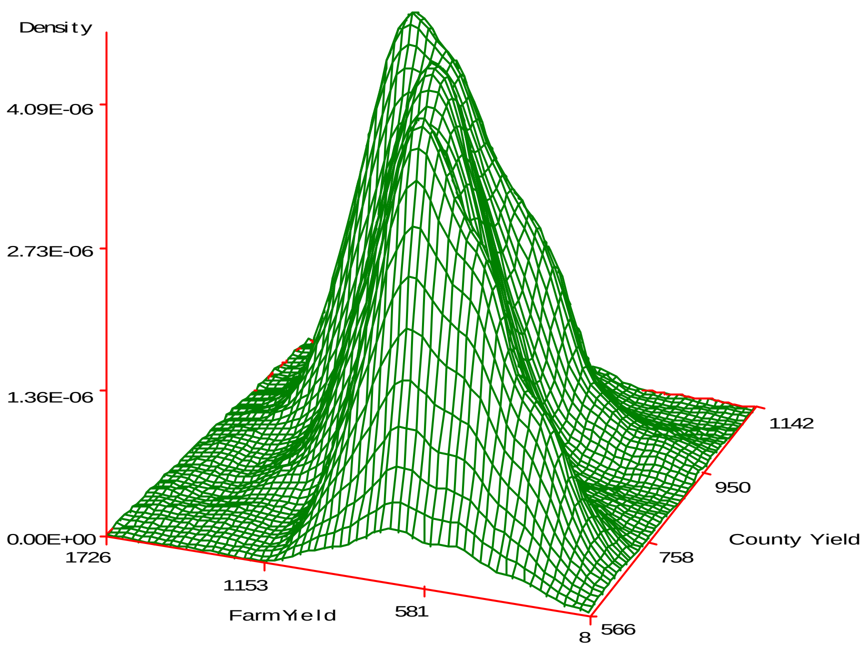


Figure 4 Density Plots of Simulated Farm and County Cotton Yields (Frank Copula)

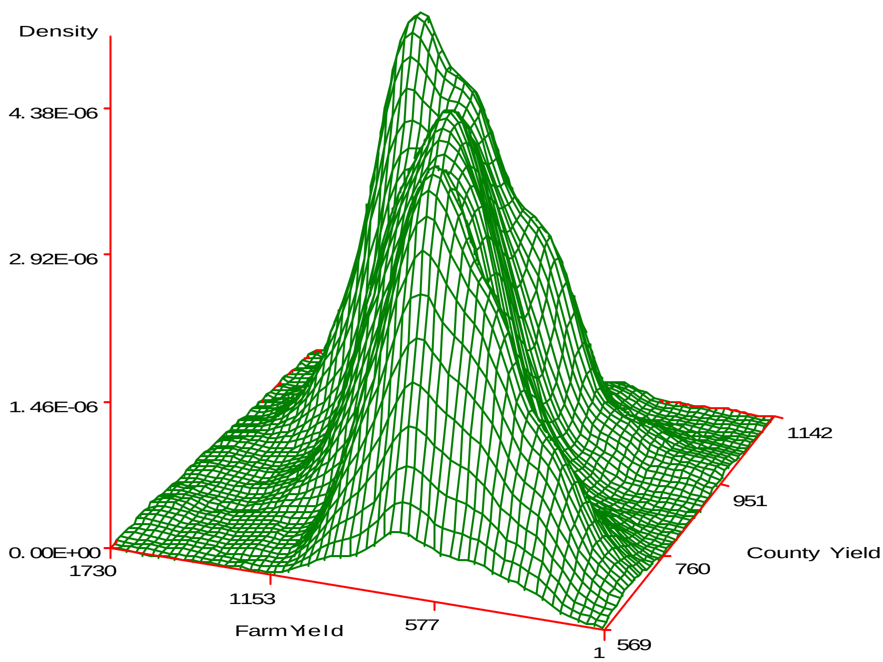
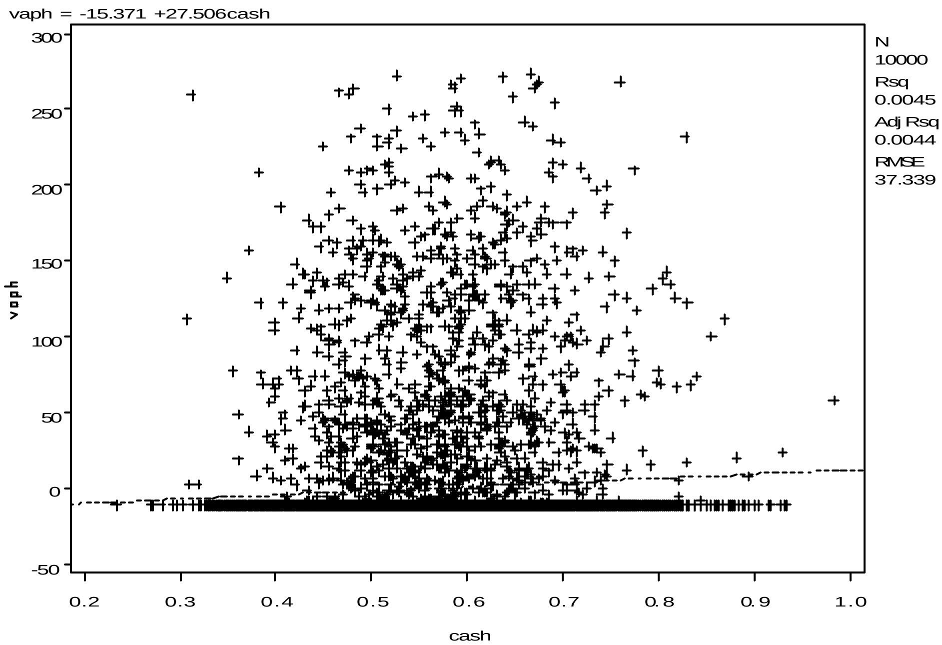
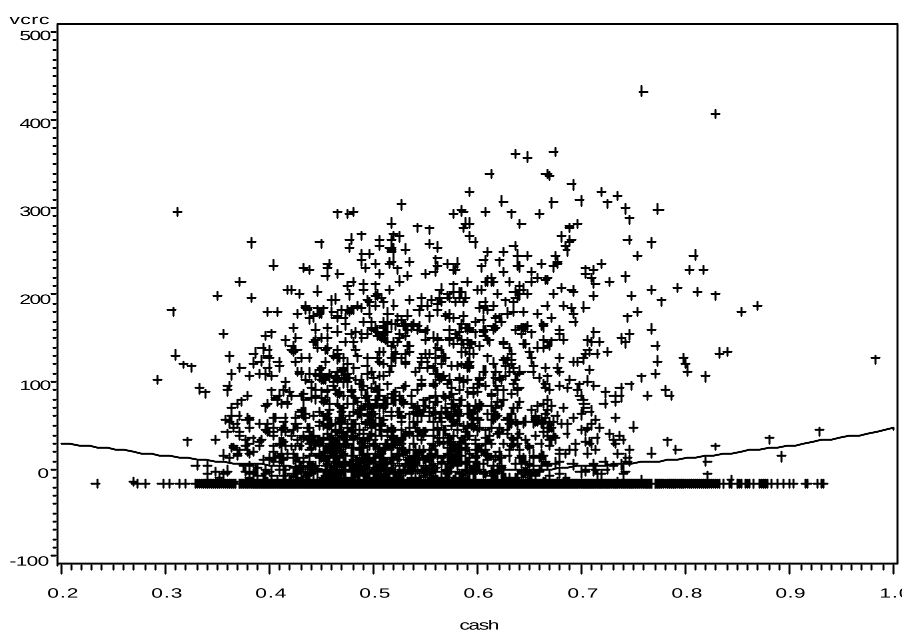


Figure 5 Positive Relationships between the Value of APH and Cash Price in the Simulated Cotton Data (Frank Copula).



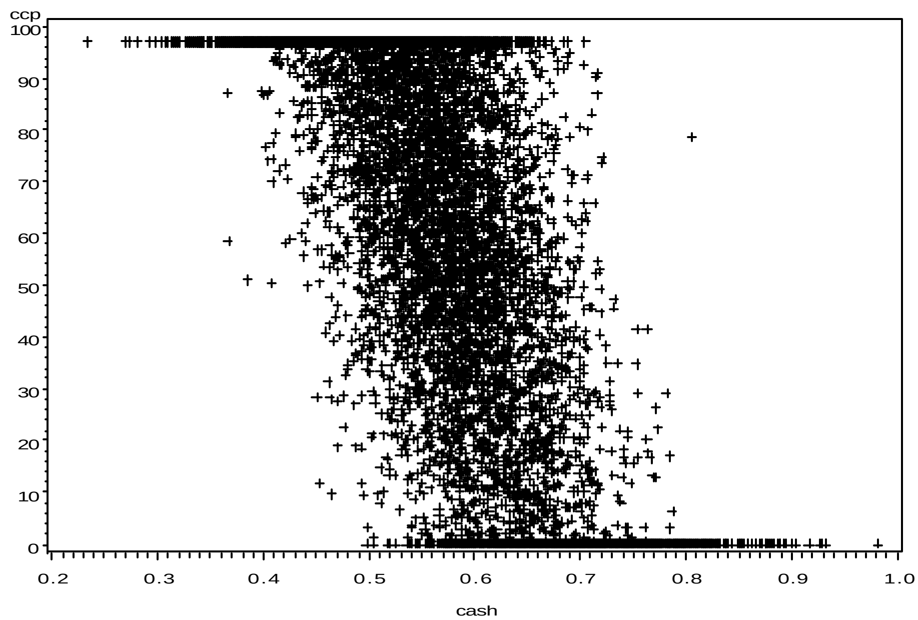
Note: the slope of the fitted line has P-value <0.0001.

Figure 6 Quadratic Relationships between the Value of CRC and Cash Price in the Simulated Cotton Data (Frank Copula)



Note: All three parameters of the fitted quadratic curve have P-value < 0.0001.

Figure 7 Bear-spread Shaped Payoffs of CCP in the Simulated Data for Cotton (Frank Copula)



Appendix I

The hedge portfolio including APH plan is

$$p_{APH} = py + h_X(f_0 - f_1)Ey + h_Z[\max(f_1 - k, 0) - v_Z]Ey + NV_{APH} - C(Ey)$$

where $NV_{APH} = p_{APH} \cdot \max(dy_{APH} - y, 0) - v_{APH}$. The y_{APH} is the APH yield of the representative farmer, d is the coverage level, and p_{APH} is the indemnity price. The actuarial fair premium is used, which is obtained by setting $v_{APH} = E(p_{APH} \cdot \max(dy_{APH} - y, 0))$.

The payoff of the hedge portfolio including CRC is

$$p_{CRC} = py + h_X(f_0 - f_1)Ey + h_Z[\max(f_1 - k, 0) - v_Z]Ey + NV_{CRC} - C(Ey)$$

with $NV_{CRC} = \max[d \max(f_{CRC0}, f_1)y_{APH} - f_1 y, 0)] - v_{CRC}$ and

$v_{CRC} = E(\max[d \max(f_{CRC0}, f_{CRC1})y_{APH} - f_1 y, 0)])$

The portfolio with futures, options and DP has payoffs as

$$p = py + h_X(f_0 - f_1)Ey + h_Z[\max(f_1 - k, 0) - v_Z]Ey + DP - C(Ey)$$

with $DP = p_{DP} \cdot y_{DP}$, which is already known at the planting time. p_{DP} and y_{DP} are the direct payment rate and the base yield fixed from 2002 through 2007.

The representative farmer's portfolio, including DP and LDP, is

$$p_{LDP} = py + h_X(f_0 - f_1)Ey + h_Z[\max(f_1 - k, 0) - v_Z]Ey + DP + LDP - C(Ey)$$

where $LDP = \max(p_{LDP} - p, 0) \cdot y$, p_{LDP} is the loan rate.

The portfolio including DP, LDP and CCP is

$$p_{CCP} = py + h_X(f_0 - f_1)Ey + h_Z[\max(f_1 - k, 0) - v_Z]Ey + DP + LDP + CCP - C(Ey)$$

where $CCP = \max[p_{CCP} - p_{DP} - \max(p_{MYA}, p_{LDP}), 0] \cdot y_{DP}$, p_{CCP} is the target price of CCP and p_{MYA} is the market year average price.