Evaluation of Risk Reductions Associated with Multi-Peril Crop Insurance Products

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Abstract

This research examines risk-return tradeoffs across a full range of crop insurance products and coverage levels. Results indicate that farm-level products reduce risk for low probability events, but that risk reductions often are not large for events that occur with more regularity. Risk reductions vary with yield variability; with counties that have higher yield variability also experiencing greater risk reductions through the use of crop insurance.

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Since the early 1990s, there has been a rapid expansion in the availability of crop insurance alternatives available to farmers. New revenue products have been developed to complement traditional yield products, available coverage levels have been expanded, unit and practice options have been expanded, and new crops have been covered. During the same time, the Federal government has increased subsidies to crop insurance products, thereby lowering the premiums farmers' pay for insurance products. These changes were made with the goal of improving the attractiveness of crop insurance to farmers for managing crop revenue risks. Reasonably high current participation rates provide an often-cited measure of success of these programs, which has the stated goal of improving crop revenue risk management by farmers.

Despite the stated goal of improving risk management by farmers, little direct evidence exists about the effects of the use of crop insurance on crop revenue risk, and still less work examines the relative performance across insurance alternatives (e.g., types and coverage levels) and across different yield risk conditions. In response to the lack of direct evidence, this research evaluates the risk implications of a full range of crop insurance products in actual farm contexts. Risk implications are analyzed by simulating gross revenue distributions under no insurance, and then comparing the no insurance revenue distributions to gross revenue distributions that result from the inclusion of insurance products. Products include both yield and revenue insurance products that determine indemnifications based on farm or county yields over a wide range of coverage levels. Results are developed for the case of corn across all counties in Illinois. Extensive farm-level data from the Illinois Farm Business Farm Management (FBFM) record keeping system are used in conjunction with NASS county-level data to develop the case farms. Illinois counties differ substantially in average yield and yield variability. Therefore, this organization allows a direct assessment of how risk reductions differ by insurance product choice, coverage level, and underlying yield variability.

This research contributes to the literature that examines how crop insurance products perform in farm level contexts. Research has examined issues related to the use of farm-level versus county-level insurance products on farms (Wang et al.), changes in marketing programs that result because of crop insurance use (Coble et al.), and the impacts of different risk criteria on crop insurance choice (Gloy and Baker). This research extends this literature by analyzing the full range of crop insurance products that have been implemented during the 1990s. It also analyzes entire gross revenue distributions under alternative products, thereby providing more complete evidence of impacts of crop insurance use.

Results will be of use to farmers in different circumstances as they evaluate likely effects of risk management alternatives on their own operations. Lenders should find this research useful as they evaluate the riskiness of their farmer borrowers using different crop insurance products. Policy makers will find these results useful as they evaluate crop insurance programs. All multi-peril crop insurance programs evaluated in this paper are federally subsidized and have the expressed intent of reducing risks faced by farmers. Thus, an accurate assessment of the degree of reductions associated with the products is also key in evaluating the effectiveness of the programs.

Gross Revenue Distributions and Insurance Products

Gross revenue is simulated across a wide range of crop insurance products at different coverage levels. Simulated gross revenue is composed of crop revenue (r_c), loan deficiency payments (r_{ldp}), crop insurance indemnity payments ($r_{i,j}$), and crop insurance premium costs ($c_{i,j}$):

$$g_{i,j} = r_c + r_{ldp} + r_{i,j} - c_{i,j} \qquad (1)$$

where $g_{i,j}$ is gross revenue for product i at coverage level j. Crop revenue is measured at harvest using a cash price (p) equal to the futures price (f) minus a local cash basis (p_b). Crop revenue is formally stated as yield (y) times cash price (p):

$$r_c = y \cdot p. \tag{2}$$

Futures prices and yields are random variables. Local bases vary across counties in the state but are assumed known at the time crop insurance decisions are made.

The Loan Deficiency and Marketing Loan programs make payments when prices are below loan rates and provide an important source of price stabilization, potentially substituting for risk protection provided by crop insurance products. The impacts of these programs are incorporated into revenue distributions by including loan deficiency payments (LDPs) equal to the loan rate (p_{rate}) minus the cash price whenever the cash price is below the loan rate.[1] When they occur, LDPs are received on all yield. Hence, LDP revenue (r_{ldp}) equals:

$$r_{ldp} = y \cdot \max(0, p_{rate} - p) \tag{3}$$

Gross revenue distributions are evaluated for all five types of different multi-peril insurance products available in Illinois. There are three farm-level products that make payments based on yields from a farm or unit. These products are 1) yield insurance (i.e. Actual Production History), 2) revenue insurance without a guarantee increase (Revenue Assurance with a base price option) and 3) revenue insurance with a guarantee increase (Crop Revenue Coverage). Alternatives exist to the farm-level revenue insurances (i.e., Income Protection and Revenue Assurance with the harvest price option). Within a type, the alternative that has the most sales in 2000 and 2001 is selected for this evaluation.[2] There are two county-level products making payments based on county yield: 1) yield insurance (Group Risk Plan) and 2) revenue insurance without a guarantee increase (Group Risk Income Plan). These products and their associated indemnity functions are described below.

Actual Production History (APH) insurance. APH yield insurance makes payments when yield falls below a guarantee. The guarantee equals a coverage level (a percent a farmer selects) times the APH yield (usually based on a yield history from the farm unit). When yield falls below the guarantee, APH makes a payment ($r_{aph,j}$) equal to the yield shortfall times an indemnity price. Algebraically, indemnity payments from APH equal:

$$r_{aph,j} = p_{aph} \cdot \max(0,\ y_{aph} \cdot c_{aph,j} - y) \tag{4}$$

where p_{aph} equals the indemnity price, y_{aph} is the APH yield, and $c_{aph,j}$ is the j^{th} coverage level. By increasing the coverage level, the range of yields at which the APH policy will make payments increases, the amount of indemnity payment when they occur rises, and the policy's premium cost is increased.

Revenue Assurance with the base price option (RA-BP) insurance. RA-BP makes payments when indemnified crop revenue falls below a guarantee. The guarantee equals the coverage level (a percent a farmer selects) times the APH yield (same as under APH policies) times the RA base price (For corn, the average of the settlement prices of the December corn contract traded on the Chicago Board of Trade during the month of February.). RA-BP makes payments when the revenue guarantee is higher than yield times a harvest price. The harvest price is determined by the average of the settlement prices of the December CBOT corn contract during the month of November. For the simulations, the harvest price is assumed to be equal to the futures price at harvest (*f*). Indemnity payments from RA-BP then are stated as:

$$r_{ra,j} = \max(0,\ p_b \cdot y_{aph} \cdot c_{ra,j} - f \cdot y) \tag{5}$$

where p_b is the base price and $c_{ra,j}$ is the j^{th} coverage level. Increasing the coverage level of RA-BP is intended to reduce risks.

Crop Revenue Coverage (CRC) insurance. CRC makes payments when indemnified crop revenue falls below a guarantee. The guarantee depends on the level of the base pricre relative to the harvest price.[3] The base price is used when the harvest price is below the base price, the harvest price is used when the harvest price is above the base price but below an upper limit (p_b + I, where I is limit increase), and the upper limit is used when the harvest price is above the upper limit.[4] Algebraically, CRC's guarantee equals $\max(p_b, \min(f, p_b + I))\, y_{aph} \cdot c_{crc,j}$ and CRC's indemnity payment equals:

$$r_{crc,j} = \max(0, \max(p_b, \min(p, p_b + I)) \cdot y_{aph} \cdot c_{crc,j} - f \cdot y)) \qquad (6)$$

where $c_{crc,j}$ is the j^{th} coverage level. The guarantee increase associated with CRC causes payments from CRC to differ from RA-BP when the harvest price is above the base price. CRC and RA-BP will have the same indemnity payments when the base price is below the harvest price.

CRC often is marketed as a product that allows for aggressive pre-harvest hedging using either cash forward price contracts of futures contracts. More specifically, CRC's guarantee increase provision is argued to provide protection against losses incurred while hedging. Hedging losses may result when the harvest price is above the base price. CRC's higher payments potentially offset hedging loses.

Group Risk Plan (GRP) insurance. GRP makes payments when county yield falls below a guarantee. The guarantee equals the coverage level times the expected county yield[5]. Indemnity payments equal:

$$r_{grp,j} = \max(0, w_{grp} \cdot (y_{ec} \cdot c_{grp,j} - y_c) / y_{ec} \cdot c_{grp,j}) \qquad (7)$$

where w_{grp} is the protection level, y_{ec} equals expected county yield, $c_{grp,j}$ is the j^{th} coverage level, and y_c is county yield which is a random variable. The protection level is chosen by the farmer from the range specified by the insurance contract. The expression $(y_{ec} \cdot c_{grp,j} - y_c) / y_{ec} \cdot c_{grp,j}$ equals the percent yield shortfall from the guarantee.

GRP avoids many of the moral hazard and adverse selection problems associated with farm level products (Miranda). Avoiding these factors reduces GRP's costs relative to farm-level products. However, GRP may not result in as much risk reductions as APH because county yields are not perfectly correlated with farm yields.

Group Risk Income Plan (GRIP) insurance. GRIP makes payments when county revenue falls below a guarantee. The guarantee equals the coverage level times the base price (similar to that for RA-BP and CRC) times the expected county yield (same as for GRP).[6] When county revenue is below the revenue guarantee, GRIP makes an indemnity payment ($r_{grip,j}$) equal to:

$$r_{grip,j} = \max(0, w_{grip} \cdot (p_b \cdot y_{ec} \cdot c_{grip,j} - f \cdot y_c) / p_b \cdot y_{ec} \cdot c_{grip,j}) \quad (8)$$

where w_{grip} is the protection level and $c_{grip,j}$ is the j^{th} coverage level.

Coverage Levels. Gross revenue distributions are generated for each insurance product at different coverage levels. For APH, RA-BP, and CRC, coverage levels between 65 and 85 percent in five percentage increments are examined. For GRP and GRIP, distributions are generated for coverage levels between 70 and 90 percent in five percentage increments. In addition, a gross revenue distribution is generated for the case with no crop insurance. Hence, a total of 26 gross revenue distributions are generated for each case farm (five distributions for each product and one distribution for the no insurance case).

Simulation parameters

Distributions of the simulation model's three random variables (futures price, county yield, and farm yield) as well as other model parameters are set to represent 2002 Illinois conditions. Farm yield distributions and crop insurance premiums for each county's case farm are parameterized to represent an "average" acre of corn in that county.

Prices. In keeping with previous research, the future price distribution is parameterized as lognormal. Futures and options data from the last trading day in February 2002 from Chicago Board of Trade December corn futures contracts are used to estimate the coefficients of the futures price distribution. The method used was to minimize the summed squared errors between observed option prices and option prices implied by the fitted distribution. All put and call options that traded on February 28, 2002 with a volume greater than 10 were used. In total, options across 11 strikes with underlying volume of 4,979 were used in recovering the implied distribution (see Sherrick, Garcia, and Tiruppatur; of Fackler and King for more detail on the methods used).[7] The resulting distribution has an expected value of $2.32 per bushel and a standard deviation of $.43 per bushel.

Local basis (p_b) values are calculated from data provided by the Illinois Agricultural Marketing Service (AMS). AMS collects cash prices from each Thursday from elevators in Illinois and then reports average cash prices for seven regions in Illinois. Futures closing prices on respective Thursdays for the December CBOT corn are subtracted from the cash prices to arrive at local basis. An average basis for each of the seven region is calculated using data during the month of November for 1999 through 2001. Basis across the counties varies from $.28 per bushel to $.34 per bushel

Loan rates represent actual 2002 loan rates for each county in Illinois as of February 28, 2002. These were unchanged from 2001 and range from $1.87 per bushel to $2.06 per bushel in Illinois counties, with an average of $1.94 per bushel.

Yield distributions. Previous research suggests that the Weibull distribution can be used to represent corn distributions in Illinois (Zanini). County yield distributions are parameterized using yields from 1972 through 2002 as reported by the National Agricultural Statistical Service (NASS). Yield series were detrended using linear models and stated in terms of 2002 yields. The Weibull distributions were fit to the detrended series using method of moment procedures. Expected values of fitted county distributions range from a low of 97 bushels per acre to 167 bushels, with southern Illinois having a concentration of low yields and northern and central Illinois having a concentration of high yields. Yield variability also ranges across the state, with standard deviations ranging from 15 bu. up to 26 bu.

The expected yield of each case farm is set equal to the expected yield of its county distribution. Farm data from 4,417 farms in the FBFM record keeping system with at least 12 years of data are used to rescale county yield standard deviations to reflect farm yields. Each farm series in the FBFM database was detrended and fitted to a Weibull distribution. Ratios of farm standard deviation to county standard deviations were computed for each farm in the county and then averaged. The case farm distributions then were solved for subject to the constraint that their standard deviations equaled the county standard deviation times the average ratio of farm to county standard deviations.

Correlations between random variables. Farm to county yield correlations are calculated using the same set of farm data as used to calibrate the farm yield distributions. The correlations are calculated between the detrended county and farm-level data series for all counties with at least 10 farms. The average correlation between farm and county level yield is .74 with a range from .52 to .85. The correlation between futures price at harvest and yield also is calculated using prices at harvest by county and both county average yield and each set of farmer yield series. The correlations range from -.36 to -.69 across counties.

Insurance specifications. Simulations require estimates of 2002 per acre premium costs for each of the insurance products at each coverage level. A basic unit option is used to generate premiums for APH, RA-BP, and CRC products. APH yields used to generate premiums were set equal to the expected value for the farm yield. Custom coded computer programs generated insurance premiums with rates obtained from RMA. Resulting premium are available at farmdoc (www.farmdoc.uiuc.edu/cropins/index.html) and represent premiums farmers pay for insurance products after government subsidies have been subtracted. Resulting premium have been spot checked with quotes from the online premium quote software available at RMA's website (www.rma.usda.gov).

Other simulation variables include the indemnity price for APH products (p_{aph}), which is set to the 2002 maximum level of \$2.00. The indemnity price for generating revenue guarantees (p_b) is equal to \$2.32. Protection levels for GRP and GRIP are set at their maximum levels using data from RMA (www.rma.usda.gov).

Simulating and Comparing Gross Revenue Distributions

Standard simulation techniques are used to generate gross revenue distributions. A total of 5,000 observations of gross revenue were used to generate the gross revenue distributions. For each observation, three uniform random variables were generated and then transformed to represent the futures price, farm yield, and county yield. The resulting observations were checked against the theoretical relationships and found to be accurate, with simulated averages differing from their theoretical means by less than .001% on average, simulated standard deviations from theoretical standard deviations by less than .01% on average, and simulated correlations differing from specified values by less than 3% on average. Indemnity payments and gross revenues for each insurance product and each coverage level were generated for each coverage level.

There are several potential approaches to summarizing and comparing gross revenue distributions including maximum expected values, values-at-risk (VARs), probabilities below a benchmark return, Sharpe ratios, and stochastic dominance techniques (Gloy & Baker). In addition to these techniques, other studies have used willingness to pay (Wang et al.) and certainty equivalence returns (Hart and Babcock) to evaluate different risk management strategies.

The focus of this paper is to provide objective estimates of risk reductions across alternatives. To do so, various measures of risk and revenue outcomes under insurance are presented relative to the base case of no insurance. This formulation allows decision makers with a wide variety of objectives to still assess the impacts on risk from their own perspective. By design, crop insurance products are intended to reduce risk by limiting the downside potential, while shifting the location of the remainder of the revenue distribution by the amount of the premium paid. Hence, methods for analyzing the risk impacts of crop insurance products should also explicitly evaluate their ability to accomplish this task.

To provide as complete descriptions as possible, two sets of measures for comparing across gross revenue distributions are emphasized. The first considers impacts on expected values of the gross revenue distributions and summary measures of distribution location. Gross crop revenue with no insurance is presented as the base case. The net cost then is presented for each insurance case. The net cost for a crop insurance product equals the expected value of gross revenue under no insurance minus the expected value of gross revenue with crop insurance. This measure gives the change in expected value of the gross revenue distribution from the inclusion of insurance. It also equals insurance premiums paid for the product minus the expected value of the indemnity payments. A positive net cost indicates that the premium exceeds average indemnity payments, and a negative net costs indicates that the premiums are less than average indemnity payments. All else being equal, an individual prefers a product with lower net cost.

In addition to net costs, revenue values associated with 5%, 10%, and 25% value-at-risk (VAR) levels of the gross revenue distributions are provided. These VARs are convenient means to summarize the lower tail of the revenue distributions. The 5% VAR represents a low probability event that happens once in twenty years, on average. The 10% VAR represents revenue associated with a one in ten year occurrence, and the 25% VAR represents low revenues that occur with some regularity of about one in four years.

To summarize the risk impacts of insurance, the changes in VARs relative to the no insurance case are provided. For example, the 5% VAR change associated with an insurance product equals the 5% VAR for that insurance product minus the 5% VAR under the no insurance case. A positive VAR change implies that the insurance product improved revenue at that point in the cumulative revenue distribution while a negative VAR impact implies that the insurance product lowers the VAR at the associated probability level.

Insurance products also will be compared using first- and second-order stochastic dominance techniques to determine if farmers with certain types of utility functions can eliminate particular insurance products from consideration. The revenue distribution of one insurance product (*x*) exhibits first-order stochastic dominance over the revenue distribution of another insurance product (*z*) if the cumulative probability distribution for the first product $F_x(t)$ always lies below the other's cumulative distributions $F_z(t)$:

$$F_x(t) \leq F_z(t) \tag{10}$$

for all t (Ingersoll). Farmers with increasing utility functions prefer products that have first-order dominance over other products. An insurance product (x) exhibits second-order stochastic dominance over insurance product (z) if and only if the accumulation of x's cumulative probability distribution lies below z's cumulative distribution:

$$\int_a^t F_x(v)\, dv \leq \int_a^t F_z(v)\, dv \qquad \text{for all t.} \tag{11}$$

Farmers with expected utility functions that are increasing and concave (i.e., risk averse) prefers products that display second-order dominance (Ingersoll).

Results for Logan County

Detailed results are first presented for a specific case farm located in Logan County, Illinois to fully describe risk reduction impacts of crop insurance in a specific location. Then, results are summarized across all Illinois counties. Logan County is located in central Illinois on productive soils. Descriptive statistics for the case's farm yield, county yield, and gross revenue distribution are shown in table 1. Overall, expected yield is 158 bu. and expected gross revenue is $339 per acre.

Insurance products range in premium costs (see panel A of table 2). For a given coverage level, APH has the lowest cost of the farm-level products, followed by RA-BP, and CRC. At an 85% coverage level, for example, APH's premium is $10.53, RA-BP's is $12.03, and CRC's is $17.54. GRP and GRIP have lower premiums than farm-level products. At an 85% coverage level, GRP's premium is $5.89 and GRIP's premium is $7.82.

As expected, payment frequency increases as coverage level increases (see panel B of table 2). For example, RA-BP policies pay indemnity payments in 4% of the years at a 65% coverage level, 11% of the years at a 75% coverage level, and 25% of the years at an 85% coverage level. Farm-level revenue products pay more often than yield products. At an 85% coverage level, APH pays in 19% of the years, RA-BP pays in 25% of the years, and CRC pays in 32% of the years. Because of its guarantee increase, CRC pays in more years than RA-BP. At a given coverage level, county-level products pay out less often than farm-level products due to the lower variance on county yields compared to farm yields. At an 85 percent coverage level, APH pays in 19 percent of the years while GRP pays in 14 percent of the years.

All farm-level products have positive net costs (see panel C of table 2). APH at an 85% coverage level, for example, has net costs of $3.66. Positive net costs mean that the premiums exceed the expected value of the insurance payments (by $3.66 for APH at the 85% coverage level) and that expected value of gross revenue decreases by using this crop insurance (again by $3.66).

Net costs for county level products decrease and become negative as coverage levels increase (see panel C of table 2). Net costs for GRP are $.55 per acre at a 70% coverage level, -$.26 at an 80% coverage level, and -$4.20 at a 90% coverage level. Negative net cost means that the insurance premium is less than the expected value of the insurance payments (by $4.20 for the 85% coverage level) and that the expected value of gross revenue increases by purchasing GRP (by $4.20). Similar to GRP, the net costs of GRIP also decrease and become negative as coverage levels increase.

All insurance products increase 5% VARs, indicating that the insurance products increase revenues when measured at a .05 probability level (see panel D of table 2). For example, APH at an 85% coverage level has a 5% VAR change of $15.25, indicating that the 5% VAR without insurance of $238 is increased by $15.25 by using this insurance. VAR changes increase with higher coverage levels. For APH, the 5% VAR change is $1.59 at the 65% coverage level, $7.54 at the 75% coverage level, and $15.25 at the 85% coverage level. RA-BP at the 85% coverage level has the highest 5% VAR change at $30.00. This $30.00 translates into a 12.6% increase from the 5% VAR of $238 for the no insurance case. Percentage changes range from .7% up to 12.6%

All 10% VAR changes are less than the 5% VAR changes (see panel D of table 2). RA-BP has a 10% VAR change of $11.48, a 62 percent reduction from the 5% VAR change of $30.00. The 10% VARs become negative at lower coverage levels. Stated as percentages, 10% VAR changes range from -.6% of the 10% VAR without insurance.

All farm-level products have negative 25% VAR changes (see panel F of table 2). At an 85% coverage level, APH has a 25% VAR change of -$4.25, RA-BP has a -$2.59 change, and CRC has a -$1.29. Negative changes indicate that crop insurance increases the severity of lower gross revenues at a .25 probability level. At coverage levels below 75%, GRP and GRIP also have negative 25% VAR changes, indicating that insurance reduces revenues at these points.

Relationships between net costs and VAR changes are illustrated by showing cumulative distributions for insurance products at their respective maximum coverage levels. Figure 1 shows these distributions for gross revenues between $240 and $320 per acre. APH at an 85% coverage level eliminates all probability of revenues below $251. APH would not eliminate all low revenues with the LDP program. The cumulative distribution then rises and crosses the no insurance distribution at gross revenue of $280 and cumulative probability of .162 probability. Because the cumulative distributions cross at .162 probability, APH at the 85% coverage level has higher VARs than the no insurance case when the probability level is below .162. As previously illustrated in table 2, the 5% and 10% VAR changes for 85% coverage level respectively are $15.25 and $5.86. APH has lower VAR changes than the no insurance case at probability levels above .162. As previously illustrate in table 2, the 25% VAR change is -$4.25.

Clearly, APH does not exhibit first-order stochastic dominance over the no insurance. Graphically, no dominance is indicated when one distribution's cumulative distribution crosses the other distribution. Furthermore, APH does not exhibit second-order stochastic dominance over the no insurance case. Between the two cases, farmers who place more weight on having higher revenues and less weight on lower revenues are likely to prefer the no insurance case.

Use of RA-BP insurance eliminates the probability in the lower tail of the distribution, as illustrated by the intersection of the cumulative distribution with the horizontal axis at $260 of per acre revenue. The cumulative distribution of RA-BP rises and intersects the no insurance distribution at $290 of gross revenue and .200 probability. Thus, RA-BP has higher VARs than the no insurance case at probability levels below .200 and lower VARs at probability levels above .200. RA-BP does not exhibit first- or second-order stochastic dominance over the no insurance case.

RA-BP does not exhibit first- or second-order stochastic dominance over APH. Nonetheless, there are several factors that suggest most individuals will prefer RA-BP to APH: RA-BP's net cost of $2.18 is less than APH's net cost of $3.88, indicating that RA-BP is less costly than APH; RA-BP has higher VARs than APH for probability levels less than .053, and the cumulative distributions for the two distributions are never far apart for gross revenues above $335. At probability levels above .53, the distance between RA-BP and APH is never more than their $1.50 difference in the premium costs between RA-BP and APH.

Similar to APH and RA-BP, the cumulative distribution under CRC crosses the cumulative distribution for the no insurance case (see figure 1) and CRC does not exhibit first- or second-order stochastic dominance over the no insurance case. Similar to RA-BP, CRC eliminates very low revenue outcomes but the cutoff point is less than under RA-BP due to the higher premium costs for CRC. CRC eliminates per acre revenues less than $254.95, which is $5.51 less than RA-BP and equals the difference between CRC's premium and RA-BP premium.

The cumulative distribution for CRC crosses the distribution for RA-BP at two points: $268 (.055 probability) and $312 (.350 probability). Below $268, RA-HP's distribution lies to the right of CRC's distribution, primarily because of lower premium costs associated with RA-BP. Between $268 and $312 of gross revenue, CRC's distribution lies to the right of RA-BP's distribution. This "bulge" in CRC's distribution causing it to cross RA-BP's distribution is due to CRC's revenue guarantee. This guarantee results in higher insurance payments at intermediate revenues in which yields have fallen but harvest prices are above base prices. Above $312 of gross revenue, RA-BP's distribution lies to the right of CRC's distribution, primarily because of lower premiums associated with RA-BP. CRC does not exhibit first- or second-order stochastic dominance over RA-BP.

The cumulative distribution for GRIP lies to the right of the distribution for the no insurance for all but extremely low revenues and extremely high revenues. The crossing at low revenues occurs at cumulative probabilities of less than .001. In these cases, the county-level GRIP product does not make a payment while farm yields are extremely low. The intersection at high revenue occurs at a cumulative probability greater than .981. In these cases, prices and yields are high such that insurance payments do not occur. At .999 probability the difference between the two distributions is $12.03, the amount of GRIP's premium. Because of these relationships, GRIP does not exhibit first- or second-order stochastic dominance over the no insurance case.

GRIP does not cut off the revenue distribution tail like the farm-level insurance products because county yields are not perfectly correlated with farm yields. There is always some probability, often very small, that farm yields will be extremely low while county yields are not low. As a result of this possibility, GRIP does not eliminate the possibility of catastrophic events.

Figure 1 does not show a probability distribution for GRP as it is very similar to the distributions for GRIP. GRP is not first- or second-order stochastic dominate either GRIP or the no insurance case.

Different coverage levels for the same insurance produce almost always result in cumulative distributions that cross each other. Figure 2 illustrates this phenomenon by showing the cumulative distributions for RA-BP at 75% and 85% coverage levels. The cumulative distribution for the 85% coverage level lies to the right of the cumulative distribution for the 75% level up to $291 of gross revenue. The $291 gross revenue corresponds to a .241 probability. Above $291 the distribution associated with the 75% coverage level lies to the right of the 85% coverage level. Within a product class, different coverage levels do not exhibit first- or second-order dominance over other coverage levels.

The fact that the cumulative distributions intersect indicates that criteria attempting to summarize a distribution's variability; such as a standard deviation, value-at-risk, or probability below benchmark revenue; can not be used with any degree of confidence for ranking the riskiness of alternatives. VARs, for example, will give different answers depending on the probability level chosen. The full probability distributions of the alternatives need to be considered when determining an appropriate choice for an individual decision-maker.

For the Logan county case farm, no insurance product at any coverage level exhibits first- or second-order stochastic dominance over other insurance products. While insurance products can not be eliminated from consideration, the nature of the crop insurance choice can be easily characterized. Farm-level products protect against low probability events by eliminating their low gross revenues. Beyond catastrophic events, however, protection begins to fall and, in the Logan County case, quite quickly. Even at a .05 probability level, or events that happen in one in twenty years, the maximum increase in VAR across all insurance products for the Logan county farm is 12 percent. While this increase will be helpful, farms experiencing these events will have low gross revenues and likely face financial stress. By the .25 probability level, or adverse situations that occur with some frequency, none of the farm-level products increase gross revenues. Therefore, farm-level products can be described as protecting against low gross revenues in catastrophic situations.

County-level products do not provide a floor under revenue and, hence, do not as fully low frequency – high severity events. However, net costs for county level products often are positive and the products increase VARs over a wide range of probabilities. Individuals who are lese risk averse, or who have the capacity to withstand some crop revenue risk, may select county level products to increase expected gross revenue.

Summary Results across All Illinois Counties

Table 3 shows premiums, payment frequencies, net costs, and VAR changes averaged across all the case farms in Illinois. Compared to the Logan county farm, the most notable differences are:

1. Average premium costs are higher across Illinois. For example, the average premium for CRC at the 85% coverage level is $22.41 for the state (see panel A of table 3) compared to $17.54 for the Logan county farm.
2. Average net costs are higher across Illinois. For example, the net costs for CRC at the 85% coverage level averages $9.49 for the state (see panel C of table 3) compared to $3.06 for the Logan county farm.
3. Average VAR changes are lower across Illinois. For examples, the 5% VAR change for CRC at the 85% coverage level averages $19.63 for the state (see panel D of table 3) compared to $29.50 for the Logan county farm.

For the farm-level products, all products have average 5% VAR changes that are positive, 10% VAR changes that are less than the 5% VAR changes, and 25% VAR changes that are negative. This result indicates that the cumulative distributions for most farm-level insurance products cross distributions for no insurance somewhere below the .25 probability level.

At 85% coverage levels for farm level products and 90% for county level products (the maximum coverage levels), RA-BP has the highest average 5% VAR change ($23.45 (see panel D of table 3)) followed by CRC ($19.63), APH ($10.43), GRIP ($8.77), and GRP ($6.72). This sequence (*ra-crc-aph-grip-grp*) has the farm-level revenue products providing the most reduction when measured at the .05 probability level followed by the farm-level yield insurance. County products offer the least risk reductions. At their maximum coverage levels, county-level products have the lowest net costs (-$.99 for GRP and $.77 for GRIP (see panel C of table 3)), followed by RA-BP ($4.71), APH ($8.38) and CRC ($9.39).

The 5% VAR change sequence of (*ra-crc-aph-grip-grp*) is remarkably consistent across the county case farms with 31% of the farms having this exact sequence (see table 4). Farm-level revenue products usually provide the highest 5% VAR changes, with 87 percent of the counties having RA-BP and CRC in the first two positions. Counties where this pattern does not occur are near metropolitan areas or in counties with small corn acreages. A county-level product provides the least increase in 5% VARs in 64% of the cases, with APH occupying the last spot in the other 36% of the cases. Similarly, the net costs sequence of *grip-grp-ra-aph-crc* is remarkably consistent across the counties with 38 percent of the farms having this exact sequence (see table 5). All counties have one of the county-level products as the lowest net costs with APH and CRC having the highest costs in all counties.

These sequencing results indicate the stability in relative insurance product performance across counties. In the vast majority of cases, county-level products have the lowest net costs, APH or CRC having the highest net costs, one of the farm-level revenue products (RA-BP or CRC) provides the highest 5% VAR change, and the county level products have the lowest 5% VAR change.

Whiles sequences are stable, the degree of overall risk reductions offered by all products varies across counties. For example, 5% VAR changes for RA-BP at the 85% coverage level range from $5.46 to $52.25. The correlation between 5% VAR changes and county standard deviations is .816. A graphical description of this relationship is shown in figure 3, which plots each county's standard deviation and 5% VAR change. As the standard deviation increases there is more yield variability, and hence more risk. As one would expect, crop insurance products reduce risks more in areas where there is more risk.

The point showing the Logan county farm is labeled in figure 3. As can be seen, this case has a 5% VAR change roughly in the middle of all VAR changes. Also labeled is Dekalb County, the case with one of the lowest 5% VAR change, and Livingston County, a case with one of the highest VAR changes. The same cumulative distributions shown for the Logan

County case are shown for the Dekalb and Livingston County cases to illustrate the stability in relationships between the insurance products.

Relationships between the cumulative distributions of Dekalb County are similar to those shown for Logan County: Cumulative distributions for APH, RA-BP, CRC, and GRIP cross the distribution for the no insurance case and the RA-BP and CRC distributions cross each other twice (the second cross is outside the range of figure 4). Intersections, however, differ between Dekalb and Logan Counties. In general, intersections for the Dekalb County case occur at lower probability levels than for the Logan county cases, indicating that VAR changes for Dekalb County insurance products become negative at lower probability levels. For example, Dekalb County's APH cumulative distribution intersects the no insurance case at $244 of gross revenue corresponding to a .0481 probability level. Logan County's APH distribution intersected the no insurance case at .162 probability. Intersections for cases with higher county yield standard deviations occur at higher probabilities, as illustrated for the Livingston County case (figure 5). For this case, the intersection between the APH cumulative distribution and the no insurance case occurs at $255 of revenue and .303 of probability. Overall, these figures illustrate that the basic relationships between the products do not change substantially across locations even though intersection levels and yield variabilities differ greatly.

Summary and Conclusions

This research examines risk reduction possible for a wide range of crop insurance products. Data from Illinois FBFM and NASS have been used to develop a case for each county in Illinois that represents an average acre of corn production in each county. For each county, gross revenue distributions have been developed for a no insurance case and cases representing different insurance products. Simulated insurance products include farm-level products (APH, RA-BP, and CRC) and county-level products (GRP and GRIP) at a wide range of coverage levels. Risk reduction impacts of the insurance products are quantified using net costs, VARs, cumulative distributions, and stochastic dominance techniques.

Use of farm-level revenue products result in revenue guarantees that effectively eliminate low revenues caused by catastrophic or low probability, events. However, with LDP provisions, farm-level yield insurance also eliminates extremely low revenues. Farm-level products provide less revenue protection for events that occur with regularity, particularly in counties that have relatively low yield variability. This result is somewhat expected given the design of crop insurance products. However, farmers, lenders, and others need to understand that insurance will provide protection against catastrophic events but little protection against adverse events that occur with some regularity and thus often result in meaning full reductions in mean revenue. Crop insurance, for example, has provided little protection for the low commodity prices that have occurred since 1998.

County-level products do not provide similar protection against catastrophic events. Compared to farm-level products, county-level products have lower, and often negative, net costs. This suggests that there may be risk-return tradeoffs between county-level products and farm-level products. Farmers who are less risk averse and wish to increase returns may prefer county-level products to farm-level products. However, it is likely that the absence of absolute revenue guarantees offered by county-level products will be a continuing hindrance to their use.

In most cases, none of the insurance products exhibit second-order stochastic dominance over other products. This is somewhat expected given the design of insurance products. For example, the choice of different coverage level implies a risk-return tradeoff. It is, however, possible to design crop insurance products that exhibit second-order dominance. GRIP would dominate the no insurance case, for example, by including a catastrophic clause that would provide payments in the rare cases of low farm yields and higher county yields. It is highly likely that revenue products could be developed that dominate existing products. This is an important area for future research given the Federal government's commitment to crop insurance programs. Designing products that dominate existing products could lead to less need for crop insurance subsidies.

The farm-level products involve a risk-return tradeoff because a farmer will incur net costs to insure against low revenues. Other risk management strategies such as hedging, maintaining liquidity, and maintaining debt reserves can substitute for crop insurance. The costs of alternatives may be less than the current crop insurance products. Studies evaluating these tradeoffs, most likely in a multi-period context, should be conducted.

This research shows that risk reductions possible with insurance depends on yield variability, with areas with higher yield variability experiencing greater risk reductions with the use of crop insurance. The relationships also suggest that areas with low variability may be disadvantaged as their products do not perform as well in a relative sense. This issue may be important given federal subsidizes involved with crop insurance. Further research could examine designs of crop insurance that provide the same relative risk protections in low yield variability as in high yield variability areas.

This research has a limited geographical scope and only examines one crop. Future research should extend the research presented here to other crops and other locations. This work could examine whether or not the relationships shown in this paper can be replicated. In particular it would be useful to look at risk-returns outside of Illinois. While Illinois has a wide range of conditions, it would still be considered a high yielding, low variability area. Thus, It would be useful to see if the relationships between VAR changes and net costs hold in other areas.

Footnotes

[1]Loan deficiency payments are actually based on posted county prices that may differ from cash prices. Posted county prices closely follow cash prices; hence, this assumption is accurate.

[2]Sales information is available from the Risk Management Agency, U.S. Department of Agriculture (see http://www.rma.usda.gov/data/).

[3]There is a difference in the way harvest prices are calculated for CRC and RA-BP, For CRC, settlement prices of the December Chicago Board of Trade contract during the month of October are averaged to determine the harvest price while RA averages settlement prices during November.

[4]The limit is $1.50 per bu. for corn and $3.00 for soybeans.

[5]The Federal Crop Insurance Corporation determines the expected yield for each county based on a trend-line evaluation of previous yields from that county.

[6]RA and CRC determine there base price averages settlement prices for the December Chicago Board of Trade contract for the entire month of February. GRIP averages settlement prices from the last five business days in February.

[7]In specific, equation (7) of Sherrick, Garcia, and Tiruppatur is used to determine the parameters of the futures price distribution.

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Table 1. Yield and Gross Revenue Distributions for Logan County, Illinois, 2002.

Yield distribution	
Expected value	158 bu.
Standard deviation	23 bu.
5% VAR	118 bu.
10% VAR	239 bu.
25% VAR	140 bu.
County yield distribution	
Expected value	158 bu.
Standard deviation	28 bu.
5% VAR	108 bu.
10% VAR	120 bu.
25% VAR	135 bu.
Gross revenue	
Expected value	$339
Standard deviation	$58
5% VAR	$238
10% VAR	$262
25% VAR	$302

Table 2. Insurance Results for Logan County Illinois Farm.

Coverage Level	APH	RA-BP	CRC	GRP	GRIP
Panel A. Insurance Premium ($ per acre).					
65%	$2.16	$2.22	$3.65		
70%	$2.83	$3.30	$4.77	$2.11	$1.88
75%	$4.22	$5.07	$7.07	$2.87	$3.00
80%	$6.60	$7.82	$11.01	$4.58	$5.24
85%	$10.53	$12.03	$17.54	$5.89	$7.82
90%				$8.62	$12.43
Panel B. Frequency of Payment (Percent of years).					
65%	3%	4%	5%		
70%	5%	7%	9%	3%	3%
75%	9%	11%	15%	5%	7%
80%	13%	17%	22%	9%	12%
85%	19%	25%	32%	14%	20%
90%				22%	31%
Panel C. Net Costs ($ per acre).					
65%	$1.34	$1.28	$2.03		
70%	$1.35	$1.40	$1.68	$0.55	$0.85
75%	$1.63	$1.57	$1.60	$0.07	$0.43
80%	$2.29	$1.77	$1.89	-$0.26	-$0.30
85%	$3.66	$2.18	$3.06	-$2.14	-$2.65
90%				-$4.20	-$5.22
Panel D. 5% VAR Change ($ per acre).					
65%	$1.59	$2.17	$4.31		
70%	$3.94	$5.08	$9.98	$1.86	$1.95
75%	$7.54	$10.43	$17.24	$2.78	$4.02
80%	$11.55	$20.19	$24.18	$4.36	$6.53
85%	$15.25	$30.00	$29.50	$7.26	$10.13
90%				$11.17	$16.29
Panel E. 10% VAR Change ($ per acre).					
65%	-$1.49	-$1.52	-$0.60		
70%	$0.03	$0.34	$3.09	$0.02	-$0.14
75%	$2.03	$2.85	$7.93	$1.51	$2.38
80%	$4.04	$6.59	$11.61	$2.95	$4.87
85%	$5.86	$11.48	$11.61	$5.86	$8.40
90%				$8.24	$11.77
Panel F. 25% VAR Change ($ per acre).					
65%	-$1.82	-$2.17	-$3.04		
70%	-$2.24	-$2.62	-$3.07	-$0.98	-$1.00
75%	-$2.93	-$2.97	-$2.54	-$0.74	-$0.52
80%	-$3.70	-$2.97	-$1.59	-$0.77	$0.47
85%	-$4.25	-$2.59	-$1.29	$0.70	$3.06
90%				$1.85	$4.60

Table 3. Insurance Results Averages for Case Farms in all Illinois Counties.

Coverage Level	APH	RA-BP	CRC	GRP	GRIP
Panel A. Insurance Premium ($ per acre).					
65%	$3.01	$3.28	$4.67		
70%	$3.94	$4.38	$6.12	$1.97	$1.82
75%	$5.86	$6.24	$9.07	$2.65	$2.77
80%	$9.18	$9.14	$14.13	$4.08	$4.83
85%	$14.65	$13.54	$22.41	$5.48	$7.18
90%				$8.09	$11.28
Panel B. Frequency of Payment (Percent of years).					
65%	4%	4%	6%		
70%	6%	7%	10%	2%	2%
75%	9%	11%	15%	4%	5%
80%	14%	17%	23%	7%	9%
85%	20%	25%	32%	11%	16%
90%				18%	25%
Panel C. Net Costs ($ per acre).					
65%	$2.15	$2.32	$3.03		
70%	$3.37	$2.55	$3.15	$0.73	$1.06
75%	$3.37	$2.96	$4.00	$0.50	$1.00
80%	$5.16	$3.62	$5.86	$0.51	$1.11
85%	$8.38	$4.71	$9.49	-$0.28	$0.14
90%				-$0.97	-$0.77
Panel D. 5% VAR Change ($ per acre).					
65%	-$3.72	$1.02	$3.25		
70%	$3.18	$4.12	$7.97	$1.03	$0.95
75%	$5.38	$9.32	$13.16	$1.78	$2.28
80%	$7.70	$16.21	$17.62	$2.59	$3.59
85%	$10.43	$23.45	$19.63	$4.47	$5.92
90%				$6.72	$8.77
Panel E. 10% VAR Change ($ per acre).					
65%	-$4.00	-$1.68	-$0.70		
70%	-$0.40	-$0.23	$2.22	$0.45	$0.04
75%	$0.88	$2.09	$5.20	$1.21	$1.15
80%	$1.58	$5.12	$7.13	$1.94	$2.63
85%	$0.87	$8.72	$7.40	$3.57	$4.78
90%				$4.90	$6.70
Panel F. 25% VAR Change ($ per acre).					
65%	-$5.33	-$3.10	-$3.83		
70%	-$3.19	-$3.53	-$3.95	-$0.78	-$1.03
75%	-$4.25	-$4.04	-$4.36	-$0.66	-$0.81
80%	-$5.85	-$4.43	-$5.15	-$0.80	-$0.77
85%	-$8.47	-$4.94	-$7.33	-$0.31	$0.32
90%				-$0.19	$1.02

Table 4. Ranking of Insurance Products By 5% VAR Across Illinois Counties.[1]

Order[2]	Percent of Counties
ra-crc-aph-grip-grp	31
ra-crc-grip-grp-aph	18
ra-crc-aph-grp-grip	16
ra-crc-grip-aph-grp	11
crc-ra-aph-grip-grp	5
crc-ra-grip-grp-aph	4
ra-grip-crc-grp-aph	3
crc-ra-grip-aph-grp	2
grip-ra-grp-crc-aph	1
ra-crc-grp-grip-aph	1

[1]Rankings are for policies at the maximum coverage level.

[2]An order of ra-crc-aph-grip-grp means that the RA policy has the highest VAR, followed by CRC, etc.

Table 5. Ranking of Insurance Products By Net Costs Across Illinois Counties.[1]

Order[2]	Percent of Counties
grip-grp-ra-aph-crc	38
grp-grip-ra-aph-crc	35
grip-grp-ra-crc-aph	12
grp-grip-ra-crc-aph	9
grp-ra-grip-aph-crc	5
grp-grip-crc-ra-aph	1

[1]Rankings are for policies at the maximum coverage level.

[2]An order of ra-crc-aph-grip-grp means that the RA policy has the lowest net cost, followed by CRC, etc.

Figure 1. Cumulative Revenue Distributions for Logan County Farm, Illinois, 2002.

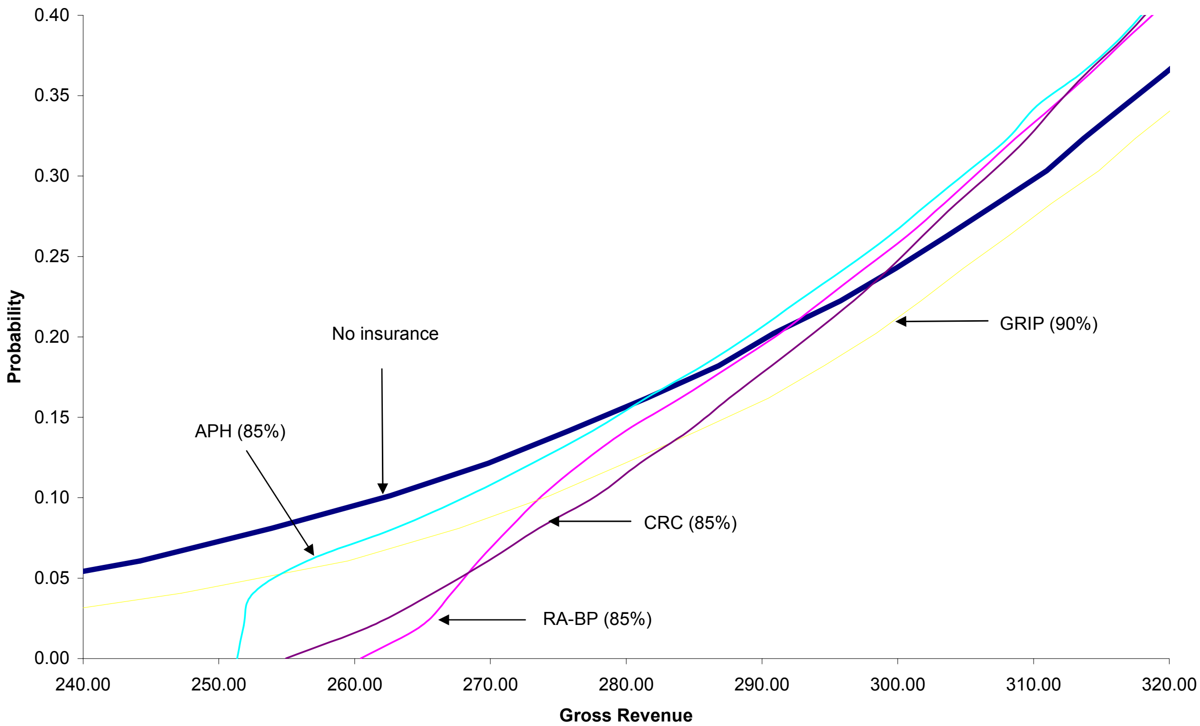

Figure 2. Cumulative Revenue Distributions for Revenue Assurance, Logan County Farm, Illinois, 2002.

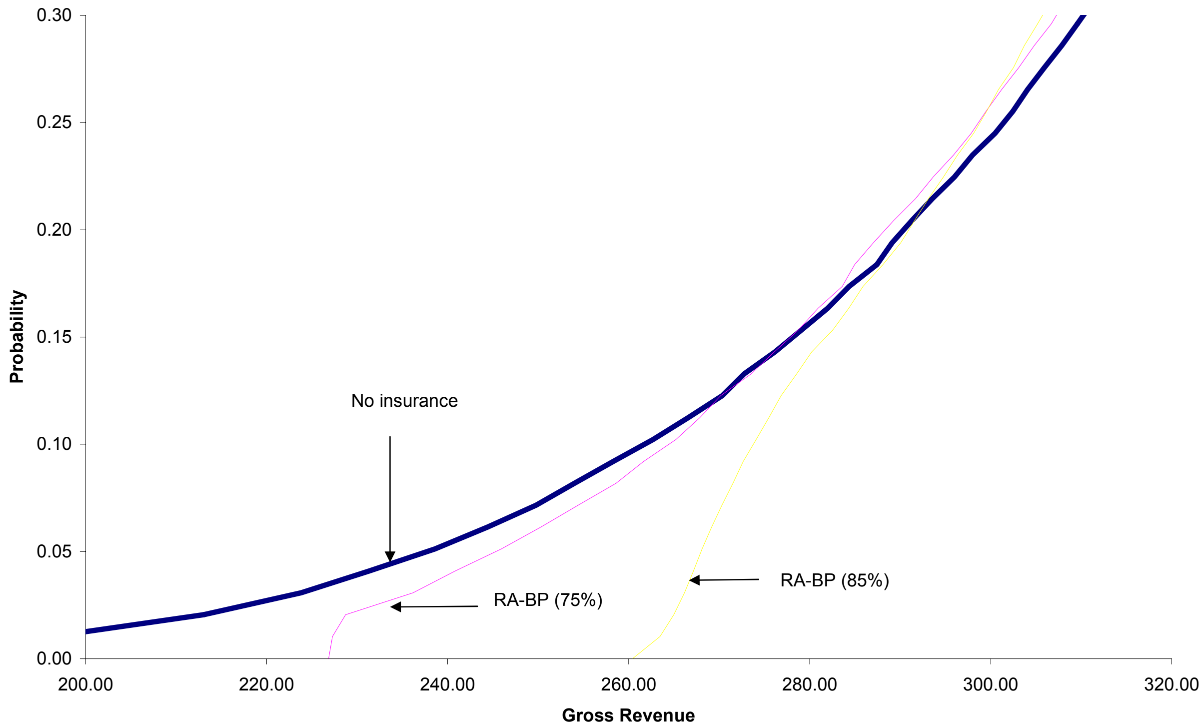

Figure 3. Relationship between 5% VAR Change on Revenue Assurance -- Base Price at 85% Coverage Level and County Yield Standard Deviation.

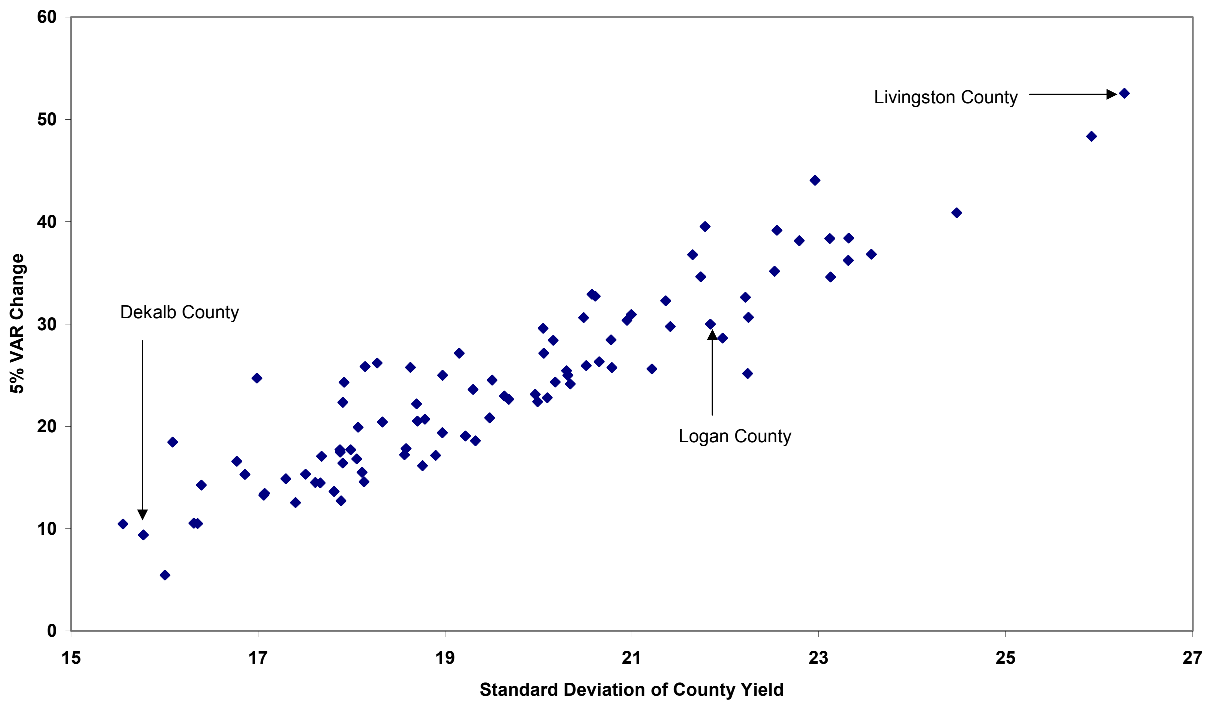

Figure 4. Cumulative Revenue Distributions for Dekalb County Farm, Illinois, 2002.

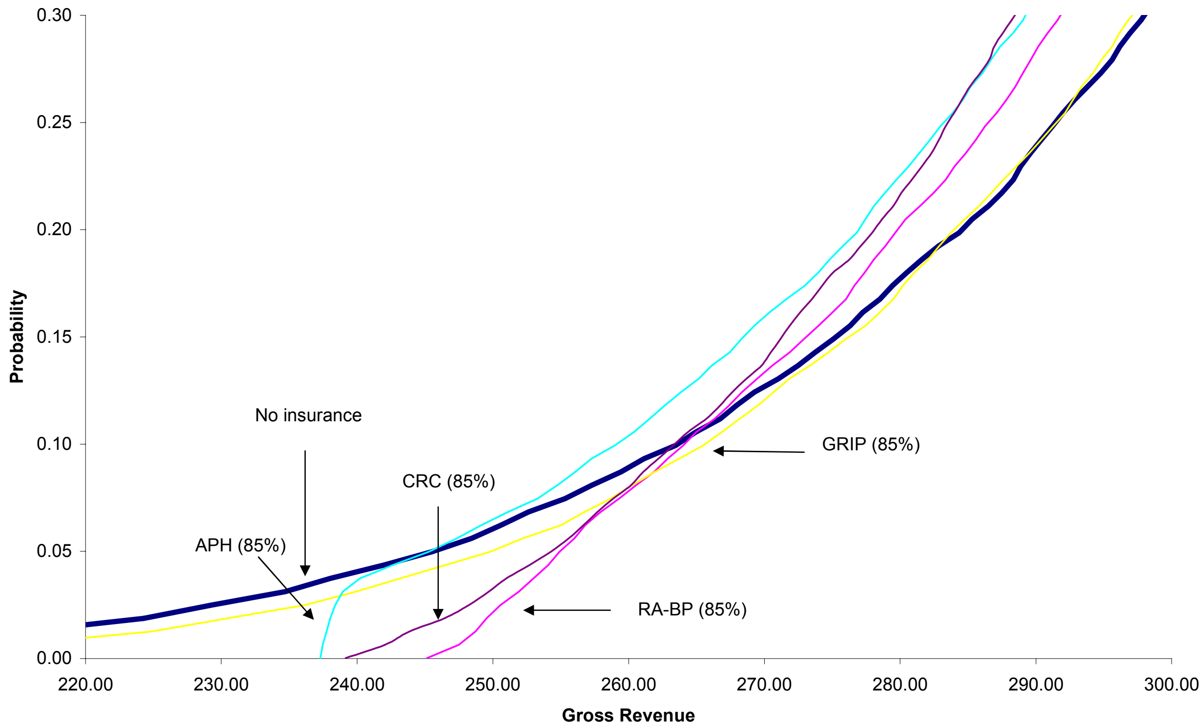

Figure 5. Cumulative Revenue Distributions for Livingston County Farm, Illinois, 2002.