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# Linkages Between Crop Insurance and Pre-Harvest Hedging

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ABSTRACT

The impact pre-harvest hedging and crop insurance strategies have on expected revenue and associated risk as well as how producers' risk attitudes affect optimal strategies was analyzed for Kansas wheat farms. No insurance, Catastrophic (CAT), Actual Production History (APH), and Crop Revenue Coverage (CRC) were considered. Average revenue was similar across alternatives, but APH and CRC resulted in the least income variability. Risk reduction effects of hedging were small and the advantage of CRC over APH decreases as hedging increases. This historical study provides useful information; however, if future market conditions differ significantly from the past, optimal strategies may change.

**Key Words:** crop insurance, hedging, revenue insurance, risk management.

The Federal Agricultural Improvement and Reform (FAIR) Act of 1996 represented a dramatic shift in U.S. farm policy from the preceding 60 years. Virtually total cropping flexibility is allowed, affording new economic freedoms. However, income-stabilizing deficiency payments are replaced with fixed but annually declining production flexibility contract payments. Thus, increasing uncertainty associated with net income will likely be an undesirable byproduct of FAIR. Historically, government-backed crop insurance has focused on yield (production) risk. However, because farm financial risk is intimately tied to price *and* production risk, it is difficult to address one without considering the other.

Although potentially risk reducing, little crop production is typically hedged or forward sold ahead of harvest (Goodwin and Schroeder), which may partly be due to yield risk (Lapan and Moschini; Tomek). Specifically, producers fear large forward contracting penalties associated with insufficient production when coupled with rising prices into harvest. Recently, USDA, via the Federal Crop Insurance Corporation (FCIC), has approved and backed various revenue insurance policies that address both price and yield uncertainty. Potentially, revenue insurance could mitigate the perceived yield risk barrier to forward pricing and ultimately lessen annual net income uncertainty. However, depending on farm-level price/yield relationships, the structure of revenue insurance policies, and insurance premium levels, reductions in income uncertainty may not be greater than with traditional insurance policies.

This research examines relationships between pre-harvest hedging and a revenue insurance policy, Crop Revenue Coverage (CRC). The principal objective is to determine if risk averse producers would be more inclined to purchase CRC relative to Actual Pro-

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duction History (APH) crop insurance as the level of expected production hedged increases.[1] In other words, it examines whether CRC and pre-harvest hedging are complements or substitutes, relative to APH. Specifically, does the difference between income risk associated with CRC and income risk associated with APH increase with higher levels of pre-harvest hedging? This study looks at tradeoffs of both expected income and minimum income over years across levels of pre-harvest hedging and crop insurance coverage for three insurance policies. It uses a simulation involving a sample of Kansas wheat producers from 1973 to 1995. Additionally, a decision criterion for producer behavior is developed that depicts the optimal pre-harvest hedging and crop insurance strategy depending on attitudes concerning income risk. The issues addressed here are important to those who must deal with potentially increased income uncertainty associated with FAIR.

## Background

Various government-subsidized crop insurance policies designed to help producers lessen net income risk have recently emerged. In place since the early 1980s, APH represents the most common of these policies. APH covers a farm's *yield* shortfall beyond a preselected deductible yield at a price announced prior to planting. Catastrophic crop insurance (CAT) covers 50% of expected yield at 60% of the APH price. Other than an administrative fee, CAT is free to producers; taxpayers implicitly pay the full premium. In 1996 a revenue insurance policy, CRC, was offered on a pilot basis for corn and soybeans in Iowa and Nebraska. Availability has since been expanded to include other crops and other states. CRC covers *revenue* shortfalls; thus, indemnity payments can be triggered by either low yields or low prices (CRC depends on a planting time price and a harvest time price). By insuring a revenue level, if prices decline from planting to harvest, effective insured yield rises to keep insured revenue constant (the lower the harvest price, the smaller the yield loss required to trigger an indemnity). However, if prices rise from planting to harvest, insured price rises to reflect the higher cost of replacing a yield shortfall. That is, rising prices lead to increased insured revenue (indemnity-triggering yield losses stay the same regardless of how high harvest prices go). While the concept of revenue insurance is a change from APH, it is not a new concept as similar Federal Crop Insurance policies were available in the 1930s (U.S. Government Printing Office).

Although the crop insurance literature is large, revenue insurance, in particular CRC, has rarely been studied. Gray, Richardson, and McClaskey analyzed farm program alternatives and found that a revenue assurance program provides more income stability for Kansas wheat producers than policies such as those provided in the 1990 Farm Bill. The revenue assurance program they considered has similarities to CRC but did not explicitly consider crop insurance. Hart and Smith compared average per-acre indemnity payments for CRC and APH for corn in Iowa. They found that CRC indemnity payments are typically greater than APH indemnity payments. The Food and Agricultural Policy Research Institute (FAPRI) examined CRC and APH in a drought scenario and concluded that CRC has higher government costs in both the drought year and on average over time. However, the relatively short time period of their study allowed the drought year to significantly affect the average for the entire period. Additionally, differences in farm income between the two crop insurance policies were not considered. While there is considerable pressure to reduce government spending, the public may support subsidizing crop insurance if it reduces financial risks for producers. Hennessy, Babcock, and Hayes compared a revenue insurance policy with the 1990 Farm Program for a representative corn and soybean farm in Iowa. They concluded that a revenue insur-

[1] Actual Production History (APH) crop insurance has historically been referred to as multiple peril crop insurance (MPCI). However, as an anonymous reviewer pointed out, there are a number of multiple peril products available (e.g., APH, GRP, CRC, IP, CAT, and RA) and thus MPCI is a more generic term while APH refers to the specific insurance product.

ance program is more efficient, as measured by the increase in producer welfare per dollar of government spending, than the 1990 Farm Program. Thus, in addition to the cost of the program to the government, it is important to consider the impact CRC has on farm income and income variability.

## Conceptual Framework

In a framework involving only crop production, pre-harvest hedging, and insurance purchasing, assuming all other costs are constant, net revenue per acre is defined by

$$(1)\quad \textit{Net revenue} = \textit{yield} \cdot \textit{cash price received} + \textit{hedge profits} + \textit{indemnity payments received} - \textit{insurance premiums paid.}$$

In a decision context, with the exception of insurance premiums paid, variables in (1) are expectations. Further, expected hedge profits depend on both expected price changes and on the amount of expected production hedged. Expected indemnities and insurance premiums depend on the type of insurance and coverage level selected.

When considering a new risk management strategy, such as CRC, producers focus on how it is expected to differ in terms of some income or risk measure from an alternative, perhaps more familiar strategy, say APH. If revenue (net) is the measure that most interests producers, and historical yield and price relationships provide reasonable expectations for future relationships, then a reasonable expectation for CRC's revenue advantage over APH is the average annual historical difference in CRC and APH revenue. Thus, simulated farm level historical revenues associated with CRC and APH are compared.

To make meaningful comparisons, annual revenue associated with alternative crop insurance policies should hold other decisions constant. Thus, the question becomes, "On average, conditioned on levels of hedging and insurance coverage, how does CRC revenue compare to APH revenue over the years examined?" Formally, the average revenue for farm *i*, had it hedged a given level of expected production and purchased a given insurance policy at a set coverage level each year, is identically defined with equations of the form broadly defined in (1). Since underlying equations are identities, variables of interest can be isolated for exposition, with other variables embodied directly in the average revenue:

$$(2)\quad AVGREV_i = f_i(\textit{policy, coverage level, hedge \%, hedge time}),$$

where $AVGREV_i$ denotes the average historical revenue for farm *i*; *policy, coverage level, hedge%,* and *hedge time* denote the crop insurance policy, insurance coverage level, percent of expected production hedged, and time hedge is placed, respectively. If the function $f_i$ is approximated as $f$, estimating parameters using multi-farm data and including an error term and other explanatory variables to aid the generalization, then the information contained in (2) can be generalized across farms as

$$(3)\quad AVGREV_i = f(\textit{policy, coverage level, hedge \%, hedge time, other variables, } \beta, \epsilon).$$

In general, a risk averse producer is interested in both expected income and some measure of risk associated with that income. Because tradeoffs between income and risk are specific to individuals, it is helpful to characterize expected income changes resulting from a new risk management strategy independently from expected risk changes. Traditionally, risk is characterized as variability about the mean. However, because producers are likely more concerned with downside income variability, they may be interested in worst-case years: What would my revenue have been in the least revenue year with CRC? with APH? That is, minimum annual revenue becomes the focus rather than average or variance. In that context, to generalize risk differences between insurance policies, equation (3) would merely require respecification in terms of minimum revenue rather than average:

$$(4) \quad MINREV_i = f(policy, coverage\ level, hedge\ \%, hedge\ time, other\ variables, \beta, \epsilon).$$

where $MINREV_i$ denotes the minimum of historical revenue for farm $i$, and other variables have already been defined.

Equations (3) and (4) provide a framework to compare expected income and a measure of risk across crop insurance policies *given* a hedging strategy and insurance coverage level. Alternatively, to compare insurance policies, policy, hedging strategy, and insurance coverage level might be optimally *selected* according to some decision rule incorporating income and risk. For example, producers interested in expected income as well as the worst-case year (i.e. minimum income) might make decisions according to the criterion:

$$(5) \quad INC_{i,p,h,m,c} = \theta \cdot AVGREV_{i,p,h,m,c} + (1 - \theta) \cdot MINREV_{i,p,h,m,c}$$

where *INC* is an income index to be maximized; *AVGREV* is the average revenue; *MINREV* is the minimum revenue; $i, p, h, m, c$ are indices for farm, crop insurance policy, hedge percent, hedge month, and insurance coverage level, respectively; and $\theta$ is a value between 0 and 1. Using equation (5), the decision rule is to maximize *INC* subject to a given $\theta$. When $\theta = 1$, equation (5) is consistent with a risk neutral producer maximizing expected revenue. When $\theta = 0$, equation (5) is consistent with the maximin decision criterion (Hazell and Norton; Hey; McKenna). The maximin criterion is a very pessimistic view as it only considers the worst-case scenario; thus, it is likely that $\theta$ is valued somewhere between 0 and 1 for most risk averse producers. If equation (5) is a reasonable representation of producer behavior, then optimal pre-harvest hedging and crop insurance strategies can be determined at various attitudes toward risk and uncertainty ($\theta$).

The conceptual framework outlined presents two ways to examine the producer decision to purchase CRC crop insurance. The regression approach, equations (3) and (4), examines expected revenue and a measure of expected risk for *given* crop insurance and preharvest marketing strategies, answering the question, "How do policies compare holding all else constant?" This same framework can be used to examine decisions concerning APH versus CAT or no insurance (NOINS) so that results can be placed in a broader insurance purchase context. The optimization approach, equation (5), is based on producers choosing the optimal crop insurance and marketing strategy given their attitude towards risk and uncertainty. Thus, this approach is useful for answering the question, "What is the optimal insurance and marketing strategy given my attitude towards risk and uncertainty?"

## Data and Methods

Individual annual dryland wheat yields for 331 farms in the Kansas Farm Management database were obtained for 1973 through 1995 (Langemeier).[2] Deleting farm-years with no wheat acres resulted in 7,036 farm-year yields. A farm-year yield is the average yield for the entire farm that year. However, indemnity payments for CAT, APH, and CRC are based on farm units, which are often geographically smaller subsets of farms. Unit-level yields from a private insurance company were obtained to adjust whole farm yields from the Farm Management database to unit-level yields.[3] The private insurance company data

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[2] Farms in the Kansas Farm Management Association are broadly representative of commercial (full-time) farming operations in Kansas (Featherstone, Griebel, and Langemeier). Further, the 23-year mean (across annual observations of across-farm mean yields) of database dryland wheat yields could not be statistically distinguished from the 23-year mean of Kansas dryland wheat yields from the Statistics Division of the Kansas Department of Agriculture. We did not find a significant trend in Kansas wheat yields over the 23 years examined.

[3] Using yield variability for insurance purchasers to infer yield variability for nonpurchasers may overstate yield variability as previous research has shown that purchasers of crop insurance have higher yield variability than nonpurchasers (Goodwin).

included unit yields and acres associated with 13,570 Kansas dryland wheat APH policies from 1986 through 1995. A measure of yield variability for an individual farm in the private insurance company database was calculated using

$$\bar{Y}_{it} = \frac{1}{J}\sum_{j=1}^{J} Y_{itj}, \quad \text{and}$$

$$YVAR_{it} = \frac{1}{J-1}\sum_{j=1}^{J} (Y_{itj} - \bar{Y}_{it})^2;$$

where, $Y$ is yield, $YVAR$ is variance of yield across units, $J$ is the number of units insured, and $i$, $t$, and $j$ are indices for farm policy, year, and unit, respectively.

Schurle found that dryland wheat yield variability in Kansas was related nonlinearly to the size of the enterprise and negatively related to mean rainfall, but not significantly related to mean yield. Goodwin found that the standard deviation of dryland wheat yields in Kansas was positively related to mean yield. Accordingly, unit-level yield variance was specified as a function of acres and mean yield:

$$(6) \quad YVAR_{it} = \alpha_0 + \alpha_1 TA_{it} + \alpha_2 TA_{it}^2 + \alpha_3 \bar{Y}_{it} + \alpha_4 \bar{Y}_{it}^2 + \epsilon_{it},$$

where $TA_{it}$ is total dryland wheat acres for farm $i$ in year $t$ (sum across units), $\alpha_0$, $\alpha_1$, $\alpha_2$, $\alpha_3$, and $\alpha_4$ are parameters to be estimated, $\epsilon_{it}$ is an error term, and other variables are as already defined. Using the parameter estimates from OLS-estimated equation (6), estimates for yield variance across units within a year for the Farm Management database were derived as

$$(7) \quad \widehat{YVAR}_{it} = \hat{\alpha}_0 + \hat{\alpha}_1 TA_{it} + \hat{\alpha}_2 TA_{it}^2 + \hat{\alpha}_3 \bar{Y}_{it} + \hat{\alpha}_4 \bar{Y}_{it}^2,$$

where independent variables are from the Farm Management database rather than from the private insurance company data.

On average, farms in the insurance company database had 3.06 units. Based on this, for each farm-year observation in the Farm Management database, three random yields were drawn from a normal distribution with a mean equal to the observed farm-year yield and a variance equal to that estimated with equation (7).[4] In addition to estimating a yield for each unit, actual production history yields (APH yield) are needed to simulate insurance premiums and indemnity payments.[5] APH yields were generated for each farm for each year based on the farm's previous 10-year yield history. Missing yields in a 10-year farm history were replaced with county yields adjusted by that farm's average 1973–1995 farm-to-county yield ratio. Each unit on a farm was assumed to have the same APH yield.

Crop insurance indemnity payments are determined by yield and price. In general, a unit's insured yield equals APH yield times the percent coverage level (APH and CRC coverage levels range from 50 to 75% in increments of 5%, CAT is only available at 50% coverage). For APH and CAT the price level affects the magnitude of any indemnity payments, but not the frequency. With CRC, price levels—specifically price *changes* between planting and harvest—affect the magnitude and possibly the frequency of indemnity payments. The price election used each year in this analysis for APH is the maximum price election available that year (FCIC); the price election for CAT is 60% of the APH price. CRC uses the greater of a planting time price and a harvest price. The planting price equals 95% of the average Kansas City Board of Trade (KCBT) July wheat futures price during

[4] The three units on a particular farm were assumed to be of equal size. To avoid negative yields, negative draws were redrawn from a triangular distribution, with the lower bound set to 0, the upper bound set to the farm-year yield, and the most likely occurrence set to 0. To preserve observed information the three yields were adjusted proportionately so their mean exactly equaled the observed farm-year yield. Research has regularly found yields to be non-normally distributed over time (Gallagher; Moss and Shonkwiler; Nelson). However, it is important to note that yield distributions examined here are within year unit yields—yields that likely vary due to geographical variability.

[5] Actual production history yields (APH yields) are not to be mistaken with the insurance product APH (commonly referred to as MPCI—see Footnote 1). Historical proven yields are the same for CRC, APH, and CAT.

August in the year preceding harvest, and the harvest price equals 95% of the average KCBT July wheat futures price in June of the harvest year. Historical KCBT July wheat futures prices were collected to calculate CRC planting and harvest prices in 1973 through 1995 (Bridge).

Premiums for APH are based on the liability level (insured yield × APH price) and a base rate determined by FCIC, less a producer subsidy. CRC premiums are APH premiums adjusted upwards to account for price risk. Premium rates for APH and CRC for 1997 were used to simulate premiums for years 1973 to 1995 based on historical APH prices and CRC planting prices and farm APH yield.[6] CAT premiums are assumed to be 0 because CAT incurs no direct premium, only a $50 administrative fee for each crop in each county.[7]

Revenue generated per acre equals yield times cash selling price plus any indemnity payments less premiums incurred. If a producer makes pre-harvest marketing decisions, revenue increases (decreases) by any gain (loss) arising from these decisions. Pre-harvest marketing scenarios considered are hedging 0, 25, 50, 75, and 100% of expected production using July KCBT wheat futures. Expected production is defined as current year APH yield. In addition to various hedging quantity levels, September, December, and March were considered as alternative times hedges were placed.[8] Wheat production was assumed sold at harvest each year in the cash market at the average July price for the crop reporting district in which the farm is located (Kansas Agricultural Statistics). Insurance coverage levels considered for APH and CRC are 50, 55, 60, 65, 70, and 75%.

Unit revenue was calculated for each crop insurance alternative (NOINS, CAT, APH, and CRC) at the different coverage levels, hedging percent, and hedging time horizons according to

$$(8) \quad REV_{itj,p,h,m,c} = YLD_{itj} \cdot CP_{it} + IP_{itj,p,c} - PREM_{it,p,c} + HG_{it,h,m},$$

where *REV* equals revenue ($/acre); *YLD* equals yield (bu./acre); *CP* equals cash price at harvest ($/bu.); *IP* equals indemnity payment ($/acre); *PREM* equals producer-paid crop insurance premium ($/acre); *HG* equals hedging gain ($/acre); *i, t,* and *j* are indices for farm, year, and unit, respectively; *p* denotes the insurance policy selected (NOINS, CAT, APH, and CRC); *h* denotes hedging percent selected (0, 25, 50, 75, 100); *m* denotes month hedge was placed (September, December, March); and *c* denotes insurance coverage level (50, 55, 60, 65, 70, 75).[9]

Estimating returns on a per-unit basis is important because unit yields determine indemnity payments. However, because producers are assumed to be interested in farm level income and risk, unit returns were aggregated before analysis, causing *j* to drop from equation (8) as all results are developed on a per-acre basis. Following the conceptual framework presented in equations (3) and (4), average revenue and minimum revenue were calculated for each farm over the 23-year period and for each insurance/marketing strategy. For example,

$$(9) \quad AVGREV_{i,p,h,m,c} = \frac{1}{23} \sum_{t=1}^{23} REV_{it,p,h,m,c}$$

represents the 23-year average revenue for

[6] A more detailed explanation of the price risk premium is available from the authors. Premium rates are expressed as percent of liability. Current (1997) FCIC APH premium rates and current CRC premium rates implicitly or explicitly incorporate historical yield and price variability (through 1996). If these historical variabilities are greater today than in the past, using 1997 insurance premium rates may have overestimated premiums and underestimated historical returns to insurance simulated in this study.

[7] For very small farms a $50 administrative fee is significant on a per acre basis. For most farms, however, a $0 CAT premium assumption imposes little distortion.

[8] Futures contracts were assumed divisible. A commission and slippage charge of 2¢/bu. was assigned. Hedges were placed at a monthly average price and lifted at the average June price. No significant trends in wheat prices during the 1973–1995 period were uncovered.

[9] Crop insurance premium and hedging gain are not indexed by crop unit because APH yield is assumed to be constant across units.

**Table 1.** Definition of Variables Used to Explain *AVGREV* and *MINREV* (Equations 3 and 4)[a]

| Variable | Definition |
|---|---|
| $YLD_i$ | Average wheat yield (over 23 years) for farm $i$ |
| $TA_i$ | Average wheat acres (over 23 years) for farm $i$ |
| $H$ | Hedge percent |
| $H2$ | Hedge percent squared |
| $CRCH_p$ | Hedge percent if $p$ equals CRC; else = 0 |
| $CRCH2_p$ | Hedge percent squared if $p$ equals CRC; else = 0 |
| $DEC_m$ | Binary variable = 1 if $m$ equals December; else = 0 |
| $MAR_m$ | Binary variable = 1 if $m$ equals March; else = 0 |
| $CAT_p$ | Binary variable = 1 if $p$ equals CAT; else = 0 |
| $CRC50_{p,c}$ | Binary variable = 1 if $p$ equals CRC and $c$ equals 50; else = 0 |
| $CRC55_{p,c}$ | Binary variable = 1 if $p$ equals CRC and $c$ equals 55; else = 0 |
| $CRC60_{p,c}$ | Binary variable = 1 if $p$ equals CRC and $c$ equals 60; else = 0 |
| $CRC65_{p,c}$ | Binary variable = 1 if $p$ equals CRC and $c$ equals 65; else = 0 |
| $CRC70_{p,c}$ | Binary variable = 1 if $p$ equals CRC and $c$ equals 70; else = 0 |
| $CRC75_{p,c}$ | Binary variable = 1 if $p$ equals CRC and $c$ equals 75; else = 0 |
| $APH50_{p,c}$ | Binary variable = 1 if $p$ equals APH and $c$ equals 50; else = 0 |
| $APH55_{p,c}$ | Binary variable = 1 if $p$ equals APH and $c$ equals 55; else = 0 |
| $APH60_{p,c}$ | Binary variable = 1 if $p$ equals APH and $c$ equals 60; else = 0 |
| $APH65_{p,c}$ | Binary variable = 1 if $p$ equals APH and $c$ equals 65; else = 0 |
| $APH70_{p,c}$ | Binary variable = 1 if $p$ equals APH and $c$ equals 70; else = 0 |
| $APH75_{p,c}$ | Binary variable = 1 if $p$ equals APH and $c$ equals 75; else = 0 |
| $SC_i$ | Binary variable = 1 if farm $i$ is in SC region; else = 0 |
| $SW_i$ | Binary variable = 1 if farm $i$ is in SW region; else = 0 |
| $NE_i$ | Binary variable = 1 if farm $i$ is in NE region; else = 0 |
| $NW_i$ | Binary variable = 1 if farm $i$ is in NW region; else = 0 |
| $SE_i$ | Binary variable = 1 if farm $i$ is in SE region; else = 0 |

[a] Model defaults are NOINS (no insurance), September hedge horizon, NC region. CAT = Catastrophic insurance; APH = Actual Production History insurance; CRC = Crop revenue coverage insurance; $i$, $m$, $p$, $c$ are indices for farm, hedge month, insurance policy, and insurance coverage level, respectively.

farm $i$, hedging $h$ percent of expected production in month $m$, and purchasing $c$ coverage level of insurance policy $p$. Similarly, $MINREV_{i,p,h,m,c}$ is also defined as the minimum revenue over the 23 years. When all combinations of coverage level, hedging percent, and hedging horizon are included there are 25,818 observations [331 farms × 6 coverage levels × (4 hedging percent × 3 hedging time horizons + no hedge)] for both APH and CRC. For NOINS and CAT there are 4,303 observations [331 farms × (4 hedging percent × 3 hedging time horizons + no hedge)]. Summing across crop insurance policies there is a total of 60,242 observations for each of average revenue and minimum revenue, where each observation is itself a farm-level summary statistic across the 23-year time period.

Because producers are interested in competing risk management/marketing alternatives, the relevant issue is how the alternatives compare to each other. Therefore, the data need to be analyzed so that differences between crop insurance polices with respect to expected income and risk can be compared. In order to determine the relationships between average and minimum revenue with crop insurance policies and risk management strategies (coverage level, hedging percent, and hedging time horizon), equations (3) and (4) were specified as ordinary least squares linear regressions with the explanatory variables presented in Table 1.

The $AVGREV_{i,p,h,m,c}$ and $MINREV_{i,p,h,m,c}$ values calculated (equation 9) were used with equation (5) to determine producers' optimal crop insurance and pre-harvest hedging strategy at various levels of $\theta$ between 0 and 1.

**Table 2.** Summary Statistics of Selected Farm and Crop Insurance Data

| Name | N[a] | Mean | Std Dev | Minimum |
|---|---|---|---|---|
| Wheat acres | 331 | 334.42 | 292.14 | 9.83 |
| Total crop acres | 331 | 933.41 | 636.22 | 61.09 |
| Yield (bu/acre) | 331 | 33.38 | 4.60 | 20.85 |
| NOINSAVG | 4,303 | 104.63 | 15.10 | 61.22 |
| NOINSMIN | 4,303 | 35.16 | 21.59 | −23.01 |
| CATAVG | 4,303 | 105.90 | 14.97 | 63.51 |
| CATMIN | 4,303 | 46.22 | 14.71 | 3.62 |
| CRCAVG | 25,818 | 104.39 | 15.10 | 58.51 |
| CRCMIN | 25,818 | 55.75 | 13.47 | 11.46 |
| APHAVG | 25,818 | 104.99 | 15.04 | 60.14 |
| APHMIN | 25,818 | 54.57 | 12.92 | 10.87 |

*Notes:* NOINS = No insurance, CAT = Catastrophic insurance, APH = Actual Production History insurance, CRC = Crop revenue coverage insurance, AVG = average revenue ($/acre), MIN = minimum revenue ($/acre). Using *CRCMIN* as an example, combined variable names read as follows: Across 6 insurance coverage levels, 13 hedging level-time horizon combinations, on average, the revenue associated with the *minimum* revenue year for the 331 farms, when they were using *CRC*, equals $55.75/acre. Each observation underlying the summary statistic for wheat acres, total crop acres, and yield is itself a 23-year average for a farm (or over less years if wheat was not raised every year).

[a] NOINS and CAT: 4,303 = [(4 hedge levels × 3 hedge horizons + no hedge) × 331 farms] APH and CRC: 25,818 = [6 coverage levels × (4 hedge levels × 3 hedge horizons + no hedge) × 331 farms].

Using this approach it is possible to determine how a producer's optimal insurance/hedging strategy might change as his or her attitude towards risk changes.

## Results

Summary statistics for selected data are presented in Table 2. Across insurance alternatives, the average revenue for CAT was the highest at $105.90 and lowest for CRC at $104.39 per acre. This narrow range indicates that, on average, across insurance coverage levels and marketing strategies, routinely purchasing crop insurance is essentially a break-even proposition in this study.[10] The mean of minimum revenue was greatest for CRC at $55.75 and lowest for NOINS at $35.16. On average, the minimum income of CAT was $11.06 higher than for NOINS. The minimum income for APH was $8.35 higher than for CAT, but $1.18 less than for CRC, on average. In all cases, investing more in insurance premiums to presumably further reduce risk increased income in the worst-case year (i.e. minimum income) with little effect on mean income. The minimum of minimum income ranged from a negative $23.01 for NOINS to a positive $11.46 for CRCMIN. The low value for NOINS (−$23.01) is the result of a com-

[10] This is not to say that the federally subsidized crop insurance program has been actuarially sound over the years. From 1973 to 1995 the total-premium loss ratio (indemnities/total premiums), which includes the producer subsidy paid directly to the insurance company, for insurance-purchasing Kansas wheat producers was 1.27 (Actuarial Division of the Risk Management Agency (RMA) in Kansas City, Missouri). Under our assumptions, if the farms in our database each purchased APH at 65% coverage annually, the computed total-premium loss ratio would be 0.7, and the producer-paid-premium loss ratio (indemnities/premium paid by farmers) would be 1.2. This difference (0.7 vs. 1.27) could be due to 1) adverse selection among crop insurance purchasers, 2) underestimation of within-year across-unit yield variability by our methods, 3) prevented-planting payments and loss-of-quality payments which we have not considered are included in RMA's indemnity measure, or 4) using 1997 premium rates which may have been higher than rates in previous years due to ongoing emphasis on making the program more actuarially sound. Consequently, the loss ratios may not be directly comparable. Because our inferences regard typical commercial farmers who are considering insurance purchasing in the future, using 1997 premium rates should be appropriate. Moreover, as long as our measures of within-year across-unit yield variability are appropriate and historical yield variability is a reliable estimate of future variability, then our results should hold for current decision makers.

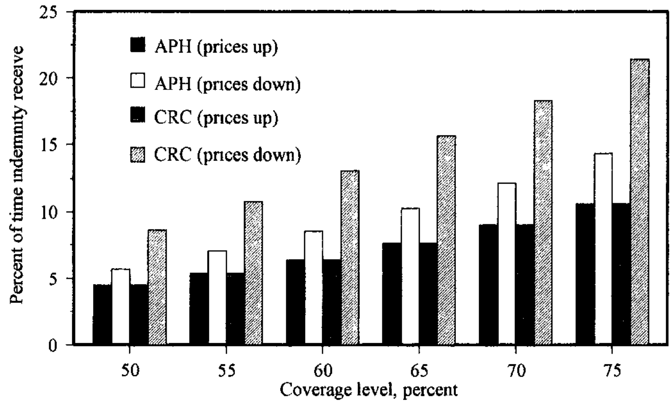


**Figure 1.** Percent of times indemnity payment collected with APH and CRC

bination of a very low yield and pre-harvest hedging when prices increased.

To estimate unit yield variance for each farm-year, equation (6) was estimated giving

$$(10) \quad \widehat{YVAR}_{it} = \underset{(4.468)}{20.395} + \underset{(0.0097)}{0.0432TA_{it}} - \underset{(7.0E-6)}{0.00002TA_{it}^2} + \underset{(0.2889)}{3.4511\bar{Y}_{it}} - \underset{(0.0048)}{0.05938\hat{Y}_{it}^2},$$

where standard errors are in parenthesis ($R^2$ = 0.021). Equation (10) shows unit yield variance in a given year to be rising in total wheat acres through 1,080 acres and subsequently falling. However, the effects are not large. The average (across all farm-years) unit yield variance was 72.44 and the model-predicted unit yield variance for a 1,000-acre wheat farm is only 6.6 greater than that of a 500-acre farm. Also, unit yield variance rises in farm yield through 29 bu./acre and subsequently falls. The unit-level yields used in equation (8) were randomly generated using whole farm yields and estimated variance from (10). Due to truncating at 0 and the method of redrawing negative yields, slightly over half (51.5%) of the 21,108 (7,036 farm-years by 3 units) unit-level yields were greater than the mean yield of 33.38 bushels per acre.

Due to the structure of CRC, whenever an indemnity payment is paid with APH, CRC also receives a payment (assuming equal coverage levels), but it is possible for CRC to receive an indemnity payment when APH would not. Figure 1 shows the percent of time an indemnity payment was collected for CRC and APH at various coverage levels. Incidence of payments is segregated according to whether prices increased or declined from planting to harvest. When prices increased from planting to harvest both policies received indemnity payments for the same amount of time. However, when prices decreased from planting to harvest CRC received indemnity payments more often. For example, at the 65% coverage level, CRC received an indemnity payment 23.3% of the time and APH 17.9% of the time, with all increased frequency of CRC indemnities coming in years when price had fallen into harvest.

### *Regression Approach Results—Equations (3) and (4)*

Regression results from *AVGREV* (equation 3) and *MINREV* (equation 4) models are reported in Table 3. Average revenue per acre increased as the average yield for a farm increased as would be expected; however, average revenue decreased slightly as the number of wheat acres increased. The binary variables for the different regions of the state are all statistically significant, indicating that average revenue varies geographically.

The hedge level parameter (*H*) is significant and indicates average revenue increased by $0.65/acre for each additional percent

**Table 3.** Regression Results for Average Revenue and Minimum Revenue Models (Equations 3 and 4)

| | *AVGREV* Model | | *MINREV* Model | |
|---|---|---|---|---|
| Variable | Parameter Estimate | *t*-Statistic | Parameter Estimate | *t*-Statistic |
| *INTERCEPT* | 4.26699** | 29.69 | −33.30629** | −82.08 |
| *YLD* | 3.04489** | 872.46 | 2.05564** | 223.91 |
| *TA* | −0.00286** | −42.69 | −0.00253** | −14.36 |
| *H* | 0.64541** | 12.91 | 8.29148** | 12.12 |
| *H2* | —[a] | N/A | −9.36481** | −15.83 |
| *CRCH* | —[b] | N/A | −3.53108** | −3.46 |
| *CRCH2* | —[b] | N/A | 1.25911 | 1.42 |
| *DEC* | −0.58251** | −14.74 | 1.15098** | 11.07 |
| *MAR* | −1.29503** | −34.06 | 0.68003** | 6.65 |
| *CAT* | 1.27187** | 15.50 | 11.0515** | 51.27 |
| *CRC50* | 0.21563** | 2.63 | 18.70675** | 58.16 |
| *CRC55* | 0.24469** | 2.98 | 20.45661** | 63.60 |
| *CRC60* | 0.17583* | 2.14 | 21.96998** | 68.31 |
| *CRC65* | 0.44370** | 5.41 | 23.58984** | 73.34 |
| *CRC70* | −0.40840** | −4.98 | 24.07915** | 74.86 |
| *CRC75* | −2.13826** | −26.06 | 23.73689** | 73.80 |
| *APH50* | 0.83751** | 10.21 | 15.59363** | 72.25 |
| *APH55* | 0.81103** | 9.89 | 17.36983** | 80.48 |
| *APH60* | 0.69212** | 8.44 | 19.02219** | 88.14 |
| *APH65* | 0.93695** | 11.42 | 20.89374** | 96.81 |
| *APH70* | 0.17720* | 2.16 | 21.74944** | 100.77 |
| *APH75* | −1.30794** | −15.94 | 21.85440** | 101.26 |
| *SC* | −0.87960** | −15.49 | 3.20931** | 21.48 |
| *SW* | −6.65200** | −98.42 | −2.86504** | −16.11 |
| *NE* | 5.03285** | 85.03 | −0.32421* | −2.08 |
| *NW* | −6.09969** | −84.68 | −7.93330** | −41.87 |
| *SE* | 0.98347** | 18.17 | −1.08137** | −7.60 |
| $R^2$ | 0.936 | | 0.561 | |
| RMSE | 3.806 | | 10.011 | |
| Observations | 60,242 | | 60,242 | |

*Note:* Two asterisks and one asterisk denote coefficients which are significantly different from zero at the 0.01 and 0.05 levels, respectively. *AVGREV* and *MINREV* are in $/acre. Hedge percent are in decimal form.

[a] *H2* not needed because percent of hedging impacts average revenue linearly.

[b] *CRCH* and *CRCH2* not needed because hedge and crop insurance decision are independent in terms of average revenue.

hedged. This is because, on average, September hedging was slightly profitable during the 1973–1995 period analyzed (before subtracting $0.02 for commissions, average September-less-June futures price moves were $0.063/bu. with a standard deviation of $0.62). However, based on average December- and March-less-June price moves of $0.043 and $0.003, respectively, initiating a hedge in December (DEC) or March (MAR) was slightly less profitable than in September (default). Not too much should be made of these results as they are quite time sensitive—adding 1996 price data would have caused average September hedging to be negative (−$0.01/bu. before commissions). Nonetheless, that hedge returns are near 0 suggests efficient futures markets during the study period. By this measure, price movements in this analysis should be reasonably representative in a broader context.

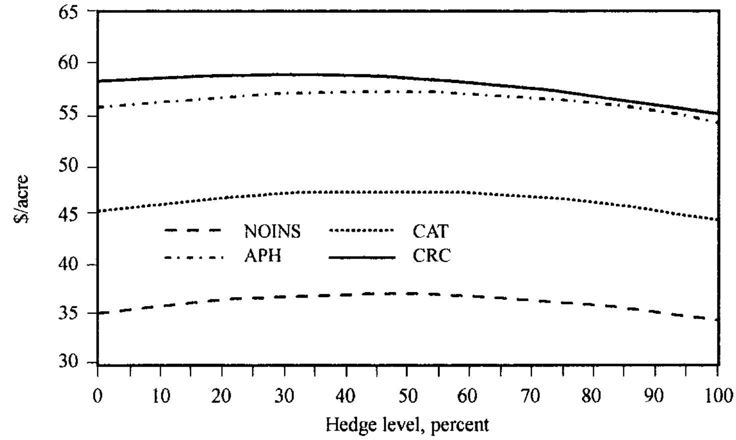


**Figure 2.** Predicted minimum revenue (September hedge, 65% coverage level for APH and CRC, NC Kansas)

The average revenue for CAT was significantly greater than the average revenue for NOINS (default in model). CRC and APH coverage level variables are included as binary variables because coverage level is not continuous and the producer subsidy level is not proportional across coverage levels. Average revenue for CRC was greater than NOINS at coverage levels less than 65% but was lower at coverage levels of 70 and 75%. Average revenue for APH was greater than NOINS at coverage levels between 50 and 70% but was lower at the 75% coverage level. For both CRC and APH average revenue was greatest at the 65% coverage level and least at the 75% coverage level.[11]

Similar to average revenue, minimum revenue per acre increased as the average yield for a farm increased but minimum revenue decreased slightly as the number of wheat acres increased. The binary variables for the different regions of the state are all statistically significant, indicating that income risk, as measured by minimum revenue, varies geographically.

Hedge level parameters are significant and indicate that minimum revenue for NOINS, CAT, and APH increased as hedge percent increased from 0 to 44%, and then decreased as hedge level increased beyond 44%. Thus, a producer wanting to maximize income in the worst-case year (i.e. maximin) would hedge 44% of expected production pre-harvest. The interaction term between CRC and hedge percent is significant, resulting in minimum revenue for CRC being maximized at a hedge level of about 30%. Figure 2 shows the model-predicted minimum revenue for the different crop insurance policies at various September hedge levels at the 65% coverage level for CRC and APH in NC (north central) Kansas. The advantage CRC has over APH in terms of minimum revenue decreases as the hedging level increases. This indicates that a producer who would choose APH over CRC in the absence of pre-harvest hedging likely has less of an incentive, from a minimum revenue standpoint, to purchase CRC when considering pre-harvest hedging. While initiating a pre-harvest hedge in either December or March resulted in lower *average* revenue than initiating the hedge in September, the *minimum* revenue was higher for hedges initiated in December or March compared to September.

[11] Although the differences between average revenue for CRC and APH are small, parameter estimates are statistically different at equal coverage levels for all coverage levels. It is important to note that these results, like all results in a historical study of this type, might be due to the unique relationships among premium subsidies, yields, and prices observed during the period of study. Nonetheless, this is consistent with the casual observation that most Kansas insurance purchasers purchase 65% coverage.

**Table 4.** Average Price Move (CRC Harvest Price Less CRC Planting Price) Associated with Minimum Revenue Years ($/bu)

| Hedge Level | NOINS | CAT | APH | CRC |
|---|---|---|---|---|
| 0% | −0.24 | −0.31 | −0.57 | −0.26 |
| 25% | −0.11 | −0.14 | −0.31 | −0.08 |
| 50% | 0.01 | 0.01 | −0.07 | 0.08 |
| 75% | 0.12 | 0.15 | 0.12 | 0.22 |
| 100% | 0.22 | 0.26 | 0.29 | 0.34 |

Based on minimum income over time as a risk measure, this analysis indicates that producers who routinely hedge pre-harvest have less of an incentive to purchase CRC than producers who do not hedge pre-harvest. While this is perhaps counterintuitive for those who view CRC and pre-harvest hedging as complements, it can be explained with some characterization of minimum-revenue years. Table 4 shows the average price move (CRC harvest price less CRC planting price) in years of minimum revenue associated with each of the insurance policies. Across all policies, as hedge level increased average price moves became larger. At sufficiently high levels of hedging, average price moves were positive. Across years, planting-to-harvest price moves are highly correlated with hedge-entry-month-to-hedge-exit-month price moves, so positive values in Table 4 are indicative of hedge losses. As the level of hedging increases, the minimum-revenue years for farms tend to be more focused on years when prices rose into harvest, implying greater per bushel hedge losses (i.e. as hedging increases, minimum revenue years are more likely to be associated with hedge losses rather than yield losses). Hedge losses associated with minimum-revenue years may be too great to be offset with gains in cash price received, implying that the minimum revenue associated with the minimum-revenue year may itself fall upon increased hedging, ultimately increasing risk.

Table 4 also shows that at all levels of hedging CRC minimum-revenue years are associated with greater up moves in price (less negative if prices moved down) than APH, CAT, and NOINS. That is because low-yield/down-price combinations are more frequently offset with indemnity payments with CRC than with APH, causing such years to be less dominant in minimum-revenue years for CRC. Because larger up-moves in price are likely tied to greater hedge losses (or smaller hedge profits), increased hedging causes revenue associated with CRC minimum-revenue years to fall relative to revenue associated with APH minimum-revenue years (i.e. the CRC−APH revenue difference becomes smaller with increased hedging as seen in Figure 2).[12]

The minimum revenue for CAT and for all coverage levels of CRC and APH was significantly greater than the minimum revenue for NOINS. The minimum revenue for CRC was statistically greater than the minimum revenue for APH at all coverage levels but the difference decreases as the insurance coverage level increases. Figure 3 shows the model-predicted minimum revenue when hedging 25% of expected production in September for CRC and APH at the different coverage levels for NC Kansas. The minimum revenue for both CRC and APH increased at a decreasing rate as the coverage level increased from 50 to 75%. Minimum revenue for CRC actually decreases at the 75% coverage level compared to the 70% level, indicating the increased premium cost was greater than the increased indemnity payments.

### *Optimization Approach Results—Equation (5)*

The results of maximizing equation (5) to find producers' optimal crop insurance and pre-harvest marketing strategies are presented in Figure 4 and Table 5. Figure 4 shows the number of producers that would optimally choose the various crop insurance policy alternatives (summed across all coverage levels) at various attitudes towards risk and uncertainty ($\theta$). As $\theta$ increases from 0 to 1, a producer's behavior

[12] Differences between CRC and APH are partly due to differences in APH and CRC price elections within the same year. To test whether these differences were driving the results, simulations were performed setting APH price equal to the CRC planting price. None of the conclusions changed.

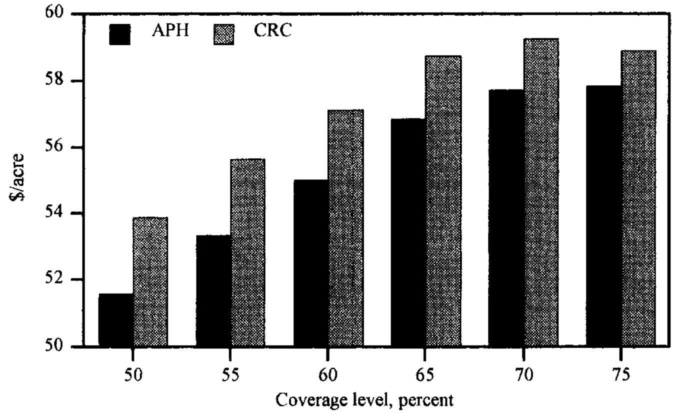


**Figure 3.** Predicted minimum revenue (25% hedge in September, NC Kansas)

would be characterized as being less averse to risk (θ = 1 represents risk neutral behavior). When θ = 1, 189 of the 331 producers optimally would have purchased CAT (57%) and only 43% would have purchased either CRC or APH. Of the producers purchasing CRC or APH, 80% (112 out of 140) would have purchased insurance at the 65% coverage level (data not shown). When θ = 0, almost 90% (297 of 331) of the producers' optimal decisions would be to purchase CRC or APH while only 10% would have purchased CAT. Producers are about equally split between purchasing CRC and APH at 46% and 44%, respectively. Two-thirds of producers purchasing either CRC or APH choose a coverage level greater than 65%—the optimal rate for risk neutral producers. Thus, as would be expected, as producer behavior is characterized as more risk averse, more producers optimally purchase insurance and increase their coverage level. Comparing APH and CRC, the percent of producers optimally choosing CRC and APH is roughly equal at the extreme cases of θ = 0 and θ = 1; however, at all other values of θ more producers optimally choose APH than CRC.

Table 5 shows the number of producers that would optimally choose the various pre-harvest marketing strategies by crop insurance alternative at various attitudes towards risk and uncertainty (θ). As θ increases the optimal pre-harvest hedge percent increases. However, this is a characteristic of the particular time period

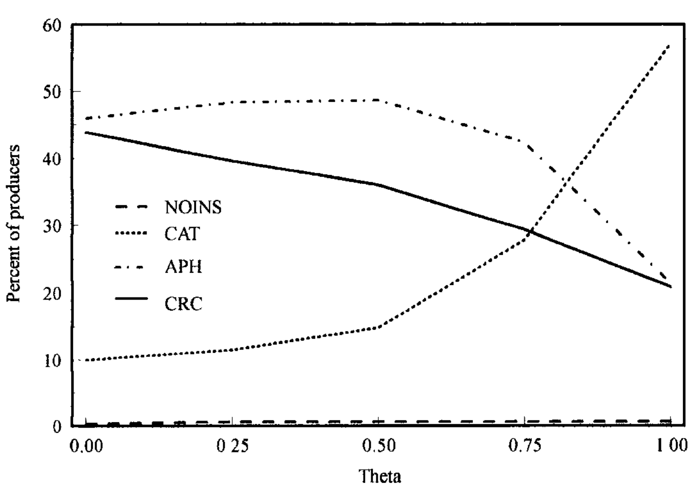


**Figure 4.** Percent of producers optimally choosing different crop insurance alternatives

**Table 5.** Optimal Pre-Harvest Marketing Strategy for Producers at Various Risk Preferences (331 Total Producers)[a]

| Insurance Policy | Hedge Percent | | | | | | Hedge Month | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0% | 25% | 50% | 75% | 100% | Total | Sep | Dec | Mar | Total |
| Theta = 0.0 | | | | | | | | | | |
| NOINS | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| CAT | 7 | 5 | 12 | 2 | 7 | 33 | 11 | 13 | 9 | 33 |
| CRC | 54 | 24 | 32 | 16 | 19 | 145 | 28 | 52 | 65 | 145 |
| APH | 47 | 34 | 39 | 12 | 20 | 152 | 30 | 45 | 77 | 152 |
| Total | 108 | 64 | 83 | 30 | 46 | 331 | 70 | 110 | 151 | 331 |
| Theta = 0.25 | | | | | | | | | | |
| NOINS | 0 | 1 | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 2 |
| CAT | 9 | 8 | 13 | 2 | 6 | 38 | 13 | 14 | 11 | 38 |
| CRC | 48 | 19 | 27 | 17 | 20 | 131 | 26 | 48 | 57 | 131 |
| APH | 48 | 33 | 41 | 18 | 20 | 160 | 34 | 50 | 76 | 160 |
| Total | 105 | 61 | 81 | 37 | 47 | 331 | 74 | 113 | 144 | 331 |
| Theta = 0.50 | | | | | | | | | | |
| NOINS | 0 | 1 | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 2 |
| CAT | 9 | 13 | 15 | 5 | 7 | 49 | 20 | 19 | 10 | 49 |
| CRC | 40 | 19 | 22 | 13 | 25 | 119 | 26 | 47 | 46 | 119 |
| APH | 50 | 32 | 39 | 19 | 21 | 161 | 40 | 52 | 69 | 161 |
| Total | 99 | 65 | 76 | 37 | 54 | 331 | 87 | 119 | 125 | 331 |
| Theta = 0.75 | | | | | | | | | | |
| NOINS | 0 | 1 | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 2 |
| CAT | 19 | 16 | 24 | 11 | 22 | 92 | 52 | 20 | 20 | 92 |
| CRC | 27 | 14 | 22 | 11 | 23 | 97 | 44 | 24 | 29 | 97 |
| APH | 40 | 24 | 29 | 17 | 30 | 140 | 45 | 45 | 50 | 140 |
| Total | 86 | 55 | 75 | 39 | 76 | 331 | 142 | 90 | 99 | 331 |
| Theta = 1.0 | | | | | | | | | | |
| NOINS | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 2 |
| CAT | 5 | 0 | 0 | 0 | 184 | 189 | 179 | 5 | 5 | 189 |
| CRC | 1 | 0 | 0 | 0 | 68 | 69 | 67 | 1 | 1 | 69 |
| APH | 3 | 0 | 0 | 0 | 68 | 71 | 66 | 2 | 3 | 71 |
| Total | 9 | 0 | 0 | 0 | 322 | 331 | 314 | 8 | 9 | 331 |

[a] A value of $\theta = 1$ indicates risk neutral behavior (i.e. maximize expected revenue) and a value of $\theta = 0$ indicates behavior that is very averse to risk (i.e. maximize the minimum revenue).

analyzed and not necessarily a robust result (discussed earlier). Across values of $\theta$ and hedge percent, there is no increased tendency for producers to purchase CRC over APH as higher hedge percents are optimally selected. For example, at 0% hedged (across all $\theta$ values), 47% (170/358) of those who would purchase either CRC or APH would purchase CRC; at 50% hedged 41% (103/251) would purchase CRC; and at 100% hedged 49% (155/314) would purchase CRC. This suggests there is not a strong relationship between CRC and pre-harvest hedging. If anything, at lower levels of hedging (likely what might actually be observed), as hedging is increased CRC purchasing falls relative to APH purchasing. As producers' aversion to risk increases, the optimal time horizon to initiate a pre-harvest hedge shifts from September to December or March.

Based on either the regression approach or the optimization approach, with respect to the measure of risk considered (minimum revenue), any linkage between CRC purchasing and pre-harvest marketing strategies indicates the two are substitutes as opposed to complements—the *more* a farm pre-harvest hedges the *less* likely its risk management strategy will include CRC crop insurance.[13]

## Conclusions

If historical prices, yields, and their variabilities are reliable indicators of future values, simulating returns associated with alternative marketing and risk management strategies based on historical data indicates expected revenue and revenue variability. This information is useful to producers as they consider alternative management strategies for dealing with price and production risk. Using historical annual wheat yields from 331 Kansas farms over 1973 to 1995, and estimated variance for within-year yield variability, unit-level farm yields were simulated, allowing returns to be calculated for various crop insurance and marketing strategies. This makes it possible to test for linkages between different crop insurance policies and pre-harvest marketing strategies in terms of expected revenue and revenue risk. No insurance; Catastrophic insurance (CAT); Actual Production History insurance (APH); and a revenue insurance product, Crop Revenue Coverage (CRC), were examined. The primary objective was to test whether usage of the CRC revenue insurance policy is expected to lead to increased pre-harvest hedging.

On average, there was little difference in average net revenue for no insurance and the crop insurance policies examined, indicating crop insurance is essentially a breakeven proposition over time given the government subsidized premium. However, risk as measured by minimum revenue (lowest farm revenue in 23 years) was significantly reduced with crop insurance. The minimum revenue increased over $10/acre with CAT and around $20/acre with APH or CRC compared to no insurance. The minimum revenue with CRC was $1.18/acre higher than with APH, but the average revenue was $0.60/acre lower. This indicates there are relatively large risk-return tradeoffs going from no insurance or CAT to APH. However, further gains in risk reduction going from APH to CRC are much smaller.

Few producers use pre-harvest marketing alternatives, partly due to their concern with yield risk. Therefore, if a risk management strategy were available that provided useful linkages between yield and price risk, producers may be more comfortable making pre-harvest marketing decisions. New revenue insurance products, such as CRC, have the potential to do just that. Based on this analysis, with respect to revenue variability as measured by minimum income over years, any linkage between pre-harvest hedging and CRC is weak and, if anything, perverse. That is, although revenue risk is generally lower with CRC than APH, as hedging increases the risk reduction advantage of CRC over APH decreases. Thus, the more a farm tends to pre-harvest hedge the less likely its risk management strategy will include CRC. Because crop insurance and marketing issues are explicitly probability issues, inferences drawn here depend on historical price/yield relationships holding in the future.

[13] It should be noted that this analysis focuses on across-year risk associated with insurance/hedging strategies. Producers who focus on within-year risk may still be more inclined to pre-harvest hedge or forward contract with CRC. However, in a 1996 survey, Kansas producers indicated the goal of a marketing strategy should be to decrease long-term risk over marketing years rather than to focus on an individual year (Schroeder et al.).

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